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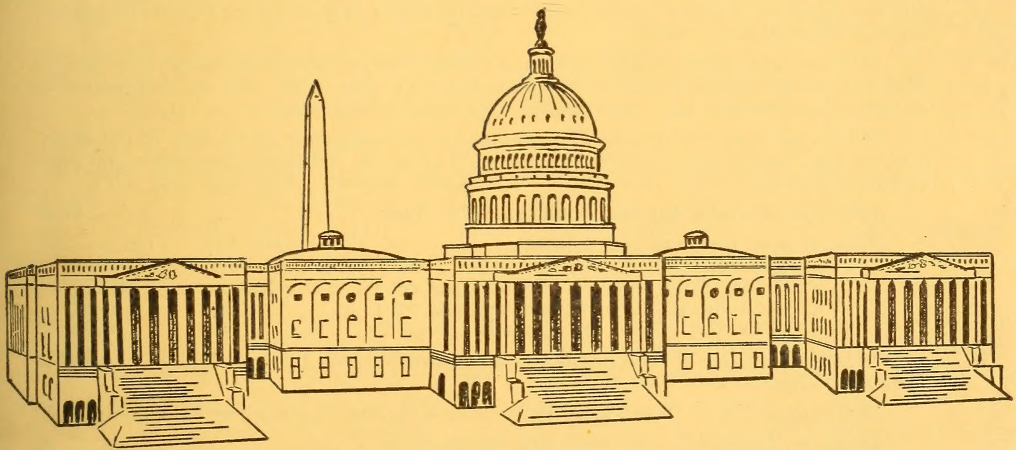

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SCIENCE ADMINISTRATION.—*Pay plans and people.* Crawford R. Buell, U. S. Post Office Department, Washington, D.C. (Communicated by Waldo L. Schmitt.)

(Received January 6, 1959)

Financial and psychic compensation of scientists and engineers has long posed a dilemma of no small proportions for all government agencies which prosecute engineering and scientific research and development. World events within the past year or two have emphasized the urgency of reaching satisfactory conclusions. Toward this end, the writer, during the past three years, has studied the rank-status concept, giving particular attention to scientists and engineers engaged in research and development. This study developed in some detail the philosophical and historical background of rank-status that had emerged as a concept for civilian employment in the Federal Government in the United States less than 20 years ago. The problems and situations which give rise to consideration of the usefulness of a rank-status philosophy in the administration of research are many. The effect of the administrative climate upon the scientist and, in turn, the attitudes of the scientist and his effect upon that administrative climate are matters that relate to the quality of scientific and engineering achievements that are so necessary in this prespace age. Some of these elements and situations brought Reimer to the conclusion that, "The futility of the fight against status is gradually being recognized in the Western world and, in certain forms at least, its conscious use is again respectable."[1]

Appraisal of existing techniques used to evaluate positions and to evaluate the people in these positions or applying for them is of especial importance to considerations of rank-status. Considerable attention was given, therefore, to the expressed opinions of groups and of individuals concerning appraisal of these techniques or tools. Evaluation of positions includes job evaluation and position classification. Evaluation of the people includes such aspects of personnel administration as merit rating and qualifications appraisal. From this aspect of the study it was concluded that sophistication of technique does not, by itself, lend validity to any of these techniques. Sophisticated job evaluation and merit-rating techniques may be no more valid and reliable than are some of the less sophisticated tools that frequently are used in rank-status plans.

This paper deals with a specific aspect of rank-status—a comparison of six different pay plans with the Classification Act of 1949, as amended. It is a summarization of what the writer has found to be the methods, techniques, and philosophies used in determining the salary of scientists and research and development engineers in various private and government organizations. It compares the techniques and policies used in six important pay systems or research organizations with those found existing under the Classification Act of 1949, as amended.[2]

[1] Reimer, Everett, *Modern personnel management and the Federal service.* The Federal Government Service: Its Character, Prestige, and Problems, Sixth American Assembly, Arden House, p. 161. Graduate School of Business, Columbia University, New York, 1954

[2] Additional material prepared from the notes of the writer concerning these six pay plans, and other aspects of rank-status mentioned earlier, is available from the writer for publication if deemed desirable or to interested students of position classification, pay administration, or research administration.

The term rank-status is used in this paper to indicate systems where rank and pay are based on the person rather than on the position occupied by the person. It is used interchangeably with the terms rank-in-the-person and personal-rank. Rank-status and job evaluation systems each occur in many variations—neither category should be thought of as an absolute. Rank-status is used here to refer to a system where the emphasis is on the *man*, job evaluation to refer to a system where the emphasis is on the position.

Rank-status is a concept which is often misunderstood and which, partly for that reason, has evoked widespread claims, both pro and con, that are as unrealistic as are similar exaggerations concerning job evaluation systems. "The only inherent feature of the rank concept," Stahl has said, "is that status (pay, prestige, rights, etc.) inheres in the individual regardless of the nature of his assignments."[3]

In a rank-status system the various functional areas of personnel administration are oriented toward the man rather than toward the position. Recruitment and selection, and even salary, are based upon the long-range needs of the agency. Recruitment and selection of the individual are based upon the potential of the scientist or engineer rather than upon his immediate usefulness. Hirings and promotions under this concept look toward accomplishing the agency's over-all objectives and goals even though jobs and programs may change from year to year. So too, training emphasizes the next assignment, at least, rather than increased effectiveness in the present assignment. A forester could well characterize rank-status as "viewing the forest instead of the trees," while a social scientist might look upon it as being based on the "inner man" rather than upon the more mundane demands for food, clothing, and a swept-wing motor car. The rank-status concept gives more attention to human relations and less to job relations. It seeks to "oil the inner springs" of man, as someone has said, to motivate the man rather than to emphasize reliance upon organization charts and other mechanistic devices for facilitating the accomplishment of the agency objectives. Rank-status may almost be thought of as a philosophy or a "climate" within which men effectively work toward a common goal, rather than to consider it as a "system."

[3] STAHL, O. GLENN, *Public personnel administration* (4th ed.), p. 178. Harper & Brothers, New York, 1950. See also pp. 181, 182, for the first suggestion that the writer has found as to the usefulness of rank-status for scientific research work.

The study covered selected plans for determining the compensation of scientists and of research and development engineers in the field of mathematics, the physical and biological sciences, and the medical and related sciences. In another sense, it was also a study about people—the people who work under the terms and conditions of those pay systems—and the people of quality whom the Government is seeking to attract to its employment and to retain.

The pay plans which were compared with the Classification Act of 1949 were:

The Los Alamos Scientific Laboratory
The Mellon Institute for Industrial Research
The British Scientific Service
The Public Health Service Commissioned Officer Corps
Public Law 313, 80th Congress, Professional and Scientific Service, Department of Defense
Public Law 692, 81st Congress, Public Health Service

PAY SYSTEMS COMPARED WITH THE CLASSIFICATION ACT OF 1949

I. LOS ALAMOS SCIENTIFIC LABORATORY

The Los Alamos Scientific Laboratory, New Mexico, is an organization of the University of California which performs work under contract for the Atomic Energy Commission. Its personnel policies that have been approved by the Atomic Energy Commission are set forth in each contract. At the time of this writer's visit in 1953, raises of $1,000 or up for persons receiving $12,000 or more per year could be approved by the Los Alamos Field Office, A.E.C., without referral to the Atomic Energy Commission headquarters office in Washington. The plan here discussed covered some 50 senior staff members and 845 staff members.

Under the contracts, salaries paid to persons in the scientific categories must average at the salaries or "salary line" computed by least squares in terms of "dollars per month" for up to 40 years beyond the last degree granted. This permits hiring applicants either above or below the salary line or exactly on the line if management so chooses. The supervisor is considered to be the person best able to judge the merit of a scientist or engineer and his contribution to the program. "Supervisor" is here used to indicate "levels of supervision" within line management as differentiated from determinations made by staff personnel as to compliance with laws.

The conference of division leaders is the key element in determining what monthly salary will most nearly represent the value of the individual scientist or engineer to the laboratory for that year—all within the frame of reference developed from the annual survey of salaries and in terms of equity with the salaries paid to other staff members. In addition to various "salary line" measures, the personnel office prepares "pictures" of the staff members in useful groupings through the use of mechanical tabulating and other equipment. These background data are then used by line officials in conference in a very informal manner. Part of this process has been described to this writer as:

> The technical organization is sensibly used to provide an upward flow of ideas, feelings, and arguments about the worth of individuals. We are informal, very much so, but we do not operate in a vacuum, nor do we play games with dollars and people.
>
> Very quickly, in such a process of looking at people in terms of similar people, dollar-levels and people levels become apparent; or reverse it if you prefer: certain qualities of persons identify rather precise dollar-levels. The exceptions leap to the eye and demand correction. By slowing down of money to people who are obviously overpaid and the speeding up of money to those underpaid, a "System" starts to be born. The factors are humans. The rating scales are humans. In all of this, administration with a capital "A" supplies information and assistance, maybe an idea now and then, nothing more.[4]

II. MELLON INSTITUTE OF INDUSTRIAL RESEARCH

The Mellon Institute of Industrial Research, Pittsburgh, is an organization of the University of Pittsburgh. At the time that most of the information was obtained it was organized for the purpose of "practical cooperation between Science and Industry." Emphasis has subsequently shifted to fundamental research.

Salary levels for the Institute as a whole were set in a manner somewhat similar to that used at the Los Alamos Scientific Laboratory. The salary lines were based upon annual rather than monthly rates and comparison was based upon the age of the individual rather than on the number of years following the last degree.

Statistics were prepared each year. This included sorting the employees according to degrees held (bachelor, master, and doctor) and then grouping according to the age of the individual. The average salary of each age group was plotted with respect to age, and a straight line drawn to represent approximately the average trend. This line was used simply as a guide and not as a hard and fast rule. The director of research explained that if an individual salary is above or below the line by too great a distance (particularly below), an adjustment is made to minimize the discrepancy. The director, subsequent to his retirement has recently written:

> There are always gross exceptions. But broadly we have judged a man on the character of work that he is doing, his accomplishments, on his personality, his relationship with his donor organization, and of course in later years on the "cost of living." In research, as you know, it is the individual and not the "position" that determines his worth.[5]

III. THE SCIENTIFIC OFFICER CLASS OF THE BRITISH CIVIL SERVICE

The scientific officer class is the highest of the three classes of the scientific civil service of Great Britain. It includes scientists engaged in research, and scientists and engineers engaged in research and development. The fields of work covered are substantially the same as those covered by a large number of occupational specialties which were under the professional service of the Classifictaion Act of 1923 and now are under the Classification Act of 1949. Within the British service, however, the

[4] Personal correspondence from John A. Woodward, wage and salary administrator, Los Alamos Scientific Laboratory, Los Alamos, N. Mex., July 22, 1957.

[5] Personal correspondence from E. Ward Tillotson, July 22, 1957.

scientists and engineers are not "catalogued" either by themselves or by the personnel system into as narrow specialties as is customary in the United States. The Royal Commission on the Civil Service, 1953–55, reported some 3,400 employees in the seven "grades" or "classes," each of which is titled "scientific officer" with an adjective being used to indicate the level.

There are two principles that constitute the major base upon which the salary scales for all British civil servants are built. However, the Royal Commission report stated:

> It seems to us desirable that there should be one set of principles of pay for the whole Service ... But this is not to say that there can be one short formula that can by itself solve all wage and salary problems.[6]

The principle of "fair comparison" (with current remuneration of outside staffs employed on broadly comparable work, taking account of differences in other conditions of service) is the primary principle of pay. The secondary principle is the maintenance of "internal relativities." Internal relativities may be "vertical relativities" between grades within a class or service or may refer to the relationship between classes engaged on the same broad type of work. Internal relativities may also be "horizontal relativities" or comparisons between grades or classes held to be of comparable status or of roughly the same level of responsibility in different hierarchies.

Most of the scientific officer grades have a broad salary range wherein annual promotion is customary and with fixed annual increments. Some of the grades have a "bar" in the middle of the range, beyond which bar the scientific officer cannot pass without affirmative action of a reviewing panel of scientists. Once this action has been taken he can proceed to the top of his grade range by larger annual increments. For the chief scientific officer grade there were two rates of pay adopted, partly because there were sufficient variations between the posts to warrant it (job evaluation) and partly for the advantage if it were necessary to recruit from outside the service. "Posts above chief scientific officer" were "broadbanded" on the span of £3,500–£6,000 per year with no stated intermediate steps.

Specialized posts in the higher grades are occasionally filled from the outside. If the applicant is from industry, the civil service selection board (of scientists) will look at his present salary and may appoint him at one of the higher steps within the class to which he would normally be appointed. It could, if it wished, place him in a higher grade if such action were needed in order to recruit (or retain) a specific individual.[7] The principle of fair comparison makes comparison with industry salaries feasible, even though the government scientific officer salaries were considered by some to be unfavorable compared with industry. In recruiting for the very highest posts, public advertisement is not favored. Instead,

> ...all government and other scientists of the required standing are considered by high level scientists and administrators, working in conjunction with the Civil Service Commission, and the most suitable individual available *would be invited* [italics not in original] to accept the appointment.[8]

It may be noted in passing that the flexibility in determining starting salaries for the two lowest grades is limited to one salary step. This flexibility in determining the starting pay of scientists and engineers accomplishes in a direct manner that which so often is achieved under the Classification Act of 1949 only after a struggle—accomplished sometimes on merit as gauged by job evaluation, but probably more often accomplished either with the connivance of position classification authorities, or by what has been euphemistically called "outwitting" the classification authorities.

Flexibility is also found in another procedure whereby under the "special merit promotion scheme" posts may be created outside the normal organizational hierarchy for outstanding individual research workers. This recognizes the value,

> ...of scientists of marked creative ability whose advancement should not involve any break in their

[6] Royal Commission on the Civil Service, 1953–55, *Report*, p. 23. Her Majesty's Stationery Office, London, 1955, Cmd. 9613.

[7] Personal interview with H. J. Hadow, head of United Kingdom Scientific Mission, July 31, 1957.

[8] Royal Commission, p. 130.

scientific work; in such cases, subject to the recommendation of a high-level selection board, the Treasury may approve promotion on "individual merit."[9]

An unusual characteristic of the British scientific service is that the recruitment, promotion, pay and other personnel processes are each scientist-oriented rather than personnel technician-oriented.

IV. PUBLIC HEALTH SERVICE COMMISSIONED OFFICER CORPS

The Public Health Service Commissioned Officer Corps is composed of some 10 occupational categories. The scientist officer category includes those officers whose primary function is research, although others may also do research to a lesser degree. The research is both basic and applied, and may be performed in the laboratory, in the field, or in clinical situations. Some of the titles carried by the officers include bacteriologist, biochemist, psychologist, physiologist, and protozoologist. There were somewhat more than 200 scientist officers, as of August 1957, of a total corps of close to 6,500.

The corps is a nonmilitary organization of highly trained professional men and women of many occupations. Personnel and pay procedures are the same whether for the scientist officer, the medical officer, or any other category. The corps is made up of officers who typically intend to spend most or all of their working careers in the corps.

The pay system and the pay scales are those of the military forces. Flexibility for pay determination within a stated pay grade does not exist. Judgments about an officer applicant or about the promotability of a scientist officer are typically the result of group judgment of his peers. Usually at least one of those peers is in the same specialty field or the same professional field as the person being judged. Provision exists for "selection out" of the officers who are not considered qualified for promotion by a promotion board.

The organization rates and ranks the man upon his over-all usefulness to the service. This relieves the scientist officer of concern as to whether an individual assignment might result in professional down-grading such as might occur under the Classification Act of 1949 for positions which are subject to that Act. It is the responsibility of the organization to place the scientist officer in such assignments as are appropriate, when possible. Thus rank—and assignments—follow the man.

The rank-in-the-person follows length of service in grade for permanent promotions but it follows more closely the personal ability of the man when it comes to temporary promotions. Pay follows the rank to which the officer is promoted, with the pay grades being the same as for the military.

Although not tied directly to determining annual salary, it is interesting to note that sophisticated systems are used in applicant rating by interview and file evaluation boards and used in performance appraisal and selection for promotion. While it is significant that sophisticated systems are characteristic of this corps, the fact that they are used by typical scientist officers rather than by personnel technicians or administrators may be of equal significance to the corps from the standpoint of morale.[10]

V. PUBLIC LAW 313, 80TH CONGRESS, DEPARTMENT OF DEFENSE

The act of August 1, 1947, usually known as Public Law 313, 80th Congress, established a special pay system for professional and scientific positions which were established to effectuate research and development activities of what were then known as the War Department and the Naval Establishment.

Although World War II fighting had long since ceased, the research and development emphasis of national defense was not fully achieved. Many competent scientists and engineers were resigning from the activities of the Department of Defense (then War and Navy) for more lucrative positions outside of the Federal Government. A one-day hearing on H.R. 4084 brought testimony from less than half a dozen officials, chiefly military, that the work to be assigned em-

[9] McCRENSKY, EDWARD, *Scientists in the British Civil Service*. Science **124**: 569. Sept. 28, 1956.

[10] Basic material on the corps was obtained from the writings of Sidney H. Newman, Ph.D., chief, Officer Selection and Evaluation Program, and interviews with him and with Paul M. Camp, chief, Division of Personnel.

ployees under this proposal was of such scope and responsibility as would normally be assigned to an officer of the rank of general. As to "why not make them generals?" Admiral Hussey replied that the civilian scientists wouldn't stand for it, that they feared military regimentation. The proposed positions were to be established under a procedure "fully in accord" with section 13 of the Classification Act of 1923.[11]

Public Law 313 was a 3-paragraph act which provided simply the following:

1. Each department was authorized to establish fifteen positions in the professional and scientific service, each being established to effectuate research and development functions, and any and all other activities which require specially qualified scientific or professional personnel, provided that the rates of compensation [then $10,000 to $15,000] shall be subject to the approval of the Civil Service Commission.
2. Appointments shall be made without competitive examination upon approval of the proposed appointee's qualifications by the Civil Service Commission *or such officers or agents as it may designate for this purpose*. [It is noted that all decisions have been made within the Commission, no delegation having been made to other agencies.]
3. An annual report to Congress was required, showing names of employees, functions performed, and salaries.

At the time the rest of this statement was prepared, Public Law 313 had been amended to include not more than 120 positions in the Department of Defense, 25 in the National Security Agency, and 30 in the National Advisory Committee for Aeronautics. Due to Public Laws 85-462 (June 20, 1958) and 85-568 (July 29, 1958), the present (January 1959) authorizations under Public Law 313, as amended, are: Department of Defense, 292, National Security Agency, 50; Interior, 5; Agriculture, 5; Health, Education, and Welfare, 5; and Commerce, 25. [In January 1959, in addition to the authorizations of Public Law 313 listed above, there are some 380 other positions authorized under the same general philosophy. These include 85 in the Public Health Service, which are discussed under Public Law 692, and 260 in the National Aeronautics and Space Agency.]

[11] U. S. Congress, House of Representatives, Committee on Post Office and Civil Service, Report to Accompany H.R. 4084, July 16, 1947, House Report 953, 80th Congress, 1st Session, 3 pp. (Not printed.)

The first review of a submission received by the Civil Service Commission (typically received as a "name case") is in terms of the Classification Act of 1949. Is it a scientific or professional position established within the requirements of P.L. 313 and what would be the grade level of the position if it were under the Classification Act of 1949? This preliminary evaluation includes consideration of the following factors:

1. The nature, magnitude, and scope of the agency's research and development program and its relation to the international situation.
2. The career of service and the scientific accomplishments of the incumbent.
3. The approximate comparison as to scope of program and weight of responsibility with other jobs which may be comparable.
4. The nature of the agency's organizational structure.
5. Whether during a transitional period there is an attempt to maintain consistency between the former pay rate and the proposed pay rate in the total range of pay.

The second and fifth items are factors not used in the evaluation of Classification Act positions.

Following this, a comparison is made between the salary recommended by the agency and the GS grade appropriate if it were under the Classification Act. This is done by dividing the P.L. salary range into three subranges approximately equal, each subrange to be roughly the equivalent of one of the three "supergrade" levels, GS-16, 17, and 18. Conformance to this rough guide would result in recommendation by the Personnel Management Review Division that the salary be approved, subject to review of the qualifications of the man by the Examining Division. It is believed that no case has been rejected on the qualifications aspect that had been approved by the position evaluation. Where disparity exists between salary *range* that would appear appropriate from the position review and the salary recommended by the agency, a conference is held with agency officials, seeking additional information concerning the man, the program, or the scarcity of men of the required qualifications. A denial of an agency recommendation would come only after such inquiries had been made. The Commission no longer determines on its own initiative what the appropriate salary is. It either accepts or rejects the recommendation of the agency. An agency may resubmit a case with a different recommendation if it chooses.

While the Commission studiously avoids taking original action that is the responsibility of the agency, it appears to be equally desirous of avoiding a rubber-stamp role, requiring substantially equal justifications for recommendations of changes of salary downward that it requires on changes upward.[12]

As with super-grades, each military agency has two administrative problems—approval of a Public Law 313 "space" and getting the man for the space. Approval of the space is internal within the Department of Defense, yet the layers of review of proposals may be far more time-consuming and hazardous than obtaining salary and qualification approval from the Commission.

VI. PUBLIC LAW 692, 81ST CONGRESS, PUBLIC HEALTH SERVICE

The Act of August 15, 1950, was identical to Public Law 313 except that it applied to the Public Health Service.

Senate Report No. 1102 described the reasoning back of this pay system that was established outside of the Classification Act of 1949, saying,

> Authority to pay reasonable salaries to outstanding scientific and professional persons engaged in research is essential if the quality as well as the quantity of medical research is to increase.
>
> The full potentialities of the whole research staff of the Public Health Service can be brought out only if those who guide its research activities combine research talents of the highest order with ability to stimulate others and administer large programs. This combination of talents is rare. Persons who possess them command high salaries.

The personnel manual of the Public Health Service contains statements concerning the approving authority, general policy, promotion policy, eligibility criteria for individuals, determination of salary levels, and processing procedures that are unusual in setting forth useful criteria succinctly for all interested parties. The designation of these positions and the determination of salary levels are considered part of the career development program that cannot be met within the commissioned corps or the Classification Act pay systems. The position and the salary will be identified with the incumbent or prospective incumbent and will exist only during the period that the position is occupied by the incumbent. This recognizes administratively the rank-status basis of Public Law 692, rather than considering it merely as an extension of the Classification Act with the "position" concept.

The manual contains criteria for determination of salary levels. There are two general guides that apply to all categories of P.L. 692 personnel, these elements being:

> 1. An assessment of the demonstrated competence of the candidate, whether applicant or incumbent.
> 2. The extent to which competition for scarce manpower or other factors tends to raise nongovernment salaries.

The three categories of personnel each have a separate and additional criterion, as follows:

1. *Independent Investigators*
   Up to $15,500—may be paid to those who are fully competent, mature and highly productive.
   Up to $17,500—may be paid to those of exceptional competence with international reputations.
   Up to $19,000—may be paid to those who are, by general consensus, recognized as fully competent to occupy the most distinguished academic chairs or to assume key research positions in industrial research.
2. *Clinical Specialties*—may be paid salaries generally comparable, within the $19,000 ceiling, with the total earned income of their counterparts in academic teaching and research posts, but not with the income of those engaged full time in the practice of medicine.
3. *Program Leaders*—the importance and complexity of the position, and the size and complexity of the program for which the incumbent is responsible.

The manual also provides that, in formulating their recommendations, chiefs of bureau as well as chiefs of division may utilize the technical advice of such groups of professional peers or supervisors, of the

[12] Most of the material concerning administration of P.L. 313 within the Commission was obtained in interview with Ralph Remley, chief, Classification Appeals and Special Services Office, U. S. Civil Service Commission, April 2, 1957.

candidate or incumbent as they may determine to be needed.[13]

VII. OTHER SYSTEMS

The Battelle Memorial Institute, Columbus, Ohio, has had a form of rank-status since it was founded in 1929. Its former metallurgist director has said,

> The ideal criterion for personal recompense in any business is *productivity* [italics in original]. The persons who produce the most deserve the most pay . . .
>
> . . . In modern research this difficulty of measuring productivity is increased many fold. . . . To take the results of team research and to say that this percentage is creditable to that person's efforts, is to destroy the structure that makes research effective. Consequently, we must use empirical rather than mathematically precise means to evaluate each man's worth. We do this by appraising other qualities of the individual that experience tells us are usually related to his productivity.
>
> These qualities determine the "merit" of the technical man to the research organization, and salary increases based on such evaluation are called merit raises.[14]

Every staff member's situation is reviewed quarterly; there are no standard or automatic increases of any type, and no arbitrary rules for determining the amount of increases, if any, to be given at any one time. These appraisals rely heavily upon evaluation of personal traits. Among these are initiative, willingness to put out some extra effort, tenacity to follow through, and economic "sense" superimposed on the basic technical knowledge required. Other traits evaluated are salesmanship (including report writing—because their only product is the research report—and vocal presentation and interpretations of the user's needs), administrative talent, and, importantly, scientific integrity and selflessness.

The policy at Standard Oil Co. (of New Jersey) apparently recognizes the inadequacy of job evaluation as a basis for pay for research workers. In an answer to an inquiry from the writer concerning rank-status the manager of the Employee Relations Department wrote as follows:

> Job evaluation does not seem to be appropriate to professional engineers and scientists because none of them perform according to a job description. Job classifications are based primarily on traditional relationships between jobs, skills required and responsibility exercised. The professional employee's effectiveness depends on his individual contribution within a team effort. Perhaps a more important factor determining pay is the condition of supply and demand. It sets salaries far more than a job classification. The very large turnover among professional employees in research organizations is an indication of the dominance of economic factors over rigid classification systems.[15]

During the summer of 1957 General Electric was in the process of changing some of its personnel and pay policies, and so was not in a position to discuss plans which it expected would be installed. Bearing upon the goal sought by some persons of having a single pay system for all civilians in the Federal service, the multiplicity of plans within GE is of interest. A consultant with GE has written,

> As a part of our broad decentralization program, substantial latitude is provided for managers of our decentralized departments in establishing the particular practices they believe most appropriate for their particular operations. As a consequence, it is difficult to generalize and develop statements that are truly accurate for the General Electric Co. as a whole. We have, for example, more than 35 position evaluation methods now in use in our Company.[16]

The consultant called attention to the 1957 report of the Defense Advisory Committee on Professional and Technical Compensation, of which Ralph J. Cordiner (president of General Electric) was chairman. The point was made that the report contained statements of some of the basic concepts which are considered, at General Electric, to be important in the development of compensation structures and suitable compensation relationships.

The chart herewith, "Generalized Comparisons Between Various Aspects of Selected Pay Systems," is a summary of some of the comparisons between the seven pay plans given major attention.

[13] Basic material on administration within the bureau was obtained during interview with Paul M. Camp, chief, Division of Personnel, August 15, 1957.

[14] WILLIAMS, CLYDE, *Bases research worker salary structure on merit system*. Industrial Science and Engineering, January 1955: 33.

[15] Personal correspondence, a statement prepared by research people as an attachment to a letter signed in the name of R. L. Mason, manager, Employee Relations Department, Standard Oil Co., New York, N. Y., July 7, 1955.

[16] Personal correspondence from L. L. Ferguson, consultant, Employee Compensation Research, General Electric Co., New York, July 17, 1957.

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Generalized Comparisons between Various Aspects of Selected Pay Systems

(Conclusions based upon study of the systems — in some instances based upon inference rather than specific facts found)

Pay Plan Aspects	Los Alamos Scientific Laboratory (A)	Mellon Institute (B)	British Scientific Service (C)	Public Health Service Commissioned Officer Corps (D)	Classification Act of 1949 as Amended F	Public Law 313 (D.O.D. Agencies) (F)	Public Law 692 (Public Health Service) (G)
1. Pay based primarily or entirely on the MAN or on the JOB?	Pay is based on the MAN.	Pay based on the MAN	Pay is based primarily on the MAN, for higher levels. Broad job evaluation is used for most posts in B.S.S. but at the higher levels "scientific officers" may be placed in a higher grade if necessary to recruit from industry or to retain. (Job evaluation for B.S.S. is typically a means of determining posts to which men of specified rank are normally assigned.)	Pay is based primarily on the MAN. A job evaluation plan is not used, although some specific higher posts carry specified ranks & may be filled through "spot" promotions	Pay is based on the JOB. Job evaluation plan is based on duties, responsibilities and qualifications required. It is used to place the position in a "class" to which is attached a specific pay range.	Pay consideration in agencies of D.O.D. varies. It may be either based on the MAN or the JOB. C.S.C. determination is based primarily on JOB—with the MAN's qualifications sometimes influencing doubtful cases.	Pay consideration in P.H.S. is usually based on the MAN. C.S.C. determination is same as for P.L. 313.
2. Pay geared to accomplishment of long-range or short-range objectives of agencies?	Pay administration is geared to long-range program with considerations of the man's potential & expected achievement at end of, say, next 5 years.	Apparently it is the same as for Los Alamos although no direct information was obtained.	Pay administration is geared to long-range objectives.	Pay administration is geared to long-range objectives	Pay administration within D.O.D. agencies is geared to short-range objectives—to the immediate job to be done.	Pay administration within D.O.D. agencies is geared usually to long-range objectives; within C.S.C. it is geared to the immediate job to be done	Pay administration within P.H.S. is geared to long-range objectives as part of a career development program that can not be achieved under P.H.S. Commissioned Officer Corps or under Classification Act. Within C.S.C. it is geared to the immediate job, as is case with P.L. 313.
3. Assignments based on pay or rank—or pay or rank based on assignments?	Assignments are based typically on pay of the scientist or engineer. (High quality job performance may cause a salary increase? Lack of quality may cause salary stagnation.)	Same as Los Alamos	Assignments are based typically on rank of the scientific officer. Occasionally for higher posts it will be reversed and "spot" promotions used.	Assignments are based typically on rank held by "scientist officers." However, rank and pay of those assigned to a few "restricted" positions are based on the job itself.	Pay is based on assignments which have been evaluated by job evaluation & assigned to a class (including grade level). "Details" (supposedly of short duration) involve no change in pay.	C.S.C. typically bases pay upon assignments. Once this has been done, agencies typically assign S & E's upon the basis of salary and ability. (See 3. E. concerning "details.")	Same as for P.L. 313
4. Effect of assignment to lower level work.	No effect unless it is permanent or prolonged and due to lack of competence.	Same as Los Alamos.	Assignments to lower level work typically have no effect on pay or on future assignments.	Assignments to lower-level work would not be the cause of reduction in rank or pay. Career management is practiced—it relieves the man of concern as to whether an individual assignment might harm his pay or career.	Grade and pay are lowered if found on survey or job audit—unless management is given opportunity to reassign duties or employees. Pay is not lowered in a few "savings" cases provided for in the Act.	There is no known effect if assigned to lower-level work except that if it appeared in position descriptions or certifications required periodically by C.S.C. it would presumably affect pay adversely. Management may initiate action	Same as for P.L. 313.
5. Effect of assignment to higher level work.	No immediate effect. Quality of work done may result in higher salary from next salary review.	Same as Los Alamos	Assignments to higher level work have no immediate effect. Level and quality of work would be considered by next promotion or selection board (for promotions to 2d and 3d levels "without waiting for a vacancy," or for promotion to "individual merit" positions).	No immediate effect. Level and quality of work would be considered by next selection board.	Grade and pay would be raised if the S & E is legally qualified for such grade	If duties are to remain of a higher level, presumably the agency would request review by C.S.C. and a higher salary. C.S.C. would not initiate it.	Same as for P.L. 313.
6. Methods of evaluating the MAN. A. Applicant evaluation based on: scholastic history, potential, or work-or-salary history.	*Applicants* are evaluated on basis of education (kind of degree) and comparison with curve of salaries of other S & E's in U. S. for the same number of years beyond last degree earned. Potential is included.	Essentially the same as for Los Alamos, except (1) salary history is based on age rather than on years since last degree, and (2) the acceptability to (or relationship to) the donor organization in regard to salary.	*Applicants* are evaluated, for entrance to lowest grades, on basis of review of scholastic honors (univ. degree with 1st or 2d class honors required) & on potential for growth, by means of oral & written exams & reference checks. For higher levels, graduate work, acceptable work history, & salary history are used, including industry pay.	*Applicants* for first 2 levels always are given written professional exam, an oral interview, a file exam (entire background, education, training, & experience, & supervisor & teacher reference checks). For full grade & above, oral & written exams may be waived.	NOT APPLICABLE: Neither (A) nor (B) is applicable, because the position is evaluated separately from the MAN.	C.S.C. evaluation of *applicant* is based on S.F. 57, Application for Federal Employment, plus agency letter of transmittal—sometimes supplemented by additional information from applicant, or from "American Men of Science," etc. Agency & D.O.D. evaluations vary greatly as to kind.	C.S.C. evaluation of *applicant* is same as for P.L. 313. P.H.S. *recommendations* are made initially by chiefs of bureaus or divisions (professional men) who are encouraged to use the technical advice of groups of "peers" or of supervisors as needed. All line officials over a P.L. 692 man are professional. Action in Dept. of Health, Education, & Welfare was not learned.
B. Employee evaluation based on: job performance or empirical solutions designed to represent job performance which is considered to be immeasurable directly.	*Employees'* evaluation includes the above, plus evaluation of last year's work and comparisons with other employees.		*Employees* are evaluated on basis of record obtained when applicants, plus annual job performance evaluation A and B, seek to determine the man's stage in growth.	*Employees* are evaluated annually on job proficiency, forced choice rating by worker-associates, & measures of work attitudes & job performance items. Selection boards are used for promotions & selection-out.		Same as above, if not already in the file.	Same as above.
7. Making of salary determinations or effective recommendations for same: A. As to person or group making them. B. As to extent to which they are made by "peers," i.e., by scientists and engineers (S & E's).	Supervisory scientists initiate the salary recommendations and the division leaders' conferences make effective review of these recommendations, though not necessarily having the last word.	Salary recommendations and determinations were made by persons who were scientists or engineers. It is not known whether group action was used in making the determinations.	Salary recommendations (usually tantamount to determinations) are made by panels of senior scientists which have some leeway in determining starting pay at lowest two levels & may authorize placing an applicant from industry, or an employee, in higher grade if necessary to attract or retain in B.S.S. May promote to special merit posts (subject to Treasury approval).	Group evaluations are used for pay & tenure determinations. Some or all of applicant-interview panel of scientist officers are in same professional category as the applicant; file evaluation board members are scientist officers; worker-associates ratings are by "peers"; investigation boards must contain one member of same profession; selection board is also a "peers" group.	Positions of S & E's typically are classified in agencies by position classifiers (who are not also S & E's unless by chance) or by administrative or personnel officials on classifier recommendations. Group evaluation is seldom used (P.H.S. uses). For supergrade S & E positions, C.S.C. commissioners have lately delegated their authority to C.S.C. classifiers.	Effective recommendations are made by position classifier (if more than one, the others are reviewers). Final determinations are made by the Commissioners as a group. No one in C.S.C. is a practicing scientist or engineer. None who pass on these matters would have been so trained, unless by chance.	C.S.C. recommendations & determinations are made same as for P.L. 313. (Note that in C.S.C. a group—commissioners—*acts on recommendations of an individual position classifier review* of the agency recommendation. In P.H.S. a line official (professional) frequently *acts upon a recommendation of a group of professional peers.*)
8. Orientation of salary plan and its administration.	Oriented toward line management. ("Line Management" here is a group composed of the senior scientists or engineers.)	Same as Los Alamos	To a considerable degree it is oriented toward line management scientists and engineers. In addition, the job evaluation used in part does not have the degree of orientation toward the personnel technician that is found in the Classification Act of 1949.	Oriented toward line management which here is that of commissioned officers of whom some are scientists and some are engineers.	Oriented toward one specialty of personnel technician the position classifier.	The total system partakes both of orientation toward position classifiers and, in some agencies, of orientation toward administrative or military personnel (rather seldom oriented toward scientists and engineers).	The system is oriented toward position classifiers and administrators at the C.S.C. level; and to professional personnel (including scientists and engineers) at the P.H.S. level.

(Note: "Job Evaluation" is used in the general sense of analysis and evaluation of the duties, responsibilities, and qualifications required for minimum satisfactory performance required by a position)

CONCLUSIONS AND RECOMMENDATIONS

The facts and opinions assembled during this study furnished convincing evidence that categorical and sweeping generalizations on the subject of rank-status for scientists and engineers would be hazardous. They might be as unsound as the chant, "Four legs good, two legs bad," used by some of George Orwell's animal characters as a means of differentiating the "good" animals from the "bad" humans in his *Life on the animal farm.* In one sense, rank-status may be considered to be almost a philosophy or a symbol of principle rather than necessarily a pay plan.

Aside from the Classification Act of 1949, as amended, all the pay plans studied in detail represent, to this writer, variations of rank-status pay plans. The matters of principal interest in this study are the variations in the degree to which pay is based upon the qualifications of the man or upon the production of the *man* rather than the duties and responsibilities of the *position.*

Although there is a common philosophic approach to the problem of pay, in practice there are restrictions of one kind or another which result in a variety of methods used. On the other hand, the Classification Act of 1949, as amended, which furnished the point of departure for the study was the single strictly job evaluation plan that was studied. More scientists and engineers in research and development are paid under the Classification Act of 1949 than under any other pay system. It is useful, therefore, as a specific against which to compare other systems. But to consider the Classification Act as being "THE" job evaluation plan and representative of industrial job evaluation plans would be grossly misleading. Industrial plans for job evaluation not infrequently include evaluations of the contributions made by the individual as well as evaluations of the duties and responsibilities that are assigned by management and of the working conditions as they are found to exist. An example of such a composite plan for evaluating creative engineers has been described by Chaffee.[17] In addition to the duties and responsibilities of a position that would be measured under the procedures used in organizations whose positions are under the Classification Act of 1949, numerous personal qualities would be measured, as would job performance. The total evaluation, if scored high enough, would place the incumbent in a merit subgrade. This technique is in accord with the more generalized proposal of the Purvis committee for premium salary "which will give recognition to the skills and abilities brought to the job by the individual . . . over and above job evaluation techniques now used to determine an incumbent's grade and pay."[18]

This study may be considered to be a comparison between one specific type of job evaluation plan (the Classification Act of 1949, as amended) and several other pay plans, each of which has some of the "flavor" of rank-status.

SUMMARY OF CONCLUSIONS

1. *Conclusion: Research and development personnel is an unusually rapid growing occupational group in the work population of the United States today, yet it is in short-supply when considered against current needs—especially as the needs relate to the defense of the nation.* This group, with its high professional standards and working habits and with a different kind of logic from that characteristic of nonprofessional personnel, has attitudes that are hostile to many aspects of administration. Personnel administration as it has been practiced *on* them is typically anathema. Salary and prestige associated with their professional attainments mean much to scientists and engineers—although not to the exclusion of adequate salary. The "social handles of the pay cup" concept which emphasizes the social aspects or prestige that follows the pay itself is important to scientists and engineers, although apparently not to the extent found by Whiting a quarter-century ago in his study of laboring groups.

Because of a combination of salary prob-

[17] CHAFFEE, RANDOLPH W., *Evaluating engineers to recognize talent and reward achievement.* Machine Design, June 1951: 143–172.

[18] U. S. Congress, Senate Committee on Post Office and Civil Service, *Administration of the Classification Act of 1949 and the compensation process established by the act,* Senate Document 34. 83d Congress, 1st Session, p. 22. 1953.

lems (e.g., comparisons with the trades and crafts) and lack of attention by management to status and recognition for their work, scientists and engineers are either "on the move" or at least are preconditioned to accepting an offer of employment from another organization. Absurdities and extremes have existed in the use of status and prestige symbols, ranging from the kind of carafe available to an executive, to parking lot privileges, to priorities in obtaining Asiatic flu vaccine, and to other more tangible rewards. The fact that absurdities have existed has not blinded many organizations to the value of a reasoned use of status and prestige. The conscious use of status in the Western world is again becoming respectable. It will probably become increasingly recognized now that the launching of the Russian "sputnik" as the first earth satellite has caused additional attention to be focused, perhaps belatedly, upon the problems of training, recruiting, and retaining an adequate supply of quality scientists and engineers.

2. *Conclusion: Different principles and practices in personnel administration are needed for scientists and engineers in research and development than for persons in other occupations and functions.* Scientists and engineers do not usually fit into the administrative process either by personal traits or by process or function. "Supervision" is a term that is anathema to them, particularly so the closer one gets to basic or "pure" research or to the higher levels of research and development. Especially in these areas the organizational structure tends to emphasize the man rather than the position. Personnel administration as developed by personnel administrators who are not scientists or engineers is especially obnoxious to them—they object to having such personnel administration "applied *to* them." Because of these things, administrators attempt to adjust both the substantive work organization and the facilitative organizations to conform to the needs of the personnel who are to accomplish the mission of the work organization. In the facilitating organizations which are responsible for the personnel administration function this is most noticeable in the reduction in procedures and in the use of "committees of peers" for decisions in the personnel areas. As Boehm quoted a research director, "Research can be managed in a businesslike way, but not in a way like other business."[19]

3. *Conclusion: The subject of rank-status or rank-in-the-person has been discussed for only about two decades in the United States but neither the concept nor the application is of recent origin.* Extensive application of the concept existed in the government of China during the early centuries of the Christian Era. In the Western world it appeared in the military, in the Catholic Church, in the civilian governmental organizations of European and other areas, and in United Nations organizations before consideration for use in civilian government situations in the United States. Beginning with the proposal by Graham in 1939, the subject has come to be increasingly in the public eye as a result of recommendations of congressional and presidential committees, and the writings and speeches of public-spirited groups and individuals from many walks of life who have broad knowledge of public affairs. Among the groups which have favored emphasis upon rank-status or at least further study of the usefulness of rank-status to the Federal Service are: the Advisory Committee on Natural Scientists (1942), the Senate Committee on Post Office and Civil Service (1953, Purvis Committee), the Commission on Organization of the Executive Branch of the Government (1955) (the second Hoover Commission), the Sixth American Assembly (1954), the Society for Personnel Administration (1955), and the Defense Advisory Committee on Professional and Technical Compensation (1957, Cordiner Committee). Some of these groups were studying government as a whole, while others concerned themselves specifically with the work of scientists and engineers or with administrative personnel.

4. *Conclusion: In research and development the degree of development of the scientists and engineers may be of more importance than their precise duties or the particular work assignments by their super-*

[19] Boehm, George A. A., *Research management: The new executive job.* Fortune **54**(4): 222. October 1957.

visors. This is signally the case in basic research done by an individual or by the team approach to either research or development. Assignments to a scientist, especially, may be couched in the most general terms. They may sometimes only name the area of study that management is interested in. In other instances, a general outline of study that is defined by management may be deviated from to a high degree because of the scientist's findings or because of lack of specific findings at intermediate points. Deviations may also occur because of "fringe thoughts" —random thoughts that have come to the scientist, seemingly "out of the blue," as a result of his lifetime of preparation in college or university plus the complex of his later experience. The work assignment to two scientists or engineers may be the same, especially under the team approach, but the contributions of an Einstein may be far different from the contributions of a John Doe, Ph.D. Classification of a research and development position independent of an examination of an individual's qualifications and potential has been referred to, with some justification, as an absurdity, and classification without regard to performance as nonsensical.

5. *Conclusion: The job evaluation or position classification concept that "if work (duties and responsibilities) can be assigned it can be described and can be evaluated" falls short of realization for research and development positions.*

This is either the conclusion or the general implication of Graham (1939), Steelman (1947), the Senate Committee on Post Office and Civil Service (the Purvis Committee—1953), the Chief, Bureau of Ordnance, Department of the Navy (1949), Wengert (relating to job evaluation systems in general—1950), Renzetti (1952), and various technical directors of research. Others who have also held similar opinions include Mason (1955), Clyde Williams (1955), and the Defense Advisory Committee (the Cordiner Committee—1957).

6. *Conclusion: Job evaluation plans (including the Classification Act of 1949) are typically unsatisfactory tools with which to determine the salary of scientists and engineers in research and development.* Measuring the duties and responsibilities of scientists and engineers by job evaluation techniques is difficult in itself and, when obtained, often does not measure the value to the organization of the scientist or engineer. One of the reasons for this is that job evaluation plans used in the Federal Government, at least, are not designed to evaluate the effect of the man. In research and development the abilities of the scientist or engineer so often have greater effect upon his contribution to the research program than do the assignments of work and responsibility made by the supervisor.

It is difficult to evaluate scientific and engineering research and development positions and to evaluate the qualifications and the abilities of the scientists and engineers themselves. It appears to be equally difficult to appraise the value of the work product of such scientists and engineers either when engaged in individual research or team research. It is difficult for scientists and engineers themselves to make these evaluations even if they are research and development administrators in charge of the total work operations. It is still more difficult in many of those areas for a person to make valid evaluations if he is not a scientist or engineer.

There has been much criticism of the Classification Act of 1949, as amended, as a tool for measuring the difficulty and responsibility of positions—of work assignments made to scientists and engineers. There has also been criticism that the Classification Act is designed to measure only the difficulty and responsibility of positions with the objective of achieving "equal pay for equal work," whereas what should be measured is the total contribution *of a man* to the research and development program in which he is engaged. There also has been much criticism of various systems used to appraise the worth of individuals, whether in meeting the qualification requirements of the Civil Service Commission for appointment or promotion or in the area of performance appraisal. Particular criticisms and cautions have been voiced against placing too much reliance upon systems which use techniques which involve numeric treatment or obtain results which in some other way have an aura of exactness that is misleading.

It would be hazardous to believe that either simplicity or sophistication in evaluation techniques is, by itself, either desirable or useful. Rules of thumb in these areas would produce serious inequities as may complicated systems, which produce "reliable" though "invalid" results. So-called "objective" systems (which frequently are also sophisticated) are subject to the same possibility of creating false illusions of accuracy in measuring what they purport to measure.

Job evaluation techniques and man evaluation techniques have been developed in some few situations that afford promise of much greater usefulness than is characteristic of the Classification Act, for example. Typically, however, *reliance on any technique to the exclusion of the considered judgment of operating personnel would be unduly optimistic at this time.*

7. *Conclusion: The present inadequacies of many sophisticated job evaluation plans and man evaluation plans and the criticism that results from such inadequacies emphasize the need for much additional research and development in these areas of personnel administration.* The fact that many techniques fall far short of what is desirable in measuring either research and development positions or in measuring the scientists and engineers themselves should not lead to the conclusion that these decisions should in the future be made as snap judgments or made by intuitions without an array of information available to the authority who is to make the decisions. In the Los Alamos Scientific Laboratory and the Mellon Institute much material is gathered for the authorities who recommend or determine what the salaries will be for the individual scientists, but so far as the actual evaluation of Scientist John Doe is concerned the processes that are used are unsophisticated. On the other hand, some of the evaluation techniques used within the Public Health Service are sophisticated. In each of these organizations and in the British scientific service the techniques used are planned as *aids to* an evaluation by man—not as a substitute for man's judgment. On this point Worthy and Urwick each considered that the various measures of the objective and sophisticated varieties could be very useful to the executive, but that they would be used to "sharpen his judgment" rather than replace it.

8. *Conclusion: The Classification Act of 1949, as amended, appears to be more criticized for positions of scientists and engineers in research and development than for positions in other fields of work.* The criticism in this area comes from employees and management alike. It was found, however, that serious criticism of the Classification Act was not universal, for in some cases there was found the belief that the administration of the Act was more to be criticized than the Classification Act itself.

9. *Conclusion: Rank-status pay plans for scientists and engineers recognize* (1) *the unsuitability of the usual job or position evaluation techniques to research and development work, and* (2) *the antagonism of research and development scientists and engineers to a job evaluation form of administrative stricture with its concomitant lack of recognition for personal contributions.* Part of the unsuitability stems from the previous conclusion which emphasizes the development of the man rather than the job assignment. This suggestion by Graham in 1939 was corroborated by the Advisory Committee on Natural Scientists which looked on the caliber of the job as being a reflection of the man *in* the job and that the classification should rest upon the research contribution of each man. The unsuitability question was again raised in 1947 by Steelman—unsuitability both as to present classification principles and classification techniques for many research and development positions. Renzetti differentiated between the degree of unsuitability or suitability of the Classification Act for research work as compared with nonresearch engineering work which lends itself to a pyramidal structure. The Purvis Committee cited Einstein as an example of a man to whom application of the Classification Act of 1949 would be unsuitable. Basing the salary on the position tends to ignore the contribution of a gifted engineer, in the view of Nicholson.[20] The survey of scientists and engineers

[20] NICHOLSON, SCOTT, *How much is an R/D boss worth?* Research and Engineering, December 1956: 6.

in research and development made by the Department of the Army indicated that scientists and engineers in research and development do not fall into the "readily identifiable levels" that are envisioned by the Classification Act and that the precise duties should not be the sole measure of value of the individual. Adding weight to the conclusions as to unsuitability and antagonism is the fact that the Committee on Scientists and Engineers for Federal Government Programs found that nine out of ten scientists and engineers considered that pay should reflect substantial differences in quality of work performed, something not permitted by the Classification Act or by many other job evaluation systems.

In arriving at his conclusion, the writer was not unmindful that Chaffee attributed to mental laziness and the lack of an organized demand the fact that job evaluation had not (by 1950) really developed for creative engineering, though Chaffee's own work indicated the technical feasibility of such application of job evaluation. So also Sykes, who saw merit in each of the two concepts and appeared to lean toward the Classification Act for areas he had considered.

10. *Conclusion: Rank-status should not carry the connotation of "unlimited license for administrative indiscretion."* It should not be thought of as the discredited system that was not uncommon at the turn of the century which saw the owner-manager's son "start at the bottom and rise to the top" in three or four years. In each of the plans studied there was some form of control over the exact salary to be paid to an individual scientist or engineer. Pay at a stated number of years beyond his last degree was found to be used as a guide for individual salaries at the Mellon Institute of Industrial Research and as a control measure for total salary expenditures at the Los Alamos Scientific Laboratory.[21] At the latter laboratory, since it was engaged on government work, there was also a review control exercised by the Atomic Energy Commission to see that individual salaries did not become absurd. The British scientific service, operating under the principle of "fair comparison" with industry pay for comparable work, has controls upon salary decisions made by agency boards and officials through two means. The first is the existence of salary standards with Civil Service Commission review and approval of entrance salaries above the normal rate. The second is the Treasury review and approval of recommendations for special merit promotions of outstanding individual workers. The scientist officer class of the Public Health Service commissioned officer corps has over-all controls established in congressional legislation and comparable to the military pay system. Its uniqueness stems from the effectiveness of the sophisticated modern techniques used in evaluating personnel for appointment, promotion, and selection-out, and from the fact that the techniques are used by other scientist officers—sometimes in board actions where other members of the board may be from commissioned officer classes other than the scientist officer class.

In the Department of Defense and in the Public Health Service strong accent upon rank-status exists in determining the salaries of those scientists and engineers whose positions come within the purview of Public Law 313, 80th Congress (1947), and Public Law 692, 81st Congress (1950), respectively. With initial control invested in the operating agencies, the Civil Service Commission has review authority over the particular salary to be paid to an individual, including the final determination by that body as to the qualifications of an incumbent or proposed incumbent of a specific position. These public laws were approved with the intention that they would be "in accord with" the compensation schedules of the Classification Act of 1923, as amended, specifically with section 13 which described the then existing grade levels and which prescribed the pay rates for those grades. Although the preliminary review within the Civil Service Commission considers the grade in which the position would be placed, were it under the Classification Act, the ultimate decision of approval or denial of the agency recommendation is based typically on the Commission review of matching the qualifications of the individual with the assigned duties and responsibilities.

[21] Pay at stated ages used at Mellon Institute.

It was learned that in the Canadian civil service the technique for determining the salary of scientists and engineers is a position classification plan but that the control exercised by Treasury is flexible enough to permit it granting salaries above the stated range of salaries for the classification of the position when there are exceptional circumstances.[22] Another recent step toward the principle of recognition of the man in the job, rather than the job alone, was the setting up of some 300 different titles into three classes for the purpose of achieving greater flexibility of personnel and to enable a man to receive the salary that he is worth without always relating his job to a particular classification.[23]

11. *Conclusion: The concept of rank-status or rank-in-the-person—rather than rank-in-the-position—is used successfully as the basis for salaries of scientists and engineers in the organizations of high repute which were studied.* In nongovernmental organizations such as the Los Alamos Scientific Laboratory and the Mellon Institute of Industrial Research and the Battelle Memorial Institute rank-status has been the basis for pay plans that have been used effectively for many years. The British scientific service is based upon this principle as part of its integrated career service. The Public Health Service Commissioned Officer Corps used many of the principles of rank-status, though the specific salaries paid are within the framework of the military pay schedules. Both Public Law 313 positions and Public Law 692 positions have principles of rank-status firmly imbedded in the basic law. The Classification Act of 1949, as amended, is still basically the Classification Act of 1923 with respect to the principle under study. It disregards the qualifications of the "person" except insofar as they are requirements for minimum satisfactory performance of the work described for the "position." No account is taken of unusual qualifications of a scientist or engineer for the position which he is filling.

[22] Personal interview with David M. Watters, Secretary of the Treasury Board, Department of Finance, Ottawa, Canada, May 6, 1957.

[23] Personal correspondence from David M. Watters, October 16, 1957.

12. *Conclusion: A significant practice that was found in most of the rank-status type pay plans for scientists and engineers that were studied was an "evaluation by one's peers."* This practice was found frequently in some form of group appraisal of the scientist or engineer as one of the techniques used in achieving a final determination as to compensation. Although the evaluation methods varied greatly in the degree of sophistication of the process, the significance probably lay as much in the psychological value of the evaluation by one's peers as in the technical results.

13. *Conclusion: Sophisticated systems for evaluating men and jobs are useful to management but should supplement, rather than be a substitute for, the considered judgment of responsible research and development administrators.* Sophisticated systems of job evaluation (e.g., the Classification Act of 1949) are of relatively greater use at the lower levels of scientific and creative engineering work than for the higher levels and they are progressively of less use the more the work proceeds from the routinized or regularized toward the unknown. As Worthy has succinctly expressed it, when referring to executives, rather than to scientists or engineers, "As to methods of determining a man's contribution, I think there is no substitute for executive judgment." And as to measure of the men themselves, "... techniques of this kind [test batteries] cannot be used in isolation nor as a substitution for executive judgment. They can, however, be an excellent means for helping sharpen executive judgment."[24]

14. *Conclusion: Scientists and engineers generally favor having their salaries include considerations of their individual backgrounds of education and training and their contributions to the program.* They are particularly antagonistic toward the practice of having their pay based solely upon a position description—in part because the description so often bears relatively little resemblance to what the incumbent actually does or what he must actually know.

15. *Conclusion: Scientists and engineers*

[24] Personal correspondence from James C. Worthy, March 19, 1957.

usually favor having their contributions to the research and development programs judged by persons with generally the same backgrounds as they themselves have. Scientists and engineers usually believe that a person who is untrained in a particular field of knowledge or work cannot classify positions in that area as well as if he were trained in that work area. As in other controversial matters, there are extreme opinions on both sides of the question. A view frequently held was described in the report of the Committee on Engineers and Scientists for Federal Government Programs as, substantially, that eleven out of twelve Federal scientists and engineers believed that a person could not classify satisfactorily jobs in a professional field unless he were trained in that field. When scientists evaluate scientists they frequently have their own particular disciplines represented. This is found in the provisions of the Public Health Service Manual for the use of the advice of groups of peers in the making of recommendations for the appointments and salaries of scientists under Public Law 692. It is also found in the interview boards used in the Public Health Commissioned Officer Corps and in the panels for fellowship awards by the American Academy of Science.

16. *Conclusion: Rank-status pay plans are more acceptable to management than is the Classification Act of 1949, as amended,* even though controls in the use of rank-status practices are exercised by some level above the laboratory or office concerned. The various writings examined and testimony read indicated to the writer that it is now quite generally recognized that in Government, as well as in most industrial situations, there are few persons, indeed, who make unreviewed and unreviewable decisions in regard to salary and status matters.

17. *Conclusion: The Classification Act of 1949 and its administration often exert a degree of domination over the legitimate needs and desires of management to the extent that operating officials resort to unethical practices in an attempt to escape such domination.* Along with the growth of "scientific management" during the 1920's came the dependence upon classification specialists for carrying out most of the administration of the Classification Acts of 1923 and 1949. Management rather willingly abdicated to what has become an "elite corps of classifiers,"[25] to use the characterization of the Cordiner Committee. Emphasizing mechanics and process rather than the people in the position, the administration of the Act gradually resulted in a separateness from line management of the process and the classification personnel which in some cases was absolute. Position classifiers either made final grade level decisions themselves or served as staff to another staff man, rather than to line management. They were "on top" rather than "on tap" as staff assistance to line management. This dominance appears to the writer to have reached full-flowering in the Federal Government about the end of the Korean conflict.

It frequently happens that an administrator can not increase the salary of a scientist or engineer whose position is under the Classification Act unless he can "rewrite" a position description that will get a higher classification. Because of this, the administrator may covertly or overtly encourage distortions in descriptions of duties. A contest between an administrator's skill at writing descriptions and a classifier's skill in ferreting out the facts through work audits often results in disharmony that injures both the work program and the classification program. Even when harmony persists there may be intense distrust on each "side." Under such situations, position descriptions may degenerate into "job sheets" which are merely exercises in dissimulation. It is not unusual, therefore, to find that the "job sheets" are not believed either by the man who wrote them or by those who read them.

In this connection it is recognized that there is often a broad "zone" within which it is difficult to determine whether the exaggerations and misleading statements of many position descriptions are not only un-

[25] Defense Advisory Committee on Professional and Technical Compensation, Civilian Personnel. Vol. 2 of "A Plan of Action to Attract and Retain Professional, Technical, and Managerial Employees for Defense." Tab. J of Vol. 2 (of Vol. 2), "Problems of Salary Administration Under the Classification Act," by Study Group II, p. 3. Washington, 1957.

ethical practices but are also illegal practices of falsification of a Government pay record.

The writer has concluded that if administrators and employees together resort to unethical practices, the position classifier can usually only delay the action sought by the administrator but can seldom prevent the action from eventually taking place—even though it takes a paper reorganization to accomplish it.

RECOMMENDATIONS

1. The present importance of attracting and retaining qualified scientists and engineers in research and development calls for the utmost in Congressional leadership in authorizing the use of rank-status plans. It also calls for the utmost in administrative leadership and skill in developing and administering one or more rank-status pay plans for the higher level scientists and engineers that will be acceptable to the scientist and engineer and to management. Such plans must meet the American philosophy of pay based upon what the employee is worth to the government organization which hires him. The "worth" of a scientist or engineer should be viewed as the contribution toward the end result or program accomplishment rather than as "equal amount of work" or "equal assignments."

2. The Civil Service Commission should encourage agencies to make more of the agency classification decisions (for positions under the Classification Act of 1949) at top levels of line management rather than in the personnel staff office. The emphasis should be on extensive and intensive use of personnel administrators and technicians as consultants participating in the discussions leading to line management decisions. The Commission should also give added stimulus to constructive interpretation by scientists and engineers of the Classification Act of 1949, as amended, both in development of sound classification standards and in the application of those standards.

3. Legislation should be sought which would:

a. Provide for a Research and Development Corps, outside of the existing Classification Act, in which would be placed the positions of scientists and engineers engaged in research and development, which are now under Public Laws 313 and 692 or which are under the Classification Act of 1949, as amended, at levels above grade GS-15, the pay schedule of this corps to have a minimum and a maximum rate that are at least as high as those currently existing under Public Law 313, but to have no specified pay steps within the range. Provision should be made that positions not initially to be placed under this corps would be eligible for such status upon review and approval by the Civil Service Commission that each position so recommended by an agency was above the level that is characteristic of grade GS-15 under the Classification Act of 1949. It is proposed that there be no statutory ceiling placed upon the numbers of such additional positions.

A case could be made for inclusion of all levels of professional scientists and engineers in the proposed corps.[26] Initial limitation, however, is believed to be more useful, through inclusion of only those whose salaries are above the salaries of the equivalent of GS-15. The proposed corps would thus cover the levels where rank-status is most needed from the standpoint of salary determination. These same levels are where recruitment and retention of the highest caliber personnel would be the most profitable in terms of the personal contributions of the scientists and engineers to the substantive aspects of research and development programs and of their effect as lodestones in drawing junior scientists and engineers of promise into government organizations. This limitation would reduce some of the serious criticisms that would come from employees in other occupations whose pay would continue to be fixed under the Classification Act of 1949, and from other interested parties such as Members of Congress, the Civil Service Commission, and others who would resist any attempt to remove such a large group of positions from the operation of the Classification Act.

[26] See particularly Belsley, G. Lyle, *Notes for the Hoover Commission Personnel Task Force on subject of rank-in-the-person* (written presentation to the task force dated March 5, 1954), pp. 2, 3. (Typewritten.)

b. Place the determination of salary levels for individual positions of the Research and Development Corps upon the executive department or agency authorized to have such positions. The agency should be required to file with the Civil Service Commission a plan of administration of this program which would utilize the concept of a board of professional scientists and engineers to make individual salary determinations or recommendations to the head of the agency. Provision should also be made for agencies to change their plans when they see fit, and to file the revised plan or a new plan with the Commission within 30 days after adoption.

The determinations as to salary for an individual should not be subject to disapproval or change by any authority outside the agency. As part of the salary determination process under the professional peer concept proposed, provision could be made for nonvoting participation by a representative of the Civil Service Commission. This representative could be required to file with the agency head any disagreement with a salary decision of the board. The agency also might well be required to transmit such statements to an appropriate committee of the Congress annually, with agency comments, if the agency chooses to make any. So also, the Civil Service Commission could be required to make annual reports to the same committee concerning its findings as to over-all administration of the plan by agencies that are operating under it.

c. Reduce the number of grades of the Classification Act of 1949 to provide for greater rate ranges within the grades to which positions of the scientists and engineers in research and development would be assigned if not coming within the purview of the Research and Development Corps pay schedule. Theoretically this would cover the levels from the present grade GS-5 through grade GS-15. The broader zones would reduce the number of border-line controversial cases which often create friction between line personnel and position classifiers.

d. Revise the Classification Act of 1949 by abolishing specific step rates and provision for periodic step increases for grades GS-13, GS-14, and GS-15. Substitute for those provisions salary increases on the basis of not more than one per year and make the amount of increase to be not less than, say, $250 a year or more than one-half the difference between the minimum rate of the grade and the maximum rate.

e. Provide for an independent and nonpartisan advisory body of scientists and engineers and public-spirited citizens to study the operation of the pay systems for scientists and engineers that are covered by these recommendations, to study the need for an integrated career corps of such scientists and engineers (a collaborative study with operating agencies), and to report to the President its findings in these and related matters. It is proposed that the study be limited to the scientist and engineer areas because of the present critical situations in these areas and because different problems exist in other areas.

4. Additional study by individuals or committees could produce useful information and recommendations on areas that are closely related to, or intertwined with rank-status pay plans for scientists and engineers, such as:

a. The possibility that entrance to a proposed Research and Development Corps should be planned as eventually beginning at a level lower than that recommended for immediate action.

b. The national effects, favorable and unfavorable, of changing the salary basis for scientists and engineers in research and development to fair competition with nongovernmental activities, either on a local or a national prevailing rate basis.

c. The extent, if any, to which the national interests make it desirable to provide a special pay raise under existing pay plans for scientists and engineers that would be different from the amount of any raise for other groups.

d. The practicability of decentralizing to agencies the authority currently residing in the Civil Service Commission to pay new recruits and present employees above the minimum step of the grades—making it on the basis of agency need and occupational specialty rather than on the broad occupational coverage that is now used.

SELECTED REFERENCES NOT CITED IN TEXT

Advisory Committee on Natural Scientists. *Reports of the Advisory Committee on Natural Scientists.* Documents and Reports to Accompany the Report on Civil Service Improvement **1.** Government Printing Office, Washington, 1942.

American Assembly. *The Federal Government service: Its character, prestige, and problems,* Sixth American Assembly, Arden House. Columbia University, New York, 1954.

Belsley, G. Lyle. *Notes for the Hoover Commission Personnel Task Force on subject of rank-in-the-person,* 11 pp. (Typewritten, dated Washington, D. C., March 5, 1954.)

Brown, Alvin. *The armor of organization: A rational plan for the armed forces and, as a preliminary thereto, an inquiry into the origins of existing military organization.* Hibbert Printing Co., New York, 1953.

Burgess, Carter L. *Similarities and contrasts in military and civilian career services.* Personnel Admin. **18** (September): 16–23. 1955.

Bush, George P. *The principles of administration in the research environment.* Ch. 23 of "Scientific Research: Its Administration and Organization," George P. Bush and Lowell H. Hattery, editors. American University Press, Washington, 1950.

Committee on Engineers and Scientists for Federal Government Programs [Young Committee]. *Survey of attitudes of scientists and engineers in government and industry.* Government Printing Office, Washington, 1957.

Corson, John J. *Executives for the Federal service: A program for action in time of crisis.* Columbia University Press, New York, 1952.

Defense Advisory Committee on Professional and Technical Compensation. *Civilian personnel.* Vol. 2 of "A Plan of Action to Attract and Retain Professional, Technical, and Managerial Employees for Defense." 2 vols. and 2 separately numbered appendices. [Cordiner report.]

Department of the Army. Office of the Deputy Chief of Staff for Personnel. Office of Civilian Personnel. *Survey of civilian personnel management: Engineers and scientists in research and development activities, May–October 1956.* 38 pp. and appendix. Department of the Army, Washington, 1956.

Drucker, Peter F. *Management and the professional Employee.* Harvard Bus. Rev. **30** (May–June): 84–90. 1952.

Frost, Connie Curtis. *Supplementing pay with recognition.* Personnel Admin. **19** (November–December): 18–20. 1956.

Graham, George A. *Significant personnel practices in business organizations.* (In Vol. 3 [no title] of "Documents and Reports to Accompany the Report on Civil Service Improvement," pp. 60–63. 3 vols.) Government Printing Office, Washington, 1942.

Grand, Joseph A. *Manpower crisis in Federal labs.* Chem. and Eng. News (April 1): 26–28. 1957.

Hensel, H. Struve. *Ways and means of recruiting capable Federal executives.* Public Admin. Rev. **13** (Spring): 129. 1953.

Howell, William F., and Fowler, Donald D. *Personnel programs of international organizations.* Public Personnel Rev. **17** (October): 281–287. 1956.

Interdepartmental Advisory Committee on Scientific Personnel. *The scientist as a government employee.* [U. S. Civil Service Commission, Washington 1947.] (Mimeographed.) [Trytten report.]

Miller, Delbert C., and Form, William H. *Industrial sociology: An introduction to the study of work relations.* Harper & Brothers, New York, 1951.

Mosher, Frederick and Edith. *Distinguishing marks of the Federal Government service.* "The Federal Government Service: Its Character, Prestige, and Problems," Sixth American Assembly, Arden House, pp. 113–151, Columbia University, New York, 1954.

Patton, Arch. *Incentive compensation for executives.* Harvard Bus. Rev. **29** (September): 35–46. 1951.

Reimer, Everett. *The case against the senior civil service.* Personnel Admin. **19** (March–April): 31–40. 1956.

Shepherd, Clovis, and Brown, Paula. *Status, prestige, and esteem in a research organization. Admin. Sci. Quart.* **1** (December): 340–360. 1956.

Somers, Herman M. *Some reservations about the senior civil service."* Personnel Admin. **19** (January-February): 10–18. 1956.

Steelman, John R. *Administration for research.* (Vol. 3 of "Science and Public Policy." Prepared with the assistance and counsel of the President's Scientific Research Board. 3 vols.) Government Printing Office, Washington, 1947.

The Editor's Say ... Executive development conference debates the senior civil service." Personnel Admin. **19** (January–February): 2, 3. 1956.

Urwick, Lyndall F. *Management education in American business.* American Management Association, New York, 1954.

U. S. Commission on Organization of the Executive Branch of the Government. *Personnel and civil service: A report to Congress.* 101 pp. Government Printing Office, Washington: 1955. [Hoover commission.]

Wengert, E. S. *Rethinking the personnel mission.* Public Personnel Rev. **11** (October): 210–216. 1950.

ENTOMOLOGY.—*A new subfamily, genus, and species of Lygaeidae (Hemiptera-Heteroptera) from Australia.*

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(Received December 15, 1958)

The present paper designates a new subfamily of bugs in the very large and heterogeneous family Lygaeidae to hold a remarkable species and genus described as new herein from Australia. The type series of 24 specimens of the new species were all collected by the Australian hemipterist Henry Hacker in Queensland.

Since the hierarchal characters of the undescribed species were found inapplicable for its inclusion in any of the present subfamilial taxa of Lygaeidae, it has been necessary to erect a new genus and new subfamily for its reception. These new categories are being named in honor of the lygaeid specialist Dr. James A. Slater, who is now engaged in classifying and cataloguing this family of insects for the world.

In their comprehensive check-list of the families and subfamilies of Heteroptera, China and Miller (1955) recognize 15 subfamilies in the family Lygaeidae. The fundamental subfamily classification of Lygaeidae was established by Stål (1862, 1865, 1872) and has remained essentially the same except for the addition of five subfamilies by Berg (1879), Reuter (1878) Douglas and Scott (1865), Breddin (1907), and Barber and Bruner (1933). Additional subfamily characters have been developed by Hutchison (1934), Slater and Hurlbutt (1957), Ashlock (1957), and Scudder (1957). Analytical keys to the subfamilies of Lygaeidae for various regions of the world may be found in the publications of Stål (1862, 1865, 1872, 1874), Walker (1872), Saunders (1892), Barber (1917), and Stichel (1925, 1957).

For many helpful suggestions and advice on phylogeny and classification, we wish to express our sincere thanks to the following hemipterists: Dr. W. E. China, British Museum (Natural History), London; Dr. J. Carayon, Muséum National d'Histoire Naturelle, Paris; Dr. J. A. Slater, University of Connecticut, Storrs, Conn.; and Dr. R. I. Sailer, H. G. Barber, and P. D. Ashlock, all of the U. S. Department of Agriculture, Washington, D.C. The illustrations were prepared as follows: Figure 1 was drawn by Arthur Smith, artist, British Museum (Natural History), London; the photograph of figure 2 is by Dr. J. Carayon, Muséum National d'Histoire Naturelle, Paris; the remainder were prepared by the junior author.

MORPHOLOGY

In order to determine accurately the characteristics and systematic position of this insect, the following detailed analysis of its morphology has been made:

Head: The general shape of the head may be characterized as being distinctly broad and short and moderately declivent (Figs. 1, 3). The compound eyes are strongly protruding and widely separated and have rather coarse facets. The eyes are almost contiguous with the thorax. The ocelli are present. The tylus is narrow and strongly produced anteriorly, while the juga are short, flat, and inconspicuous. The bucculae are well developed and open in front, extending back over about a third of the ventral surface of the head. The beak is 4-segmented and straight and reaches to just beyond the procoxae. The antenniferous tubericles are moderately small, and the antennae are short and 4-segmented. The small segments are rather thick and subcylindrical except for the last segment, which is fusiform (Fig. 4).

Thorax: The prothoracic coxal cavities are closed posteriorly (Fig. 6), and the pleural suture is distinguishable only on the prothorax. The meso- and metathoracic sterna are fused, but the intersegmental suture is distinct. There are well-developed scent gland ostioles (SgO) on the metathorax. Internally the metathoracic scent gland consists of a median, unpaired, reservoir (Fig. 10, SgR) into which lateral, branching scent glands open (Sg). The afferent ducts of the scent-gland reservoir pass through the base of the metasternal apophyses to their external opening in the scent-gland ostioles. The structure of the scent gland is essentially the same as is found in other lygaeids as well as in most other families of Pentatomorpha except the aradids.

The metacoxal articulation is the trochalopodous type. The tarsi are 3-segmented (Figs. 7, 8, 9), the second segment being small and incompletely fused to the third; arolia are present.

Wings: The clavus and corium are distinct, and the membrane appears to have a reticular pattern of venation (Figs. 1, 2). However, there are five distinct longitudinal veins extending through the membrane, and the reticulation has probably developed secondarily. The second and third longitudinal veins are in some cases partly coalesced at the base (Fig. 1), and in others they are entirely separate.

The metathoracic wing venation is greatly reduced (Fig. 11). The terminology used here for the veins follows that of Leston (1953) and of Slater and Hurlbutt (1957). The subcosta is absent; the radius (R) is well developed; the hamus is not distinguishable except possibly as a broad, indistinct veinlike thickening between R and Cu near the base of the wing. The distal branch of the media from R, characteristic of the pentatomorphs, is in this insect only a small stub. The cubitus (Cu) is distinct and is followed by the bifurcate vanal furrow (VF). The intervanal veins are absent, and the vanal veins (V) are present and fused basally. The so-called jugum is absent.

Abdomen: The first abdominal segment is reduced in a manner characteristic of Heteroptera, and thus only the median tergite of that segment can be distinguished (Fig. 12, I). Segments II through VII are distinct, and all the pregenital terga are fused to one another except for tergites II and III, between which there remains an intersegmental membrane. On the venter of the abdomen the second, third, and fourth segments are fused, but the intersegmental sutures are distinct (Fig. 13). The remaining segments are free ventrally. The connexiva are distinctly formed, and the dorsal connexival sutures are modified into convoluted membranes (Fig. 12, CxM) which enable dorso-ventral expansion and contraction of the abdomen. The ventral connexival sutures are very indistinct (Fig. 13). The first abdominal spiracles are apparently absent; spiracles II through VI are dorsal on the connexivum (Fig. 12), and spiracle VII is ventral on the connexivum (Figs. 13, 19). Spiracle VIII of the female is also ventral and is normally concealed under the seventh segment (Fig. 14); the eighth spiracle of the male is absent. Two closely set pairs of trichobothria are found on the venter of segments III and IV; a widely separated pair is found on each side of the fifth and sixth segments near the connexival suture, and a single trichobothrial hair is found on each side of the seventh segment (Fig. 13). Scars of the nymphal scent glands are present between tergites IV and V, and V and VI (Fig. 12, Sg).

Female genitalia and genital segments: The eighth and ninth tergites are compressed ventrad and lie in an almost vertical plane, and the tenth segment is reduced to a small tubular sclerite projecting from beneath the ninth tergum (Fig. 14, X). The seventh segment is very deeply cleft

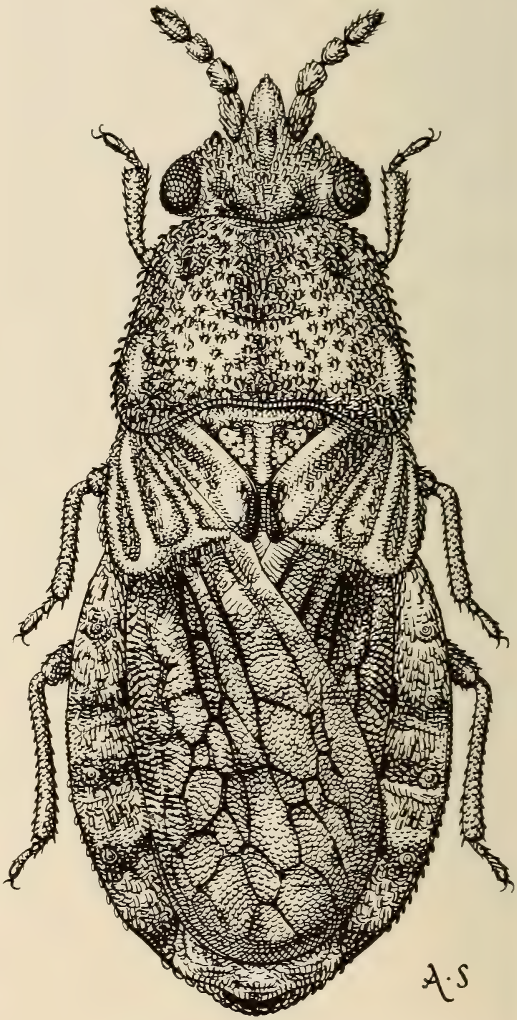


FIG. 1.—*Slaterellus hackeri*, n. gen. and sp.

mid-ventrally and normally overlaps the base of the ovipositor (Fig. 13, VII). When the ovipositor is in use, its anterior end is extended downward and posteriorly into the position shown in Fig. 14. This manner of extension of the ovipositor is especially characteristic of the lygaeids. In this extended position the gonocoxopodites (valvifers) of the eighth segment are seen to be large triangular sclerites (Fig. 14, Gcp 1). The gonocoxopodites of the ninth segment are not shown but are considerably reduced and lie beneath the ventral margins of that segment. The gonapophyses (valvulae) of the eighth segment extend from the anterior apex of the gonocoxopodites and are joined ventrally by a membrane (Fig. 14, Gap 1). The first gonapophyses are also attached to the ventral margins of the ninth paratergites by means of sclerotized rods, the inner rami, extending from their base (not shown). The second gonapophyses are joined for most of their length and are united to the first gonapophyses by the usual tongue-in-groove mechanism found in the heteropteron ovipositors. The third gonapophyses (= styloids of Dupuis, 1955) although usually present in other Hemiptera, can not be distinguished.

Internally the female genital chamber consists of a simple cuticular sac. Posteriorly its lumen extends into the ovipositor, and the common oviduct extends from it anteriorly. Arising from the roof of the genital chamber there is a complex tubular gland, the spermatheca (Fig. 15). At the base of the spermatheca the roof of the genital chamber is differentiated into a pouch-like structure with a groove extending posteriorly from it. This structure possibly functions to direct the vesica of the phallus (see below) into the spermatheca during copulation. The spermatheca consists of a double tube, the *ductus receptaculi* (DR), at the end of which is a distinctive chamber, the *capsula seminis* (Ca S). Various studies of other Heteroptera show that the spermatozoa are retained in the seminal capsule. The distal portion of the duct is sclerotized (PI) and is possibly equivalent to what has been termed the *pars intermedialis* in the pentatomid spermatheca (Dupuis, 1955). The proximal end of this structure is encircled by a ridge which presumably serves for the attachment of muscles extending from it to the lower rim of the seminal capsule. In the lumen of this duct there is a second and much narrower duct which also

FIG. 2.—*Slaterellus hackeri*, n. gen. and sp.

extends from the genital chamber to the seminal capsule.

Male genitalia and genital segments: The eighth segment of the male is reduced considerably, and only the ventral portion of it is sclerotized (Fig. 19, VIII). This segment and the ninth, or *pygophore* (Pg), are normally retracted compactly into the seventh segment. The tenth and eleventh segments are very reduced and are incorporated into the *proctager*, which lies over the top of the pygophore (Fig. 16). The parameres (Fig. 17) are symmetrical and are similar in form to those found in many lygaeids. The phallus is extremely small, and it has been impossible to obtain it in the erect condition and to study many of the details of its structure. At its base is the usual stirrup-shaped *plaque basalis*, or stapes (Fig. 18, BP). The phallus is clearly differentiated into *phallosoma* (Ps) and *endosoma* (Es), and the latter is in all probabil-

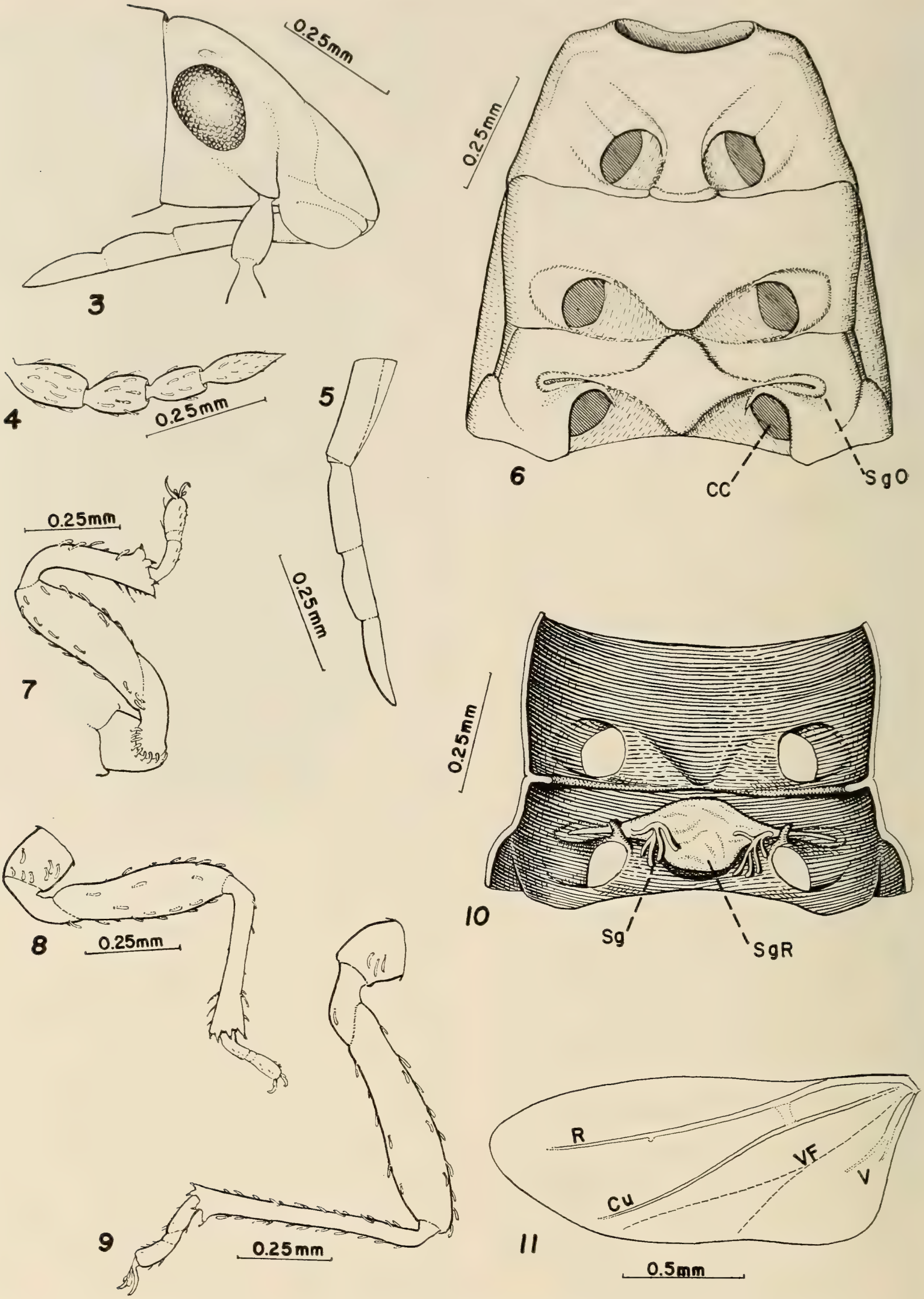
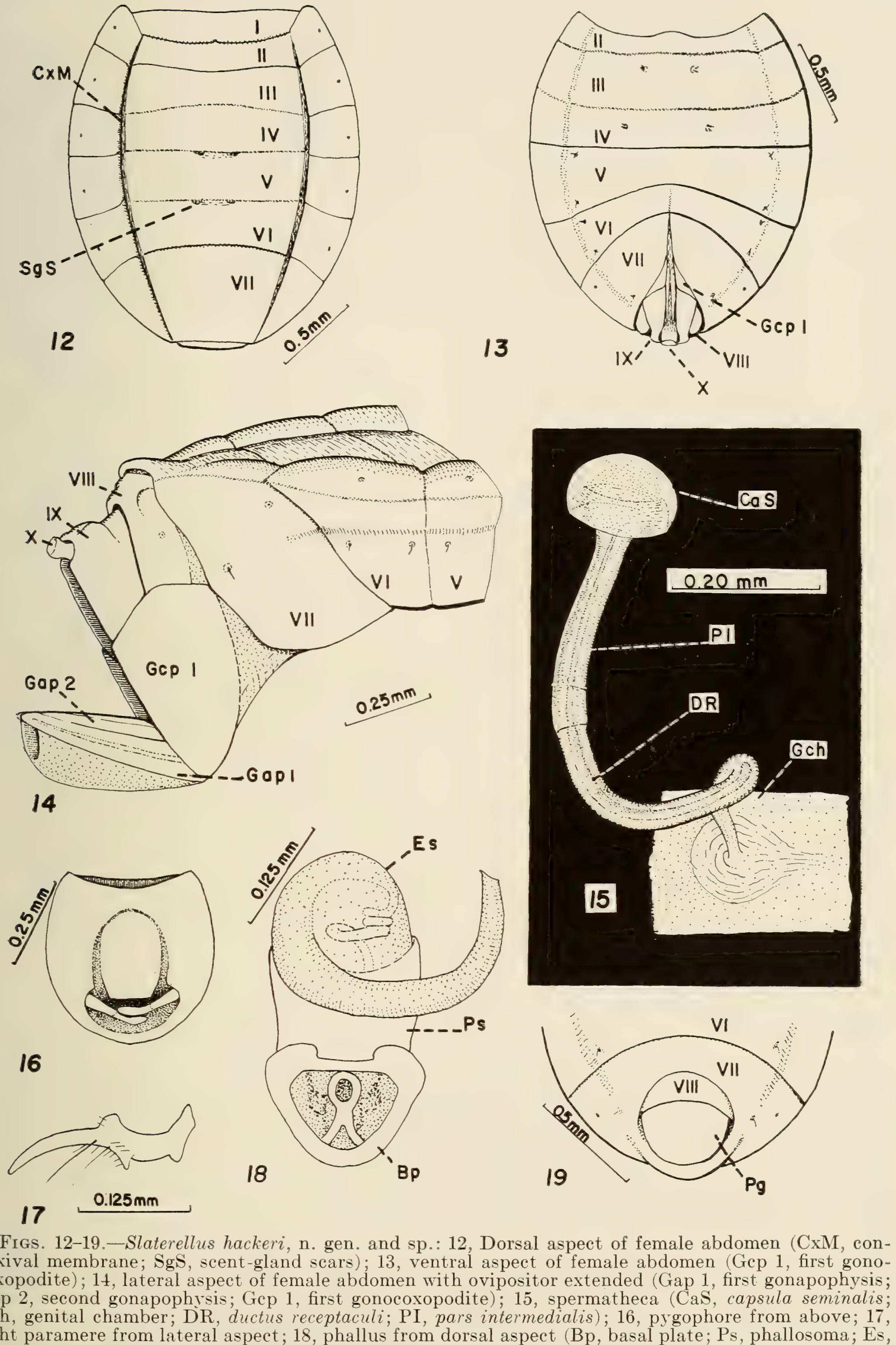


FIG. 3–11.—*Slaterellus hackeri*, n. gen. and sp.: 3, Lateral view of head; 4, antenna; 5, lateral view of labium and labrum; 6, ventral view of thorax with legs removed (CC, coxal cavity; SgO, scent-gland ostiole); 7, left prothoracic leg; 8, right mesothoracic leg; 9, right metathoracic leg; 10, internal view of meso- and metathorax showing scent-gland apparatus (Sg, scent gland; SgR, scent-gland reservoir); 11, metathoracic wing (Cu, cubitus; R, radius; V, vanal veins; VF, vanal fold).



FIGS. 12–19.—*Slaterellus hackeri*, n. gen. and sp.: 12, Dorsal aspect of female abdomen (CxM, connexival membrane; SgS, scent-gland scars); 13, ventral aspect of female abdomen (Gcp 1, first gonocoxopodite); 14, lateral aspect of female abdomen with ovipositor extended (Gap 1, first gonapophysis; Gap 2, second gonapophysis; Gcp 1, first gonocoxopodite); 15, spermatheca (CaS, *capsula seminalis*; Gch, genital chamber; DR, *ductus receptaculi*; PI, *pars intermedialis*); 16, pygophore from above; 17, right paramere from lateral aspect; 18, phallus from dorsal aspect (Bp, basal plate; Ps, phallosoma; Es, endosome); 19, ventral view of terminal segments of male (Pg, pygophore).

ity differentiated into *vesica* and *conjuctiva*. The phallosoma lacks processes.

SYSTEMATIC POSITION

The ventral trichobothria, the type of spermatheca, and the type of phallus are the principle features relating this insect to the group of families of Geocorisae designated as the Pentatomorpha (Leston, Pendergrast, and Southwood, 1954). Of the several families of Pentatomorpha this insect clearly belongs to the Lygaeidae, as is indicated by its possession of the following combination of characteristics: Ocelli present; labium and antennae 4-segmented; tarsi 3-segmented; antennae inserted below a line from the middle of the eyes to the apex of the tylus; five longitudinal veins in the membrane of the hemelytra.

This insect differs from all other lygaeids in having the longitudinal veins of the membrane irregularly connected to one another by cross-veins which form a variable reticular pattern. It also differs from all other lygaeids except the Malcinae and Chauliopinae in having a vestiture of short, scalelike hairs. However, in addition to the characteristic venation of the membrane it is unlike these subfamilies in having closed coxal cavities and in having a different arrangement of abdominal spiracles. It appears to be most closely related to the Blissinae, since it has the same pattern of distribution of abdominal spiracles as the blissines as well as having a head with similar proportions of width to length, similarly shaped pronotum, and similar characteristics of the clavus and claval commissure. The unusually short corium of this insect is also characteristic of some but not all blissines. In addition to the very distinctive vestiture and membrane venation, this insect differs from the Blissinae in lacking swollen fore-femora and in having a punctate corium and clavus.

The lack in this insect of certain additional definitive characters of other subfamilies may be noted. Unlike most Megalonotinae, the suture between segments IV and V is straight and complete, and the paired setae near the eyes are lacking. Unlike the Lygaeinae and Cyminae the hind margin of the pronotum is not convex. The sulcate tylus characteristic of most Geocorisae is lacking and unlike the Megalonotinae, Oxycareninae, Heterogastrinae, and Pachygronthinae the fore-femora are not armed.

Slaterellinae, n. subfam.

Body clothed above and beneath and on appendages with a vestiture of short, scalelike hairs; head with transocular width greater than median length, inserted into pronotum almost to eyes; eyes strongly convex, ocelli present, bucculae moderately short, high, open in front. Forefemora unarmed, not incrassate; tarsi 3-segmented and with arolia; metacoxae trochalopodous; fore-coxal cavities closed. Metathoracic scent gland ostioles distinct; pronotum not constricted into anterior and posterior lobes. Mesothoracic wings with corium short and truncate, forming approximately the basal fourth of the wing, the membrane correspondingly longer; sides of the clavus almost parallel, claval commissure short but more than half as long as the scutellum; membrane with five longitudinal veins that are irregularly connected to one another by cross-veins so as to form a variable and indefinite network. Metathoracic wings with distal branch of media vestigal, hamus reduced or absent, and with intervanal veins and jugal lobe absent. Spiracles dorsal on connexival segments II through VI and ventral to the connexivum on segments VII and VIII, and with VIII absent in the male. Segments II through IV fused but with sutures distinct and straight. Segment V and VI narrowed and segment VII completely divided midventrally in the female. In the male segment VI and VII narrowed midventrally and segment VIII and IX of the female reduced and mostly concealed beneath tergite VII. Pygophore of male concealed beneath tergite VII and with symmetrical parameres. Spermatheca of female terminating in a bulb.

Type genus, *Slaterellus*, n. gen.

Slaterellus, n. gen.

Head depressed, sloping gently forward, transocular width slightly greater than anterior width but less than posterior width of pronotum, and with tylus conical and projecting, jugum short and flat, antenniferous tubercles small, ocelli widely separated, bucculae extending backward forming very low obliquely converging carinae, eyes exserted, large, and widely separated. Antennae thick, very short, scarcely longer than the head. Pronotum depressed, punctate, with lateral margins gradually converging anteriorly, hind margin roundly excavated. Legs with second tarsal segment reduced and fused to third. Hemelytra not extending to the apex of the abdomen nor covering the connexival segments; clavus and corium sparcely punctate. Ventral trichobothria on segments III and IV consisting of two patches with a pair of closely set hairs, on segments V and VI a pair of patches on each side with a single hair, and a single patch with one hair on each side of segment VII.

Type species, *Slaterellus hackeri*, n. sp. This monobasic genus is known only from the Australian mainland.

Slaterellus hackeri, n. sp. (Figs. 1, 2)

Small, oblong, fuscous-brown tinged with grayish or testaceous, with blackish patches on head and pronotum, usually also with broad, blackish fuscous; hemelytral membrane grayish with veins fuscous. Antennae (Fig. 4) dark fuscous. Legs (Figs. 7, 8, 9) brownish fuscous with femora largely blackish fuscous. Modified hairy vestiture of body and appendages whitish. Length 2.90 mm (male), 3.34 mm (female); width 1.30 mm (male) and 1.50 mm (female).

Head wider across eyes (0.80 mm) than median longitudinal length (0.55 mm), interocular space slightly longer (0.60 mm) than median length of head (0.55 mm), apex extending slightly beyond tips of first antennal segments; eyes moderately large, strongly excerted, slightly less than half of their width extending laterally beyond front margin of the pronotum; ocelli widely separated, with space between them twice that between an eye and an ocellus. Antennae short, stout, moniliform, 0.54 mm long, subequal in length to width of vertex, segmental measurements: I, 13; II, 10; III, 9; IV, 13; (80 units equal 1 mm.). Labium moderately stout, 4-segmented, extending to base of prosternum. Bucculae very broad, very short, with cariniform bases converging sharply inward. Orifice of metathoracic stink gland plainly visible on metapleura and provided with an upright channel (Fig. 10). Legs short, stout, the anterior pair apparently subfossorial.

Pronotum trapezoidal (Fig. 1), slightly depressed, coarsely but not very closely punctate, broadly roundly excavated behind, wider across base (1.25 mm) than front margin (0.85 mm). Abdomen 1.25 mm long, widest a little behind middle; connexiva wide, very thick, moderately reflexed so as to form a fairly deep trough with abdominal tergites; hemelytra (Fig. 1) not extending to tip of abdomen or covering most of connexival segments; basal coriaceous part very short, extending less than half its length beyond apex of scutellum. Membrane overlapping apically so as to be jointly rounded behind, covering very little of connexival segments and of seventh abdominal tergite (Fig. 1). Scutellum moderately large, triangular, wider across base than median length (38:22), with median carinae and rimmed edges prominently raised. Venation of metathoracic wings as in Fig. 11. Male genitalia as in Figs. 17 and 18. Female genitalia as in Figs. 14 and 15.

Holotype (male) and *allotype* (female), Goodna, Queensland, Australia, December 12, 1926, Drake Collection (U.S. Nat. Mus.). *Paratypes:* 20 specimens same data as holotype; 2 specimens, Manjo District, Queensland, November 1927, and 2 specimens, Forest Hills, Queensland, January 1933; all collected by Hacker.

Paratypes have been deposited in the British Museum (Natural History) London; California Academy of Science, San Francisco; Muséum National d'Historie Natural, Paris; U.S. National Museum, Washington, D.C., and the collections of Drs. J. A. Slater and N. T. Davis, Storrs, Conn., and T. W. Woodward, Brisbane, Australia.

This singular species is named in honor of the eminent entomologist Henry Hacker, whose large collection of insects contains many rare and undescribed species of Australian Hemiptera.

LITERATURE CITED

Ashlock, P. D. *An investigation of the taxonomic value of the phallus in the Lygaeidae (Hemiptera-Heteroptera).* Ann. Ent. Soc. Amer. **50:** 407–426. 1957.

Barber, H. G. *Synoptic keys to the Lygaeidae (Hemiptera) of the United States.* Psyche **24:** 129–135. 1917.

———. (Continuation of the above.) Psyche **25:** 71–88. 1918.

———. *Hemiptera-Heteroptera (excepting the Miridae and Corixidae). In* "Insects of Puerto Rico and the Virgin Islands." New York Acad. Sci. **14**(3): 263–441. 1939.

Barber, H. G., and Bruner, S. C. *A new subfamily of Lygaeidae including a new genus and two new species of* Pamphantus *Stål (Hemiptera-Heteroptera: Lygaeidae).* Journ. New York Ent. Soc. **41:** 531–542. 1933.

Berg, C. *Hemiptera Argentina. Enumeravit Specieque Novas:* 1–316. Bonariae, 1879.

China, W. E., and Miller, N. C. E. *Check-list of family and subfamily names in Hemiptera-*

Heteroptera. Ann. Mag. Nat. Hist., ser. 12, **8:** 257–267. 1955.

Douglas, J. W., and Scott, J. *The British Hemiptera* **1.** Ray Society, London, 1865.

Dupuis, C. *Les genitalia des Hemipteres Heteropteres*. Mém. Mus. Nat. Hist. Nat., ser. A, **6:** 183–278. 1955.

Hutchinson, G. E. *Report on terrestrial families of Hemiptera-Heteroptera: Yale North India Expedition*. Mem. Connecticut Acad. Arts Sci. **10:** 119–146. 1934.

Leston, D. *Notes on the Ethiopian Pentatomoidea (Hemiptera): XVI, an acanthosomid from Angolia, with remarks upon the status and morphology of Acanthosomidae Stål*. Publ. Cult. Comp. Diam. Angolia **16:** 121–132. 1953.

Leston, D., Pendergrast, J. G., and Southwood, T. R. E. *Classification of the terrestrial Heteroptera (Geocorisae)*. Nature **174:** 91. 1954.

Reuter, O. M. *Note sur une nouvelle espèce d'Hemiptera*. Ann. Ent. Soc. France, ser. 5, **8:** 144. 1878.

Saunders, E. *The Hemiptera-Heteroptera of the British Islands*. London, 1892.

Scudder, G. G. E. *New genera and species of Heterogastrinae (Hemiptera, Lygaeidae) with a revision of the genus* Dinomachus. Opus. Ent. **22:** 161–183. 1957.

Slater, J. A., and Hurlbutt, H. W. *A comparative study of the metathoracic wing in the family Lygaeidae*. Proc. Ent. Soc. Washington **59:** 67–79. 1952.

Stål, C. *Synopsis Coreidum et Lygaeidum Sueciae*. Öfv. Vet.-Akad. Förh. **22:** 203–225. 1862.

———. *Hemiptera Africana* **2:** 1–200, Stockholm, 1865.

———. *Genera Lygaeidarum Europae disposuit*. Öfv. Vet.-Akad. Förh. **29** (pt. 7): 37–62. 1872.

———. *Enumeratio Hemipterorum, Pt. IV*. Svenska Vet.-Akad. Handl. **12**(1): 1–186. 1874.

Stichel, W. *Illustrierte Bestimmungs Tabellen der Deutschen Wanzen, Pt. III*. Berlin, 1925.

Walker, F. *Catalogue of the specimens of Hemiptera-Heteroptera in the collection of the British Museum, Pt. V*. British Museum, London, 1872.

It is the great destiny of human science, not to ease man's labors or prolong his life, noble as those ends may be, nor to serve the ends of power, but to enable man to walk upright, without fear, in a world which he at length will understand and which is his home. Charles Darwin did not kill the faith of mankind. He wrought mightily, and others with him, for a newer and greater faith—faith in universal order, whose secrets open themselves to men truly free to question, to communicate, and to arrive at agreement as to what they have seen.—Paul B. Sears.

ICHTHYOLOGY.—*Description of a new sandfish,* Kraemeria sexradiata, *from Japan, with special reference to its osteology.*[1] KIYOMATSU MATSUBARA and TAMOTSU IWAI, Kyoto University, Maizuru, Japan. (Communicated by Leonard P. Schultz.)

(Received November 6, 1958)

The sandfishes referred to the genus *Kraemeria* are inhabitants in the sandy shallow waters of the tropical Pacific and are by no means familiar even to ichthyologists. Remarkably enough, the members of this inconspicuous little group, attaining about 40 mm in total length, appear to exhibit a high endemism, and no one has found them before in the Japanese area.

Although the genus *Kraemeria* has been included in the family Trichonotidae or Gobiidae or sometimes placed in the independent family Kraemeriidae, their systematic position was in a state of confusion until Gosline's (1955) paper placed the family Kraemeriidae in the suborder Gobioidei based upon the results of his osteological studies.

The recent expedition to the Amami Islands, Kagoshima Prefecture, greatly augmented our limited knowledge of the ichthyological fauna of the southernmost district of Japan. Among a number of fishes collected, there were three specimens of the genus *Kraemeria* possessing sufficient distinctive characters to warrant the erection of a new species. The descriptions presented below are based on the material obtained from the sandy tide pools at Ankyaba and Usyuku, Amami Oshima, the largest island of Amami Islands.

In order to make a comparison of osteological features of the species with those of a known species, *K. samoensis*, a study of the bones of the present new species was undertaken. Counts and measurements of the bodily parts were made according to standard practice as outlined by Matsubara (1955, pp. 60–69). In the osteological examination the skeletal elements were stained with alizarin red and cleared with potassium hydroxide and glycerol.

[1] Contributions no. 1 from the Marine Biological Institute of Kyoto University. The Institute is located at Tannawa, Sennan-gun, Osaka Prefecture. It was established for our Department by the Nankai Electric Railway Co., Ltd., on March 20, 1958. We wish to acknowledge generous financial assistance from the Company.

Kraemeria sexradiata, n. sp. (Fig. 1)

SUNA-HAZE (new Japanese name)

HOLOTYPE.—MIKU (Marine Biological Institute of Kyoto University) no. 1744, a mature male specimen, 33.0 mm in standard length (38.0 mm in total length), collected in the tide pool of Usyuku, Amami Oshima, on July 10, 1958.

PARATYPES.—2 specimens, MIKU no. 1745, 30.2 and 30.5 mm (36.5 and 36.0 mm), collected in the tide pool of Ankyaba, on June 30, 1958.

Diagnosis.—*K. sexradiata* is a dwarf species, full-grown ova are found in a small female measuring 36.0 mm in total length. The body is slender and compressed laterally. The eye is very small. The lower jaw strongly projects far beyond the upper jaw. The pectoral fin consists of 6 rays, the lower 5 are branched. Scalloped flaps on the lower edge of the gill-cover number 3 to 5. In the fresh condition prior to preservation, the body is transparent. Counts and proportional measurements of bodily parts of types are shown in Table 1.

TABLE 1.—COUNTS AND PROPORTIONAL MEASUREMENTS IN TYPES OF KRAEMERIA SEXRADIATA

Items	Holotype	Paratypes	
Standard length in mm	33.0	30.5	30.2
Dorsal fin	V, 14	V, 14	V, 14
Anal fin	I, 13	I, 13	I, 13
Pectoral fin	6	6	6
Ventral fin	I, 5	I, 5	I, 5
Gill-rakers	9	—	9
Vertebrae	—	—	26
Sex	male	female	male
In standard length:			
Head length	4.1	3.8	3.8
Depth of body	8.5	6.2	8.6
Predorsal distance	3.1	3.2	3.1
Preanal distance	1.8	1.8	1.8
Length of pectoral fin	12.2	11.7	12.1
Depth of caudal peduncle	16.5	15.3	15.1
Length of caudal peduncle	16.5	16.9	16.8
In head length:			
Snout	6.7	6.7	6.7
Diameter of eye	26.7	26.7	26.7
Interorbital width	20.0	20.0	20.0
Length of upper jaw	3.8	4.0	4.2
Length of lower jaw	2.7	2.7	2.7

Description of the holotype.—Body slender and compressed laterally, without scales. Head rather broad, about twice as wide as body. Opercle relatively large and the lower edge armed with 5 scalloped flaps. Posterior margin of membranous gill-cover extending over base of pectoral. A series of minute sensory papillae present along lower edge of preopercle, upper lip fold, and mandibular fold. Small nasal tube midway between tip of snout and eye. Eye very small. Mouth moderately large and obliquely directed. Lower jaw projecting far beyond tip of upper jaw when mouth is closed. Gill-membranes extend forward and narrowly joined to isthmus before a vertical through posterior margin of preopercle. Nine gill-rakers on ceratobranchial bone of first gill-arch, but no rakers on epibranchial and hypobranchial. No gill-rakers on other gill-arches. Pseudobranchae absent. Branchiostegal rays slender and 5 in number. Small conical teeth closely set on both upper and lower jaws, slightly curved, directed inward.

Dorsal fin consisting of 5 anterior spines and 14 soft rays, the posteriormost one bilobed. First dorsal spine originating above a vertical through posterior end of pectoral. Anal fin with 1 spine and 13 soft rays, the last one bilobed. Anal spine arises below membrane between second and third soft dorsal rays. Pectoral fin rays 6, all branched except the uppermost simple one. Pelvic fin with 1 spine and 5 branched soft rays, inserted below a vertical through posterior margin of opercle. Caudal fin 6 + 7 + 6 + 6.

Anal papilla slender, the posterior tip pointed.

In fresh condition prior to preservation body and fins transparent.

Description of paratypes.—The systematic characters of paratypes generally agree with those of the holotype except for scalloped flaps on the lower edge of the opercle, the flaps being 3 in one specimen and 4 in the other.

Remarks.—In some characters this new species closely resembles *K. cunicularia* Rofen but differs in having 6 pectoral rays (8 or 9 in *cunicularia*) and slender anal papilla with pointed posterior tip (flat anal papilla with notched posterior tip). Compared with the other species, *K. nudnum, K. sexradiata* is seen to differ in the fewer number of pectoral fin rays, 6 as against 8 (Regan, 1908, p. 246), and in having the scalloped flaps on the opercle (3–5 versus none).

Although Rofen (1955, p. 182) utilized the number of scalloped flaps on the lower edge of the opercle as an important character in distinguishing the species of this group, our specimens show a rather extensive variation in this character as aforementioned.

Name.—*K. sexradiata* is named in reference to the six pectoral rays of this fish. The Japanese name Suna-haze means sand-goby, in reference to its habitat.

OSTEOLOGY

In this section the skeletal system of *K. sexradiata* is described based upon the dissection of a specimen, 30.2 mm in standard length.

Jaws (Fig. 2, A).—The upper jaw consists of a premaxillary and maxillary. There is no supramaxillary. The premaxillary is a stout bar forming the anterior half of the upper edge of the gape, and armed with about 20 small conical teeth directed slightly inward. The maxillary is a well ossified curved bone overlying the dorsal surface of the premaxillary. The posterior end reaches to the lower prong of the dentary.

The lower jaw consists of a dentary, articular and angular. The dentary is the largest bone, bearing about 23 small conical teeth on the upper surface. At the anterior end the bone strongly projects downward. Posteriorly the dentary is bifurcated, the lower prong is longer than the upper one. The articular is a slender forked bone attaching to the posterior border of the dentary

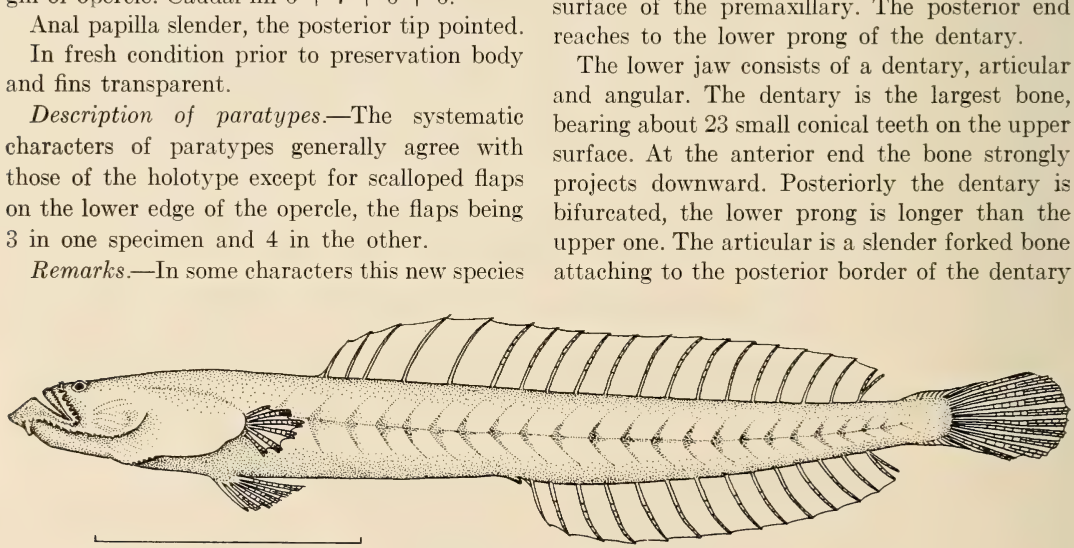


FIG. 1.—Lateral aspect of holotype of *Kraemeria sexradiata*, n. sp. Scale bar indicates 10 mm.

and abuts on the condyle of quadrate posteriorly. The lower wing of the bone becomes slenderer anteriorly and reaches to below the middle of dentary. The angular is a small heavy bone lying on the posterior end of the articular.

Suspensorium (Fig. 2, A).—The hyomandibular is roughly triangular in shape. Its dorsal border articulates along the ventrolateral margin of the pterotic. Posteriorly it articulates with the opercle by a small condyle. Anterior to the hyomandibular there extends a slender metapterygoid. The quadrate is a relatively large bone, bearing 3 projections. The first projection on the dorsal surface abuts against the pterygoid. The second one on the dorsoposterior edge meets the anterior end of the metapterygoid, and the last one on the posterior edge extends posteriorly along the dorsal border of the preopercle. The bone bears a heavily ossified condyle at its ventral corner for the articulation of the articular of the mandible. It is a remarkable fact that there is a broad interosseous space between the

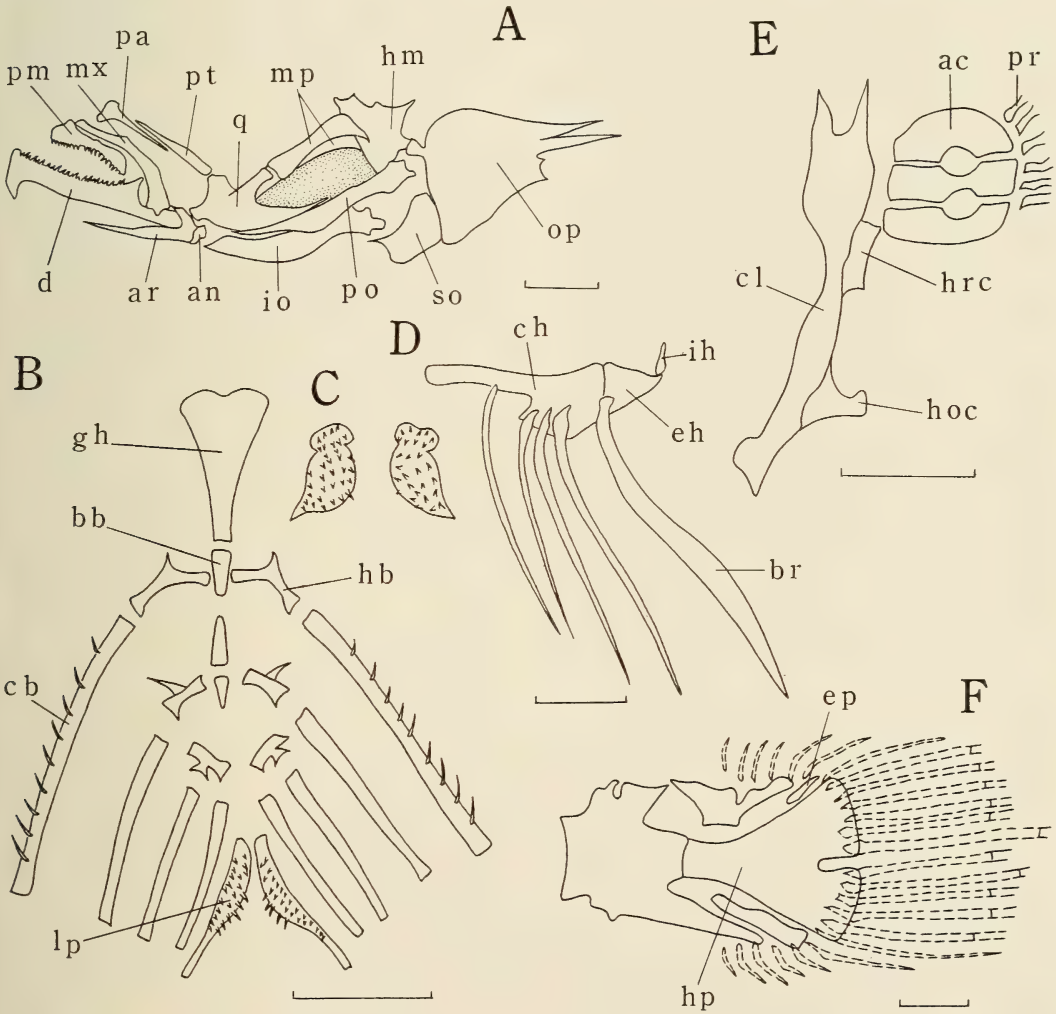


Fig. 2.—Lateral aspects of jaws, suspensorium (A), lower half of branchial arches (B), upper pharyngeal teeth (C), hyoid arch (D), shoulder girdle (E), and caudal skeletons (F) of *K. sexradiata*. (Each sale bar indicates 1 mm. *ac*, actinost; *an*, angular; *ar*, articular; *bb*, basibranchial; *br*, branchiostegal ray; *cb*, ceratobranchial; *ch*, ceratohyal; *cl*, clavicle; *d*, dentary; *eh*, epihyal; *ep*, epural; *gh*, glossohyal; *hb*, hypobranchial; *hm*, hyomandibular; *hoc*, hypocoracoid; *hp*, hypural plate; *hrc*, hypercoracoid; *ih*, interhyal; *io*, interopercle; *lp*, lower pharyngeal; *mp*, metapterygoid; *mx*, maxillary; *op*, opercle; *pa*, palatine; *pm*, premaxillary; *po*, preopercle; *pr*, pectoral fin ray; *pt*, pterygoid; *q*, quadrate; *so*, subopercle.)

hyomandibular - metapterygoid - quadrate strut and the preopercle (dotted area in Fig. 2, A).

Symplectic and mesopterygoid could not be detected, although it is difficult to manifest the absence of these bones.

The pterygoid is a thin, slender, rodlike bone lying between the quadrate and the palatine. Anteriorly it overlies the posterior portion of the palatine. The palatine is a small and edentulous T-shaped bone. Its dorsoanterior condyle articulates with the ethmoid region of the cranium with an intervention of the cartilagenous band.

Opercular series (Fig. 2, A).—All four opercular elements are present. The preopercle is a slender bone tapering anteriorly. The anterior half of it abuts against the ventral border of the quadrate. Dorsally it meets the ventroposterior border of the hyomandibular. The opercle is the largest bone among the opercular series. On the anterior edge, it bears a small condyle for the articulation of the hyomandibular. Posteriorly it is bifurcated into two sharp projections. The subopercle is quadrant in shape, and lies between the opercle and the interopercle. The interopercle, resembling the preopercle in shape, is attached to the lower edge of the preopercle.

Hyoid arch (Fig. 2, D).—The interhyal is a small bone, rodlike in shape, and capped with cartilagenous band at each end. The upper end of the bone is inserted on the proximal side of the juncture between the hyomandibular and the preopercle, and the lower end is attached to the dorsoposterior end of the epihyal. The epihyal is a flat, nearly triangular bone. The ceratohyal is a well ossified bone. The anterior half is slender, but the posterior half is abruptly expanded, being nearly as wide as long and about three times wider than the anterior half. The posterior end is sturdily joined with the epihyal. The hypohyal is not discernible.

There are 5 long branchiostegal rays, the last of which articulates with the junction between the epihyal and ceratohyal. Another 4 are set on the ceratohyal, the anteriormost one of which is attached to the slender portion of the bone and widely separated from the other 3 which are attached to the wider section.

The glossohyal is edentulous. It is a flat, fan-shaped bone having a shallow notch at the tip (Fig. 2, B, *gh*). Posteriorly it articulates with the first basibranchial.

Branchial arch (Fig. 2, B).—The branchial apparatus consists of five branchial arches diminishing in size posteriorly. The median floor of the arches is composed of 3 basibranchials which lie longitudinally behind the glossohyal. All bones are rodlike in shape. There are hypobranchials on the first three branchial arches. The hypobranchial of the first arch is a slender bone with a projection at the anterior bend, and meets the first basibranchial. That of the second arch is similar to the first bone in shape, but about half as long as the first one. The third one is modified into a small tridentate bone. There are five slender ceratobranchials decreasing in length posteriorly. Only the first ceratobranchial is armed with a single row of short gill-rakers. The fifth one is modified into the lower pharyngeal bone bearing three rows of small conical teeth, apparently separated from the fellow of the opposite side (Fig. 2, B, *lp*).

Epibranchials are present on the first three arches. Since all of these bones are not well ossified, their detailed structures are obscure. The upper pharyngeal teeth are confined to a small patch on bony plate extending on the third and fourth branchial arches. The plates on two sides are not fused together along the median line (Fig. 2, C).

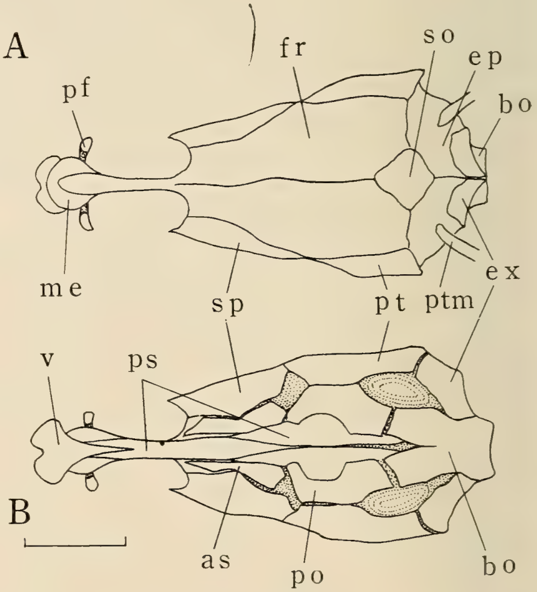


FIG. 3.—Cranium of *K. sexradiata*: (A) Dorsal aspect and (B) ventral aspect. (Scale bar indicates 1 mm. *as*, alisphenoid; *bo*, basioccipital; *ep*, epiotic; *ex*, exoccipital; *fr*, frontal; *me*, mesethmoid; *pf*, prefrontal; *po*, prootic; *ps*, parasphenoid; *pt*, pterotic; *ptm*, posttemporal; *so*, supraoccipital; *sp*, sphenotic; *v*, vomer.

Cranium.—On the dorsal aspect (Fig. 3, A), the anterior corner of the cranium is occupied with an unpaired thin bone which is thought to be mesethmoid. Anteriorly it is broadened and extends ventroanteriorly to the dorsal surface of the vomer.

The prefrontals are merely small rodlike bones on the lateral edges of the mesethmoid and not joined directly with the mesethmoid, but attached with the latter by an intervention to the cartilagenous patch.

The frontals are the largest flat bones covering a vast part of the top of the cranium. At the interorbital region, they are abruptly constricted in width and so securely fused together along the midline that the suture is not apparent on this region (Fig. 3, A, *fr*). The anterior end of the fused frontal overlies the mesethmoid. Behind the orbit each frontal expands and abuts against the sphenotic and pterotic laterally, and against the supraoccipital and epiotic posteriorly.

The dorsal surface of the sphenotic is narrowly exposed along the lateral border of the frontal.

The pterotics are slender bones lying behind the sphenotics. Each bone meets the frontal laterally and epiotic posteriorly. The latero-posterior end of the bone is pointed.

The parietals appear to be absent.

The supraoccipital is a median dorsal bone extending between the frontals and also epiotics. Its rhombic dorsal portion is well ossified. It is separated from the exoccipital by an intervention of the epiotic.

The epiotics form a portion of posterolateral edge of the cranium. The dorsoposterior part of each bone receives the anterior end of the posttemporal. The bone is bounded with the pterotic and frontal anteriorly and with the exoccipital posteriorly. Mesially it meets the counterpart of the opposite side at the midline, and separates the supraoccipital from the exoccipital.

The exoccipitals contribute to form most of the posterior surface of the cranium. They meet along the dorsal median line. Dorsally the bone slightly overlies the epiotic. In the ventral aspect they curve ventroanteriorly to meet the dorsoposterior edge of the basioccipital.

On the ventral aspect (Fig. 3, B), the vomer forms the anterior corner of the cranium. It is a fanlike bone with a rather deep notch at the tip. Posteriorly it becomes abruptly narrower, sliding under surface of the anterior part of the parasphenoid. No teeth could be found on the vomer.

The parasphenoid, running along the midline of the ventral surface of the cranium, is a long narrow bone. From near the bilobed posterior end over the basioccipital the bone widens anteriorly and sends the lateral wings on both sides extending toward the prootics. Then it becomes narrow between the orbits and the anterior end is inserted between the vomer and the ethmoid cartilage.

The median basioccipital forms the posterior end of the ventral surface of the brain case. Anteriorly, it is deeply excavated and each arm attaches to the parasphenoid and prootic. Posteriorly it is thickened to form a condyle for the articulation of the atlas.

There is no opisthotic. The portion of the otic bulla is covered by the interosseous membrane (posterior dotted area in Fig. 3, B).

Each prootic forms a suture for the alisphenoid anteriorly, for the parasphenoid ventrally, for the pterotic dorsally, and for the basioccipital posteriorly.

The alisphenoids are slender elements and they are united dorsoanteriorly under the frontals.

There is no basisphenoid.

Shoulder girdle (Fig. 2, E).—Although almost all the skeletal elements are present in the shoulder girdle, the ossification is imperfect. The posttemporal, hypercoracoid, and hypocoracoid are much reduced in size. The posttemporal is a simple strut and is bound tightly to the upper edge of the epiotic. Ventrally it articulates with the dorsal edge of the supraclavicle which is slender in shape.

The dorsal extremity of the clavicle is shallowly furcated. It extends ventroanteriorly and is forklike in general appearance.

The hypercoracoid, rectangular in shape, lies behind the clavicle. The dorsoposterior edge meets the lowermost actinost.

The hypocoracoid is roughly triangular in shape and attached to the posterior edge of the lower bend of the clavicle. It is well separated from both the hypercoracoid and actinosts.

There are 3 large actinosts with a large foramen between each of them, all of them lying a short distance behind upper portion of the clavicle (Fig. 2, E, *ac*).

No postclavicle could be recognized.

Caudal skeletons (Fig. 2, F).—All hypural bones are fused together and modified into a fan-like plate (Fig. 2, F, *hp*). It is deeply excavated at the middle of the posterior border. The suture between the urostyle and hypural plate is obscure. There is a single epural above the upper border of the hypural fan. The neural process of the urostyle is separated from the hypural plate and directed upward. There is a splint-like bone between the hypural plate and the last haemal spine. The last two vertebrae contribute to support the caudal fin rays.

There are 26 vertebrae including hypural plate.

CONSIDERATIONS AND CONCLUSION

In general, the osteological features of *K. sexradiata* agree with those of *K. samoensis* as given by Gosline (1955, pp. 158–170), with the exception of some minor points. The differences between them are as follows: (1) Gosline drew a large symplectic bone below the metapterygoid, but so far as our observations go, the bone recognized by him as symplectic appears to be a bony shelf extending from the metapterygoid. Evidence that the interhyal bone articulates with the juncture between the preopercle and the posterior end of the quadrate strongly suggests that the reduced symplectic bone, if present, may lie near this area. (2) Although Gosline stated that the alisphenoid appears to be lacking, in our specimen this paired bone is recognizable in front of the prootic. (3) Lower pharyngeals are evidently separated in our species versus they are entirely fused without suture in *samoensis*. That the individual bones of the skeletal system in such small fishes as *Kraemeria* are not sufficiently demarcated owing to unsatisfactory ossification might explain these differences.

Koumans (1931, p. 14) included the Psammichthyidae (=Kraemeriidae) in the order Gobioidea. Schultz (1941, p. 269) stated that *Kraemeria* has features that resemble the trichonotids more than the gobiids.

Gosline (1955, p. 165) placed *Kraemeria* in a distinct family Kraemeriidae and assigned the latter to the suborder Gobioidei on the basis of the following features: (1) the parietals are absent, (2) the branchiostegal rays are 5 in number, the first one of which is far separated from the others, (3) there is a broad interosseous space between the metapterygoid and preopercle, and (4) the hypural plate bears detached splint-like bone on both dorsal and ventral sides. He concluded that these features of *Kraemeria* agree with those of gobioid fishes but disagree with those of both blennid and trichonotid fishes.

Results of our osteological observation, as well as such peculiar external features as steeply projected lower jaw and scaleless body would be sufficient to justify the retention of *Kraemeria* in a separate family. On the other hand, the fishes of the genus *Kraemeria* seem to be closely related, in general physiognomy, to those of the family Trichonotidae. But, at the present, there is no adequate information on the osteological features of the trichonotid fishes, which will enable us to compare both groups. Accordingly, the decision whether the family Kraemeriidae belongs to the suborder Gobioidei or other separate suborder, should be withheld until such a time as more information becomes available concerning the anatomical features of the trichonotid fishes, although the fact that the pelvic fins are united for one-fifth the length of inner rays by a membrane in *Kraemeria tongaensis* and for their full length in *Gobitrichinotus radiocularis* (Rofen, 1958, p. 182), both of which are referred to Kraemeriidae, may support Gosline's conception concerning the allocation of Kraemeriidae to the gobioid group.

REFERENCES

Gosline, William A. *The osteology and relationships of certain gobioid fishes, with particular reference to the genera* Kraemeria *and* Microdesmus. Pacific Sci. **9**(2): 158–170, 7 figs. 1955.

Koumans, F. P. *A preliminary revision of the genera of the gobioid fishes with united ventral fins*: iv + 174 pp. Lisse, 1931.

Matsubara, Kiyomatsu. *Fish morphology and hierarchy* **1**: xi + 789 pp., 289 figs. Tokyo, 1955.

Regan, Charles Tate. *Report on the marine fishes collected by Mr. J. Stanley Gardiner in the Indian Ocean.* Trans. Linn. Soc. London, Zool. (2) **12**(13): 217–255, 10 pls. 1908.

Rofen, Robert R. *The marine fishes of Rennell Island. In "The natural history of Rennell Island, British Solomon Islands"* **1**: 149–218, 1 fig., 11 pls. Copenhagen, 1958.

Schultz, Leonald P. Kraemeria bryani, *a new species of trichonotid fish from the Hawaiian Islands.* Journ. Washington Acad. Sci. **31**(6): 269–272, 1 fig. 1941.

"NIGHT-GOWNED" FISHES

There are fish that wear "nightgowns." They are among the most resplendent of all sea creatures. They have teeth in their throats. These are the "parrotfishes," a family distributed worldwide through tropical waters where they frequent coral reefs. The first systematic zoological description of this group as a whole, by Dr. Leonard P. Schultz, U. S. National Museum curator of fishes, has recently been published by the Smithsonian Institution.

The strange practice of donning night robes before retiring, cited in the report, is an observation by Dr. Howard E. Winn, of the University of Maryalnd, and presumably is restricted to one or two species found in West Indian waters. These fishes pass the hours of darkness resting on the shallow sea bottom. They lean against rocks, arms of coral, or other stable objects. Sometimes they retire inside conch shells. But as night approaches the fish starts secreting a transparent mucous envelope from a special secretory system. It starts with the mouth and is extended backward, until the transparent envelope completely encloses the body. There is a little flap with a hole in the center in front of the open mouth. There is another small hole at the rear. The mouth flap moves back and forth as the animal breathes. The openings assure a constant flow of water around the gills, without which the animal could not live.

The entire process of nightgown-making requires from a half hour to an hour-and-a-half. It stops entirely, Dr. Winn observed, whenever light was turned on the aquarium but was resumed immediately with darkness. As the folds progress the breathing rate is reduced. The purpose of wearing nightgowns can only be surmised. The thin garments, he believes, may afford some sort of protection against nocturnal enemies. Also it may protect the body from becoming surrounded by silt.

The gown-weaving, as well as the practice of spending the night leaning against some solid object, apparently is dictated by some nervous mechanism which is set off by darkness. So far as known, the practice is unique in nature. But, as cited by Dr. Schultz, this is only one of the parrotfish curiosities. Colors, of males, become more and more brilliant as adulthood is approached, and a fully matured individual of some species is one of the handsomest denizens of the deep. Females of some species, however, may remain throughout life rather drab individuals.

"Many species," says Dr. Schultz, "pass through from one to three color phases. In general these are juvenile, in which the color may consist of two or three alternating dark and light streaks, or spots that are dark or mottled pale and dark; immature, in which the color pattern is usually some shade of red, brown, or purple; and adult, in which the color pattern seems to be reached somewhat before or at sexual maturity, with the predominating colors generally green, blue, pink, red, orange, and yellow. A few species are brownish. Some of these are females, but the males predominate in shades of green or blue and with green teeth."

Color changes, it is explained, are a factor which makes species classification quite difficult. Living in the shelter of coral banks and quite secretive in their ways of life these parrotfishes, or Scaridae, have remained among the least known of the fish groups.

Their food, for the most part, consists of algae which are scraped from the coral branches. This necessitates the so-called pharyngeal mill, or teeth in the throat, designed to crush coralline algae, coral fragments, and other food items. The upper pharyngeal teeth are paired and fit snugly against the base of the skull. The number of rows on each upper pharyngeal bone varies from one to three, according to genera. The lower pharyngeals consist of a single bone with a toothed surface. This arrangement constitutes a grinding mill operated by powerful muscle attached to the shoulder girdle and base of the skull.

Some species, Dr. Schultz points out, apparently have a very wide distribution, while others have very restricted habitats, but more collecting in numerous island groups will be required before the distribution of individual species can be determined.

Major regions where these strange animals are found are the central and west Pacific, Hawaiian and Johnston Islands, some offshore islands of the east Pacific adjacent to the American continents, west Atlantic and Bermuda, east Atlantic, the Indian Ocean, Andaman Islands, and Ceylon. There are about 80 valid species for the whole world, the report says.

COMPRESSIVE PROPERTIES OF HUMAN ENAMEL AND DENTIN

For many years the National Bureau of Standards dental research laboratory has investigated the basic properties of dental materials in cooperation with the American Dental Association and the Federal dental services. As part of this program, a study was recently undertaken by J. W. Stanford and G. C. Paffenbarger, research associates of the American Dental Association, and J. W. Kumpula and W. T. Sweeney of the Bureau staff to obtain precise data on the compressive properties of human enamel and dentin.[1] Data derived from the work will be used in evaluating dental filling materials, in designing cavity preparations, and in demonstrating physical changes in teeth.

In the past, abundant information has been compiled on the properties of restorative materials used in dentistry, but relatively few data have been published about hard tooth tissue, the foundation for these materials. An obvious explanation for this lack is the limited supply of human enamel and dentin available, and the difficulties inherent in testing small specimens. However, since a successful dental restoration depends equally on the restorative material and the tooth, knowledge of both is necessary.

In the Bureau tests of human enamel, the highest strength, modulus of elasticity, and proportional limit were obtained for specimens of cusp enamel, the tapering projections on the crown of the tooth. Intermediate values for these properties were found for specimens prepared from the sides of teeth; and lowest values for the occlusal surface or chewing part of molar teeth. Although dentin showed a higher compressive strength than did enamel, it had a lower modulus of elasticity.

The specimens used in the tests were prepared from freshly extracted teeth. Made in the shape of cylinders 0.044 inch in diameter and from 0.075 to 0.082 inch in length, they were ground from block sections of enamel, dentin and combinations of the two. All cutting and grinding operations were accomplished under a steady dripping of water on the field of cutting.

After the specimen ends were made plane and parallel, the specimen was placed upright in a testing machine between two hardened steel platens. Because of the small size of the specimens, two optical strain gages had to be fastened across the specimen length on the sides of the platens (rather than on the specimen). These strain gages were used to determine the deformation occurring in the specimens under load. In conducting the tests, the 0–1,000-pound range of a 2,000-pound-capacity testing machine was uesd to measure the loads as they were applied.

The strain measurements included errors resulting from deformations in those portions of the steel platens within the gage length, and possible non-parallelism of the platens. To evaluate these errors, tests were conducted on metals for which the moduli of elasticity are well known. Small cylinders of carbon steel, aluminum alloy, and magnesium alloy, were prepared in a manner similar to that used in preparing the tooth specimens, and were tested in compression. The results obtained with these metals were used to correct the experimentally determined moduli of elasticity of the hard tooth tissues.

Stress-strain diagrams derived from the data showed an important difference between the enamel and the dentin. The enamel, largely inorganic, showed little plastic flow in comparison with the more organic dentin. This is also shown by the data in Table 1. It was found that the more brittle enamel broke at a load slightly higher than its proportional limit, while the dentin exhibited plastic flow from its proportional limit of approximately 25,000 psi up to its compressive strength of about 50,000 psi.

Average values computed for the three enamel areas range from 1.8×10^6 to 8.2×10^6 psi for modulus of elasticity; 15,000 to 34,000 psi for

TABLE 1.—COMPRESSIVE PROPERTIES OF HUMAN ENAMEL AND DENTIN

Material	Modulus of elasticity	Proportional limit	Compressive strength
	10^6 psi	*psi*	*psi*
Enamel:			
Cusp	8.2	34,200	40,200
Side	6.0	21,200	28,200
Occlusal surface	1.8	15,400	18,200
Dentin	2.2	25,100	50,400
Dentin and enamel	3.6	23,900	34,200

[1] For further technical details, see *Determination of some compressive properties of human enamel and dentin*, by JOHN W. STANFORD, G. C. PAFFENBARGER, JOHN W. KUMPULA, and W. T. SWEENEY, Journ. Amer. Dental Assoc. **57**: 487. 1958.

proportional limit; and 18,000 to 40,000 psi for compressive strength. In tests of dentin specimens, values determined for these three properties, in the same order, are 2.2×10^6 psi; 25,000 psi; and 50,400 psi. These values for dentin are comparable to values previously found by Peyton, Mahler, and Hershenov.[2] The crushing strength of both enamel and dentin earlier reported by G. V. Black[3] is not inconsistent with the values for compressive strength derived from the present study.

[2] *Physical properties of dentin*, by F. A. Peyton, D. B. Mahler, and B. Hershenov, Journ. Dent. Res. **31**: 366. 1952.

[3] *Physical characters of the human teeth*, by G. V. Black, Dental Cosmos **37**: 353. 1895.

EXPERIMENTAL MAP PAPERS CONTAINING SYNTHETIC FIBERS

The National Bureau of Standards, in work sponsored by the Army Engineer Research and Development Laboratories, has investigated the strength characteristics of synthetic-fiber map paper. Tests for dimensional stability, folding endurance, and bursting and tearing strengths were made on specimens of three experimental handsheets and two commercially produced papers. Results show that a polyester-cellulose sheet has high dimensional stability, a prerequisite for military map paper, and better strength properties than commercial map paper. A paper containing polyamide fibers has low dimensional stability, but exceptional folding, tearing, and bursting strengths.[1]

For many years the Bureau has conducted research on the properties of paper and related materials. In previous experiments a dimensionally stable paper, that is, a paper with low moisture expansivity, was developed by laminating two thin sheets to a backing of polyester film.[2] G. L. McLeod of the Bureau staff undertook the present study to find out whether synthetic fibers with less affinity for water than cellulose could impart the desired moisture stability to map paper. Also, while cellulose is and probably will remain the backbone of the paper industry, growing interest is being displayed in the use of synthetic fibers to improve the properties of special-purpose papers.

Initial attempts to prepare handsheets from a suspension containing 100 percent synthetic fibers were unsuccessful. The sheets tore and disintegrated when removed from the mold. A suspension was then prepared containing cellulose fibers and synthetic fibers in a 1-to-3 proportion. From this suspension it was possible to produce handsheets that could be manipulated and treated with an acrylic binding agent. After treatment, the sheets were dried for 1 hour in a forced-air oven, and cured in a flat-bed press at 160°C with a pressure of 300 lb/in.^{2} for 45 seconds. The synthetic fibers in the three different handsheets were poylester, polyacrylate, and polyamide (nylon). Table 1 shows the results of tests on these handsheets compared with results obtained from all-cellulose sheets made with the same handsheet apparatus.[3]

Similar tests were conducted on machine-made paper containing 40 percent synthetic fiber, 40 percent cellulose rag fiber, and 20 percent acrylic binder. Only two of the synthetic fibers, polyester and polyamide, were used in the machine-made paper. Table 2 gives the results of these tests compared with identical tests on commercial map paper. Included in this table are the Federal specifications for map paper.

In general, test results of the handsheets and the machine-made paper follow the same pattern. The polyester-cellulose sheets are superior in dimensional stability to moisture, and have higher bursting, folding, and tearing strengths than does regular map paper. The polyacrylic-cellulose sheets, tested only in the form of experimental handsheets, are superior to the polyamide-cellulose and the all-cellulose sheets in dimensional stability but inferior to the polyester-cellulose sheets. The polyamide-cellulose paper has the lowest dimensional stability of all the papers tested, which makes it unsuitable for map paper. However, because of its exceptional folding endurance and high tearing strength, this paper map prove to be valuable for other purposes.

No difficulties were encountered in printing on

[1] For further technical details, see *Properties of some experimental map papers containing synthetic fibers*, by G. L. McLeod, TAPPI **41**: 430. 1958.

[2] *Improved dimensional stability in laminated paper*, by G. L. McLeod and Thelma L. Worksman, TAPPI (in press); and *Improved map paper*, NBS Tech. News Bull. **42**: 148. 1958.

[3] *Preparation of fiber test sheets*, by M. B. Shaw, G. W. Bicking, and L. W. Snyder, Paper Trade Journ. **90**(16): *T.S.* 69. 1930.

the synthetic-fiber papers, in either black and white, or in the regular five-color lithographic process used for Army maps. The smoothness and opacity ratings of the synthetic fiber sheets are lower than those of regular map paper, but these are minor deficiencies which can be easily overcome. That the synthetic-fiber papers have less dry tensile strength than commercial map paper is attributed to the low fiber-to-fiber bonding in the synthetics. Dry tensile strength, however, is a relatively unimportant factor in papers used for military maps.

TABLE 1.—COMPARISON OF TEST RESULTS FOR HANDSHEETS FROM BLENDS OF 75 PERCENT SYNTHETIC FIBER AND 25 PERCENT CELLULOSE FIBER WITH 100 PERCENT CELLULOSE HANDSHEETS

Tests performed	Test results			
	50–50 cotton and linen waterleaf	75% nylon	75% polyacrylate	75% polyester
Basis weight (17 × 22–500), in pounds	23.8	34.6	30.2	31.9
Thickness, in inches	0.0054	0.0118	0.0059	0.0108
Expansivity for relative humidity change between 65 and 50%, in percent	...	0.25	0.037	0.014
Folding endurance, Schopper, double folds	Approx. 1200	100,000	4260	31,600
Bursting strength, points	46	122	86	76
Tensile strength, kg/15 mm:				
Dry	25.6	6.1	5.8	4.4
Wet	2.5	2.0	1.3	3.5
Tearing strength, in grams	156	864	323	590

TABLE 2.—TEST RESULTS OF MACHINE-MADE POLYESTER-RAG, NYLON-RAG, AND COMMERCIAL MAP PAPER

Tests performed	50:50 Polyester-rag	50:50 Nylon-rag	Commercial map paper	Federal specification requirements
Basis weight (17 × 22–500), in pounds	26.2	22.6	23.7	24 ± 5%
Expansivity for relative humidity change between 65 and 50%:				
Machine direction	0.059	0.196	0.071	0.075 max.
Cross direction	0.10	0.28	0.21	0.25 max.
Brightness, in percent	83.1	82.1	71.7	70.1
Acidity, pH, hot extraction	4.8	5.7	5.0	4.5
Smoothness (Bekk), in seconds	33	8	60	50–100
Water resistance, dry indicator, in seconds	94	77	70	55
Thickness, in inches	0.0052	0.0054	0.0041	0.0042 ± 0.0005
Folding endurance, Schopper, double folds:				
Machine direction	14,300	40,000	1410	1000
Cross direction	11,300	13.500	1300	1000
Bursting strength, in points:				
Dry	49	50	50	50
Wet	46	30	30	20
Tensile strength, dry, in kg./15 mm:				
Machine direction	7.5	6.5	11.8	11.0
Cross direction	5.2	4.5	6.8	6.0
Tensile strength, wet, in kg./15 mm:				
Machine direction	5.3	3.4	4.4	3.5
Cross direction	4.2	2.3	2.8	2.5
Tearing strength, in grams:				
Machine direction	151	168	85	95
Cross direction	141	108	94	95
Opacity, in percent	75.8	67.1	93.2	91.0

[a] All figures are minimum values unless otherwise designated.

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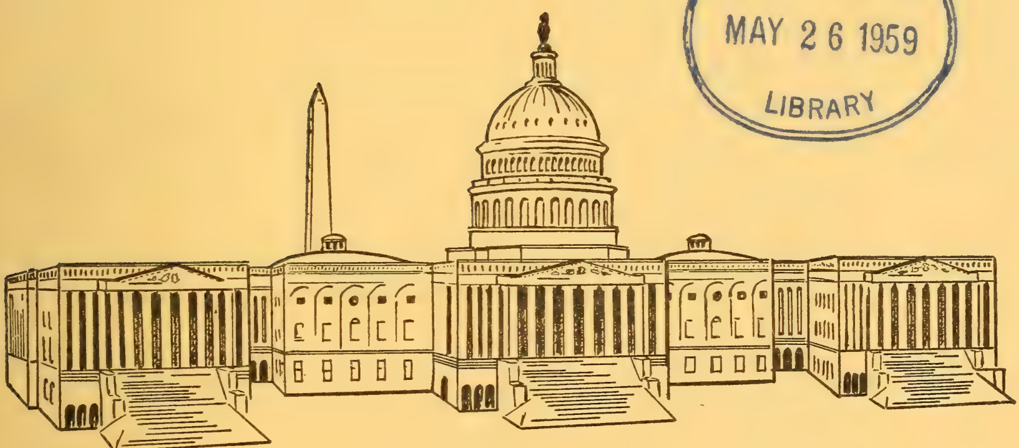

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The organization of the Membership Committee of the Washington Academy of Sciences has been altered to increase its effectiveness. The Committee now consists of seven panels, each panel representing a general field of science. Those who constitute each panel are listed below.

A nomination for election to the Academy is considered by that panel which is best suited to evaluate the nominee's record. The chairmen of the various panels meet once a month with the general chairman to consider the action of the panels. Those nominations which have been recommended for election are presented to the Board of Managers with a request for favorable action.

A change in the procedure for submitting nominations has been made. This change was adopted in order to eliminate the difficulty often encountered in obtaining complete information on a nominee's background and still maintain secrecy with regard to the nominee's knowledge of this action. The matter of secrecy has been eliminated. The potential nominee may complete the nomination application over the signatures of a sponsor and two endorsors. It may then be submitted to any member of an appropriate panel or to Mrs. Fell at the office of the Academy, 1530 P Street, NW. Nomination blanks may be obtained by calling Mrs. Fell at ADams 4-5323.

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"DE-LOUSING" SHRIMP

There is a tiny blue-and-white shrimp in the Bahamas that lives on the "lice" that infest fishes, sets up permanent de-lousing stations to which louse-plagued fish make regular visits like men to barber shops, and which advertises its places of business by swaying from side to side and vigorously waving its exceptionally long white antennae in the water to attract transient customers.

Specimens of this shrimp, discovered by Vern and Harry Pederson and collected a few months ago in the Bahamas by Conrad Limbaugh of the Scripps Institution of Oceanography of La Jolla, Calif., have just been added to the marine invertebrate collections of the Smithsonian Institution.

The phenomenon of fish de-lousing by other sea organisms often has been described and probably is world-wide. This, however, is by far the most complex case ever reported. The shrimp, as described by Mr. Limbaugh, "sets up shop" on the head of a sea-anemone, flower-like member of the coral family, whose petals are stinging tentacles. These tentacles protect the tenant from all natural shrimp predators. The anemone, in turn, cannot survive without the presence of another species of shrimp at its base.

The de-lousing shrimp cleans its fish customer meticulously from head to tail of parasitic copepods, the so-called "lice of the sea," often almost invisibly minute, which infest most marine higher organisms. It also removes other minute parasites and cuts away small patches of dead tissue. It works inside and out. The fish helps the shrimp to forage within its gill cavities, mouth, and throat by opening them one at a time as the forager approaches them. It also allows the "barber" to make minor incisions in its skin to get at parasites which have bored into the flesh.

Apparently such a shrimp always does a rushing business. The fish cleaned react to the waving tentacles by approaching the cleaner, stopping or slowing down. They even assume awkward positions, seemingly as if hypnotized. Sometimes certain varieties may change colors. Often they will fight for the right to be cleaned, or "having firsts" on the barber chair, and there are vicious battles. More docile forms crowd one another, sometimes completely obliterating the cleaner from view.

Mr. Limbaugh is engaged in an essentially world-wide study of fish-cleaner organisms. There is, he reports, considerable variation in the complexity of the phenomenon which seems to have arisen, in its various forms, over long periods of evolution. Nothing hitherto reported, however, has approached the complexity of the Bahama case. There may be, however, other organisms that maintain permanent cleaning stations. These, indeed, may constitute a very important phase of sea biology. The stations may be set up on individual coral heads, on reef formations, in sea floor depressions, or merely in certain general areas."

Certain species of fish and other organisms, as well as shrimp, engage in this cleaning activity. "In general," Mr. Limbaugh reported recently to the Western Society of Naturalists, "the concept may be expanded to include very large areas or physical features. I am now convinced that this is one reason fish visit the edges of kelp beds, where species of cleaner fish dominate the fauna. I believe also that many famous fishings grounds (off the Pacific coast) may be cleaning stations. Among these I would include certain islands and shoals." He continues:

Visiting fishes at the small cleaning stations in the Bahamas showed a definite time pattern in their daily arrival, obviously related to a diurnal patterned life. Longer term studies undoubtedly would have shown seasonal trends. The number of fish processed at a small station during a six-hour daylight period may be large, up to 300 for one cleaning fish. In areas inhabited by thousands of cleaner organisms, the numerical significance begins to take on meaning. Often a fish will visit more than one station and return many times during the day. This is particularly true of an injured or sick fish.

In an experiment in the Bahamas, I removed all the known cleaners from two small isolated reefs where fishes were particularly abundant. Within a few days the numbers of fish were drastically reduced. Within two weeks all except territorial fishes had disappeared. Many of these developed white fuzzy blotches, swelling, ulcerated sores and ravaged fins. Later small shrimp and juvenile fish cleaners appeared. Most of the original fish did not return but were replaced by juveniles.

Known organisms involved as cleaners in the sea include eight families of 21 species of fishes, several families of shrimps, involving six species, a worm, a bird, and a crab. Relationships of cleaners to the cleaned organisms frequently are so casual as to seem accidental, but in other cases it involves integrated and complex behavior. In warm seas, cleaning organisms generally are colored to contrast with their environment. In general they are solitary, paired or slightly gregarious. In temperate waters they are not brightly colored or contrastingly marked. Often they are highly gregarious. They are more numerous than in warmer waters but there are fewer species.

GENERAL SCIENCE.—*Moon bound.*[1] RAYMOND J. SEEGER, National Science Foundation.

(Received January 2, 1959)

Man always has been and still is moon bound. From earliest times he has been fascinated by the very appearances of the moon. The baby in his crib reaches for the bright moon; the child in the nursery wonders at the "man in the moon." A Hebrew story tells that this man was banished to the moon because he picked up sticks on the Sabbath; his sticks are now the shadows on the moon. Young men yearn for a "lady in the moon," and old men dream of "the old moon in the new moon's arms." Literature[2] abounds in fanciful speculations about the moon, for example, writings of Dante, Ariosto ("Orlando Furiosa"), Milton, Jonson ("News from the New World Discovered in the Moon"), Shakespeare, Donne, Keats ("Endymion"), Rostand ("Cyrano de Bergerac"). Men have always been susceptible to wonderful stories about this wonderland. One of the most celebrated was the so-called "moon hoax," which appeared in an August issue of "The Sun" in 1835. R. A. Locke, a newspaperman, reported that Sir John Herschel had just discovered flying men and animals on the moon by means of a new large telescope in Africa. The only truth about the whole account was the rapid increase in the newspaper circulation. Nevertheless, beneath man's superficial stories is a genuine curiosity as to just what is on the surface of the moon.

As man became interested in nature for its own sake, he felt a burning desire to "save the appearances," to uncover the φύσις (physics) beneath the φαινόμενα (appearances). For example, in Plato's educational program for the future leaders of his Republic, he discussed the merits of astronomy as a possible subject, not for its applications in agriculture or in navigation, but because of its relation to the intelligible principles behind phenomena. For centuries man had been observing the irregular planetary and lunar motions. He saw chaos, he sought to unveil cosmos; he looked for order amid the apparent disorder. It was the fall of a meteorite near Aegos Potamoi in 467 B.C. that stimulated Anaxagoras's interest in the heavens as a sequence of understandable events. He visualized moonlight as reflected sunlight; he explained the phases and eclipses of the moon. Above all, he regarded the surface of the moon as earth-like. For this very reason this first philosopher of distinction in Athens was banished in the so-called golden age of Pericles for impiety. It was Hipparchus of Nicea who determined later (about 129 B.C.), parallactically, the distance of the moon from the earth (within 0.1 percent of the modern value).

The telltale telescope of Galileo revealed the nature of the heavens in a dramatic way comparable to that of the visible Sputnik—far more compelling than any theoretical speculation. The announcement of the moon's appearance was made in the Siderius Nuncius. In the church of Santa Maria Maggiore in Rome, a portrait of the Virgin shows a small picture of the moon as first glimpsed by Galileo. There one sees outlined the mountains of the moon; for example, the Apennine range, 450 miles long and with 3,000 peaks such as Huygens (19,000 feet high). Galileo himself estimated the mountains to be about 4 miles in height. All these ranges have familiar European names; for America had not yet been explored in detail. If the moon's hidden face is ever revealed to us, mountain ranges there will undoubtedly be named after those on our Western Hemisphere. One observes also many large flat regions, which have been given fanciful names: the Sea of Serenity, the Ocean of Storms, the Bay of Rainbows, the Lake of Death, et al. A moot scientific

[1] Luncheon address given at the "Unveiling of the Moon Building," Sheraton-Carleton Hotel, Washington, D. C., October 28, 1958.

[2] GODWIN, F. *The man in the moon.* 1638; WILKINS, J. *The discovery of a world in the moon.* 1638; BOHN, A. *The emperor in the moon.* 1687; FOWLER, G. *A flight to the moon.* 1813; WELLS, H. G. *First man in the moon.* 1901; COFFIN, C. M. *John Donne and the new philosophy.* 1937; ALLOT, K. *Jules Verne.* 1941; NICOLSON, M. *Voyages to the moon.* 1948.

question today persists as to whether these areas are actually lava flows or dust bowls. Particularly striking are craters such as Archimedes, which is 40 miles in diameter and which could have been formed by a meteorite having a weight of 25 billion tons. For comparison, we think of Meteor Crater in Arizona, which is less than a mile wide and which is supposed to have been produced by a meteorite of only 200,000 tons. Sad to relate, Galileo too suffered imprisonment at the end of his life of research of the heavens. His view of the moon and other celestial phenomena did not agree with the socially accepted doctrine of his times.

There is an apocryphal story that Newton conceived his theory of gravitation when he was struck by an apple falling from a tree. There might have occurred to him the thought: "Suppose it had been the moon; suppose the moon were an apple!" "In such a case," he might have surmised, "moons and apples would be subject to the same law of gravitation—a universal law." In any event we have all come to believe that we do live in a universe with laws that apply equally to moons and to apples.

In more recent times, a Washingtonian, Simon Newcomb (1835–1909), director of the Nautical Alamanac from 1877, became so fascinated by lunar motions as to investigate them in considerable detail. You recall that tidal slowing of the rotating earth (about 0.001 second in a century) results in an increasing angular acceleration and consequential recession of the moon about ten centimeters each month. Even today lunar motions still present a formidable challenge to man, including the earth-moon enigma that these two bodies might have been closely associated about 5 billion years ago. More amazing than our ignorance, however, is our knowledge about the moon and other astronomical phenomena. How unbelievably well has man succeeded in "saving the appearances"—without ever going to the moon! Laplace's remark is still worth considering: "Because of the majesty of its subject and the perfection of its theories astronomy is the most beautiful monument of the human spirit, the noblest claim of its intelligence."

It is not surprising, therefore, that much science fiction has been written with respect to our nearest neighbor in space. A particularly interesting book was written in 1900 by Newcomb himself.[3] It tells of a Harvard professor of molecular physics who began about 1941 a secret project in a brickyard on a nearby Potomac Island. Later he expanded his operations to the island of Elba, where he built Uraniberg (a heavenly city) in the tradition of Tycho Brahe. His unique invention was a space ship, which had been made possible by the discovery of a new material called etherene. Its reaction with ether vibrations was conceived to be analogous to that of the wings of a bird with the air through which it flies. A new source of energy, therm, akin to electricity, was also available. The time came for the unveiling of the motes, as these space ships were called (hi motes traveled a hundred miles high). Newcomb noted that Professor Gale, an English physicist, believed such motion to be impossible owing to air friction. He overcame this difficulty by flying the ships above the atmosphere, the height of which was found on flight to be greater than that previously calculated. On the occasion of the unveiling, formal invitations were sent to the President of the United States, to the heads of the several Government departments, to members of the Judiciary, to high officials of the Army and Navy, as well as to presidents and professors of various universities. A dinner was arranged in their honor prior to the unveiling ceremony. About one-third of the individuals offered excuses for not coming, another third came in order to see who the third third really were that could be seriously interested in such a subject. The book concluded by revealing the true motivation of the project and its secrecy; it was aimed at the establishment of a "defender of the peace of the world." In the same spirit, United States satellites today are rightly called Explorers and Pioneers, for they are much more significant as rockets for peace than as missiles for war. So much for the superscience of Newcomb's fiction!

In a strictly technical paper[4] on "The Outlook for the Flying Machine," Newcomb

[3] Newcomb, S. *His wisdom—the defender.* 1900.
[4] Newcomb, S. *Sidelights of astronomy.* 1906.

reviewed later (1906) Langley's aircraft failure. He concluded, "Let us discover a substance a hundred times as strong as steel, and with that some form of force unsuspected which will enable us to utilize this strength, or let us discover some way of reversing the law of gravitation so that matter may be repelled by the earth instead of attracted—then we may have a flying machine. But we have every reason to believe that mere ingenious contrivances with our present means and form of force will be as vain in the future as they have been in the past."

Truth has once again turned out to be stranger than fiction. The accomplishments of our age surpass not only the sober expectancy of great scientists of yester years but even their science fiction. I wonder what Simon Newcomb would say if he knew that we are now shooting for the moon.

In all our technological development, however, we need to distinguish carefully both between science and science fiction, and between science and technology. We speak of these times as a space age. Yesterday it was an atomic age. In neither case has it been truly a scientific age. At a meeting of the Federal Schoolmen's Club in Washington last year, a talk was given about satellites. At the end two educators asked these questions: (1) "What keeps the satellite up?" (2) "What keeps it going?" Mind you, 300 years after Newton had told clearly how well-behaved moons travel in public space!

What is science? It is not information, please! It is not mysterious gadgetry! It is not powerful magic! Science, i.e., knowledge, is the result of the use of the scientific method, a method that is peculiar to the scientist. May I stress again that the "what" of science is less important than the "how" of the scientific method, all of which is meaningless except in terms of the "who," the scientist that observes, that relates, that imagines. As Henri Poincaré once said, "Science is no more a collection of facts than a house is a collection of stones." The end of science is a comprehensive view, an imaginative vista, an interpretive theory. Its means is a workshop, i.e., a laboratory. Work, let us remember, can and should be adventuresome; it can and should be wonder-full; it can and should be joy-full. The scientist in his laboratory is akin to the artist in his studio; to the child in his kindergarten. Science, above all, can and should be fun-full; for science is exploration. With our modern satellites we are now abel to reach the upper atmosphere, the very edge of the earth, where we meet incoming cosmic rays and meteors from outer space.

The surface of the moon is a member of our planetary family that affords unusual physical conditions. The very lack of an atmosphere, as indicated by the sharpness of the moon's shadows, allows incoming radiation there to be free from atmospheric influences. The surface, too, is free from erosion although it undergoes large temperature changes from minus 243° F. to plus 214° F. on a single day. It is evident that any design for building on the moon must necessarily be quite different from that on the earth. For example, gravitational force there is only one-sixth as great so that the weight of building materials will actually be less on the moon than on the earth. The inertial mass, however, remains the same. Consequently, vibrational phenomena, which involve both gravitational stresses and inertial masses, will behave quite differently from those upon the earth.

We moderns are literally moon bound. We dream of Luniberg, a city on the moon, with buildings that are truly out of this world. We visualize a lunar observatory for man's penetration into the space about him and his reflection upon the earth he has left behind him.

Meanwhile, as we stand moon bound on the earth, let us all insist upon a scientific outlook!

BOTANY.—*Supplementary studies in* Aeschynomene, *I: Series Viscidulae, including a new species and five new varieties.* Velva E. Rudd, U. S. National Museum.

(Received February 13, 1959)

A considerable number of *Aeschynomene* specimens have come to my attention since publication of "The American Species of Aeschynomene" (Contr. U.S. Nat. Herb. **32:** 1–172. 1955). Some of these specimens are old, representing collections that have been ascribed to "familiar," widespread species without critical examination or that have spent years in the limbo of "indet" folders. Others are types and historical collections that I did not have access to earlier.

Among such specimens I find a few that I believe to represent new taxa and others that amplify the concepts of the old. This paper is essentially a recapitulation of the *Viscidulae* series of the genus *Aeschynomene,* but without repetition of detailed descriptions and explanations of synonymy given before. Included in this treatment is the description of one new species and five new varieties, presentation of a new specific name for an old variety, and reinstatement of two old specific names that have been kept in synonymy for a century or so. Material from the Old World is also considered. A revised key is provided.

For the material on which this study is based, I am deeply grateful to the curators of the herbaria cited, for their help in providing types and other pertinent specimens. The initials of the herbaria, as cited, are those of Lanjouw and Stafleu (Index Herbariorum, ed. 3. 1956).

This series, named for the earliest described species of the group, *Aeschynomene viscidula* Michx., includes a few closely related species of the section *Ochopodium* Vog. The plants are disconcertingly similar in appearance, all prostrate to suberect herbaceous or suffrutescent perennials arising from woody roots. The leaves, flowers, and fruits are relatively small, the leaflets ranging from about 2 to 30 mm long, the flowers from 5 to 13 mm long, and the articles, or joints, of the loments from 2 to 5 mm in diameter. The stipules are attached at the base, and the calyx is campanulate with five subequal lobes, or teeth.

In general, characters of the fruit are the most useful for separating the taxa. The number of articles can be counted, the length of the stipe and the dimensions of the articles can be measured. The kind and degree of pubescence is distinctive in a few species. Unfortunately, there is some instability, especially in certain species, that casts suspicion on the genetic composition and presents difficulties in key construction.

Since full descriptions are not included in this paper, except for new taxa, the following rather detailed key is presented.

KEY TO SPECIES AND VARIETIES

Fruit (1-) 2- or 3- (rarely 4- or 5-) articulate and short-stipitate, the stipe commonly 1–4 mm long, scarcely extending beyond the calyx, or, in a few cases, 5–7 mm long; bracteoles usually about half as long as the calyx or longer.
- Leaves 5–9-foliolate, the leaflets obovate to cuneate; articles of fruit (3-) 4–5.5 mm in diameter.
  - Articles densely white-tomentulose and usually also beset with glandular hairs, sometimes the terminal article glabrate, 3.5–4 mm in diameter; stipe of fruit 1–3 mm long, mostly contained within the calyx (southern United States to northern and eastern South America) .... **1. Ae. viscidula**
  - Articles glabrous to moderately appressed-pubescent, (3-) 4–5.5 mm in diameter; stipe of fruit 2–7 mm long, usually extending 1–4 mm beyond the calyx.
    - Fruit with articles 4–5.5 mm in diameter, glabrous, the stipe 4–7 mm long; bracteoles about as long as the calyx (Mexico .... **2. Ae. acapulcensis**
    - Fruit with articles about 3–4 mm in diameter, appressed-pubescent to glabrate, the stipe 2–7 mm long; bracteoles about one-half as long as the calyx (South Africa; Madagascar; Mauritius; Réunion; eastern Australia) **3. Ae. brevifolia**
- Leaves 10–32-foliolate, the leaflets obovate to linear-oblong, occasionally some leaves with fewer leaflets; articles of fruit 2–3 (-5) mm in diameter.
  - Stipe of fruit 3–7 mm long, commonly hispidulous with hairs about 1 mm long.

Surface of articles crisp-pubescent to subglabrous and also best with glandular hairs; stipe 3–4 (-5) mm long; leaves mostly 10–20-foliolate, the leaflets obovate to oblong.

Fruit 2- or 3-articulate, rarely 4-articulate, the stipe 3–4 mm long; leaves predominantly 10–14-foliolate, the leaflets obovate or obovate-elliptic.

Flowers 5–8 mm. long; articles of fruit 2.5–3 mm long, 2–3 mm wide (widespread in tropical America)
4a. Ae. brasiliana var. **brasiliana**

Flowers about 10 mm long; articles of fruit 4–5 mm long, 3–4 mm wide (Upper Orinoco, Venezuela)
4b. Ae. brasiliana var. **carichanica**

Fruit 4- or 5-articulate, the stipe 4–5 mm long; leaves 14–20-foliolate, the leaflets oblong or obovate-oblong (northern Venezuela)
4c. Ae. brasiliana var. **venezolana**

Surface of articles crisp-puberulent to glabrate; stipe 5–7 mm long; leaves about 20–32-foliolate, the leaflets elliptic (Minas Gerais, Brazil) .... **5. Ae. vogelii**

Stipe of fruit 1.5–3 mm long, hispid, the hairs 2–4 mm long, concentrated at base of the first article; surface of articles glabrous to moderately pubescent but lacking glandular hairs.

Articles of fruit 2–2.5 mm in diameter; flowers 4–7 mm long; leaflets entire, oblong-elliptic, rarely somewhat obovate.

Leaflets 4–6 (-8) mm long, 1.5–3 mm wide; stipules linear-lanceolate, about 1 mm wide at the base, 4–5 mm long; stems usually prostrate.

Fruit with articles glabrous to moderately crisp-puberulent; stems and leaves moderately pubescent or often glabrate (widespread in Central and South America)
6a. Ae. histrix var. **histrix**

Fruit with articles appressed-pubescent; stems and leaves canescent (Central and South America; one collection from Florida)
6b. Ae. histrix var. **incana**

Leaflets 7–12 mm long, 2–4 mm wide; stipules broadly lanceolate, usually 2–3 mm wide at the base, 5–15 mm long; stems suberect (Mexico to South America)
6c. Ae. histrix var. **densiflora**

Articles of fruit 2.5–3 mm in diameter; flowers 7–9 mm long; leaflets setiferous, ovate or linear-oblong, or sometimes entire and linear-oblong.

Leaflets 2–5 mm long, 1–2 mm wide, ovate to elliptic-oblong, each bearing one or more yellowish, bulbous-based, glandular setae (Paraguay; Missiones, Argentina)
6d. Ae. histrix var. **multijuga**

Leaflets 5–10 mm long, 1.5–2 mm wide, linear-oblong, entire of ciliate (Paraguay)
6e. Ae. histrix var. **apana**

Fruit 4–9-(infrequently fewer) articulate and long-stipitate, the stipe (4-) 5–15 mm long; bracteoles about 1 mm long, or one-third as long as the calyx.

Articles of fruit 2–2.5 mm in diameter; stipe commonly 10–15 mm long; leaves mostly 10–18-foliolate, the leaflets obovate or obovate elliptic (widespread in tropical America) .... **7a. Ae. elegans** var. **elegans**

Articles of fruit 3–5 mm long, 2.5–4 mm wide.

Leaves predominantly 9–32-foliolate.

Flowers 5–10 mm long; fruit with articles 3–4 mm long and 3 mm wide.

Leaflets obovate or obovate-elliptic; leaves 5–14-foliolate; stipe of fruit (4-) 5–8 mm long.

Fruit with articles 3–4 mm long and 3 mm wide; flowers 8–10 mm long; leaflets about 10–20 mm long, 5–10 mm wide (Goyaz, Brazil)
7b. Ae. elegans var. **robustior**

Fruit with articles about 3 mm in diameter; flowers 5–7 mm long; leaflets 3–10 mm long, 2–4 mm wide (coastal Brazil; Puerto Rico)
8. Ae. gracilis

Leaflets elliptic or oblong-elliptic, 5–15 mm long, 3–4 mm wide; leaves 16–20-foliolate; flowers 7–10 mm long; articles of fruit 3–4 mm long and 3 mm wide; stipe 7–10 mm long (southeastern Colombia; western Brazil)
9a. Ae. foliolosa

Flowers 10–15 mm long; fruit with articles about 5 mm long and 4 mm wide; leaflets elliptic or obovate-elliptic, 7–20 mm long, 5–10 mm wide (Rio de Janeiro, Brazil) .... **10. Ae. bradei**

Leaves 5–8-foliolate.

Leaflets obovate or obovate-elliptic, obtuse, entire, 3–15 mm long, 2–6 mm wide.

Flowers 7–10 mm long; leaves not more than 8-foliolate; fruit usually 6–8-articulate, the stipe 6–14 mm long.

Fruit with articles about 3–4 mm long, 2.5–3.5 mm wide; flowers 7–9 mm long (widespread in tropical South America)
11a. Ae. falcata var. **falcata**

Fruit with articles 4–5 mm long and 3–4 mm wide; flowers 8–10 mm long (Paraguay)
11b. Ae. falcata var. **hassleri**

Flowers 5–7 mm long; leaves 5–12-foliolate; fruit (3-) 4–7-articulate, the stipe (4-) 5–8 mm long (costal Brazil; Puerto Rico) ...... **8. Ae. gracilis**

Leaflets elliptic-oblong, acute, 12–30 mm long, 5–10 mm wide, the margins closely ciliate; fruit 3- or 4-articulate, the stipe about 5–7 mm long, the articles about 3 mm in diameter (Minas Gerais, Brazil)
12. Ae. warmingii

1. **Aeschynomene viscidula** Michx. Fl. Bor. Am. **2:** 74. 1803, non Roxb. ex Willd. 1809.
   Aeschynomene prostrata Poir. in Lam. Encyc. Suppl. **4:** 76. 1816.
   Secula viscidula (Michx.) Small, Fl. Miami 90, 200. 1913.
   Aeschynomene eriocarpa Standl. & Steyerm. Field Mus. Publ. Bot. **23:** 9. 1943.

This species is easily recognized by its short-stipitate, densely tomentulose fruits. Even though geographically widespread, the morphological characters are generally uniform in all the material observed. The chief instability appears to be in the fruit indument; the glandular hairs may fail to develop, or sometimes the terminal one or two joints of the loments may be glabrous.

2. **Aeschynomene acapulcensis** Rose, Contr. U.S. Nat. Herb. **5:** 191. 1899.
   Aeschynomene picachensis Brandeg. Univ. California Publ. Bot. **6:** 181. 1915.

On the basis of the fruit characters indicated in the key, this glabrous-fruited Mexican species has been retained as separate from the pubescent-fruited *Ae. brevifolia* which occurs in the Old World. It is my strong feeling, however, that the two taxa might ultimately be proved conspecific. The geographic separation could be explainable in terms of early sailing routes and the practice of transporting animals and fodder, but the evidence is scanty. Thus far I have seen only three collections from Mexico and but slightly more material from Africa, Madagascar, and the other known localities for *Ae. brevifolia.*

Vegetatively, the plants of *Ae. acapulcensis* and *Ae. brevifolia* are virtually indistinguishable. They may range from glabrous to pubescent, and there is considerable variation in stipe length of the fruit, even on individual specimens.

3. **Aeschynomene brevifolia** L. ex Poir. in Lam. Encyc. **4:** 451. 1797.
   Hedysarum micranthos Poir. in Lam. Encyc. **6:** 446. 1806.
   Aeschynomene micrantha (Poir.) DC. Prodr. **2:** 321. 1825.
   Patagonium racemosum E. Mey. Comm. Pl. Afr. Austr. **1:** 123. 1835.

As already indicated in the key and in the comments under the preceding species, *Ae. brevifolia,* based on a collection from Madagascar, is scarcely distinguishable from *Ae. acapulcensis* from Mexico. Except for differences in fruit indument, some of the specimens with glabrate leaflets and fruits, from Madagascar and Réunion, for example, are quite similar to material of the type collection of *Ae. acapulcensis.* Other specimens with more glandular development, such as most from South Africa, vegetatively resemble the type collection of *Ae. picachensis,* which I consider referable to *Ae. acapulcensis.*

I have seen a sheet from L that I presume to be an isotype of *Patagonium racemosum* E. Mey. collected by Drege in Africa. It is essentially identical with other collections of *Ae. brevifolia* from Africa.

The collections from Australia seem to belong to this species but approach *Ae. gracilis* in longer leaf axis, and *Ae. falcata* in fruit characters, having longer stipes and sometimes four or five articles instead of the customary two or three. The bracteoles are slightly shorter than average. Bentham (Fl. Austral. **2:** 227. 1864) considered this material as "quite identical" with *Ae. falcata* var. *paucijuga* from Brazil, and cited *Ae. micrantha* as a synonym.

There has been a question as to the correct name for this taxon. Apparently Poiret validated the Linnaean name *Ae. brevifolia,* based on a collection by Commerson in Madagascar, and then, later, published *Hedysarum micranthos* based on material of presumably the same collection. I have not yet learned the circumstances of Linnaeus's connection with the Commerson collection, nor has a sheet been located with "*brevifolia*" in Poiret's handwriting.

From P I have seen isotypes of *H. micranthos* and a photographic negative of the type. One sheet with Commerson's handwriting attests to the authenticity of the collector's name and locality. The type and one of the isotypes have been annotated by Poiret as *Hedysarum micranthos.* On two other sheets, including one from Desvaux's herbarium, are the three names, *Hedysarum micranthos, Aeschynomene micrantha,* and *Aeschynomene brevifolia.* It would appear that Desvaux's interpretation of the three names as synonymous would be correct and that the name *Ae. brevifolia* should have priority.

Unfortunately, the sheet in the Lamarck herbarium, labeled as the type of *Ae. brevifolia,* appears to be incorrect. A fragment of ample size for determination, lent me from P, is identical with type material of *Hedysarum falcatum,* based on a Commerson collection in Brazil. There must have been an error in labeling this particular sheet.

There are additional labels on this putative, but apparently erroneous, type sheet. Annotations "du bresil," "de Commerson," and "Aeschinomene brevifolia. Dict. No. 10" are in Lamarck's hand. Desvaux added the names "hedysarum falcatum Poir. enc. en Desv." That Desvaux recognized a confused situation is indicated by other labels, "hedysarum micranthos Poir. enc. en Desv." and "Ces deux plantes etoient sous un seul nom dans cet herbier *Aesch. brevifolia* mais j'ai la certitude que la *brevifolia* est l'hedys. micranthus du meme auteur et que l'autre qui n'est pas de Madagascar mais du brésil est l'hedys. falcatum Poiret."

I am greatly indebted to Dr. Alicia Lourteig for doing considerable research for me in locating the pertinent specimens, transcribing certain labels, and photographing types that could not be lent.

4a. **Aeschynomene brasiliana** (Poir.) DC. var. **brasiliana.**

Aeschynomene brasiliana (Poir.) DC. Prodr. **2:** 322. 1825.

Cassia biflora Mill. Gard. Dict. ed. 8, no. 14. 1768, non L. 1753.

Hedysarum brasilianum Poir. in Lam. Encycl. **6:** 448. 1804.

Cassia houstoniana Collad. Hist. Nat. Med. Cass. 132. 1816.

Aeschynomene paucijuga DC. Prodr. **2:** 321. 1825.

Aeschynomene paucijuga var. *subscabra* DC. Prodr. **2:** 321. 1825.

Hedysarum hirtum Vell. Fl. Flum. 319. 1825; Icon. **7:** tab. 151. 1835.

Aeschynomene brasiliana β Vog. Linnaea **12:** 90. 1838.

Aeschynomene biflora (Mill.) Fawc. & Rendle, Fl. Jam. **4:** 27. 1920.

Aeschynomene guaricana Pittier, Bol. Tecn. Minist. Agric. & Cría, Serv. Bot. Caracas **5:** 41. 1944, without Latin diagosis.

This widely distributed species is readily identifiable by the fruit, flower, and leaf characters given in the key. The material is generally uniform, with minor variation in size of vegetative parts due, probably, to habitat factors. A few specimens show reduction in fruit indument. What appear to be more significant variations are indicated in the following two taxonomic varieties.

4b. **Aeschynomene brasiliana** (Poir.) DC. var. **carichanica** Rudd, var. nov.

A varietate typica floribus fructibusque majoribus differt.

The plants are more robust and the flowers and fruits significantly larger than those of the typical variety, the flowers about 10 mm long, the articles of the fruit 4–5 mm long and 3–4 mm wide.

Type in the U.S. National Herbarium, no. 2167562, collected on the north end of Cerro Carichana (Cerro Gavilan), elevation 100–300 m, December 21, 1955, by J. J. Wurdack and J. V. Monachino (no. 40885). Duplicates at NY and VEN.

4c. **Aeschynomene brasiliana** (Poir.) DC. var. **venezolana** Rudd, Contr. U.S. Nat. Herb. **32:** 80. 1955.

This variety, known only from northern Venezuela, differs from the typical variety in leaf and fruit characters, the leaves consistently narrower and the fruits with longer stipes and more numerous articles.

5. **Aeschynomene vogelii** Rudd, nom. et stat. nov.

Aeschynomene podocarpa var. β Vog. Linnaea **12:** 89. 1838.

Aeschynomene falcata var. γ *multijuga* Benth. in Mart. Fl. Bras. **15**(1): 68. 1859.

This taxon appears to warrant specific status, and designation of a new name is necessary. The epithet *vogelii* is chosen in honor of Dr. J. R. Theodor Vogel, the author of many of the taxa of this series, including the variety on which this species is based.

In my earlier paper I treated *Ae. podocarpa* and its var. β as synonymous. Since then I have had the privilege of examining additional specimens and have concluded that the fragment at F, labeled as *Aeschynomene podocarpa,* must be a portion of the Sellow collection on which var. β was based, rather than typical *Ae. podocarpa.* The identity of typical *Ae. podocarpa* is problematic, but I now believe that it is referable to *Ae. elegans.*

Bentham based his *Ae. falcata* var. γ *multijuga* on *Ae. podocarpa* var. β and cited two Brazilian collections. One, the type, is the Sellow collection from Serra Itambé, Minas Gerais, and is the basis of my *Ae. vogelii.* The other, collected by Weddell "in arenosis maritimis Rio de Janeiro," is represented by a sheet at P, annotated in what appears to be Bentham's hand, but it actually is *Ae. elegans* and is quite unlike the Sellow collection.

There are two additional collections from Minas Gerais that seem to belong to this taxon: *Riedel* 943, from Serra de Lapa (NY), and *Markgraf, Mello Barreto, & Brade* 3455, from Serra do Grão Mogol (RB; US, fragment). The material is essentially like the specimens of the Sellow collection except that the leaflets average a little smaller in size and exhibit more glandular development, with the margins mostly glandular-denticulate.

6a. **Aeschynomene histrix** Poir. var. **histrix.**
Aeschynomene histrix Poir. in Lam. Encyc. Suppl. **4:** 77. 1816.
? *Aeschynomene cassioides* Desv. in Ham. Prod. Pl. Ind. Occ. 51. 1825.
? *Aeschynomene echinus* Vog. Linnaea **12:** 92. 1838.
Aeschynomene conferta Benth. Ann. Nat. Hist. **3:** 433. 1839.
Aeschynomene mucronulata Benth. Hook. Journ. Bot. **2:** 56. 1840.
Aeschynomene histrix var. *mucronulata* Benth. in Mart. Fl. Bras. **15**(1): 69. 1859.
Secula hystrix (Poir.) Small, Man. Southeast Fl. 728. 1933.
Aeschynomene pineticola Standl. & Wms. Ceiba. **1:** 79. 1950.

This species *sensu latior* is polymorphic and fairly widespread in Tropical America. The principal variations are indicated in the key.

In this paper I am following Bentham who assigned *Ae. echinus* to *Ae. histrix* "ex descr." Although I am tentatively placing *Ae. echinus* under the typical variety of *Ae. histrix,* it is possible that it is the same as *Ae. histrix* var. *densiflora.* The specimens that I previously determined as *Ae. echinus* are referred in this paper to two other varieties of *Ae. histrix,* var. *apana,* and var. *multijuga.*

Presumably Vogel in his examination of the Sellow specimens from Brazil made few comparisons with specimens from beyond that country's borders. He must have disregarded *Ae. histrix* from French Guiana (*Ae. densiflora* from British Guiana was not yet published) and initiated the new species *Ae. echinus.* In his description of *Ae. echinus* he states that the stipules, racemes, and flowers are as in the preceding species, which is his *Ae. incana,* another variety of *Ae. histrix,* according to the present treatment.

6b. **Aeschynomene histrix** Poir. var. **incana** (Vog.) Benth. in Mart. Fl. Bras. **15**(1): 69. 1859 (As *Ae. hystrix* var. *incana*).
Aeschynomene puberula DC. Prodr. **2:** 321. 1825.
Aeschynomene incana Vog. Linnaea **12:** 90. 1838, non G. F. W. Mey. ex DC. 1825, as synonym.

As indicated in the key, var. *incana* is very similar to the typical variety, differing chiefly in indument.

6c. **Aeschynomene histrix** Poir. var. **densiflora** (Benth.) Rudd, Contr. U.S. Nat. Herb. **32:** 84. 1955.
Aeschynomene densiflora Benth. in Hook. Journ. Bot. **2:** 56. 1840.

Although there is intergradation between varieties of *Ae. histrix,* the specimens of var. *densiflora* usually are readily distinguished, especially from those of the typical variety, by their robust habit, and larger leaflets and stipules.

6d. **Aeschynomene histrix** Poir. var. **multijuga** (Chod. & Hass.) Rudd, comb. et stat. nov.
Aeschynomene brasiliana (Poir.) DC. forma *multijuga* Chod. & Hass. Bull. Herb. Boiss. II. **4:** 882. 1904.

This taxon, originally published as a form of *Ae. brasiliana,* has the principal characteristics, especially the dolabriform fruit structure, of *Ae. histrix.* It differs from typical *Ae. histrix* in having slightly larger flowers and fruits, and leaflets that are mostly denticulate with bulbous-based glandular setae.

Specimens of the type collection of this variety indicate a rather luxuriant, suffrutescent herb, 0.5–1.5 m tall. It was collected by Hassler (No. 5814) "in campo pr. flumen Carimbatay," Paraguay. I have seen isotypes from GH, MO, and NY.

The three other collections that I am assigning to this variety are from Missiones, Argentina, as follows: "On the Parana 26°–27° S. Lat.," *Parodi* 100 (K); Loreto, *Ekman* 1720 (NY); San Ignacio, *Burkart* 15344 (US). They apparently are from lower, more compact plants, with shorter internodes and slightly smaller leaflets. In the character of the fruits, flowers, and glandular setae, however, they appear to be essentially the same as specimens of the type collection.

In my earlier paper I interpreted this material as representing *Ae. echinus.* While the exact identity of *Ae. echinus* is still in doubt, I now think that it is more likely to be the same as typical *Ae. histrix,* or possibly *Ae. histrix* var. *densiflora.* The type locality of *Ae. echinus* also is not exactly known but on the basis of what is known of Sellow's itinerary, presumably it is from farther south or east than the above cited specimens. So far I have seen nothing like var. *multijuga* from the range of Sellow's travels.

6c. **Aeschynomene histrix** Poir. var. **apana** Rudd, var. nov.

A varietate typica foliolis elongatis, floribus fructibusque majoribus differt.

The specimens of this variety, because of the linear-oblong leaflets, 5–10 mm 1.5-2 mm wide, have an aspect quite different from others of *Ae. histrix*, yet the flowers and fruits are all essentially the same. Occasional leaflets of var. *apana* have a few marginal glandular setae such as are found in var. *multijuga*.

Type in the U. S. National Herbarium, no. 1177243, collected near the Río Apa, at Centurión, Paraguay, December 9, 1908, by K. Fiebrig (no. 4387). Duplicate at GH. Additional material is the Hassler collection no. 11021 (F, GH,NY,US), also from near the Río Apa, Paraguay.

7a. **Aeschynomene elegans** Schl. & Cham. var. **elegans.**

Aeschynomene elegans Schl. & Cham. Linnaea **5**: 583. 1830.
Aeschynomene tecta Vog. Linnaea **12**: 87. 1838.
Aeschynomene falcata Vog. var. *plurijuga* Benth. in Mart. Fl. Bras. **15**(1): 68. 1859.
Aeschynomene falcata Vog. var. *elegans* (Schl. & Cham.) O. Ktze. Rev. Gen. **1**: 158. 1891.
Aeschynomene falcata Vog. var. *elegans* (Schl. & Cham.) O. Ktze. forma *glabrior* O. Ktze. Rev. Gen. **1**: 158. 1891.
Aeschynomene arenicola Brandeg. Univ. California Publ. Bot. **10**: 408. 1924.

This species is easily recognized by its slender, long-stipitate, small-jointed, moniliform fruits. It is one of the most widespread of the series, ranging from Mexico to southern Brazil.

Many of the collections annotated and cited by Bentham as *Ae. falcata* actually are specimens of *Ae. elegans*. His *Ae. falcata* var. *plurijuga*, based on *Ae. tecta* and *Ae. podocarpa*, certainly must be the same as *Ae. elegans*. Sellow specimens from Brazil annotated as *Ae. tecta*, presumably isotypes, are *Ae. elegans*.

The identity of typical *Ae. podocarpa* still is in question. I have seen no Sellow specimens annotated as such or any that I can relate to the original description.

Previously, on the basis of characters in the original description and examination of a small photographic negative of type material, I decided that *Ae. gracilis* should be placed in synonymy under *Ae. elegans*. I have now seen isotypes of *Ae. gracilis* and conclude that it should be reinstated as a distinct species.

7b. **Aeschynomene elegans** Schl. & Cham. var. **robustior** Rudd, var. nov.

A varietate typica foliolis fructibusque majoribus differt.

As characterized in the key, this more robust variety of *Ae. elegans* is recognized by its relatively larger leaves with 10–14 leaflets, 10–20 mm long and 5–10 mm wide, and fruit with larger articles, 3–4 mm long and 3 mm wide. The fruit stipe is about 5–8 mm long, in contrast to the 10–15 mm long stipe that is customary in typical *Ae. elegans*.

Type in the Herbarium of the Royal Botanic Gardens, Kew, collected at Brejon, near Santa Cruz, Goyaz, Brazil, by J. E. Pohl, in 1820.

There are two other sheets at K that appear to belong to the same collection, labeled no. 1101, but without collector's name.

8. **Aeschynomene gracilis** Vog. Linnaea **12**: 89. 1838, non Miq. 1844.

Aeschynomene portoricensis Urb. Symb. Antill. **1**: 325. 1899.

After examining isotypes of *Ae. gracilis* from Brazil and *Ae. portoricensis* from Puerto Rico, it seems appropriate to combine the two species. Their close similarity was mentioned by Urban in connection with his publication of *Ae. portoricensis*. The former species is known only from the type collection by Sellow in Brazil between Campos, Rio de Janeiro, and Victoria, in Espirito Santo. The latter species, which has been frequently collected in Puerto Rico, is somewhat variable as to leaf size, number of articles per fruit, and stipe length, but several specimens are essentially identical with the Sellow collection from Brazil.

There is some similarity to *Ae. falcata* in fruit characters but the stipe of *Ae. gracilis* is usually shorter and the loments have fewer, obliquely semioval joints. The flowers are smaller. The leaves seem to be intermediate between *Ae. elegans* and *Ae. micrantha*.

9. **Aeschynomene foliolosa** Rudd, Contr. U.S. Nat. Herb. **32**: 91. 1955.

This is a distinctive species with panicles of small flowers and slender long-stipitate fruits. The leaves are relatively long with 16–20 oblong-elliptic leaflets.

In the original description only two localities are cited, both from the outer periphery of the Amazon Basin. Recently another collection from a somewhat intermediate area has been recognized, *Ducke* [Herb. No.] 12382 (MG), collected December 14, 1912, at Campo da Frequezia Velha, Coary, Brazil.

10. **Aeschynomene bradei** Rudd, sp. nov. Fig. 1

Suffrutex diffusus, ad sectionem *Ochopodium* pertinet, foliis 3–5 cm longis, 9–16-foliolatis, foliolis ellipticis, adpresse pubescentibus; *Ae. elegans* var. *robustior* affinis sed imprimis floribus fructibusque majoribus differt.

Stems suffrutescent, rusty-tomentose when young, somewhat glandular-hispidulous, glabrescent; stipules lanceolate or lanceolate-ovate, about 5–8 mm long, attenuate, 1–2 mm broad at the base, pubescent like the stem; leaves about 3–5 cm long, 9–16-foliolate; leaflets elliptic or obovate-elliptic, 7–20 mm long, 5–10 mm broad, obtuse, mucronulate, entire, moderately appressed-pubscent on both surfaces, the hairs colorless or sometimes rusty; inflorescences axillary, racemose, slightly longer than the subtending leaves; bracts deltoid-ovate, about 1 mm in diameter, pubescent, the bracteoles ovate, about 2 mm long and 1 mm wide; flowers yellow, 10–15 mm long; calyx 3–5 mm long campanulate with 5 subequal lobes about 2 mm long, ciliate, subglabrous to glandular-hispidulous; standard 10–15 mm long, the claw 2–3 mm long, the blade suborbicular, 8–10 mm in diameter, pubescent on the outer face; wings and keel slightly shorter than the standard, the wing blades oblique, 4–5 mm broad, the keel blades about 2 mm broad, bent at about a 90° angle; stamens 8–12 mm long, monadelphous, the filaments united from base to midlength, the sheath open on the carinal side; ovary 5-ovulate, pubescent; fruit 2–5-articulate, the stipe subglabrous, 7–10 mm long, the articles crisp-pubescent, about 5 mm long and 4 mm wide; seed brownish black, sublustrous, 3 mm long, 2 mm broad, and compressed to 1 mm or less in thickness.

Type in the herbarium of the Jardim Botanico do Rio de Janeiro, no. 28707, collected at Pedra Dubois, Santa Maria Madalena, Rio de Janeiro, Brazil, altitude 1,100 m. February 27, 1935, by Santos Lima and A. C. Brade (no. 14220). Fragment and photograph at US.

Only one other specimen is known, a unicate at RB, collected at Pedra das Flores, Santa Maria Madalena, Rio de Janeiro, Brazil, altitude 1,200 m, March 4, 1934, by Santos Lima and A. C. Brade (no. 13273). Fragment at US

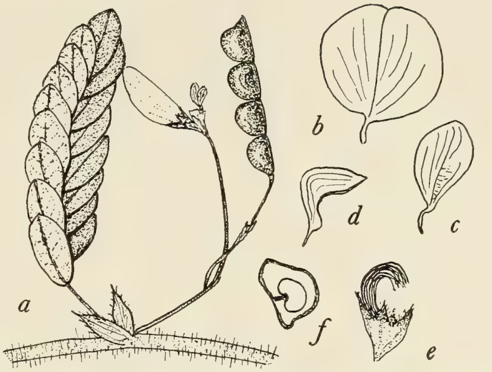


Fig. 1.—*Aeschynomene bradei: a,* Portion of stem with leaf, immature flower, and fruit (nat. size); *b,* standard; *c,* wing; *d,* keel; *e,* calyx and stamen filaments; *f,* one article of fruit, open, showing seed. (*b–f,* ×2.)

This species, represented by the two collections cited above, is readily referable to series *Viscidulae* of section *Ochopodium.* In general structure it resembles such related species as *Aeschynomene falcata, Ae. elegans, Ae. vogelii,* and *Ae. foliolosa.* In aspect it is rather distinctive due to more robust, woody growth, larger flowers and fruits. The critical characters are indicated in the key.

11a. **Aeschynomene falcata** (Poir.) DC. var. **falcata.**

Aeschynomene falcata (Poir.) DC. Prodr. **2:** 322. 1825.

Hedysarum falcatum Poir. in Lam. Encyc. Meth. Bot. **6:** 448. 1804.

Hedysarum diffusum Vell. Fl. Flum. Text 320. 1825; Icon. **7:** pl. 155. 1835.

Aeschynomene falcata (Poir.) DC. var. *paucijuga* Benth. in Mart. Fl. Bras. **15**(1): 67. 1859.

Aeschynomene apoloana Rusby, Bull. New York Bot. Gard. **6:** 511. 1910.

An isotype and a photographic negative of the type of *Hedysarum falcatum* Poir., on which *Ae. falcata* is based, have recently been sent to me from Paris. This authentic material, in the Jussieu Herbarium, was collected by Commerson in Brazil. It has characteristic falcate fruit and 5–8-foliolate leaves, and confirms our concept of the species.

As explained under *Ae. brevifolia,* material from a sheet in the Lamarck Herbarium and labeled as the type of *Aeschynomene brevifolia* L. ex Poiret, appears to be identical with the type material of *H. falcatum.* According to the description, *Ae. brevifolia* was collected by Commerson in Madagascar. There must have been an error in labeling the collection, however, as this specimen does not fit the description of *Ae. brevifolia,* and must really be a duplicate of Commerson's Brazilian collection of *Hedysarum falcatum.*

11b. **Aeschynomene falcata** (Poir.) DC. var. **hassleri** Rudd, var. nov.

A varietate typica foliolis fructibus floribusque majoribus differt.

In comparison with material of typical *Ae. falcata,* the specimens of this variety are outstanding in appearance due to more vigorous growth, especially their larger flowers, fruits, and leaves. The differences apparently are in degree rather than structural pattern.

This is another example of specimens from Paraguay being significantly more robust and with larger organs than their closest relatives.

Type in the Herbarium of the Royal Botanic Gardens, Kew, collected in a thicket near Concepción, Paraguay, September 1901, by E. Hassler (no. 7461). Isotype at NY.

There is an additional sheet at K, also collected by Hassler (no. 10977), "In altaplanitie, Sierra de Amambay," Paraguay, 1913.

12. **Aeschynomene warmingii** Micheli, Vid. Medd. Nat. Foren. Kjøbenhavn 68. 1875.

As indicated in the key, this species from Lagoa Santa, Minas Gerais, Brazil, is distinctive with its fairly large, 5–7-foliolate leaves. Unfortunately, it is known only from the type collection.

INSECTS AS FLYERS

Insects are the most efficient flying animals. They surpass both birds and bats. They are superior in some ways to any "flying machine" yet invented by man. The air was their exclusive domain for at least 100 million years before any rival winged creatures appeared. During this time they developed two flight systems, direct and indirect, which are in use today, although the former is confined to a few groups such as the dragonflies.

This is the claim of Dr. R. E. Snodgrass, research associate of the Smithsonian Institution, in a report on arthropod evolution recently published by the Institution. The earliest known insects, with highly developed jumping mechanisms, were wingless. There are some wingless forms today. But, Dr. Snodgrass points out, the earliest known winged insects in the fossil record had the flying mechanism fully developed so that its evolutionary development largely is a matter of conjecture.

The first step, as deduced by Dr. Snodgrass, was the emergence from the sea of some long extinct many-footed wormlike creature. The feet were fleshy lobes by means of which it had moved clumsily along the sea bottom. A first evolutionary step was the elimination of these lobes on all but the first three segments of the body behind the head. These gradually evolved into legs.

The earliest insects, Dr. Snodgrass says, to come on land presumably were provided with so-called "paranotal lobes," small appendages attached to the back in the region of the thorax. These are not hypothetical structures which since have disappeared, he says, since there are traces of them in various modern insects and in others; during the nymph stage, wings first appear as lobelike extensions from the back.

"Presumably," says Dr. Snodgrass, "when these paranotal lobes became sufficiently large in the primitive insects they first served as gliders. If the at first rigid lobes became flexible at their bases they could then, by action of the thoracic muscles, be flapped up and down, thus enabling the gliding insect to sustain itself longer in the air. Even this simple wing movement, however, involved modifications of the thoracic skeleton and some degree of adaptation in the musculature."

Eventually, he points out, the back muscles became differentiated to the point where they could move the wings without the help of any wing muscles per se. This is the "indirect" system of most insects.

Development of wings was evidently a response to demand. The first winged insects appear very shortly after the appearance of the first tall plants in the primeval swamps.

The direct up-and-down movement, with various modifications, continues in the "direct flight" system, best exemplified by the dragonflies.

During the long period of their undisputed domain of the air both systems developed. Then came the birds and bats to dispute their aerial supremacy. They fed chiefly on insects whose only defense was the development of greater speed and flying accuracy.

As a result the less efficient systems tended to become eliminated and the present methods of insect flight better developed.

NEWS OF MEMBERS

Dr. Bernard Frank is the new forestry officer, Forest Research Institute, Dehra Dun, Uttar Pradesh, India.

Mr. Thomas G. Digges has been honored with the first annual George Kimball Burgess Memorial Award of the Washington Chapter of the American Society for Metals.

Mr. Conrad V. Morton, curator of the division of ferns, U. S. National Museum, Smithsonian Institution, is one of two American botanists who have been awarded honorary life memberships in the American Gesneria Society for their important contributions to the world's knowledge of the plant family Gesneriaceae, which includes the African violet and gloxinia.

To understand Nature we must first study man thoroughly, because there is nothing in the universe which is not to some degree hidden in man's nature. Man is verily a universe in miniature.—Pliny the Elder.

ZOOLOGY.—*A review of the gorgonacean genus* Placogorgia *Studer, with a description of* Placogorgia tribuloides, *a new species from the Straits of Florida.*
FREDERICK M. BAYER, U. S. National Museum.

(Received December 5, 1958)

The extensive dredging operations of the U.S. Fish Commission steamer *Albatross* brought to light a great many zoological novelties, not a few of which are still awaiting description. Among these is a new gorgonian coral of the genus *Placogorgia,* which is now described and figured.

The genus *Placogorgia* as presently constituted contains four species in the Atlantic Ocean. All are characterized by calicular thorn-scales with a rather broad, branched, basal root and a stout, more or less laciniated but usually blunt spine, which projects above the surface of the calicles, giving them a thorny appearance. Although the thorn-scales of the four species are not identical, they are so similar that only exhaustive descriptions could point out the differences between them, and the species are distinguished mainly upon differences in the size and ornamentation of the cortical spindles.

The new species of *Placogorgia* that is the subject of this paper differs rather strikingly from the four previously known Atlantic species in the huge size of its calicular thorn-scales, which, moreover, have a quite acute spine and therefore bear a strong resemblance to the thorn-scales of *Paramuricea.* In this study, it has been necessary to reexamine all the Atlantic species of *Placogorgia* and to reappraise their position in respect to *Paramuricea* and related genera with calicular thorn-scales.

Genus **Placogorgia** Studer

Placogorgia Studer, 1887, Arch. Naturg. **53**(1): 56. [No species described.]

Placogorgia Wright and Studer, 1889, *Challenger* Zool. **31** (part 64): 113. (Type species, *Placogorgia atlantica* Wright and Studer, fixed by subsequent monotypy.)

not *Placogorgia* Nutting 1910, *Siboga* Exped. Monogr. **13b**: 76. [= *Discogorgia* Kükenthal.]

Placogorgia Nutting, 1912, Proc. U.S. Nat. Mus. **43**: 83.

Pseudothesea Kükenthal, 1919, Ergebn. deutschen Tiefsee-Exped. **13**(2): 843. (Type species, *Thesea placoderma* Nutting, by original designation.)

As described, *Placogorgia* is difficult to separate from *Paramuricea* and *Echinomuricea.* Most of the species of *Placogorgia,* including some from the Indo-Pacific assigned to *Thesea* by Nutting (= *Pseudothesea* Kükenthal), have large, rude spindles that often become platelike, with strong external spines, and small, rather blunt calicular thorn-scales. *Paramuricea* has large, sharp thorn-scales (sometimes with the basal part much reduced), and small spindles usually without external spines—rarely flat scales with a central projecting process or boss. Unfortunately, the type species of *Placogorgia* has small cortical spindles with little or no indication of external spines, and rather sharp, but small, calicular thorn-scales (both characters like *Paramuricea*); and *Paracuricea multispina* Deichmann has cortical plates with a projecting process, and blunt calicular thorn-scales (characters approaching *Placogorgia*). Except for *E. atlantica, Echinomuricea* has stellate thorn-scales with a smooth or nearly smooth spine; its distribution is primarily Indo-Pacific. I am inclined to think that the *Echinomuricea atlantica* described and figured by Thomson (1927, p. 40, pl. 4, fig. 3) is actually Johnson's *Acanthogorgia grayi* (Johnson 1862, p. 195) rather than *atlantica*—compare the spicules!—and that it belongs to *Placogorgia* and not to *Echinomuricea* or *Paramuricea.* Its calicular thorn-scales and cortical plates are similar to those of the new *Placogorgia* described herein, but Thomson gives no measurements and the magnification of his figures is not indicated, so its identity remains uncertain. Kükenthal (1924, pp. 225–226) suggested that both *atlantica* and *grayi* are referable to *Paramuricea.* This disposition is contraindicated in the case of *grayi* (Thomson's *atlantica*) by the large plates with several projecting spines, but could be valid for the true *atlantica.* There seem to be no species in the Atlantic Ocean that can be assigned to the genus

Echinomuricea as defined by most authors, which is characterized by calicular thorn-scales of a particularly distinct type.

Nutting (1910) described a number of East Indian species under the generic name *Placogorgia,* but most of them have been referred to other genera, notably *Discogorgia* (Kükenthal 1924, p. 212). He also described some muriceids with calicular thorn-scales and large, spinose cortical spindles and plates, which he placed in *Thesea.* Since they had nothing to do with the original *Thesea* of Duchassaing and Michelotti, Kükenthal in 1919 established for them the genus *Pseudothesea,* with *Thesea placoderma* Nutting as its type species. The character of its calicular thorn-scales leaves no doubt that *T. placoderma* is congeneric with *Placogorgia atlantica* Wright and Studer, and its cortical plates are not unlike those of *Placogorgia rudis* Deichmann. Most, perhaps all, of the other species described by Nutting in his monograph of the *Siboga* Muriceidae belong to other genera. *Thesea sanguinea* and *T. simplex,* of which I have seen type material, are referable because of their thorn-scales (which are of the "leaf-club" type) to *Echinogorgia,* a genus which perhaps should be ranked among the Plexauridae (Bayer, 1958, pp. 43, 48).

The paramuriceid species characterized by thorn-scales in the calicle are a closely interrelated complex, within which the generic distinctions—if such exist—must be drawn upon highly arbitrary grounds, at least until detailed studies can be made upon all pertinent type specimens. Until adequate studies can be undertaken there is no alternative but to recognize at least the most distinct of the genera that have been established. These genera are based mostly upon the form of the calicular thorn-scales. The thorn-scales of some genera, such as *Villogorgia, Trachymuricea,* and *Echinogorgia* (which possibly belongs in quite another family), are very distinctive, whereas those of other genera are only modifications of a simple, basic type, between which it is almost impossible to draw hard and fast boundaries.

The accompanying chart (Fig. 1) shows the major types and varieties of calicular thorn-scales (A–G) and cortical sclerites (H–N) found in the genera of Paramuriceidae sensu lato. (Excluded are *Bebryce* and *Acanthacis,* which are so distinctive that they need not enter into the present discussion.) The combinations of these types that occur in the various genera are indicated by the numbered connecting lines.

CALICULAR THORN-SCALES

A. The *Menella*-type (genus *Menella* Gray: Kükenthal, 1924, p. 184).—A single smooth, tapered spine rises from a root-part consisting of irregularly diverging branches. So far as I can tell from the literature, this type is always associated with cortical spindles that may produce strong external spines (J). I have seen only *Menella rubescens* Nutting, whose thorn-scales are illustrated (A); final definition of the genus will depend upon a reexamination of the type species, *M. indica* Gray, the holotype of which must be in the British Museum of Natural History.

B. The *Echinomuricea*-type (genus *Echinomuricea* Verrill: Kükenthal, 1924, p. 185).—A single smooth, tapered spine originates abruptly from a root-part consisting of four or five widely diverging branches, the whole producing a stellate body. These are usually, if not always, combined with simple, symmetrically sculptured spindles in the cortex (K). Similar thorn-scales, but with shorter projecting spine, are found in the genus *Eubrandella,* established by Deichmann (1936, p. 128) to replace Verrill's *Lissogorgia,* which was based on a single specimen said to have come from Florida; nothing like it has ever again been found in Florida, suggesting that it may have originated elsewhere—most likely in the Indo-Pacific. It resembles some of the species of *Echinomuricea* from that region.

C. The *Paramuricea*-type (genera *Paramuricea* Kölliker and *Placogorgia* Studer: Deichmann, 1936, pp. 134, 141).—Large thornscales with a stout, acute, more or less aculeate spike arising from a complicated, branched or lobed basal root. In combination with very large spindles and plates with (I) or without (H) spines, it is found in *Placogorgia japonica* (6) and *P. tribuloides* (3); with smaller spindles, sometimes knee-bent, it occurs in *Paramuricea placomus* (7).

D. The *Villogorgia*-type (genus *Villogorgia* Duchassaing and Michelotti, including *Acamptogorgia* Wright and Studer, *Brandella* Gray, *Paracamptogorgia* Kükenthal, and *Perisceles* Studer, all synonyms: Aurivillius, 1931, p. 204).—A projecting part that consists of a cluster of fingerlike processes, or thin radiating folia, arises

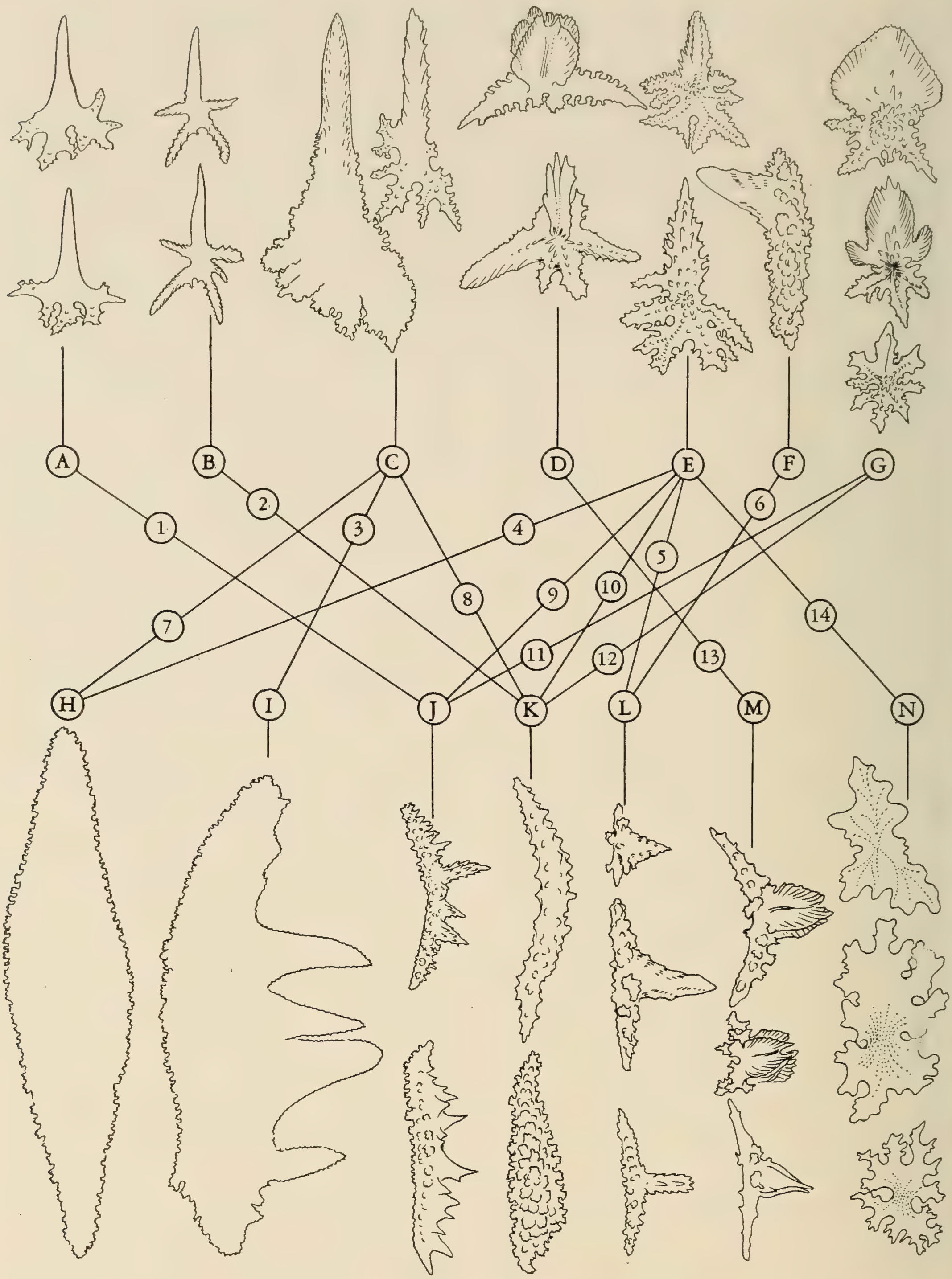


FIG. 1.—(See opposite page for legend).

from a widely diverging pair of flattened roots curved to fit the calicular walls. The various modifications that prompted the establishment of several genera were shown by Aurivillius (1931) to represent but a single type of spicule. Always associated with small 4-armed bodies having a pyramidal or winged central process (M, middle figure), sometimes with two arms suppressed to form a spindle with a median projection (M, top and bottom figures).

E. The *Placogorgia*-type (genera *Placogorgia* Studer and *Paramuricea* Kölliker: Deichmann, 1936, pp. 134, 141).—Similar to the *Paramuricea*-type but usually the root is more strongly developed laterally and somewhat curved to fit the calicular wall, and the spine is thick, comparatively blunt, and conspicuously serrated or laciniated. Usually smaller than the typical thorn-scales of *Paramuricea* (C, upper figure) but occasionally surpass them in size, in which cases the root is more complicated and its branches coalesce more or less completely. In *Placogorgia* they are found in combination with simple spindles both small (K) and excessively large (H), large and small unilaterally spinose spindles (I, J, and L, lower figure), and marginally lobate scales (N, lower figure). Some species of *Paramuricea* have *Placogorgia*-type thorn-scales combined with lobated scales (N, the two upper figures), indicating that some generic reallocation may be necessary.

F. The *Trachymuricea*-type (genus *Trachymuricea* Deichmann, 1936, p. 132).—The laciniated spine projects obliquely from a root that is only a simple spindle. Always in combination with small spindles having a conical external process (L, upper two figures) much like some of the cortical sclerites of *Villogorgia*. Only two species known at present, both of them further distinguished from species of *Paramuricea* and *Villogorgia* by a very high collaret.

G. The *Echinogorgia*-type (genera *Echinogorgia* Kölliker, *Plexauroides* Wright and Studer, and *Paraplexaura* Kükenthal: Kükenthal, 1924, pp. 124, 130, 198).—A simple, stellate type of thorn-scale in which the projecting spine is greatly expanded into a thin leaf as in *Echinogorgia* and *Plexauroides* (three stages of modification are shown in G, bottom to top) and sometimes much thickened as in *Paraplexaura*. Since it is possible to trace the development of the foliate thorn-scales found in *Plexauroides* and some species of *Echinogorgia*, and the massive thorn-scales of *Paraplexaura* from the simple, stellate type of some Echinogorgias, it seems obvious that these genera are inseparable. The thorn-scales may be the predominant type of sclerite, or they may be combined with simple or unilaterally developed spindles (I and K). The generic distinctions are somewhat vague and dependent largely upon the development of the anthocodial armature, which is said to relegate *Echinogorgia* to the Paramuriceidae, and *Plexauroides* and *Paraplexaura* to the Plexauridae. Inasmuch as the anthocodial spiculation may be reduced in those species of *Echinogorgia* that have a thick rind into which the polyps retract fully, just as it is in the species of *Plexauroides* and other plexaurids that have thick rinds, it is a character of no value at the generic and familial levels. At this time it remains a moot point whether all of these species should be transferred to one family or the other; it is certainly improbable that they will continue to span two families.

CORTICAL SCLERITES

The basic type of cortical spicule is the simple spindle (K), which may grow excessively large (H), and by flattening and expansion of the margins develop into thick plates or thin scales (N). Simple spindles usually occur even in those species that have characteristically modified cortical sclerites, although in certain species they

Fig. 1.—Types of calicular thornscales (A–G) and cortical sclerites (H–N), and their various combinations (1–14): A, Calicular thorn-scales of *Menella rubescens*; B, of *Echinomuricea indomalaccensis*; C, of *Placogorgia tribuloides* (left) and *Paramuricea placomus* (right); D, of *Villogorgia zimmermani* (above) and *V. nigrescens* (below); E, of *Placogorgia tenuis* (above) and *P. atlantica* (below); F, of *Trachymuricea hirta*; G, of *Echinogorgia flexilis* (top and middle) and *E. pseudosassapo* (bottom); H, cortical sclerite of *Placogorgia mirabilis*; I, of *Placogorgia tribuloides*; J, of *Placogorgia rudis* (above) and *Thesea flexilis* (below); K, of *Paramuricea placomus* (above) and *Placogorgia atlantica* (below); L, of *Trachymuricea kükenthali* (top and middle) and *Placogorgia tenuis* (bottom); M, of *Villogorgia zimmermani* (top and middle) and *V. nigrescens* (bottom); N, of *Paramuricea grandis* (top), *P. echinata* (middle), and *Placogorgia dendritica* (bottom). 1, spicular combination found in the genus *Menella*; 2, in *Echinomuricea*; 3, in *Placogorgia* (some species); 4, in *Placogorgia* (some species); 5, in *Placogorgia* (some species); 6, in *Trachymuricea*; 7, in *Placogorgia* (some species); 8, in *Placogorgia* and *Paramuricea* (some species); 9, in *Placogorgia* (some species); 10, in *Placogorgia* (some species); 11, in *Echinogorgia*; 12, in *Echinogorgia*; 13, in *Villogorgia*; 14, in *Paramuricea* and some species of *Placogorgia*.

may be largely suppressed by the thorn-scales of the calicular region, which then dominate throughout the rind (*Echinomuricea* and *Echinogorgia*). A common sculptural modification found in several genera and species is the unilaterally spinose spindle (J, L) which may become very large (I).

It may be useful to summarize the types of thorn-scales in the form of a dichotomous key to serve as a guide to the holaxonian genera having these peculiarly modified sclerites. As in the discussion above, *Bebryce* is not included because its superficial layer of rosettes and deeper layer of stellate plates render it absolutely unmistakable.

1. Cortex consisting of a single layer of spicules in the form of large, flattened spindles or plates. Thorn-scales around calicular aperture with a stout, rough, sometimes branched spine arising from a rather small, tuberculate base Genus Acanthacis Deichmann
   Cortex consisting of an outer layer of spicules, large or small, and a more or less complete inner layer of smaller spicules surrounding the axis........2

2. Calicular thorn-scales noticeably broader than high, the root-part developed mostly at right angles to axis of calice, with two main, spreading branches curved to fit the calicular wall; projecting portion consisting of several radiating folia or a laciniated, digitate process (Fig. 1, D). Cortex containing 4-armed bodies with a pyramidal, sometimes foliate central process; sometimes modified into simple spindles with median process (Fig. 1, M) Genus Villogorgia Duchassaing and Michelotti
   Calicular thorn-scales typically higher than wide, not with two main diverging roots curved to fit the calicular walls........3

3. Calicular thorn-scales are spindles with an obliquely set, more or less laciniated, pyramidal process near the distal end (Fig. 1, F) Genus Trachymuricea Deichmann
   Calicular thorn-scales with a flattened, branched, lobed or platelike base........4

4. Projecting portion of the calicular thorn-scales is usually a single spine........5
   Projecting portion of the thorn-scales is a foliate expansion sometimes lobed or cleft into broad fingers (Fig. 1, G), sometimes thickened into a massive head. . Genus Echinogorgia Kölliker

5. Projecting spine of the calicular thorn-scales is a smooth or nearly smooth, tapered spike. . . 6
   Projecting spine of the thorn-scales is an echinulate or laciniate digitate process........7

6. Projecting spike of calicular thorn-scales gradually merging into root portion, which consists of several irregularly divided branches (Fig. 1, A)........Genus Menella Gray
   Projecting spike of thorn-scales abruptly set off from the root portion, which consists of four or five widely diverging, slender branches (Fig. 1, B).....Genus Echinomuricea Verrill

7. Root portion of the calicular thorn-scales consists of several tuberculate lobes more or less completely fused together; projecting spine echinulate or strongly laciniate (Fig. 1, E). Cortical plates and spindles often with one or more strong spines. . Genus Placogorgia Studer
   Root portion of the thorn-scales consists of several diverging branches not extensively fused together; projecting spine echinulate (Fig. 1, C, right hand figure). Cortical spindles usually without spinous projections Genus Paramuricea Kölliker

PLACOGORGIA TRIBULOIDES, n. sp.

Figs. 2–9; 15

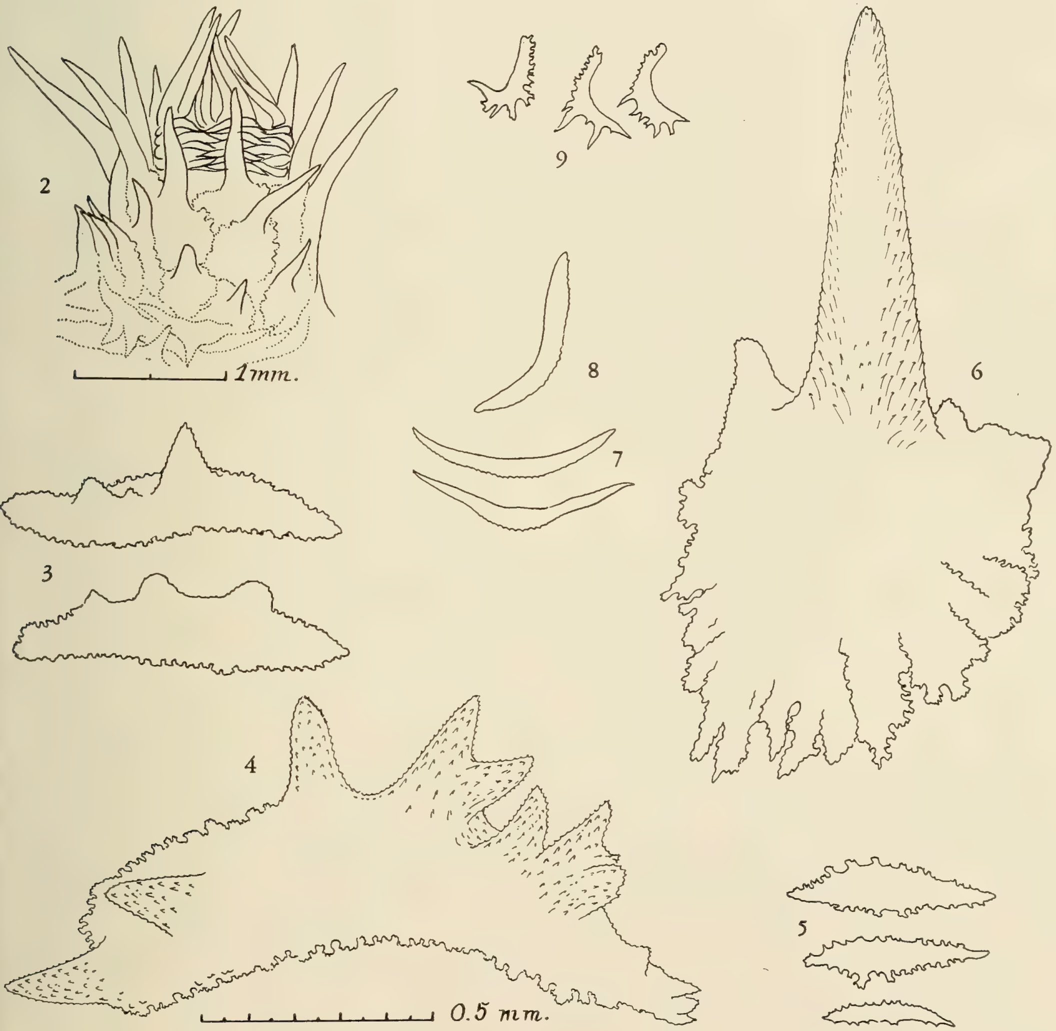
Diagnosis.—Calicular thorn-scales nearly 2 mm in length, projecting spine about 1 mm. Cortical spindles large (1.5 mm+), flattened, especially near branch tips, with several stout projecting spines. A single pair of large bent spindles and some small accessory rods in each opercular sector; collaret with 3–6 rows of transverse spindles. Branching dichotomous.

Description.—The type is a small, nearly complete colony measuring 5 cm from base to tip of the tallest branch. Ramification is in one plane and dichotomous; the main stem bifurcates within 5 mm of the base and both branches again bifurcate at about 10 mm from the first division. Further dichotomies are asymmetrical, since not all the branches subdivide. The trunk has a diameter of 2.5 mm, the major branches 1.5 mm (exclusive of calicles), and the terminal twigs about 1.0 mm (excluding calicles). Most of the calicles are inclined toward one face of the colony (the "front"), and are closely set, their bases almost touching one another. The calicles are low cylinders filled with very stout, acute, imbricating thorn-scales (Fig. 2). The anthocodiae are armed with a prominent, conical operculum consisting of a ringlike collaret usually 3–5 spicules in height, surmounted by eight points each made up of one pair of large, bent spindles of subequal size, and some small accessory rods.

The coenenchyme has a dense outer layer of glassy, irregularly tuberculate spindles, the largest of which bear one to several strong, sharp, projecting spikes. Toward the branch tips some of these become broad and platelike, with several spines, closely resembling the sclerites of certain species of *Paracis*. Between and beneath the large outer sclerites there are small, irregular spindles that form a discontinuous inner layer.

Spicules.—(a) Cortex: roughly tuberculate, coarse spindles with one or several outward projecting, finely echinate processes (Fig. 3). Near the calicles these sclerites increase in size, reaching a length of 1.5 mm or longer, and bearing several stout processes some of which may be marginal (Fig. 4). Toward the branch tips, the large deposits may become quite broad and platelike, after the manner of *Paracis*. Lying between and beneath the large deposits are numerous smaller spindles, more or less flattened and with irregular edges (Fig. 5), forming a discontinuous axial sheath.

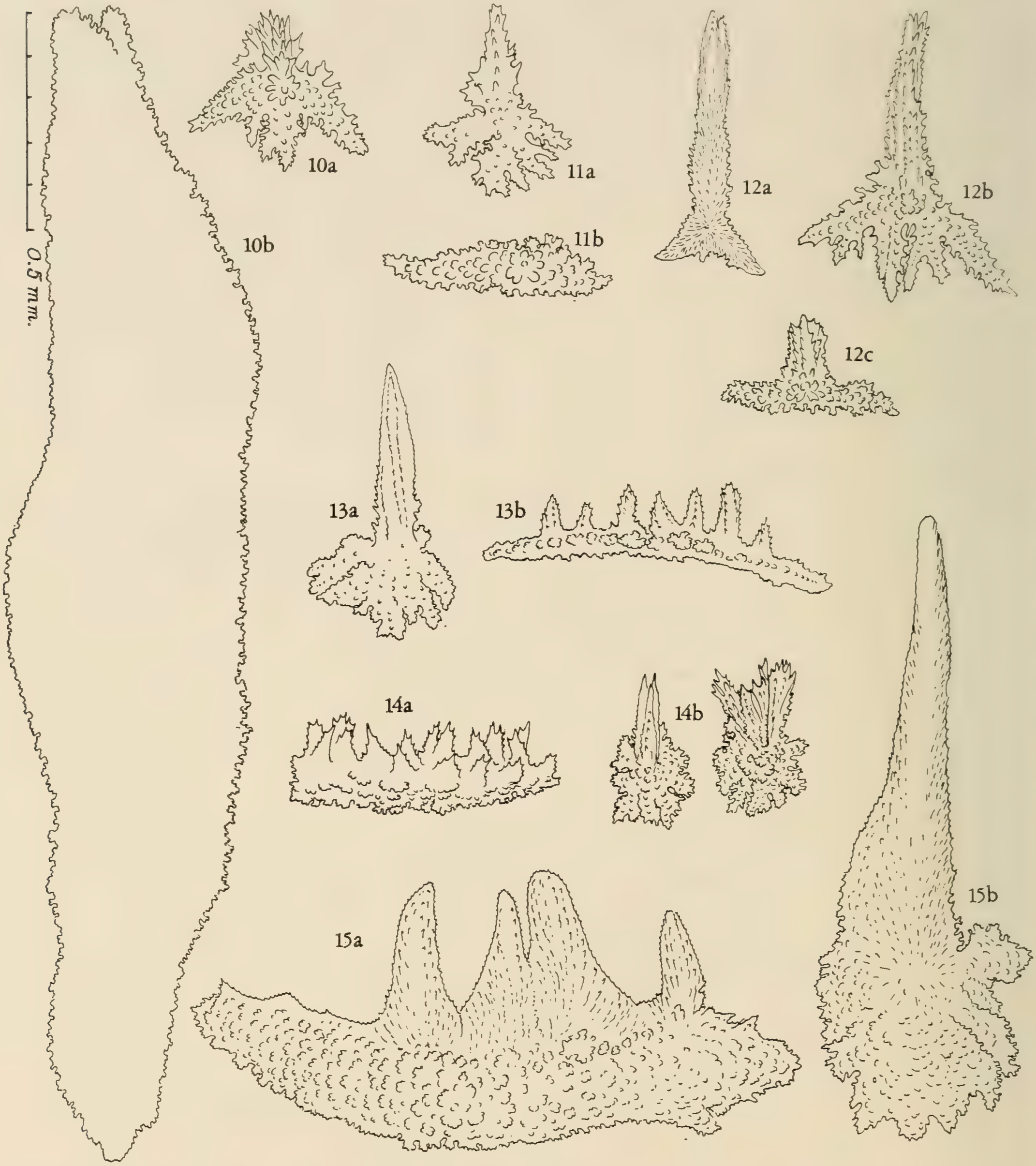
(b) Calicles: large thorn-scales with a stout, sharp, echinulate spine arising from the distal margin (Fig. 6). The broad, tuberculate basal part of the scale may have a width of 0.8 mm, and the spine may exceed a length of 1 mm.



Figs. 2–9.—*Placogorgia tribuloides*, n. sp.: 2, Side view of calicle with operculum; 3–4, cortical sclerites; 5, spindles of axial sheath; 6, calicular thorn-scale; 7, spindles of collaret and 8, of points; 9, spicules from the tentacles. All spicules enlarged to scale shown beneath Fig. 4.

Their appearance *in situ* on the calicles is shown in Fig. 2.

(c) Polyps: the collaret contains about 5 transverse rows of curved spindles, in smaller polyps as few as 3 rows, in larger individuals as many as 5 or occasionally 6 rows. In polyps of average size they have a length of 0.5 mm (Fig. 7). Surmounting the collaret, the eight opercular points contain one pair of large, bent spindles about 0.5 mm long (Fig. 8) and another pair or two of smaller but similar accessory rods. The appearance of the closed operculum, partly retracted within the calicle, is shown also in Fig. 2. The tentacles contain the small, flat, bent rod-



FIGS. 10–15.—Spicules of *Placogorgia*: *P. mirabilis* (10a, calicular thorn-scale; 10b, cortical spindle); *P. atlantica* (11a, calicular thorn-scale; 11b, cortical spindle); *P. tenuis* (12a, crutch-shaped rod from opercular sector; 12b, calicular thorn-scale; 12c, cortical sclerite); *P. rudis* (13a, calicular thorn-scale; 13b, cortical sclerite); *P. placoderma* (14a, cortical sclerite; 14b, calicular thorn-scales); *P. tribuloides* (15a, cortical sclerite; 15b, calicular thorn-scale).

lets with laciniated edge that are characteristic of paramuriceid genera (Fig. 9).

Color.—White, the light brown axis showing through the translucent spicules.

Holotype.—U.S.N.M. no. 10204. Straits of Florida, off Havana, Cuba: 23° 10′ 39″ N., 82° 20′ 21″ W., 204 fathoms, January 19, 1885; collected by tangles. *Albatross* station 2335.

Remarks.—Four other species of *Placogorgia* are known to occur in the Atlantic: *Placogorgia atlantica* Wright and Studer, *P. mirabilis* Deichmann, *P. rudis* Deichmann, and *P. tenuis* (Verrill). *Placogorgia tribuloides* differs from all these species in the large size of its thorn-scales, which approach the type found in *Paramuricea.* That genus, however, lacks the large cortical spindles or plates with serried processes. *P. tribuloides* further differs from *P. mirabilis* in the absence of excessively large (4 mm) spindles in the cortex; from *P. rudis,* which has similar cortical spindles, by its large and sharp thorn-scales; and from *P. tenuis* by the frequent development of several spines on the cortical spindles and the lack of the single large, crutch-shaped rod in the opercular segments. These differences may be set forth in the form of a dichotomous key:

1. Cortex contains large spindles up to 4 mm in length, clearly visible to the unaided eye (Fig. 10b). Anastomosis of branches frequent *Placogorgia mirabilis* Deichmann

   Largest spindles of cortex less than 2 mm in length. Anastomosis of branches infrequent or absent 2

2. Operculum usually with a single large, crutch-shaped rod (Fig. 12a) in each sector. Cortical spindles up to approximately 0.6 mm in length, usually with only one projecting process (Fig. 12c), sometimes none *Placogorgia tenuis* (Verrill)

   Operculum with at least two large, bent spindles in each sector, not a single crutch-shaped rod 3

3. Cortical spindles small, usually not exceeding a length of 0.5 mm, without a row of prominent external spines (Fig. 11b). Thorn-scales 0.5 mm long, spine 0.3 mm, sharp and aculeate (Fig. 11a) *Placogorgia atlantica* Wright and Studer

   Cortical spindles larger, up to 1.5 mm in length, many of them with a row of spines (Figs. 13b, 15a) 4

4. Calicular thorn-scales large, 1.7 mm over-all, with a strong, sharp spine as much as 1 mm in length (Fig. 15b) *Placogorgia tribuloides,* n. sp.

   Calicular thorn-scales smaller, usually not more than 0.5 mm over-all, spine stout, mostly blunt or moderately sharp (Fig. 13a), commonly 0.2–0.25 mm long and rarely up to 0.4 mm, often with several prominent terminal subdivisions.......*Placogorgia rudis* Deichmann

REFERENCES

Aurivillius, Magnus. *The gorgonarians from Dr. Sixten Bock's expedition to Japan and Bonin Islands 1914.* Kungl. Svenska Vet.-Akad. Handl. (3)**9**(4): 337 pp., 65 figs., 6 pls. 1931.

Bayer, Frederick M. *Les octocoralliaires plexaurides des côtes occidentales d'Amérique.* Mém. Mus. Nat. Hist. Nat., Paris, nouv. sér. (A)**16**(2): 41–56, 6 pls. 1958.

Deichmann, Elisabeth. *The Alcyonaria of the western part of the Atlantic Ocean.* Mem. Mus. Comp. Zool. **53**: 317 pp., 37 pls. 1936.

Johnson, James Yate. *Descriptions of some new corals from Madeira.* Proc. Zool. Soc. London 1862: 194–197, 14 figs. 1862.

Kükenthal, Willy. *Gorgonaria.* Wiss. Ergebn. deutschen Tiefsee Exped. **13**(2): 946 pp., 318 figs., pls. 30–89. 1919.

———. *Gorgonaria.* Das Tierreich **47**: xxviii + 478 pp., 209 figs. Berlin, 1924.

Nutting, Charles Cleveland. *The Gorgonacea of the Siboga Expedition. III. The Muriceidae.* Siboga-Exped. Monogr. 13^b: 108 pp., 22 pls. 1910.

———. *Descriptions of the Alcyonaria collected by the U.S. Fisheries steamer "Albatross," mainly in Japanese waters, during 1906.* Proc. U.S. Nat. Mus. **43**: 1–104, pls. 1–21. 1912.

Studer, Théophile. *Versuch eines Systemes der Alcyonaria.* Arch. Naturg. 53 Jahrg. (1): 1–74, pl. 1. 1887.

Thomson, J. Arthur. *Alcyonaires provenant des campagnes scientifiques Prince Albert Ier de Monaco.* Rés. Camp. Scient. Albert Ier Monaco **73**: 77 pp., 6 pls. 1927.

Wright, Edward Perceval, and Studer, Théophile. *Report on the Alcyonaria collected by H.M.S. Challenger during the years 1873–1876.* Repts. Voy. *Challenger,* Zool., **31** (part 64): lxxii + 314 pp., 43 pls. 1889.

ARCHEOLOGY SALVAGE PROGRAM IN CHATTAHOOCHEE VALLEY

Five thousand years of buried history are represented in the lower valley of the Chattahoochee River of Alabama and Georgia, which soon will be inundated by a group of dam-created reservoirs. This is indicated in a preliminary survey by archeologists of the River Basin Surveys—joint project of the Smithsonian Institution, National Park Service, and Corps of Engineers—to explore sites of archeological and historic significance which will be flooded in extensive dam-building plans.

Largest of the areas to be inundated will be the Walter F. George Basin, named for the late senior senator from Georgia. The survey revealed 117 sites in Georgia and 90 on the Alabama side of the Chattahoochee, and they are to be explored more thoroughly—the most worthwhile with extensive excavations—before the Army engineers complete their work.

These sites range from simple Indian village locations to areas containing remains of several different cultures, and from single mounds in which Indians buried their dead to multiple groups of mounds surrounding ceremonial plazas. There also are two historic sites of considerable importance. One is the Spanish fort of Appalachicola, dating from 1689 to 1691, and the other the historic Creek Indian town of Roanoke, which was occupied by white settlers and then attacked and burned by the Indians in 1736. The fort will lie just outside the pool area, but, because the exact dates of its occupancy are known, it will be tested as it should provide an important check point in working out the chronology of the area. The remains of Roanoke also will be helpful in that respect and should be quite productive of archeological specimens. Plans are being made to start excavations there this spring.

The Indian sites in the Walter F. George Basin date from about 4,000 B. C. to relatively late Creek villages of the period from 1675 to 1836. These latter present the possibility of a specific identification of sites from ethno-historical and other documentary evidence.

Two other Chattahoochee Valley dams are also under construction—the Columbia Dam, which is another project of the Army Engineers, and the Oliver Dam of the Georgia Power Co. The basins to be flooded by these reservoirs are an integral part of the picture and must be studied in conjunction with the Walter F. George Basin. Work is just beginning at the Columbia Dam, while the Oliver Dam is virtually completed and will be closed in April. Two River Basin Survey parties will start excavations at the Columbia Dam site in February. Complete coverage of that Basin was not possible in the preliminary survey, but 14 sites were located. One, a major mound probably dating from about 300 years before Columbus, already is half destroyed by the river and will be the scene of operations of one of the field parties. The University of Georgia is cooperating in the salvage program and since last fall has been testing a series of sites in the Oliver Basin. Much useful information has been obtained. The work there has been supported by a grant from the Georgia Power Co.

Only sporadic archeological work has been done in the Chattahoochee area in the past, and an extensive program of excavations is indicated. In addition to the University of Georgia, Alabama and Florida institutions probably will cooperate with the Smithsonian Institution and the National Park Service in the salvage program.

GRASS PRIMER REPRINTED

The Smithsonian Institution announces the publication of a new edition of *First Book of Grasses*, by Dr. Agnes Chase, one of the world's foremost agrostologists. Formerly botanist of the United States Department of Agriculture and now honorary Fellow of the Smithsonian Institution, Mrs. Chase will observe her ninetieth birthday on April 20, 1959. Much of her scientific work has appeared in this JOURNAL.

Since it first appeared in 1922, this book has been the companion of succeeding generations of beginning students of grasses. It has been out of print for several years. The present revised (3d) edition, 150 pages in length, contains 94 of the author's drawings of grasses, plus a frontispiece reproduced in color of Albrecht Dürer's painting "Das grosse Rasenstück." Dr. Leonard Carmichael, Secretary of the Smithsonian Institution, has contributed a new Foreword.

Clarence Raymond Shoemaker

March 12, 1874—December 28, 1958

Love of the outdoors and natural history ran strong in the Shoemaker family, staunch, thrifty, purposeful Quaker farming folk who originally settled in Cheltenham, Pa., in the days of William Penn. Some became businessmen, others millers; a few became well-known naturalists.

Clarence Shoemaker's grandfather, George, who left Pennsylvania for Georgetown in 1818, was a miller, who controlled the former Columbia Flour Mills. He served as local flour inspector for 48 years and, interestingly enough, was an amateur horticulturist and fruit grower. Clarence's first cousin, Ernest (1866–1957), became a well-known coleopterist. His exceptionally fine personal collection of beetles, butterflies, and moths was bequeathed to the U. S. National Museum, while his extensive collection of American Indian arrowheads went to the American Museum of Natural History in New York.

Clarence's bent for natural history developed early on spacious grounds graced with forest trees, ornamental shrubbery, and gardens surrounding his home in then bucolic Georgetown. The place was always alive with birds far beyond what one can find today in that now more settled area. Here he lived from the age of seven until his death, December 28, 1958, at the age of 84. It was quite natural that in his teens he should become one of the very early members of the Washington Audubon Society. As one of its most dedicated and ornithologically knowledgeable members, he was much sought after as a bird-walk leader. Equally interested in native wild flowers, he was also for many years an active and enthusiastic participant in the botanical "excursions" conducted by the Wildflower Preservation Society. Moreover, the Foundry Flour Mill, managed by his father, Francis Dodge Shoemaker, and his uncle, David, which supplied large quantities of flour to the Federal Government during the Civil War, was situated on Foundry Branch near the crossing of the first Potomac aqueduct, between the river and the Chesapeake and Ohio Canal, from which it drew its waterpower. Though scarcely a quarter of a mile beyond the town that then was Georgetown, it was an unspoiled wooded area where wildlife and flowers abounded and where virtually all the local species of either could be found at one season or another.

Shoemaker was educated in a private school in Georgetown. From this he went for a year to the Western High School but graduated from Central three years later, in 1897. In this latter school he received his first formal instruction in biology. He also took (1910–1911) collegiate work in that subject at George Washington University but did not continue, for, as he expressed it, he already knew more zoology than was then taught to undergraduates there. That rather comprehensive knowledge he had gained in the field and through his long association with the Smithsonian Institution.

It was quite natural that, as a young man born in Washington and with his interest in natural history, he should turn to the Nation's pioneer scientific establishment nearby in search of a future. The first opening that came his way, however, was a clerkship in the Smithsonian's International Exchange Service of which an older cousin, Coates W., was the chief. Given this opportunity, he further developed another interest—spiders—that he had earlier acquired on the home and mill grounds. Not only did he continue assiduously to collect them and build up an extensive library of arachnid literature, but he so well mastered the systematics of the group that he was soon recognized as an authority on the local fauna. As a consequence, he was frequently called upon by the U. S. Department of Agriculture and others to identify spiders. Later his spider collection was left to the National Museum and is incorporated in its larger study collections.

In 1910 Dr. Mary J. Rathbun, in charge of the marine, aquatic, and terrestrial invertebrates in the National Museum, gave him his first opportunity for full-time zoological work as scientific aide in her division. He was promoted to assistant curator in 1921 and associate curator in 1942. Retiring in 1944 at the age of 70, he was given the honorary title of research associate in the Smithsonian Institution. It was Miss Rathbun who assigned to him the study of the vast and largely, at the time, unworked collection of amphipod crustaceans to which he thereafter rather closely devoted the rest of his life. Though relinquishing his interest in spiders and giving somewhat less attention to his fieldwork with birds and flowers, he continued to maintain his very colorful iris garden. In its heyday it was one of the show places in Old Georgetown.

Throughout his life Mr. Shoemaker was an active member of the Audubon and the Wildflower Preservation Societies already mentioned, the Biological Society of Washington, the Washington Biologists' Field Club, the American Association for the Advancement of Science, and the Washington Academy of Sciences to which he was elected in 1939. He was also a member of the American Ornithologists' Union and a charter member of the American Society of the Mammalogists and of the Society of Systematic Zoology.

His scientific reports on the Amphipoda figuratively covered the world, for, because of his very special knowledge of that group of crustaceans, he received collections for study from a number of important scientific expeditions. Among these expeditions are to be numbered the South Georgia and Belgian Congo Expeditions and the biological survey of Porto Rico and the Virgin Islands of the American Museum of Natural History in New York; the Bermuda Expeditions of the New York Zoological Society; the Canadian Cheticamp and Hudson Bay Expeditions; the Canadian Arctic Expedition, the U. S. Antarctic Expedition of 1939–1941; the Point Barrow, Alaska, Expedition; various West Indian expeditions, including his own to the Florida Keys and the American Virgin Islands; the Johnson-Smithsonian Expedition to the Porto Rican Deep; and the Presidential Cruise to the Galápagos Islands. Up to the time of his retirement he had published 56 papers on these forms, and since that occasion some 14 others. Beyond these, by the time of his first serious illness preceding his death by a bare three weeks he had completed and illustrated several additional manuscripts that are about ready for the printer except for typing. The very last of these contained the descriptions of two new and unusual species of amphipods taken on the Smithsonian-Bredin Caribbean Expedition in the spring of 1958.

He was a meticulous worker. His desk and laboratory table (they were one), his instruments and optical equipment, notes, card files, and publications were left in excellent order. There have been few specialists on amphipods who knew them as well, loved them as much, and described and figured them as carefully as Mr. Shoemaker. He was his own artist, and his drawings were exceedingly clear and accurate; no essential detail was ever glossed over or overlooked.

As a kindly, unassuming friend, and a scientifically productive individual, he will long be remembered by his colleagues in this Museum and coworkers elsewhere around the world.—WALDO L. SCHMITT.

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OF THE

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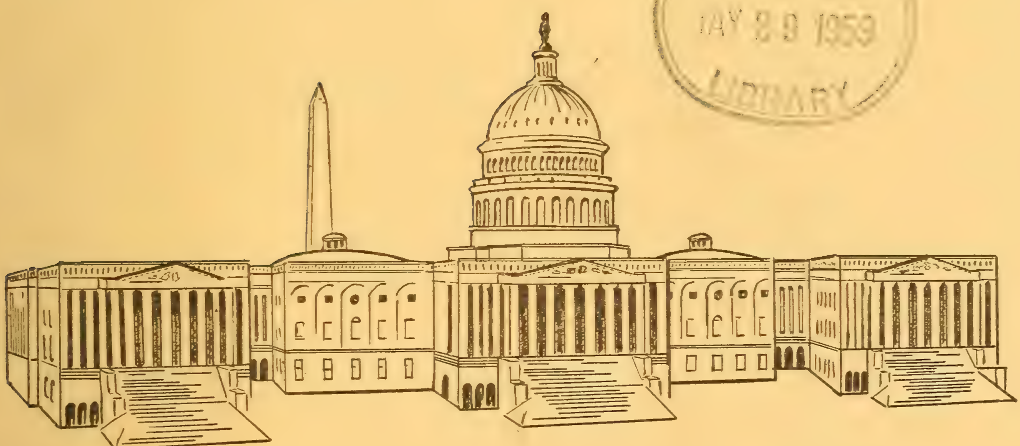

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PAPERS COMPRISING A SYMPOSIUM ON THE SUBJECT "EXTRAMURAL SCIENCE PROGRAMS OF THE FEDERAL GOVERNMENT," ARRANGED BY A COMMITTEE OF THE WASHINGTON ACADEMY OF SCIENCES (GEORGE W. IRVING, CHAIRMAN) AND PRESENTED SUNDAY MORNING, DECEMBER 28, 1958, AT THE SHERATON-PARK HOTEL, WASHINGTON, D. C., AS THE ACADEMY'S CONTRIBUTION TO THE 125TH MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Introductory Remarks by Dr. A. T. McPherson, Presiding

It is a great pleasure for me, as the President of the Washington Academy of Sciences, to welcome you to the symposium on "Extramural Science Programs of the Federal Government." This symposium is the Washington Academy's contribution to the 125th meeting of the American Association for the Advancement of Science. As you know, Washington is the scientific as well as the political Capital of the United States. Every major scientific activity in our Government has its headquarters in or nearby Washington. Moreover, several of the national scientific societies have established their national headquarters here in Washington, owing at least in part to their desire to be near the scientific activities being conducted here at the seat of Government. Among these is, of course, our own Association.

Since Washington is unique in being the center of Federal scientific activity, it was felt in planning this symposium that our most useful contribution would be to have representatives of the principal agencies of the Federal Government describe some aspect of the research supported by them. Inasmuch as many who attend the AAAS meetings have conducted research under Federal support or may wish to, it occurred to us that the aspect that would be of most interest to the greatest number would be the extramural science programs each agency sponsors. It is particularly appropriate, we feel, that the Washington Academy of Sciences has been given the opportunity to do this since it is the one scientific society in the Nation's Capital that counts among its membership representatives of all the scientific disciplines. Included in its membership also are many of the policy-making scientists of the Federal Government.

Perhaps it is appropriate at the outset to indicate what we mean by "extramural" science programs. We mean, simply, any programs that are conducted outside of the physical facilities of an agency and staffed predominantly by non-Federal employees. This includes scholarships, fellowships, grants, grants-in-aid, loans, contracts and cooperative programs.

It would be impossible in the time allotted this session to include a description of every extramural program that is now in effect in the Federal Government. We have selected, rather, the six Federal agencies which, together, support the majority of extramural research and science education programs in the country. They are, as your program indicates, the National Science Foundation, the National Institutes of Health, the U.S. Department of Agriculture, the Department of Defense, the Atomic Energy Commission, and the National Aeronautics and Space Administration. The representatives of these agencies here with us today can speak authoritatively on the extramural programs for which their agencies are responsible, since they occupy in each case high positions in their respective agencies.

The order of presentation is immaterial except for the first. We have asked the representative of the National Science Foundation to lead off since the NSF, in addition to its responsibility for its own direct extramural programs, has certain coordinating responsibilities for science programs in all Federal Government agencies as well.

We hope that this symposium will give you a clear picture of the extramural research and science education program of the Federal Government in its entirety.

Extramural Science Programs of the National Science Foundation

By Robert B. Brode, *Associate Director for Research, National Science Foundation*

We are here as representatives of several of the Federal agencies to discuss the nature and scope of our respective agencies' extramural programs for research and education in science. The National Science Foundation conducts no research or education programs itself. All the support of education and research by the Foundation is through extramural grants and contracts.

The nature of the activities of the Foundation and its objectives are adequately described in the Act of Congress which was approved by the President in May 1950 and led to the establishment of the National Science Foundation as an independent Federal agency. Section 3 of this Act states that the Foundation is authorized and directed "to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences; to initiate and support basic scientific research . . .; to appraise the impact of research. . . ."

In carrying out these directives the Foundation is itself forbidden to operate any laboratories or pilot plants. The Act permits the making of contracts or grants for scientific research through the utilization of appropriations available in such a manner as will best realize the objectives of the Foundation. There is very great freedom given to the Foundation in the choice of organizations or institutions to which grants or contracts may be given. While nonprofit organizations are particularly identified, the Foundation is not exclusively restricted to this type of agency. It may make grants to such institutions, individuals, agencies of the United States, and the several States as are qualified to best realize the objectives of the Foundation—in particular, the advance of basic research.

A very substantial part of the business of the National Science Foundation is the support of basic research in science through institutions and individuals that are best qualified to pursue such research. Advisory panels and program officers of the Foundation consider many factors in assessing research proposals: the qualifications and promise of the investigator; the nature of the proposed research project; and the facilities and support provided by the institution.

The Foundation is very conscious of the outstanding contributions made by a small number of scientists with exceptional ability. These men, together with a much larger number of good but not remarkable workers, will create the new developments in basic science. The Foundation is constantly looking for the young scientist who shows signs of real originality and boldness in his approach to scientific research.

In some areas of research the scientist's needs are easily met—books, pen, and paper may satisfy the mathematician. In most fields, however, the success of basic research in science depends on the accessibility of the necessary tools and assistants. Some of the modern research facilities are very costly and require large staffs of scientists and technicians for their operation. Nuclear reactors, cyclotrons, computers, radio and optical astronomy observatories have been built in part or wholly by Foundation grants.

In addition to providing the equipment required, Foundation support of research projects provides employment opportunities as research assistants for more than 6,000 graduate students studying for the Ph.D. degree.

Most of the basic research in this country is carried forward by our colleges and universities. It is therefore not surprising that nearly all the Foundation support of basic research is given to institutions of higher learning. This support is provided in almost every case through the use of a grant rather than by a contract.

In addition to its support of basic research, the Foundation supports a substantial program for the promotion of education in the basic sciences. The Foundation is directed by Congress to develop and encourage a national policy for the promotion of education in the sciences and in particular to award scholarships and fellowships. The award of fellowships to graduate students appears to have been an unusually successful enterprise, and thousands of scientists have been assisted by this program. Fellowship support has been extended to postdoctoral research workers and even to junior and senior faculty to assist them in developing new research programs or to enhance their competence as teachers. The competition for National Science Foundation fellowships is severe, and the award of a fellowship is considered as recognition of very high scholastic achievement and research promise.

Foundation support of education in the sciences extends to universities and colleges in all States through establishment of science teacher institutes. These are designed to improve the training of science teachers, especially secondary-school teachers, in the subject matter of science. Approximately 350 summer institutes will be functioning under this program in the summer of 1959. In addition, about 35 academic year institutes will begin in the fall of 1959, as well as some 200 in-service institutes designed to benefit the teacher who lives in the vicinity of the college or university by offering courses taught at night or on Saturdays.

The Foundation has developed several experimental programs in education; most of these are built upon patterns established either by the fellowship or the institute program. The Foundation is also extending substantial support to curriculum improvement programs for secondary-school science courses, in physics, mathematics, chemistry, and biology, but extending as well to many of the other sciences.

Knowledge is society's most precious possession, and a very important and rapidly growing area of knowledge is basic science. The value and use of knowledge can be assured for future generations only if we record in publications the results of our research. The critical problem of scientific literature is illustrated by the tremendous volume that must be assimilated. If the auditorium were full, all of the people in this room reading 24 hours a day could not keep up with our present output of scientific literature. The rate of increase of literature is such that the world's output in pages per year will double in the next 8.5 years. The National Science Foundation has contributed substantially to this flood of scientific literature by making grants to scientific societies to aid in the establishment of new journals or in the expansion in size of existing publications. The importance of Soviet scientific developments has been recognized in our program for English translations of important journals and books that are available only in the Russian language.

Not only is it necessary to print and store in our libraries the full account of our total knowledge, but we must also develop the means of identification and retrieval of this knowledge. We are assisting abstract journals as well as general studies of new means of searching for information. The Office of

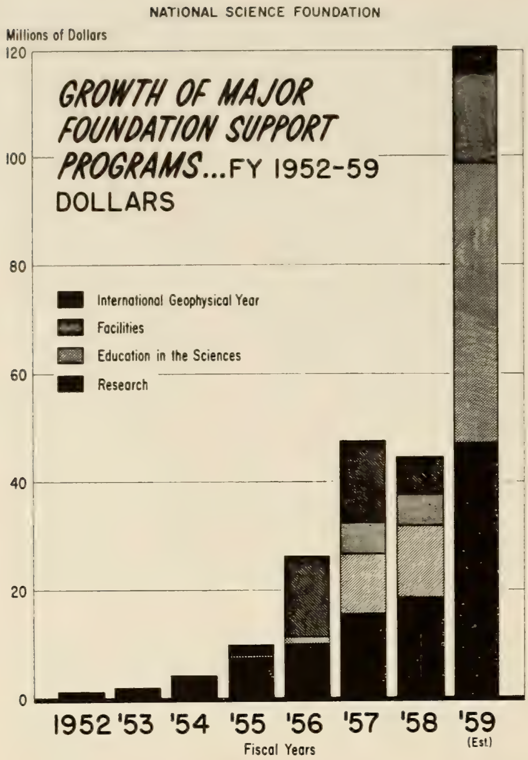

CHART 1

Science Information Service is a division of the Foundation that provides assistance and coordination to Government and private abstracting and information-handling services. It is not a Government office set up to answer requests of the general public or of Government agencies for information about specific technical questions.

There have been two events since the initiation of the Foundation in 1950 which have appreciably changed the anticipated growth of Federal support for this agency. The International Geophysical Year, which officially ends next Wednesday, has been an intensive burst of scientific effort with a year of preparation and an 18-month year of coordinated observations. For some years to come the results and deductions from this period of observation will be published in scientific journals. The second event that affected the Foundation's budget was the awakening of the world by the Russian Sputnik. We have suddenly realized that leadership can be substantially influenced by the intellectual and technical attainments of a nation. This leadership requires not only adequate support for the research of its talented scholars but also an educational system that identifies potential scholars and gives them the best possible preparation for their careers. Chart #1 shows the growth and magnitude of the support given the Foundation.

The National Science Foundation makes grants to scientists on the basis of proposals submitted to it and reviewed by panels of specialists and by the Foundation's program offices. Some of these grants assure support for three to five years, while others are for one or two years. The funds provided by Congress have only been sufficient to enable the Foundation to grant less than a third of the proposals it receives. It is quite natural that the scientist who has won the competition for an award will return after a year or two for further support and he will then, because of the greater opportunity provided by the Foundation funds, present an even better justification for his support. The percentage of proposals for research support to which grants were awarded is shown in Chart #2. This is by no means an established pattern of support. Many meritorious proposals are now refused grants. At times we have been able to grant less than one-third of the requests considered worthy of support by the review panels.

The use of substantial funds by the Foundation has enabled it to support the construction of such facilities as the National Radio Astronomy Observatory, Green Bank, W. Va., and the Kitt Peak National Observatory, Tucson, Ariz. These national laboratories and institutes carry with their creation an implied commitment for continued operating budgets. The Foundation is indeed concerned with the problem of providing adequate support for the major facilities, and for the continued support of able scientists who justify essentially life time support. To this committed support load must be added the encouragement and opportunity which the Foundation must be prepared to offer to the young scientist beginning his independent research activity.

Congress has directed that the Foundation avoid undue concentration of research and education activities. A measure of the needs for basic science research support may be indicated by the number of graduate students or by the dollar grants. Chart #3 shows that the grants given are in reasonable balance with these two measures of need.

Support for education through fellowships and institutes for teacher training has been nationwide but not in all cases as well distributed as would be desired for a nationwide program. We have attempted to correct these discrepancies as they are iden-

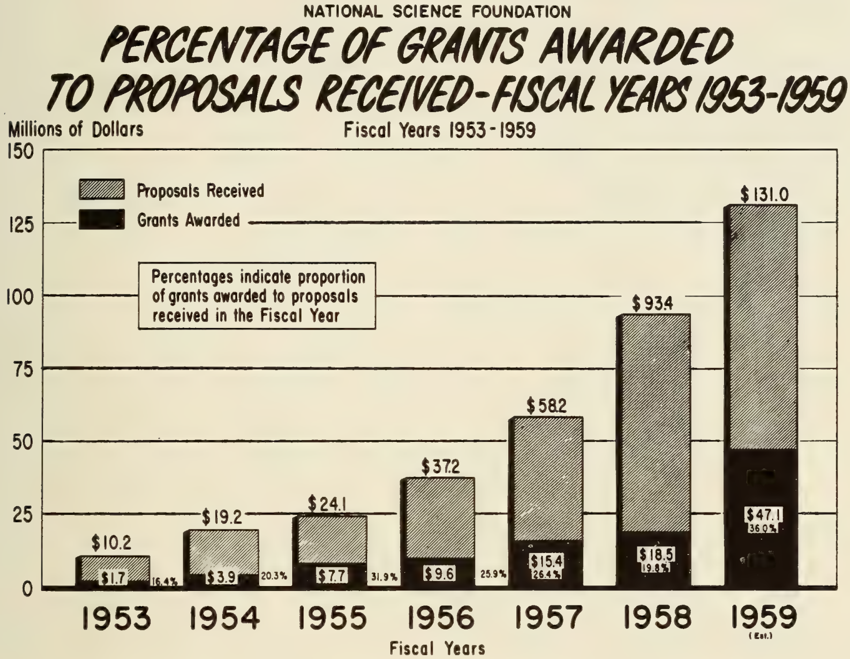

CHART 2

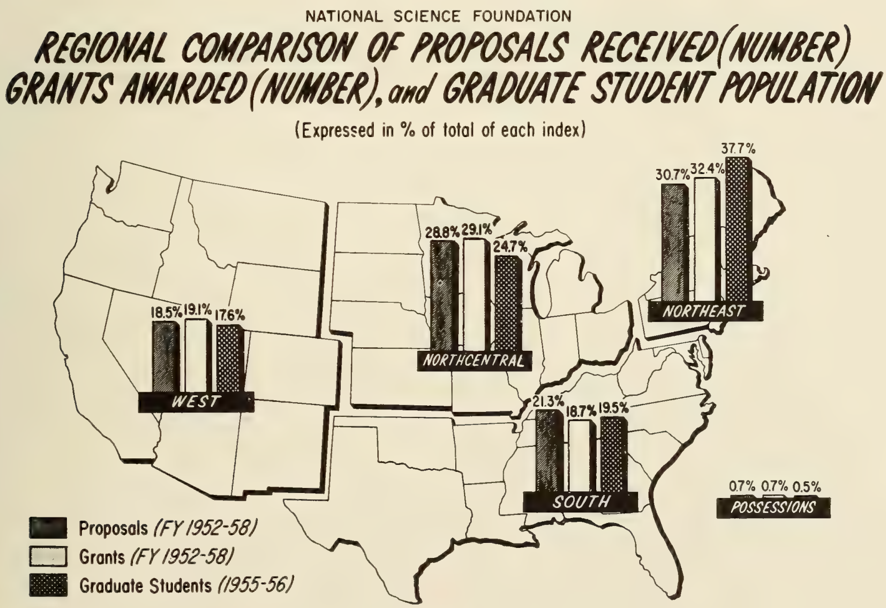

CHART 3

tified. A program of cooperative fellowships is being introduced this year which will provide a much wider distribution of fellows throughout the Nation, but still permit the applicant to select freely the institution through which he seeks to compete for the fellowship.

The activities of the Foundation are not restricted entirely to this country. Fellowships are granted only to citizens, but they may use their grants for study at foreign universities. Funds in support of research have frequently been used by grantees to carry on their studies in foreign countries; and in exceptional cases grants have been made to a few foreign investigators whose work was considered essential to our own programs or involved the active participation of American scientists or students. We have responsibilities for assistance to participants in international conferences and congresses. In our Office of Science Information Service we arrange for the exchange of publications and for the translation of some of these so that they will be generally available to scientists.

The principal objective of the National Science Foundation is the development of basic science in the United States. We are attempting to do this by direct support of the scientist in his research program, by supplying him with the means of publishing his results, with ready access to the results of the work of other scientists, and by improving our educational system so that promising scholars are given a better foundation for their future careers. Some very valuable and exciting advances have already been made in science through our support, but the major impact of such a broad program as we have undertaken will not be measured by the visible splashes but rather by the rising tide of general basic science development and the technological benefits that later come to society through their application and use.

Extramural Science Programs of the Department of Defense

By George D. Lukes, *Executive Secretary, Defense Science Board, Office of the Director of Defense Research and Engineering*[1]

I appreciate the invitation of the Washington Academy of Sciences to participate in this symposium and to make the Defense contribution on extramural science programs of the Federal Government. We in Defense find a symposium of this nature an excellent opportunity to get across to the scientific community at large the nature and scope of our scientific research activities and, particularly in the theme of today's session, how our extramural activities contribute to the achievement of Defense objectives. Within this framework I shall also weave some of the more significant aspects of our policy on basic research in the hope of furthering understanding.

[1] Formerly Office of the Assistant Secretary of Defense (Research and Engineering).

DOLLAR MAGNITUDE, PERFORMANCE COMPONENTS, AND RESEARCH SUPPORT LEVELS

It is important to provide, first, a backdrop of the total dollar effort of Department of Defense scientific research and development. The first chart shows graphically the DOD obligations for fiscal year 1959 in relation to those of the other Federal Government agencies. Something like 62 percent of all Federal funds devoted to research and development represents the Defense Department's share of the Federal effort. The second chart displays the approximate distribution of these funds in terms of the three major performance components: Government laboratories, industrial contractors, and university and other nonprofit institutions. You will note that industry performs about 60 percent of the total effort supported from the research and development appropriations of the Department of Defense, universities and other nonprofit institutions conduct about 9 percent, and Government laboratories perform the balance of 31 percent. Of funds for in-house performance, approximately 14 percent is for research and development *per se* conducted internally by Government scientists and engineers, 13 percent is for test and evaluation, and 4 percent is for contract monitoring.

I should now hasten to add that an additional source of funds is available for support of scientific and engineering activities of the Department of Defense, primarily the latter. These, in appropriation language, are principally the Procurement and Production funds, of which something like $3.2 billion in fiscal year 1959 go to the support of development, test, and evaluation of new weapons of the distinctively hardware variety—the B-58 and the IRBM and ICBM programs are good examples. The charts presented do not include the funds from this source; within the theme of this symposium—extramural science—their omission is of little consequence, however.

Now let us discuss the scientific research activity of the Defense effort. The third chart displays the character distribution of the Defense research and development program. Of our fiscal year 1959 research and development programs, 15 percent, or $391 million, is devoted to research; and of this $109.6 million is for basic research. The balance, 85 percent of the total program, is for development. We estimate that almost two-thirds of the $391 million of research funds supports extramural activities, and at least 70 percent of the $109.6 million basic research funds is devoted to extramural support of basic research.

NATURE AND SCOPE OF DEFENSE SCIENTIFIC RESEARCH ACTIVITIES

The science programs of the Department of Defense comprise activities in the physical and engineering sciences, in the life sci-

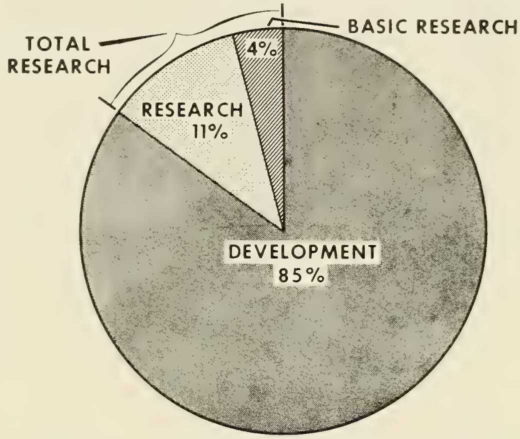

CHART 1. Estimated Distribution of FY 1959 Federal Government Research and Development Obligations.

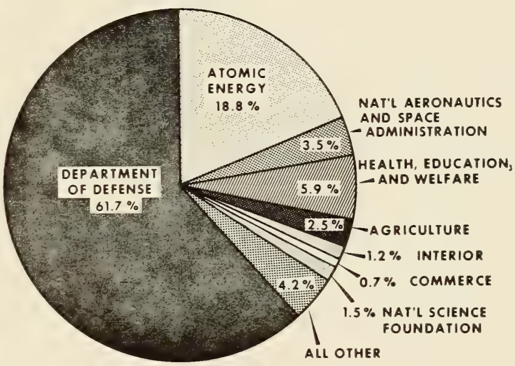

CHART 2. Where Defense Research and Development is Performed.

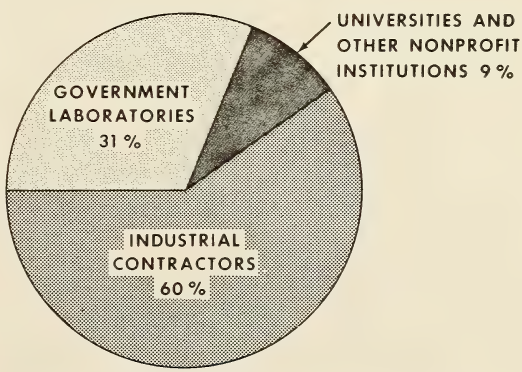

CHART 3. Character of Defense Research and Development Program for FY 1959.

ences, in psychology and the social sciences, and in operations research.

About 80 percent of the funds devoted to scientific research support activities in the physical and engineering sciences; this amounts to about $313 million in fiscal year 1959 Defense program. Within this broad category the typical fields of endeavor and the program objectives are as follows:

In *physics* the objective is the advancement, through systematic and exploratory research, of those selected aspects of pure and applied physics which contribute to an increase in military capability. The present program, totaling about $33 million in extramural effort, includes solid-state physics, extreme-temperature physics, statistical physics, physics of atoms and molecules, nuclear physics, physical acoustics, upper-air physics, electron physics, optics, magnetism, instrumentation for physical measurements, and electromagnetic radiation.

In *chemistry* the objective of the program may be divided into two parts: (1) a balanced effort of selected fundamental research which serves as a foundation for the varying needs of the military and (2) specific applied projects aimed at satisfying short-term defense needs. The present program includes research support in relevant areas of analytical, inorganic, organic, physical, polymer and radiation chemistry. The extramural support runs about $31 million yearly.

In *mathematics* the objective is the systematic advancement of this science, closely geared to the objectives of the other scientific programs, and in response to expanding needs for direct qualitative information about the design and operations of weapons and weapons systems. The present program includes algebra, analysis, geometry, topology, probability, statistics, logistics, communications, and computers. Extramural support runs about $5 million yearly.

With respect to those fields of endeavor that are more characteristically the engineering sciences, the scope of the programs and the broad objectives are as follows:

Mechanics: The objective of the research program in mechanics is the systematic advancement of engineering knowledge and principles bearing directly upon design criteria for the development of new weapons systems and components. Studies on the following are included in the present program: the dynamics of gases, liquids and solids; aerodynamic problems; problems involving structural design, strength of solids, hydromechanics, propulsion, heat and mass transfer, soil mechanics; and problems involving the development and synthesis of mechanisms. Extramural support runs about $25 million yearly.

Materials: The objective of the research program is the systematic advancement of knowledge on the fundamental properties and behavior of materials to provide the best possible selection for designers and fabricators of military weapons and equipments. The present program includes studies on metals, minerals, ceramics, elastomers, adhesives, transparent materials, organic structural materials, fibers and fibrous materials, insulating materials, and dielectric and magnetic materials. Extramural support runs about $27 million yearly.

Combustion: The objective of the research program in the field of combustion is to gain an increased understanding of the total process of transforming the chemical energy of reactants into thermal and kinetic energy of reaction products, so the design of military propulsion devices can be put on an increasingly rational basis. The present program includes investigations of basic phenomena in selected areas of physics, chemistry, fluid mechanics, thermochemistry, and thermodynamics; and also fundamental investigations of processes that are interrelated combinations of these phenomena. Extramural support runs about $6 million yearly.

Electronics: The objective of the research program in electronics is to ensure maximum extension and acceleration of all our senses for military purposes. The present program includes acoustics and underwater sound; antenna theory, electromagnetic propagation and reflection; communications, data handling, and information theory; electronic instrumentation and standards; electronic countermeasures and counter-countermeasures; IFF theory; infrared; navigation; radar; electronic tubes, parts, and semiconductors; and electron and ion plasma. Extramural support runs about $43 million yearly.

In the *geophysical sciences* the objective is the advancement through systematic and exploratory research of those selected aspects which will increase the capability of the military to utilize, predict, and control the natural environment. Included in the present program are meteorology, climatology, oceanography, marine geology, geochemistry, cartography, geodesy, geography, astronomy, astrophysics, magnetism, and gravity studies. Extramural support runs about $19 million yearly.

Turning now to the broad category of life sciences, the DOD supports major programs in the medical sciences and in biology. The scope and the objectives are:

In the *medical sciences,* to provide support of the mission of military medicine by studies in—

(a) Preventive medicine: research on methods of physical examination and health surveillance, promotion of physical fitness, preventive dentistry; nutrition, environmental physiology and pathology, disease and injury prevention, toxicology; protection against radiation and blast, the effects of chemical and biological agents, with methods of casualty prevention; industrial and public health studies.

(b) Studies relating to the medical problems of aviation, astronautics, submarine and diving medicine, man in relation to the machines of war in all media, terrain and climates; and survival techniques.

(c) Improved methods of medical, surgical, dental and psychiatric care and rehabilitation of the sick and injured.

The medical sciences program runs about $24 million yearly, of which about $15 million is the extramural effort.

In the *biological sciences* the objective is the systematic development of this field in areas of military interest. The present program includes hydrobiology, biogeography, ecology, the biomechanism of complex data reception and control in living systems, bacterial fungal, viral genetics and nutrition, the ecology of disease vectors, the mechanism of infection, and the survival of microorganisms. Extramural support runs about $7 million yearly.

As to the *psychological and social sciences,* the support level is about $21 million, of which $15 million is the extramural effort. Program content and the objectives are: the advancement through systematic and exploratory research of those selected aspects of pure and applied psychological and social sciences which contribute to an increase in the military capability. The present program includes studies leading to new concepts, techniques, devices, and principles applicable to the solution of military problems, including military manpower needs and the availability, selection, classification, assignment and proficiency measurement of personnel; education; training and training devices; motivation; morale; leadership; human organization; human engineering; psychological and unconventional warfare; intelligence operations; and civil affairs and military government.

Finally, coming to *operations research* as a field of scientific activity in its own right, the objective is to provide quantitative bases for executive decisions on military and related scientific matters. The present program includes contracts totaling about $28 million in support of work with RAND, the Operations Research Office, the Operations Evaluation Group, the Combat Operations Research Group, the Institute for Defense Analyses, the Human Resources Research Office, the Naval Warfare Analysis Group, and the Naval Warfare Research Center.

In total, these scientific research programs comprise a fiscal year 1959 Defense effort amounting to about $391 million, providing about $137 million to the conduct of intramural effort and $254 million to the support of extramural science activities.

DEPARTMENT OF DEFENSE POLICY ON BASIC RESEARCH

Let us turn now to objectives stated even more broadly. About a year ago Secretary McElroy issued a strong policy directive setting forth the principles governing the support of a Department-wide basic research program, conceived and anchored in imaginative long-term planning and long-term funding. This policy recognizes that "the needs of national defense are uniquely characterized by pressing demands for new facts and knowledge very close to the frontiers of science" in order to protect the security of the United States and its vast Defense investment against both technological surprise and obsolescence. It emphasizes also that the costs of basic research are small in proportion to the potential military strength to which basic research is capable of contributing and that "sustained support of basic research offers one of the most promising opportunities for effecting long-range economies in other aspects of the military program."

Specifically, the directive states:

A. It is the policy of the Department of Defense:
   1. To support a broad and continuing basic research program to assure the flow of the fundamental knowledge needed by the military departments as prime users of scientific facts and to evolve novel weapons of war; and
   2. To maintain, through such a broad support program, an effective contact between the military departments and the scientists of the country so that the military departments are continuously and growingly aware of new scientific developments and the scientists are aware of the military needs.

B. It is further the policy of the Department of Defense to coordinate its basic research program with the National Science Foundation and to encourage the support of sound basic research programs by government and private agencies, recognizing that these programs are essential to the full development, utilization and growth of the nation's scientific resources and, hence, to national defense.

Within the guidance of this policy, the Department of Defense substantially increased fiscal year 1958 funding for some research programs judged critical for the improvement of military weaponry. The increased funding for each field was: $31.6 million for the physical, medical, and geophysical sciences; $10 million for materials research; and $12.5 million for the vital areas of electron tubes and electronic parts. $30 million of these funds went to the support of basic and supporting research programs at academic institutions. The main effect was to restore research to the level from which it had sagged over the past several years owing to inflation and the increased costs of modern instrumentation. In addition to the above funds, $12 million was made available to the Army and Air Force in June of this year for the explicit purpose of financing certain contractual research programs for periods longer than the annual program increment or to provide for program longevity.

NEW GRANTS AUTHORITY UNDER PUBLIC LAW 85-934

The recent session of Congress saw the passage of Public Law 85-934, an act to authorize the expenditure of funds through grants for the support of scientific research. Heretofore the Department of Defense has been limited to the use of a research contract in engaging the services of an educational or other nonprofit organization. The Grants Act provides the authority to make grants to such institutions or organizations for the support of basic scientific research, where such action is deemed to be in furtherance of the objectives of the agency; it also grants discretionary authority to vest title of research equipment in the organization carrying out such research. Increased flexibility will accordingly result from this authority in Defense support of basic scientific research. A directive is presently being drafted in the Department of Defense to establish a uniform policy among all military agencies in the awarding and administration of research grants and the transfer of title to research equipment acquired under such grants.

This, I believe, covers the highlights of Defense science programs and our broad objectives in their support, the program content and technical objectives of our scientific effort in some discrete fields, and certain aspects of Defense policies designed to be constructive, forward-looking, and to lend stimulation and sustenance to science from the Defense end of the Federal Government.

Extramural Science Programs of the National Institutes of Health

By C. J. VAN SLYKE, *Deputy Director, National Institutes of Health; Assistant Surgeon General, Public Health Service, U. S. Department of Health, Education, and Welfare*

It is a pleasure to appear in this symposium on the extramural science programs of the Federal Government.

The program chairman has asked that I cover briefly the objectives and nature of the National Institutes of Health with respect to our extramural activities, leaving time for questions and discussion. What I shall present, therefore, is a thumbnail sketch of the NIH grants and awards programs.

I shall not attempt to include the NIH intramural program—its conduct of research—nor all the extramural programs of the U. S. Public Health Service, of which the NIH constitutes the principal research branch. Nor will this outline cover extramural scientific activities of other components of the Department of Health, Education, and Welfare, in which the Public Health Service is a part.

Now to turn to the NIH extramural program. The objective of the National Institutes of Health and of the Public Health Service is contained in the public laws which form our enabling legislation and which impose upon us grave obligations and duties. The purpose of all our activities is stated, in simplest terms, in public law as being "to improve the health of the people of the United States."

The methods for achieving this objective are, again in the shortest words, the conduct and support of research and training and aid in the application of knowledge.

In the legislation upon general duties, there is a charge to "conduct in the (Public Health) Service, and encourage, cooperate with, and render assistance to other appropriate public authorities, scientific institutions, and scientists in the conduct of, and promote the coordination of, research, investigations, experiments, demonstrations, and studies relating to the causes, diagnosis, treatment, control, and prevention of physical and mental diseases and impairments of man . . ."

In legislation establishing the Institutes which compose the NIH, such as the NHI, NCI, and so on, there are mandates directing the conduct and support of research and training and other activities aimed at the acquisition and application of knowledge concerning cancer and heart disease and other "categorical" disease fields.

Additionally, through the Health Research Facilities Act of 1956, there is provided a program of support for the construction of research facilities in the sciences related to health.

NATURE OF THE PROGRAM

These, then, are the objective and the methods of NIH extramural activities in general, legislative terms. What has been built upon this framework, what is it for, how does it operate, what are its characteristics, what is it accomplishing, what is its future? These and other broad questions occur, and the answers, though they be partial, will portray the nature of our grants and awards programs.

To begin the answers upon a historical note, I was privileged to author a paper, upon the real beginning of the NIH extramural program, in the issue of *Science* for Friday, December 13, 1946. The day and the date have turned out to be more auspicious than the general belief holds about enterprises connected with Friday the thirteenth. The paper began with these words:

> A large-scale, nationwide, peacetime program of support for scientific research in medical and related fields, guided by more than 250 leading scientists in 21 principal areas of medical research, is now a functioning reality. The program, based on U. S. Public Health Service Research Grants financed by public funds, supports research—conducted without governmental control—by independent scientists. The purpose of these grants is to stimulate research in medical and allied fields

by making available funds for such research and by actively encouraging scientific investigation of specific problems on which scientists agree that urgently needed information is lacking. Accompanying this purpose is complete acceptance of a basic tenet of the philosophy upon which the scientific method rests: The integrity and independence of the research worker and his freedom from control, direction, regimentation, and outside interference.

The U. S. Public Health Service Research Grants, in operation as a medical research program of scientists and by scientists, may have early and profound effects upon the course of medical history and the national health.

The program, both in principle and as administered, has been welcomed and approved wholeheartedly by leaders in medical research.

ORGANIZATIONS OF ACTIVITIES

The organization, programming, and appropriations responsibilities of the NIH extramural activities today fall into the following categorical Institutes and Divisions:

National *Cancer* Institute, National *Heart* Institute, National Institute of *Allergy and Infectious Diseases*, National Institute of *Arthritis and Metabolic Diseases*, National Institute of *Dental Research*, National Institute of *Mental Health*, National Institute of *Neurological Diseases and Blindness, Division of General Medical Sciences, Division of Hospital and Medical Facilities, Division of Nursing Resources, Division of Sanitary Engineering Services*, and *Division of Special Health Services*. Noncategorical or general research and training grant funds are available from the Division of General Medical Sciences for scientists whose interest do not fall within the scope of responsibility of the categorical Institutes and Divisions. The Division of Research Grants of the National Institutes of Health has administrative responsibility for the management of the research grants programs, and for the Health Research Facilities construction grants.

NATIONAL ADVISORY COUNCILS

By Federal law, nine National Advisory Councils have been established as advisers to the Public Health Service. No research or training grant may be paid by the Surgeon General unless recommended for approval by one of these Councils. Seven of the Councils advise the seven so-called categorical Institutes on their respective programs, in addition to reviewing and recommending appropriate action on applications for grant support. The National Advisory Health Council reviews applications for general or noncategorical research grants and advises the Surgeon General on matters relating to health activities and functions of the Service. The Federal Hospital Council advises the Surgeon General on matters relating to the Administration of the Hospital Survey and Constructions Program and reviews applications for grants in aid of projects in research, experiments, or demonstrations relating to the development utilization, and coordination of hospital services, facilities, and resources.

The National Advisory Council on Health Research Facilities, established in July 1956, reviews and recommends appropriate action on applications submitted by universities or other nonprofit institutions for assistance in the construction and/or equipping of additional facilities for the conduct of research in the sciences relating to health. The Federal share can not exceed 50 percent of the total cost of building of research space.

SCIENTIFIC STUDY SECTIONS

In view of the large number of applications which must be evaluated, and the need for skilled scientific review covering the entire range of medical and biological research, more than 30 Study Sections of special nonfederal consultants expert in various fields of research have been established. These study sections act as technical advisers to the National Advisory Councils and to the Surgeon General. They accept responsibility not only for providing technical advice on applications for research support but also in conjunction with the Councils, for surveying as scientific leaders the status of research in their particular fields in order to determine areas in which additional activity should be initiated or expanded.

TYPES OF EXTRAMURAL ACTIVITIES

The grants and awards of NIH are comprised in four main categories: (1) research grants, (2) research fellowships, (3) training grants and traineeships, and (4) health research facilities grants. I shall discuss each in a highly summary fashion, sketching their general functions.

1. Research Grants

These grants are made to universities, medical schools, hospitals, laboratories, and other public or private institutions and to individuals for support of research in health, medicine, and allied fields. The major objectives are: to expand medical and biological research in scientific institutions throughout the country; to stimulate new investigations in fields needing exploration; and to provide, incidentally, on-the-job training for scientific personnel in connection with the research being conducted. The funds provide for salaries, equipment, supplies, travel, overhead, and certain other expenses.

Research grants are financed from appropriations made to each of the seven Institutes concerned with "categorical" disease fields and from an appropriation to the NIH (for general research and services) to support needed research lying outside the "categorical" disease fields.

Grants are made on a yearly basis. However, continuity and stability, both for the work and the man, are of paramount importance and have been so considered since the beginning of the program. Therefore, the duration of the investigation is a vital consideration of the Study Sections and Advisory Councils in their decisions regarding recommendations for action. These bodies have consistently provided for continuity and have indicated to grantees continued favorable action as long as congress appropriates necessary funds. The Congress has recognized the importance of these moral commitments and has sustained them in principle and practice.

That we have steadily progressed toward greater stability is shown in the fact that, early in the life of the program, the average duration of a grant was about two years. Today, the average duration is some five years, and many meritorious investigators have received support since 1946.

Research under the program is conducted by the investigator with full independence and autonomy. Support of research through the use of research grants does not imply in any way any degree of Federal control, supervision, or direction of the research studies. Although the investigator submits a proposal in his application, he is free to pursue the project in any manner he deems most promising. The autonomy of the individual researcher implied in this philosophy does not, however, exclude self-imposed guidance entailed in the over-all plan of an organized, cooperative research project in which several groups of investigators may collaborate.

In order not to divert the time of the researcher unnecessarily from the actual conduct of the research, he is requested to submit only informal annual progress reports, and their distribution is limited to the reviewing consultants.

Neither these advisers nor those who administer the program in the NIH review grantee papers proposed for publication. Grantees, fellows, and trainees may publish results of any work supported by grant or award when and where they wish, and responsibility for direction of the work is never and should never be ascribed to the NIH, Public Health Service. This does not indicate any lack of interest in the results of research projects, but is aimed solely at avoiding any degree of governmental restriction. Grantees are requested, however, to provide 10 copies of reprints after papers have been published. It is also requested that published papers carry footnote acknowledgment of the financial assistance through the grant.

The research grants program has grown steadily. While financial figures are far from being the only factor which shows growth, they are at least easily apparent. In fiscal year 1949, some 10.8 million dollars was appropriated for the purpose; in fiscal year 1959 the appropriation for research grants is 141.5 million dollars. This year there will be some 7,000 or more research grants awards, so dispersed geographically that every corner of the country where there is real research potential will be reached and the nation will be aided with this support. Some 5,000 or so professional papers will be published by these grantees in a wide range of journals, and it is these fruits of the work that best testify to the quality of the endeavors supported.

This is research in the public interest and in which the public is vitally interested for, as we all know, medical research is a subject which the public eagerly devours when presented through the media of public communication. Since studies done with research grants are supported with public funds, there is no desire on the part of NIH to assume credit for this work; credit belongs to the investigator and his institution and to the people who, through their Congress and Administration, make possible today so much more medical research than used to be conducted. Therefore, it is of public interest to say that, year by year, many of the medical research findings hailed in the press and among the professions have received NIH grant support. The quality of the program and the quality of the judgment exercised by the Study Sections and Councils is reflected, for example, in the fact that a total of 27 Nobelists in medicine and physiology have been recipients of NIH-PHS grant support, including this year's winners.

2. Research Fellowships

Research fellowships are intended to increase the number of scientists qualified to carry on independent research. Seven types of fellowships are presently available:

(1) *Predoctoral research fellowships* are awarded to students with a bachelor's degree or equivalent, for the pursuit of graduate research training in the fields related to the health sciences. Stipend rates are $1,600, $1,800, and $2,000 for the first, second, and third years, respectively. Allowances for dependents, travel, and tuition are added to the stipend.

(2) *Postdoctoral research fellowships* are awarded to qualified persons holding a Doctor's degree in medicine, dentistry, or related fields. Stipend rates are $3,800, $4,200, and $4,600 for the first, second, and third years, respectively. Allowances for dependents, tuition, and travel are added to the stipend.

(3) *Special research fellowships* are awarded to qualified candidates who have demonstrated unusual competence in research or who require specialized research training. The stipend, including necessary allowances, is determined at the time of the award.

(4) *Student part-time research fellowship grants* are awarded to schools of medicine, dentistry, nursing, and public health. The awards are designed to give students in the health sciences an opportunity to explore the research field in the hope that many of those supported will enter into full or part-time research careers. Units of $600 are provided for part-time research work during the school term, or for full-time research work for two months during any time when curriculum work is not scheduled for the student.

(5) *Senior research fellowship grants* are awarded to schools of medicine, dentistry, and public health in support of competent scientists who wish to conduct research and teaching in the preclinical sciences. These fellowships provide support between the completion of postdoctoral training and the time of eligibility for appointment to permanent or higher academic posts. The awards are made for 5-year periods, are renewable, and provide for salary, plus partial research expenses not exceeding $2,000. Senior Research Fellows may also apply for additional support for their research needs.

(6) *Post-sophomore research fellowship grants* are awarded to schools of medicine and dentistry for support of students who wish to obtain research training prior to completion of their professional degrees. Participants must be willing to drop out of regular courses for one, two, or three years. The stipend is set by the school in amounts not to exceed $3,200 annually. Allowances for dependents and tuition are added to the stipend.

(7) *Foreign research fellowships* are awarded to a limited number of scientists who wish to study in United States laboratories. The purpose of the program is to provide an opportunity to strengthen medical research by mutual exchange of research methods, scientific philosophy, and cultural values. Nominations will be made by respective National Research Organizations in each Western European country. Candidates must have (a) completed a doc-

toral degree in one of the medical or related sciences, and demonstrated proficiency in research, (b) made satisfactory arrangements with the laboratory in the United States where training will be obtained, and (c) acquired a workable reading and speaking knowledge of the English language. Scientists will be brought to the United States on an exchange-visitor's visa, which requires return to the homeland for a period of at least two years at the end of the training period. Stipends are $3,800 for the first year and $4,100 for the second year. Dependency, travel and certain other allowances are added to the stipend.

In fiscal year 1957, over 2,000 research fellowships were provided in a total amount of $5,300,000.

3. Training Grants and Traineeships

Training grants are intended to augment the nation's supply of qualified scientific investigators by assisting in the establishment, expansion, and improvement of training and instructional programs in universities and other institutions. Aid to the institution is provided by grants in two general classes—undergraduate and graduate.

Traineeships to individuals may be awarded either through one of the graduate training grants or directly to the individual in training. Traineeships are intended to increase the number of qualified investigators by encouraging advanced training in specialized areas of medical and related research, as well as in the fields of public health and nursing. Stipend rates vary according to the nature and requirements of the different fields covered.

(1) *Undergraduate training grants* are awarded to schools of medicine, dentistry, nursing, and public health to assist in developing expanded and better integrated undergraduate instruction relating to the prevention, diagnosis, and treatment of cancer, mental illness, and cardiovascular diseases. It is the responsibility of the institution to determine the most appropriate use of the funds.

(2) *Graduate training grants* are awarded to public and private nonprofit institutions interested in providing special training for researchers, teachers, and prospective practitioners interested in public service. Funds may be used to improve facilities and to provide salaries for faculty and staff, stipends for trainees, and necessary supplies and materials.

In fiscal year 1957, over 1,100 training grants were made in a total amount of $25,000,000. Approximately 1,950 trainees were supported under these grants. In addition, 405 direct traineeships in a total amount of $1,857,000 were made.

4. Health Research Facilities Grants

Under the Health Research Facilities Act of 1956, the Congress authorized the establishment of a program to assist in the construction of additional facilities for the conduct of research in the sciences relating to health. The program provides grants in aid on a matching basis to public and private nonprofit institutions. The amount of Federal funds awarded may not exceed 50 percent of the total costs of the research portion of the facility, and the remaining sum must be provided from non-Federal sources. The sum of $30,000,000 has been appropriated yearly for this program since its inception and to date, and meritorious applications submitted to the National Advisory Council on Health Research Facilities have requested funds far in excess of the appropriations, even though the applicants must, as indicated, match the Federal dollars. Several hundred awards have been made to institutions in all parts of the country under this program, and already new research facilities are in operation that would not otherwise have been made possible.

Here it is well to point out that the programs described above, for research, for training, and for facilities, supplement and complement each other—and help achieve the balance that always must be sought between these necessary components of research: funds for skilled investigators to do research with, facilities in which to work, and training to develop scientific manpower to do research.

In the above, I have portrayed most of the major components of the NIH extramural program. I should mention that I have not included a relatively new area for us, that of contract research, because it is in developmental stages and is concerned largely only with the specialized area of cancer chemotherapy. Many of you, of course, know the program of our National Cancer Institute's National Cancer Chemotherapy Service Center. Through this Center a large endeavor is underway, employing contract work as one of the mechanisms, to screen many, many thousands of compounds for possible anticancer effects and to develop, ultimately and hopefully, chemotherapeutic agents useful against human cancers.

The future is bright for not only this but also the other extramural programs which I have discussed, in the opinion of the more than one thousand representatives of America's scientific community who advise upon and guide these programs. This summer a final report was issued by a group of consultants to the Secretary of the Department of Health, Education, and Welfare who had been appointed to study and advise upon the advancement of medical research and education through programs of the Department. This group, known as the Bayne-Jones Committee since it was chaired by Dr. Stanhope Bayne-Jones, foresaw and recommended a future of strong growth and development for medical and related research and medical education.

In the final analysis, of course, the continued success of the NIH program, as one of the partners in the nation's medical research enterprise, rests upon the human and economic benefits that accrue from productive scientific investigation. That the past decade has seen many such benefits, in terms of new drugs and other therapies, for example, is well known.

In the paper to which I referred earlier, presented in 1946, these thoughts were expressed:

> The great benefits from all medical research, wherever conducted, are received by the millions of people whose lives are made healthier, happier, and longer through widespread application of knowledge gained in research larboratories. Conversely, research not conducted for want of funds is very costly to the same millions. The essence of these facts, as related to the Research Grants program, has been stated by the National Advisory Health Council: "There are few purposes for which public funds could be used more appropriately than to discover ways to prevent and cure illness and to prolong useful years of life." The function of the Research Grants is to make it possible for workers in medical and allied sciences to expedite, extend, and intensify health-saving and life-saving research.

The function of the whole extramural program of NIH, comprising today 80 percent of this year's total of $324.4 million in public funds, remains essentially the same in 1958 as in 1946.

Extramural Science Programs of the United States Department of Agriculture

BY BYRON T. SHAW, *Administrator, Agricultural Research Service*

Some of the other representatives on this panel may contradict me, but I believe that the Department of Agriculture administers the oldest extramural science program in the Federal Government. We have actually had such a program since 1887. But before discussing our *extra*mural research, I want to say a few words—by way of background—about our *intra*mural or regular research program.

As you know, the Department has the responsibility in the Federal Government for agricultural research. This responsibility goes back to 1862, when the Department was established "to acquire and diffuse useful information on subjects connected with agriculture in the most general and comprehensive sense of the word." Beginning in a small way, and expanding as the needs of agriculture and the Nation increased, the Department's research program today covers all phases of production, marketing, and utilization of agricultural products. It utilizes all the life sciences, nearly all the physical sciences, and to an increasing extent the social sciences as well.

Our intramural science program is a dispersed cooperative endeavor, involving some 10,000 employees and an appropriation of approximately $90 million. We have research locations in every State, ranging in number from 1 to 28 and in size from small 1-man field stations to the large regional utilization laboratories and the Research Center at Beltsville, Md. We are also doing a limited amount of regular research in other countries—in Latin America, Europe, and Africa.

About 90 percent of our research is cooperative with other public and private organizations—including Federal and State agencies, private research institutions, and farmer and industry groups. More than half of the work is in cooperation with State agricultural experiment stations.

Through the years, the States have also provided increasing support for agricultural science. At the present time State agricultural experiment stations are spending an estimated $100 million of non-Fedreal funds for State and regional research. In addition, they are spending $31½ million made available by Congress as Federal grants. These Federal-grant funds are appropriated to the Department for payment to the States and constitute our oldest and largest *extramural* science program.

The Federal-grant program had its origin in the Hatch Act of 1887, which authorized an annual Federal grant of $15,000 to each State for the partial support of State agricultural experiment stations. Additional acts successively increased the amounts of these payments, each act setting up its own formula for distributing the funds. In 1955, Congress consolidated these acts into one statute, which now serves as the authority for all Federal-grant payments to State experiment stations.

Administration of these funds is delegated by the Secretary to the Agricultural Research Service, and we have a Deputy Administrator for Experiment Stations—Dr. E. C. Elting—who is responsible for this activity. Dr. Elting and a small scientific staff prescribe standards for Federal-grant research, approve projects to be supported by Federal-grant funds, and determine that the funds are spent in accordance with the purposes intended by Congress.

Each State experiment station director develops his own State research program in terms of State and Federal resources available to him. He submits to the ARS well-defined projects for which he proposes Federal-grant support. Projects that are approved then become an integral part of the State program and may or may not be carried out in cooperation with the Department. Publication of results and any patentable materials that may develop in Federal-grant research are entirely the property of the State experiment station and are not subject to Federal printing or patent regulations. Close to 6,000 State experiment station projects are currently being supported entirely or in part by Federal-grant funds.

The department's role in the Federal-grant research program is primarily one of service. Although we must assure that certain legal requirements are met, a far more important responsibility is the technical assistance we're called on to give. This assistance includes comprehensive reviews of Federal-grant research, participation in planning of regional research, and coordination of research effort among the States as well as between the States and the Department. This broad review and coordinating service helps all of us to avoid duplication of effort, to recognize gaps that need to be filled, and to plan and carry out a more effective Federal-State program of agricultural research.

Our second extramural science program was initiated about 10 years ago under the Research and Marketing Act of 1946. This act for the first time gave us authority to contract for research outside the Department, when such work can be done more rapidly, more effectively, or at less cost than it can be done within the Department. Originally, this contracting authority applied only to utilization and marketing research, but in 1954 it was broadened to include all phases of Department research. At the present time, we have approximately 200 research contracts in force, totaling close to $4 million, and divided roughly fifty-fifty, in terms of public and private organizations doing the work.

I mentioned that in Federal-grant research, the States make most of the decisions. In contrast, we make most of the decisions in our contract research program. We determine what research *needs* to be done, what *will* be done, and, by mutual agreement with the contractor, *how* it will be done. In each case, we negotiate as to terms, conditions, length of time, and cost of the research to be undertaken. Research results must be published in a manner approved by the Department, and any patentable materials developed are assigned to the Secretary of Agriculture for public use.

Although, in a few cases, we have contracts involving *basic* research, it is extremely difficult—because of the very nature of basic research—to negotiate this type of contract. And we were pleased when the recent Congress, recognizing this problem, gave the Department authority, for the first time, to make discretionary grants for basic research. No special money has been appropriated for such grants, however, and our present funds are all obligated. But we hope, through future adjustments in our program, to make funds available for this purpose.

We are convinced that through both contracts and grants, we can help to obtain more efficient use of our Nation's scientific manpower and facilities and thus make faster progress in agricultural research.

The same kind of thinking is the basis of our third extramural science program, which has been initiated during the past year. This time we are undertaking—also through contract and grant arrangements—a rather extensive program of research by foreign scientists in foreign scientific institutions. Authority and funds for this work come from the Agricultural Trade Development and Assistance Act of 1954—generally called public Law 480. As you know, under this Act, our Government sells surplus agricultural commodities to foreign countries and receives payment in foreign currencies. It is these currencies that we are using for our overseas research. The Act originally limited use of these funds to research that would extend our markets for agricultural commodities. Last spring, Congress added a new authority, and we can now use Public Law 480 funds for all phases of agricultural research.

We expect to obligate something like $10 million (in foreign currency equivalent) during this fiscal year, to be spent over a period of 5 years. These obligated funds represent money now available, and they will cover the entire cost of grants and contracts negotiated. This is to assure that we will have enough money to complete any overseas research jobs that we start.

The program is being developed by three survey teams, who are visiting the various countries to evaluate the potential of their scientists and facilities and to determine the willingness of their governments to sanction the research. One team is working in Europe and the Middle East, the second in the Far East, and the third will be in Central and South America after the first of the year.

Several grants have already been executed for work in the United Kingdom and Israel, and we are well along with our negotiations in France, Italy, Spain, and Finland. Other countries—including Poland, Yugoslavia, Pakistan, Indonesia, India, and Chile—are in the survey stage. And still others will probably become eligible for participation, as additional sales of surplus products are made and additional foreign currencies become available.

Both basic and applied research, as well as developmental work, will be included in this foreign program. All basic studies will be done through grants, and all developmental work will be carried out under contract. Both grants and contracts will be used for applied research; each proposed project will be considered on its own merits.

Although no hard and fast rule has been established, we expect to concentrate the basic research in Europe, because European scientists are especially noted for their contributions in this area of research. The applied and developmental work will be done in all the countries participating in the program.

We know there is a vast reservoir of scientific manpower in the free world. And we believe, through the P. L. 480 program, that we can help to make more effective use of this manpower—to our own benefit as well as that of the countries concerned.

I want to stress that this foreign research is supplementary to our own domestic program. We are looking for institutions having scientific personnel with specialized experience and facilities that will enable them to carry out needed research more rapidly or more effectively than can now be done here in the United States.

In the utilization, marketing, and home economics research, we hope to develop new uses and new markets for agricultural products, both in the United States and in the country concerned. These studies will include quality evaluation of farm commodities, biochemical changes that occur in maturing fruits and vegetables, market disease and insect problems, and consumer habits and preferences in foreign countries.

In the farm and forestry studies, we will give special attention to foreign diseases, insects, and other pests that constitute potential threats to American agriculture. We also want to study the genetic traits of foreign livestock breeds, potential new crop plants under native conditions, and old-world soils, which may help us find out how to halt soil deterioration in this country.

Results of this overseas research will be made available to the United States public in the same way results of our domestic research are made available. And we reserve the right to publish results in other countries, including the country where the work is done, if the contractor fails to do so. All patentable materials will be assigned to the Secretary of Agriculture for United States use anywhere in the world. Rights to the use of such patents in other countries will of course be in accordance with the patent policies of those countries.

Needless to say, we are quite optimistic about this new world-wide resource for agricultural research. We believe it has great potentials for helping us solve some of our important farm problems.

Taken all together, our extramural science programs—including Federal grants to the States and the domestic and foreign contract-and-grant programs—constitute a powerful supplement to the Department's research effort. They not only represent additional manpower and facilities for getting ahead faster—they also promote better understanding and closer cooperation among all groups working to advance agriculture. And I am convinced that where we have understanding and cooperation, we have an environment for outstanding progress.

Extramural Science Programs of the Atomic Energy Commission

By Charles L. Dunham, *Director, Division of Biology and Medicine, U. S. Atomic Energy Commission*

The Atomic Energy Commission has well-defined responsibilities for the conduct of scientific research and development programs. Its science programs with the notable exception of its Health and Safety Laboratory in New York City are almost exclusively accomplished by contract and so contain practically no intramural activities in the usual sense of the word. Its national laboratories, such as the Oak Ridge National Laboratory, the Brookhaven National Laboratory, and the Argonne National Laboratory, and its other major research and development facilities such as Los Alamos Scientific Laboratory and the Ernest O. Lawrence Radiation Laboratories at Livermore and Berkeley, are largely government-owned but contractor operated, in fact, chiefly by universities or groups of universities. Exceptions are the Oak Ridge National Laboratory and the research and development activities at the Hanford Works which are under contract with industrial firms. I have assumed for purposes of this symposium that my remarks should be directed primarily toward that part of our science program carried out in non-Government owned facilities, i.e., our offsite research program.

In order to get a proper picture of our total effort, one must bear in mind that the onsite and offsite aspects of our programs are closely integrated. In general, work at the major AEC laboratories is work especially appropriate to the unique facilities and talents at hand. Interdisciplinary research and research projects involving large collaborative efforts by many scientists have proved especially effective in such an environment. This is not to say such projects can not or should not be undertaken at universities. In fact the AEC does support this type of work in its offsite programs where the situation is favorable and we have not hesitated to provide major items of equipment, building modifications and the like to universities and independent or private-owned laboratories so as to further such efforts.

Before sketching our program, and our program interests, I should give you some background.

The AEC emerged from the Manhattan Engineering District with a total monopoly in this country of nuclear-weapons research and nuclear reactor research, practically all of which was being conducted at Government-owned but contractor-operated institutions. It also found itself supporting directly or in collaboration with the Office of Naval Research a large share of the country's nuclear physics and nuclear chemistry research whether conducted at Government facilities, universities, or independent laboratories. In addition, it was supporting a program of radiobiological research. Almost all the latter was being conducted in Government-owned facilities. This was the situation at the time the Atomic Energy Act of 1946 was passed.

Section 1(a) of the Act concluded as follows: "Accordingly, it is hereby declared to be the policy of the people of the United States that, subject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace."

The Act went on in Section 1(b) to define the purpose of the Act as follows:

> Purpose of Act—It is the purpose of this Act to effectuate the policies set out in Section 1(a) by providing, among others, for the following major programs relating to atomic energy.
>
> (1) A program of assisting and fostering private research and development to encourage maximum scientific progress;
>
> (2) A program for the control of scientific and technical information which will permit the dis-

semination of such information to encourage scientific progress, and for the sharing on a reciprocal basis of information concerning the practical industrial application of atomic energy as soon as effective and enforceable safeguards against its use for destructive purposes can be devised;

(3) A program of federally conducted research and development to assure the Government of adequate scientific and technical accomplishment.

It then went on to say that the AEC was established to accomplish these objectives. In order to implement these parts of the Act, recognizing that nuclear science and radiobiology must advance as rapidly and as free of security restrictions as possible under the Act, the AEC developed its research program in such a way as to encourage extramural research activities at universities, colleges and independent laboratories throughout the country. In the first few years of both its physical research and its biomedical research programs the AEC leaned heavily on the ONR through cooperative arrangements with that agency for rapid implementation of the program.

The reactor program continued for the most part at AEC laboratories and at AEC facilities operated by contracts with industry until the Atomic Energy Act of 1954 was passed which directed the AEC to remove from classification restrictions data whose publication and dissemination would not cause undue risk to the common defense and security. The weapons development program has continued almost exclusively in AEC installations and on a classified basis to date.

Our physical-research program exclusive of work on controlled thermonuclear reactions has grown on the basis of annual operating cost from about $21,000,000 in 1948 to about $89,000,000 in the current fiscal year. Meanwhile over and above what was inherited from the MED the AEC has spent for construction for physical research facilities more than $100,000,000, roughly three-fourths of which was spent for major research machines and associated housing, a number of which were located on university campuses. At present some $34,000,000 of the Division of Research's $89,000,000 total annual operating funds go to support work not conducted at AEC-owned major research centers. Through all its activities whether concerned with onsite or offsite research this Division shapes the programs in such a way as to foster the development of new talent for its future needs.

Work in basic physical research breaks down into four major areas: physics and mathematics, controlled thermonuclear reactions, commonly known as "Sherwood," chemistry, and metallurgy and materials.

In physics, the major effort centers around attempts to learn all that can be learned about the fundamental properties of nuclear matter through research with high energy particle accelerators as well as through the use of high flux research reactors and low energy accelerators. Although the Nation's two largest particle accelerators are located at AEC laboratories, more than one-third of the AEC funds supporting high-energy physics and nuclear structure research goes into offsite programs.

Mathematics research and research in the field of computers are sponsored for what they may contribute to advancing knowledge and in the case of computers for what these machines may contribute to a great increase in research per scientific man-year.

Work performed under the so-called Sherwood project is aimed at the development of a controlled thermonuclear reaction for the ultimate purpose of generating economic power for industrial and civilian use. This effort, currently costing between $35,000,000 and $40,000,000 annually, is limited by our present incomplete understanding of the fundamental properties of plasmas. Hence more and more work is devoted to understanding cooperative phenomena in a completely ionized gas. The major costs in this program except for the stellerator project at Princeton University are incurred at AEC laboratories.

Chemistry research includes work devoted to such very practical problems as solvent extraction and ion-exchange techniques, analytical techniques for process control and methods for producing usable amounts of rare earth salts, pure metallic uranium, thorium, zirconium, hafnium, niobium, tantalum, and the like as well as transuranic elements, all of interest to the atomic-energy program. Geochemical and geophysical research is supported principally at universities and the U. S. Geological Survey. Fundamental research in the program category "Chemical properties and reactions," with considerable emphasis on the nuclear and chemical properties of the heavy elements, takes place under heavy AEC support at universities, as well as at the AEC laboratories.

Finally, our physical research program includes heavy emphasis on metallurgy and materials. Research in this area falls into the categories of production, treatment, and properties of metals, alloy theory, and irradiation effects.

The science program of the Division of Reactor Development includes research and development activities categorized under AEC's civilian power and supporting programs and costing this fiscal year about $162,000,000. These activities are directed towards development of nuclear reactors for economic, electrical power, space heat, gasification of coal, polymerization processes, and for the propulsion of merchant vessels. This Division also administers the military reactor program which includes nuclear propulsion units for submarines, surface vessels, aircraft and rockets as well as package power units for military installations.

The civilian power program is for the most part carried out at AEC installations and at industrial establishments with some university and independent laboratory participation. The program includes not only the design and construction of research reactors and reactors for testing purposes, experimental and prototype reactors, but in addition there is a research program concerned with fuel element development, separations systems development, i.e., fuel element processing for recovery of fissionable material, radioactive waste treatment and waste disposal development, and reactor safety development.

The Atomic Energy Commission has recently inaugurated a program for accelerating the development of the industrial uses of radioisotopes. This year it will spend about $4,000,000 for applications development, high-intensity radiation studies, and to increase training opportunities for practicing industrial scientists and engineers.

In the biomedical field AEC's offsite science program is closely related to and supplements its onsite program. Of the $43,000,000 operating funds for the current fiscal year for biomedical research about one-third goes for the support of over 500 separate totally unclassified contracts with universities and independent laboratories for work in the following areas; the biological effects of the various ionizing radiations including acute and delayed effects, and effects produced by various beam intensities. Objects for study include the gamut from effects on simple biological systems to the most complex organisms including wherever possible effects on man himself. A major effort is directed to the genetic and carcinogenic effects of ionizing radiations whether from external sources or from radionuclides incorporated into the living organism. Another important area for research support is in the development of methods for altering or combatting radiation effects and for removing deposited radionuclides from the body. A third area of scientific effort is the monitoring of radioactive materials distributed around the world as fallout from nuclear weapons testing, and studies of the movement of radionuclides in the stratosphere, troposphere, the soil, plants and animals and animal products. All this is in an effort to gain an understanding of the mechanism of transport and incorporation into the food chain of these materials. The fourth category concerns work carried on at field tests, at AEC laboratories and to a lesser extent at private institutions on problems concerned with understanding and estimating effects of radiation, including radioactive fallout, thermal radiation effects and primary and secondary blast effects from nuclear weapons. A fifth category is radiation dosimetry and instrumentation. The last category we call the beneficial uses of atomic energy. Except for our cancer research program, it is very largely carried out in university laboratories and is devoted to exploiting the tools of atomic energy—reactors, and accelerators, and the byproducts of atomic energy—radioisotopes, in the advancement of knowledge in medicine, agriculture, and biology generally.

In addition to these research and development programs the AEC science program includes training and education activities. This year we are spending approximately $15,500,000 for this purpose. We have special fellowship programs in industrial medicine, industrial hygiene, and radiological physics all carried out principally on university campuses. In addition there are reactor engineering fellowships. The training for these is partly at universities and partly at AEC laboratories. We sponsor jointly with the National Science Foundation a number of programs aimed at improving science teaching in secondary schools. This latter category includes summer workshops in radiobiology and radiological physics for high school science teachers. Finally, AEC has a program of grants for radiation equipment to be used in colleges and universities in courses in reactor engineering, courses in radiation health, and courses in the life sciences and physical sciences generally.

In summary: The AEC program in science is accomplished almost exclusively by contract with universities, groups of universities, industry, and independent laboratories. Its major operations are carried out for the most part in Government-owned facilities but contractor operated. Its offsite research involves the support of many hundred totally unclassified research projects chiefly in university laboratories and planned to supplement the work of the large laboratories. In physical science the goal is to keep the United States at the forefront in the atomic energy field. In reactor engineering—to produce economic and safe nuclear power plants for a variety of purposes.

In biology and medicine its goal is to produce as complete as possible a body of knowledge concerning the effects of ionizing radiations on biological systems and how to alter and to protect against these effects. It also aims to exploit the tools and byproducts of atomic energy activities for the benefit of mankind in medicine, biology and in agricultural sciences.

Finally the AEC devotes a considerable effort to strengthening education and training in the fields of its principal interests.

Extramural Science and Research Activities of the National Aeronautics and Space Administration

By Ira H. Abbott, *Assistant Director of Research, NASA*

The National Aeronautics and Space Administration will be three months old in a few days. With the agency at this tender age I am certain that you will appreciate the difficulty of my speaking in detail about the nature and scope of our extramural science and education activities and the contribution made by these activities to the achievement of our objectives. We do, however, have some fairly definite thoughts and plans about these activities.

The NASA was formed with the old National Advisory Committee for Aeronautics as its nucleus. The NASA is not merely an enlarged NACA but is a new agency which includes the former NACA and other organizations which have been transfered to it. I believe it would, nevertheless, be appropriate to say a few words about the former NACA for the benefit of those of you who may not be familiar with it.

The NACA was established in 1915 to conduct research in the fields of aeronautics. Its main responsibilities were:

1. Foresight in the planning of research that would produce new research information when needed,
2. The conduct of such research, mainly in its own laboratories, and
3. Effective communication in making its research results rapidly and generally available.

The NACA fostered close contact and cooperation with other Government agencies, with industry, and with the scientific community. Its advisory committees served the broader purpose of providing a mechanism for the exchange of scientific information and opinion, and thus encouraged the informal coordination of research through this exchange of information.

The NACA started its research activities through contracting with others for the conduct of research. In the first five years of operation, 82 technical reports were issued of which only 7 were prepared by the NACA staff, and 5 of these were in the fifth year. Through a combination of circumstances which I need not dwell upon, the NACA was unable to extend this program of contract research to meet the needs of the country, and it established its own laboratories to conduct most of its research. The total contract research program of the NACA never exceeded one million dollars a year and was usually much smaller. Even this small program was of great value in supplementing its own research because it permitted the utilization of special skills and talents that existed only in the universities and research institutions.

Because of the small size of the NACA extramural research program, the agency only occasionally sought out people or organizations to undertake research on problems proposed by itself, and limited the program to nonprofit organizations. Usually selection was made from the numerous proposals made by people who desired sponsorship for the research they wished to undertake. This system worked well for such a small program because it assured a high degree of enthusiasm and competence by the research workers. In this program the NACA operated within a rather narrow authorization. Consequently, the program was conducted with one-year fixed-price contracts. Within this limitation a sincere attempt was made to keep the program as flexible as possible. The contracts called only for work of a certain type or within an area, and a report on the results. Continuity was obtained to such a degree that a few institutions have worked continuously on certain problems for a dozen years or more.

The National Aeronautics and Space Act of 1958 creating the NASA continued all the functions of the NACA and added the direct responsibility for research in space technology, for the design, development, construction, and operation of space vehicles for peaceful purposes, and for the conduct of scientific research in space. These are grave responsibilities involving the preservation of the role of the United States as a leader in aeronautical and space science and technology.

We plan to continue our research programs at the Langley, Ames, and Lewis Research Centers to support both aeronautical and space activities. In this work we shall continue to cooperate as in the past with other Government agencies, the industry, and with educational and research institutions. With regard to our new functions in space technology, we intend to develop in our own staff a relatively small but highly skilled organization with the technical capabilities fully to meet our responsibilities in planning and conducting our programs. We expect to contract with industry for the design, development, and construction of space vehicles and components. We intend to conduct an intensive program of scientific research in space, both to assist in the development of space technology and to explore and study the natural phenomena occurring outside the earth. This program will offer unique opportunities for cooperative activity between NASA and the educational and research institutions in conducting scientific experiments using sounding rockets, satellites, deep space probes, and interplanetary vehicles.

It is obvious that the proper discharge of our responsibilities will require the full and efficient utilization of all the scientific and technical skills that should be brought to bear on this task, wherever they may exist. Consequently, the NASA plans to sponsor a greatly increased program of research in educational and research institutions. The NASA is aided in these plans by having a broad authorization for the conduct of this program. It will be under the direction of Dr. Lloyd Wood of our Headquarters staff. Our preliminary planning has established the following general principles:

1. The research may be either basic or applied

2. The research should be relevant to the mission of the NASA
3. The research should be coordinated with and supplementary to NASA Research Center programs
4. The research should be coordinated with that sponsored by the National Science Foundation and other Government agencies.
5. Continuity of support should be provided so the investigators can plan their research most effectively and make the commitments necessary to retain capable assistants.

In order to implement point 5, it is planned to make the initial obligation of funds to cover costs for periods up to three years. Insofar as practicable, notice of termination or extension of support will be given at least one year in advance. Overhead will be paid according to approved Government practices with the intent of paying the indirect cost of research activities. It is also planned to use both contracts and grants as appropriate to support the research.

It is apparent that research relevant to the mission of the NASA will include many branches of science. In addition to the usual physical and engineering sciences, we shall be interested in the cosmological sciences, the life sciences, and, at least to some degree, socio-economic studies.

I would like to emphasize the new opportunities the NASA offers for educational and research institutions to participate as full partners in the conduct of scientific research in space. The law specifically provides that one of our functions is to "arrange for participation by the scientific community in planning research measurements and observations to be made through use of aeronautical and space vehicles and conduct or arrange for the conduct of such measurements and observations."

We are confident that the educational and research institutions will be fertile sources of ideas for worth-while experiments to be conducted in space. Within the limit of our resources we shall be happy to contract with such institutions to follow up on their ideas and to reduce them to properly instrumented experiments. In some cases the engineering and operating problems may be entirely within the capabilities of the contracting institution. Such may be the case, for example, with sounding rockets. In other cases the NASA itself, either through its own resources or through industrial contracts, will necessarily play a major role in the engineering and operating phases of the program. Obvious examples would be relativistic clock experiments to study the gravitational effect and orbiting astronomical laboratories. In these cases we shall assist in such work as appropriate by arranging for instrumentation and for instrumentation packaging, by providing the vehicles, by launching and tracking them, by obtaining the data and reducing them to understandable form so that the contracting institution can analyze and interpret the information and report the results.

The coming space age is opening up vast new avenues of scientific exploration and achievement. Where they will lead I cannot say because our imaginations are too limited for us to foresee the potentials ahead. I am certain that the exploration of these avenues is a task that we must all undertake together in a spirit of scientific cooperation. We in the NASA intend to undertake our work in this spirit and to pursue it as vigorously and rapidly as will be possible with the resources made available to us.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

782D MEETING

The 782d meeting of the Society was held in the John Wesley Powell Auditorium, January 8, 1958, President CARLE H. DANE presiding.

Informal communication.—JOHN B. MERTIE, JR.: *A monazite lode in South Africa.*

Program.—HARRY KLEMIC, A. V. HEYL, A. R. TAYLOR, and JEROME STONE: *Rare earth deposit at the Scrub Oaks mine, Morris County, New Jersey.*

ISIDORE ZIETZ, G. E. ANDREASEN, and ARTHUR GRANTZ: *An aeromagnetic study of the Cook Inlet area, Alaska.*

Twenty-seven east-west aeromagnetic traverses were flown across the Cook Inlet depression at a flight elevation of approximately 2,500 feet above mean sea level. The northernmost line crosses the area between Willow and Kashwitna, and the southernmost line crosses Cook Inlet at about Homer. The lines traverse part or all of four Mesozoic tectonic elements that dominate the structure of the Cook Inlet area. These are the Talkeetna geanticline, the Matanuska geosyncline, the Seldovia geanticline, and the Chugach geosyncline.

The aeromagnetic data, compiled as total intensity magnetic profiles, show several significant features that are consistent with the structural grain of the area. A 2-dimensional anomaly is observed near the eastern edge of the area on all profiles except the southernmost lines where the feature becomes obscure. Geologic evidence strongly suggests that this feature, called the Knik Arm anomaly, is produced by granitic rocks that have been intruded along the axis of the Seldovia geanticline.

Near the western shore of Cook Inlet the magnetic pattern changes abruptly. This line of abrupt change implies a lithologic contact trending approximately northeast. This inferred contact joins the Castle Mountain high-angle reverse fault, which has been mapped along the north side of the Matanuska Valley and which separates the rocks of the Talkeetna geanticline to the north and northwest from the rocks of the Matanuska geosyncline to the south. The southern end of the inferred contact joins a similar fault. This contact, which has been named the Moquakie contact, marks the western edge of the Matanuska geosyncline; it is interpreted as a possible major fault or fault zone.

A structural basin lies between the Moquakie contact and the Chugach-Kenai Mountains. This basin is wide at the southern end of Cook Inlet and narrows to the northeast. The few anomalies over the basin area suggest depths to the basement rocks of 2 to 4 miles. A 2-dimensional, broad anomaly of about 200 gammas in magnitude trends northeast from the Richfield well, northeast of Nikishka, to the Susitna Flats area. This anomaly, called the Point Possession anomaly, is believed to be produced by a rock mass buried about three to four miles. The data suggest that this trend also continues southwest from the well.

783D MEETING

The 783d meeting of the Society was held in the John Wesley Powell Auditorium, January 22, 1958, President CARLE H. DANE presiding.

Program.—D. M. KINNEY, W. J. HAIL, JR., and A. D. ZAPP: *Latest Cretaceous and earliest Tertiary rocks between Castlegate and Green River, Utah.*

W. L. NEWMAN, A. T. MIESCH, and E. M. SHOEMAKER: *Chemical composition as a guide to the size of sandstone-type uranium deposits, Colorado Plateau.* Concentrations of uranium, yttrium, sodium, iron, zirconium, manganese, calcium, and nickel in 75 mill pulp samples of uranium deposits in the Salt Wash member of the Morrison formation on the Colorado Plateau seem to be significantly related to the sizes of the deposits represented by the samples. Linear correlation coefficients between element concentrations, as determined by semiquantitative spectrographic analysis, and sizes of deposits in tons, range from /0.37/ for uranium and yttrium to /0.24/ for nickel. The lowest significant correlation coefficient for the 75 samples at the 95 percent level of confidence is 0.228. Three methods of size estimation were developed: one based on simple linear regression theory and two based on multiple regression theory. About 80 percent of the size estimates based on simple linear regression theory are within a factor of 12 to 14 of the true size. Estimates based upon multiple regression theory range within approximately the same orders of magnitude. Although the error of the estimates may be quite large, the methods permit classification of the deposits within reasonable confidence limits into the following size groups: very large deposits (10,000 to more than 100,000 tons), large deposits (1,000 to 10,000 tons), medium deposits (100 to 1,000 tons), small deposits (10 to 100 tons), and very small deposits (1 to 10 tons). These methods will be useful in estimating the sizes of deposits where exposures of ore are limited, or where an estimate is desired that is independent of other estimates.

Charles Milton, Mary E. Mrose, and E. C. T. Chao: *Recent developments on the mineralogy of the Green River shales.*

784th meeting

The 784th meeting of the Society was held in the John Wesley Powell Auditorium, February 12, 1958, President Carle H. Dane presiding.

Informal communication.—Preston Cloud: *Mode of locomotion of an Upper Cambrian trilobite.*

Program.—Ralph L. Miller: *Faulting in the southern Appalachians.* David M. Raup: *The effect of environment on echinoid morphology.* The scutellid echinoid genus *Dendraster* L. Agassiz has a geologic range from Pliocene to Recent. Sand-dollars of this genus live now from central Baja California to Vancouver Island, British Columbia. Fossils occur in central and southern California and in Baja California. In the past, *Dendraster* has been classified into 25 species, subspecies, and varieties. In all these forms, the apical system is posteriorly eccentric. Variations in the eccentricity of the apical system figure prominently in approximately two out of every three taxonomic distinctions within the genus.

The position of the apical system in *D. excentricus* (Eschscholtz) varies widely. Variation in this character between adjacent populations of this single living species often exceeds variation between species in the fossil record. Furthermore, variation in the eccentricity of the apical system in *D. excentricus* is correlated with water turbulence. In areas of high water turbulence, such as those just beyond the surf zone along the exposed coast, sand-dollars of this species exhibit high eccentricity; that is, the apical system is located near the posterior margin of the test. In quiet water, whether it be at depth along the exposed coast or in shallow protected bays, sand-dollars have a nearly centered apical system (low eccentricity). In intermediate environments, intermediate morphology obtains. The correlation between turbulence and morphology is interpreted as nongenetic variation (nonheritable) resulting from the effect of environmental forces. The high degree of eccentricity enables sand-dollars living under turbulent conditions to be stable in the feeding position and still have the madreporite exposed (in the feeding position, they are inclined to the sea bottom with the anterior portion of the test buried).

Variation in eccentricity in fossil *Dendraster* is interpreted in light of the above findings. The three prominent Pliocene species, *D. coalingaensis* Twitchell, *D. ashleyi* (Arnold), and *D. gibbsii* (Rémond), have previously been distinguished from each other partially on the basis of this character. Statistical analysis of these forms shows *D. ashleyi* and *D. gibbsii* to be indistinguishable on the basis of this character. Further, the amount of difference in eccentricity between *D. coalingaensis* and *D. gibbsii–D. ashleyi* is of the same order of magnitude as that between populations of the living species occurring under conditions of differing water turbulence. Thus, the eccentricity differences between *D. coalingaensis* and *D. gibbsii–D. ashleyi* are interpreted as the result of differing water turbulence and not genetic change. This does not mean that the three species are synonymous but only that the differences in eccentricity are not genetic. The mean eccentricity of the three Pliocene forms, on the other hand, is greater than that of the living species, *D. excentricus.* Thus, there appears to have been evolution toward a less eccentric apical system between Pliocene and Recent.

Therefore, the eccentricity of the apical system shows genetic change over time whereas at a given point in time, it shows non-genetic change and hence is an indicator of past environmental conditions.

R. A. Bagnold: *Correlation between wind and sand-dune directions in the light of present-day conditions.*

785th meeting

The 785th meeting of the Society was held in the John Wesley Powell Auditorium, February 26, 1958, Vice-President LLOYD G. HENBEST presiding.

Program.—JOHN C. REED, JR.: *Crystalline rocks of the Potomac River Gorge near Washington, D. C.* Below Great Falls, about 10 miles northwest of Washington, the Potomac River is entrenched in a spectacular gorge which affords unexcelled exposures of the crystalline rocks of the Piedmont. The major rock types exposed between Great Falls and Stubblefield Falls are: (1) Mica schist and arkosic quartzite, assigned by Keith (1901) to the Carolina gneiss, and by Cloos (1953) to the Wissahickon formation, (2) amphibolite bodies, probably representing sills or lava flows, interlayered in the schist and quartzite sequence, (3) granitized schist (in part the Sykesville formation of Cloos, 1953), and (4) sodic quartz diorite or granodiorite in small discordant intrusive bodies. The age of the rocks is problematical: the quartzite-schist sequence has been considered by some geologists to be Precambrian, and by others to be an eastern metamorphosed equivalent of lower Paleozoic rocks in the Blue Ridge.

The quartzite occurs in massive beds as much as 40 feet thick, and as thinner beds, commonly regularly interlayered with schist. Locally, graded bedding and crossbedding are preserved. Bedding in the schist has been largely obliterated, and the only conspicuous planar structures are sets of S-planes marked by parallel orientation of micaceous minerals. The earliest of these is parallel to bedding in the associated quartzites, whereas the younger set is subparallel to axial planes of folds. Locally the axial plane cleavage is a closely spaced slip or fracture cleavage, but generally it is marked by a parallelism of new micas. In many places formation of the new cleavage has destroyed all trace of the older bedding plane foliation.

Petrographic evidence indicates that the quartzite-schist sequence has undergone at least two periods of metamorphism. Large bent and ragged books of biotite and muscovite, very rare relicts of andalusite, and indeterminate sericite pseudomorphs, probably after andalusite or other aluminum silicate minerals, are believed to be relicts of the early stage. During the later metamorphism new biotite, muscovite, and garnet were formed, and the earlier aluminum silicates were almost completely altered to sericite. In the interlayered mafic rocks the earlier metamorphism produced the assemblage andesine-green hornblende-clinozoisite, which during the later metamorphism was locally converted to an assemblage of oligoclase-epidote-biotite with green hornblende as a relict. Perhaps these two metamorphic episodes can be correlated with the formation of the two sets of S-planes in the schist.

The granitized schist was apparently produced by interaction of the normal schist with soda-rich solutions, probably at a late stage in the second metamorphic cycle. All gradations exist between schist with thin oligoclase-quartz filaments along the two sets of S-planes to rocks in which thin micaceous wisps, still preserving the orientation and relationships of the S-planes in the adjacent schist, appear "suspended" in a granitic matrix of quartz and oligoclase.

Field relationships indicate that small discordant plugs and dikes of leucocratic quartz diorite, identical in mineralogy with the quartz-feldspathic components of the granitized schist, may represent local intrusion of material derived from the granitized schist. Small granitic bodies may have originated by migration of material into regions of low pressure near brittle amphibolites and quartzites, while still others may have been formed entirely by metosomatic replacement.

It is hoped that this brief outline will encourage others to continue studies in this easily accessible and extremely well exposed area.

REFERENCES CITED

CLOOS, ERNST. *Geologic map of Montgomery County, Maryland.* Maryland Department of Geology, Mines, and Water Resources. 1953.

CLOOS, ERNST, and ANDERSON, J. L. *Geology of Bear Island, Potomac River, Maryland.* Johns Hopkins Univ. Studies in Geology, no. 16, pt. 2. Baltimore, 1950.

KEITH, ARTHUR. *Description of the Piedmont Plateau,* in *Washington folio,* U. S. Geol. Survey Folio 70. 1901.

F. G. HOUTERMANS: *Effects of cosmic radiation in meteorites and the earth's atmosphere.*

786TH MEETING

The 786th meeting of the Society was held in the John Wesley Powell Auditorium, March 12, 1958, President CARLE H. DANE presiding.

Communication.—JOHN B. MERTIE: *A memorial to Fred H. Moffit.*

Program.—U. S. Geological Survey investigations at the Nevada test site: E. B. Eckel and C. B. Read: Geological phase; W. H. Diment and others: Geophysical phase.

787th meeting

The 787th meeting of the Society was held in the John Wesley Powell Auditorium, March 26, 1958, President Carle H. Dane presiding.

Program.—M. Gordon Wolman and Lucien M. Brush, Jr.: *Laboratory study of equilibrium channel shape in noncohesive material.*

J. T. Hack: *The relation of manganese to surficial deposits in the Shenandoah Valley, Virginia.* Manganese mines and prospects in a narrow zone at the northwest foot of the Blue Ridge occur in residual clays of the Cambrian Tomstown dolomite and Waynesboro formation. They are covered by a mantle of quartzite cobbles washed from the mountain slopes. The deposits are thought by some to have formed on the Harrisburg peneplain in Tertiary time under conditions of lesser relief and warmer climate, as residual concentrates from carbonate rocks.

Mapping of the surficial deposits of the Shenandoah Valley reveals no evidence to support the concept of multiple erosion cycles or of a valley floor peneplain that might have provided a site for manganese concentration. The features of the region are better explained as the result of long-continued and deep erosion of a folded area that is now close to isostatic equilibrium. Alluvium occurs where streams enter the limestone valley from areas of resistant sandstone and quartzite and is spread by laterally migrating and degrading streams that form pediment-like aprons near the mountain foot. The spreading is aided by piracies of the main streams by their own tributaries. Residuum, or saprolite, occurs on limestone where the insoluble residues are protected from erosion by a resistant capping of either transported gravel or of coarse-grained chert residual from the limestone itself.

The manganese deposits are residual concentrates in the clay, preserved not because they are uneroded remnants on a Tertiary surface but because they have been formed under an armor of alluvial cobbles and gravel. The process of manganese concentration is a continuous one and may possibly be going on at the present time.

Earl Ingerson: *The Moscow symposium on petrochemistry, December 1957.*

788th meeting

The 788th meeting of the Society was held in the John Wesley Powell Auditorium, April 9, 1958, President Carle H. Dane presiding.

Program.—G. W. Wetherill, G. R. Tilton, and G. L. Davis: *Age of the Baltimore gneiss.*

David Landen: *New developments in photogrammetric measurements for geologists.* One of the recent developments in the Geological Survey has been the introduction and use of modern photogrammetric mapping equipment in geologic investigations. While aerial photographs have long been one of the most important tools of the geologist, the use of modern double-projection stereoscopic plotting equipment has taken place only within the last few years. As a result of recurring problems which concerned the application of photogrammetric techniques to geologic mapping, the chief topographic engineer and the chief geologist in 1953 formed an Interdivision Committee on Photogrammetric Techniques in Geology. This group cut across the lines of the largest Divisions in the Survey and soon became a potent force in the advancement of photogrammetry in geology through instrument development, training, publications, and technical assistance.

Advances in the design and use of stereoscopes, simple photogrammetric measuring equipment, and the use of modern double-projection plotting equipment such as the Multiplex, Kelsh, and ER-55 for geologic use are described. Several new instruments, useful for making measurements under a stereoscopic plotter, were sponsored by the Interdivision Committee; these included the photogrammetric profile plotter, the photogrammetric dip-and-strike indicator, and others. The stereoplotted grid was designed to facilitate transfer of geologic data from photograph to map. The orthophotoscope machine and its product, the orthophotograph, were developed primarily for geologic use. The orthophotograph is a photograph in which essential detail has been rectified to an orthographic, or plan, projection. It has become today one of the great advances in surveying and mapping technology. A new photographic technique, useful to paleontologists, was also developed—photographs of fossils in orthographic projection.

It is concluded that one of the best means of advancing a science such as geology is to advance its measuring and mapping techniques. Aerial photographs and photogrammetry, by their very nature, should be among the geologist's most fundamental operations—that of making accurate measurements.

VINCENT C. KELLEY: *Structure and fracture systems of the Colorado Plateau.* The Colorado Plateau is a relatively undeformed structural segment within the Cordilleran orogenic systems. It consists of irregularly interspersed uplifts, basins, platforms, and lesser fold belts of mild or moderate intensity. Most of the deformation, however, is concentrated along great monoclinal flexes which bound certain parts of the uplifts and basins.

Fracture sets have been mapped on a scale of 1:62,500 on photomosaics for a large part of the Plateau. The joint sets range greatly in stratigraphic and areal extent, in spacing, in orientation, and in numbers. Dominant joint sets are nearly vertical in areas of low-dipping rocks, but inclined longitudinal and oblique joint sets are common along monoclinal flexes. From this relationship and from the fact that the fracture systems reveal little regular relationship to folds in most places, it is concluded that many of the sets are older than the Laramide folding. Some, however, are clearly younger than the principal folding.

The fracture systems of the several major uplifts are largely dissimilar. The lack of similarity of uplift fracture patterns may be due to (1) differences in the uplift forms and their regional settings, (2) differences in stratigraphy, (3) differences in rate and manner of uplift growth, and (4) the fact that many of the sets appear by areal distribution to be related to crustal disturbances of much greater extent than the uplifts and of quite different mechanics of deformation.

Numerous joints probably formed early for nonorogenic reasons such as differential compaction, differential loading, original-dip gliding, and epeirogenic warping. Nevertheless, the existence of some consistency of orientation of dominant regional sets in northeasterly, northwesterly, and easterly directions makes it appear that there were over-all deep-seated stress systems, responsible, in complicated ways, for many of gross aspects of the fracture pattern.

Three east-west lineaments of fracture zones, the Cache Valley, Rico, and Rattlesnake, are "rooted" in part in the Precambrian structures to the east and are thought to be reflections of shearing before and during Laramide in the basement.

Two phases of Laramide deformation on the Plateau are postulated. The first resulted from a major stress oriented easterly or southeasterly which formed the northerly and northeasterly trending monoclines. The second phase resulted from a major regional stress oriented southwesterly which formed the northwesterly trending folds and uplifts.

789TH MEETING

The 789th meeting of the Society was held in the John Wesley Powell Auditorium, April 23, 1958, President CARLE H. DANE presiding.

Informal communications: EDWIN ROEDDER reported on the Science Fair held in Georgetown on April 19, at which he had been a judge, and introduced a prize winner, Philip Perkins.

L. T. ALDRICH reported the seismic detection in the Washington area and in New York State of the Ripple Rock blast in the Seymour Narrows, British Columbia.

Program.—GORDON E. ANDREASEN, ISIDORE ZIETZ, and ARTHUR GRANTZ: *Structural interpretation of aeromagnetic data observed in the Copper River Basin, Alaska.*

Z. S. ALTSCHULER and E. J. YOUNG: *Relations between Tertiary sedimentation and structural history in west-central Florida.*

RICHARD H. JAHNS and C. WAYNE BURNHAM: *Preliminary experimental evidence on pegmatite crystallization.*

790TH MEETING

The 790th meeting of the Society was held in the John Wesley Powell Auditorium, October 8, 1958, President CARLE H. DANE presiding.

Program.—The deferred presidential address of W. D. JOHNSTON, JR.: *Outside Interior, or the Geological Survey's part in foreign technical assistance, 1940–1958.*

791ST MEETING

The 791st meeting of the Society was held in the John Wesley Powell Auditorium, October 22, 1958, President CARLE H. DANE presiding.

Program.—ADRIAN RICHARDS: *Eruption of Capelinhos Volcano, Faial Island, Azores, a report of the Cranbrook Expedition, 1958.*

IRVING FRIEDMAN: *Deuterium and the age of Arctic sea ice.* The deuterium fractionation that occurs upon the change of state of liquid water to ice has been measured under natural conditions. The ice is enriched in deuterium by 2 percent relative to the water in equilibrium with it.

Consecutive samples from an ice-core collected near ice island T-3 (80°N, 113°W) was analyzed for its relative deuterium content. A plot of relative deuterium content versus depth in the 10-foot core shows several minima. These minima are interpreted to be due to the freezing of snow melt water that runs off the surface of the ice in summer. If this thesis is correct, the ice flow represents the accumulation of 4 years of winter ice.

D. F. HEWETT: *Deposits of the manganese oxides.* The program of field work on manganese deposits during the war permitted the collection of many specimens of manganese oxides over the entire nation as well as in Cuba and Mexico. X-ray analyses of about 250 specimens from the United States, 150 specimens from Cuba, and 100 from Mexico have been made by Richmond and Axelrod of the Geological Survey to determine mineral character, and partial and complete chemical analyses have been made of many specimens by Fleischer of the Survey. Some of the results of this work have been announced by Fleischer and Richmond. Recently, Hewett has continued the study of the manganese oxides by interpreting the geological environment under which the 250 specimens from the United States were formed.

From this review of the mode of occurrence of the oxides of manganese, 33 in number of which 27 are known in the United States, the conclusion has been reached that (1) some of the oxides are uniformly supergene throughout the United States, (2) another group is uniformly hypogene, and (3) another group that includes the common oxides, psilomelane, hollandite, cryptomelane, coronadite, hetaerolite and pyrolusite, is supergene in some places and hypogene in others. To reach this conclusion, a group of criteria to distinguish between supergene and hypogene origin was set up.

The study indicates that in the broad arc from central New Mexico across Arizona into southern California and Nevada there are many veins of the manganese oxides, at least 100, of which at least 30 are extensively explored, largely made up of psilomelane, hollandite with minor cryptomelane, coronadite, and pyrolusite, which are hypogene in origin. Most of the veins follow fractures and breccia zones in layered volcanic rocks of middle Tertiary age. Associated with the manganese oxides, in some places younger and in other places older, are opal, chalcedony, quartz, zeolites, fluorite, barite, and calcite, in part hydrothermal in origin. In the same broad arc there are numerous deposits of stratified manganese oxides which contain small but noteworthy amounts of tungsten, lead, and copper, which are also found in the vein oxides. It is concluded that the veins of oxides are related to the stratified oxides; that hot waters from depth contained manganese which was deposited as oxides in the veins where the solutions met the shallow zone of ground water containing oxygen. The remaining manganese was carried to the surface where flocculent oxides were formed and carried as sediments to nearby basins. This interpretation is supported by the presence in the region of hot springs that are now depositing oxides of manganese that contain the same minor metals as the veins and stratified oxides.

792D MEETING

The 792d meeting of the Society was held jointly with the Paleontological Society of Washington in the John Wesley Powell Auditorium, November 12, 1958, Vice-President ALICE ALLEN presiding.

Program.—ALFRED S. ROMER: *Rocks, fossils, and Darwin.*

793D MEETING

The 793d meeting of the Society was held in the John Wesley Powell Auditorium, December 10, 1958, Vice-President LLOYD G. HENBEST presiding.

Program.—The Presidential address; CARLE H. DANE: *The New Mexico geologic map—a summary of 30 years of geologic progress.* Preliminary versions of the geology of the northwestern and southeastern parts of New Mexico, by Carle H. Dane and George O. Bachman, have been published by the U. S. Geological Survey, and first compilation has been completed for the remainder of the State. These preliminary maps were assembled and exhibited as a new summary picture of the geology of New Mexico, 30 years subsequent to the issuance of the previous U. S. Geological Survey geologic map of New Mexico by N. H. Darton. The new map will show many more geologic units than were previously recognized, hundreds of faults and intrusive dikes not previously shown, and much greater detail of geology, summarized from more than 150 different sources of data, published and unpublished. During the 30-year interval between the two maps, vertical air photographic coverage of the whole State has become available, and the reconnaissance and semidetailed phase of geologic mapping of the State has been nearly completed. During this interval the concepts of intertonguing and of facies changes have become firmly established in geologic thinking, in part as a result of detailed studies of the Permian, Cretaceous, and Tertiary rocks in New Mexico, and these concepts are reflected in the new map.

The general geology of the State was briefly described with particular reference to the distribution of units selected for discrimination on the compilation, and the geology of six selected areas was described more fully to illustrate the more detailed geologic mapping that is now available for generalization and to show the variety of sources from which data was derived. Some new facts about the geology of the State discovered in recent years and during reconnaissance in connection with the State map project were mentioned. The excellent record of geologic assistance and guidance in the discovery and development of mineral resources in New Mexico was summarized, and it was pointed out that the annual value of production of mineral resources in the State has increased more than tenfold in the last 30 years, due chiefly to spectacular increases in the value of oil and gas, potash, and uranium produced. The geologist has thus made a substantial contribution to the improvement of the general welfare in the State.

66TH ANNUAL MEETING

The 66th annual meeting was held immediately following the 793d meeting, President Carle H. Dane presiding. The reports of the secretaries, treasurer, and auditing committee were read and approved. The Awards Committee presented first prize to G. W. Wetherill, G. R. Tilton, and G. L. Davis for their paper *Age of the Baltimore gneiss* and second prize to Isidore Zietz, G. E. Andreasen, and Arthur Grantz for their paper *Aeromagnetic study of Cook Inlet, Alaska*. The Sleeping Bear Cup was presented to W. H. Bradley for his devastating demolition of a special Cloud effect.

Officers for the year 1959 were then elected:

President: Joseph W. Greig
First Vice-President: Charles A. Anderson
Second Vice-President: Louis C. Conant
Secretary (2 years): J. Thomas Dutro
Treasurer: Helen F. Weissenborn
Members-at-large of the Council (2 years): Charles S. Denny, John E. Johnson, Robert C. Stephenson.

The Society nominated Carle H. Dane to be a Vice-president of the Washington Academy of Sciences for the year 1959.

If our scholars would lead more earnest lives, we should not witness those lame conclusions to their ill-sown discourses, but their sentences would pass over the ground like loaded rollers, and not mere hollow and wooden ones, to press in the seed and make it germinate.—Thoreau.

Vice-Presidents of the Washington Academy of Sciences Representing the Affiliated Societies

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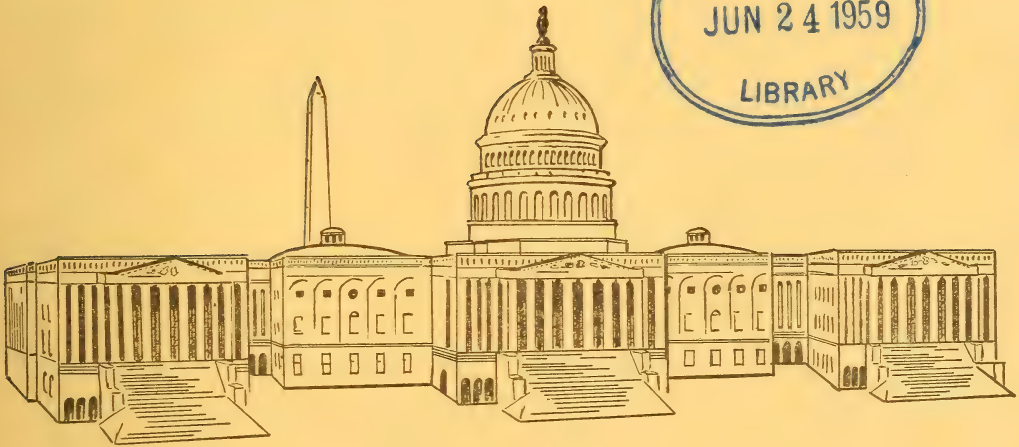

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Science and Education in the Washington Area

By Frank L. Campbell

President, Washington Academy of Sciences

(A radio address delivered on *Engineering News-Report*, March 1, 1959)

Yesterday in Washington three scientific lectures for high school students and teachers were given at 10:30 a.m.: one by Dr. Raymond J. Seeger, of the National Science Foundation, entitled "Faster Than Sound"; the second by Dr. R. Kenneth Lobb, of the Naval Ordnance Laboratory, on "Hypersonic Flight in the Frontiers of Space"; and the third by Dr. Sterling B. Hendricks, of the U.S. Department of Agriculture, on the "Action of Light on Plants." They spoke at the Carnegie Institution of Washington, the U.S. National Museum, and the National Institutes of Health, respectively. All three are outstanding scientists, particularly Dr. Hendricks, who is a member of the National Academy of Sciences and who recently received an award from the President of the United States in recognition of his scientific work.

Why were these distinguished men lecturing on a Saturday morning when they might have been resting? Because, like hundreds of other scientists and engineers in the Washington area, they feel that it is their civic duty to give freely of their time and experience in order to transmit to younger people some understanding of their work and of their enthusiasm for it. Call it free advertising, if you like, for these men are selling science and engineering to students who have yet to choose a career. They do it not only because they know that our country needs an ever-increasing number of persons skilled in science and technology but also because they believe in their work as a deeply satisfying way of life. So they speak partly as missionaries, trying to convert those who do not understand the ethical values of work that requires great devotion and absolute honesty.

The lectures just mentioned were part of a series of nine. How were they arranged and how in general is the great scientific and engineering talent of the Washington area brought to bear on young people? It is done by joint effort of two federations of local societies; one is called the Washington Academy of Sciences, the other the D. C. Council of Engineering and Architectural Societies. The Academy unites 26 scientific and engineering societies; the Council 29 engineering and architectural societies. Six engineering societies are common to both. It would have been chaotic if each of the 49 local societies had tried to do its own proselyting in the schools of the Washington area; even independent action by the Academy and the Council would have been inefficient if not irritating. The problem was solved in 1955 by the creation of the Joint Board on Science Education; i.e., joint between the Academy and the Council, but to a considerable degree independent of both. The Joint Board has many other functions beside the arrangement of the lecture series first mentioned. Its most remarkable feature is its Secondary School Contacts Committee. This is an organization of eight divisions covering junior and senior high schools in six areas in and around the District of Columbia as well as parochial and private preparatory schools in the whole Washington area. For each of the 150 schools of the area there is a scientist or engineer who had volunteered to help the science and mathematics teachers and students of his chosen school in any way he can. Through the Contacts Committee he may get Career Day speakers, speakers for science clubs, films on science and engineering topics, advice and assistance on science projects, and assistance for local science fairs. Occasionally the science or mathematics teachers of the area wish to go to national science teachers' meetings on school days. Then the Contacts Committee arranges for their classes to be taken by professional scientists and engineers, who, though inexperienced in teaching, are willing to brave hostile or indifferent students in order to carry their message to the students willing to listen.

I could tell you of many other achievements of the Joint Board and of its parents, the Academy and Council, but time is lacking. We scientists and engineers in the Washington area are proud of what we are doing for our successors. Looking at the fine membership of our Junior Academy of Sciences, at the science fairs held here, and at other evidence of scientific interest and competence of many of our young people, we are optimistic about the future of science and engineering in this community.

PHYSICS.—*Men and electrons.*[1] L. MARTON, National Bureau of Standards.

(Received February 18, 1959)

Several months ago I came to the conclusion that the history of the electron (or of electrons) might be a good subject for the address of the retiring president of this society. In the meantime, I had ample opportunity to study the subject and found, to my surprise, that there is even more historical material than I ever imagined. Under the circumstances it seems preposterous to add one more history of the electron to the existing ones unless one can say something new. I take courage, however, from the fact that my interpretation of one or the other phase of the development does not seem to agree entirely with those derived from earlier papers. I present here, therefore, a slightly different version of the history of the electron or, to be more precise, some fragments of the history of the electron.

To start, I should like to show a tabulation of the properties of electrons, as we know them now. Though incomplete this represents a few of the salient facts we have acquired in the past and allows us to look at the different aspects of the behavior of the electron. At the same time this permits us to group our discussion around certain conceptual aspects of this development, and the first of these conceptual aspects is the corpuscular nature of the electron. We shall try to examine, therefore, how the concept of the elementary charge emerged and who are its originators. In other words, my presentation of the history of the electron will not be a strictly chronological one. However, within the framework of whatever conceptual device I may follow, I shall use a more or less chronological development.

PROPERTIES OF ELECTRONS AND RELATED DEFINITIONS

CHARGE	$\epsilon = \pm 4.8 \times 10^{-10}$ e.s.u.
REST MASS	$m_0 = 9.1 \times 10^{-28}\ g$
MASS	$m = m_0[1 - (v^2/c^2)]^{-1/2}$
RADIUS (CLASSICAL)	$r = e^2/m_0c^2 = 2.8 \times 10^{-13}$ cm
VELOCITY	v
MOMENTUM	$p = mv$
KINETIC ENERGY	$E = c^2(m - m_0)$
WAVE LENGTH	$\lambda = h/p$
SPIN	$s = \frac{1}{2}$
MAGNETIC MOMENT	$\mu = 0.93 \times 10^{-20}$ erg/gauss
STATISTICS	Fermi

It is customary to start the history of the electron with the famous utterings of Benjamin Franklin. These appeared first in 1756 and are as follows: "The electrical matter consists of particles extremely subtle, since it can permeate common matter, even the densest metals, with such freedom and ease as not to receive any appreciable resistance." This statement is usually taken as a clear proof that Benjamin Franklin for the first time conceived the idea of electricity consisting of very small particles and was aware of this corpuscular nature of electricity. I can not agree entirely with that viewpoint. Let us examine this statement in the light of what was known when Franklin announced it and what kind of background existed. In those times the commonly accepted theory described electricity in terms of two fluids; one so-called vitreous and one resinous. In case someone should be inclined to take this 2-fluid theory as a precursor of the present conception of electrons and of positrons, I must warn you that the two fluids had to be present in equal quantities to describe the phenomena known at that time. Franklin took the very important step of replacing this 2-fluid theory with a 1-fluid theory in which all known phenomena could be described in terms of one type of electricity or by the lack of it. This was a tremendous step forward, and its importance can not be sufficiently underlined. It paved a way toward our modern conception of electricity, and indeed it paves a way toward the electron concept, but—and here comes a very important "but"—the fact that the description was in terms of "particles" does not have the same meaning as when we talk today of particles of electricity.

In a chapter of the first edition of the Handbuch der Physik, Walter Gerlach compared the role played by Franklin in the development of electron theory to that of Democritos in the development of the atomic theory of matter. I would agree par-

[1] Address of the Retiring President of the Philosophical Society of Washington, delivered on January 16, 1959.

tially with this viewpoint. Both Democritos and Franklin used the atomistic concept in describing certain phenomena: Democritos, those of matter; Franklin, those of electricity. Neither man had very ample experimental material at hand on which to base such a conception. In both cases the concept of smallest possible particles was an extremely vague one, so in one sense their roles were very similar, but here the analogy ends. Whereas Democritos's atomistic conception remained alive through the writings of Lucretius, that of Franklin was forgotten for quite a while. In fact, I have no evidence that Franklin's utterances were remembered at all until the time of the emergence of the corpuscular concept. They were not resuscitated until J. J. Thomson dug them out of oblivion in his Silliman lectures in 1903 given at Yale University. Nowhere in the famous papers preceding that of Thomson, dealing with the subject of the electron, could I find any trace of their being aware of Franklin's prediction, and in that sense Franklin's statement was without very much influence on the subsequent development. In the Silliman lectures Thomson, speaking of the determination of e/m, the charge to mass ratio of the elementary charge, says:

> These results lead us to a view of electrification which has a striking resemblance to that of Franklin's "One-Fluid Theory of Electricity." Instead of taking, as Franklin did, the electric fluid to be positive electricity we take it to be negative. The "electric fluid" of Franklin corresponds to an assemblage of corpuscles, negative electrification being a collection of these corpuscles.

One more remark about the use of the word "particles" in Franklin's famous statement. At the time of Franklin the atomistic concept of matter was already quite well advanced. In fact, at least a century earlier the famous natural philosophers had conceived of heat in terms of what we would regard nowadays as a kinetic theory. Bacon, Boyle, and Hooke professed surprisingly modern views about the nature of the heat. Take, for instance, Hooke in his *Micrographia*: "Heat is a property of a body arising from the motion or agitation of its parts." Or listen to Boyle: "Nature of heat" consists in "a various, vehement, and intestine commotion of the parts among themselves." It is hardly surprising, therefore, that, when matter has been considered as being constituted of small particles, Franklin should borrow the expression "particles" for a supposed fluid. We must remember that Franklin's fluid was something material and tangible. Another interesting parallel is that, like Franklin's views that were forgotten for so long, the kinetic views of Bacon, Boyle, Hooke, and others were also forgotten for quite a while. Take this quotation from Whittaker's remarks in his *History of the theories of aether and electricity*:

> Perhaps nothing in the history of natural philosophy is more amazing that the vicissitudes of the theory of heat. The true hypothesis, after having met with general acceptance throughout a century, and having been approved by a succession of illustrious men, was deliberately abandoned by their successors in favor of a conception utterly false, and, in some of its developments, grotesque and absurd.

Franklin's 1-fluid theory found slowly a universal acceptance. It became a good working theory for Faraday, who created the next important step in the theory. In January 1834 Faraday wrote as follows:

> The theory of definite electrolytical or electrochemical action appears to me to touch immediately upon the *absolute quantity* of electricity or electric power belonging to different bodies. It is impossible, perhaps, to speak on this point without committing oneself beyond what present facts will sustain; and yet it is equally impossible, and perhaps would be impolitic, not to reason upon the subject. Although we know nothing of what an atom is, yet we cannot resist forming some idea of a small particle, which represents it to the mind; and so we are in equal, if not greater, ignorance of electricity, so as to be unable to say whether it is a particular matter or matters, or mere motion of ordinary matter, or some third kind of power or agent, yet there is an immensity of facts which justify us in believing that the atoms of matter are in some way endowed or associated with electrical powers, to which they owe their most striking qualities, and amongst them their mutual chemical affinity.

There are two important details to be retained from this statement. One is that there is no mention at all of either Franklin or of any other predecessor. The second is that gradual emergence of the notion of the elementary charge. This elementary charge does not yet exist separately from matter.

It is linked to the atom or atoms and exists only in the electrolytic exchange of electricity. There is no prediction about the existence of such an elementary charge in the normal conditions of conductivity.

The first instance of attributing the phenomena of electrodynamics to the agency of moving electric charges is that of Weber. In 1873 Maxwell, writing on the work of his predecessors, said:

> The electromagnetic speculation which was originated by Gauss and carried on by Weber, Riemann, J. M. C. Newmann, Lorenz, etc. is founded on the theory of action at a distance, but depending either directly on the relative velocity for the particles, or on the gradual propagation of something, with a potential or force, from one particle to the other.

This I have quoted from the foreword of the first edition of Maxwell's famous *Treatise on electricity and magnetism*. No wonder that on page 312 of the same volume, in a section dealing with electrolysis, I find the following quotation:

> Suppose, however, that we leap over this difficulty by simply asserting the fact of the constant value of the molecular charge, and that we call this constant molecular charge, for convenience in description, one molecule of electricity.

Eight years later Helmholtz went even further in his Faraday memorial lecture delivered before the Royal Institution of Great Britain. In this year of 1881 Helmholtz formulated his thought as follows:

> Now the most startling result of Faraday's law is perhaps this; if we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions which behave like atoms of electricity.

All these statements taken together could be interpreted as a clear conception of the corpuscular nature of the elementary charge of electricity. I am somewhat skeptical of this view. None of these statements mentions the evidence obtained in gaseous discharges and for that type of evidence we have to go back almost 20 years.

Exactly 100 years ago, in 1859, the German mathematician and physicist Plücker made a rather surprising discovery. He was investigating the discharge of electricity through a rarefied gas. He was in a better position to investigate that type of phenomenon than were any of his predecessors, because his institution had an outstanding technician named Geissler who invented a new pump for producing a better vacuum. The Geissler tubes, as they soon became known, showed surprisingly beautiful colored phenomena in the discharge which took many forms and shapes. Plücker was in the fortunate position of being the first investigator of this behavior. One particular fact emerged: that there exists a kind of rectilineal propagation of part of the electrical discharge, originating on the negative electrode, hence the name "cathode rays." Without attempting any explanation of their nature, Plücker, and later his pupil Hittorff, observed that these rays can be deflected by a magnetic field. Plücker was originally professor of mathematics and was recognized as one of the leading geometers of his time. When he took over the physics chair, he conducted all his physics research in a remarkably unquantitative way. I deliberately use the word unquantitative, instead of qualitative, because one would expect from a leading mathematician an attempt at a somewhat quantitative formulation of the phenomena he is investigating. Plücker did nothing of the kind, and his successor Hittorff followed in the same way. The German physicist Goldstein did quite a bit to investigate these discharge phenomena, and so did the British physicist Crookes. Slowly, however, people started to speculate about the nature of these strange rays and gradually two views emerged. One was that of Crookes, who maintained that in an electrical discharge, particularly in the cathode rays, matter finds itself in what he called a fourth state of aggregation—a state of aggregation beyond the known three: solid, liquid, and gaseous. The German school of thought was somewhat opposed to this view. Based upon the experiments of Hertz and his pupil Lenard, the view became preponderant on the eastern side of the Rhine that cathode rays consist of some kind of an ether vibration. Lenard found that cathode rays can penetrate through a thin film of aluminum, or other thin material, and can even enter the outer atmosphere. No corpuscle, it was thought, would be able to penetrate through dense matter like this, and that is why the electromagnetic wave explanation was preferred by the Germans. Apparently nobody thought that this strange substance could be electricity in free flight, and nobody tried to identify it with electrolytic phenomena or with the conduction of electricity in matter.

The naming day of the electron did not occur until 1874, or 1881, depending on which year is taken as the proper date. In 1874, before the Belfast meeting of the British Association, J. Johnstone Stoney read a paper in which he proposed that the elementary charge of electricity be called the electron. His paper, however, was not published until 1881. Stoney's proposal was a reasonably logical one. Faraday used the word ion quite often in his electrolytical and electrochemical investigations, and ion was accepted for quite a long time. But the noun electron was not derived from the ion; it was derived from the Greek word for amber, from which the word electricity itself has been derived. It was, however, responsible for the introduction of the ending t-r-o-n in our language. This fateful event did not occur until the first or second decade of our century when the magnetron and kenotron were so named. From then on, all kinds of devices were given names ending in "tron," through the somewhat mistaken idea that t-r-o-n means something. I should have preferred that this ending be reserved for elementary particles like the positron and the meson, which was originally called mesotron. However, as the "tron" ending has now been taken over by all kinds of gadgets, it may be just as well that the mesotron has been renamed meson and cannot be confused with the perhapsatron and the swindeltron. Still, I sometimes wonder what some people may think of the electron who are familiar only with the various complicated instruments ending in "tron." Perhaps they think of the electron too as a complicated gadget.

Another remark may be pertinent at this point. At the beginning of the century, particularly in European countries, the word electronics was used to describe the physics of the free electron. Here is another sad instance of the corruption of a word that was reasonably straight-forward and reasonably short. Nowadays, particularly in this country, electronics is completely devoted to the description of high-frequency phenomena, and nobody who wants to speak of the free electron can ever use the word electronics without it being misunderstood.

The real emergence of the modern concept of the elementary charge or elementary particle had to wait until the closing days of the last century. Stoney's electron was still the elementary charge associated with the electrolytic process. The discovery of the photoelectric effect in 1888 by Heinrich Hertz, and its later further development by Hallwachs, did not contribute in any manner to the identification of the gaseous ion with the electrolytic one. This great event did not occur until 1895–1897. Those years saw three very essential steps. First was Perrin's identification of the charge carried by cathode rays with the negative charge. The next extremely important step was the theoretical work of Lorentz, who in 1897 interpreted the then quite new observations of Zeeman and showed that their only possible interpretation was in terms of the action of electrons associated with the atoms. Lorentz also calculated the famous equation of Lorentz force. Later in the same year came the extremely important work of J. J. Thomson, who determined quantitatively for the first time the deflection of an electron beam and determined in this manner the ratio of the charge to the mass of the elementary particles carrying the elementary quantity of electricity. These were the essential steps necessary for formulation of the modern concept, and of the three I should be inclined to say that Lorentz's contribution was perhaps the greatest, although I do not want to belittle Thomson's and Perrin's contributions either. The early part of the twentieth century saw determination of the elementary charge by Millikan. This achievement, however, did not change the conceptual formulation which by that time had been acquired.

The word electron did not find immediate acceptance, and even as late as 1906, the date of the second edition of Thomson's famous book *Conduction of electricity* *through gases*, the word never appears. In that book Thomson always calls the elementary charge negative ion. Even slower was the acceptance in certain circles of the notion of the elementary charge, and to many the famous struggle waged by Ehrenhaft against Millikan and many others remains still vivid. Ehrenhaft was convinced that smaller charges than those measured by Millikan and others exist, and he put up a long, hard fight to prove that subelectrons can exist. Ehrenhaft, although somewhat a strange character, was a very good physicist, and he devised many beautiful experiments in an effort to prove the existence of subelectrons. He was very much hurt when his own students became convinced of the futility of his views. He was too stubborn to recognize it, and stories are still going around about his complaint that he has sent one of his best students to California to convince Millikan and instead of that his best student was corrupted by Millikan. I have to thank Dr. DuMond for an anecdote illustrating this controversy. One day Millikan was asked by a lady: "Dr. Millikan, do you spend your *whole time* proving that electricity consists of electrons?" He answered with a smile that thanks to Dr. Ehrenhaft there was getting to be more truth than pleasantry in that question.

When I said that the twentieth century saw essentially the consolidation of the conception of elementary particles, I did not mean to imply that nothing has happened. Since the turn of the century several very important investigations occurred which should be mentioned here. One was the discovery by Kaufmann that the mass of the electron varies with its velocity. This became a splendid confirmation of the special relativity theory. The second important series of investigations demonstrated the inert mass of the electron through the so-called gyromagnetic effects. Four such effects have been listed in the literature. One was Maxwell's proposed experiment, which would show that a magnet, rotated around any axis not coinciding with the direction of magnetization, must act as a gyroscope. The second is the Barnett effect of magnetization by rotation. The famous Einstein–de Haas effect is third: it consists of rotation by magnetization. And last is gyroscopic magnetization by the rotation of a magnetic field, investigated by Fisher and by Barnett.

The last important new feature of twentieth-century work which can be derived essentially from Lorentz's equation of force is known nowadays under the generic term of electron optics. As it is impossible to discuss electron optics without referring at least briefly to the dual nature of the electron, it may be better at that point to close the particle chapter and start the wave chapter.

In concluding my remarks about the corpuscular aspects of the electron, I should like to give a few short quotations. One is drawn from Rosenfeld's book *Theory of electrons:*

> When Thomson's estimate of the specific charge of the cathodic corpuscles became available, no doubt was left as to the identity of Lorentz oscillators with electrons in harmony with Thomson's atomic model.

My other quotation comes from Weisskopf, a review called *Recent Developments in the theory of electron*, which was published in April 1949 in the Reviews of Modern Physics:

> There was hardly any other discovery which left the understanding of so many and varied phenomena as the discovery of the electron...It was mainly H. A. Lorentz who brought the classical electron theory into a consistent frame. These were his fundamental assumptions: the electron is an elementary particle with a charge e and a mass m; the motion of the electrons is determined by classical mechanics if the force acting on the electron is given by the expression:
>
> $$\vec{F} = e\vec{E} + (e/c)(v \times \vec{H})$$
>
> where e and v are the charge and velocity of the electron and $\vec{E}$ and $\vec{H}$ are the electric and magnetic field strengths. The electromagnetic field in turn is given by the Maxwell equations.

And last but not least a few words from Albert Einstein:

> No longer...do physicists of the younger generation fully realize, as a rule, the determinant part which H. A. Lorentz played in the formation of the basic principles of theoretical physics. The reason for this curious fact is that they have absorbed Lorentz' fundamental ideas so completely that they are hardly able to realize to the full the boldness of these ideas, and the simplification

which they brought into the foundations of the science of physics.

I should like to return now to the tabulation shown at the beginning of this presentation. As we know now, the chief characteristic of the electron, or for that matter of any elementary particle, is the duality of its nature. Depending upon the experiment we carry out, it can behave either as a corpuscle or as a wave. It is logical now that we consider the wave properties of the electron. I briefly mentioned earlier that the late nineteenth century saw a clear division of opinion about the nature of the electron between physicists east of the Rhine and west of the Rhine. In that respect it is interesting to quote the foremost representative of the western opinion. In his classical paper in 1897, J. J. Thomson wrote as follows:

> The most diverse opinions are held as to these rays; according to the almost unanimous opinion of German physicists they are due to some process in the aether to which—inasmuch as in a uniform magnetic field their course is circular and not rectilinear—no phenomenon hitherto observed is analogous: another view of these rays is that, so far from being wholly aetherial, they are in fact wholly material, and that they mark the paths of particles of matter charged with negative electricity.

Yet Thomson's investigations disposed of the wave nature of the electron only temporarily. In 1924, in his famous thesis, de Broglie reintroduced the wave concept in the fundamental properties of the electron. This wave, however, is something different from that of Hertz and of Lenard. The early wave was a truly electromagnetic phenomenon. De Broglie's wave is a guide wave of the particle, not electromagnetic in nature; it is always linked with a particle, it cannot be dissociated from it. The question then may legitimately arise: who were the predecessors of this conception and how was it born? As usual we do find ancestors of the idea, as they are most generously acknowledged in the same thesis of de Broglie. Part of the concept goes back to Einstein. Einstein in his famous paper of 1905 introduced the concept of the dual nature of light where light behaves both as a particle and as a wave. The "needle radiation" concept of Einstein was hard to accept for his contemporaries. Nevertheless, it paved the way for de Broglie, who acknowledges it handsomely. But this is only part of the picture. The more important part of it is that two important fundamental principles of physics—that of Fermat and that of Hamilton–Maupertuis—show more than formal resemblance. On page 24 of his thesis, de Broglie says:

> Guided by the idea of a profound identity of the principle of least action and that of Fermat, from the beginnings of my researches on this subject I was led to admit that, . . . the dynamically possible trajectories of a moving particle coincide with the possible rays of its wave.

He is even more positive on page 35:

> Fermat's principle, applied to the phase-wave, is identical with the principle of Maupertuis, applied to the moving particle.

The conclusion is simple:

> The preceding results . . . establish a link between the movement of a moving particle and the propagation of a wave.

The experimental verification was not long in coming. The wonderful work of Davisson, Germer, and of G. P. Thomson is well known to everyone and does not need to be repeated here. What needs perhaps to be repeated is the role Elsasser played in these investigations. Elsasser was, at the time of de Broglie's thesis, a young research student, and he was the first one who found that there may be some experimental evidence in the work of Davisson and Kunsman for the physical existence of de Broglie's waves. In a manner of speaking, this observation by Elsasser stimulated Davisson and Germer to their now classical results. I deliberately used the words "in a manner of speaking" because Davisson emphasized that the first interpretation of Elsasser was not quite right. I am quoting from a note countersigned by Davisson and published in a biography of Davisson by K. K. Darrow.

> The attention of C. J. Davisson was drawn to W. Elsasser's note of 1925, which he did not think much of because he did not believe that Elsasser's theory of his (Davisson's) prior results was valid. This note had no influence on the course of the experiments. What really started the discovery was the well-known accident with the polycrystalline

mass, which suggested that single crystals would exhibit interesting effects. When the decision was made to experiment with the single crystal, it was anticipated that "transparent directions" of the lattice would be discovered. In 1926 Davisson had the good fortune to visit England and attend the meeting of the British Association for the Advancement of Science at Oxford. He took with him some curves relating to the single crystal, and they were surprisingly feeble (surprising how rarely beams had been detected!). He showed them to Born, to Hartree and probably to Blackett; Born called in another Continental physicist (possibly Franck) to view them, and there was much discussion of them. On the whole of the westward transatlantic voyage Davisson spent his time trying to understand Schroedinger's papers, as he then had an inkling (probably derived from the Oxford discussions) that the explanation might reside in them. In the autumn of 1926, Davisson calculated where some of the beams ought to be, looked for them and did not find them. He then laid out a program of thorough search, and on 6 January 1927 got strong beams due to the line-gratings of the surface atoms, as he showed by calculation in the same month.

Nevertheless we have to recognize that Elsasser's ideas were brilliant. He mentioned them at that time to different people, one of them being Einstein. Einstein's answer was: "Young man, you are sitting on a gold mine."

It so happened that the year 1924 was also the year I finished my studies. During the years that followed I saw an extremely rapid change in our picture of the nature of the electron, and with it the whole foundation of physics changed. Let me mention just a few highlights from the five years 1924 through 1928. Following de Broglie's thesis came Schrödinger's famous wave equations. The next year, 1926, saw the introduction of the electron spin concept by Uhlenbeck and Goudsmit. The years 1926 and 1927 saw the birth of electron optics, and 1928 was the year in which Dirac presented his famous theory of the electron. There were so many things happening in those years that one almost forgets that during those same years Heisenberg announced his famous indeterminacy principle.

I should like to examine a little closer one or two aspects of this rapid evolution. First of all, most of these discoveries affected a much greater area of physics than the electron itself. This is in keeping with the older tradition: many years earlier the investigations of J. J. Thomson led into considerations about the structure of the atom. In a similar way the discovery of the wave equation led Schrödinger to a much wider investigation and much more important consequences than the wave behavior of a particle alone.

An interesting example of the application of present-day concepts is the case of electron optics. Electron optics nowadays covers a very wide field. The common interpretation of this expression corresponds to the ray optics of light and covers all phenomena of the interaction of electrons with macroscopic fields of forces. I rather like to distinguish, in close analogy to light optics, between two kinds of electron optics: geometrical and physical electron optics. Geometrical optics considers everything that can be explained with a simple ray concept. Physical optics requires the application of wave principles. In this manner electron optics, in its wider conception, represents a very beautiful example of our present-day concept of the electron at large. At the time of the conception of geometrical electron optics, some beginnings of physical electron optics existed. Scattering had been known for a long time, and electron diffraction was just being discovered. Electron interference was far in the future and so was electron polarization. Geometrical electron optics could very adequately have been described in terms of particle concepts alone. Electron ballistics could be created using the particle concept and all the interactions of the electron in a macroscopic field were properly described in terms of very general equations derived from the Lorentz equation. This description is quite adequate for macroscopic considerations, but it cannot represent the observed phenomena when we reach microscopic dimensions. To explain the resolving power of an electron microscope we must have recourse to the wave concept. This concept also leads to the highly satisfactory give and take which one finds in other branches of physics. The wave concept led us to the discovery of electron interferences and vice versa; the observation of electron interferences gives a more beautiful demonstration of the wave concept than we had before. The recent invention of the electron interferometer at the National Bureau of Standards and its further development in Germany and elsewhere is a good case in point. It shows that very fruitful analogies can be drawn from other branches of physics and applied to the physics of the electron. Here an application of electron interferometer principles taken over from light optics has shown that the optical path difference concept can be extended to electron optics.

Much more could be said about the history of the electron without exhausting the subject. I have not even touched, for instance, such important matters as how Dirac's theory led to the discovery of the positron or Yukawa's theory to the discovery of the meson. Both particles were discovered by Anderson. The meson was originally known under the name of "heavy electron." It is interesting to note that this concept is being resuscitated in a recent note by M. Goldhaber, who suggests that the electron and the μ-meson are two states of the same particle. Here I am attaching a label to the meson, and so we must distinguish between the π- and the μ-mesons. The meson theory of nuclear forces, as we know it today, applies to the π-meson. At the time of its discovery it was thought that the μ-meson would satisfy Yukawa's theory.

These are extremely fruitful and interesting speculations, and one could spend an enormous amount of time on them. My remarks may be summarized in the following fashion: Three names stand out above the others as the chief architects of the present conception of the electron. These are H. A. Lorentz, J. J. Thomson, and Louis de Broglie. In emphasizing their names I do not mean to minimize the contributions of many others. However, I believe that conceptually we owe these three more than we do any other investigators.

This is the end of *my* story, but not that of the electron. After having spent the evening reviewing some phases of the past, I should like to spend one more minute on the future. For me some of the most fascinating aspects of future work on the electron concept lie in the directions indicated by the current fight between the "Copenhagen school" and the "determinists" or "positivists." As is well known, the Copenhagen school's interpretation of quantum events is a statistical one, while the opposing school wishes to ascribe a "physical reality" to the microevent. The arguments used in this fight range all the way from physics to metaphysics; from philosophy to dialectical materialism. Some of the arguments sound like a quotation from Lewis Carroll's *The hunting of the snark:*

> Just the place for a Snark! I have said it twice:
> That alone should encourage the crew.
> Just the place for a Snark!—I have said it thrice:
> What I tell you three times is true.

My hope is, however, that this sometimes acrimonious debate will lead us to a reformulation of the concept which will be acceptable both to the determinist and to the indeterminist.

Wherever modern Science has exploded a superstitious fable or a picturesque error, she has replaced it with a grander and even more poetical truth.—George Perkins Marsh

MYCOLOGY.—*Two new species of* Harposporium *parasitic on nematodes.*

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In Petri-plate cultures prepared with decaying plant detritus, eelworms were observed undergoing destruction by two mucedinaceous fungi markedly different from any hyphomycetous parasite hitherto recorded as attacking nematodes. The two fungi are herein described as new species of *Harposporium* Lohde (1874) though neither of them produces conidia of the distinctive crescentic shape signalized in the name of that genus. However, both fungi resemble *H. anguillulae* Lohde emend. Zopf (1888), the widespread species on which the genus was erected, in forming their conidia for the most part on minute slender sterigmata arising from globose cells borne laterally on hyphal elements extended from parasitized animals.

1. **Harposporium baculiforme** sp. nev.

Hyphae assumentes incoloratae, intra vermiculos nematoideos viventes evolutae, simplices vel ramosae, plerumque 2–4.5μ crassae, primo parce septatae sed postea ex magna parte in cellulis 3–20μ longis constantes; genitabiles rami externi, incolorati, clavati, saepius 4–15μ longi, basi 0.6–1.0μ lati, apice 1.5–2.5μ lati, ibi aliquot (fere 2–12) cellulas conidiferas (phialas) ferentes; cellulae conidiferae vulgo globosae sed interdum elongato-ellipsoidae vel obovoideae, 2.5–6μ longae, 2.5–4μ crassae, 1–2 sterigmatibus praeditae; sterigmata vulgo 1–3μ longa, circa 0.6μ crassa; conidia incolorata, baculiformia, aliquando sursum leviter attenuata, basi et apice rotundata, plerumque 2.5–5μ longa, 0.7–1.5μ crassa.

Vermiculos nematoideos interficiens habitat in foliis arborum putrescentibus prope Durango et Steamboat Springs in Colorado.

Assimilative hyphae colorless, growing within living nematodes, in small host animals simple or only sparingly ramified but in larger animals forming moderately branched mycelia, mostly 2 to 4.5μ wide, at first rather scantily septate though later becoming divided into cells mostly 3 to 20μ long, from some of which lateral branches are extended that narrowly perforate the host integument and elongate externally into conidiophores; conidiophores colorless, somewhat club-shaped, 4 to 15μ long, 0.6 to 1.0μ wide at the base, 1.5 to 2.5μ wide at the tip, whereon are borne several (mostly 2 to 12) conidiiferous cells in loosely capitate and sometimes partly in catenulate arrangement; conidiiferous cells commonly globose though sometimes elongate-ellipsoidal or inverted egg-shaped, 2.5 to 4μ wide and 2.5 to 6μ long exclusive of the 1 or 2 sterigmata; sterigmata commonly 1 to 3μ long, about 0.6μ wide; conidia colorless, cylindrical or tapering very slightly toward the apex, always with rounded ends, 2.5 to 5μ long and 0.7 to 1.5μ wide.

Type of species: Figs. 1–14.

Harposporium baculiforme came to light in several maize-meal-agar plate cultures which after being permeated with mycelium of *Pythium ultimum* Trow had been further planted with small quantities of leaf mold collected in woods near Durango in southern Colorado early in July 1958. Later it appeared also in some maize-meal-agar plate cultures that after being overgrown by *Pythium debaryanum* Hesse were further planted with leaf mold gathered in woods near Steamboat Springs in northern Colorado on July 23, 1958. In both sets of cultures it subsisted by parasitizing eelworms referable to a species of *Plectus*. Mostly it attacked relatively young individuals, in each instance extending through the small animal host a single assimilative hypha with scarcely any vegetative branches (Figs. 1–5). Moderate ramification was usual when a more robust animal was invaded (Fig. 6). An assimilative hypha could in some instances be seen to have originated from a conidium lodged in the forward region of the stoma (Figs. 1, a; 5, a). A manner of initiating attack corresponding to that found usual in my *H. bysmatosporum* (Drechsler, 1946, 1954; Aschner and Kohn, 1958) was thus disclosed. Many infected eelworms, however, did not show any recognizable conidium within the stoma, and in these animals the avenue of attack remained conjectural.

The conidiophores of *Harposporium baculiforme* differ markedly in their small dimensions from the robust filamentous conidiophores found in all known congeneric forms as well as in all known nematode-destroying members of the related *Cephalosporium-Verticillium-Acrostalagmus* series. Soon after they have been extended from an infected animal they commonly give rise directly from the slightly expanded tip to globose conidiiferous cells in numbers varying from 1 to 5 (Figs. 1, b, c; 2, a–f; 3, a–g; 4, a, b; 5, b; 6, a–c; 7–11). Some of the globose cells may give rise to 1 or 2 others, so that usually 5 to 12 conidiiferous cells, interspersed with a few sterile cells of similar subspherical shape, become assembled in a loose irregular cluster. Although the globose cells in relatively young clusters most often bear only a single sterigma, many cells in older clusters are provided with two sterigmata (Fig. 11).

If left undisturbed the conidia produced on individual sterigmata tend to cohere side by side in compact sheaves (Fig. 12). Since usually a large proportion of them are moved short distances in different directions by roving eelworms and protozoans they commonly are seen lying separately in haphazard disorder (Figs. 13, 14) around infected eelworms. On careful scrutiny some appear to have a very slightly tapering shape—a spore 1μ wide at its base, for example, diminishing to a width of 0.9μ at its rounded tip.

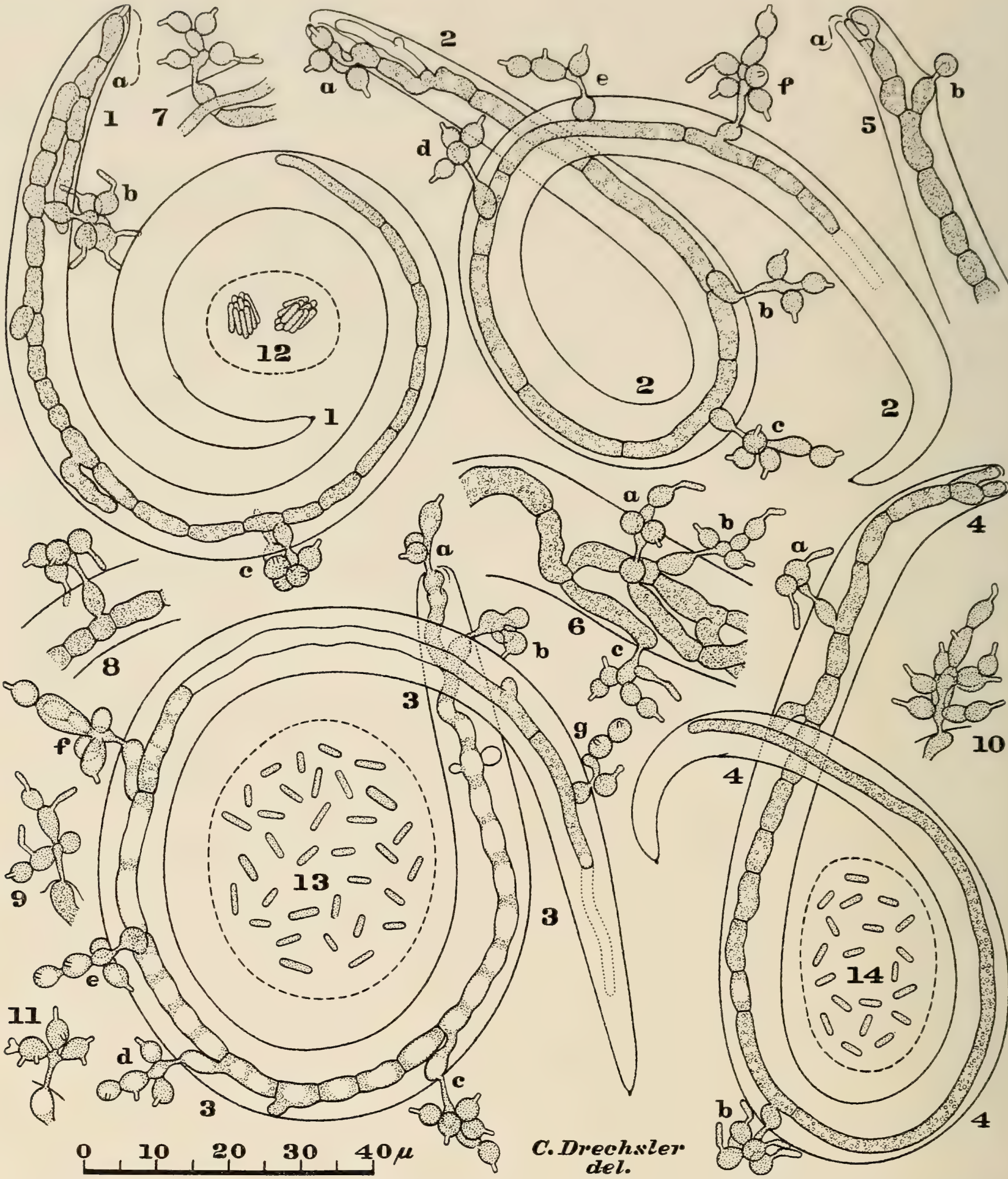
2. **Harposporium sicyodes** sp. nov.

Hyphae steriles incoloratae, intra vermiculos nematoideos viventes evolutae, parce vel mediocriter ramosae, primo parce septatae sed postea in cellulis plerumque 5–20μ longis et 2–4μ crassis constantes; hyphae fertiles extra animal emortuum evolutae, interdum in materia animal ambiente omnino immersae interdum omnino vel ex magna parte procumbentes vel ascendentes, in axe simplices vel ramosae, saepius 10–200μ longae, in cellulis plerumque 4–25μ longis et 2–3.5μ latis constantes, cellula terminalis vulgo conidia ex 1–2 sterigmatibus gignens, aliae cellulae saepius 1–6 ramulos conidiferos ferentes; ramuli conidiferi saepissime globosi sed interdum lageniformes, plerumque 2.8–3.7μ crassi, 1–2 sterigmatibus 1.2–3.7μ longis et 0.6–0.8μ latis praediti, in toto vulgo 4–8μ longi; conidia incolorata, cylindrata, recta vel leviter curvata, basi et apice rotundata, ita cucumiformia (fructui *Cucumeris sativi* similia), plerumque 3–5μ longa, 0.9–1.2μ lata.

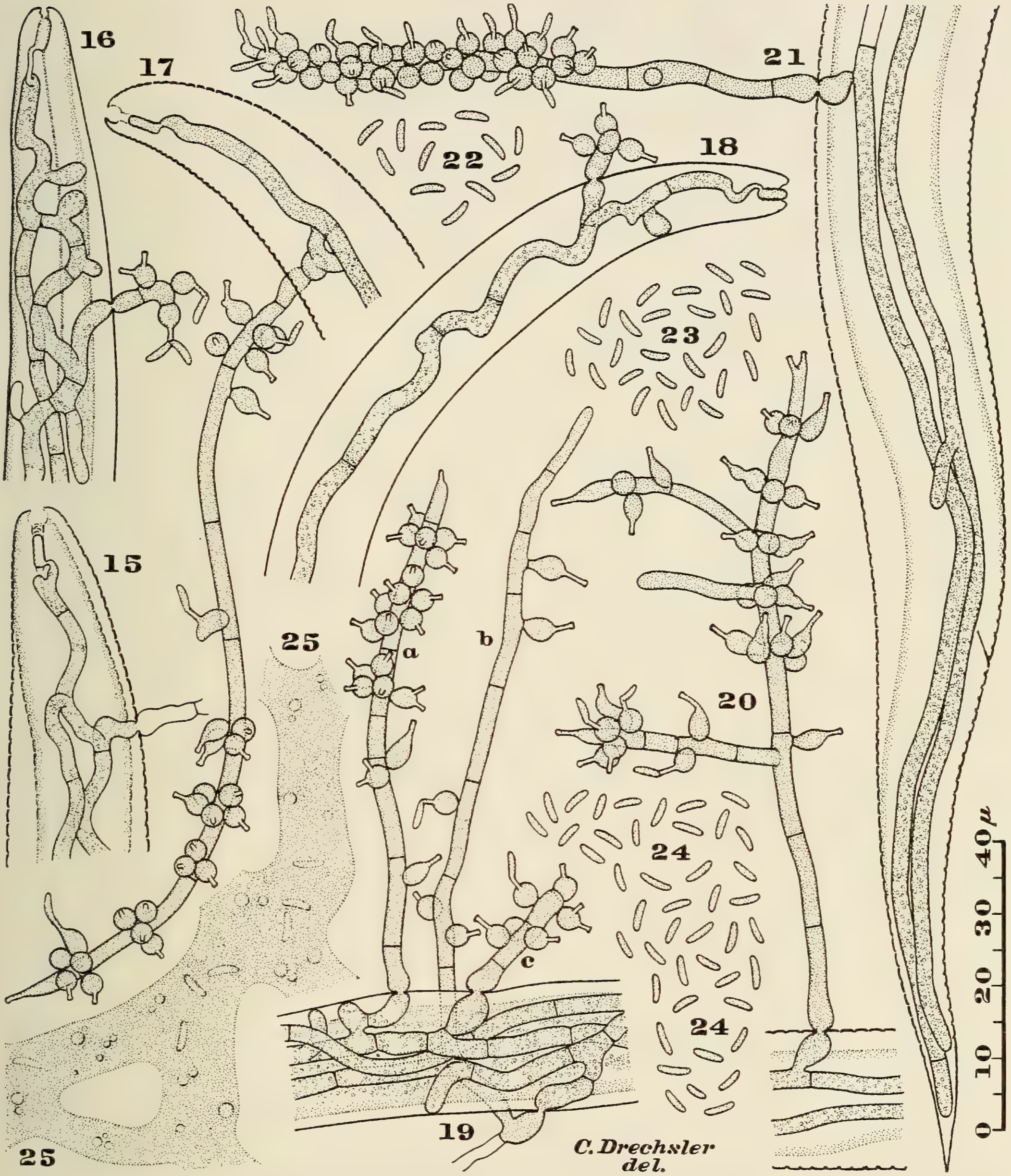
Vermiculos nematoideos interficiens habitat in foliis arborum putrescentibus in Arlington, Virginia.

Assimilative hyphae colorless, growing within living nematodes, in young condition rather sparingly septate, later becoming divided into segments mostly 5 to 20μ long and 2 to 4μ wide; conidiophores developed outside of dead host animal, sometimes submerged and sometimes in varying measure procumbent or ascending, simple or sparingly branched, mostly 10 to 200μ long, composed of cells mostly 4 to 25μ long and 2 to 3.5μ wide—the terminal cell often producing conidia on 1 or 2 sterigmata whereas some or all of the other cells bear 1 to 6 conidiiferous branches (phialides); conidiiferous branch often globose, then 2.8 to 3.7μ in diameter and provided with 1 or 2 sterigmata 1.2 to 3.7μ long, but sometimes variously flask-shaped and 4 to 8μ in total length—the sterigma in either instance often becoming widened at the tip; conidia colorless, somewhat cylindrical though tapering slightly toward both broadly rounded ends, straight or slightly curved, hence resembling cucumber (*Cucumis sativus* L.) fruits in shape, mostly 3 to 5μ long and 0.9 to 1.2μ wide.

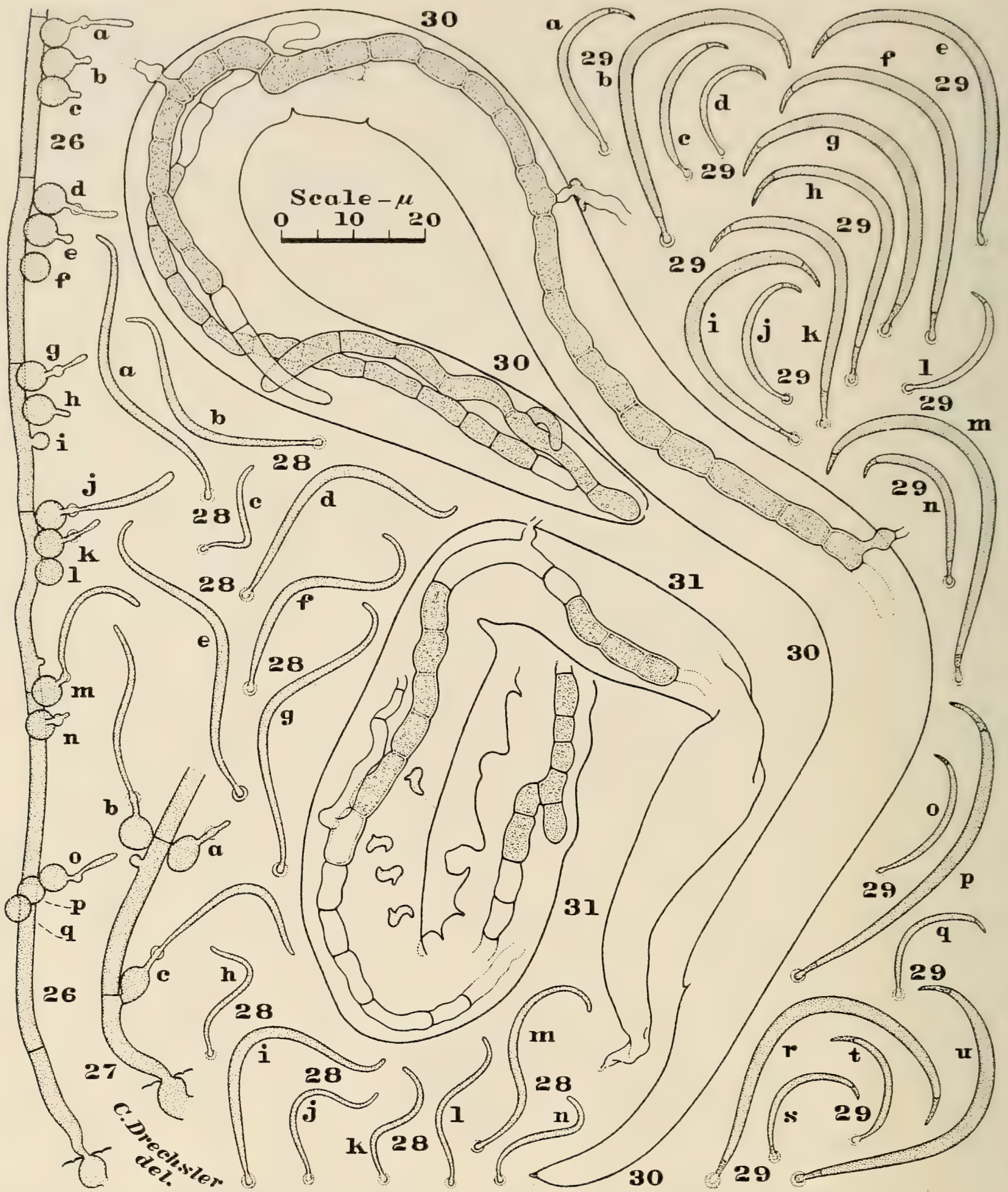
Harposporium sicyodes was found in a maize-meal-agar plate culture that after being overgrown with mycelium of *Pythium vexans* deBary had been further planted with leaf mold taken from woods bordering a watercourse in Arlington, Virginia, on October 11, 1958. It subsisted by parasitizing a sharp-tailed nematode which A. L. Taylor, who kindly examined several infected specimens, held probably referable to a species of *Panagrobelus*. In many infected animals a tubular connection was discernible, though usually with some difficulty, between an assimilative hypha and a conidium lodged in the stoma (Figs. 15–18). Some parasitized eelworms showed one or two ellipsoidal bodies lodged within the oesophagus 20 to 50μ from the anterior end. These bodies may have been swollen infective condia but owing to their deeply imbedded positions the presence of hyphal connections with any assimilative hypha could be neither established nor disproved. Invasion of the eelworm was accompanied often by pronounced withdrawal of the musculature from the



FIGS. 1–14.—*Harposporium baculiforme* from leaf mold gathered in Colorado, partly near Steamboat Springs (1, 4, 5, 8, 13) and partly near Durango (2, 3, 6, 7, 9–12, 14), drawn to a uniform magnification with the aid of a camera lucida, × 1000: 1, eelworm (*Plectus* sp.) with infecting conidium, a, in its stoma, and with 2 conidiophores, a and b; 2, infected eelworm (*Plectus* sp.) with 6 conidiophores, a–f; 3, infected eelworm (*Plectus* sp.) with 7 conidiophores, a–g; 4, infected eelworm (*Plectus* sp.) with 2 conidiophores, a and b; 5, forward portion of eelworm (*Plectus* sp.) showing origin of assimilative hypha from conidium, a, lodged in stoma, and a young conidiophore, b; 6, middle portion of infected eelworm (*Plectus* sp.) with branched assimilative mycelium and 3 conidiophores, a–c; 7–11, conidiophores; 12, conidia cohering in sheaves; 13, 14, two assortments of conidia, each assortment being from a separate infected eelworm.



FIGS. 15–25.—*Harposporium sicyodes* developing parasitically on an eelworm (probably *Panagrobelus* sp.), drawn to a uniform magnification with the aid of a camera lucida, × 1000: 15, forward portion of infected eelworm showing origin of assimilative mycelium from conidium lodged in stoma; 16–18, forward portions of 3 infected eelworms, each showing an assimilative hypha connected with a conidiophore and with a conidium lodged in the stoma; 19, median portion of infected eelworm with 3 conidiophores, a–c; 20, middle portion of infected eelworm with a branched conidiophore; 21, posterior portion of a large eelworm showing a simple conidiophore; 22–24, three assortments of conidia, each assortment being taken from a separate eelworm; 25, eight conidia ingested by a proteomyxan rhizopod (probably *Leptomyxa reticulata*).



FIGS. 26, 27.—Proximal portions of two conidiophores of *Harposporium helicoides* showing, respectively, 17 conidiiferous cells, a–q, and 3 conidiiferous cells, a–c, at different stages of development, × 1,000. FIG. 28.—Detached conidia of *H. helicoides*, a–n, × 1,000. FIG. 29.—Detached conidia of *H. oxycoracum*, a–u, × 1000. FIG. 30.—Indurated hyphae of *H. diceraeum* within integument of an eelworm (*Plectus* sp.) in a culture 65 days old, × 1,000. FIG. 31. Portions of indurated hyphae of *H. diceraeum* that have given rise within integument of an eelworm to 4 new conidia about 45 days after production of conidia on external conidiophores had ceased in the 65-day-old Petri-plate culture, × 1,000.

integument (Figs. 15, 16, 19, 20, 21). Development of assimilative hyphae, especially in posterior regions of large eelworm hosts (Fig. 21), appeared rather less abundant than in nematodes attacked by most related parasites.

The conidiophores of *Harposporium sicyodes*, like those of all congeneric species other than *H. baculiforme*, are moderately stout filamentous hyphae whether they are short (Figs. 16; 18; 19, c) or long (Figs. 17; 19, a, b; 20; 21). They usually remain simple, yet axial branching (Fig. 20) is not exceptional among them. Their unicellular conidiiferous branches, or phialides, are mostly shaped like a Florence flask, with the globose main part being abruptly distinct from the narrow sterigma arising from it. In more than a few instances, however, the distended main part tapers upward and merges with a distal sterigma, so that the conidiiferous cell appears transitional to the type of phialide familiar in species of *Cephalosporium* and *Verticillium*. The slight distension often noticeable at the tip of a sterigma would seem to come about in the abscission of the first conidium.

Harposporium sicyodes, like nearly all of its known congeners, conveniently continues to produce conidia while exposed to microscopical examination in an agar slab under a cover glass. Assortments of its conidia formed on conidiophores extended from separate individual animals (Figs. 22, 23, 24) show only moderate variability in shape and size. In my culture a large proportion of the detached spores were being constantly ingested by a proteomyxan rhizopod (Fig. 25) provisionally identified as *Leptomyxa reticulata* Goodey (1914).

SUPPLEMENTARY OBSERVATIONS ON THREE OTHER SPECIES OF HARPOSPORIUM

Several maize-meal-agar plate cultures which had been planted with leaf mold of the same collection that yielded *Harposporium sicyodes* permitted abundant development of *H. helicoides* Drechsler (1941). Occasion was taken to study more closely the manner in which the phialides of the latter species give rise to conidia (Figs. 26, a–q; 27, a–c). The individual phialide originates as a wart-like protuberance (Fig. 26, i) that continues to grow until it reaches a diameter of 3.5 to 4.5μ (Fig. 26, f, l, p, q). It then puts forth a sterigma usually 0.7 or 0.8μ wide (Fig. 26, c, h), which soon appears to swell distally in forming a terminal globular knob often about 1.5μ in width (Fig. 26, b, e). From this globular knob is now extended a slender outgrowth, approximately 0.5μ wide, whose tubular membrane is clearly continuous not with the globular contour but with a somewhat narrowing tube passing centrally through the knob (Figs. 26, a, d, g, k, n, o; 27, a). The outgrowth elongates first with gradually increasing and later with gradually diminishing width, at the same time describing a helicoid spiral of left-handed rotation (Figs. 26, j, m; 27, b, c). Ultimately the helicoid filament is cut off by a cross-wall at the lower boundary of the knob and then readily becomes detached as a conidium (Fig. 28, a–n). Manifestly the peripheral substance of the knob is of plastic consistency, since in detached spores it covers the basal membrane, and thus persists as a minute deposit of mucus that clothes the very slightly widening proximal end. In all cultures the conidia of *H. helicoides* are given to pronounced variations with respect to size, some measuring as much as 48μ in length and 1.7μ in greatest width, while others have corresponding dimensions of only 20μ and 0.7μ, respectively.

The conidia of *Harposporium oxycoracum* Drechsler (1941) resemble those of *H. helicoides* in having the slightly expanded basal end enveloped in a small quantity of mucus. They often show considerably greater dimensions than were assigned to them in the original account of the species. Thus, among the conidia produced by the fungus (Fig. 29, a–u) in Petri plate cultures that had been planted with forest detritus collected near Beltsville, Maryland, in April 1958, some measured no less than 60μ in total length and fully 2.3μ in greatest width. Moreover, in many of the larger conidia not only the tip but also a proximal portion, usually 2 to 5μ in length, appeared to be filled solidly with wall material.

The lot of forest detritus from southern Colorado that yielded *Harposporium baculiforme* supplied also some development of *H. diceraeum* Drechsler (1941) in several Petri plate cultures. Destruction of the nematode (*Plectus* sp.) parasitized by *H. diceraeum* was apparently completed about 20 days after the cultures had been prepared. When the cultures were 65 days old all external conidiophores of the fungus, together with all the conidia they had borne, had disappeared, but within the integuments of many parasitized animals could be seen variable portions of somewhat indurated living mycelium (Fig. 30). Some of the integuments loosely inclosed a few living conidia of *H. diceraeum* (Fig. 31), which in each instance must have been recently formed on a small conidiophore extended from a single indurated segment. As the hyphal segments here had undergone only slight thickening of their walls and showed only faint yellowish coloration they seemed less strongly modified for endurance than the chlamydospores always produced within eelworms destroyed by *H. anguillulae*.

REFERENCES

Aschner, M., and Kohn, S. *The biology of* Harposporium anguillulae. Journ. Gen. Microbiol. **19**: 182–189, pls. 1–2. 1958.

Drechsler, Charles. *Some hyphomycetes parasitic on free-living terricolous nematodes.* Phytopathology **31**: 773–802. 1941.

———. *A species of* Harposporium *invading its nematode host from the stoma.* Bull. Torrey Bot. Club **73**: 557–564. 1946.

———. *Production of aerial arthrospores by* Harposporium bysmatosporum. Bull. Torrey Bot. Club **81**: 411–413. 1954.

Goodey, T. *A preliminary communication on three new proteomyxan rhizopods from soil.* Arch. Protistenk. **35**: 80–102. 1914.

Lohde [Georg]. *Ueber einige neue parasitische Pilze.* Versamml. Deut. Naturf. und Aerzte **47**: 203–206. 1874.

Zopf, Wilhelm. *Zur Kenntnis der Infections-Krankheiten niederer Thiere und Pflanzen.* Nova Acta Leop.-Carol. Deut. Acad. Naturf. **52**: 314–376. 1888.

GRAPHICAL DIAGNOSIS OF INTERLABORATORY TESTS

A simple way to analyze the discrepancies between different testing laboratories that presumably use the same test procedure was recently worked out at the National Bureau of Standards.[1] Devised by W. J. Youden of the NBS applied mathematics laboratory, the method employs a graphical presentation of the test data which allows each laboratory to tell at a glance how its performance compares with that of others. The graph can point the way to corrective action to eliminate the bias, if any, in the technique used by a particular laboratory; or it may indicate the need for an improved test procedure—one that lends itself better to uniform application by all laboratories. In addition, it provides an estimate of the precision of the test-procedure results.

DISCREPANCIES, NORMAL AND ABNORMAL

Duplication of tests by two or more laboratories is constantly being undertaken in science and industry in order to verify results, to detect systematic errors, and in general to monitor the techniques of measurement. Sooner or later all important results in the physical sciences are checked by other laboratories. In industry, the same quality-control tests may be used by the various plants of a single company and—perhaps alternatively—the same acceptance tests are performed by laboratories at different depots of the purchaser.

In all such cases, discrepancies in the results from different laboratories are not only expected, but inevitable. It is basic to all measurement processes (except those of the crudest sort or those involving only simple counting) that when the same procedure is repeatedly carried out on the same specimen with the same equipment and personnel, the results are not all identical but are scattered over a certain range of values. When the same measurements are made by a number of different laboratories, using nominally identical equipment, the scatter is even greater. In any case, the more precise the procedure, the narrower the range of scatter.

However, when the scatter is unusually large or when a particular laboratory differs markedly from most of the others, something must be wrong. The problem—which the present method of analysis is intended to help solve—is to determine just where the difficulty lies. The difficulty may be due to a number of factors, some of the most important being (1) intrinsic lack of precision in the procedure; (2) faulty technique in carring out the procedure; (3) ambiguity or vagueness in the formulation of the procedure,

[1] For further technical details see the following articles by W. J. Youden: *Presentation for action,* Ind. and Eng. *Chem.* **50**: 91A. Oct. 1958; *Circumstances alter cases, ibid.* **50**: 77a. Dec. 1958; *What is a measurement? ibid.* **51**: Feb. 1959.

causing differences in the way it is applied by different laboratories; (4) differences in the specimens measured; and (5) simple mistakes, such as misreading a dial.

COORDINATING INDUSTRIAL TESTS

The importance of identifying the factors responsible for the discrepancies is clear enough in scientific research. In industry, undiagnosed errors in the carrying out of quality-control tests and errors intrinsic to the test procedure itself are a severe handicap to efficient production. To allow for testing errors, the usual practice is to aim at a higher quality product than the specifications call for. The larger the test errors, the greater the amount of excess quality needed to insure that a reasonable proportion of the finished items will pass the tests—which are still based on the same specifications. Even a modest improvement in the precision or in the uniformity with which tests are carried out could thus lead to a substantial drop in costs.

Under the stimulus of a high rate of new-product development, much attention has re-

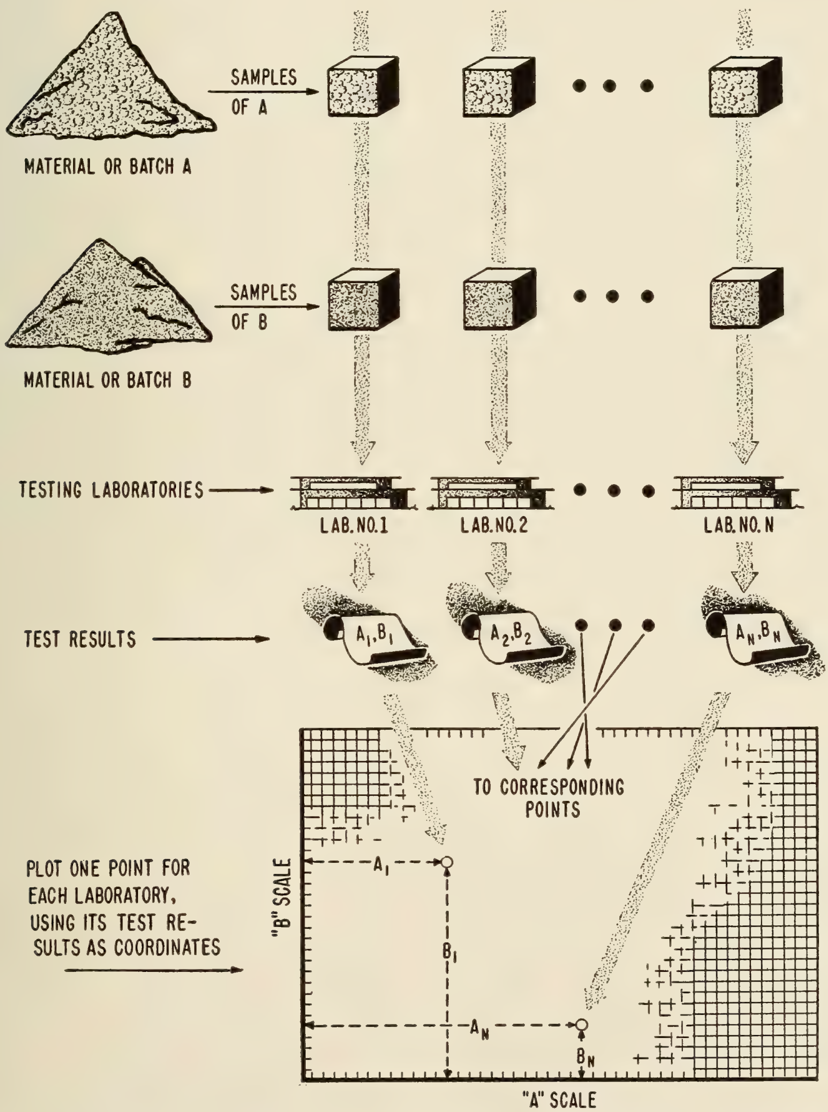


FIG. 1.—Statistical design for diagnosing discrepancies in results from different testing laboratories. The interlaboratory design was developed by the National Bureau of Standards.

cently been given to the problem of coordinating quality-control or acceptance tests in different laboratories. These schemes often use advanced statistical techniques to attack the problem with various degrees of thoroughness, but the practical results have been generally disappointing.

Part of the difficulty seems due to the very sophistication of the methods used. Though modern mathematical techniques have added many powerful tools to the statistical analyst's arsenal, their use demands considerable skill. In contrast, experience with the present method indicates that in a large majority of cases it provides data that "speak for themselves." However, there are circumstances that require a more elaborate or comprehensive interlaboratory test design; but even in such cases the present method might well be used for a preliminary survey of the situation.

THE STATISTICAL DESIGN

In the present statistical design, samples of two fairly similar materials, A and B, are sent to the various laboratories; and each laboratory is asked to carry out the test procedure on each sample. The test results may be single readings or averages, provided that the same number of readings are used for each average. (If there are only a few laboratories, a second pair of samples is distributed later; this is of advantage even when not required by the fewness of the laboratories.)

When the results come in they are used to prepare a graph. The two test measurements from each laboratory are interpreted as the coordinates of a single point; the x-coordinate is the test result on sample A and the y-coordinate the result on sample B. There is thus one point for each laboratory (Fig. 1).

A horizontal median line is then drawn; i.e., a line parallel to the x-axis and placed so that there are as many point above the line as there are below it. A second median line is drawn vertically; i.e., parallel to the y-axis and so that there are as many points to its left as to its right.

For example, when two cement samples were sent to 25 laboratories for tests of 7-day tensile strengths, the results gave the graph shown in Fig. 2. Here two of the laboratories were so definitely separated from the other 23 that they were not used in locating the median lines.

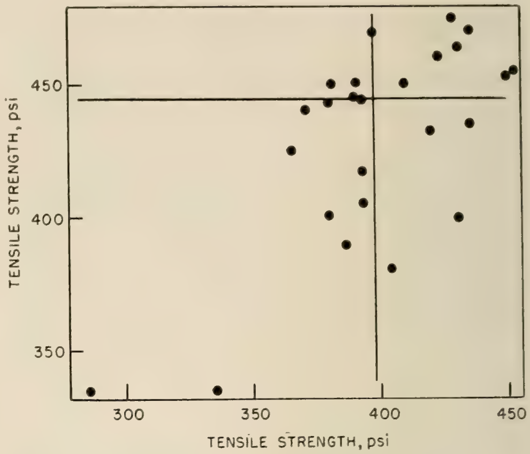


Fig. 2.—Plot of 7-day tensile strength of two cement samples as reported by 25 laboratories.

INTERPRETATION OF GRAPH

The most important general feature of the graph is the way the points are distributed among the four quadrants into which the graph paper is divided by the median lines. If only random errors of precision were present the points should be equally numerous in all quadrants.

However, in all cases to which the method has been applied thus far, there has been a more or less definite tendency for the points to concentrate in the upper right and lower left quadrants. In view of the way the points were obtained, this means that some laboratories tend to get high results on both samples and other labora-

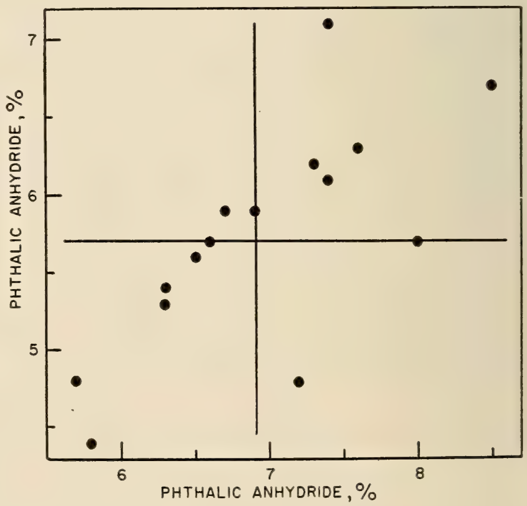


Fig. 3.—Results of phthalic anhydride determinations reported by 15 laboratories in two samples of paint.

tories get low results on both samples. That is, it indicates the presence of individual laboratory biases. Evidence of this state of affairs is seen, for example, in the cement tests (Fig. 2).

The more pronounced the individual laboratory biases, the greater the departure from uniform, circular distribution of the points about the intersection of the medians. Fig. 3 illustrates a case in which the points (with a few exceptions) lie in a long narrow oval with its long axis at about 45° with the x-axis. These points were plotted from phthalic anhydride determinations reported by 15 laboratories on two samples of

Results of the kind shown in Fig. 3 suggest rather clearly that the test procedure needs more careful formulation. In its present form the procedure is apparently open to individual modifications that produce differences in the results obtained. Indeed, the more carefully each laboratory follows its own interpretation of the test procedure, the more closely the points will cluster along the 45° line.

DEVIANT LABORATORIES

Points that deviate far from the intersection of the medians tend to fall into two categories. Either they are far out but close to one of the median lines or they are far out but close to the 45° line (see, e.g., Figs. 3 and 4).

In the first case, the result is fairly good on one material and rather bad on the other. A single instance of this kind might be due to a simple mistake or blunder; but if the same laboratory obtains similar results in succeeding pairs of materials, carelessness may be the reason.

A quite different explanation applies to a point for out on the 45° line. Here the laboratory in question is doing very consistent, careful work; but it has introduced some modification into the procedure so that the results are all too high (or too low). A thorough check on its procedure to discover the source of the bias is in order.

In the copy or the interlaboratory test report that is sent to a particular laboratory, it might be helpful to circle its point in red. This would save the laboratory the trouble of consulting its files to locate itself and would present a vivid picture of its position in respect to the other laboratories.

When an individual point is exceptionally far from the intersection of the medians it is better not to compress the scale in order to include it in the graft. As was done in the example of the cement tests (Fig. 2), such points should be ignored in locating the median lines.

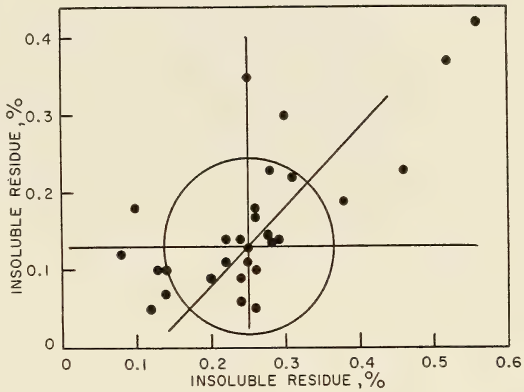


Fig. 4.—Percent insoluble residue in two samples of cement as reported by 29 laboratories. Circle has radius equal to 2.5 times the standard deviation. According to elementary statistical theory, 95 percent or more of the points are expected to fall inside the circle if there are no systematic differences in the techniques used by the different laboratories.

ESTIMATING PRECISION

The graphical presentation of test results, as described above, may also give information on the standard deviation (σ) of a single result. An estimate of σ can be obtained rather simply if it is assumed that (1) the two materials are sufficiently alike so that the dispersion among the results for A should be about the same as that for B; and (2) the differences in precision among the various laboratories are relatively unimportant in comparison to other sources of difference. The first condition can be satisfied by proper choice of the materials and experience shows that as a rule the second condition is then also fulfilled.

One way to get the desired estimate, under the assumptions mentioned, is to find the average distance of the points from the 45° line through the intersection of the medians, and then to multiply this average by $\sqrt{\pi/2}$ or 1.2533. Alternatively, the same estimate can be found by simple numerical calculations from the given results for A and B, without having to measure distances on the graph.

According to elementary statistical theory, a circle centered on the intersection of the medians and having a radius of 2.5 σ should contain 95 percent or more of the points provided there are no constant errors. Laboratories whose points fall outside such a circle almost certainly are erratic or are following a procedure which deviates substantially from that followed by the other laboratories.

POSSIBILITY OF SAMPLE VARIATION

Could a pattern of points like that of Fig. 2 be caused by differences in the samples? It is not difficult to see that the answer must be in the negative. If the stock from which the A samples were taken were inhomogeneous, and similarly for the B samples, then the pairs of samples distributed to the laboratories would be of four kinds:

high in A, high in B
high in A, low in B
low in A, high in B
low in A, low in B

Since any one of these combinations is as likely to occur as any other, the points representing the test results should be nearly equally divided among the four quadrants. A concentration of points along the 45° line can not be charged to variation among the samples.

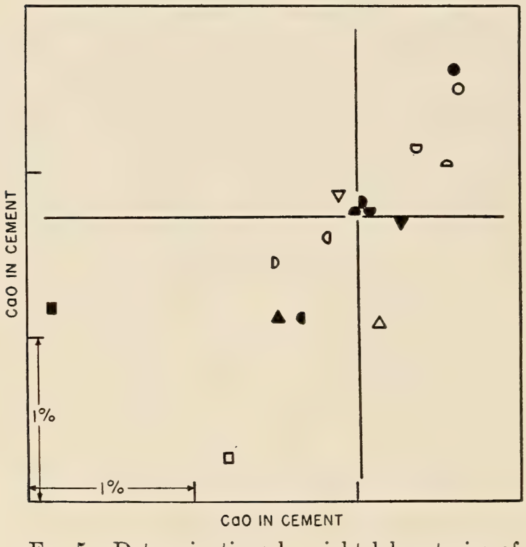


FIG. 5.—Determinations by eight laboratories of CaO in cement. The number of laboratories being so few, each was asked to make determinations on two pairs of samples. Hollow symbols show results for first pair and corresponding solid symbols show results of same laboratories on second pair of samples. The graph indicates that the test procedure is vulnerable to individual bias. Thus, two of the laboratories appear in the same region for both pairs. The "circle" laboratory is very consistent—and gets the highest results. The "square" laboratory gets very low results and is not very precise as shown by the fact that its two points (hollow and solid squares) are farther apart than are the pairs for other laboratories.

However, if there is a roughly circular distribution of points, but with a disappointly wide scatter, the diagram does not reveal whether this arises from sampling difficulties or from poor precision in testing. Further light on this problem can be obtained by a modification in the method of assigning samples. If there are 2N laboratories, N *double-size* samples of each material are prepared. By mixing or otherwise, it should be possible to divide each double-size sample into two closely matching halves. The samples are now distributed in such a way that if the two halves of a particular double sample of A go to laboratories X and Y, then these same laboratories receive the two halves of a double sample of B.

If sample variation is the trouble, the points in the new graph will tend to appear as N closely spaced pairs—like double stars in the heavens. On the other hand, if the points corresponding to the two halves of a double-size sample are separated as much (on the average) as points from different double samples, the scatter cannot be ascribed to sample heterogeneity.

SUMMARY OF ADVANTAGES

The present interlaboratory test scheme requires of each laboratory the relatively light task of measuring only two samples; and the collation of test results involves a minimum of computation. Interpretation of the graph requires no professional statistical background to follow the reasoning; yet it permits a fairly searching examination of the test procedure itself and of the way it has been carried out by the individual laboratories.

Directions for improvement are clearly indicated. A long narrow ellipse directs attention to a more careful description of the procedure or even to the need for its modification. Points far out and near one of the medians indicate erratic work; points far out along the 45° line are strong evidence of deviations from specified procedure. Use of a circle with a radius of 2.5 σ shows the individual laboratory whether or not its technique has in some way become saddled with a substantial constant error. Experience has already shown that a certain few laboratories turn up all too frequently in the most distant positions from the intersection of the medians. Improved performance from those few laboratories may go far to restore confidence in a test procedure.

ENTOMOLOGY.—*A new grasshopper of the genus* Achurum *from eastern Texas* (*Orthoptera: Acrididae*). Ashley B. Gurney, Entomology Research Division, United States Department of Agriculture.

(Recieved February 18, 1959)

One of the most distinctive genera of North American grasshoppers is *Achurum* Saussure,[1] characterized by a very slender and elongate body and an extremely oblique, or ventrally "undercut," face. An individual clinging parallel to a grass stem with its antennae extended forward would scarcely be distinguishable from the vegetation. Since the publication of Hebard's review of the genus (Trans. Amer. Ent. Soc. **48:** 89–93. 1922), the genotype, *A. sumichrasti* (Saussure), has been the only included species. It was shown in habitus illustration by Ball et al. (Univ. Arizona Techn. Bull. 93: 287. 1942). The characters of the genus were also treated by Hebard in his key to Nearctic genera of Acridinae (Trans. Amer. Ent. Soc. **52:** 47–59. 1926). Though of distinctive appearance, specimens of *Achurum* are uncommon, and in the United States *sumichrasti* is known only in southeastern Arizona and southwestern Texas.

For the privilege of studying the new species here described I am very grateful to John R. Hilliard, of the staff of McMurry College, Abilene, Tex., who collected all the material, and to whom I am glad to dedicate the species in recognition of his unpublished studies of grasshoppers and in appreciation of his cooperation. I am also grateful to J. A. G. Rehn, Academy of Natural Sciences of Philadelphia, for the loan of specimens of *sumichrasti* needed for comparative purposes to supplement specimens in the U. S. National Museum.

The new species averages larger than *sumichrasti*, and it is separated by differences which in the main are subtle rather than striking. The most noticeable differences are that the male subgenital plate of *hillardi* is more elongate and acute and the fastigium of the vertex has wider marginal areas.

[1] Saussure (Rev. Mag. Zool. 1861:313) adapted the name *Achurum* from the "Greek" achyron, meaning chaff, husk, or scale.

Achurum hilliardi, n. sp.

Figs. 1, 2, 6, 8, 9, 11, 13

Male (holotype): General appearance much as in *sumichrasti*; fully winged. Apex of fastigium in dorsal view angulate rather than evenly rounded (usually but not always true of *sumichrasti*), and with marginal areas laterad of impressed longitudinal grooves (Figs. 5, 6, *lg*) wider than in *sumichrasti*, in lateral view with lateral margins decurved at apex (Fig. 1, *lm*) and with portion of frontal costa (*fc*) anterior to antennal bases obtuse-angulate rather than more broadly rounded as usual in *sumichrasti*.

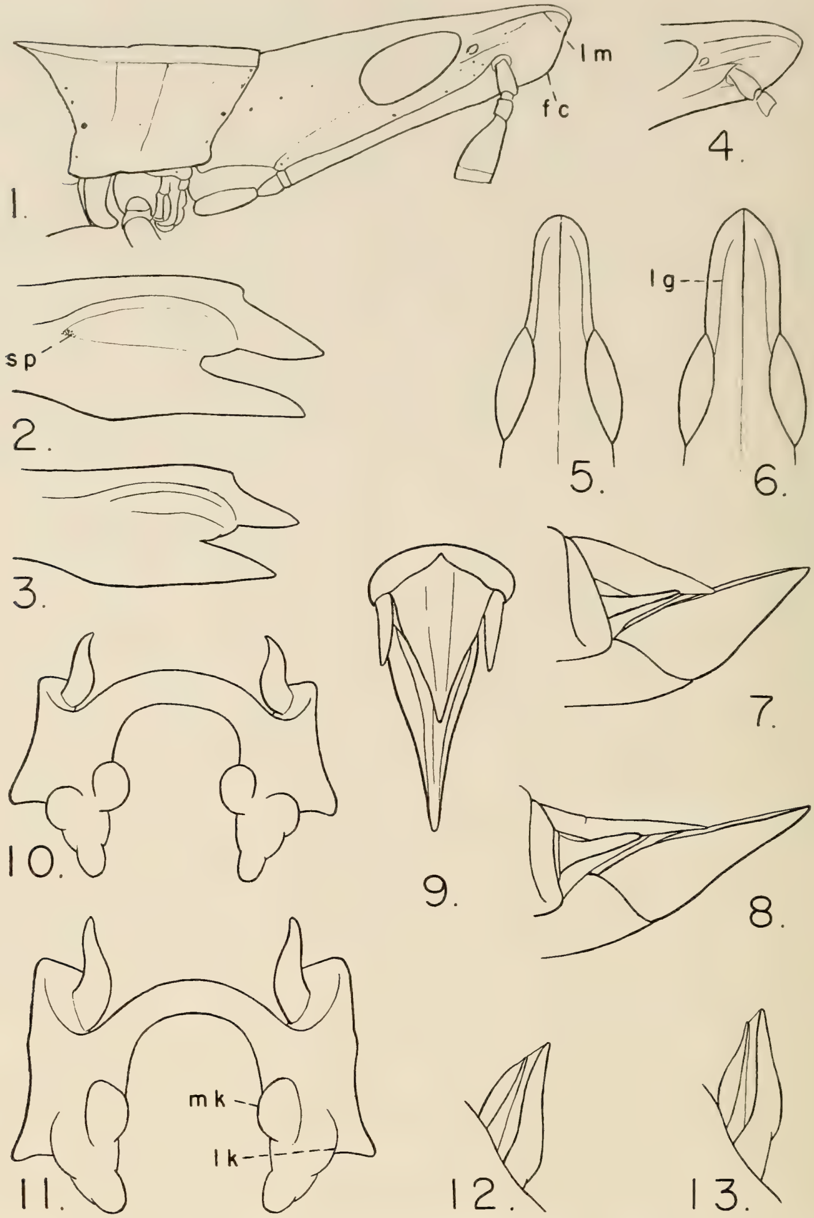
Pronotum, tegmina, and wings essentially as in *sumichrasti*; hind femur with both mesal and lateral dorsal and ventral genicular lobes produced toothlike somewhat longer than in *sumichrasti* (Figs. 2, 3); hind tibia with variable number of spines (left: 17 lateral, 22 mesal, one apical on mesal only; right: 16 lateral, 19 mesal, one apical on each side), apical spurs similar to those of *sumichrasti*.

Subgenital plate apically produced, not essentially triangularly acute in lateral view as in *sumichrasti* (Figs. 7, 8); supra-anal plate (epiproct) elongate (Fig. 9); cercus slender, elongate, as in *sumichrasti*; (phallic complex not extracted, described under *variation* below from paratypes).

Coloration: In general pale brown; antennae and compound eyes reddish brown; dorsal surfaces of closed tegmina much paler than lateral surfaces; dorsal surface of pronotum somewhat paler than lateral lobes, latter with conspicuous blackish spot near anterior margin, another spot near posterior margin (Fig. 1); hind femur with tiny dark spots (10 left, 12 right) along the mid-longitudinal line of the lateral (outer) paginal area, both mesal and lateral genicular disk with blackish spot at anterior margin (Fig. 2, *sp*.).

Measurements (length in millimeters): Body, 32.2; antenna, 14.0; fastigium anterior to compound eyes, 2.5: pronotum, 4.7; tegmen, 28.0; hind femur, 14.5; greatest width of hind femur, 1.8.

Variation among other specimens: The shape



FIGS. 1–13.—1, *Achurum hilliardi*, n. sp., lateral view of head and prothorax of holotype, only bases of antenna and leg shown; 2, *A. hilliardi*, apical portion of left hind femur of holotype; 3, *A. sumichrasti* (Saussure), same view as Fig. 2, male from Cuernavaca, Mexico; 4, *A. sumichrasti*, laterial view of apical portion of head of male from Baboquivari Mountains, Ariz.; 5, *A. sumichrasti*, dorsal view of anterior portion of head, same specimen as Fig. 4; 6, *A. hilliardi*, same view as Fig. 5, holotype; 7, *A. sumichrasti*, lateral view of apical portion of abdomen, male from Fort Grant, Ariz.; 8, *A. hilliardi*, same view as Fig. 7, holotype; 9, *A. hilliardi*, dorsal view of apex of abdomen, holotype; 10, *A. sumichrasti*, dorsal view of epiphallus, KOH preparation, male from Baboquivari Mountains, Ariz.; 11, *A. hilliardi*, same view as Fig. 10, paratype; 12, *A. sumichrasti*, lateral view of aedeagus, KOH preparation, same specimen as Fig. 10; 13, *A. hilliardi*, lateral view of aedeagus, KOH preparation, paratype. (*fc*, frontal costa; *lg*, longitudinal groove of fastigium; *lk*, lateral knob of epiphallus; *lm*, lateral margin of fastigium; *mk*, mesal knob of epiphallus; *sp*, dark spot on genicular disk.) (Drawings by author.)

of the fastigium in dorsal view varies somewhat among the paratypes, but in none is it evenly rounded at the apex as is usual in *sumichrasti*. In lateral view the position of the frontal costa anterior to the antennal bases is always decidedly obtuse-angulate, but specimens of *sumichrasti* occasionally are sufficiently angulate so that this feature is not a constant separating character. Spines along the hind tibia vary as follows as regards extremes and averages: Lateral, 13–18, av. 16.1; mesal, 17–21, av. 18.9. In contrast, the tibial spines of 9 males of *sumichrasti* from Texas, Arizona, and Mexico have been examined with the following corresponding results: Lateral, 13–16, av. 14.8; mesal, 16–20, av. 17.7. The apex of the supra-anal plate is weakly sclerotized and consequently the length of the organ varies, but in most specimens an acute apical portion is moderately developed. This organ in *sumichrasti* is very similar, not always as short and blunt as might be inferred from Hebard's description (Trans. Amer. Ent. Soc. **48:** 93. 1922). The female nymphs (not considered paratypes) show a very elongate second portion of the supra-anal plate similar to that described and figured for *sumichrasti* by Hebard.

The phallic complex of four paratypes has been examined and compared with examples of *sumichrasti*. The shapes of the aedeagal valves may differ slightly in the two species (Figs. 12, 13), but individual variation in preparations appears to render separation on this basis uncertain. Figs. 10 and 11 depict epiphalli of *sumichrasti* and *hilliardi*, and the limited dissections made indicate that differences occur in the mesal and lateral knobs of the lophus. The lateral knob of *hilliardi* (Fig. 11, *lk*) is more evenly rounded when seen in lateral view than that of *sumichrasti*, which is rather abruptly terminated at its anterior margin. The mesal knob of *hilliardi* (*mk*) apparently is less produced mesally than that of *sumichrasti*.

The general coloration of the paratypes is comparatively uniform, but two specimens lack dark spots on the lateral paginal area of the hind femur, and one of them has the two dark spots on the lateral lobe of the pronotum obsolete.

Measurements (extremes and averages, in millimeters) of the paratypes are as follows: Body, 29.0–33.0, av. 31.6; antenna, 13.5–15.5, av. 14.1; fastigium anterior to eyes, 2.3–2.6, av. 2.5; pronotum, 4.3–4.9, av. 4.6; tegmen 27.4–30.5, av. 28.7; hind femur, 14.5–15.0, av. 14.8; greatest width of hind femur, 1.6–1.8, av. 1.75.

To show the average larger size of *hilliardi*, 14 males of *sumichrasti* from localities throughout the latter's range have been measured for three dimensions, with results as follows: Pronotum, 3.6–4.6, av. 4.1; tegmen, 22.0–28.0, av. 25.8; hind femur, 11.5–14.0, av. 13.1. It should be noted that tegmen length has been measured "from the distal extremity of the tubercle formed by the junction of the subcostal and radial veins" to the extreme tip. (Proc. 4th Internat. Locust Conference, Cairo: 97. 1937). Dirsh (Anti-Locust Bull. 16, fig. 1. 1953) illustrated this dimension.

Type: U. S. National Museum no. 61125.

Type locality: A bog 2 miles south of Warren, Tyler Company, Tex.

The holotype male, 8 male paratypes, and 3 females apparently in the instar preceding maturity bear identical data, having been taken at the type locality April 24, 1955, by J. R. Hilliard. Paratypes will be deposited in the collection of Mr. Hilliard, and those of the Academy of Natural Sciences of Philadelphia, the University of Michigan, and the U. S. National Museum.

Mr. Hilliard has furnished the following ecological notes:

The site is located just off U. S. Highway 287/69. The lumber road leading to the collection site turns off the main highway 2 miles south of Warren, Tyler, Tex. The specific area is a low, wet, boggy meadow just across the Texas and New Orleans Railroad tracks and includes the railroad right of way. The area is an open meadow dotted with crayfish chimneys. The fine, light sandy soil supports a lush growth of sedges, grasses, and numerous clumps of the pitcherplant *Sarracenia sledgei* McFarlane. The adjacent wooded area consists of pine, oak, and magnolia.

This locality is a part of Tharp's region no. 1, the Longleaf Pine Region of Texas (Vegetational Regions of Texas, in *Texas range grasses*, by B. C. Tharp, 1952). According to Tharp's map of the average annual precipitation, which is adapted from *Climate and man* (Yearbook of Agriculture, 1941), the average annual precipitation in this region would be between 48 and 50 inches.

The habitat of *hilliardi* apparently contrasts sharply with that of *sumichrasti*; the latter has seldom been discussed, but so far as recorded it is much different from the boggy environment occupied by *hilliardi*. Hebard (l. c.: 93) stated that Rehn captured a single specimen while beating bear grass (*Nolina* sp.) in the Sierritas

Mountains, Ariz. Ball (Journ. Econ. Ent. **29:** 680. 1936) said that it feeds on broom rape (*Andropogon barbinodis* Lag.), and in 1942 (Ball et al., l. c.: 286) stated that it is found on "coarse grasses on rocky slopes in desert grassland of the Lower and Upper Sonoran zones of southeastern Arizona." In the Chinati Mountains near Shafter, Tex., Tinkham (Amer. Midl. Nat. **40:** 565, 574. 1948) found a localized colony in tall grass at the bottom of a steep cut on the slope of a high plateau at about 5,500 feet elevation, and his figure 24 is a photograph of the habitat.

The distribution of *sumichrasti* was stated by Ball et al. (l. c.: 286) as "Southeastern Arizona west to the Baboquivari and Quinlan Mountains; north to the Catalina and Pinaleno Mountains . . . southwestern Texas, and south to Mexico and Guatemala." Texas records are limited to Jeff Davis, Brewster, and Presidio Counties. Specimens from El Salvador (L. Olomega, Dept. San Miguel) and Nicaragua (Managua) are in the U. S. National Museum, but there is no information about the ecological conditions of the localities where they were taken. Saussure (l. c.: 313) originally described *sumichrasti* from temperate Mexico, and Tinkham (l. c.: 646) regarded it in the United States as belonging to the Mexican Upper Sonoran fauna. Coahuila and Veracruz are nearer to eastern Texas than any other Mexican areas from which *sumichrasti* has been recorded.

BIRD MIGRATION STUDIES

Some of the familiar present-day mass bird migrations in spring and autumn may stem from habit developed during forced ebb and flow of avian populations in the Pleistocene or Ice Age, which ended 30,000 years or less ago. In some way the migratory instinct seems to have been built into the annual life cycle of the species. This thesis is discussed by Dr. Alexander Wetmore, Smithsonian Institution research associate, in a publication recently issued by the Institution. It appears to be corroborated, he says, by the route patterns of migrations from different parts of North America.

"Among the multitudes of migrants that come south into Central America," Dr. Wetmore says, "eastern and western species mix in abundance as far as southern Guatemala. Farther south, eastern species predominate, and comparatively few of those that nest between the Rocky Mountains and the Pacific coast reach the Isthmus of Panama.

"The ice front of the last glacial period in the eastern half of North America extended south to Long Island, the Ohio Valley, and the Missouri River above St. Louis, with consequent displacement of Temperate Zone conditions far southward. In the west, where the ice front lay a relatively short distance below the United States-Canadian boundary, pressures toward the south would have been far less severe. Eastern species either had to cross the water barrier of the Gulf or to follow the shoreline west and southwest, and so tended to penetrate farther into Central America. Western populations on the other hand had necessity for shifts of less extent."

One interesting migration, Dr. Wetmore says, is that of certain species of vireos. The red-eyed vireo breeds commonly over a wide area from British Columbia to Nova Scotia and south to Texas and central Florida. In the fall this vast group of individuals goes south to winter in the upper basin of the Amazon. A closely related species, the yellow-green vireo, nests in the Tropics from Mexico to Panama. This bird certainly has no need for a seasonal migration because of climate. But it migrates also in September and October to join the redeyes in the upper Amazon. Another, the black-whiskered vireo, nests in southern Florida and the West Indies, where cold of changing seasons is never a problem. But most of these birds also migrate into the same general region as their relatives.

"We may theorize," says Dr. Wetmore, "that there is some tie for this habit back to Pleistocene climatic conditions. This appears clear in the case of the red-eyed vireo, but obscure with the others that now nest in regions that are tropical. It seems possible that during the period of the Wisconsin ice sheet temperature conditions in these areas of the northern Tropics were so different that an annual migration was established which now continues though there is no apparent present necessity for it."

History of the northward surges of bird populations may be repeating itself today, the ornithologist points out. During the past century weather records in the Northern Hemisphere show a slight but steady advance of warmer temperatures toward the north. The shift seems to have been accelerated in the past 30 years. Slowly birds are following the change that this brings. In Iceland it is reported that due to warmer conditions in the past 50 years, indicated by retreat of glacial ice and the decrease of the ice pack on the northern coast, seven species of birds have been added to the breeding population. These include such diverse forms as the starling, short-eared owl, herring gull, and tufted duck. There also has been an increase in migrant species and in those that remain through the winter.

In Greenland there has been recorded a more interesting instance. Twenty years ago there was a chance invasion of a flock of fieldfares, an Old World thrush that nests in birch and coniferous forests of northern Europe and northwestern Siberia, ranging north nearly to the tree line. Wanderers remained in southern Greenland to establish a breeding colony, thus populating a land area quite remote from their previous range. Some Greenland birds migrate in fall to return in spring, but the fieldfare, although a migrant in its proper home in northern Eurasia, remains a resident in southern Greenland.

EXCAVATIONS AT LA VENTA

On an inland island, a dry land area of about 2 square miles surrounded by a jungle swamp in southeastern Mexico, stood, between 2,000 and 3,000 years ago, one of the great religious centers of the aboriginal New World. It consisted of a stone pyramid 103 feet high and with a base of more than 10,000 square feet, a ceremonial court where rites were conducted and sacrifices made to a fantastic jaguar god, and various other structures. This was the La Venta site in the Tabasco province near Veracruz, chief extant monument of the mysterious Olmec people who apparently evolved a civilization roughly contemporaneous with, but quite distinct from, those of the Mayas and Incas to the south. They preceded by many centuries the Aztecs whose culture was dominant in Mexico at the time of the first European explorations.

The La Venta site has been the scene of excavations by archeologists for nearly 20 years. Latest of these was the uncovering of the ceremonial court, just north of the great pyramid, by a cooperative expedition of the Smithsonian Institution, the National Geographic Society, and the University of California, under the direction of Dr. Philip Drucker, Smithsonian archeologist, and Dr. Robert F. Heizer of the University of California. It was a mammoth job, carried out with pick, shovel, and wheelbarrow—for machinery could not be brought into the site—by a labor force of 50 men in 100 days. Helpful advice and assistance were provided by the Instituto Nacional de Antropología e Historia and the Museo Nacional de Antropología of Mexico.

The joint report on this work, by Drs. Drucker, Heizer, and Robert J. Squier, has recently been published by the Smithsonian's Bureau of American Ethnology. The findings throw considerable new light on the ways of life, especially the religious practices, of the Olmec people. Datings by the carbon-14 technique show that artifacts found there covered a range between about 2,300 and 3,000 years ago. This is essentially contemporaneous with the Maya cultures of Yucatán and Guatemala. Still, very little is yet known as to the vanished Olmecs who had disappeared long before the 16th century, essentially "without a history" and leaving almost no clues as to their identity. A little, however, can be reconstructed from the results of these investigations. La Venta, the authors hold, was a ceremonial center operated by a small group of priests, or priest-kings—and their personal servants, supported by tributes from villages in the general vicinity and with large labor forces recruited from these same villages. Even after the original construction, the excavations show, much labor was essential for repair and maintenance.

The fact that the site was in continuous use for about 400 years is a clear indication of extraordinary cultural stability and singleness of purpose. The Olmec religion must, at the time of the beginning of the site, have already been a well-worked-out system which had sufficient meaning, tradition, and purpose to insure its continuance for nearly half a millennium.

That the society which built and gloried in the La Venta site had an agricultural economy seems quite likely, although we have no direct evidence. No actual remains of maize have been found although the mano and metate, usually associated with maize agriculture, do occur. That this culture group had master artisans who could sculpture basalt, work jade, and polish metallic mirrors is established. But all this tells us little else than the fact that . . . some rather elaborate sociopolitical or socioreligious organization was in existence.

ZOOLOGY.—*Taxonomy of the copepod genera* Pherma *and* Pestifer. R. U. GOODING, University of Washington. (Communicated by Fenner A. Chace, Jr.)

(Received February 2, 1959)

In 1923, C. B. Wilson instituted the genus *Pherma* for a new species of copepod, *P. curticaudatum*, specimens of which had been collected from an annelid off the coast of Lower California. He placed it in the Clausiidae, a family containing a number of other annelid associates. However, in revising this group, M. S. Wilson and Illg (1955: 135) considered that "it would be impossible to assign (*Pherma*) to any family, since C. B. Wilson omitted a description of the oral appendages."

Twenty-one years later, in a paper published posthumously, C. B. Wilson (1944) described another new genus, *Pestifer* (with genotype *P. agilis* also from an annelid but in the Gulf of Mexico), which he referred this time to the Clausidiidae. Again the mouthparts were not discussed.

His descriptions of these two species were sufficiently similar for Wilson and Illg (loc. cit.) to suggest an investigation into their possible congeneracy. Accordingly, advantage was taken of a visit to the United States National Museum in September 1958 to pursue this problem (as part of a taxonomic analysis of the Clausidiidae, on which I am currently engaged) Examination of the type material available there of both Wilson's genera indicated that a single species is represented; this is redescribed.

Pherma curticaudatum C. B. Wilson, 1923

Synonym.—*Pestifer agilis* C. B. Wilson, 1944: 546–547, pl. 31, figs. 165–171.

Material examined.—The syntypes are "three adult females, one of which bore egg strings ... from the parapodia of an unnamed annelid, dredged from a depth of 645 fms. by the Bureau of Fisheries steamer 'Albatross' off the coast of lower California in April, 1911. These ... are deposited in ... the American Museum of Natural History (Cat. No. 4617)." (Wilson, 1923.) Two specimens—one ovigerous but without maxillipeds, the other lacking the cephalosome and one of each of the three pairs of swimming legs—were found in the U.S. National Museum collections (no. 59354: the label with them also lists the *Albatross* station number as D5685); both were dissected for study. The third is still in the original repository. It was examined without dissection after clearing in methyl salicylate. This specimen lacks only the right maxilliped and caudal rami but unfortunately, in the course of preparation, broke in half.

The other specimens studied were two females, from the skin of an annelid dredged near the Tortugas Islands, Gulf of Mexico, in 380 fathoms, July 18, 1932; USNM no. 79641. Although Wilson (1944) lists one of these as the holotype of *Pestifer agilis,* both were included in the same vial. It is possible that the female which I dissected is the one on which most of Wilson's drawings were based, since it was devoid of one of each pair of the appendages he figured and both maxillipeds. The other was examined as a temporary whole mount in lactic acid; one maxilliped and both ovisacs have been removed during the course of this investigation.

To simplify reference to these specimens, the following abbreviations are used: "Ph. 1," the ovigerous *Pherma* female; "Ph. 2," the mutilated *Pherma* female; "Ph. 3," the *Pherma* female in the American Museum; "Pe. 1," the relatively undamaged *Pestifer* female; and "Pe. 2," the *Pestifer* female which I (and Wilson?) have dissected.

Female.—Wilson's figure of the habitus (1923, fig. **1**)[1] is better than any which could be attempted with the existing material; it shows very well the delimitation of the first pedigerous segment both from the second and from the cephalosome,[2] the remainder of the metasome swollen and fused into a single mass whose three constituent segments are indicated by constrictions at approximately equidistant intervals along the body, and the abrupt narrowing at the origin of the 3-segmented urosome. Lacking, however, is any clear indication that the first segment of the urosome is set off from the last

[1] All references to figure numbers from C. B. Wilson's papers have here been placed in boldface type.

[2] The latter division, as he mentions in the text, is absent on the ventral side.

metasomal segment; a definite line of thickening does in fact occur at this point. The dorsal boundary between the genital and anal segments is also less well defined than shown in his drawings.

Another fact which he does not mention or indicate in his figures is that the genital segment can be seen in ventral view (Fig. 16) to have an irregular thickened line, running transversely just anterior to the openings of the oviducts, which divides it into an anterior and a posterior part. In the latter of these, two dark areas (which may represent paired seminal receptacles) show up very distinctly even in cleared specimens.

The caudal rami (Fig. 9) are neither "jointed" (Wilson, 1944) nor "destitute of setae" (Wilson, 1923). This confusion has evidently arisen because the middle seta of the three terminal ones on each ramus is enlarged nearly to the diameter of the ramus itself. There is a slight transverse constriction in its proximal portion which probably corresponds to the end of the basal "peg" characteristic of one or two of the terminal caudal setae in less modified copepods. The other two setae at the end of each caudal ramus are slender and, in most of the specimens, lie close to the shaft of the main one, so that it is not easy to determine their exact lengths. There are also two short setae on the outer face of the ramus, both in the distal half, and one dorsally—all slender and inconspicuous.

The considerable difference between the lengths which Wilson gives for the body of *curticaudatum* (4.40 mm) and of *agilis* (6.24 mm) is not shown by the specimens. It was difficult to make measurements since the only whole animals curved; rough estimates, for which a ruler and dissecting microscope were used, indicate that Ph. 3 was about 4.5 mm long (without caudal rami) and Pe. 1 more than 3.7 mm. Since the metasome and urosome of Pe. 2 are of comparable size to those of Pe. 1, it is probable that Wilson's first figure is the more accurate.

In all the specimens which possessed a cephalosome there is a groove separating the anterior part of the ventral surface from the wide, nonprotuberant rostrum (Fig. 10). The "ventral cephalic shield" so delimited partially overhangs (in ventral view) the lateral depressions where the antennules and antennae insert, and its border continues thereafter as a thickened ridge, terminating eventually at the extreme posterior corner of each maxilla (Fig. 11).

No postoral protuberance, between the maxillipeds and first pair of legs, could be distinguished.

The antennules are slender structures with six podomeres (Fig. 1). No evidence could be found for the division of the basal podomere into the two short ones shown by Wilson (1944, pl. 31, fig. **167**)—no doubt the reason why he termed this appendage 7-segmented—nor for his claim (loc. cit., p. 547) that "the only setae are terminal on the end segment." The pattern appeared to vary among the specimens; its most complete form (Ph. 1, left) was—proximal to distal podomeres: 2, 6, 3, 2, 2 plus 1 aesthete, and 7 plus 1 aesthete.

The antennae (Fig. 2) may have three or four podomeres, since the division between the third and fourth—a line at best—is sometimes completely absent. The terminal armature accords well with what I consider to be basic among poecilostomes: a row of curved setae (here three instead of the more usual four) between, on the one side, two more slender setae, which are located in a depression behind the tip of the appendage toward its outer face, and one more distally placed on the other; but that on the third podomere is reduced to a single seta, usually accompanied by three small elements. Nothing could be found on the first two podomeres. It is possible that Wilson (1944) partially confused the antennae with the maxillipeds since, in his generic diagnosis of *Pestifer* (p. 546), he speaks of them as "prehensile" and figures (pl. 31, fig. **168**) what is obviously the other appendage under the title "second antenna".

The mouth is placed more anteriorly than is usual in copepods (under the median part of the labrum in Fig. 11). In ventral view the labrum forms a shallow, wide area with thickened exoskeleton; its posterior edge is broken by three projections. The middle one of these has heavily sclerotized sides but a thin ventral surface, so that it generally appears medially incised rather than, as is in fact the case, posteriorly acuminate especially if viewed from behind instead of ventrally. In the latter aspect it may be seen to be divided for most of its length by a line parallel to the sides. This medial structure appears to correspond to the labral area of more typical poecilostomes, while the two lateral "hooks," which extend backward nearly to the maxillae, are a distinctive feature of *curticaudatum*. Under each is a local modification of the ventral exoskeleton (its outline shown dashed on the right side of Fig. 11) which fits into the depression in the anterior surface of the mandible. A fleshy, protuberant structure arising just posterior to the angle of the maxillae (and presumably preventing excess posterior movement in these) is believed to represent the labium. The heavily sclerotized borders around the bases of the maxillae fuse medially to delimit the labium from an anterior, triangular area which continues uninterrupted to the mouth. In it, at the level of the median maxillar insertions, is a longitudinal ridge bearing, like the surrounding parts of this surface, a few tiny spinules. Nothing resembling characteristic paragnaths could be found but two small flaps clothed in short cilia occur—one on either side of the midline—under the inner lobes of the maxillules (and thus hidden by them in Fig. 11).

The mandible is oriented with its flat surface almost parallel to the plane of the mouth region, the main shaft extending forward at an angle of about 45° to the transverse and the tip curving backward (Fig. 11). Terminally (Figs. 3, 4) it bears a stout curved spine, with a toothed flange on its ventral side, and a short fimbriate lamella, both articulating with the body of the appendage and pointing somewhat posteriorly. As is typical in clausiids, the appendage is small and, in an undissected specimen, very difficult to distinguish under the labrum and inner lobe of the maxillules.

The maxillules (Fig. 5) are unimerous but bilobed: the outer, bearing three setae, is thinly sclerotized and protrudes in a transversely posteroventral direction from the lower side of the appendage, while the two setae of the inner lobe —one covering the other in a ventral view— extend toward the mouth. One or more of these setae on both lobes sometimes could not be discerned: this is presumed due to variation, to the hazards of dissection, or to difficulties in observation.

The maxillae (Fig. 6) insert over a considerable area of the cephalosome. They appear to resemble closely the same pair of appendages in *Clausia* (Giesbrecht, 1893), and, like these, their segmentation is difficult to distinguish. It seems probable that each has two podomeres, the basal being greatly expanded, the distal inserted eccentrically upon it and bearing a thickly spinulose dorsal lobe. Neither podomere is armed in the conventional fashion, but it is possible that the dorsal lobe, which appears to articulate at its base, represents a modification of the terminal armature. One may speculate that, by grinding the tips of this pair of appendages together, the animal could triturate the relatively soft skin of its host and feed on the resultant debris.

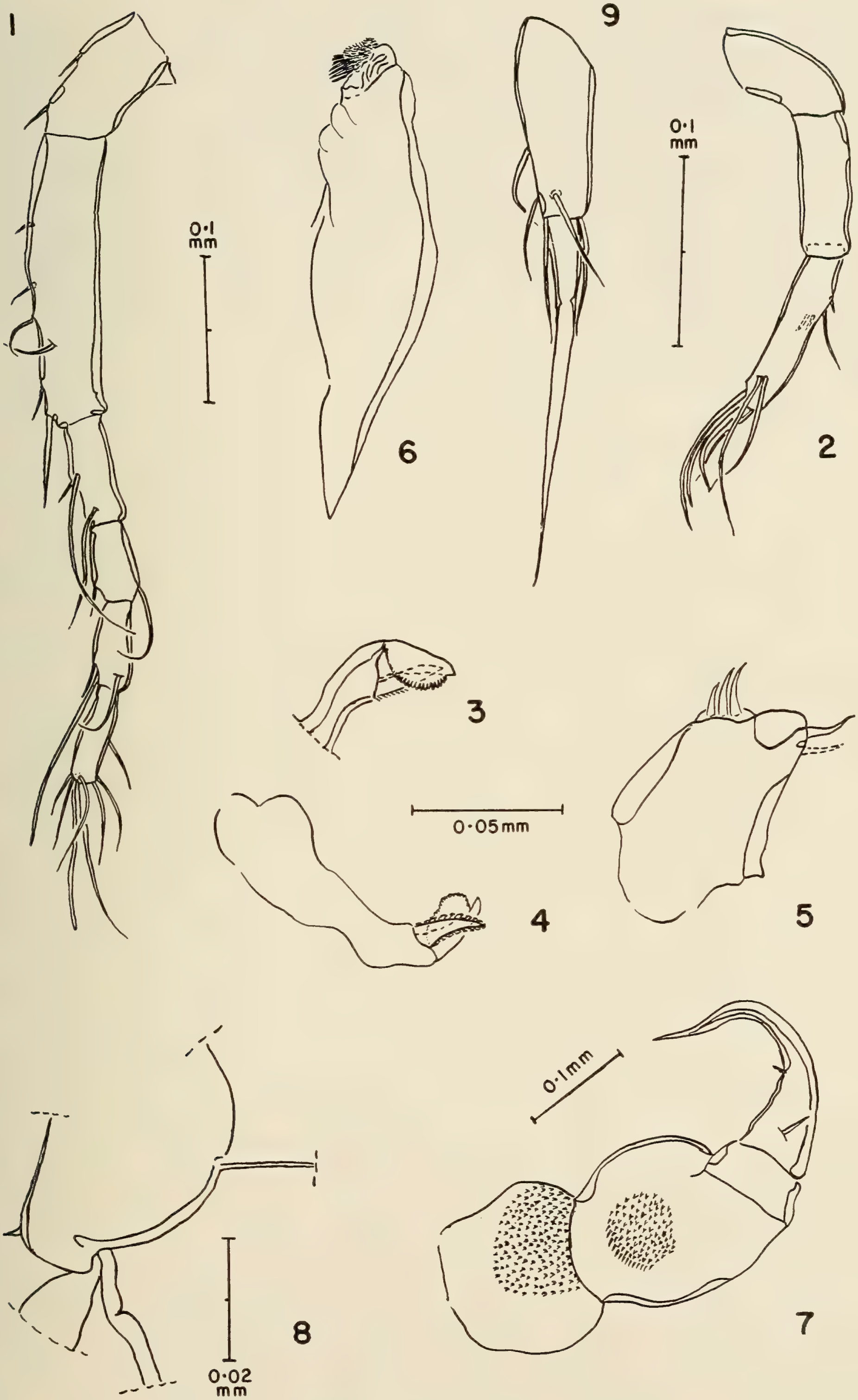
The maxillipeds form the main prehensile apparatus. Each is strongly developed and tetramerous (Fig. 7). The first two podomeres are somewhat inflated and the fourth produced into a strong, tapering, hooklike structure. Patches of fine spinules on the inner surface of the first and second podomeres represent the only ornamentation. The armature consists of a short seta on the inner surface of the fourth podomere and a small element near the inner curvature of the hook.

Despite Wilson's statement (1944: 546, 547), there are only three pairs of legs on the metasome, no trace being found of the fourth. Each is small and is borne just anterior to the middle of its respective somite. The legs are biramous, the two rami and the protopodite having two podomeres respectively, although the division between those of the endopodite is sometimes very difficult to distinguish. The armature is somewhat irregular: the basic pattern appears to be:

	prot. 1	*prot.* 2	*endp.* 1	*endp.* 2	*exop.* 1	*exop.* 2
Leg 1	– –.	I 1.	1 –.	6 –.	– I.	4 IV.
Leg 2	– –.	– 1.	1 –	5 –.	– I.	4 III.
Leg 3	– –.	– 1.	1 –.	4 –.	– I.	3 III.

but, as shown in Figs. 12–14, this may vary even between the legs of a single pair. The main differences occur in the second legs, where the last podomere of the endopod may have four (Ph. 2, left leg), five (Ph. 1, L; Ph. 3, both legs; Pe. 1, B; Pe. 2, L), or six setae (Ph. 1, R) and that

FIGS. 1–9.—*Pherma curticaudatum* Wilson, female: 1, Left antennule, ventral; 2, left antenna, dorsal; 3, tip of left mandible, ventral; 4, left mandible, dorsal; 5, left maxillule, dorsal; 6, left maxilla, dorsal; 7, right maxilliped, medial aspect; 8, right sixth leg and adjacent structures, ventral; 9, left caudal ramus, dorsal. (Figs. 1, 2, 4-6, 9, and 12–16 are of Ph.1; 10 of Ph.3; 11 of Pe.1; and 3, 7, and 8 of Pe. 2. A camera lucida was used for Figs. 10 and 11; the others were drawn with a carbon-arc type of projection apparatus. Scales refer to the figure (or figures) nearest them, and were made from a stage micrometer.)



Figs. 1–9.—(See opposite page for legend).

of the exopod three (Ph. 1, R; Ph. 2, L) or four (Ph. 1, L; Ph. 3, B; Pe. 1, L; Pe. 2, R). It is interesting to note that on the exopod spines of all the legs distal setules—so characteristic a feature in a number of poecilostome genera that they may represent a primitive tendency in this group—are present (Fig. 15).

The fifth pair of legs is completely lacking, but sixth legs are considered to be represented in some of the specimens by a small stout seta just anterior to the origin of the ovisacs on either side of the genital segment (Fig. 8).

Male.—No male was present in either of the collections, and I know of no account in the literature of a copepod which could be so assigned. This is unfortunate since a knowledge of the morphology of males from each locality might do much to clear up the taxonomic dilemma posed in the next section.

Remarks.—There seems little doubt that the genera *Pestifer* and *Pherma* are synonymous, but I should like to consider briefly the reasons why I have identified *Pe. agilis* with *Ph. curticaudatum.* As noted in the description, the available specimens exhibit differences in the armature of the antennules, antennae, maxillules, and metasomal legs, in the segmentation of the antennae and legs, and in the shape of the ovisacs. None of the first six characters is apparently consistent within the specimens of one species, and variation may occur even between the appendages on opposite sides of the same animal. In some of the cases where changes in armature are involved it has been possible to infer accidental loss of certain setae.

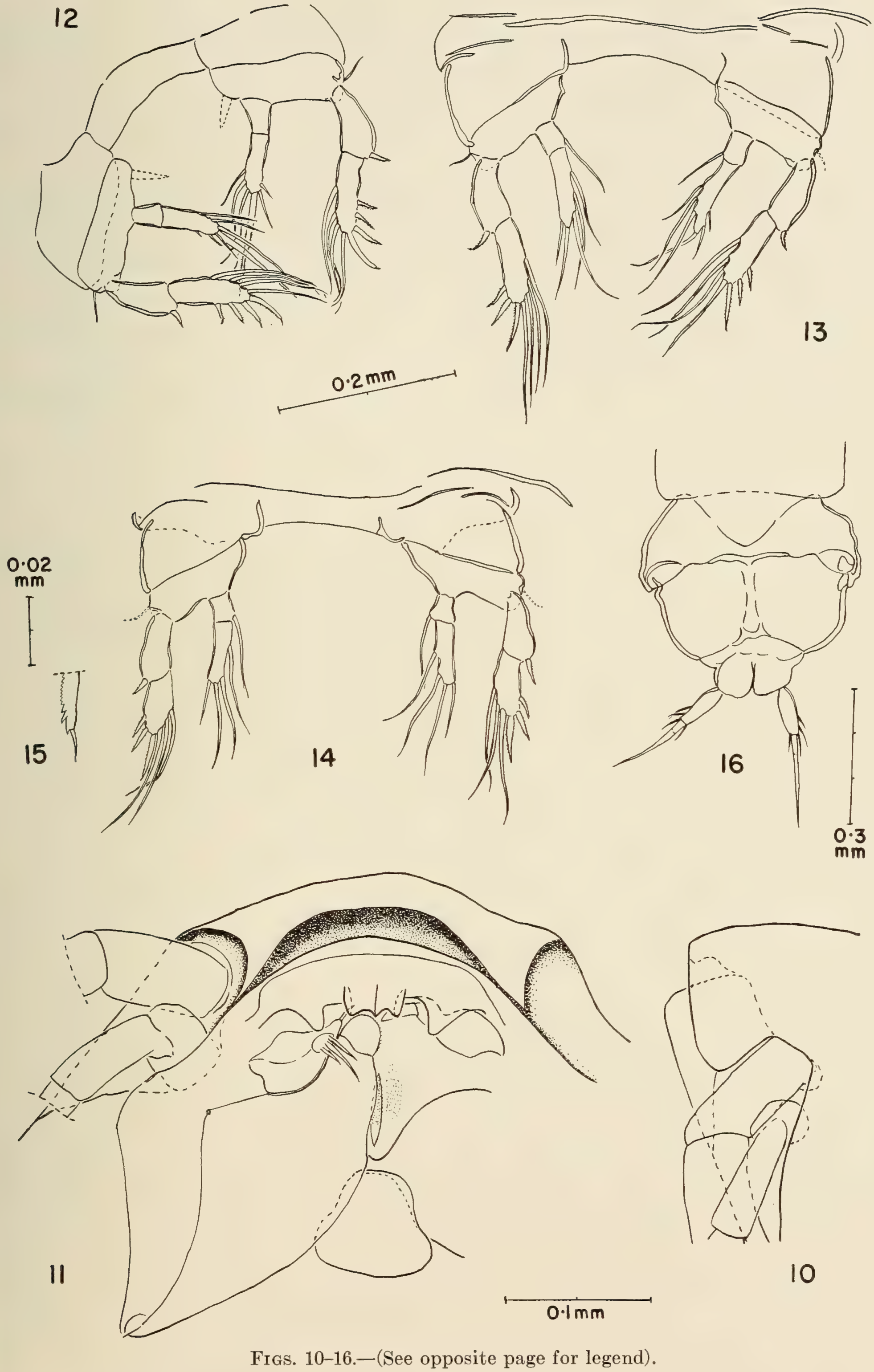
The last of the differences (shape of the ovisacs) is evident from a comparison of Wilson's (1923) fig. **1** and (1944) pl. 31, fig. **165,** and borne out by my examination of his specimens. Although there is usually considerable variation in the form of the ovisacs even in a single population of a particular copepod, the mean may prove valid as one of the complex of characters which distinguishes that species. But here only one representative in each collection possessed intact ovisacs. I should not like to diagnose two species on such a basis, particularly since the specimens are from different geographical areas and might thus be expected to show some slight variation.

Comparative zoogeography, however, suggests that the two collections are more likely to represent different species than to compromise a single one and, although this argument is purely inferential, it seems suitable to consider it here. According to Ekman (1953), archibenthal animals (both *curticaudatum* and *agilis* fall into this category) show only limited distribution patterns. If one assumes that the depth at which these copepods were found represents their lower limit, then there still exists evidence that the tropical shelf fauna on either side of Central America possesses many more pairs of closely related species than forms with an amphi-American range, and that the latter are all very ancient. (Paleontological information about copepods is almost nonexistent.) Even if these copepods extend into the abyssal region, a continuous distribution is not very probable. Nor do their hosts provide more assistance on this topic since neither was identified further than to group.

The position is, then, that on morphological grounds the available material appears to represent a single species whose phenotypic variation is not in excess of that to be expected in an animal modified for a strictly associated existence, nor does it provide a basis for specific separation. On the other hand, the locations from which the specimens were collected might lead one to expect the presence of two similar species. The number of specimens is too small to decide conclusively between these alternatives. But, since copepod taxonomy is still dependent almost entirely on morphological criteria, the former has seemed preferable. I shall thus leave to some future worker, with more material at his disposal, the onus of proving that speciation or subspeciation has occurred in *Pherma curticaudatum* (in which case Wilson's name *agilis* may be revived for the West Indian form).

It seems possible now to refer *Pherma* to the

FIGS. 10–16.—*Pherma curticaudatum* Wilson, female: 10, View of the anterior part of the cephalosome from the left side, showing groove between rostrum and mouth area, and insertions of the antennule and antenna; 11, ventral view of the anterior part of the cephalosome: the mandible and framework around the base of the maxilla are shown on the right side of the figure; the bases of the antennule and antenna, the maxillule and maxilla on the left; 12, first pair of legs and coxal plate, ventral; 13, second pair of legs and coxal plate, ventral; 14, third pair of legs and coxal plate, ventral; 15, detail of tip of terminal exopod spine on leg 3; 16, part of urosome, ventral. (In Figs. 12–14, certain elements of the armature whose absence in the specimen from which they were drawn is presumed to be accidental have been indicated by dashed outlines. Figs. 10 and 11 are somewhat diagrammatic.)



Figs. 10–16.—(See opposite page for legend).

Clausiidae, a step which makes some changes necessary in the present definition of that family (M. S. Wilson and Illg, 1955). Treatment of this will be deferred to a later paper.

This study was begun at the U.S. National Museum and completed in the Department of Biology, Boston University; it has been supported in part by a research grant to Dr. Paul Illg from the State of Washington Initiative 171 Fund for Research in Biology and Medicine. My thanks are due to the authorities of the institutions mentioned for the use of their facilities, and to Dr. Libbie Hyman and Dr. Thomas Bowman for their assistance in obtaining type material on loan. Dr. Illg and Dr. Arthur Humes have been kind enough to read and criticize the manuscript.

LITERATURE CITED

Ekman, Sven. *Zoogeography of the sea:* xiv + 417 pp. London, 1953.

Giesbrecht, Wilhelm. *Mittheilungen über Copepoden.* Mitt. zool. Stat. Neapel **11:** 56–106. (5. Clausia lubbockii *Claparède*: S. 79–83.) 1893.

Wilson, Charles Branch. *A new genus and species of parasitic copepod from Lower California.* Amer. Mus. Novit. **81:** 4 pp. 1923.

———. *Parasitic copepods in the United States National Museum.* Proc. U. S. Nat. Mus. **94:** 529–582. 1944.

Wilson, Mildred S., and Illg, Paul L. *The family Clausiidae (Copepoda, Cyclopoida).* Proc. Biol. Soc. Washington **68:** 129–142. 1955.

DR. FRIEDMANN AWARDED ELIOT MEDAL

Dr. Herbert Friedmann, acting head curator, department of zoology, U. S. National Museum, Smithsonian Institution, has recently received the Daniel Giraud Elliot Medal of the National Academy of Sciences for his book *The honey-guides*. The Elliot Medal is awarded for the most meritorious work in zoology or paleontology published each year.

Dr. Friedmann's studies of the honey-guide, issued by the Smithsonian, clarified several puzzling problems about these birds. Prior to this work it was thought that the birds fed chiefly on the honey and bee larvae in wild bees' nests, but being unable to open such nests by themselves, the birds led or guided humans to the hives (hence the name honey-guide), and then after the men had taken their fill, they came back to feed on the remnants left strewn about. Since the only use to the bird of the guiding habit depended upon the cooperation of a totally independent creature, man, the habit could not have had any value until it was perfected by both participants, and in such a way as to help the birds. It was found that the African natives deliberately substituted themselves for the original "partner" of the bird, the ratel or honey-badger. The guiding behavior, which appears so purposive, is merely an excitement reaction of the bird when it meets with a potential foraging associate, and which calms down when it sees or hears bees. Since this usually happens near a bees' nest, the effect is that the follower is usually led to a hive. Many observations show that the behavior is purely instinctive and involves no "planning" or preknowledge by the bird. It was also found that the birds' interest in the hives was in the wax of the comb not in the honey or bee larvae. Studies showed that the birds depend on was-splitting microbes in their digestive tracts to make the wax digestible.

Born in New York City April 22, 1900, Dr. Friedmann took his undergraduate training at City College in New York and received his Ph.D. in ornithology from Cornell University in 1923. He was a National Research Council fellow at Harvard University from 1923 to 1926, an instructor at Brown University, 1926–27, and at Amherst College, 1927–29. He has been a curator in the Division of Birds at the U. S. National Museum since 1929. He is the author of many ornithological works, including *The parasitic cuckoos of Africa,* Monograph No. 1 of the Washington Academy of Sciences.

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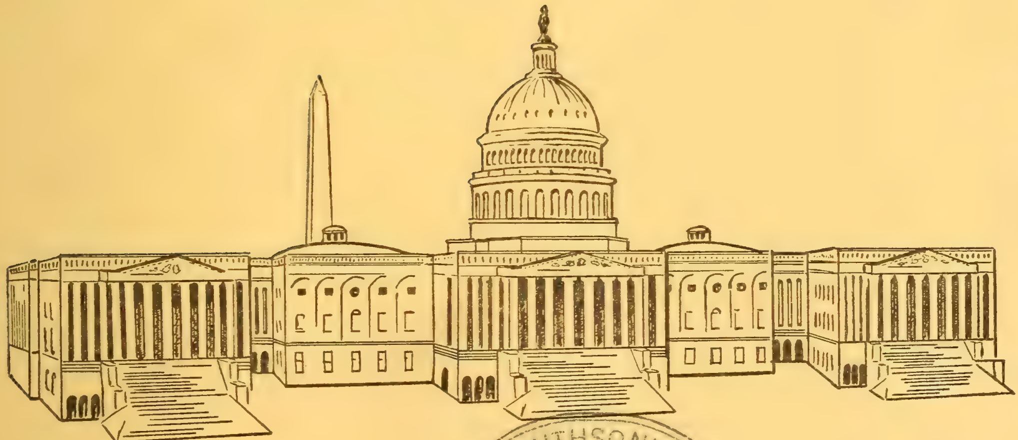

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HISTORY OF SCIENCE.—*Franklin as a physicist.*[1] Raymond J. Seeger, National Science Foundation.

(Received April 17, 1959)

There are many souvenirs of Benjamin Franklin (1706–1790).[2]

There are also many portraits, some of them famous. For example, the White House library contains the 1759 portrait done by Benjamin Wilson (1721–1788) in Philadelphia, the only nonpresidential one there. It was taken by Maj. John André during the American Revolution and then sent to England. The family of Sir Charles Grey, who had been in charge of the troop evacuation from Philadelphia at that time, presented it in 1906 to the White House. Harvard University boasts the earliest known (Sumner) portrait, made in 1748 by Robert Febe in Philadelphia. In the Pennsylvania Academy of Fine Arts there is David Martin's "thumb" portrait, done in 1767. The New York City Metropolitan Museum of Art has the portrait by Joseph S. Duplessis of Paris, a picture of Franklin in 1778, the year of his presentation at the Versailles Court. In 1955 the Duplessis 1779 portrait was placed in Independence Hall by Harry S. Truman; it had been given in 1945 by Charles de Gaulle. This picture had originally belonged to Madame Claude Adrien Hevetius, who had received it from Franklin. The famous portrait done by J. Wright in 1782 hangs in the Royal Society of London.

Franklin statues, too, adorn our public squares and parks throughout the nation. In front of the City Hall of Boston a statue portrays Franklin the printer in the front and the kite experiment in the rear, the 1783 Treaty of Paris and the Declaration of Independence on the sides. The statue at the Philadelphia Post Office in 1906 honored Franklin as "admired for talent"; a large one is in Franklin Hall of the Franklin Institute. In Washington a statue commemorates Franklin, on one side as a philosopher, on another as a patriot, on the third as a philanthropist, and in the front as a printer. In the east room of the White House, there is a Limoge porcelain bust of Franklin together with busts of Washington, Jefferson, and Lincoln; they were presented by France to Theodore Roosevelt during his term as President. The choice of a statue of Franklin to guard the entrance of the Palmer Physical Laboratory together with one of Joseph Henry (1797–1878) presents an interesting enigma. Henry's association with

[1] Based upon talks given at meetings of the American Association for the Advancement of Science (Section L, 1936) and the Philosophical Society of Washington (1956).

[2] Pamphlets by the National Franklin Committee of the Franklin Institute (Philadelphia, 1956): *Life of Benjamin Franklin* (year by year, 1706–1790); H. B. Allen, *Philosopher with a twinkle in his eye*; E. T. Benson, *The foundation for peace grows on the farm; Benjamin Franklin, innovator; Benjamin Franklin: Printing and the graphic arts; Benjamin Franklin, the well-doer; Benjamin Franklin and aeronautics; Benjamin Franklin and business; Benjamin Franklin and economics; Benjamin Franklin and education; Benjamin Franklin and electricity; Benjamin Franklin and meteorology; Benjamin Franklin and the mutual philosophy*.

Condorcet, M. J. A. N. de, *Éloge de M. Franklin lu a la séance publique de l'Académie des Sciences.* Paris, 1790.

Crane, V. W., *Benjamin Franklin.* Baltimore, 1936.

Van Doren, C., *Benjamin Franklin.* New York, 1938.

Ford, P. L., *The many-sided Franklin.* New York, 1899.

Franklin, W. T., *Memoirs of the life and writings of Benjamin Franklin.* London, 1833.

Smith, W., *Eulogium on Benjamin Franklin.* Philadelphia, 1792.

Princeton University is well known. What, if any was Franklin's connection?

Perhaps the most personal souvenirs of Franklin are his writings.[3] At the age of 23 he suggested for his own epitaph: "The Body of Franklin, Printer." In his will he declared, "I, Benjamin Franklin, Printer, Late Minister Plenipotentiary for the U.S.A. to the Court of France." John Bartram once remarked that Franklin was the only person in Philadelphia who had made a success of the printing trade. He was appointed public printer for the Middle Atlantic States. *Poor Richard's Almanac* (1733, et al.) could well be taken as an American symbol of a local boy making good—without the benefit of formal education. We are all familiar with his *Autobiography*, called by Carl Van Doren "a masterpiece of memory and honesty." (Unfortunately, it was left incomplete as of 1757.) The Saturday Evening Post, which owed its origin to the Pennsylvania Gazette established in 1728, still carries the caption "Founded by Benjamin Franklin." I wrote recently to Ben Hibbs, its editor, to inquire if the Post had ever published an article on Franklin's interest in physics. The answer was, "No record in our files!" To me this is prima-facie evidence of the neglect of Franklin as a physicist. Because of a general fear of his unpredictable puns, he was not invited in 1776 to participate in writing the Declaration of Independence; although he was the oldest member of the Second Continental Congress. Incidentally, he was also the oldest member of the Constitutional Convention (1787). Honoré de Balzac (1799–1850) once remarked that Franklin was the inventor of the lightning rod, the hoax, and the republic.

In connection with science Franklin is commonly regarded as a gadgeteer. We recall the Franklin stove, or Pennsylvania fireplace, which he invented in order to retain heat and at the same time to provide fresh air by converting most of the smoke into flame. It was his first invention (1742). The Metropolitan Museum of Art has a 1795 model of such a stove that was completed in 1773. Another famous invention of Franklin was his modification (1759) of the so-called armonica, a specimen of which is in the Boston Museum of Fine Arts. It consisted of 37 glass hemispheres, of different diameters, attached to an iron spindle controlled by a belt and treadle. By means of a finger or light drum stick one could cause these glass hemispheres to vibrate (a keyboard was added later). Wolfgang Amadeus Mozart (1756–1791) and Ludwig van Beethoven (1770–1827) both composed music for it; for example, Mozart's Adagio and Rondo in C. Franklin's mahogany chair with a ladder beneath the cowhide seat is an equally famous invention; the American Philosophical Society has one that was constructed in 1785. Most of us, however, are more familiar with the bifocals which were made in 1784 for Franklin by a Paris optician, after he had been using ordinary spectacles for 25 years. Franklin wrote humorously to George Whately the next year, "I understand French better by the help of my spectacles." At the age of 80 he invented an instrument for taking down books from high shelves—later used frequently by grocers.

His formal education having been completed at the age of 10, Franklin then learned his trade—and thus acquired some important skills. He said later, "It has been useful to me to construct little machines for my experiments, while the intention of making the experiments was fresh and warm in my mind." (See the Franklin machine at the Franklin Institute and the one at the American Philosophical Society in Philadelphia—invented by Philip Syng (1703–1789), Junto member.) Some instruments invented by him for the lectures of Ebenezer Kinnersley are at Harvard University[4]; for example, the profile of a house

[3] Sparks, J., *Works of Benjamin Franklin.* Boston, 1844.

Franklin Papers, including I. Minis Hays's Calendar (1908), at the American Philosophical Society.

Ford, W. C., *List of the Benjamin Franklin Papers in the Library of Congress.* 1905.

George Simpson Eddy Collection of Princeton University on Benjamin Franklin.

Benjamin Franklin Collection of Yale University.

[4] Kinnersley, E., *A course of experiments in electricity.* Philadelphia, 1764.

Cohen, I. B., *Some early tools of American science.* Cambridge, 1950.

that had a lightning rod grounded by means of a square that popped out in case of an incomplete circuit. The celebrated "Thunder House," purchased in 1789 from the Rev. John Prince of Salem, contained a small charge of gunpowder that made the house collapse if a short circuit occurred from the lightning rod to the ground.

Even when we do think of Franklin as a scientist we are apt to regard him primarily as an amateur. In "The Amateur in Science," of the July 1956 issue of Endeavour, an amateur was defined as "one for whom the pursuit of science is a secondary activity in life." In this sense Franklin was certainly an amateur. In those days, however, the frontiers of many sciences were so vaguely defined by the newly developing professional domains that it was easy for amateurs to reach vantage points in a relatively short time and to direct important advances. It is still possible today in those scientific areas where observational experience is still more necessary than precise experiments. As we have accelerated the expansion of knowledge with refined and quantitative apparatus, it has become less probable for amateurs to make much headway—for instance, nowadays in physics and in chemistry—but a phenomenon like tribo-electricity (cf. Johan C. Wilcke's (1732–1796) tribo-electric series, 1757) still challenges our understanding.

As an amateur Franklin was particularly active in the formation of learned societies,[5] notable among these being his Junto (corrupt for Junta, i.e., council), which was organized in 1727 and which met Friday evening as does the present Philosophical Society of Washington. There were only 10 members; increase in membership was provided through the organization of subordinate clubs. This group, sometimes called the Leather Apron Club, did represent a remarkable combination of mechanics and sages. For example, it included Thomas Godfrey, a glazier; Michael Scull, a surveyor; William Parsons, a shoemaker; and William Maugridge, a joiner. These individuals were wont to discuss questions of natural philosophy, politics, and morals. They prepared and read papers. (The comparatively rare informal communications of the Philosophical Society of Washington are in the same tradition.) They would discuss such questions as: "What is the reason the tides rise higher in the Bay of Fundy than the Bay of Delaware? Why does the flame of a candle tend upward in a spiral? Whence comes the dew that stands on the outside of a tankard that has cold water in it in the summer-time?" To nonmembers they addressed this mind-searching question: "Do you love truth, for truth's sake?" In 1743, with the Royal Society of London as a model, there was a "proposal for promoting useful knowledge among the British Plantations in America." In this document it was argued "that one society be formed of virtuosi or ingenious men residing in several colonies to be called the American Philosophical Society, who are to maintain correspondence." The Penn family proceeded later to "pack" the society, so that it declined about 1762 and had to be revived about 1766. Meanwhile, however, in 1750 a young Junto, including two of Franklin's sons, became organized as the "American Society for Promoting and Propagating Useful Knowledge." It combined in 1768 with the other organization to form the present American Philosophical Society for Promoting Useful Knowledge; Franklin was the first president of the enlarged group.

Sometimes we forget that Philadelphia, being the second largest city in the whole British Empire, was a significant cultural center during this colonial period. The Library Company of Philadelphia (organized in 1731) had one of the best collections of scientific books in the country. For example, its first order, in 1732, included William J. 'sGravesande's *Mathematical elements of natural philosophy* (1726), Herman Boerhaaves's *A new method of chemistry* (1727), Hayes's *Fluxions*, Drake's *Anatomy*, L'Hospital's *Conic sections*, and Deshall's *Euclid*. Despite his apparently poor preparatory education, Franklin read much. Peter Collinson presented him with the *Philosophiae naturalis mathematica principia* of Sir Isaac Newton (1642–1727). By 1740 he had read 'sGravesande's book on natural philosophy and Boerhaave's one on chemis-

[5] Lingelbach, W. E., *Franklin and the scientific societies*. Journ. Franklin Inst. **261**. 1956.

try, as well as Stephen Hale's *Statical essays* (1738), J. T. Desagulier's *A course of natural philosophy* (1738), and Newton's *Optics* (1728). It may be recalled that he and Benjamin Thompson, Count Rumford (1753–1814), both attended lectures of John Winthrop (1714–1779) at Harvard.[6]

Notable among Franklin's scientific activities were the contacts he maintained with European scientists.[7] Prior to 1728, seven of the eight Americans elected to the Royal Society of London had been Bostonians. (It is truly remarkable that Boston did not develop science more at that time.) During this period, to be sure, the Royal Society elected nonscientists as well as scientists, in a ratio of about two to one. Physicians were the largest single group (their election was a tribute to the broad scientific training they had received); they included such individuals as Sir William Watson (1715–1787), Sir John Pringle (1707–1782), John Fothergill (1712–1780), and John Mitchell (1680–1772). On Franklin's first trip abroad he met Sir Hans Sloane (1660–1753), physician, naturalist, and secretary and later president of the Royal Society, and sold him an asbestos purse. About the same time he met also Henry Pemberton (1694–1771), Gresham professor of physics and editor of the third edition of the *Philosophiae naturalis mathematica principia*, and popularizer of Newton's ideas. Another noted European was Peter Collinson (1694–1768), gentleman, Quaker, gardner, botanist, and a merchant of cloth; he became a fellow of the Royal Society in 1728 and a member of its council in 1732. Franklin's friends included Fothergill; Erasmus Darwin (1731–1802), physician and botanist, poet, and "The Sage of Lichfield"—not to mention his being the grandfather of Charles Darwin; Capt. James Cook (1728–1779), for whose letter of safety he received in 1779 a Cook gold medal from the Royal Society; James Watt (1736–1819); Joseph Black (1728–1799); Sir William Herschel (1738–1822); and the Reverend Dr. Joseph Priestley (1733–1804), a kindred devotee of intellectual, political, and religious freedom, who claimed to have become interested in science by meeting Franklin in 1765 and who was urged by him to write a famous history of electricity.[8]

Franklin was equally active in maintaining contacts with American scientists.[9] For example, he was the one who first sent from Europe seeds of Chinese rhubarb, Scotch cabbage, and kohlrabi. He encouraged John Bartram (1699–1777), whom Carolus Linnaeus (1707–1778) called "the greatest living natural botanist." In 1749 an electrical machine was given by him to Yale University; it had to be replenished in 1789 and is now in the collection there. In 1758 a machine was sent to Winthrop; it was lost in the Harvard Hall (library) fire of 1764. Wherever Franklin lived he became a source of scientific communication. He corresponded with almost every scientist of note on the two continents.

If we do think of Franklin as more than an amateur in science, we are inclined to stress his interest in useful knowledge.[10] He is regarded as a utilitarian par excellence. In this connection one quotes from Franklin's 1749 "Opinions and Conjectures" in the April 29, 1750, letter to Collinson, two years after his beginning experiments with electric phenomena: "Nor is it of much importance to us to know the manner in which nature executes her laws; it is of real use to know that china left in the air unsupported will fall and break, but how it comes to fall, and why it breaks, are matters of speculation. Tis indeed a pleasure indeed to know them, but we can preserve our china without it," and, in the last paragraph, "Chagrined a little that we have been hitherto able to produce nothing in this way of use to mankind." In a letter (September 20, 1761) to Mary Stevenson he wrote: "What signifies philosophy that does not apply to some use?" It will be recalled that Francis Bacon,[11] the great promoter of science, was

[6] Brasch, F. E., *John Winthrop, America's first astronomer and the science of his period*. Astron. Soc. Pacific. 1916.

[7] Metropolitan Museum of Art, *Benjamin Franklin and his circle*. New York, 1936.

[8] Priestley, J., *The present state and history of electricity*. London, 1767.

[9] Hendle, B., *The pursuit of science in Revolutionary America*. Chapel Hill, 1956.

[10] Pledge, H. S., *Science since 1500*. London, 1940.

[11] Farrington, B., *Francis Bacon, philosopher of industrial science*. New York, 1949.

also a prophet of the usefulness of science. It became an article of faith in the eighteenth-century age of enlightenment that science should be applicable to the improvement of the natural conditions of life. Moreover, the British wars, which had been going on with Spain since 1739 and with France since 1744, emphasized economic needs. With respect to pupils in academies, Franklin once remarked, "It would be well if they could be taught everything that is useful and everything that is ornamental." As to the current Harvard education, he did observe, "They learn little more than how to carry themselves handsomely and enter a room genteely and from whence they return, after an abundance of trouble and change, as great blockheads as ever, only more proud and self conceited." Colleges in those days were created primarily for the dissemination of knowledge (particularly theological) and not for creative research. In his own thinking, however, Franklin was concerned first of all with the quest for knowledge and then only with a search for its usefulness. He was not purely utilitarian, otherwise he would not at all have become interested in electrical phenomena. In June 1783 in connection with the first balloon experiment of Jacques Étienne Montgolfier (1745–1799) and Joseph Michel Montgolfier (1740–1810), we recall his celebrated comment: "What is the use of a balloon? What is the use of a new born baby?" Franklin certainly did not follow his investigations primarily for personal gains.[12] He refused the invitation of the Pennsylvania Governor to patent his stove. He was a genuine scientist, although he was undoubtedly first of all a citizen. For example, his "Plain Truth" grew out of his concern about the French and Spanish privateers which were harboring within 20 miles of Philadelphia in 1747.

Let us look briefly at Franklin as he was viewed by his contemporaries. As for honors, he received a master of arts degree from Harvard in July 1753, its first honorary degree in the European sense. In September of that same year he received a master of arts degree from Yale and in 1756 a master of arts degree from the College of William and Mary[13]—the only honorary degree granted by that institution prior to the Revolution. In 1759 he received an LL.D. from St. Andrews and in 1762 a D.C.L. from Oxford. On November 30, 1753, he became the first foreigner to receive the Sir Godfrey Copley Medal of the Royal Society of London. In 1756 he became a member of the Royal Society through the initiative of Watson. His admission, indeed, was somewhat unique in that he was able to qualify without petitioning, without signing the charter book, and even without paying the normal fee. He was made a council member in 1760, 1765, 1766, and 1762. In 1772 he became one of the eight foreign associates of the Académie Royale des Sciences—the next American to become a member was the Swiss-born Jean Louis Rodolphe Agassiz (1807–1873), 100 years later (1872). He was elected to 24 scientific and educational societies, including the Russian Academy of Sciences. Many claims were made on behalf of Franklin. He was called the "modern Prometheus" by Immanuel Kant (1724–1804), the "father of electricity" by the Reverend William Stukeley (1685–1765), the "Newton of the age," the "Newton of electricity." The physiocrat Anne Robert Jacques Turgot, Baron de l'Aulne (1727–1781), wrote, "Eripuit coelo fulmen, sceptrumque tyrannis." John Adams (1735–1826) said, "His reputation was more universal than that of Leibniz or Newton, Frederick or Voltaire; and his character more beloved and esteemed than any or all of them." Priestley remarked that the kite experiment was "the greatest that has been made in the whole compass of philosophy since the time of Newton." Franklin, it must be emphasized, was investigating electricity when world-wide knowledge of it had public interest at a peak. Electrical phenomena were awe-inspiring; they produced an effect on the public mind akin to that of the atomic bomb and more recently of Sputnik. In a letter of April 15, 1759, van Musschenbroek advised Franklin, "I should wish, however, that you would go on making experiments entirely on your own initiative, and thereby pursue a path entirely different from that of the Europeans, for you shall certainly find many other things which have been hidden

[12] Cohen, I. B., *Franklin and the twentieth century*. Journ. Franklin Inst. **261**: 289. 1956.

[13] William and Mary Quart. **2**: 208. 1894.

to natural philosophers through the space of centuries." Franklin was not hampered by conventions, by concepts, or even by language itself. But the glamor of lightning flashes, of cloud electrification, and of the lightning rod has always overshadowed his real contributions.

How has Franklin been regarded in the light of history? There is an anonymous letter to Benjamin Franklin, LL.D., F.R.S., 1777, entitled "In which his Pretensions to the Title of Natural Philosopher are Considered." The writer compared Franklin and Newton; he felt the latter better qualified as a scientist because he was "skilled in the science of magnitude and number." It is noteworthy that the Newtonian period in American science was much more prevalent in Boston than in Philadelphia. I. Bernard Cohen has written a suggestive article on Franklin as a Newtonian scientist.[14] He focused attention to two seemingly different Newtons. The one personality apparently was responsible for the *Principia*; a work couched in Latin, a work concerned with theory and mathematics, a work which concluded with the system of the world. The other Newton evidently wrote the *Optics* in English; he dealt essentially with experimental observations; he ended it with queries and hypotheses. In short, the *Optics* was not a completed theoretical synthesis based upon established experimental optical facts. Franklin's own misunderstanding of Newtonian mechanics was notorious (cf. his 1747 letter to Cadwallader Colden (1688–1776)). Franklin, it is true, did emphasize the importance of experiments. In this sense he was truly a Newtonian; some of his speculations were similar to Newton's queries. I am convinced, however, that Newton was Newton —a single, but complex personality. The apparent difference in his approaches to mechanics and to optics was inherent more in the subject matter than in himself. In both cases he started with experimental concepts, sought simple relations and then attempted to create a deductive system from a few axiomatic first principles.

In later years Franklin's work has not always been held in the highest esteem. William Whewell (1794–1866),[15] who favored the two-fluid theory, accordingly was opposed to Franklin. Even in 1928 Willis Steel concluded in his *Benjamin Franklin of Paris* that "the man of science regards quizzically this ancient's inventions and so-called discoveries." In the first presidential address[16] of the American Physical Society, Henry Augustus Rowland (1848–1901) observed that there had been only four significant contributions to physics by Americans in the early days, namely, those made by Franklin, Rumford, Henry, and Mayer. At the fiftieth anniversary of the Society, Gordon Ferrie Hull commented thus on the inclusion of Franklin: "Never heard of as a scientist if not known as publisher, statesman and publicist." Basil F. J. Schonland, on the other hand, has argued that the "one-fluid theory—is today the electron theory of matter."[17] John Trowbridge (1843–1923)[18] noted in 1917, "The position of Franklin among the greatest men of electricity in the estimation of scholars is as follows; Franklin, Cavendish, Maxwell, Faraday." Sir Joseph John Thomson (1856–1940) has emphasized that "the service which Franklin's one-fluid theory has rendered to the science of electricity by suggesting and coordinating researches can hardly be overestimated." I doubt if many of us would agree with Robert Andrew Millikan (1868–1953)[19] that "The world has recently and properly celebrated the year 1947 as both the 200th anniversary of Franklin's dis-

[14] Cohen, I. B., *Benjamin Franklin: An experimental Newton scientist.* Bull. Amer. Acad. Arts and Sci. **2.** Jan. 1952.

Subsequent to my talks I read with interest Cohen's more recent publication on *Franklin and Newton* (Philadelphia, 1956). He makes a plausible case for the eighteenth-century high regard of Franklin as a Newtonian in the *Optics* tradition—perhaps, at the expense of depreciating Newton as a mathematical physicist. In this instance I myself am inclined to weigh more heavily the uniqueness of the individual's imagination than the development of social speculations, although I recognize everyone's indebtedness to his philosophical heritage and to his cultural environment.

[15] Whewell, W., *History of inductive sciences,* ed. 3. New York, 1865.

[16] Rowland, H. A., Bull. Amer. Phys. Soc. **1:** 4. 1899.

Hull, G. F., *Fifty Years of physics—a study in contrasts.* Science **104:** 238. 1946.

[17] Schonland, B. F. J., *Benjamin Franklin: Natural philosopher.* Proc. Roy. Soc. **236.** 1856.

[18] Trowbridge, J., *Franklin as a scientist.* Col. Soc. Massachusetts **18.** 1917.

[19] Millikan, R. A., *Franklin's discovery of the electron.* Amer. Journ. Phys. **16:** 369. 1948.

covery of the electron and the 50th anniversary of J. J. Thomson's unambiguous establishment of the electron theory of matter." Incidentally, is it not strange that Thomson[20] did not even mention Millikan and the oil-drop experiment in his book?[21] In his *Introduction to Modern Physics* (ed. 2, 1935) Floyd Karkas Richtmyer (1881–1939) listed Franklin with Boyle, Galileo, Gilbert, Huygens, and Newton. He then qualified this endorsement by noting, "The Franklin theory can hardly be called the forerunner of all-modern theory which grew out of experiments of a very different kind." Through painstaking experiment, through scrupulous accuracy, through refusal to surmise what carefully observed facts did not warrant, Franklin did "find electricity a curiosity and leave it a science." I agree with Thomson that Franklin was "a physicist of the very first rank."

From this point of view let us review[22] the state[23] of electricity B.F. (before Franklin). There are, I believe, four basic facts and one commonly accepted theory. First, the phenomenon of electric attraction has been known for ages; Thales of Miletus (640–546 B.C.) had noted the attraction of amber. Theophrastus of Eresus (371–287 B.C.) had called attention to a similar attraction of jet and onyx. Jerome Fracastro (1478–1553) added diamond to the list. In 1551 Jerome Cardan (1501–1576) had noted the difference between this kind of attraction and that of magnetism. William Gilbert (1540–1603) of Colchester, a physician to Queen Elizabeth I, mentioned in his 1600 *De magnete, magnetisque corporibus et de magnete tellure* a large[24] number of so-called electrics (like amber) such as glass, sealing wax, and precious stones. Substances that did not exhibit this behavior he called an-electrics (not like amber). In each instance he detected the effect by means of a versorium, i.e., an insulated, pivoted, metal needle. It was generally believed at this time that friction released electricity as a fluid similar to body humors such as blood, phlegm, choler (yellow bile), and melancholy (black bile). Attraction for a body would then be produced by its contact with the effluvia atmosphere stirred up by rubbing (cf. Query 22 in Newton's *Optics*).

Contributions came to be more frequent after Gilbert. Sir Thomas Browne (1605–1682), who first used the word electricity, pointed out in 1646 additional substances. In 1675 Robert Boyle (1627–1691), who invented the word fluid, produced the effect in a vacuum. Newton himself observed it through a plate of glass. Charles-Francois de Cisternay du Fay (1698–1737), botanist and superintendent of the King's gardens, concluded that most nonmetallic substances behaved similarly. Otto von Guericke (1602–1686) made an electric machine in 1660. A 6-inch sulphur ball was mounted on a wooden axle; it could be rubbed by hand to produce an electric effect. He noted that pointed objects were more easily attracted. Newton had a similar one made of glass in 1675. Francis Hauksbee (d. 1713), curator of instruments for the Royal Society, used a glass globe which was rubbed with flannel and which was attached by a chain to an insulated metal such as a gunbarrel. All this work was neglected until 1740, when it was revived by some Germans. For example, in 1744 Johann Heinrich Winkler (1703–1770) made a machine which had leather stuffed with cushions. The electrostatic machine soon became an important instrument for studying electrical effects.

The second primary fact known about electric phenomena was the electric repul-

[20] Thomson, J. J., *Recollections and Reflections*. London, 1936.

[21] In an informal communication of December 1958 Sir George Paget Thomson wrote the following in reply to my question about this omission: "Millikan's work on the electron came quite a long time after my father's, and indeed Millikan's method was an adaption of that of H. A. Wilson in the Cavendish Laboratory. The beauty of Millikan's work, apart from its accuracy is, of course, the fact that for the first time it was possible to see charges on a drop changing by definite steps. While this was an interesting and, indeed, fascinating confirmation of what everybody has believed, it was, I think, only a confirmation."

[22] We are concerned here with the historical facts of logical discovery rather than with their sociological developments and significance, either then or now.

[23] Whittaker, E. T., *A history of the theories of aether and electricity*. Edinburgh, 1951.

Seeger, R. J., *On understanding electric breakdown in solids*. Journ. Washington Acad. Sci. **36**: 285. 1946.

[24] Gilbert, W., *De magnete*. Mottelay translation 1893; reprint New York.

Lindsay, R. B., *William Gilbert and magnetism in 1600*. Amer. Journ. Phys. **8**: 271. 1940.

sion of a freely suspended object after contact with an electrified body. Nicolò Cabeo (1585–1650), an Italian Jesuit, first observed this effect about 1629 or 1630; but von Guericke was the first to publish it (1672). Du Fay noted that rubbed amber, when pivoted, could experience either attraction or repulsion with other electrified objects. Accordingly, he suggested in 1733 an explanation based upon two different electric fluids, vitreous and resinous. His theory involved cartesian vortices. Abbé Jean Antoine Nollet (1700–1776),[25] pupil of du Fay, preceptor to the Royal Family of Louis XV, and teacher of physics at the École de Mézières, produced a series of papers in the memoirs of the Académie in 1745. According to his view an electric fluid had two currents that moved in opposite directions, i.e., in and out of a body; they were said to be either affluent or effluent, respectively. He compared electrical effects with thermal properties. Franklin, who praised Nollet in a letter to him, incurred his distrust and enmity by having this inadvertently omitted by Collinson and Fothergill in the subsequent publication of his correspondence. In 1746 George Louis Leclerc, Comte de Buffon (1707–1788), a naturalist, summarized the status of electricity as "not yet sufficiently ripe for the establishment of the court of laws, or indeed of any one fixed, and determinate in all its circumstances."

The third basic fact was electric conduction. Von Guericke had found that attraction took place to some degree through a linen thread. Stephen Gray (1666/7–1736), a pensioner of Charterhouse, performed particularly interesting experiments, including the derivation of sparks from a boy's nose (1730), the boy being suspended while having his feet rubbed with glass. This experiment was repeated in 1744 at Philadelphia. It was Gray who differentiated experimentally between a conductor and an insulator, which he associated with a nonelectric and an electric, respectively. He found, for example, that when wires replaced silk threads no electric effects were observed, but that they could be transmitted from rubbed glass by a stick attached to an ivory ball (and thus influence a feather used as an electroscope). In this manner he was able to produce an effect over a distance as great as 765 feet. He noted that the transfer of the emanation could be accomplished independently of the electrified body; accordingly, he introduced the concept of a true fluid for the first time. Static electricity had been so-called because it was regarded as stationary. Leakage that occurred frequently because of poor insulation had only made electrical phenomena appear to be somewhat capricious and even more mysterious.

The fourth fundamental fact was concerned with electric storage. We are all familiar with Pieter van Musschenbroek's (1692–1761) famous experiment of 1746 in which he tried to store electric charges in a phial containing a gun barrel in water. He received a severe shock, which in a letter to René Antoine Ferchault de Réaumur (1683–1757) he insisted he "would not receive again for the Kingdom of France." Priestley called this the act of a "cowardly professor." On the contrary, many people wished to be thrilled by just such shocks. Spectacular experiments were performed everywhere. You will recall the Paris experiment with its 900-foot line-up of hand-in-hand Carthusian Monks. Sometimes a jar was filled with mercury or with shot. Ewald George von Kleist (d. 1748), Bishop of Pomerania, who had made the discovery independently and possibly earlier, filled a phial with alcohol containing a nail. Watson, apothecary as well as physician, noted that the shock to a human went through the arm and chest because this was the shortest path. He coated a Leyden jar with tinfoil both inside and out and thus obtained more powerful effects. People exposed themselves to shock treatments for paralysis (cf. Franklin's Dec. 21, 1757, letter to Pringle). In 1750 a hot enough spark, obtained through a wire 2 miles long, set ether afire. The Leyden jar soon became another powerful new tool for investigating electrical phenomena.

Franklin's one-fluid theory was a major contribution to the whole problem. In 1768 in a letter to Michael Collinson upon the

[25] Nollet, J. A., *Lettres sur l'électricité*. Paris, 1753.

death of Peter Collinson, his father, Franklin told of the receipt of a 3-foot sealed glass, the size of a fist, which could be rubbed with a piece of flannel, as the beginning of his own interest in electrical phenomena. On March 28, 1747, he had written a thank-you letter to Collinson for this apparatus. In the former letter he admitted that "this was the first notice I ever had of that curious subject." In his *Autobiography* he apparently corrected himself to note that Dr. Adam Spence(r), a physician from Edinburgh, who was supposed to have given some phenomenological lectures in Boston in 1743, and who actually gave them in Philadelphia in 1744, had sold him all the electric apparatus. The basic letter containing the essence of Franklin's one-fluid theory was written to Collinson on July 11, 1747, a year after his retirement from printing. In it he described a fundamental experiment, which has been called by Millikan "the most wonderful thing ever done in the field of electricity." Two men were placed on wax. The one man rubbed a glass tube and passed a spark to the other. Each one was then able to produce a spark to a third (neutral) man; but they became neutralized by contact with each other. Here for the first time we have exemplified the conservation of electric charge (cf. later work with Leyden jar), which became a foundation stone for the mathematical theory of electricity. Assuming the equality of the charges, Franklin then gave the following explanation: The electric fluid, subtle and particulate, elastic and self-repellent, did not result from rubbing; rather it was the normal content of neutral matter, which attracted it and behaved like a saturated sponge. An excess or deficiency of the fluid would exhibit itself as positive or negative electricity, respectively. The excess would then produce an atmosphere on the surface, as the smoke from a body with dry resin about it. His single fluid eliminated the problem of annihilation of effects upon contact of the two kinds of electricity. The most significant aspect of this mechanical theory was the economic association of matter and electricity (two fundamental substances rather than three). It must be admitted that the nature of Franklin's fluid was very nebulous—little understood even by himself. He was wont to compare it with fire. In his 1748 letter to Collinson he speculated: "Perhaps they may be different modifications of the same element; or they may be different elements. The latter is by some suspected." In a letter of March 10, 1773, to Jacques Barbeu Dubourg (1709–1779) he discarded the notion of any relation between electricity and magnetism on account of their difference with respect to heating and jarring. In a letter of June 25, 1784, he mused on the possibility of a universal fluid associated with fire, light, and electricity. On June 20, 1788, at the American Philosophical Society he even read a paper with similar ideas, viz., "Loose Thoughts on a Universal Fluid."

Why should the vitreous fluid be regarded as positive? Why not the resinous? Franklin had reasoned about this choice, too (cf. Mar. 16, 1752, letter to Kinnersley). The vitreous charge seemed to spread over an opposite conductor. Moreover, a candle flame appeared to be blown away by a vitreous-charged body, but toward a resinous-charged body. He admitted, however, some uncertainty in this conclusion. As today we evaluate the one-fluid theory, we note that Franklin could not resolve a major difficulty, namely, the repulsion of two fluidless, i.e., negatively charged, bodies. To answer this question, Franz Maria Ulrich Theodor Aepinus (1724–1802) insisted in 1759 that one had to postulate additionally repulsion between particles of negative matter, which effectively became a second electrical substance, but one that was not fluid. Thus the original simplicity was lost in an undefined haze. He eliminated effluvia, too, inasmuch as electric fluid did not seem carried off with air that was blown away. Consequently, without effluvia, action at a distance became plausible and gave rise to the mathematical theory of electrostatics. In 1759 Robert Symmer (d. 1763) suggested that electrification merely separated the neutral mixture of the two fluids. For example, glass, regarded as ordinarily containing both vitreous and resinous electric fluids, was supposed to lose some of the resinous electricity and thus be left with a surplus of the vitreous. No reason, however, was advanced as to what determined the fluid. Physical relations, including the nature of the forces exerted by these massless fluids, were disregarded, although the resultant neutralization of their effects upon mixing seemed reasonable. It is interesting that Antoine Laurent Lavoisier (1743–1794) included electricity as a chemical element along with heat and light in his 1789 *La traité élémentaire de la chimie.* The chief difference between the two-fluid theory and one-fluid theory was then virtually the fluidity of the negative state. The theory itself, which seemed simple, became readily accepted in France by prominent individuals: for instance, by Charles Augustin Coulomb (1736–1806), who was largely responsible for discovering the law of force between electrostatically charged bodies, and for defining electric charges quantitatively (1785); and by Siméon Denis Poisson (1781–1840), who established the mathematical theory of electrostatics (1812). It was opposed, however, in Holland by Martin van Marum (1750–1837)—and in Italy by Alessandro Volta (1745–1827). The dilemma persisted until the discovery of the electron.[26]

The law of force between electrified bodies became evident in another Franklin experiment (Mar. 18, 1755, letter to John Lining (1708–1760)). In this case a cork was placed inside a charged silver can and found to be unaffected (cf. Faraday's 1843 ice-pail experiment). In 1766, Priestley, who immigrated to the United States in 1794, repeated this experiment and inferred the inverse-square law of force in analogy with that of gravitation. It was he, indeed, who pointed out the need for instruments (no good measurements were possible up to 1760). Gray had previously noted that hollow and solid oak tubes would give the same effect which he therefore concluded in the case of repulsion, was more of a surface than a height (or volume) effect. By no means could this surmise be considered an experimental confirmation of the inverse-square law, done first by John Robison (1739–1805) of Edinburgh, who obtained an actual value of 2.06 and guessed it to be theoretically 2.0. Meanwhile, John Michell (1724–1793) had suggested a torsion balance for precise investigations. Coulomb used a torsion balance to establish the relation quantitatively; in 1785 for like (positive) charges, and in 1787 for unlike charges; he thus eliminated all further vortex speculations. Henry Cavendish (1731–1810) also made such investigations in 1779, but he failed to publish them (done in 1879 by James Clerk Maxwell (1831–1879)). In conclusion, Franklin's conservation of electric charge, plus the establishment of the inverse-square law, made possible the formulation of an exact science of electricity—insofar as an "exact" science may be said to exist.

In his September 1, 1747 and 1748, letters to Collinson he noted certain new facts which he himself had observed, namely, electrostatic induction, the significance of grounding which made it possible to obtain a permanent state of electrification, and the determination of the induced charge on a grounded body. Franklin applied his theory of induction to a dissectible condenser, specifically, to a Leyden jar (cf. 1748 letter to Collinson). Incidentally, he sent Philadelphia-made Leyden jars on various occasions to James Bowdoin in Boston. Kinnersley, a teacher of English in the Academy, had showed that a jar charged inside was charged also outside, with equal and opposite effects, but that the water itself was not electrified. Moreover, this phenomenon was reversible. Thus, if a cork were placed so that it could make contact alternately with the inside and with the outside, it would continue to oscillate until neither was charged. There appeared to be a balance of the two charges, not an accumulation of either one. On the other hand, small sparks were produced if the separating glass of a parallel-plate condenser was removed, but a very large spark occurred when the plate was replaced. This effect depended upon the thickness of the glass. Another interesting

[26] Helmholtz, H. von, *On the modern development of Faraday's conception of electricity.* Journ. Chem. Soc. **39**: 277. 1881.

Maxwell, J. C., *A treatise on electricity and magnetism,* ed. 3. Oxford, 1892.

Millikan, R. A., *Electrons (+ and −), protons, photons, neutrons, mesotrons, and cosmic rays,* rev. ed. Chicago, 1947.

Birkhoff, G. D., *Electricity as a fluid.* Journ. Franklin Institute **226**: 315. 1938.

fact was that the glass was impermeable to electric flow but not to electric influence; the electric fluid was able to pass through a dielectric like glass only if it were punctured or heated. He noted what we would now call the variation of capacitance as a chain was removed from a can (cf. Sept. 1753 letter to Collinson). In a letter dated June 14, 1783, Franklin wrote, "I would recommend it to you to employ your time in making experiments, rather than in making hypotheses, and forming imaginary systems."

In conclusion, Franklin did discover many new curious facts, but, more important, he showed a mastery of experimental techniques including the design of experiments and the testing of hypotheses. He did not merely collect random facts; he searched for significant scientific facts; experimentation must be vectorial, not scalar. Above all, he formulated a simple conceptual scheme. As J. J. Thomson remarked, "A collection of electrons would resemble in many respects Franklin's electric fluid." It is still useful today for qualitative thinking. How many of us sophisticated moderns would immediately set down Poisson's partial differential equation and attempt to solve it if asked what would happen if a piece of hard rubber rubbed with a cat's fur would be brought near another piece of hard rubber rubbed with cat's fur?

Let us now consider what I would designate as the Franklin experiment. Fothergill in his preface to Franklin's book emphasized the scientific discussion of lightning as contrasted with unbridled speculation. The so-called age of enlightenment had references only to a few leaders, not to most people. The majority of folks still had perpetual fear of the unleashing of natural forces, like lightning and earthquakes (cf. current ideas of atomic energy, rainmaking, etc.). In New England, for example, lightning was regarded by some as a personal act of an angry god. In this connection we recall Titus Lucretius Carus's (96–55 B.C.) astute remark[27] (book 6) dealing with "the very nature of fire-fraught thunderbolt":

If Jupiter
And other gods shape those refulgent vaults
With dread reverberations and hurl fire
Whither it pleases each, why smite they not
Mortals of reckless and revolting crimes—

. . . .

Nay, why, then aim they at eternal wastes,
And spend themselves in vain?

. . . .

Then for what reason shoots he at the sea

. . . .

And, lastly, why with devasting bolt
Shakes he asunder holy shrines of gods
And his own thrones of splendor?"

In a sermon on "Earthquakes, the Work of God," the Reverend Thomas Prince considered lightning as focusing in the ground and thus producing a series of violent earthquakes[28]—a common notion in the spring of 1750. On November 26, 1755, Winthrop lectured in Harvard Chapel on earthquakes[29] being "neither objections against the order of Providence, nor tokens of God's displeasure, but necessary consequences of natural laws." In Europe bells were often inscribed with the words "Fulgura Frango" (I break the lightning). Abbé Nollet, for instance, advised people to ring bells during a storm. In 1784 Fisher of Munich completed a 33-year study of lightning and found that 386 church towers had been struck and 103 bell ringers killed. In 1787 the Parliament of Paris had to renew Charlemagne's edict against bell ringing in storms. Nevertheless, a hundred years ago bells were still being rung for this purpose.

It was natural to compare lightning with electric sparks and to speculate about their possible relation. An electric spark had first been noticed by von Guericke. Its similarity to lightning had been noted individually by Hawksbee (1705), William Wall (1708), Newton (1716), Winkler (1746), John Freke (1746), and Nollet (1748). Gray, indeed, stated in 1734, "Electric fire seems to be of the same nature with that of thunder and lightning." Franklin himself wrote on July 11, 1747, "We represent lightning, by passing the wire in the dark over a china plate that has gilt flowers." Later (1749–1752) he associated the aurora borealis, too,

[27] T. Lucretius Carus, *On the nature of things* (translation by W. E. Leonard). New York, 1950.

[28] Prince, T., *Improvement of the Doctrine of Earthquakes.*

[29] Winthrop, J., *Lectures on earthquakes.* Boston, 1755.

with electric discharge. The age of superstition, however, has not been left wholly behind us. We moderns are still accustomed to believing that lightning never strikes twice in the same place, although the Empire State Building has been struck as often as 68 times in three years—not to mention the Washington Monument.

What was needed in order to identify lightning unquestionably with an electric spark was a critical experiment—the design of such an experiment was one of Franklin's most important contributions. He did not make the first analogy, nor even a correct interpretation. The basic facts were all known in 1747 (cf. July 11 letter to Collinson). With Thomas Hopkinson (1703–1751) he had observed, by means of a similarly charged cork in the neighborhood, the loss of electric charge on a cannon ball due to a steel bobkin held 6 to 8 inches away. Discharge for a blunted needle, however, occurred only when it was brought much closer. In his July 27, 1750, letter to Collinson, Franklin called attention to the St. Elmo fire associated with a pointed object. St. Elmo (Erasmus) may be recalled as being the patron saint of the Mediterranean sailors. His fire was considered a good omen, inasmuch as a storm would end soon after its appearance (cf. Columbus's encouragement of his shipmates). Franklin made a complete list of 12 apparent similarities between lightning and electric sparks in his March 18, 1755, letter to Lining, which he had copied from his own November 7, 1749, notebook. The characteristics were light, color, crooked path, swift motion, metal conduction, explosion crack, passage through ice and water, bending of a body at the base, destruction of animals, melting of metals, fire in inflammable substances, and sulphurous smell. But what about the action with respect to a point? Said Franklin, . . . "Let the experiment be made!" "It might have occurred to any electrician," he remarked in the letter. It might have but it didn't.

In the July 29, 1750, letter to Collinson, which contained 56 "Opinions and Conjectures" of 1749, Franklin first noted, "I would propose an experiment"—sometimes called the sentry-box experiment. In this case an insulated man was to be placed in a sentry box having an upright, 20–30-foot, pointed, iron rod. Expressed interest by King Louis XV of France (1710–1774) in this suggestion led to three secret attempts to perform it. Jean Francois D'Alibard, a botanist (1703–1799), was the first to do the experiment on May 10, 1752, at Marly-la-Ville, 18 miles from Paris; he used an iron rod 40 feet high, 1-inch thick, with a brass point, connected to a bottle. A soldier by the name of Coiffier first noted some action; he called a priest, Raulet, who observed the effect six times. On May 18, DeLor, a maker of physical instruments, made a rod 99 feet long with a resin base 2 feet square by 3 inches thick, at the Chateau de St. Germain. Buffon repeated the experiment on May 19. Franklin himself might have received the news of these events in June. The King instructed Abbé Guillaume Mazéas (1712–1776) to write a letter (May 20, 1752) to Benjamin Franklin via Stephen Hales (1677–1788). English experiments by John Canton (1718–1772) on July 20, by Benjamin Wilson on August 12, and by John Bevis (1693–1771), were announced by Watson to the Royal Society in December.

The second type of lightning experiment involved the celebrated kite. Alexander McAdie[30] has raised some questions as to whether this experiment was ever actually performed. Franklin, however, did describe it in detail in his letter of October 19, 1752, to Collinson. Priestley, too, cited it in his book[8] which had been read in manuscript by Franklin himself. This experiment was possibly done on June 6, 1752, near 18th and Spring Garden Street in Philadelphia between the Delaware and Schuylkill Rivers where Franklin was wont to walk. The choice of such a spot may have been owing in part to the delay in waiting for suitable conditions at the Christ Church spire—or possible fear of ridicule. Questions have been raised as to whether the rod was close enough to the cloud. The apparatus was certainly simple; a silk kite having a sharply pointed wire protruding one foot, was attached by twine to a key; a dry silk ribbon was tied to the end of the twine and held in the hand. The observer was to hold

[30] McAdie, A. G., *The date of Franklin's kite experiment*. American Antiquarian Society, 1924.

the silk in a sheltered area and bring his knuckle toward the key to test for a spark. (The popular picture showing Franklin's son as a boy assistant is, to say the least, exaggerated inasmuch as the latter was 21 years of age at the time.) The Royal Society, which was said to have previously (1750) laughed at the suggestion of such action by lightning on a point, and had refused its publication in the Transactions, was favorably impressed in December 1752 by the announcement of the successful attempt.

Newton H. Black[31] cautions, "Perhaps the most wonderful part of it was that Franklin was not killed at once." George Wilhelm Richmann (1711–1753), a Swedish physicist, was killed August 6 at the St. Petersburg Imperial Academy when he attempted to repeat the D'Alibard result. The kite experiment was done in 1754 by John Lining, in 1756 by Abbé Giacomo Battista Beccaria (1716–1781), and by van Musschoenbroek. In May 1753 Jacques de Romas used a kite which was supposed to have produced 10-foot sparks—due to interwoven wire and hemp. He also claimed priority.

On June 15, 1954, Czechoslovakia celebrated the 250th anniversary of the birth of Father Procopius Diviš, the so-called European Franklin, the scientist who erected in his garden a multiple-pointed, grounded rod as a protective device. There seems to be no way now to determine whether Franklin or this European was the first[32] to invent the lightning rod. Franklin's own suggestion[33] occurred in his July 29, 1750, letter in which he described an experiment which would permit bells to be rung in his house whenever lightning would be conducted via a lightning rod nine feet above the chimney to some Leyden jars. His own house, for which such a device was made in September 1752, was actually struck in 1787. Two methods of performing a critical experiment were also outlined. In one case the rod was to be erected so as to reduce the effect through a continuous point discharge of the clouds. In the other instance the lightning rod was to be grounded so as to permit successful conduction to the earth. Franklin, of course, expected to draw a charge from the clouds; actually he only induced a charge and obtained virtually the same result, both for the grounded and ungrounded experiments. All the 1752 experiments were with ungrounded test rods, but the records were not always clear on this matter. What we can definitely say is that lightning rods were early placed upon the Academy and the State House in Philadelphia.

In 1762 there were comparatively few lightning rods in England. Watson's house at Payne's Hill had been the first one so protected. In 1761 and 1767 St. Paul's Cathedral in London had been struck; in 1771 it was protected with a conductor. St. Bride's was hit in 1764. In 1769 lightning struck the magazine at Brescia and destroyed one-sixth of the people of the town. In 1772 the Powder Magazine at Purfleet was struck. The Royal Society appointed a committee consisting of B. Franklin, H. Cavendish, J. Robertson, W. Watson, and B. Wilson to look into the matter of protection for Purfleet—pointed conductors with good metallic connections to the ground were recommended in the August 21, 1772, report (Wilson dissented). Keen partisianship developed with respect to the report. Wilson[34] was subsequently appointed by King George III (1738–1820), to succeed William Hogarth (1697–1764) as Sergeant Painter to the Board of Ordnance. Political pressure from the King was supposed to have forced the resignation of Sir John Pringle as President of the Royal Society. Pringle commented that the King "could not reverse the laws and operations of nature." Pointed rods were soon replaced by round rods on Kew Palace and other Government installations. Nevertheless, Purfleet itself was struck a few years later—even after these rods had been erected. In France

[31] Black, N. H., *An introductory course in college physics.* New York, 1941.

[32] Cohen, I. B., and Schofield, R., *Did Divis erect the first European protective lightning rod, and was inventing independent?* Isis **43**: 358. 1952. Hujer, K., *Father Procopius Divis—the European Franklin.* Isis **43**: 351. 1952.

[33] Cohen, I. B., *The two hundredth anniversary of Benjamin Franklin's two lightning experiments and the introduction of the lightning rod.* Proc. Amer. Phil. Soc. **16**: 331. 1952; *Prejudice against the introduction of lightning rods.* Journ. Franklin Inst. **253**: 393. 1952.

[34] Wilson, B., *Observations on lightning.* London, 1773; *Further observations on lightning.* London, 1774.

Jean Paul Marat (1744–1793) and Maximilien Marie Isidore de Robespierre (1758–1794) approved the use of lightning rods; in Italy Pope Benedict XIV recommended them (they were used in some churches there). Abbé Nollet, however, contended that it was "as impious to ward off God's lightning as for a child to resist the chastening rod of the father." Some people went about with unsheathed swords overhead to simulate lightning rods—the clerics were evidently at a disadvantage. As we look back at the situation, both groups were partially right. Nollet was correct in that a cloud did not produce an appreciable inductive effect on a point and Wilson was correct in that a point was probably no better for the same purpose than a blunted object owing to the scale of the objects involved. On the same basis, however, both were partially wrong; the rod itself was definitely not harmful.

Considerable attention was soon given to the protection of public buildings. The 340-foot campanile at St. Mark's in Venice was struck nine times (on three occasions completely destroyed), but not after its protection by proper lightning rods. Likewise, Siena Cathedral, struck in 1771, received no further lightning blows after rods were appropriately erected. The New York Dutch Church finally sought protection in 1765 after damage had been done in 1750 and then again in 1763. St. Martin's-in-the Fields in London was unprotected when it was struck in 1842.

Even more significant are those buildings that were never struck.[35] First in importance is Solomon's Temple built in Jerusalem about 1000 years B. C. The roof of this building was covered with metal both inside and outside, and in addition it had iron spikes as a protection against birds and thieves; these were all connected by iron pipes to a cistern. The 202-foot-high monument in commemoration of the great London fire of 1677 was protected from lightning by virture of its pointed metal flame-figures fixed to an iron base used as steps. St. Peter's Cathedral in Geneva, it is true, had a wooden tower, but it was shielded owing to the covering of tinned iron plate connected to the ground by metal. The famous Pantheon of Rome had a roof of bronze. Various roofs of churches and palaces were made of lead and copper sheets. The Eiffel Tower was found to be uniquely protected from lightning owing to its having virtually a Faraday cage.

[35] Schonland, B. J. J., *The flight of thunderbolts*. Oxford, 1938.

In the United States today 90 percent of the lightning flashes take place in the country. Nevertheless, about 500 persons are killed and 1,300 injured annually. There is also considerable property loss each year. Yet, only one-fifth of the United States buildings that could profit from lightning protection are so protected.

Of greater scientific significance, however, is the whole matter of atmospheric electricity. In Franklin's letter of April 29, 1749, to Mitchell on thundergusts, he discussed model experiments of clouds. In the 1949 Opinions and Conjectures (※20) of the July 29, 1750, letter a cloud was simulated by a 10-foot by 1-inch pasteboard tube covered with gilt; it was discharged silently by a needle one foot away, but it produced a crack with a blunt object only 3 inches away. Incidentally, this model was wanting in that it involved essentially a surface effect, whereas the cloud represented a volume distribution of charge.

Franklin ingeniously employed his lightning rod chimes to determine the kind of charge on a cloud by charging a Leyden jar (Oct. 19, 1752, and Apr. 18, 1754, letters to Collinson). In this way he found that a cloud was usually charged negatively on the bottom. Toward the end of a storm, however, the upper positive charge would descend so that the bottom became positively charged. Such an experiment indicates that Franklin was "no vague amateur." Schonland observes that Franklin's work was the only direct and reliable information on atmospheric electricity for a period of one hundred and seventy years. Pierre Charles Lemonnier (1715–1799) had noted further in 1752 that atmospheric electricity may exist even without a cloud.

Noteworthy among recent (1902) developments has been the work of Sir Charles Vernon Boys (1855–1944), whereby he was able to use a camera in connection with the activity of lightning rods. Furthermore, electric fields have been obtained as the result of having pointed rods attached to recording galvanometers. The quantity of electricity moving to and from the earth has been actually measured by means of a water voltameter. The sign and amount of charge in the very heart of the cloud has been determined by the use of points on balloons. Paradoxically enough, we are now studying lightning more as a means of determining the nature of electric charges than vice versa. An important by-product of this information is some help in our understanding of cosmic rays, as well as the upper atmosphere.

In conclusion, let us look once more at Franklin, the natural philosopher. The pursuit of science was certainly very close to his heart; his scientific curiosity became manifest in many areas. In his March 28, 1747, letter to Collinson he confessed his enthusiastic interest in electrical phenomena: "I never was before engaged in any study that so totally engrossed my attention and my time as this has lately done . . . I have, during some months past, had little leisure for anything else." He had under varying conditions investigated charged objects. They became discharged by having sand sifted upon them, by being breathed upon, by being surrounded with smoke, by having a candle burnt near them; he noted a difference between candlelight and sunlight with respect to the loss of charge by iron shot (cf. July 11, 1747, letter). Later he expressed a hope to study the possible production of electrification by evaporation.

His broad curiosity led him to investigate also thermal phenomena. In his April 14, 1757, letter to Lining, he noted that a silver teapot should preferably have a wooden handle. He mentioned an experiment for determining relative thermal conductivity. He discussed also insulation properties of clothing. On the 20th of September 1761, he wrote in a letter to Mary Stevenson about experiments[36] he had done about 1729 and which had been repeated about 1736 by Joseph Breitnal, a member of the original Junto. Broadcloth squares were placed on sunny snow in the morning. The various colors used were black, deep blue, light blue, green, purple, red, yellow, and white. The black cloth sunk the deepest, whereas the white one was still on the surface at the end of the experiment. He observed, too, that beer before a fire was warmer in black mugs than in bright silver tankards. We are familiar with Franklin's pulse glass (German origin), which contained water at a lower boiling point owing to air having been blown out. Boiling, therefore, could be made to occur from the heat of one's palm in contact with the glass.

In his April 23, 1752, letter to C. Colden he disagreed with Newton's corpuscular theory of light and favored a wave theory; his opinion was refuted in 1780 by Governor James Bowdoin (1727–1790), first president of the American Academy of Arts and Sciences, in the inaugural address entitled "A Philosophical Discourse." Incidentally, Franklin became a member of that organization in 1781.

Franklin found delight in investigating various meteorological phenomena. A northeast storm spoiled his view of a lunar eclipse expected in Philadelphia at 9 p.m. on October 21, 1743. Nevertheless, the same eclipse was visible in Boston one hour later. He realized that such a storm must have begun in the southwest and been rotating about a moving center. In 1755 he followed a whirlwind in Maryland, where he again noted that the circular motion was more important than the linear one. Franklin, to be sure, accepted the common notion that water spouts were composed of ocean water. In 1783 he noted that the dust which resulted in a fog during summer had a cooling effect. Cleveland Abbe (1838–1916) remarked, "If he had done nothing else but his work on meteorology that would have entitled him to the highest rank."

Of particular significance was his observation (May 10, 1768, letter to Pringle) of the change in barge speed with the depth of a canal. He discussed the courses of rivers in his September 20, 1761, letter. About 1773–74 Franklin found interesting the use of oil to calm wave motion on Serpentine

[36] Cohen, I. B., *Franklin, Boerhaave, Newton, Boyle and the absorption of heat.* Isis **46**: 99. 1955; *Franklin's experiments on heat as a function of color.* Isis **34**: 404. 1943.

Pond in Hyde Park (Nov. 7, 1773, letter to S. Brownrigg). In his August 1785 letter to Julien David LeRoy (1724–1803) of Paris he noted that the fogs off Newfoundland were probably produced by the Gulf Stream. He showed some interest also in oceanography. In 1726 on his first ocean voyage, or at least on the return, he had measured the ocean currents, including their temperature, and observed various astronomical phenomena as well as meteorological conditions. On his last voyage in 1786 (at the age of 80) he compared the currents and the winds with observations of the Gulf Stream; he determined the temperature at different depths. He devised experiments to improve navigation.

In his September 9, 1782, letter to Sir Joseph Banks (1743–1820), successor to Pringle, he said, "I long earnestly for a return of those peaceful times, when I could sit down in sweet society with my English philosophic friends, communicating to each other new discoveries and proposing improvements of old ones." In his April 29, 1785, letter to Jan Ingenhousz (1730–1799) with respect to his plans for a return to Paris, he remarked hopefully, "We'll make plenty of experiments together."

Not only was Franklin truly a philosopher of nature, but he was equally a popularizer of science in the best sense of that word. He was able to expound his ideas so they could be generally understood. To John Perkins he wrote in 1753, "If my hypothesis is not the truth, it is at least naked. For I have not with some of our learned moderns disguised my nonsense in Greek, clothed it in algebra, or adorned it in fluxions. You have it in puris naturalibus." Moreover, he spread continually popular interest in science through the Chronicle, the Gazette, and the Journal, which he published. Van Doren said in 1930, "He was the best writer in America." Franklin's letters were not just personal letters, but more like Leonard Euler's "Letters to a German Princess," i.e., public letters to be read by all interested in the subject matter. He wrote to Collinson in September 1755, "You are at liberty to communicate this paper to whom you please; it being of more importance that knowledge should increase then that your friend should be thought an accurate philosopher."

Franklin is responsible for the famous book on *Experiments and observations on electricity made at Philadelphia by Mr. Benjamin Franklin* (London, 1751). It began with his first (July 11, 1747) letter to Collinson, read by a circle of friends including Watson, who discussed it on January 21, 1748. On February 5, 1750, Collinson asked Franklin if he might send this letter and other material to a printer; he sent it all in April. The book was published in April 1751 and announced in the magazines of that time. It received a generous reception in England. It is true that in January 1750 the publisher Edward Cave already had one paper in The Gentleman's Magazine, as well as one of the articles. Denis Diderot (1713–1784) remarked that this book taught man the nature of experimental art. It truly represented the "vade mecum of electrical discourse" by virtue of its logical presentation of experiments and ideas. Abbé Nollet, however, regarded the book as an affront by his own Paris enemies. The book went through ten editions in four languages: five of them were in English (1st,1751; 2d,1754; 3d,1760; 4th,1769 with notes by Franklin himself; 5th,1774); three in French (1st by D'Alilard,1752; 2d,1756; 3d by Dubourg,1773); one in German (by Welcke, 1758), and one in Italian (1774). It is remarkable that there was no American edition until 1941[37] —the sources then being the 5th English edition and the 1751 Bowdoin manuscript of a copy of the book, which had been made up by Franklin himself. The book could serve even now as an excellent illustration of scientific research and teaching for both students and teachers—particularly the excellent edition by Cohen with its helpful "Critical and Historical Introduction."

What, however, is the use of this American classic of science today? In introductory courses in physics there is a great carelessness about persons, places, and times (historical clues) and hence, more significantly,

[37] FRANKLIN, B., *Benjamin Franklin's experiments*, ed. by I. B. Cohen. Cambridge, 1941.

about the evolution of ideas—owing partially to our cultural neglect of the history of science. Of seven texts on electricity and magnetism, five make no mention of Franklin's one-fluid theory or of his lightning experiment. Of 26 modern (after 1940) college physics textbooks, I happen to have at hand, 14 do not even mention Franklin's name; 5 find noteworthy his naming the electric charges; 4 include the one-fluid theory; 2 complain of his wrong choice of the movable fluid. The palm glass is noted by one, the bifocals by someone else, and electrotherapy by still another. Only two persons consider the important modern principle of conservation of electric charge. Only three discuss lightning (two the kite, one the lightning rod). Nevertheless, many of Franklin's ideas are unnamed commonplaces in physics today; for example, the use of a semicircular wire with an insulated handle for discharging—and much of our electrical terminology.

We fail as teachers, I believe, in depriving our students of their rightful and joyous heritage. They should know who did what and when in physics; they should learn to be proud of their American scientific tradition in pure science—and thankful. American culture, past and present, should be recognized for its scientific aspects. We should not permit narrow historians who may not appreciate science—much less understand it—to distort the conception of its role in our society.

In evaluating a scientist we may ask personally, "What did he himself do?" Or we may inquire socially, "What did he receive from previous ages? What did he contribute to his own age? What did he transmit to future ages?" In various ways[38] one can thus view Franklin. From all viewpoints, however, I always see Franklin as a physicist—not the triumphing Franklin of the 1778 engraving by Jean Honoré Fragonard, painter to the King, but the thoughtful Franklin of the Mason Chamberlin portrait (1762), observing his bell-equipped lightning detector.

[38] Abbe, C., *Benjamin Franklin as a meteorologist.* Proc. Amer. Phil. Soc. **45.** 1906.
Bell, W. J., *Early American science.* Williamsburg, 1955.
Cohen, I. B., *Benjamin Franklin as scientist and citizen.* Amer. Scholar **474.** 1943.
Cohen, I. B., *The defense of Benjamin Franklin.* Sci. Amer. **179.** 1948.
Crowther, J. G., *Famous American men of science.* New York, 1937.
Diller, T., *Franklin's contribution to medicine.* Brooklyn, 1912.
Goodman, N. G., *The ingenious Dr. Franklin.* Oxford, 1931.
Houston, E. J., *Franklin as a man of science and inventor.* Journ. Franklin Inst. **159:** 16. 1906.
Jaffe, B., *Men of science in America.* New York, 1944 and 1958.
Millikan, R. A., *Benjamin Franklin as a scientist.* "Meet Dr. Franklin," Franklin Institute, Philadelphia, 1943.
Pepper, W., *The medical side of Benjamin Franklin.* Philadelphia, 1811.

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ARCHEOLOGY.—*Relationship between Plains Early Hunter and Eastern Archaic.*
WILLIAM J. MAYER-OAKES, University of Toronto. (Communicated by Waldo R. Wedel.)

(Received March 9, 1959)

This paper is a revised version of one prepared for the Archaic Conference held at Bloomington, Ind., in May 1955. It is essentially the original paper with several additions and corrections resulting from both the discussions held at this conference and the papers prepared by other participants. Some of the information presented in a later paper on the "Plains Archaic Concept" (Mayer-Oakes, N.D.*b*) has been included here, as well as certain additional data which have become available since February 1957 when this paper was cast into its present form.

From the experience of the conference and especially the evidence released since then, two major points of the paper have become more clearly the burden of my argument. Support for both of these points came from several participants in the conference. Most simply stated, these two main contentions are as follows:

(1) The cultures called "Archaic" in eastern North America are considerably longer-lived than previously considered and are part of a widespread culture base which covered much of the New World at a very early time, considerably earlier than it was previously thought to be.

(2) The cultures called "paleo-Indian," while less varied in nature and content than "Archaic," are nonetheless varied in typology and cover a considerable span of time in a rather restricted area of North America. They are at least partly contemporaneous with "Archaic."

I consider this paper an exploratory one to be followed by more detailed investigation of some of the points examined. In this presentation we shall concern ourselves primarily with North American manifestations, especially those in the United States east of the Rockies.

TERMINOLOGY

In North America east of the Rocky Mountains, the term "Archaic" has fairly general usage in at least two main ways. In one sense, Archaic is considered to be a developmental stage and generally connotes the presence of a diversified hunting-gathering-fishing type of economy accompanied by a social organization reflecting the earliest stages of semisedentary life. The presence of ceramics, agriculture, or a developed magico-religious structure is not expected in such a stage.

The other main sense in which Archaic is used is as the name for a period of time, and as such it may crosscut the first usage. In the ideal case a developmental stage would correlate directly with a time period. Such a correlation is evidently often assumed in the unspecified usage of the term. Actually, complicating factors such as the presence of cultural centers and the historical facts of cultural isolation may operate to make the stage and the time period disagree. An example of this kind of disagreement is the interpretation originally given to the Eva focus of western Tennessee by Kneberg (1952).

Likewise, the term "paleo-Indian" has been used in these two main ways. As a developmental stage, the term paleo-Indian has been applied to small nomadic hunting groups many of which give some evidence for a specialization in the game killed. In the temporal sense, paleo-Indian has been reserved for units the extreme age of which could be fairly definitely established. The geological or paleontological dating factors for this period have been supplemented recently by radiocarbon dating.

While there have been differences in the usage of the two terms, not all of the resulting confusion can be ascribed to the developmental and temporal aspects of these usages. There is still a third factor implicit in the current usage of the terms. This is the factor of a genetic cultural relationship or *tradition* and is most frequently expressed, for example, in terms of the exclusive association of fluted projectile points with the paleo-Indian unit. For Archaic an association of ground and polished stone tools with a rather heterogeneous assemblage of projectile points is most often posited. The terms have thus come to connote not only stages of culture and periods of time but actual cultural inventories.

There are valid objections to the continued use of each of the two terms. "Archaic" is far from the oldest cultural manifestation and is just as inappropriate as was the early denomination of Valley of Mexico Formative cultures as "Archaic." With "paleo-Indian" we have a loaded word, "Indian" as yet relatively unsubstantiated by physical evidence. I have no immediate suggestions for the former but would definitely prefer to use the term "Early Hunter" rather than "paleo-Indian."

ARCHAIC MANIFESTATIONS

Let us turn now to a brief consideration of some of the units called Archaic.

In the Northeast, Ritchie (1944 and paper presented at the 1955 Archaic Conference) has defined a series of apparently local developments which are fairly well placed in time and cultural stage in both the local relative sequence and by radiocarbon dates. In the Southeast and in the lower Ohio Valley, Webb (1950*a*) and others have described what must have been not only a series of local developments, but also the most intensive early occupation of North America at the time period of 3000 B.C.

There is little evidence for actual contact between these two groups although it is generally agreed that they were at the same developmental stage and equivalent absolute and relative time periods.

Some evidence for connecting links between these main Archaic areas has come to light in the upper Ohio Valley where we have found shellheap campsites (Mayer-Oakes, 1955*a*). The inventory of artifacts and the general characteristics of these sites indicate a relationship to the Southeastern materials. Within this "Panhandle Archaic" complex we are beginning to get evidence for sequent steps in both developmental and temporal terms. Major complexities beginning to appear in the Panhandle complex are the typological distinctiveness of the projectile points in an early unit and the factor of northern relationships in a later unit.

In addition, in the upper Ohio Valley, there are other Archaic complexes within which developmental steps are beginning to be recognized.

Several years ago I suggested a third major area of Archaic culture—the Plains—and have recently discussed this in detail. (Mayer-Oakes, N.D.*b*). A summary of pertinent information from this area is presented below.

This picture of an increasingly complex internal structure recognized for various regional Archaic units will probably apply to most of the area under consideration. And here we can bog down in a welter of specific typological and other considerations of artifacts or traits. But before that happens, let us push on back to the time of the Early Hunters.

EARLY HUNTER MANIFESTATIONS

Until fairly recent years there has been a tendency to equate fluted points with paleo-Indian and let it go at that. Now, however, there have been enough additional finds and enough evidence for developmental steps within paleo-Indian to warrant a reexamination of the whole question.

The old term "Yuma" has been fairly successfully supplanted by names for the more discrete projectile point types known as "Eden" and "Scottsbluff." No new type name has been applied to the parallel-flaked lanceolate point unless we consider the "Angostura" point or the "Plainview" in this category. Actually all four of these are distinct types.

Sellard's (1952) study is an important and comprehensive recent work on the subject of the paleo-Indian. (Wormington's most recent edition, 1957, has been released since this paper was first prepared.) Perhaps the biggest contribution it makes is the suggestion of a specific sequence within the general Early Hunter category. At Blackwater Draw Locality Number 1 the sequence of Clovis to Folsom to Portales has been established by stratigraphy and typology. There is even the hint of specialization in game animals; Clovis points are associated with elephant; Folsom with *Bison taylori*; Portales with *Bison*.

In the southern High Plains, Clovis and Folsom type points are perhaps easily segregated. In other parts of North America very few fluted points qualify as classic Folsom type, so naturally most are called Clovis. Because the Clovis point is more variable in size, form and character of fluting, need for more precise typological work is indicated.

The Portales complex is interesting since it apparently includes not only Eden and Scottsbluff types, but also Plainview and possibly Clovis types. Two radiocarbon dates that apply to Plainview have been released—5150 B.C. ±160 (0–171), and 7220 B.C. ±500 (Lamont, unpublished; Krieger, 1957). Two samples (0–169 and 0–170) place the Portales complex at 4350 B.C. ±150 and 4280 B.C. ±150, respectively.

With this rather solid stratigraphic foundation let us consider other situations indicating relative sequence within the Early Hunter unit. Forbis and Sperry (1952) report a stratigraphic sequence of points in Montana that runs from Folsom to Scottsbluff to Signal Butte II. Davis (1953) has described materials from the Red Smoke and Lime Creek sites in Nebraska that constitute a sequence from Scottsbluff to Plainview types. An average radiocarbon date of 7574 B.C. ±450 (C-471) for the Lime Creek site suggests contemporaneity with Folsom. Holder and Wike (1949) report the materials for the Allen site on Medicine Creek in Nebraska to be similar to Signal Butte I. The radiocarbon date for the Allen site, 8543 B.C. ±1500 (C-470), is at considerable variance with the date for Signal Butte I—1495 B.C. ±120. (L-104A, Kulp, Feely, and Tryon, 1951: 566.)

Eden and Scottsbluff types were found at the Finley site (Moss, 1951) which has been dated geologically as between 5000 and 7000 B.C. This dating agrees roughly with the culturally similar Sage Creek site for which the average of two radiocarbon dates is 4926 B.C. ±250 (C-302).

Hughes (1949) has reported on South Dakota materials characterized by a lanceolate point he designates as the "Long" type, but which is now known as the "Angostura" point. Radiocarbon dating places this complex at 5765 B.C. ±740 (C-454). A more recent test for this unit yielded the date of 7430 B.C. ±500 (M-370).

The Signal Butte finds (Strong, 1935) have been somewhat controversial. Current interpretations are based on a reexamination by Bliss (1948) and a rather late radiocarbon date (L-104A, average of two, 1495 B.C. ±120, Kulp, Feely, and Tryon 1951: 566) for the early stages of this unit. These facts indicate a late time position rather than the originally suggested Early Hunter time.

A provocative unit recently mentioned in print is the Lucy site in central New Mexico (Roosa, 1956). Early Hunter in stage, the blowout context of the site has produced Clovis, Folsom and Sandia points as well as mammoth and bison bones. Aside from the presence of the rare Sandia type the site is unique in producing two *fluted* Sandia points. Significance of this combination of point styles is not clear but it may be evidence for cultural as well as temporal correlation of two otherwise distinct point styles.

Without an attempt to examine in detail these few situations, two conclusions seem obvious. First, a real variety in forms of projectile point definitely represents the Early Hunter stage and period. Secondly, we appear to have evidence for a series of typologically developmental steps, in effect a dynamic projectile point style tradition: (1) fluted points of general or Clovis type; (2) fluted point of special or Folsom type; (3) lanceolate point; (4) stemmed point. This sequence of types, however, appears at variance with some of the chronologic data, for example, the early Nebraska materials; the Scottsbluff and Angostura points with mammoth remains in central Mexico and Clovis points with the Portales complex. The Sandia point, moreover, cannot easily be fitted into this sequence.

A fact to remember here is that at this early period there are apparently complexes of artifacts and points, especially in the Southwest and Far West, which seem to be of totally unrelated types (Jennings, 1957; Haury, 1950).

Perhaps a consideration of types of points of the Early Hunters in a fashion similar to that applied to pottery types, using popu-

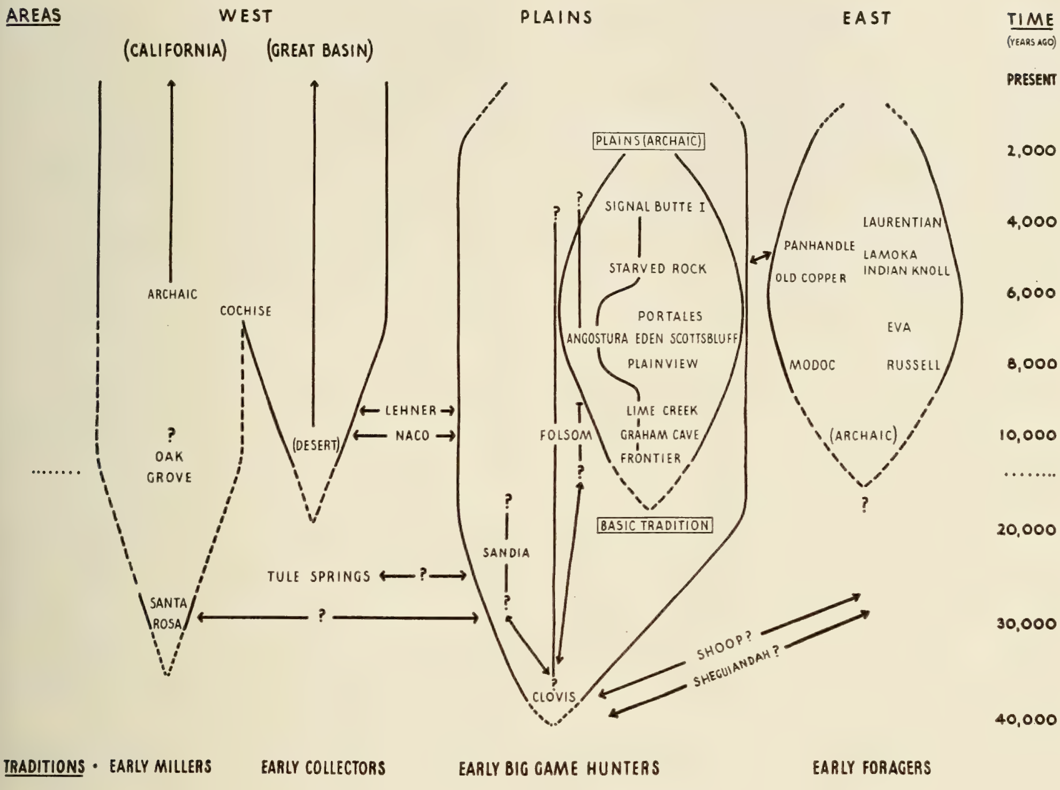

FIG. 1

larity history charts would help us to understand the meaning of current data. It certainly seems reasonable to expect both geographic and temporal variations in the popularity of forms of points rather than rigid conformance to a simplistic typological formulation. Because of the extreme paucity of data the statistical significance of this approach may not be impressive but it seems worth a try.

In addition to the variety of materials classified without much question as of Early Hunter origin, there are interesting units in the Prairies and eastern Plains which should be mentioned here. At Graham Cave in Missouri, Logan (1952) has reported a stratified sequence the lowest levels of which (because of the presence of fluted points) would in part unquestionably be classed as Early Hunter in stage or in type. Because, however, of a probable continuity with and development into the upper parts of the deposit (a generally eastern Archaic unit) the possible antiquity and significance of this site have not been stressed.

The preceramic complex which I first reported in 1949, from Starved Rock, Ill., is typologically oriented to the Plains area at the level of the Early Hunter stage rather than at the eastern Archaic stage. As a conservative pre-radiocarbon guess my range of 3000 B.C. to 500 B.C. was intended to convey a sense of time equality and slight priority to the eastern Archaic period. In the same mental operation, however, I have never been able to shake the impression that this Plains-oriented complex not only had roots back to earlier times but may itself have existed at an earlier time. The presence of a copper point at Starved Rock has led some students to postulate connections with the nearby Old Copper complex; some have seen this as a general indication of lateness within the Archaic stage.

ORIGIN AND DEVELOPMENT OF THE PLAINS ARCHAIC CONCEPT

Perhaps the earliest publication pertinent to our discussion is the report of excavations at Signal Butte, Nebr., by Strong (1935). Temporal interpretation in this report is based on geological factors. The original conclusion that the earliest levels at the site were of great antiquity would place them in an Early Hunter time period. In 1950 Bliss criticized the interpretation of Signal Butte I as an early complex. On the basis of limited testing he split Signal Butte I into three sequent typological stages and suggested an alternative and much younger dating. His contention is now supported by a radiocarbon date of 1495 B.C. ±120 (L-104A, Kulp, Feely, and Tryon, 1951: 566).

Excavations conducted in Nebraska in 1948 by Holder and Wike (1950) resulted in the definition of the Frontier complex, compared by the excavators to Signal Butte I and other early Plains units, some of which were just being discovered. Holder and Wike (1949) suggest that the Frontier complex is part of a larger Plains Archaic unit. I believe this is the first published use of the phrase to denote the present interpretive concept. A subsequent radiocarbon date on the Frontier complex of 8543 B.C. ±1500 (C-470) aligns this unit with the earliest known on the Plains and is completely at variance with the recent date assigned to Signal Butte I.

Initial studies of the prepottery unit found at Starved Rock in 1947 and 1948 indicated the cohesiveness of the unit as well as the distinctiveness of the projectile point complex. Examination of projectile point specimens from the Plains area displayed at the 1948 and 1949 Plains Archaeological Conferences, and in museums at Lincoln impressed me with resemblances between the Starved Rock Lanceolate type of projectile point and points from the Angostura reservoir in South Dakota, the Frontier and Lime Creek complexes, and the Nebo Hill complex.

The final season of excavations at Starved Rock, in 1949, was carried out with a view to *establishing* the prepottery complex suggested by the testing of the previous two years. Conclusions derived from it did substantiate and expand our knowledge of the complex I called "Starved Rock Archaic" (Mayer-Oakes, 1951). In order to fit this unit into the general framework of known units I was compelled to make use of an idea latent in much archeological discussion of the time—the concept of a Plains culture area on an Archaic stage or time level. I did, as a matter of fact, draw specific comparisons between Starved Rock and Frontier, Angostura, Nebo Hill, and Signal Butte I. None was blessed at that time with absolute dates, so comparisons of typology and stage were paramount within the general framework of prepottery times.

The concept was invoked to explain an Illinois complex of material traits which had primary similarities to early stone industries in the Plains but contained, as well, traits also found in eastern Archaic or other units. The area was conceived of as a zone of interchange between East and West during the relatively recent Archaic period.

Subsequent to my specific suggestion of a Plains Archaic, several finds gave support to the concept. Rowe (1952) has reported Plains Archaic materials from southwestern Iowa. Graham Cave (Logan, 1952) documents the progressive change from a Plains-oriented unit to an eastern Archaic unit. The lower levels of Graham Cave are definitely units to be understood as part of the Plains Archaic, both typologically (in the sense of combining Early Hunter and Archaic styles) and geographically. Dates range from 7750 B.C. ±500 (M-130) and 6680 B.C. ±500 (M-131) both for Level 6, to 5950 B.C. ±500 (M-132) from Level 4, a recognizable Eastern Archaic assemblage.

Baerreis has reported an Early Archaic site near Madison, known as the Airport Village. This site is considered to be transitional, typologically, between paleo-Indian and Early Woodland. The "mixed" assemblage is tentatively interpreted as a unit with closest affinities to Starved Rock Archaic. Here again, is a unit ascribable both typologically and geographically to Plains Archaic.

McGregor (1954) specifically aligns an Archaic complex at the Chrisman site in southern Illinois with Starved Rock Archaic, and further suggests that both are parts of an Illinois River aspect of a Plains phase within the broad Archaic pattern. This is one of the few published extensions of the concept.

The type of point from the Angostura reservoir which Hughes (1949) called the "Long" point, and is now known as the Angostura point, has become a key type in the Plains. Because its form is *identical* with that of the Starved Rock Lanceolate type. I feel it is highly significant to a discussion of the Plains Archaic concept. This type is widespread; it occurs in southern Texas (Orchard and Campbell 1954) and northwestern Canada (MacNeish, 1955). The Angostura type site is dated at 5765 B.C. ±740 (C-454) and 7430 B.C. ±500 (M-370). While the occurrence in Texas is not dated, the point occurs in an uncertain context which may be early Archaic, at about 4000 B.C. The point found by MacNeish in Pit 2, site N.W.T.53, and assigned to the Great Bear River complex is placed at 2650 B.C. ±230 (MacNeish, 1955).

Two points found with the second mammoth at Iztapan (Aveleyra, 1956) are particularly interesting because they are not fluted. Rather, they were lanceolate points, one a fair example of an Angostura, the other a "laurel leaf." While this find extends the geographic range of the Angostura type far to the south, the time factor here is unknown. The association with extinct fauna is important, however, since Angostura points are rarely in such a context.

The most recent southward extension of North American Plains point styles is reported by Cruxent and Rouse (1956) from Venezuela. A lithic complex termed "El Jobo" contains a number of points of Angostura and Plainview (or Nebo Hill and Lerma) style together with scrapers. The stylization is close enough to the North American types to suggest historical relationships. This in turn lends support for acceptance of the crude Folsom-like fluted point reported from Costa Rica (Swauger and Mayer-Oakes, 1952).

A recently reported unit which fits our concept of Plains Archaic is the Havey site near Madison, Wisconsin. A surface collection from this site is interpreted by Nero (1955) as belonging to a complex transitional between paleo-Indian and Early Archaic. Although not cited as such by the author, the Havey site is a good candidate for Plains Archaic from the point of view of both typology and geographical location.

The most recent field work relating to the Plains Archaic concept was carried out in southeastern Saskatchewan during 1957. Here, at a deep stratified site (BDR #6) on Long Creek, a tributary to the Souris River, several sequent units of an appropriate age have been excavated (Mayer-Oakes, N.D.*c*; Wettlaufer, N.D.). Three levels of occupation at depths of from 4 feet to 8 feet beneath the present surface provide evidence for a bison-hunting archeological complex characterized by Duncan and Hanna points plus some lanceolate forms in the lowest level. Radiocarbon dates for the lowest level give an antiquity of 5000 years. Here, then, is an assemblage generally similar to the eastern Archaic, but existing in the mixed-grass northern plains at 3000 B.C. when the Lamoka and Laurentian peoples were established in New York State. We have here end dates for the Plains lanceolate point tradition in this area.

RECENT DEVELOPMENTS

In a broad developmental synthesis of New World archeology, Willey and Phillips (1957) have recently made use of the Plains Archaic Concept in an effort to interpret various components known from the Plains and Prairies. They have recognized that several of these units give better evidence for a Lithic stage of development than an Archaic stage, but prefer to interpret all as basically on an Archaic level. In the light of several recent radiocarbon dates and information presented at the recent Archaic Conference, I feel this position needs revision.

For some time the well known Old Copper complex of Wisconsin has been considered a late Archaic unit and thus it was striking to note the early radiocarbon dates released in 1954 (Ritzenthaler, 1954). Two samples gave dates of 3650 B.C. ±600 (C-836) and 5560 B.C. ±600 (C-837, C-839) respectively.

One of the sites early considered as an important Plains Archaic unit is Graham Cave.

Radiocarbon dates indicate that Level 6 was occupied from 7750 B.C. ±500 (M-130) to 6880 B.C. ±500 (M-131). The intermediate level 4 is dated at 5950 B.C. ±500 (M-132). In view of the rather complete previous acceptance of this material as "Plains Archaic" the dates seem surprisingly early.

Radiocarbon dates on Tennessee Archaic units indicate that the early Eva complex goes back to 5200 B.C. ±500 (M-357). This date is some 2000 years older than other eastern Archaic dates and apparently correlates with level 4 at Graham Cave wherein the Missouri complex has taken on a decidedly eastern flavor.

Still a third series of important radiocarbon dates was published by Fowler, Winters, and Parmalee (1956: 31) in their report on the Modoc Rock Shelter. This deep stratified site produced a range of eastern Archaic materials throughout its 26 feet of deposit, with average dates ranging from 3657 B.C. to 7922 B.C. An important correlate of these dates is the observation that polished stone is present at the earliest surely Archaic level and dates to 6210 B.C. Fowler concludes that the Modoc finds extend the period of eastern Archaic culture back to at least 6000 B.C.; he sees these dates as support for and in turn supported by the dates on Old Copper. There is, however, no suggestion of a Plains Archaic connection with the Modoc materials.

The most recently released early eastern Archaic date comes from Russell Cave in northeastern Alabama (Miller, 1956). From the 14-foot level in a deep stratified deposit not yet excavated to bottom has come a date of 6210 B.C. ±300 (L-344; Miller, 1957). The associated cultural material is not fully reported but it appears to be early southeastern Archaic with point styles very much like the "Steubenville Stemmed" and "Steubenville Lanceolate" points of the Ohio Valley Panhandle complex.

In a recent description of an Early Archaic complex from the Upper Ohio Valley (Mayer-Oakes, 1955*a*) I have suggested that the typology of Panhandle Archaic projectile points is derived from late paleo-Indian complexes. A subsequent site report and seriation study of these points (Mayer-Oakes, 1955*b*) indicates the western affinities of this Early Archaic shellmound complex. Several geographers and ecologists (Borchert, 1950) have pointed out the existence of a "Prairie Peninsula" which extended eastward into Ohio, Pennsylvania, and New York during the Post-Glacial Thermal Maximum (or Altithermal) about 6000 to 3000 B.C. This wedgeshaped corridor of grassland extending into the eastern Woodlands was a convenient ecological zone for exploitation by the western hunters when and if the High Plains became too arid for normal activities.

Powell (1955) has recently suggested that we look for natural migration routes in attempting to explain movements of Early Man in North America. The Canadian glacial lakes and Great Lakes as well as the waterways of the northern Mississippi Valley form a logical route from northwest to southeast which, at the time of the eastern grassland extension, would have increased the likelihood of general movement from west to east.

This idea of a prairie peninsula is important in understanding the nature of the earliest Archaic unit in the Upper Ohio Valley. It consists of a complex of subsistence traits with emphasis on hunting, and of tools, expressed in styles of projectile points, which was brought in from the west via the Prairie Peninsula by units of the Plains Archaic. Contact with neighboring resident early Archaic units and adaptation to riverine life resulted in local development of a distinctive Archaic culture. This Panhandle Archaic continued to be influenced by northern Archaic units and gradually lost its western orientation. It changed, thus, from the most eastern component of the Plains Archaic to a unique local Archaic.

In addition to the various lines of recent evidence cited above which suggest that Archaic cultures are longer-lived than previously considered, there have also been signs in recent years that the Early Hunter cultures are quite varied in typology. Whereas the term has often been restricted to units characterized by use of fluted points, radiocarbon dates and geological dating factors indicate that various nonfluted point sites are equivalent in age to Folsom and that the general lanceolate point horizon covers a large area of North America for a span of several thousand years. I refer here to the following expressions: the Scottsbluff and Angostura points found associated with mammoth remains in the Valley of Mexico; the Early Hunter sequence at Blackwater Draw showing Clovis, Folsom, and Portales units in stratigraphic succession; the Montana stratigraphic sequence of points running from Folsom to Scottsbluff to Signal Butte II; the Lime Creek sequence of Scottsbluff to Plainview and the Red Smoke sequence of Frontier to Plainview; the early radiocarbon date on the Frontier complex; the radiocarbon dates for Eden and Scottsbluff points at Sage Creek; and the radiocarbon date on the Angostura type site.

The age of more than 37,000 years (0–235, 0–248) for hearths near Lewisville, Tex., with an associated Clovis fluted point has caused understandable consternation. Krieger (1957) discusses this find in detail. Significant to our problem in this paper is the stretching back in time of the Early Hunter stage far beyond our expectations of 1955. It is hard to believe that one point style existed for a period of at least 28,000 years. If accepted, this date certainly points up the need for defining types within the broad Clovis fluted category.

DISCUSSION

The question of Archaic origins has not yet been satisfactorily answered. In many areas of the New World, Archaic cultures appear as the first occupation for which there is much detailed evidence. Although Griffin (1946) suggested lumping Archaic and paleo-Indian together under the latter term, there do seem to be good reasons for retaining at least these two categories. Certainly the amount of time involved would indicate this; the development from a simple hunting to a diversified hunting-gathering-fishing, semisedentary pattern would also indicate such a dichotomy.

While, as Griffin suggests, there no doubt are strands of cultural continuity from the earlier to the later units, these have not yet been recorded in any detail.

Perhaps the most convincing explanation for an Archaic source is Spaulding's (1946) suggestion of an Old World impetus for the Northeastern Laurentian. While there are many aspects of the Archaic for which Old World parallels and sources have not yet been suggested, it seems reasonable to assume that strong Eurasiatic influences helped formulate the distinctive eastern Archaic as well as subsequent Woodland complexes.

What can we say about local sources for the Archaic? One line of thought has us looking to the preceding Early Hunter stage. The area east of the Mississippi has so far not been productive of evidence for this. Most of the definite Early Hunter complexes here are not tied into any local sequence and most of them show no signs of continuity with or influence on later Archaic complexes. There are three main exceptions to this: (1) Coe (communication from Witthoft) has found a stratified sequence of points in North Carolina which apparently stretches far back into the Early Hunter time period, yet bears no obvious relationship to the Plains "sequence" or the fluted point complexes of the east. (At this site we apparently get into problems of Early Hunter period complexes that are in the tradition of the Southwest and Far West rather than the fluted and lanceolate point.) (2) Ritchie (1953) has reported a paleo-Indian site in Vermont with a point inventory that includes both fluted and unfluted forms, some quite similar to the Starved Rock Lanceolate type, and thus suggestive of Plains Archaic contacts. (3) The Panhandle complex in its earliest stages.

There is one site in the east which gives fairly good evidence for the priority of fluted points to Archaic points. Aside from this unit—the Parrish site (Webb, 1951)—there is only typological evidence for the placement in time of the eastern fluted points.

The apparent gap in occupation of the Plains from about 5000 B.C. to 2000 B.C. has prompted Krieger (1950, 1953) to evoke climatic factors as explanation. This is an attractive theory and seems not only to fit the data but also to have some bearing on the problem of Archaic origins.

INTERPRETATIONS

On the basis of the recent developments sketched above, we are beginning to see the eastern Archaic as a longer-lived and more broadly conceived stage of cultural development, having continent-wide relationships.

The Early Hunter cultures are seen as a specialized development partly preceding and partly contemporaneous with the earliest part of the Archaic period and related to Archaic units in at least one well established way, as expressed in the concept of a Plains Archaic.

Taking a broad view of the cultural variety present in North America at the time period of 10,000–12,000 years ago, Sauer (1957) proposes three basic patterns of environmental adjustment. These he calls: "Old Bison Hunters" (Folsom-Yuma units); "Old Basketmakers" (Great Basin units); "Ancient Millers" (California Oak Grove and Cochise units).

While I feel that the third pattern is the least acceptable and most controversial one, it is equally possible to consider the eastern Archaic as a fourth major pattern of hunting and gathering—foraging—related by subsistence and traditions of technology to both the "Old Bison Hunters" and "Old Basketmakers," but existing as a distinctive combination of the two.

So far I have avoided qualifying the phrase "Plains Archaic." I have used it to imply both time period and stage as well as tradition. Originating as a simple space-time concept, it has developed both historical and developmental significance. At the present time the most reasonable use for the concept is as an historical continuum, comprising a tradition (in the sense of the term as defined in Willey and Phillips) of basic hunting-gathering economy expressed materially in a restricted range of projectile point styles and associated, although poorly known, tools. Out of the various styles of lanceolate points present at the earliest part of the Early Hunter period, a small number were continued for lengths of time varying with the specific area. In general, the "unfluted Folsom" style and the broad-stemmed Scottsbluff style were carried from the central Plains to the north, east, and south as Postglacial time and ecological changes went on. Contacts with resident local Archaic units resulted in complexes which can be explained and understood on the basis of this Plains Archaic lithic tradition.

The Plains Archaic concept is thus seen to comprise a cultural unit of historical continuity over a period of perhaps 7000–8000 years within the Plains and Prairies geographic areas. Roots of the tradition are in the earliest Plains lithic complexes. There is apparently no fundamental change in basic hunting-gathering economy although there is probably a change in degree to which big game herds were utilized as a major means of subsistence.

In trying to apply their "Lithic" and "Archaic" developmental stages to the Plains area, Willey and Phillips recognized the dilemma posed by the available evidence. On the basis of this evidence, I think it is practically impossible to define or segregate, meaningfully, these two stages. The relationship among *all* Plains preceramic units are too strong. However, by assuming that there was a development towards an Archaic stage, we can align some of the otherwise floating units into a schematic order based on this concept of the Plains Archaic, or more simply, a Plains *tradition*.

Perhaps the earliest well-established units of the Plains tradition series would be the Frontier complex followed by Scottsbluff and Plainview units. All these could be classed as Early Hunter in period, but since they are more generalized in typology than the fluted point units they are the best basis for the general tradition. With the increasing popularity of a complex distinguished by Angostura points we are fully into the time period *characterized* by units of Plains tradition, which continues on as at Graham Cave, Starved Rock, Nebo Hill, Airport Village, Havey site, and Signal Butte I.

The most eastward thrust of this tradition is expressed in the Panhandle Archaic of the Upper Ohio Valley, in which there is a unique combination of Plains projectile point traditions and local seasonal adaptations to a riverine ecology. Interestingly enough, the crude Plainview-like lanceolate points seem to drop out of style by late Archaic times in the east, but the Scottsbluff-like Steubenville Stemmed points continued to be a favorite style, moving eastward to the Atlantic coast (Ritchie, 1958) and forming in the Ohio Valley the basic Early Woodland style.

SUMMARY

In this paper we have briefly discussed some features of Early Hunter and Archaic relationships, restricting our geographic area of interest to the region east of the Rockies and considering only a selection of the possibilities. We have indicated how the subject terms can be used in the temporal, developmental and typological or traditional sense and have attempted to distinguish these in our discussion.

Major points proposed are:

1. Eastern Archaic is seen as part of a fairly homogeneous cultural stage—Early Foragers—incorporating both temporal and typological variety on a broadening geographic basis, but with a longer time span than was hitherto believed possible. It overlaps, in part, the time period characterized by Early Hunter remains.

2. Plains Early Hunter is seen as part of a cultural stage—Early Big Game Hunters—incorporating significant temporal and typological varieties, the latest and easternmost of which reflect some contact with the eastern Archaic.

3. The concept of Plains Archaic has been suggested as the concrete expression of the contact between the Plains tradition and the eastern Archaic. Plains Archaic may be considered as the pattern characteristic of the late period of Early Hunter culture, expressed materially as an acculturation process between two coexisting great cultural groups, the Early Foragers and Early Big Game Hunters.

An alternative approach at a more general level, making use of continent-wide data is graphically presented in Fig. 1. Here, four basic early subsistence patterns are represented as traditions rather than as stages. All but "Early Foragers" may in fact qualify as "Lithic" in the sense of Willey and Phillips's stages. There is difficulty in consistently distinguishing "Early Millers" from some of the "Early Collectors"; there may be basic direct relationships among all of these units. I feel, however, that the simple dichotomy proposed by Jennings and others (1956) is inadequate. A "Desert" culture and a "Plains paleo-Indian" as the basic early units need to be supplemented by the units proposed here in our chart. In doing this I admit to being strongly influenced by the early dates on eastern Archaic and Sauer's suggestion of an "Ancient Miller" pattern.

LITERATURE CITED

Anonymous. *Humble Oil Co. radiocarbon dates I.* Science **125**(3239): 1957.

Aveleyra A. de Anda, Luis. *The second mammoth and associated artifacts at Santa Isabel Iztapan, Mexico.* Amer. Antiq. **22**(1): 12–29. 1956.

Baerreis, David A. *The airport village site, Dane County (Da2).* Wisconsin Archeol. **34**(3): 149–164. 1953.

Bliss, Wesley L. *Early and late lithic horizons in the Plains.* Proceedings of the Sixth Plains Archeological Conference (1948). Univ. Utah Anthrop. Pap. **11**: 108–117. 1950.

Borchert, John R. *The climate of the central North American grassland.* Ann. Assoc. Amer. Geogr. **40**(1): 1–39. 1950.

Crane, H. R. *University of Michigan radiocarbon dates I.* Science **124**(3224): 664–672. 1956.

Cruxent, J. M., and Rouse, Irving. *A lithic industry of paleo-Indian type in Venzuela.* Amer. Antiq. **22**(2, pt. 1): 172–179. 1956.

Davis, E. Mott. *Recent data from two paleo-Indian sites on Medicine Creek, Nebraska.* Amer. Antiq. **18**(4): 1953.

Forbis, Richard G., and Sperry, John. *An early man site in Montana.* Amer. Antiq. **18**(2): 127–133. 1952.

Fowler, Melvin L., Winters, Howard, and Parmelee, Paul W. *Modoc Rock Shelter, Preliminary Report, Illinois State Museum.* Report of Investigations, no. 4. Springfield, 1956.

Griffin, James B. *Cultural change and continuity in eastern United States archeology.* In: "Man in Northeastern North America," Pap. Robert S. Peabody Found. Archaeol. **3**: 37–95. 1946.

Haury, Emil W. *The stratigraphy and archaeology of Ventana cave, Arizona*: 1–599. Albuquerque, 1950.

Holder, Preston, and Wike, Joyce. *The Frontier culture complex, a preliminary report on a prehistoric hunter's camp in southwestern Nebraska.* Amer. Antiq. **14**(4): 260–266. 1949.

———. *The Allen site (Ft-50): Archeological evidence of an Early Hunter's camp on Medicine Creek, Frontier County, Nebraska.* Proceedings of the Sixth Plains Archeological Conference (1948). Univ. Utah Anthrop. Pap. 11: 105–107. 1950.

Hughes, Jack T. *Investigations in western South Dakota and northeastern Wyoming.* Amer. Antiq. **14**(4): 266–277. 1949.

Jennings, Jesse D. *Danger Cave.* Soc. Amer. Archaeol. Mem. 14: 1957.

Jennings, Jesse D., et al. *The American Southwest: a problem in cultural isolation.* Soc. Amer. Archaeol. Mem. 11: 59–127. 1956.

Kneberg, Madeline. *The Tennessee area.* In: "Archaeology of Eastern United States." Chicago, 1952.

Krieger, Alex D. *A suggested general sequence in North American projectile points.* Proceedings of the Sixth Plains Archeological Conference (1948). Univ. Utah Anthrop. Pap. 11: 117–124. 1950.

———. *New World culture history; Anglo-America.* In: "Anthropology Today": 238–264. Chicago, 1953.

———. Early Man section of "Notes and News." Amer. Antiq. **22**(3): 321–323. 1957.

Kulp, J. L., Feely, H. W., and Tryon, L. E. *Lamont natural radiocarbon measurements, I.* Science **114**(2970): 565–568. 1951.

Lee, Thomas E. *The antiquity of the Sheguiandah site.* Can. Field-Nat. **71**(3): 117–138. 1957.

Logan, Wilfred D. *Graham Cave, an Archaic site in Montgomery County, Missouri.* Missouri Archaeol. Soc. Mem. 2. 1952.

MacNeish, Richard S. *Two archeological sites on Great Bear Lake, Northwest Territories, Canada.* Ann. Rep. National Museum Canada for Fiscal Year 1953–54: 54–84. 1955.

Mayer-Oakes, William J. *An early horizon in northern Illinois.* Plains Archeological Conf. Newsletter **2**(2): 12. 1949.

———. *Starved Rock Archaic, a pre-pottery horizon from northern Illinois.* Amer. Antiq. **16**(4): 313–324. 1951.

———. *Prehistory of the upper Ohio Valley; an introductory archeological study.* Ann. Carnegie Mus. **34:** 296 ii. 1955*a*.

———. *Excavations at the Globe Hill shell heap (46Hk34-1) Hancock county, West Virginia.* West Virginia Archeol. Soc. Publ. Ser. 3, 1955*b*.

———. *An early culture at Starved Rock, Illinois.* Unpublished master's thesis, University of Chicago. n.d.*a*.

———. *The Plains Archaic concept.* Paper presented at the Vth International Congress of Anthropological and Ethnological Sciences, Philadelphia. (In press.) n.d.*b*.

———. Unpublished typescript on excavations at B.D.R. #6, in the files of the Saskatchewan Museum of Natural History. n.d.*c*.

McGregor, John C. *The Chrisman site, Illinois River Valley Archaic culture.* Journ. Illinois State Archaeol. Soc. (n. s.) **4**(1). 1954.

Miller, Carl F. *Life 8,000 years ago uncovered in an Alabama cave.* Nat. Geogr. Mag. **110**(4): vol. CX, no. IV, pp. 542–559. 1956.

———. *Radiocarbon dates from an early archaic deposit in Russell cave, Alabama.* Amer. Antiq. **22**(1): 1957.

Moss, John H., *et al. Early man in the Eden valley.* Mus. Monog. University Museum, Philadelphia. 1951.

Nero, Robert. *Surface indications of a possible early Archaic campsite in Wisconsin.* Wisconsin Archeol. **36**(4): 128–146. 1955.

Orchard, C. D., and Campbell, T. N. *Evidences of Early Man from the vicinity of San Antonio, Texas.* Texas Journ. Sci. **6**(4). 1954.

Powell, Louis H. *Point profiles as an archeological tool.* Proc. Minnesota Acad. Sci. **23:** 35–45. 1955.

Ritchie, William A. *The pre-Iroquoian occupations of New York State.* Rochester Mus. Mem. 1: 416 pp. 1944.

———. *A probable paleo-Indian site in Vermont.* Amer. Antiq. **18**(3) 249–258. 1953.

———. *An introduction to Hudson Valley Prehistory.* New York State Mus. Sci. Serv. Bull. 367: 1–112. 1958.

Ritzenthaler, Robert. *A comment on the carbon-14 dates for Old Copper.* Wisconsin Arch. **35**(4): 81. 1954.

Roosa, William B. *The Lucy site in central New Mexico.* Amer. Antiq. **21**(3): 310. 1956.

Rowe, Paul R. *Early horizons in Mill County, Iowa, Part 1—Evidences of Early Man.* Journ. Iowa Archeol. Soc. **1**(3): 1952.

Sauer, Carl O. *The end of the ice age and its witnesses.* Geogr. Rev. **47**(1): 29–44. 1957.

Sellards, E. H. *Early Man in America.* Austin, Tex., 1952.

Society for American Archaeology. *Radiocarbon dating.* Memoir no. 8 (assembled by Frederick Johnson). 1951.

Spaulding, Albert C. *Northeastern archaeology and general trends in the northern forest zone.* In: "Man in Northeastern North America." Pap. Robert S. Peabody Found. Archaeol. **3:** 143–167. 1946.

Strong, W. Duncan. *An introduction to Nebraska archeology.* Smithsonian Misc. Coll. **93**(10). 1935.

Swauger, James L., and Mayer-Oakes, William J. *A fluted point from Costa Rica.* Amer. Antiq. **17**(3): 264–265. 1952.

Webb, William S. *The Read shell midden.* Univ. Kentucky Rep. Anthrop. **7**(5). 1950.

———. *The Parrish village site.* Univ. Kentucky Rep. Anthrop. **7**(6). 1951.

Wettlaufer, Boyd. Unpublished typescript on excavations at BDR #6 in the files of the Saskatchewan Museum of Natural History. n.d.

Willey, Gordon R., and Phillips, Philip. *Method and theory in American archeology II: historical-developmental interpretation.* Amer. Anthrop. **57**(4): 723–820. 1955.

———. *Method and theory in American archeology.* 1–270. Chicago, 1957.

ZOOLOGY—*Millipeds collected enroute from Florida to San Antonio, Texas, and vicinity.* H. F. Loomis, Miami, Fla.

(Received March 26, 1959)

In the latter half of December 1958, the writer and his wife visited San Antonio, Tex., spending some time collecting millipeds on the way and in the region about San Antonio. One day was devoted to searching the Kerrville area in the hope of rediscovering several of the more unusual species described from there by Prof. R. V. Chamberlin alone or in conjunction with Stanley Mulaik, and some success was had. The collection as a whole resulted in the finding of five new species, one of which represents a new genus, and in establishing further localities for several known species. Descriptions and data on these are here presented as well as descriptions of three other new species received following our return to Florida. Unless otherwise stated all collections reported were made by E. M. and H. F. Loomis.

Type specimens of all species described are deposited in the U. S. National Museum.

Family DESMONIDAE

Genus **Desmonus** Cook

Desmonus Cook, Proc. U. S. Nat. Mus. **21**: 463. 1898.

Ethocyclus Chamberlin and Mulaik, Journ. New York Ent. Soc. **49**: 58. 1941.

Specimens of this genus from five localities within a radius of approximately 100 miles of San Antonio present several interesting features. None of these millipeds appear to have been described as belonging to this genus, and all have certain characters in common that probably are generic but may be only specific; a question that can not be determined with any degree of satisfaction without additional and more widely collected material. From experience in making the present collection this should become available upon proper search.

The discovery of *Desmonus* between Bandera and Helotes came during the return from Kerr County to find additional specimens of species collected there by Mr. and Mrs. Stanley Mulaik and described in the paper by him and Professor Chamberlin (loc. cit.). It had been hoped to obtain specimens of *Ethocyclus atophus*, but no cyclodesmids were found. However, with the finding of the *Desmonus* and subsequent specimens in the region a careful reexamination of the description of *Ethocyclus* forced the conclusion that it is a desmonid rather than a cyclodesmid.

While the first three segments are of quite similar shape in the Cyclodesmidae and Desmonidae, the fourth segment in *Ethocyclus* is described as laterally broader and less acute than the fifth segment, a normal condition for the latter family but applying in only the smaller of the two genera of the former. The first segment of *Ethocyclus* is said to bear two transverse rows of setae and "on typical segments the posterior portion of tergite elevated above level of anterior portion and divided into low tubercular swellings which appear to have born(e) setae forming a transverse series." These are characters of *Desmonus* attributed to no other cyclodesmid than *Ethocyclus*, and hence the latter genus is placed as a synonym of the former.

The Texas specimens, representing three species, are in the group having 20 segments; all are essentially white in color but have a coating of organic matter; pits are at the anterior junction of carinae and dorsum of segments 3 through 20; head with a definite low ridge beginning between the antennae and extending upward halfway to segment 1, where it terminates and is succeeded by an impressed sulcus across the vertex; segments 1 to 4 with two transverse series of short, well-separated setae which are reduced to a single series on ensuing segments; segment 4 with outer margin of lateral keels elongate, sometimes slightly rounded, in shape intermediate between the keels of segments 8 and 9; dorsal tubercles usually beginning on segment 5 and continuous through segment 19 but lacking or very indefinite on segment 20; males with lateral keels of segments 5 to 15 at least, more oblique than those of female, the dorsal tubercles also more prominent.

In the accompanying descriptions and illustrations it will be seen that the three species are very closely related and a wider range of specimens may show that one or two of them will have to be reduced in rank. The dorsal tuberculation varies greatly in amount in specimens within the species but seems to be typical for each of them. None of the specimens of *distinctus* has the tubercles of segment 19 coalesced to form two enlarged swellings as occur in the other two species, and *conjunctus* does not have the tubercles of the midbody segments as high or inclined as in *crassus* but does have those of segment 19 larger than on preceding segments. Differences of the gonopods are slight between the species, as Dr. Causey has observed[1] for the other species in a recent paper on the family, while within the present species considerable variation has been noted. For none of the previously described species has mention been made of the distinct cephalic ridge, which may be a feature limited to the new forms.

Desmonus conjunctus, n. sp.

Male type and female from between Bandera and Helotes, Tex., December 26, 1958, co-collector J. C. Loomis; a male and 3 females from Landa Park, New Braunfels, and 2 males from Lake Placid, between New Braunfels and Seguin, Tex., December 29, 1958.

Description.—Largest specimen, a female, 9 mm long and 1.7 mm wide. Dorsal swellings or tubercles usually first evident on segment 6, rarely on segment 5, and increasing slightly in prominence thereafter, becoming strongest on segments 17, 18, and 19, on the latter of which the three innermost tubercles on each side are united into a single large rounded boss surmounted by the three setae of the individual tubercles (Fig. 1). In an extreme variant in sculpturing the male from New Braunfels shows much more prominent tubercles than any other specimen, and on segments 17 and 18 the three innermost ones on each side are united as on segment 19. In none of the specimens are any lateral tubercles evident below the compound ones on segment 19. Last segment without tubercles. Gonopods as shown in Figs. 2 and 3.

[1] Proc. Biol. Soc. Washington **71**: 173–78. 1958.

Desmonus crassus, n. sp.

Five males (1 the type) and 8 females from Victoria County, Tex., labeled "8-06 J. D. Mitchell" sent me for examination by Richard L. Hoffman from the National Museum collection.

Description.—This is a stouter species than either of the other two described here, attaining a length of 8 mm and a diameter of 1.9 to 2 mm. Tubercles generally more prominent than in the other two species, beginning on segment 5, where frequently they are quite distinct, and increasing in size thereafter and on the most strongly sculptured specimens they are considerably raised, inclined caudad, with setiferous apex devoid of coating and shining; segments 18, 19, and sometimes 17 with the three inner tubercles on each side united into a single large inclined tubercle with that on segment 19 smaller than that on 18; segments 18 and 19 without other lateral tubercles.

Gonopods with anterior arm showing two or three teeth, the posterior arm more slender at apex than in the other species (Fig. 4).

Desmonus distinctus, n. sp.

Five males (1 the type) and 5 females "collected under rocks and logs in closely grazed pasture land with a few oaks and cedars on the Beauregard Road about 5 miles SSW. of Boerne, Tex., January 31, 1959," by J. C. Loomis.

Description.—Largest specimen, a female, 8.5 mm long and 1.5 mm in diameter. In general the tubercles are more prominent than those of *conjunctus* but less so than in *crassus*, although in one or two females the tubercles are not individually indicated except by the location of the setae; the males, however, have tubercles beginning on segment 5, becoming stronger thereafter and quite uniform in size from seg-

FIGS. 1–23.—1–3, *Desmonus conjunctus*, n. sp.: 1, segments 19 and 20 of male, posterior view; 2, right gonopod, lateral view; 3, apex of left gonopod of Landa Park male, lateral view. 4, *Desmonus crassus*, n. sp., left gonopod, lateral view. 5, *Desmonus distinctus*, n. sp., apex of right gonopod, lateral view. 6, 7, *Ilyma digitata*, n. sp.: 6, right gonopod, lateral view; 7, apex of right gonopod, lateral view. 8, *Pseudopolydesmus bidens*, n. sp.: left gonopod, mesal view. 9, *Pseudopolydesmus minor* (Bollman): right gonopod, mesal view. 10–14, *Mecistopus varicornis*, n. sp.: 10, joints 6 and 7 of female antenna; 11, joints 6 and 7 of male antenna; 12, right anterior gonopod, lateral view; 13, ninth male legs, posterior view; 14, basal joints of tenth male legs, anterior view. 15–18, *Aniulus vestigialis*, n. sp.: 15, left mandibulary stipe of male; 16, left anterior gonopod, lateral view; 17, left posterior gonopod, mesal view; 18, left posterior gonopod, caudolateral view. 19–23, *Ziniulus ambiguus*, n. sp.: 19, stipe and first two segments of male, lateral view; 20, right anterior gonopod, lateral view; 21, right posterior gonopod, lateral view; 22, apex of right posterior gonopod, caudal view; 23, apex of uncate blade of same gonopod, mesal view.

Figs. 1–23.—(See opposite page for legend).

ment 7 to 17, although not so high or sharply marked as in *crassus*, those on segment 18 slightly larger, but only the second from within larger on segment 19, which has 2 to 5 distinct tubercles on each side with none coalesced as in the other species. Last segment with two very low, indefinite tubercles sometimes present.

Gonopods as shown in Fig. 5.

Desmonus atophus (Chamberlin and Mulaik)

In order to allow absolute verification of its family and generic position and its relationship to the species here described, a specimen of *atophus* was requested of Professor Chamberlin, but word has been received that he was unable to find the original material; hence, these matters await finding of the lost specimens or collections from the type locality, presumably Raven Ranch, although only Kerr County was so designated.

A NEW NAME IN CYCLODESMIDAE

In studying the original description of *Desmonus* (*Cyclodesmus*) *atophus* (Chamberlin and Mulaik), Dr. Carl's notes and illustration of *Cyclodesmus aztecus* Humbert and Saussure, the genotype, were reviewed in Rev. Suisse Zool. **10:** 678–9, pl. 12, fig. 109, 1902. The conclusion was reached that the West Indian species heretofore included under *Cyclodesmus* belong in a different genus for which the name **Caribocyclus** is proposed, with the Haitian *Cyclodesmus angustipes* Loomis as the genotype. This genus is differentiated from the Mexican *Cyclodesmus* by having each gonopod composed of one or two more or less slender branches rising above the basal joint. In the species having 2 branches these may be separated, partially fused, or completely united. The illustration of *C. aztecus* shows the gonopod with an expanded and curved outer joint sheathing the simple and evenly curved seminal one.

Family Stylodesmidae

Genus **Ilyma** Chamberlin

Ilyma Chamberlin, Bull. Univ. Utah **31**(11): 24. 1941.

KEY TO THE SPECIES ILYMA

1. Segment 1 with 12 primary tubercles in two transverse series of 6 each ... *colotlipa* Chamberlin
   Segment 1 with 10 primary tubercles arranged essentially in 2 rows ... 2
2. Segment 1 with outermost primary tubercle on each side larger than any of the others ... *orizaba* Chamberlin
   Segment 1 with outermost primary tubercle on each side not so large as or no larger than the others ... 3
3. Segment 19 with posterior processes greatly exceeding the tip of segment 20 ... *cajuni* Loomis
   Segment 19 with processes shorter, only equaling the tip of segment 20 ... 4
4. Processes of segment 19 broad, the sinus between them rather shallow and U-shaped ... *morela* Chamberlin
   Processes of segment 19 narrow, the sinus between them deep and V-shaped. ... *digitata* n. sp.

A mexican species, *potosina* Chamberlin, was established on a single fragmentary female, lacking two molts of maturity! Its juvenile characters are not comparable with the mature ones of the other species, and its true identity will be difficult to determine.

Ilyma cajuni Loomis

Three males and 5 females collected by Leslie Hubricht, December 12, 1954, in Cameron County, Tex., at "Rabb Ranch, near southmost (?), under palm logs," and sent me by Richard L. Hoffman.

These specimens were compared with paratypes of *cajuni* without finding specific differences. The species has the primary tubercles of segment 1 arranged as in the following species except that the space between the two median tubercles of both rows is much wider than that between any of the other tubercles.

Ilyma digitata, n. sp.

A male (type) and 4 females, one immature, found beneath logs beside U.S. Highway 190 between Kinder and LeBlanc, La., December 20, 1958.

Diagnosis.—Relationship with *morela* is indicated by the size of the body, the short processes of segment 19, and certain characters of the gonopods, although these differ materially in the two species.

Description.—Length of male and largest female 6 mm, width 0.9 mm. Vertex, first segment, and posterior divisions of other segments black; front of head, antennae, anterior subsegments, segment 20, and all ventral surfaces, including the legs, colorless.

Head with vertex not greatly raised above the front but with 20–28 sharply rounded tubercles of various sizes, the largest at the lateral margins behind the antennae but the margins not raised into a granular ridge as in *cajuni*.

First segment with only the four large, equidistant, primary tubercles in front forming a distinct row; the other six primary ones also equidistant from each other, one on each side of middle at posterior margin, a second laterocephalad of it and the third still further forward and outward, behind and laterad of the outer tubercle of the front row. In addition there are many smaller tubercles of varying sizes including a dozen or more along the posterior margin, standing erect and not projecting beyond it.

Body with lateral carinae quite narrow, descending more obliquely than in *cajuni*, the pores opening from blunt and cylindrical tubercles as long as thick, not in the least conical. Dorsum of segments with customary 4 rows of primary tubercles extending from segment 2 to 19, the median rows on the latter elevated but not thickened, and produced backward into 2 outwardly parallel processes that equal but do not exceed the tip of segment 20 which is visible in the deep V-shaped sinus between them. Secondary tubercles about 6 in number between the median primary rows but lacking behind segment 16; the 3 secondary ones between the outer and inner primary rows on the anterior four-fifths of body lacking on the posterior fifth. Last segment as in *cajuni*.

Gonopods as shown in Figs 6 and 7.

Family POLYDESMIDAE

Dixiedesmus erasus (Loomis)

Two males and 6 females from east side of Blakely River, Ala., before entering the flats east of Mobile, on U.S. Highway 90, December 19, 1958.

Pseudopolydesmus bidens, n. sp.

Seven males (1 the type) and 5 females from beside U.S. Highway 190, between Kinder and LeBlanc, La., December 20, 1958.

Diagnosis.—A small species, broader and flatter than *minor* (Bollman), with anterior corners of carinae dentate from segment 2 through 18, and with distinctive gonopods.

Description—Largest specimen of each sex 12 mm long and 1.7 mm wide. Living color dark brown, shining. Dorsum quite flat, the lateral carinae broad, thin vertically at junction with body; anterior corners scarcely rounded and each with a distinct tooth on segments 2 through 18; lateral margins nearly straight, the poriferous ones with 3 setae plus 1 on the posterior angle, the nonporiferous ones with 2 plus 1 on the angle; posterior angles larger and more produced on all segments, including 19, than in *minor*. Last segment triangular in dorsal view, its sides straight, not slightly emarginate as in *minor*. Gonopods (Fig. 8) with only 2 triangular lobes or teeth on the distomesal edge, the small papillose process located more than halfway to the tip of the gonopod.

Dr. Nell B. Causey kindly sent me a male and female of *P. minor*, collected 1.5 miles west of Conway, Faulkner County, Ark., December 24, 1953, by M. A. Jackson, which allowed me to make direct comparisons with *bidens*. *P. minor* is more slender and convex, with narrower lateral carinae which are relatively thicker where they join the body. Since a complete gonopod of *minor* has not been illustrated previously, one is shown in Fig. 9, in which the small papillose area or tubercle shown a short distance above the basal one is lacking from the opposite gonopod.

Pseudopolydesmus serratus (Say)

Male and many females from beside U.S. Highway 190, at Kinder, La., December 20, 1958.

Family EURYMERODESMIDAE

Eurymerodesmus melacis Chamberlin and Mulaik

Specimens collected in following Texas localities in December 1958: Kerrville-Bandera; Landa Park, New Braunfels; McQueeney; Schertz.

Family STRONGYLOSOMIDAE

Oxidus gracilis (Koch)

Numerous specimens from J. O. Vaughan Ranch, Schertz, and from McQueeney, Tex., December 1958.

Family LYSIOPETALIDAE

Abacion tesselatum creolum (Chamberlin)

Male and female from Ponce de Leon, Holmes County, Fla., December 19, 1958.

Abacion texense (Loomis)

Numerous specimens from Kinder-LeBlanc, La., December 20, 1958; and following Texas localities, December 1958: J. O. Vaughan Ranch, Schertz; Kerrville-Bandera; McQueeney; Landa Park, New Braunfels.

Family Rhiscosomididae

Tingupa sp.

Two specimens, 4 mm long, with 28 segments each and having essentially black markings collected beside U.S. Highway 190 at Walker, La., December 20, 1958.

Family Cleidogonidae

Cleidogona sp.

Two females near Blakely River before entering flats east of Mobile, Ala., on U.S. Highway 90, December 19, 1958.

Mecistopus, n. gen.

Type.—*Mecistopus varicornis,* n. sp.

Diagnosis.—Included among genera having ninth male legs 5-jointed but differing in the coxal joint and in having joints 4 and 5 very small. Relationship with *Rhabdarona* Chamberlin and Mulaik is indicated but the gonopods reach back along the body, when at rest, with tips inserted between the separated sterna of legs 12 and 13. Sexual differences of the last joint of the antennae also are unique.

Description.—Body of intermediate size, smooth and strongly shining with the outer dorsal seta on each side of segments 2 to 8–13 borne on a subconic tubercle set off above by a distinct longitudinal impression.

Head with labral area convex and raised above the front; last joint of antennae differing in size and shape in the sexes.

Gonopods unusually long, bent strongly caudad and lying in close contact with each other and with the ventral side of body between the coxae of legs 9 to 12 which have their sterna broadened; tips of gonopods curving up toward body between the well separated sterna of legs 12 and 13, the latter wider than the sterna that follow.

Males with legs 1 and 2 shorter and more slender than legs 3 to 7, which are crassate but have no other special modification except that the ventral face of the last joint of each leg is papillose; ninth legs 5-jointed, basal joint large and apically continued into a long, slender, erect and acute process, joints 4 and 5 very small; legs 10 and 11 with the poriforation of each coxal joint opening from a cylindrical process behind which, on leg 11, is a conic tubercle; twelfth legs lacking either process or tubercle.

Mecistopus varicornis, n. sp.

Many specimens, including male type, collected in collaboration with J. C. Loomis between Kerrville and Medina, Tex., along Highway 16, December 26, 1958; a male from beside the Beauregard Road, 5 miles SSW. of Boerne, Tex., collected January 31, 1959, by J. C. Loomis; and a male from Landa Park, New Braunfels, Tex., December 29, 1958.

Description.—Length 14 to 17 mm, the males shorter than females. Fully colored living specimens are shining dark chestnut-brown with a very narrow longitudinal median light line, a tiny light spot surrounding base of first dorsal seta, and a larger oval light spot between the two outer setae; the hyaline dorsal setae are conspicuously silvery in daylight on the living animal, giving it a coarsely fuzzy appearance.

Head with broad labral area convexly elevated above the front and with lateral margins behind it also elevated for a considerable distance; front hispid, much more densely so adjacent to the labrum; eyes well developed, triangular, in series of ocelli arranged 7, 6, 5, 4, 3, 2, 1, from above; antennae very long and slender, joint 3 longest, joint 7 differing in both length and shape in the sexes as shown in Figs. 10 and 11.

On segments 2 to 8 or 9 of female and 2 to 10–13 of male the outer seta on each side of dorsum is near the posterior margin and borne on a distinct tubercle, largest in male, which is set off from the surface above it by a conspicuous furrow extending forward halfway across the subsegment.

Anterior gonopods as shown in Fig. 12. Posterior gonopods small, reaching only to about the middle of the coxal joint of ninth legs and consisting of 2 apically thickened structures resembling wooden golf clubs on short shafts with the heads directed outward. Ninth legs 5-jointed, as shown in Fig. 13, the tiny, subhemispherical, fifth joint almost black in contrast to the nearly colorless preceding joints. Legs 10 (Fig. 14) and 11 as in generic description, the anterior face of the broad sternum of each smooth whereas the anterior median face of twelfth sternum has a strong vertical ridge with sterna thereafter having similar but smaller ridges.

Family PARAIULIDAE

Aniulus adelphus Chamberlin

Numerous Texas specimens from J. O. Vaughan Ranch, Schertz; and McQueeney, December 1958.

Aniulus craterus Chamberlin

Many specimens collected along Highway 16 between Kerrville and Bandera, Tex., in collaboration with J. C. Loomis, December 26, 1958.

Aniulus vestigialis, n. sp.

Male (type), female, and several immature females from Landa Park, New Braunfels, Tex., December 29, 1958.

Diagnosis.—Related to *austinensis* Chamberlin but differing from it and all others of the genus in having the accessory blade of posterior gonopods reduced to a vestige near the base of the broad seminiferous blade.

Description.—Male 36 mm long with 58 segments; female 31 mm long with 53 segments; both 2.6 mm in diameter. Living color mostly yellowish brown with a lateral series of dark spots at the pores.

Head with mandibulary stipes of male as shown in Fig. 15.

First segment of male about as long as segments 2 and 3 together as measured either along the dorsum or lateral margins; a single strongly raised rim along the broadly emarginate lateral margin. Second segment with two strong lateral ridges, its lateral margin little if any lower than that of segment 1; ensuing segments with more lateral striations but the intervals not raised into ridges. Apex of last segment somewhat surpassing the valves, more acute than a right angle, its sides straight, not emarginate.

Gonopods as shown in Figs. 16–18. Sternum of tenth male legs with a rounded surface swelling on each side and medianly its anterior portion developed into a long vertical ridge projecting between the posterior gonopods.

Ethoiulus oreines (Chamberlin)

Aniulus oreines Chamberlin, Bull. Univ. Utah **30** (11): 6, figs. 18, 19. 1940.

The figures cited above clearly indicate necessity of the transfer.

Ziniulus ambiguus, n. sp.

Two males (1 the type), a female, and three immature specimens collected along the Beauregard Road, about 5 miles SSW. of Boerne, Tex., January 31, 1959, by J. C. Loomis.

Diagnosis.—While the anterior gonopods closely resemble those of *Hakiulus*, the posterior ones are more typical of *Ziniulus*, especially *Z. medicolens*, and the mandibulary stipes are typical of the latter genus.

Description.—Color dark, approaching black, with minor lighter markings. Type with 48 segments, body 20 mm long, 1.7 mm wide; other specimens with 47 to 51 segments.

Mandibulary stipes of male (Fig. 19) subquadrate, with both angles of nearly equal size; dorsal edge with a raised rim.

First segment of male unusually short, the lateral margin but little longer than that of segment 2 (Fig. 19) which may have 1, 2, or 3 lateral striations. Segments with transverse sulcus broadly bowed forward where it passes in front of the pore which is separated from it by about its own diameter. Last segment with apex slightly exceeding the anal valves but not deflexed.

Anterior gonopods (Fig. 20) resembling those of *Hakiulus*, the posterior ones (Figs. 21–23) with the flattened, uncate, blade rising from near the base of the bifurcate blade rather than distad of its middle, as in *medicolens*. Sternum of segment 8 lacking a median projection in front.

Ziniulus medicolens Chamberlin

Numerous specimens of both sexes from J. O. Vaughan Ranch, Schertz, Tex., December 1958.

Family ATOPETHOLIDAE

Eurelus kerrensis Chamberlin and Mulaik

A mature female, thought to be this species, from beside Highway 16, between Kerrville and Bandera, Tex., collected December 26, 1958, in collaboration with J. C. Loomis.

The specimen has 52 segments and is 8 mm in diameter, similar in this respect to *soleatus* Cook, but is larger than is given for *kerrensis*, the smaller size of which was one of the characters on which the two species were separated.

Family SIPHONOPHORIDAE

Siphonophora sp.

A young female, 8 mm long and with but 41 segments, collected by Leslie Hubricht, March 12, 1955, in Zilker Park, Austin, Tex., and sent me by Richard L. Hoffman.

National Science Foundation Makes Educational Grant to Washington Academy of Sciences

The National Science Foundation has made a grant of $32,250 to the Washington Academy of Sciences to conduct a several-faceted program in science education. This a part of a half-million dollar program of grants to 17 State academies and similar organizations to strengthen their educational activities.

The Academy's program consists of four projects, which may be summarized as follows: To establish a community consultation service; to participate in curricular experiments integrating instruction in science and mathematics; and to organize round-table discussions among secondary school teachers, college instructors, and local scientists. The program is under the supervision of the Joint Board on Science Education, which will administer and coordinate all its phases.

With reference to the consultation service, a central office will be established, with appropriate files to catalogue the scientific resources of the community. This file in the hands of a trained clerk will serve as a means for making these resources readily available to the various schools. The round-table discussions will be designed to create a better liaison between teachers, in both secondary schools and colleges, with local scientists in the several scientific disciplines.

The curricular experiments will be conducted at both elementary and secondary school levels. Their objective will be to explore to what extent instruction in science and in mathematics may be coordinated to complement and supplement each other. Four public and two private schools in the local area have indicated their intention to participate in this program and conduct experimental courses. The grant makes it possible to reimburse these cooperators for direct costs incurred by their participation in the program.

Dr. John K. Taylor, of the National Bureau of Standards, has been named as director of the program and as such will have general responsibility for its total operation. Dr. Taylor has had a long and continuing interest in science education and has been a member of the Joint Board on Science Education since its inception in 1955. Dr. William T. Read, recently retired as scientific adviser to the Department of Defense, will be retained as executive secretary. In this capacity he will be responsible for administration and implementation of the program. Dr. Read was one of the leaders in the cooperative effort by the D. C. Council of Architectural and Engineering Societies and the Washington Academy of Sciences to coordinate the educational activities of the local technical societies which resulted in the formation of the School Contacts program and finally the Joint Board on Science Education. Dr. Read has also other extensive educational experience and is a former dean of the School of Chemical Engineering at Rutgers University.

The Joint Board has appointed special advisory committees to give technical assistance to the participants in the projects. Thirty distinguished scientists representing the disciplines of biology, chemistry, physics, engineering, mathematics, and geology, and affiliated with the major scientific and educational institutions of the area, will work in cooperation with the Joint Board's Curriculum Committee to this end. Dr. Raymond J. Seeger is chairman of this latter committee.

The program will have its headquarters in the office of the Academy at 1530 P Street, NW., Washington 6, D. C. The telephone number is ADams 4-5323. One of its projects is concerned with the establishment of a roster of scientists who can assist school teachers and their students by speaking to science clubs, consulting on science projects, and performing related activities. Dr. Read would be glad to hear from all who are interested in participating in this aspect of the program.

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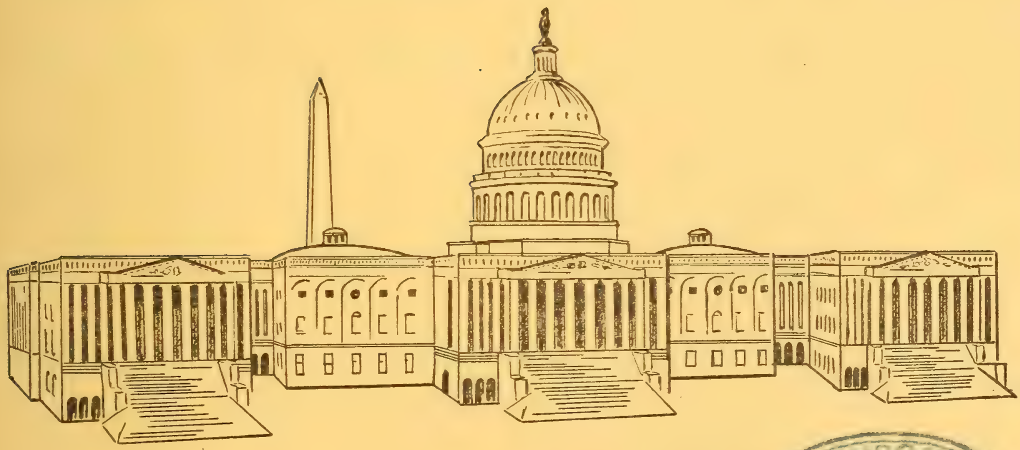

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ASTRONAUTICS.—*The exploration of space.*[1] Hugh L. Dryden, National Aeronautics and Space Administration.

(Received May 29, 1959)

The surging tide of technological development has brought us to a new frontier, the frontier of space exploration and travel. We are at approximately the same stage in the development of space vehicles as the Wright Brothers were in the development of the airplane in 1904. In those days few people were interested in the fragile wood, wire, and cloth vehicles which were the fore-runners of our modern jet transports and military airplanes. In fact, as a nation, we were so uninterested that the Wrights took their invention to Europe. When World War I broke out, we found that we had no airplanes of our own. We were compelled to build copies of airplanes developed by other nations.

Today the situation is different. There is widespread public interest. The competition is evident. Many now have faith in the great potentialities of space exploration to benefit mankind. It is a privilege for me to tell you about the steps that are being taken to insure that the United States will occupy its proper role as a leader in space research, development, and operation for peaceful purposes.

The space age began with the launching of Sputnik I by the U.S.S.R. on October 4, 1957. The United States launched its first satellite, Explorer I, on January 31, 1958. At present ten earth satellites have been launched into orbit successfully. Three space probes penetrated to distances of 63,000 to 71,000 miles from the earth. Two space probes reached a velocity high enough to escape from the earth's gravitational field to enter orbits around the sun as man-made planets. Instrumentation on board these space vehicles provided new information about the environment of nearby space, information which increases our understanding of the earth and its atmosphere; of cosmic rays, other particles and radiations encountered by our earth in its journey through space; in fact, of the physical universe in which we live. From the data already returned to earth from satellites and space probes containing equipment developed by Dr. James A. Van Allen, head of the physics department of the University of Iowa, have come the discovery and description of the Great Radiation Belt. This belt consists of clouds of charged particles whose impact on the satellite produces radiation of high intensity harmful to man and capable of damage to film and other photosensitive apparatus. There are in fact two radiation belts believed to be of different origins. The first has its maximum intensity at a height of about 2,400 miles and is believed to be produced as a result of the impingement of cosmic rays on air molecules. The second, reaching its maximum intensity at about 10,000 miles above the earth is believed to consist of particles from the sun, whose atmosphere now appears to reach to the earth and beyond. In both cases the particles are trapped by the magnetic field of the earth and persist for a long time until as they travel back and forth in spiral paths from pole to pole they collide with air molecules releasing some of their energy to form the imposing auroral lights of the far north and south.

[1] Address delivered before the Cosmos Club of Washington on April 13, 1959, and substance of a lecture delivered at the 442d meeting of the Washington Academy of Sciences on May 21, 1959.

In addition to this fascinating discovery which I am not competent to describe in detail, the four U.S.S.R. and eleven U.S. space vehicles so far launched successfully have produced exploratory data on the distribution of matter and magnetic fields encountered in space, as well as data on solar radiation, electric field, photons, heavy nuclei, positive ions, and the physiological reactions of a dog which are as yet reported only in part by U.S.S.R. scientists. Truly an imposing record for the first year and a half of the space age.

In the early months there was wide public discussion of the organization of U.S. activities in space research, development, and operation. As an interim measure cognizance over all space programs was assigned to the Department of Defense and a study of U.S. requirements in space science and technology was undertaken by the President's Science Advisory Committee under the leadership of Dr. James R. Killian. As a result of this study the President on April 2, 1958, recommended to the Congress the formation of a civilian agency to be responsible for space activities concerned with problems of civil space flight, space science, and space technology. Military programs associated with military weapons systems and military operations were continued as the responsibility of the Department of Defense. The President further recommended that the new agency be based on the existing National Advisory Committee for Aeronautics. The responsibilities of NACA in aeronautical research and services in support of military aeronautics and missiles programs were to be continued by the new agency and extended to military space programs. The functions of the new agency were to be considerably expanded over those of NACA to include the development and operation for research purposes of space vehicles.

After extensive hearings and consideration by the Congress the National Aeronautics and Space Act of 1958 became law on July 29, 1958, with most of the features recommended by the President. This Act expresses an important national policy with respect to activities in space, and the National Aeronautics and Space Administration was established to implement this policy. Section 102(a) reads as follows: "The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." In Section 102(c) the Act states the objectives of the aeronautical and space activities of the United States under this policy. In paraphrased form they are:

1. The expansion of human knowledge of atmospheric and space science;
2. The improvement of aeronautical and space vehicles;
3. The development and operation of space vehicles;
4. The study of the potential benefits to be gained for mankind through space activities;
5. The preservation of the role of the United States as a leader in aeronautical and space science and technology and in application thereof to peaceful activities;
6. The interchange of information between civilian and national defense agencies;
7. Cooperation with other nations in aeronautical and space activities and in peaceful application of the results; and
8. The most effective utilization of the scientific and engineering resources of the United States in achieving these goals.

The Act, in addition to the formulation of the policy and these objectives and the establishment of NASA, created an Aeronautical and Space Council to advise the President on all significant aeronautical and space activities and on the assignment of responsibility for specific projects. A Civilian-Military Liaison Committee was also established as a channel for advice and consultation between NASA and the Department of Defense.

On August 8 the President appointed Dr. T. Keith Glennan, president-on-leave of Case Institute of Technology, as NASA's first administrator, and myself as deputy administrator. NASA began operations on October 1, 1958, at which time it absorbed the personnel and facilities of the National Advisory Committee for Aeronautics, thus ending the 43-year existence of NACA by metamorphosis. NASA thus began with nearly 8,000 scientists and engineers, and technical and administrative personnel and five field laboratories: Langley Research Center at Langley Field, Va.; Ames Research Center, Moffett Field, Calif.; Lewis Research Center, Cleveland, Ohio; Wallops Island Station, Wallops Island, Va.; and the High

Speed Flight Station, Edwards, Calif. To carry the new responsibilities there was added to the organizational structure space flight development in addition to aeronautical and space research and business administration. The new responsibilities for development and operation of space vehicles will be carried largely by contract with existing industry and educational groups.

On October 1, as a result of prior review, the President transferred to NASA from the Department of Defense the original U.S. scientific earth satellite project, Project Vanguard, with more than 160 scientists and technologists of the Naval Research Laboratory; five space probes and three satellite projects which were under the direction of the Advanced Research Projects Agency of the Department of Defense, and a number of engine development programs from the Air Force and ARPA. On December 3 the President transferred the functions and facilities of the Jet Propulsion Laboratory, Pasadena, Calif., from the Department of the Army to NASA. At the same time NASA entered into an agreement with the Army whereby the Army Ballistic Missile Agency, Huntsville, Ala., will carry out certain NASA projects.

In the seven months of NASA's existence we have been working with a high sense of urgency on a fourfold task, (1) carrying out the on-going satellite and space-probe projects transferred to the new agency; (2) planning and initiating new projects; (3) establishing long-range plans and objectives; and (4) building an organization adequate to carry out the over-all program. In our remaining discussion together I wish to outline our over-all plans and objectives.

In our present appearances before Congressional committees we are asked to solemnly swear that our testimony will be the truth, the whole truth, and nothing but the truth. Dr. Homer Newell, NASA assistant director for space sciences, after taking this oath, remarked that we do not always know the truth in science and we can only try to tell the truth as we see it today. Space science and technology represents a new and unknown area of knowledge, and no person can now foresee the aeronautical and space activities of the future any more than the Wrights could foresee the aeronautical activities of today in 1903. As you recall, Wilbur stated that "it is not necessary to look too far into the future; we see enough already to be certain that it will be magnificent."

In line with U.S. policy as expressed in the Act, NASA has established objectives which carry out the application of space science and technology to peaceful purposes. Some of the most important relate to the applications of earth satellites to meteorology, communications, navigation, and geodetics. In some of these fields we expect that, after a period of subsidized development, the earth satellite techniques will prove less costly yet more effective than presently available methods.

The objective of NASA's meteorological satellite program is to provide the knowledge, experimental data, and component development required for an operational satellite system for weather observation, analysis, and forecasting. To accomplish this objective requires research and development on vehicles, instrumentation, data-handling techniques, and satellite flights. The increased knowledge obtainable by such a system may well lead to the possibility of doing something about the weather as well as observe and experience it.

The first meteorological satellite, a very primitive one, was Vanguard II, successfully launched on February 17, 1959. It carried two infrared photocells to scan the earth's cloud cover. The instrumentation worked well, and excellent electronic signals were received and recorded on the ground throughout the life of the satellite's batteries. However, the satellite acquired a complex wobbling motion which has greatly complicated the reduction of the data. This satellite was the first toddling step toward our final objective. A second more sophisticated satellite is under construction and later versions are in the planning stage.

Our present concept of the system which is our objective comprises six satellites in polar orbits at altitudes of 500 to 1,000 miles and three satellites in 22,000 mile equatorial orbits which travel at the same speed as the earth's surface and so remain over fixed points on the earth's surface. The satellites will be provided with instrumentation to observe cloud formations, hurricanes, tornadoes, thunderstorms, temperatures at various levels (inferred from spectral distribution of radiated energy), incoming and reflected solar radiation, etc. The data received from the satellites will be transmitted quickly (perhaps by communication satellites described below) to a central weather computing center, an enlarged version of that operated now by the U.S. Weather Bureau at Suitland, Md., near Washington, which is now engaged in numerical weather prediction. The operational system will be operated by the Weather Bureau, perhaps with NASA assistance in the satellite launchings.

A second NASA objective for the peaceful application of satellites is the development of the knowledge, experimental data, and component development required for a world-wide communication system capable of transmitting wide band messages including television pictures. The accomplishment of this objective requires development of vehicles, transmitters, antennas, receivers, and experimental data on operating equipment. The final system might be operated by an industrial group or by government monopoly as later determined by Congressional policy. One type of system, the passive system described below, permits use of the satellite component by any nation or person providing the necessary ground equipment.

NASA's first experiments are devoted to the development of components of the passive system. It is well known that the moon may be used as a reflector of radio and radar signals if very powerful transmitters and sensitive receivers are used on the ground and the geometrical relations are correct. Satellites provide smaller moons nearer the earth which require less transmitter power and less expensive equipment. According to a study by Dr. John Pierce of the Bell Telephone Laboratories a passive satellite system may prove economically competitive with ocean cable for transatlantic communication. Television transmission would be possible over this system.

The first passive satellite for experiments on this method of communication is scheduled by NASA during this year. Its launching has been delayed by lack of an adequate launching vehicle. The passive satellite consists of a large inflatable sphere 100 feet in diameter which is made of aluminized mylar plastic. The sphere weighs less than 100 pounds and will be placed in a 700- to 1,000-mile orbit. It can be packed for launching is a sphere only two feet in diameter. The satellite should be readily visible with about the brightness of Venus. In use a strong radio signal is reflected from the satellite in all directions, reaching the earth as a weaker signal which can be received by a highly sensitive receiving antenna pointing toward the satellite.

Our present concept of a passive satellite communications system involves 10 to 20 such satellites in orbits at about 3,000-mile altitude. Any nation could use the satellites as reflectors without interference with use by any other nation. Thus the launching of passive communications satellites would be an important contribution to the peaceful uses of satellites by all nations.

Time will not permit discussion of other plans and objectives for practical applications of satellites to problems of trade and commerce. I turn now briefly to the uses of satellites and space probes for the advancement of scientific knowledge of the space environment. The NASA space science program has its roots in the sounding rocket program for exploration of the upper atmosphere which began some 12 years ago with the use of captured V-2 rockets and the subsequent development of special sounding rockets. During the International Geophysical Year this program received great impetus, and the U.S. fired about 200 sounding rockets and launched its first satellites and space probes.

With the cooperation of the Space Science Board of the National Academy of Sciences–National Research Council and the National Science Foundation, NASA has formulated long-range objectives in the space science program and established a definitive program for the next few years. The term "space science" has been coined to denote scientific investigations carried out in space through the use of satellites, space probes, and other space vehicles. It is not a scientific discipline in itself. Though emphasis at present is on the physical sciences, it is clear that biological science investigations will also be included.

Our program includes a number of areas and their relations one with the other. One area is that of study of the atmospheres of the earth, sun, moon, and planets with respect to chemical composition, density, motions, diffusive processes, absorption of solar radiation, etc. A second area is that of study of the ionospheres. For the earth this region is that from say 50 to a few hundred miles. The presence of the ionosphere permits reflection of radio waves for communication beyond the horizon. The state of the ionosphere is as important to long-range radio communication as is the state of the weather in the lower atmosphere to transportation and other human activities.

A third area of study has already been mentioned, the cosmic rays in interplanetary space, the Great Radiation Belt of Van Allen, and the auroral particles.

A fourth covers the fascinating subjects of magnetism, electricity, and gravity.

A fifth is that of astronomy. Satellite observations place the observer of the sky above the distortion effects of the earth's atmosphere and its absorption of a large part of the radio waves, gamma rays, ultraviolet rays, X-rays, and visible light. As one scientist remarked, satellites permit observation of the universe in full color compared to his present black-and-white picture. Thus in the field of astronomy we are planning to establish and operate unmanned astronomical observatories orbiting above the absorbing atmosphere of the earth and to measure with precision the emission and absorption features of the sun, stars and nebulae in the unexplored ultraviolet, infrared, and X-ray regions of the electromagnetic spectrum.

The nearest object to us in space is the moon. NASA's plans and objectives include unmanned lunar exploration as a preliminary to ultimate manned exploration, and to investigate the surface and interior of the moon and the nearby space, including atmosphere and ionosphere if the moon exhibits such features. The space vehicles used will include lunar probes, lunar orbiters, and vehicles for rough landings, and soft landings of instruments. These vehicles are listed in accord with the estimated order of availability of the necessary vehicles and guidance systems.

The next nearest neighbors of the earth are the planets Venus and Mars. NASA's plans include exploratory probes of the space near these planets as our capabilities permit. At present our payload capacities are so small that only very limited data are obtainable even if the mission is otherwise successful. But as will be described now steps are under way to remedy this situation.

In order to accomplish the long-range objectives outlined and others to be described it is essential that we develop rocket boosters and vehicles capable of putting much larger payloads into space. This is the one area where our competition is definitely ahead. NASA and the Department of Defense have planned a program extending over the next 10 years to provide the vehicles required for foreseen military and nonmilitary space missions. Time permits only a brief sketch of these developments.

At present, except for Vanguard, we are using assemblies of components and vehicles that were designed for other purposes to launch satellites and space probes. They are inefficient and expensive. Improved vehicles will soon be available such as the Discoverer satellite based on the Thor ballistic missile booster and the Hustler engine originally developed for a ground to air missile. NASA is developing a 4-stage solid-propellant satellite vehicle to carry about 150 pounds into a 300-mile orbit. This vehicle, called the Scout, will be much more economical than existing vehicles and will satisfy many of the needs of our scientific program. It will be very useful in international cooperative programs.

NASA has under development the Vega, a 3-stage vehicle using a modified Convair Atlas as first stage, a second stage incorporating a modified General Electric engine which was used in the Vanguard first stage, and a JPL third stage using storable propellants. The Vega will enable us to put several tons in a 300-mile orbit and to send 1,000 pounds to the neighborhood of the moon.

Later vehicles in the program are the Centaur, Saturn, and Nova. Centaur is similar to Vega except that the second stage uses high-energy propellants, liquid hydrogen and liquid oxygen. The first stage of Saturn is being developed by the Army Ballistic Missile Agency as a cluster of existing rocket engines giving over one million pounds thrust. Nova will be based on a single chamber rocket of over one million pounds thrust, which is being developed by the Rocketdyne Division of North American under NASA contract.

The Atomic Energy Commission and NASA jointly are developing nuclear rockets for application to space missions as the state of development permits and on the study of nuclear power plants for use in satellites.

Finally, NASA's long-range objectives include the exploration of the solar system by man himself. Enroute to this objective are the milestones of orbital flight of man in the simplest vehicle (Project Mercury, much in the public eye), in advanced maneuverable vehicles, in larger satellites carrying several men, in permanent manned orbiting space laboratories, manned flight to the vicinity of the moon and back, and manned landing on the moon and return. The objective of Project Mercury is to begin the manned exploration of space by developing the technology needed to place a man in orbit about the earth for a short time and recover him safely, and by studying man's physiological and psychological performance. By restricting the altitude to a height well below the Great Radiation Belt, no heavy shielding is required. By planning for only a few orbits before recovery, existing life support systems are adequate.

As you know from the public and technical press, the man will travel in a capsule substituted for the nose cone of an intercontinental ballistic missile. The man is supported in a reclining position on a couch for protection against the accelerations imposed by launching and by reentry into the atmosphere. The capsule is provided with equipment to supply oxygen and remove carbon dioxide, communications and navigation equipment, attitude control jets, heat shield to protect from reentry heating, and a parachute for final landing on water. Reentry is initiated by firing a small rocket to slightly reduce the speed of the capsule in orbit.

The orbiting flight of the first Mercury Astronaut will be preceded by extensive tests and qualifications of the capsule and training of the astronaut extending over the next two years. Ballistic flights over short distances, instrumented ballistic and orbital flights, animal passenger flights, are included in this program of testing and evaluation.

The seven Mercury Astronauts were selected from an original group of 100 military test pilots who met the general qualifications. When 80 percent of the first 69 interviewed volunteered to proceed, the interviews were terminated. The list was then narrowed to 32 who were given extensive physical and psychological tests. The seven astronauts will receive the most intensive course of training ever offered to a party of prospective explorers. Every conceivable characteristic of space flight that can be simulated on the ground or in the air will be made a part of their personal experience. Every detail of the launching, guiding, and tracking procedures will be taught them by ground crews, until they know the operation as we know the working of an office in which we have spent the better part of our professional lives. Only one can be first, but there will be several flights in the program.

All this training of the selected pilots, and all this repeated testing of the rocket and its component parts, are directed toward one end: that the first orbital flight of the Mercury vehicle shall be as nearly routine as human ingenuity and practice can make it. We are determined that the risks to the pilot will be no greater than those experienced during the first flights of a new high-performance airplane.

The Mercury project will be followed by others. In due course a permanent manned satellite will be placed in orbit around the earth, to conduct research, and possibly as a station from which to organize deeper penetrations into space. As we master the required technology we will send an expedition to the moon, and later on to Mars, to Venus, and to more distant reaches of the solar system.

May I recall to your mind the vast extent of the reaches of space as mapped by the astronomers. The most important object in our part of the universe is the sun, source of our heat, our light, and in the last analysis our food supply. In its neighborhood are nine planets which travel in orbits around the sun and accompany the sun in its motion through space. The earth is number three, at just the right distance for our delicate bodies so that we neither roast nor freeze, at a distance of 93 million miles. Our nearest neighbor, as previously mentioned, is the moon, about 240,000 miles away on the average, moving in an orbit about the earth and accompanying us on our yearly journey around the sun. The nearest planet to us is Venus, 26 million miles, the next Mars, 49 million miles away. The farthest planet, Pluto, is 3,680 million miles from the sun.

To comprehend these tremendous distances let us suppose that we now had spacecraft able to travel at 10 miles per second, approximately the initial velocity required to escape from the solar system or 60 times the speed of a jet transport. It would take us 6 hours 40 minutes to travel the average distance to the moon, 24 days to Venus, 58 days to Mars, 108 days to the sun, 11-½ years to Pluto.

The nearest star is 25 million million miles away, and travel to it at 10 miles per second would require 80,000 years. It is evident that our exploration will be confined to the solar system for some time.

The greatest speed we know is that of light, 186,000 miles per second. We call the distance light travels in one year, a light year; it is nearly 6 million million miles. Thus the nearest star is a little over 4 light years away. Our sun is 26,000 light years from the center of our galaxy, the Milky Way. Such distances become almost beyond our comprehension.

Is then the travel of man to the stars a futile dream? You remember the verse:

> The world will last when gone are we
> Without a trace of thee or me.
> Before we came there was no void,
> And when we're gone the same 'twill be.

I wonder. Since the invention of writing the thoughts, the knowledge, and the influence of men who lived thousands of years ago are still available. Each age builds on the shoulders of the past. Who then dares to limit the horizons of the physical universe to be ultimately explored by man? The exploration of space has begun; who knows where it will end?

TRACKING CAMERA PHOTOGRAPHS VANGUARD I IN ORBIT

The Smithsonian Optical Tracking Station at Woomera, Australia, has successfully photographed the Vanguard I earth satellite at the apogee of its orbit, nearly 2,500 miles from the earth. The Woomera station is operated for the National Aeronautics and Space Administration as a part of the civilian space agency's worldwide network of tracking stations. The Baker-Nunn precision satellite tracking camera, manned by personnel of the Woomera Missile Range, took pictures of Vanguard I on three occasions, May 1, 3, and 4, 1959. No other object as small as this 6-inch sphere has been photographed from such a distance. It is comparable to aiming a camera at a golf ball 600 miles away.

The tracking camera, one of 12 located around the world, was especially designed for tracking earth satellites during the International Geophysical Year. The Woomera station is operated under the technical direction of the Smithsonian Astrophysical Observatory for the NASA. Equipment at the station is furnished by the United States; staff and buildings are supplied by the Australian Government.

In a congratulatory note to the staff at the station, Dr. Hugh L. Dryden, NASA's deputy administrator, said the tracking team's efforts demonstrated the true capabilities of the Baker-Nunn camera, thus paving the way for more accurate optical satellite tracking data, essential to precise orbital calculations.

The Vanguard I, developed by the U. S. Naval Research Laboratory for the IGY, was launched on March 17, 1958. It was the second scientific satellite launched by the United States. With a perigee of 402 miles, the satellite is currently making 76 orbits a week. During the week of May 17, it completed 4,590 revolutions around the earth since it was launched. The Vanguard program was transferred from the Naval Research Laboratory to the NASA on October 1, 1958.

The other 11 camera stations are located at: Organ, N. Mex.; Olifantsfontein, South Africa; Cadiz, Spain; Tokyo, Japan; Naini Tal, India; Arequipa, Peru; Shiraz, Iran; Curaçao, N.W.I.: Hobe Sound, Fla.; Villa Dolores, Argentina; and Haleakala, Maui, Hawaii.

GEOLOGY.—*Sulphide mineralization and associated structure in northern Union County, Illinois.*

GEORGE A. DESBOROUGH, Southern Illinois University, Carbondale, Ill. (Communicated by David Nicol.)

(Received April 20, 1959)

Minor amounts of sulphide mineralization in Union County of southwestern Illinois have been known for many years, but no attempt has been made to study this outlying occurrence in detail. The area lies midway between the Illinois-Kentucky fluorspar district and the southeastern Missouri lead district and exhibits some characteristics of both. The occurrence is in the complex fault-zone along the Rattlesnake Ferry (Ste. Genevieve) fault and appears as disseminated deposits and as vein filling of fractures in the Backbone limestone of Devonian age. The mineralization consists of galena and sphalerite with subordinate chalcopyrite plus their associated alteration products. The occurrence has characteristics normally attributed to deposits regarded as being of epithermal origin. All features indicate marked structural and stratigraphic control. Subordinate faults with small displacement along the major fault zone seem most favorable for mineralization. Although no systematic prospecting or exploration has been conducted in the area, structural and stratigraphic relationships are favorable for sulphide mineralization.

Since the early 1900's several small-scale operations have been unsuccessfully attemped to extract lead ore from mineralized zones along faults in northern Union County, Ill. These mineralized locales occur along the Rattlesnake Ferry (Ste. Genevieve) fault zone in the S. ½ of sec. 1, T. 11 S., R.3 W. (Alto Pass quadrangle), about 5 miles east of the Mississippi River in the Shawnee Hill Section of southwestern Illinois (Fig. 1).

UNION COUNTY, SOUTHERN ILLINOIS

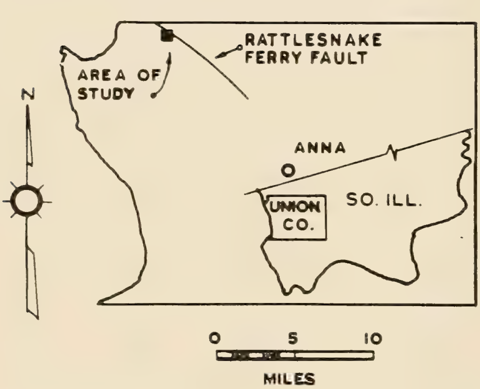

FIG. 1—Index map of area

The area is complexly faulted and, according to Weller and Ekblaw (1940, p. 25), displacement along the Rattlesnake Ferry fault may exceed 1,500 feet. In some areas the numerous faults occur in a zone one-half mile wide; however, in the vicinity of Grassy Knob (just east of the Big Muddy River and south of Rattlesnake Ferry) the zone is only a few yards wide.

On the south side of the major fault zone, the strata are almost exclusively Lower and Middle Devonian. The strata exposed on the north side of the fault are dominantly of Chesteran age (late Mississippian), although many of the hills are capped by Caseyville (Lower Pennsylvanian) outliers.

In the area immediately north of the major fault zone and west of Alto Pass, numerous north-south trending faults complicate the structural and stratigraphic relationships (Ekblaw, 1925; Desborough, 1957). At least two periods of faulting are evident in this area, one prior to Pennsylvanian deposition, and the other during post-Pennsylvanian time (St. Clair, 1917; Ekblaw, 1925; J. M. Weller and Ekblaw, 1940; Weller, 1940; Desborough, 1957).

STRATIGRAPHY

The mineralization and associated structures are apparently restricted to the Backbone limestone and the Clear Creek chert, both of Devonian age. About one-half mile north of the mineralized area Mississippian rocks of Meramecian and Chesteran age are exposed. The complete Chester series is exposed, as well as the Ste. Genevieve formation of the Meramec group. The Chester

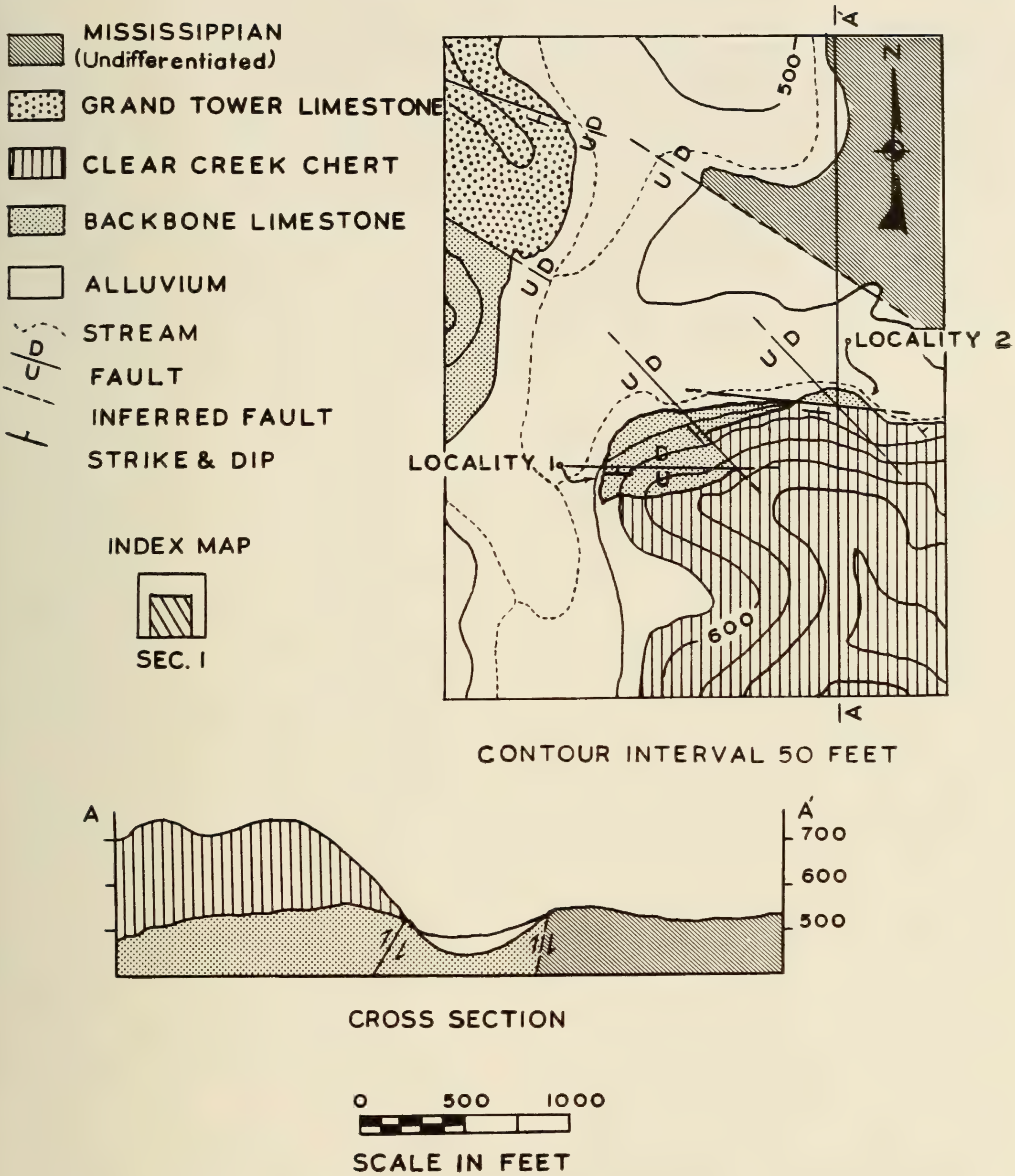

FIG. 2.—Areal geologic map and cross-section of area in Sec. 1, T. 11S., R. 3W., Alto Pass quadrangle, Illinois.

strata are overlain unconformably by Lower Pennsylvanian clastic sediments. The stratigraphic relationships of the Backbone limestone and the Clear Creek chert are as follows:

Middle Devonian
- Dutch Creek sandstone (not exposed)
- Clear Creek chert..........300 feet thick

Lower Devonian
- Backbone limestone........200 feet thick
- Grassy Knob chert (not exposed)

PAST AND PRESENT STUDIES

The general geology of this area has been studied by Worthen (1868), St. Clair (1917), Savage (1920), Poor (1923), Basset (1925), Ekblaw (1925), S. Weller and J. M. Weller (1939), J. M. Weller and Ekblaw (1940), and J. M. Weller (1945). Recently, Bradbury (1957) wrote a brief description of the mineralized area. He summarized the data obtained in the past and added new observations. Subsequently, local interest in the mineralization has been stimulated. As a result several prospect pits were made in the bedrock of sec. 1 (Fig. 2).

The blasting and removal of overburden during the late fall of 1957 and the early winter of 1958 exposed the nature of the mineralization as well as interesting structural relations. During the period of excavating and blasting, the writer frequently visited, examined, and photographed some of the significant geologic features, several of which have been obscured by later excavations. Thin sections of the wallrock and the mineralized rock were prepared and studied.

This paper attempts to describe and explain in some detail the nature of the mineralization and structure. In some aspects my interpretations differ from those of earlier writings.

Two locales of mineralization will be discussed herein, designated as Locality 1 and Locality 2. Locality 1 refers to the mineralized area at the normal fault near the stream junction (Fig. 2). Locality 2 refers to the mineralized area at the junction of the two faults exposed near the stream in the south valley wall of Hutchins Creek (Fig. 2).

LOCALITY 1

Locality 1 was apparently referred to as the "third caved shaft or prospect pit" by Bradbury (1957, p. 2). He implied that this prospect pit is situated on a northwesterly trending fault, based on Weller and Ekblaw's geologic map (1940, pl. 1). Recent excavations have revealed the mineralization to be along an approximately vertical E-W striking fault which involves only the Backbone limestone at the surface. The displacement is probably small. The brecciation and drag features of the northern fault block indicate it is downthrown.

The host, Backbone limestone, is a light gray, dense limestone, part of which has been altered to ocherous material. A few hundred feet north of the fault, the Backbone limestone contains inch-thick beds of chert. Alteration of the host rock by mineralizing solutions is not evident.

Mineralization is concentrated in the downthrown block and consists of vein calcite and subordinate galena, sphalerite, and chalcopyrite. Smithsonite and limonite occur locally as oxidation products. Galena is found in the calcite as masses up to 6 inches long and as small euhedral crystals disseminated in the limestone. Sphalerite is found as crystalline encrustations upon calcite crystals and as linings in small vugs. Chalcopyrite occurs as small disphenoids enclosed by calcite. The smithsonite is sparsely scattered between the calcite crystals in small, green, crystalline masses. Limonite occurs as pseudomorphs after chalcopyrite.

Contact relations between mineral grains indicate the following sequence of deposition: (1) calcite I, (2) chalcopyrite, (3a) calcite II, (3b) sphalerite-galena, (3c) calcite II. Calcite I is very coarse-grained and semitransparent, and it contains disphenoids of chalcopyrite. Because small disphenoids of chalcopyrite are found upon calcite I crystals in vugs, as well as included within large calcite crystals, deposition of calcite I must have begun prior to and ended after the chalcopyrite stage. Calcite II is represented by a medium-grained, white to gray variety; its contact relations with galena indicate the calcite is younger. However, subhedral crystals of sphalerite are found upon calcite II. These factors suggest the calcite II stage preceded the sphalerite-galena stage and continued after the cessation of the latter.

LOCALITY 2

Locality 2 is in the center of the W.½, E.½, SE.¼, of sec. 1 (Fig. 2). According to Bradbury's report (1957, p. 2), the exact location of the exposure is uncertain since there are many prospect pits in the vicinity. Possibly it was this exposure that Bradbury referred to as the "first shaft," because mineralization here is apparently restricted to the Backbone limestone. Bradbury probably based his locations upon Weller and Ekblaw's preliminary geologic map (1940, pl.

1), which is generalized because of its small scale.

Excavations at this location within the past year have revealed minor sulphide mineralization in the Backbone limestone and complex structural and stratigraphic relationships.

Structural and stratigraphic relationships.—The fault at Locality 2 which strikes N.45–50°W. is a normal one (Fig. 2, 3). It dips about 80° NE., and the stratigraphic displacement is probably less than 5 feet; however, a vein about 3 feet wide occupies the fracture on the north side of the N.80°W. fault (Fig. 3).

The Clear Creek chert and Backbone limestone lie in normal contact on the south side of the major fault (Fig. 3, 4). This fault strikes about N.80°W. and dips 60°SW. (Fig. 3). About 25 feet of Backbone limestone is exposed above the creek bed (Fig. 2). The exposures of Backbone limestone on each side of the fault are apparently in place, and they are almost identical in thin section and hand specimens. To establish whether or not the limestone beneath the Clear Creek chert was a calcareous component of the lower Clear Creek formation, a thin section of the Clear Creek limestone from the locality described by Weller (1940, p. 24) was studied. Mineralogically, the Clear Creek limestone contains abundant glauconite and is much more siliceous than the Backbone limestone at the mineralized locale. Both chalcedony and euhedral to subhedral quartz grains are abundant in the Clear Creek limestone, whereas the Backbone limestone thin sections are essentially quartz-free. At the mineralized locale the Clear Creek chert is not calcareous and is in beds 2 inches to one foot thick, whereas the Backbone limestone is chert-free and conspicuously styolitic. The latter has also been recrystallized by mineralizing solutions or tectonic stress.

The structural and stratigraphic relationships discussed above show that the fault block on the south must have moved down relative to the opposite block (Fig. 3). This is contrary to what one might expect, as the relative displacement along the major fault zone shows that most fault blocks on the southwest side of northwesterly trending faults are upthrown. Also, the regional displacement along the Rattlesnake Ferry fault zone demonstrates that the north side is downthrown. It is not likely that the fault in question is an antithetic fault since it is not in the downthrown block relative to the major displacement along the large fault zone (de Sitter, 1956, p. 154). It has been pointed out that movement in opposite directions along the same fault plane during two periods of faulting may have occurred a few miles northeast of the area discussed here (Desborough, 1957, p. 201). This writer proposes that the fault is probably due to normal fault movement along a former reverse fault plane.

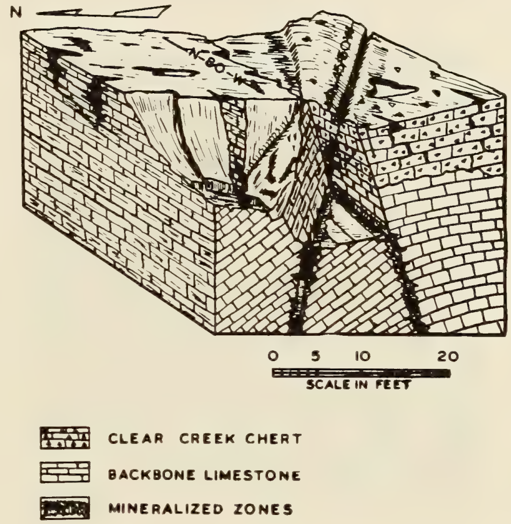

Fig. 3—Diagrammatic sketch of structural and stratigraphic relationships of the Backbone limestone and Clear Creek chert at Locality 2.

Weller and Sutton (1940, p. 852) have also suspected movement along faults "at several different times and in several different directions, with complete reversal in some places" several miles to the east in the fluorspar district of southeastern Illinois and western Kentucky. Weller and Ekblaw (1940, p. 26) recognized the existence of high-angle thrust faults in southern Illinois and attributed these to compressional forces.

The following observations collectively suggest at least two movements, in opposite directions, along the N.80°W., 60°SW. fault plane at Locality 2: (1) Stratigraphic relationships signify the south fault block is downthrown (Fig. 3). (2) The major regional displacement along the northeast side of the Rattlesnake Ferry Fault shows the south side is upthrown. (3) Empirical knowledge of the area indicates nearly all northwesterly trending faults have their north fault block downthrown. (4) Dip of strata adjacent to the fault plane due to drag effect indicates reverse fault movement because the strata dip north whereas the fault plane dips south (Fig. 3). (5) Directional

Fig. 4—Slickensides (lower left) developed along N.80°W. fault in Backbone limestone just below Clear Creek-Backbone contact (at pick handle). Locality Two.

smoothness along well-developed slickensides indicates the south fault block to be upthrown (Fig. 4).

The N.45–50°W. fault intersects, continues across, and displaces the N.80°W. fault plane (Fig. 3), indicating the N.45–50°W. fracture occurred later than the last displacement (normal fault movement) along the N.80°W. fault. The N.45–50°W. fault was present before the deposition of the mineralizing solutions which are contained in its fracture. This suggests that the mineralization emplacement may have occurred (a) later than that period of faulting during which the reverse fault occurred and (b) after the normal fault movement along the existing reverse fault plane.

Studies in the Pomona Area a few miles to the northeast have shown that two separate periods of faulting occurred in the area: post-Chesteran–pre-Pennsylvanian and later post-Pennsylvanian displacements along the same fault-plane (Desborough, 1957, p. 201). Evidence suggesting movement along the same fault plane, in opposite directions during separate periods of faulting, has been presented (Desborough, 1957, p. 201).

Weller and Ekblaw (1940, p. 26) imply that thrusting forces originating in the Ozark region resulted in the formation of the Rattlesnake Ferry Fault. The writer agrees. They also suspected this structure "originated in post-Mississippian–pre-Pennsylvanian time and has subsequently been accentuated" (Weller and Ekblaw, 1940, p. 25).

On the assumption that the first displacements along the Rattlesnake Ferry Fault originated during the post-Mississippian interval, reverse-fault movement along the N.80°W. fault at Locality 2 probably occurred at that time. According to Weller's observations (1940, p. 51), local compressional forces would cause reverse fault displacement. The displacement now evident along the N.80°W. fault (Fig. 3) is apparently due to normal-fault movement. This movement suggests tensional forces which were accommodated because a previously formed fault was present.

Mineralization.—The rock at Locality 2 is not appreciably brecciated as it is at Locality 1. Mineralization here consists of vein calcite with minor amounts of galena, sphalerite, and sparsely scattered euhedra of chalcopyrite. Vein calcite occurs abundantly only along the N.45–50°W. fault plane, the mineralized portion of which is not more than 3 feet wide. Galena occurs in chunks up to 6 inches across with well developed cube faces. Replacement is indicated by the random distribution of sphalerite in the Backbone limestone. It is also present as cavity fillings in the form of veinlets an inch in width. The veinlets probably formed along joints, as they are generally parallel to the N.40–50°W. fault. Sphalerite also occurs as cavity fillings along the styolites. It is particularly conspicuous along both fault planes, including the slickensides in the Backbone limestone (Fig. 4). Galena is present as cavity fillings in the form of veinlets with the same strike as those with sphalerite. They have not been found together in the same veinlet. Some of the veinlets have been oxidized to limonite and exhibit boxworks. Excavations along the N.45–50°W. fault in the creek bed revealed abundant vein calcite and chunks of galena as large as 6 inches in diameter with sphalerite in lesser amounts. No smithsonite was observed here.

The paragenesis at Locality 2 is vague. In one small veinlet contact relations of minerals suggest that some calcite is older than galena. Where sphalerite and calcite are found in veins the sphalerite is older. On the other hand, where sphalerite is randomly distributed in limestone and not in veins, it is younger than the associated calcite. Age relationships between galena and sphalerite are not clear. As at Locality 1, two generations of calcite are inferred if it may be assumed that in usual sequence, sulphides are deposited later than one stage of calcite (McKinstry, 1948, p. 149).

Late in the fall of 1957 an exploration hole 80 feet deep was drilled about 300 feet northeast of Locality 2. It is reported to have penetrated 80 feet of valley fill which consisted mostly of sand and gravel. This suggests that the slope of the hill on the south valley wall may continue downward as much as 100 feet vertically with the same steep gradient now exhibited by the hill above the valley-fill (cross-section, Fig. 2).

CONCLUSIONS

(1) Mineralization is concentrated along both E-W and NW-SE trending faults.

(2) The glauconite content and abundance of silicic (chalcedony and quartz) material in the Clear Creek limestone of this area permits its differentiation from upper Backbone limestone.

(3) Evidence strongly suggests movement along the same fault plane in opposite directions during two separate periods of faulting.

(4) Reverse fault movement along the Rattlesnake Ferry fault zone is suggested.

(5) The upper Backbone limestone may be a host for sulphide mineralization in adjacent areas where it is not siliceous and faults are present.

ACKNOWLEDGMENT

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REFERENCES

BASSET, C. F. *The Devonian strata of the Alto Pass quadrangle.* Trans. Illinois Acad. Sci. **18**: 360–368, 3 figs. 1925.

BRADBURY, JAMES C. *Outlying occurrences of galena, sphalerite, and fluorite in Illinois.* Geol. Surv. Illinois, Ind. Min. Notes **7**: 4. 1957.

DESBOROUGH, GEORGE A. *Faulting in the Pomona Area, Jackson County, Illinois.* Trans. Illinois Acad. Sci. **50**: 199–204, 3 figs. 1957.

DE SITTER, L. U. *Structural geology:* 522, 309 text figs. New York, 1956.

EKBLAW, GEORGE E. *Post-Chester, Pre-Pennsylvanian faulting in the Alto Pass Area.* Trans. Illinois Acad. Sci. **18**: 378–382, 1 fig. 1925.

MCKINSTRY, H. E. *Mining geology:* 680, 3 pls., 145 text figs. New York, 1948.

POOR, R. S. *The stratigraphy of the Mississippian System in the Alto Pass quadrangle.* University of Illinois master's thesis, unpublished mss.

SAVAGE, T. E. *The Devonian formations of Illinois.* Amer. Journ. Sci. **49** (4): 169–182, 1 pl., 3 figs. 1920.

ST. CLAIR, STUART. *Oil investigations in part of Williamson, Union, and Jackson Counties.* Geol. Surv. Illinois **35**: 53, 3 pls., 2 figs. 1917.

WELLER, J. MARVIN. *Geology and oil possibilities of extreme southern Illinois.* Geol. Surv. Illinois, Rept. Inv. **71**: 71, 1 pl. 1940.

———. *Geologic map of Illinois.* 1945.

WELLER, J. MARVIN, and EKBLAW, GEORGE E. *Preliminary geologic map of part of the Alto Pass, Jonesboro and Thebes quadrangles.* Geol. Surv. Illinois, Rept. Inv. **70**: 26, 1 pl. 1940.

WELLER, J. MARVIN, and SUTTON, A. H. *Mississippian border of the Eastern Interior basin.* Bull. Amer. Assoc. Petroleum Geol. **245** (5): 765–858, 10 figs. 1940.

WELLER, S., and WELLER, J. MARVIN. *Preliminary geologic maps of the pre-Pennsylvanian formations in part of southwestern Illinois.* Geol. Surv. Illinois, Rept. Inv. 59: 1 pl., 2 figs. 1939.

WORTHEN, A. H. *Geology of Alexander, Union, and Jackson Counties.* Geol. Surv. Illinois **3**: 20–83, 3 pls. 1868.

ENTOMOLOGY.—*Seven new galerucid beetles from the West Indies.* DORIS H. BLAKE, Arlington, Va.

(Received April 21, 1959)

Six of the seven new species of Galerucinae from the West Indies described in this paper were collected by Fernando de Zayas in Cuba. He has been collecting insects there for many years until he has a large number which may in time form the nucleus of a National Collection of Cuba.

Monocesta cubensis, n. sp.

Fig. 4

About 6 mm in length, elongate oblong, the elytra covered wth fine pale pubescence, prothorax with a transverse groove, dirty yellowish brown, the head with a piceous band on either side, leaving only a narrow pale vertex; elytra with broad dark humeral vitta having a violet lustre and extending to the apex and uniting with a narrow marginal vitta, a shorter subsutural vitta uniting across the base with the others but not reaching the apex; breast and abdomen except tip dark, legs and antennae bicolored.

Head with a broad piceous band extending on either side from occiput about eye, leaving a narrow pale yellow brown stripe down front; mouthparts deep brown, occiput smooth with a few short hairs at base of head, frontal tubercles distinct. Antennae with only the six basal joints present in the single specimen, these pale at base, piceous at apex, second and third joints subequal, fourth as long as second and third together, fifth shorter than fourth. Prothorax approximately twice as broad as long, almost rectangular with a strong tooth at each angle, a transverse median sulcus and a smaller one in the middle over the occiput; surface shining, impuncate, yellowish brown. Scutellum dark with a violaceous luster, densely pubescent. Elytra elongate, not perceptibly wider apically, humeri prominent, a short intrahumeral sulcus, faint subcostate ridges along the middle, surface shining feebly beneath the very fine and appressed pale pubescence, and densely, finely, and shallowly punctate; pale yellow-brown with a broad subsutural dark vitta having a violaceous luster and not reaching apex, a broad lateral vitta from humerus to apex and a marginal vitta uniting at humerus and apical curve with the lateral vitta. Body beneath with breast and abdomen except the tip dark. Legs having the anterior and middle femora pale with a median and apical dark area, the posterior femora dark at apex, anterior tibiae dark on one side, middle and posterior tibiae dark at base and apex, tarsi with apex of each joint dark. Length 6 mm; width 2.3 mm.

Type, female, in collection of F. de Zayas, from La Breña, Moa, Oriente Province, Cuba, collected by Fernando de Zayas and Pastor Alayo.

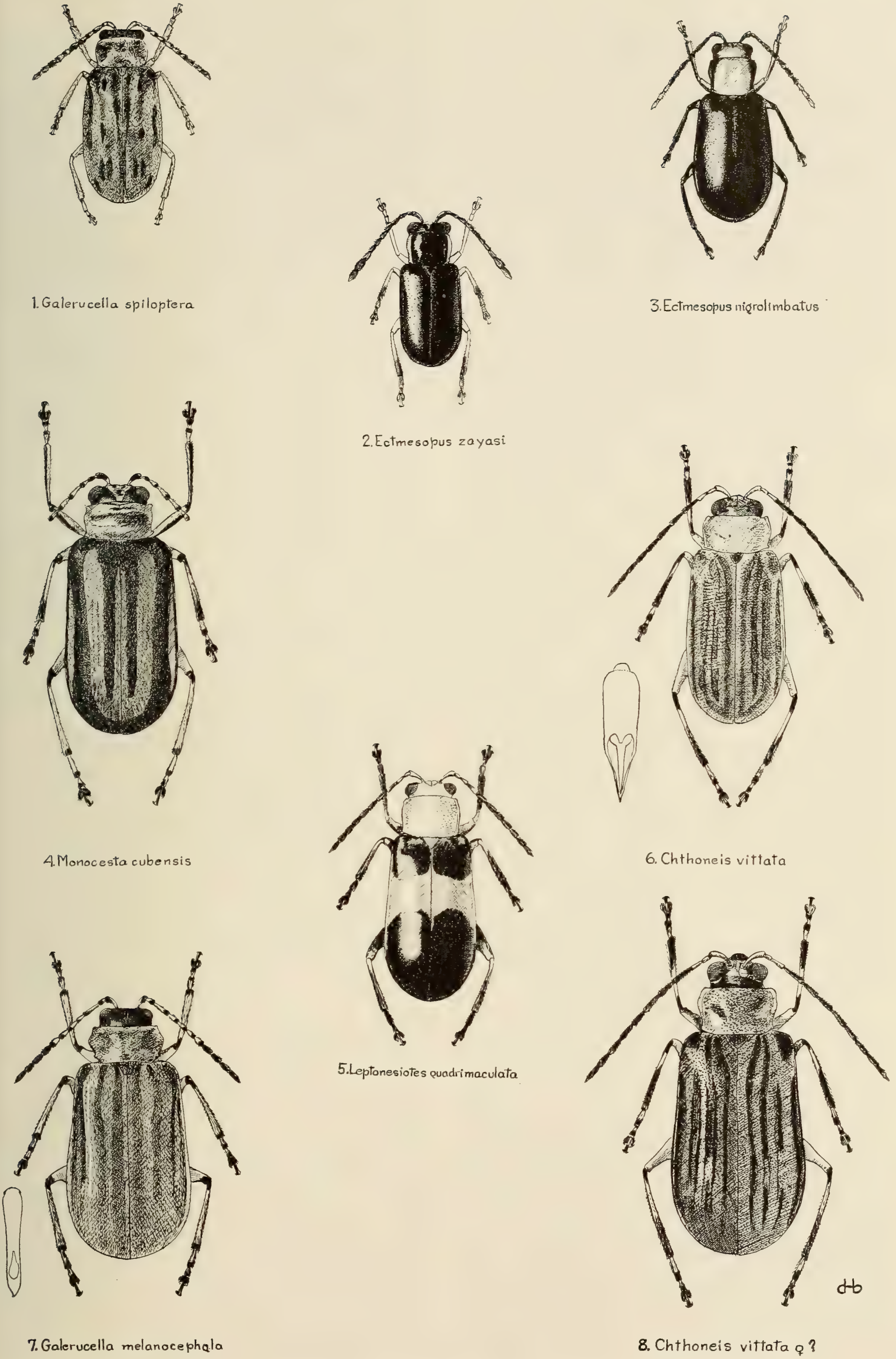
Remarks.—One species of *Coelomera* has been described from Cuba by Suffrian, *C. liturata*, and although the description resembles somewhat the present species, the beetle is evidently a true *Coelomera* in that the third antennal joint is twice as long as the second. In addition only two washed-out pale vittae are on the elytra, and the elytra are somewhat widened behind, which is not the case in the present species. This is the first *Monocesta* known from the West Indies. In Clark's classification of the genus it belongs to Division B, the smaller, more parallel-sided beetles, with the elytra not postmedially dilated.

Galerucella melanocephala, n. sp.

Fig. 7

About 5 mm in length, oblong oval, covered with short, pale, closely appressed pubescence, the elytra more densely and coarsely punctate than the prothorax, the prothorax depressed at sides and middle; pale yellow-brown, the head more or less black over occiput, antennae with apices of joints 1 to 7 black, rest dark; femora, tibiae and tarsi dark at apices, elytra with three pale reddish brown vittae on each, becoming indistinct before apex.

Head with interocular space more than half its width, a median line down occiput to frontal tubercles, upper part of head dull, closely punctate, and covered with pale pubescence; interantennal area flat, upper part of head dull black usually, sometimes dark on either side with a pale area between, from tubercles to labrum pale, labrum dark. Antennae not extending to middle of elytra, stout, the third joint longest, pale with the apices of joints 1 to 7 black,



FIGS. 1–8.—West Indian Galerucinae.

8 to 11 entirely dark. Prothorax twice as wide as long, widely depressed at sides and down the middle, lateral margin somewhat angulate, a small tooth at basal and apical angles; surface punctate, and covered with pale appressed pubescence, entirely pale. Scutellum squarish, pale. Elytra densely and strongly punctate, covered with short pale pubescence, through which on the pale yellow brown surface the punctures are apparent; three rather narrow pale reddish brown vittae on each elytron, becoming indistinct before apex, remnants of another below humerus on the side, not apparent from above. Body beneath pale with the breast and area about coxae a little darker; legs pale, the apices of femora, knee of tibiae and apices of tibiae and tarsi black. Length 5.3 to 5.8 mm; width 2.2 mm.

Type, male, U.S.N.M. type no. 64684, taken at La Breña, Moa, Oriente Province, Cuba, in June 1954 by F. de Zayas and Pastor Alayo. A second specimen was taken at Yunque, Oriente Province, in July 1955 by Zayas, and a third at Piloto, Moa, Oriente Province, June 1954, by Zayas and Alayo.

Remarks.—This is distinguished from the other Cuban species of *Galerucella* by the black or partly black occiput (one specimen from Piloto has the occiput and tubercles black with a pale area between).

Galerucella spiloptera, n. sp.

Fig. 1

About 4 mm in length, oblong oval, covered with fine pale pubescence, punctate beneath, pale yellow brown, the elytra with deep brownish spots and remnants of vittae along suture, middle of elytra and along the sides; antennae pale with apices of joints a little darker.

Head with interocular space more than half its width, a median depressed line down occiput to inconspicuous frontal tubercles, area between antennal sockets flat, lower front short, labrum small, a short, closely appressed pale pubescence covering occipital sculpture. Antennae stout, extending below humeri but not to middle of elytra, third joint longest, all joints pale with apices a little darker. Prothorax approximately twice as wide as long with slightly rounded sides, surface widely depressed on sides and in middle, covered with short, closely appressed pale pubescence hiding the punctation beneath; entirely pale. Scutellum pale. Elytra densely and strongly punctate, the punctures visible through the dense, fine, closely appressed pubescence, a long incurving intrahumeral depression, another along the suture below scutellum, and another along the side before the apex; yellow brown with cinnamon brown spots and fragments of vittae along the suture, a spot near base in middle, another half way down and two elongate ones before apex, a spot covering humerus and extending down the side, more or less interrupted to apical curve. Body beneath a little deeper brown than upper surface, shining, thinly pubescent. Legs entirely pale. Length 4.2 mm; width 1.8 mm.

Type, male, U.S.N.M. type no. 64683, taken in Miami, Fla., from a plane from Curaçao, Dutch West Indies, via Jamaica, B.W.I., collected by W. F. Buren on March 29, 1946.

Remarks.—The spotted markings, or interrupted elytral vittae, differentiate this small species from the others in the West Indies. It somewhat resembles *G. interrupta* Jacoby from South America, a larger, less pubescent species.

Chthoneis vittata, n. sp.

Figs. 6, 8

About 5 mm in length, oblong oval, shiny, densely punctate, the elytra faintly costate, dirty yellow brown, the head and breast deeper brown, antennae, except the basal joints, brown, each elytron with four more or less interrupted brownish vittae, tibiae and tarsi bicolored.

Head with interocular space approximately half width of head, frontal tubercles large and distinct, a large shallow fovea on each side near eye, a short, narrow carina between antennal sockets, lower front short; deep brown in color with the labrum darker brown. Antennae long and slender, the three basal joints pale, rest dark brown, second and third joints together equal fourth in length, rest long but not so long as fourth, and gradually diminishing a little. Prothorax almost twice as wide as long, widest apically with a broad tooth at apical angle, disk a little uneven with a slight bump on either side near margin, surface shiny, finely punctate, entirely yellow-brown. Scutellum dark brown. Elytra rather depressed, several costae more distinct in apical half; surface shiny, densely and somewhat rugosely punctate; yellow brown with four deep reddish brown vittae on each elytron, the second and third being interrupted before apex, and the lateral one broadening to cover humerus. Epipleura vanishing soon after the middle. Body beneath pale with breast in part deep brown and tibiae at knee and towards apex dark, the tarsal joints pale at base and dark at apex. Coxal cavities open, claws appendiculate. Length 5.2 mm; width 2 mm.

Type, male, U.S.N.M. type no. 64685, from Piloto, Moa, Oriente Province, Cuba, collected in June 1954 by F. de Zayas and Pastor Alayo. One paratype in collection of F. de Zayas.

Remarks.—This third species of *Chthoneis* has been collected by Zayas and Alayo in the mountains of Oriente Province, Cuba. This one differs from the other two West Indian species in being vittate, but is of the same dirty yellowish brown coloration otherwise. The aedeagus bears a strong resemblance to that of *C. insulae* Blake, also from Cuba. A specimen collected at Gran Tierra, Moa, Oriente Province, on June 5, 1951, by Zayas is considerably larger (length 7 mm; width 2.8 mm), and darker in coloring. The prothorax in relation to the elytra is not so wide. Unfortunately only one specimen, a female, is at hand, and it is not clear from this single specimen whether this is a distinct species or merely a large female specimen of *C. vittata*. A drawing has been made of it.

Ectmesopus zayasi, n. sp.

Fig. 2

About 2 mm in length, narrowly oblong, shining, deep blue above except for the wide pale margin on the prothorax and the pale lower part of the face, the legs pale with apices of middle and posterior tibiae and tarsi brownish; lower surface pale, the breast a bit darker. Antennae in male with the two terminal joints enlarged and middle tibiae notched near apex.

Head with interocular space approximately half width of head, upper part piceous with fine punctures, tubercles and lower front pale yellow; tubercles distinct, a narrow carina down lower front. Antennae in male with tenth and eleventh joints enlarged, dark brown, the basal joints a little paler. Prothorax narrow, a little wider than long, with nearly straight sides, without depressions, shining deep piceous with a bluish luster, the margins pale yellow; impunctate. Scutellum dark. Elytra shining deep blue with distinct punctation. Body beneath pale, the breast a little darker, legs pale with the apical half of middle and posterior tibiae and tarsi deeper brown. Middle tibiae in male notched. Length 2 mm; width 0.9 mm.

Type, male, from Somorrostro, San José de las Lajas, Havana Province, Cuba, collected by F. de Zayas, and in his collection.

Remarks.—None of the other species of *Ectmesopus* so far described except *E. tristis* Blake, which is entirely dark, has so nearly dark a pronotum, in this case only the margin on the sides is pale. The usual abnormality of the male antennae is in the last two thickened joints.

Ectmesopus nigrolimbatus, n. sp.

Fig. 3

About 3.5 mm in length, elongate oblong-oval, shining, the elytra densely and distinctly punctate, pale reddish yellow with the eight basal antennal joints darker, the femora with a dark streak above, tibiae and tarsi dark, sides of pronotum narrowly dark, elytra deep blue.

Head with interocular space half width of head, occiput shining and smooth, very finely punctate, frontal tubercles well defined, a narrow carina between antennal sockets running down front. Antennae not reaching the middle of the elytra, third joint a little longer than second, about half as long as fourth; basal eight joints deep brown, apical three reddish yellow. Prothorax nearly as long as wide, with slightly curved sides, disk not depressed but smoothly convex, basal angles oblique; pale reddish yellow with sides narrowly piceous, the dark area wider anteriorly, surface shining, impunctate. Scutellum reddish brown. Elytra slightly wider apically, with distinct intrahumeral sulcus and well marked humeri; shining, densely and distinctly punctate, deep blue. Body beneath reddish yellow, the femora pale with a dark streak above and at apex, front tibiae dark on upper side, pale beneath, middle and hind tibiae entirely dark, tarsi dark. Length 3.7 mm; width 1.7 mm.

Type, female, from Piloto, Moa, Oriente Province, Cuba, collected in June 1954 by Fernando de Zayas and Pastor Alayo, and in the collection of Zayas.

Remarks.—Although only a female of this species is known, I am pretty sure that the male has notched middle tibiae and probably some deformity of the antennal joints. The only two other species having a close resemblance to this are from Haiti and the Dominican Republic, *E. angusticollis* Blake and *E. leonardorum* Blake. Both species have dark sides to the prothorax but differ from the rest of the genus in being more slender.

Leptonesiotes quadrimaculata, n. sp.

Fig. 5

About 5.5 mm in length, elongate oblong oval, the elytra finely and confusedly punctate, pale reddish, the antennae, tibiae and tarsi deeper brown, the femora in basal half with a metallic luster, the abdomen also metallic, the elytra with a large basal fascia interrupted at the suture, and an apical one covering apical half, these spots being bluish green.

Head with interocular space half its width, occiput well rounded, smooth, shining, nearly impunctate; frontal tubercles distinctly marked, a short carina between antennal sockets; head entirely pale reddish. Antennae not extending to the middle of the elytra, gradually thickening toward apex, third joint shorter than fourth, basal joints pale, the remaining ones deeper brown. Prothorax a little wider than long, with nearly straight sides, apical angle obtusely truncate, disk smoothly convex, without depressions, entirely pale reddish, shining, impunctate. Scutellum pale. Elytra wider than prothorax and slightly wider apically, a short intrahumeral sulcus, surface finely punctate, shining, pale reddish with a broad basal fascia narrowly interrupted at the suture of lustrous bluish green, and another even broader area covering apical half of elytra. Body beneath reddish brown with the middle of the breast and abdomen darker brown, the abdomen having a metallic lustre, femora also with metallic lustre, except at apex which is pale; tibiae and tarsi brown. Anterior coxal cavities open. Claws appendiculate. Length 5.7 mm; width 2 mm.

Type, female, collected at Rancho Luna, Cienfuegos, Las Villas Province, Cuba, in June 1955, by Fernando de Zayas, and in his collection.

Remarks.—Although no male has been examined, I believe that this is closely related to *Leptonesiotes cyanospila* (Suffrian) and that the male has notched middle tibiae and possibly enlarged hind femora. It has a color pattern similar to that species but instead of the small basal and apical spots, the present species has spots so large as to form basal and apical fasciae.

AMERICAN INSTITUTE OF CHEMISTS HONOR AWARD

Thomas R. Henry, the *Washington Star's* science columnist, was recently presented with the annual honor award of the Washington Chapter, American Institute of Chemists. Mr. Henry was cited for his service to science as a professional writer and author and for his ability and untiring efforts in keeping the public informed of important and noteworthy advances in science through the medium of the press.

The presentation was made by Dr. Emil Ott, past-president of the American Institute of Chemists, at a dinner held at the Army-Navy Club on May 27, 1959. Dr. Ott emphasized Mr. Henry's contributions to science reporting and his efforts in the education of editorial writers on the importance of disseminating science news to the public.

The invitation address was delivered by Benjamin McKelway, editor of the *Evening Star*. He praised Mr. Henry for his ability as a reporter who has written articles on many important news events. He also praised Mr. Henry's style and firm grasp of his subjects.

In his acceptance address, Mr. Henry outlined the progress made in science reporting over the past 30 years. Further, he pointed out that journalism and science have been accepting each other and as a result have contributed to public understanding and progress of science itself.

ZOOLOGY.—*Muscles of the hip and thigh of the emperor penguin.* L. R. SETTY, School of Medicine, Howard University. (Communicated by Herbert Friedmann.)

(Received March 11, 1959)

Some emperor penguins, *Aptenodytes fosteri,* recently brought from the Antarctic to the zoo at Portland, Oreg., died from an epidemic of aspergillosis. After autopsy, some parts of the bodies of the dead birds were in a satisfactory condition for anatomical study. The musculature of the hip and thigh was one of such parts.

METHOD

One specimen was prepared to show the skeleton of the region; another, the musculature. The latter was preserved in a solution made of a mixture of equal parts of 4-percent formaldehyde, glycerine, and 95-percent alcohol. This specimen was used for the dissection of the muscles.

The function of each muscle was determined by pulling on the muscle from near the point of insertion toward the point of origin.

The descriptions of the muscles of the hip and thigh of a penguin, *Eudyptes chrysocome,* by Watson (1883) were used as a guide.

Although Watson in his work on *Eudyptes chryosocome* considered the trunk to be in a horizontal position, the natural vertical position of the trunk is taken as the basis of orientation in the present study.

RESULTS

The bones serving for the attachment of the muscles of the hip and thigh are shown in the accompanying labeled photograph (Fig. 1).

In both the fresh and the preserved conditions, the muscles are very dark red-brown. Their strong fishy odor remains even after the addition of the above preservative.

The superficial muscles of the lateral aspect of the hip and thigh (Fig. 2) are the following:

Sartorius. This is a very large, elongated muscle and the most cephalic of all the muscles of the thigh. It originates by an aponeurosis from about 2.5 cm of the cranial end of the coalesced spinous processes of the lumbosacral portion of the vertebral column and the spinous process of the four thoracic vertebrae immediately above. It arises also along the dorsolateral edge of the cephalic end of the ilium. The fibers pass obliquely to the insertion of the muscle on the anterocephalic part of the patella.

Sartorius flexes the thigh and extends the leg.

Rectus femoris. The cephalic portion of the musculoaponeurotic sheet that covers the lateral surface of the thigh is rectus femoris. It arises by an aponeurosis from the coalesced spinous processes of the lumbosacral portion of the vertebral column. The fibers run transversely to the insertion which is by a tendon in common with the tendon of extensor cruris (Fig. 3) to the posterior side of the patella.

Rectus femoris flexes the thigh and extends the leg.

Tensor fasciae femoris. The caudal portion of the musculoaponeurotic sheet that covers the lateral surface of the thigh is tensor fasciae femoris. It originates from the coalesced spinous processes of the lumbosacral vertebrae by an aponeurosis shared with rectus femoris. The fibers take a transverse course, and the insertion is by a tendon into the posterocaudal part of the patella and the cephalic end of the lateral upper tibial crest (Fig. 1).

This muscle extends the thigh and flexes the leg.

Biceps femoris. This is a large muscle immediately caudad of tensor fasciae femoris. It originates along the posterior border of the innominate bone and on the caudal margin of the tendon of origin of the tensor fasciae femoris. Its fibers run laterally and slightly caudally to the insertion which is made by a tendon on a tubercle on the outer side of the fibula at the junction of the upper and middle thirds of that bone (Fig. 1). The tendon of insertion passes through a loop of a band-like tendon extending from the distal end of the lateral surface of the shaft of the femur to the tendinous outer head of origin of a leg muscle (gastrocnemius). The loop is thickened where it makes a sharp bend around the caudal border of the tendon of biceps femoris.

The sciatic nerve lies just below biceps femoris and runs almost parallel to the long axis of this muscle. As soon as the nerve makes its exit from the pelvis, it sends branches into biceps femoris (Fig. 3).

Biceps femoris is an effective flexor of the leg.

Semitendinosus. Semitendinosus is a large muscle situated immediately caudad of biceps femoris and is essentially as wide as that muscle. Semitendinosus arises from the most posterior part of the caudal processes of the innominate bone. It also arises from the transverse processes of the third, fourth and fifth caudal vertebrae. Most of the fibers pass essentially in the transverse plane. Insertion is by a ribbonlike tendon about 3.75 cm long and 1.25 cm wide into the distal end of the medial upper tibial crest (Fig. 1).

This muscle flexes the leg and extends the thigh. If the knee joint be flexed, the posterior fibers depress the tail.

The deep muscles of the hip and thigh (Fig. 3) are as follows:

Gluteus medius. Gluteus medius is a large muscle. It arises from the whole posterior surface of the ilium and from the lateral surface of some of the coalesced spinous processes of the lumbosacral region. The fibers run caudolaterad and are inserted by a tendon on the greater tro-

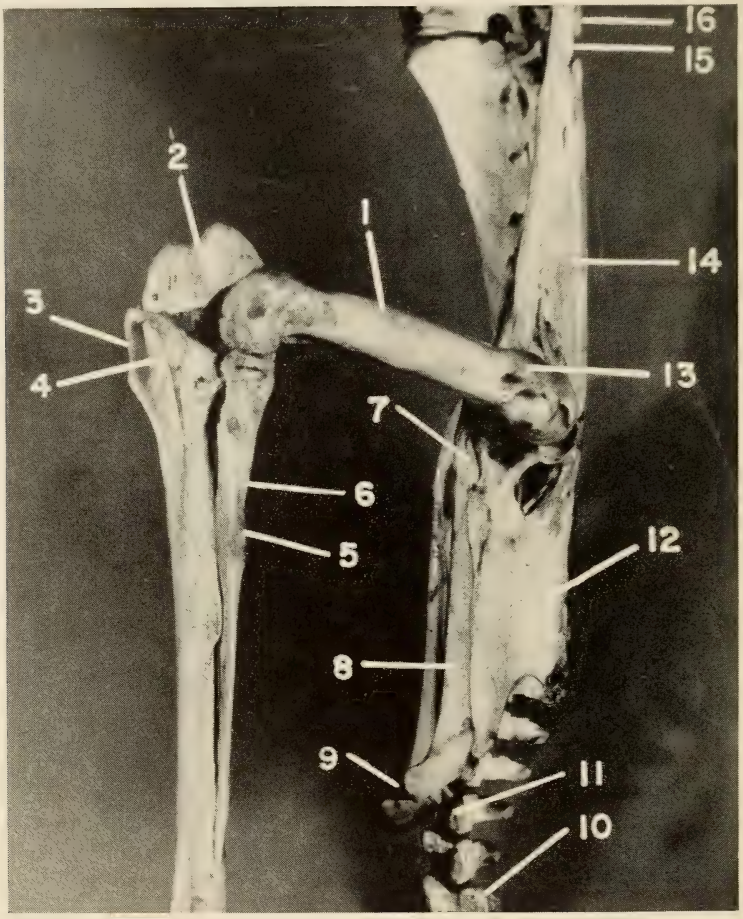


FIG. 1.—Lateral aspect of the portion of the skeleton of *Aptenodytes fosteri* to which muscles of the hip and thigh have attachment. Not all the thoracic vertebrae involved are shown. 1, Shaft of the femur. 2, Groove on the patella for the tendon of musculus ambiens. 3, Medial upper tibial crest. 4, Lateral upper tibial crest. 5, Tubercle of the fibula. 6, Groove on the fibula for the tendon of musculus ambiens. 7, Obturator foramen. 8, Pubic portion of the innominate bone. 9, Cartilaginous tip of the pubic bone. 10, Pygostyle. 11, Transverse process of a caudal vertebra. 12, Ischium portion of the innominate bone. 13, Greater trochanter. 14, Coalesced spinous processes of the lumbosacral portion of the vertebral column. 15, Ilium portion of the innominate bone. 16, Spinous process of a thoracic vertebra.

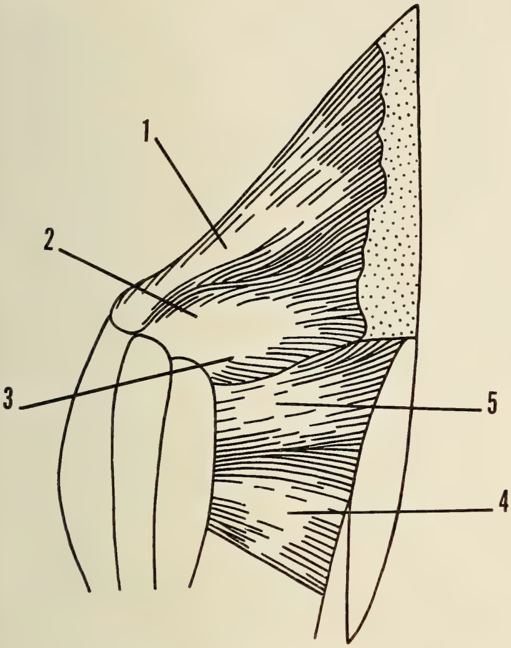


FIG. 2.—Superficial muscles of the lateral aspect of the hip and thigh of *Aptenodytes fosteri*. 1, Sartorius. 2, Rectus femoris. 3, Tensor fasciae femoris. 4, Semitendinosus. 5, Biceps femoris.

chanter of the femur and to a lesser extent on the articular capsule of the hip joint.

The cephalic third of gluteus medius is concealed by sartorius; the caudal two-thirds are covered by the aponeurosis of origin common to rectus femoris and tensor fasciae femoris.

Gluteus medius rotates the hip joint medially.

Gluteus minimus. Gluteus minimus is smaller than gluteus medius. It originates along the lateral border of the ilium and from a tendinous sheet between it and gluteus medius. The fibers run caudolaterad and insert by a tendon on the greater trochanter of the femur anterolaterad of the insertion of gluteus medius.

Much of the posterior surface of gluteus minimus is covered by gluteus medius.

Gluteus minimus rotates the hip joint medially.

A third gluteal muscle has not been recognized in penguins.

Extensor cruris. Extensor cruris is a large muscle mass which originates from the lateral and cephalic surfaces of the shaft of the femur. The part on the cephalic surface is much larger than the part on the lateral surface, and it arises about 2.5 cm more proximally than that on the lateral surface. The cephalic part inserts into the upper truncated extremity of the patella. The lateral part inserts into the tendon of tensor fasciae femoris and hence reaches the lateral surface of the patella and the cephalic end of the lateral upper tibial crest.

Extensor cruris is covered laterally by the musculoaponeurotic sheet formed by rectus femoris and tensor fasciae femoris.

Extensor cruris functions as an important extensor of the leg.

Adductor longus. This muscle arises from about 3 cm of the posterior border of the ischium portion of the innominate bone. The fibers run obliquely to the point of insertion near the distal end of the caudal border of the shaft of the femur.

Adductor longus is crossed laterally by the sciatic nerve. This nerve and adductor longus are concealed by biceps femoris. At its origin, the adductor longus crosses obturator externus;

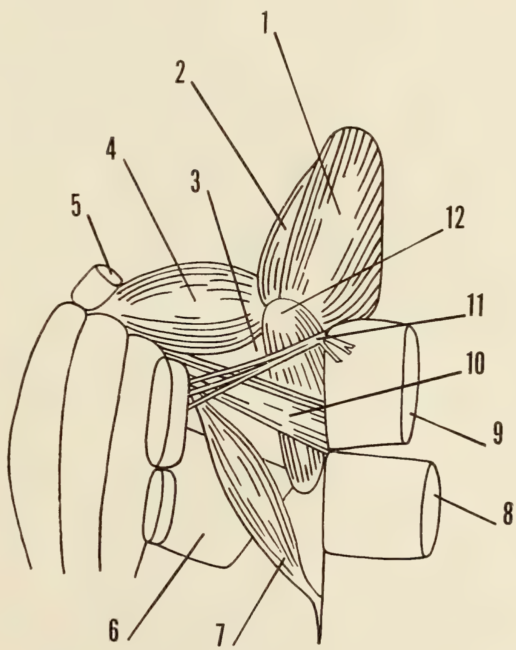


FIG. 3.—Lateral surface of the deep muscles of the hip and thigh of *Aptenodytes fosteri*. Sartorius has been cut off at its insertion. Rectus femoris and tensor fasciae femoris have been entirely removed. Also biceps femoris and semitendinosus have been bisected and their cut ends reflected. 1, Gluteus medius. 2, Gluteus minimus. 3, Adductor magnus. 4, Extensor cruris. 5, Sartorius. 6, Semimembranosus. 7, Crurococcygeus. 8, Semitendinosus. 9, Biceps femoris. 10, Adductor longus. 11, Sciatic nerve. 12, Obturator externus.

at its insertion, it makes contact with adductor magnus. Its tendon of insertion unites with that of crurococcygeus.

The action produced by adductor longus is extension of the thigh.

Crurococcygeus. Crurococcygeus is a long muscle, tapering at each end and measuring over 22.5 cm from the origin to the insertion. It arises by a flat tendon for a distance of 1.25 cm from the cephalolateral border of the pygostyle. The tendon becomes slender and rounded before joining the muscle proper. The muscle fibers take an oblique course; and insert by a long, narrow tendon into the lateral side of the shaft of the femur distad to the tendon of insertion of adductor longus to which it is fused. Just distad to the insertion of crurococcygeus is the attachment of the upper end of the fibrous pulley through which the tendon of insertion of biceps femoris passes.

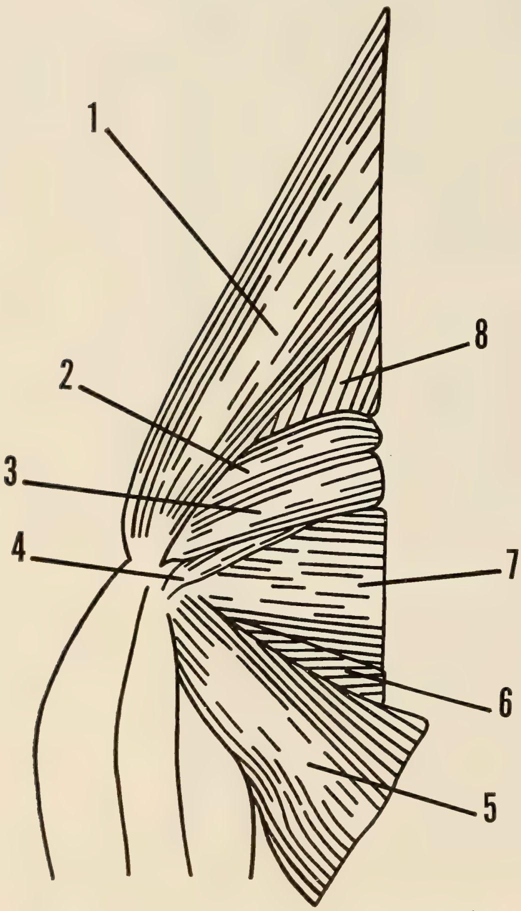


Fig. 4.—Superficial muscles of the medial aspect of the hip and thigh of *Aptenodytes fosteri.* 1, Sartorius. 2, Extensor cruris. 3, Musculus ambiens. 4, Gracilis. 5, Semimembranosus (abdominal head). 6, Semimembranosus (pubic head). 7, Adductor magnus. 8, Gluteus minimus.

Crurococcygeus is covered by semitendinosus and biceps femoris laterally and by semimembranosus and adductor magnus medially.

Acting with its fellow of the opposite side, crurococcygeus depresses the tail. If the tail be fixed, the muscle is an extensor of the thigh.

Obturator externus. Obturator externus arises from the whole lateral surface of the innominate bone caudad of the acetabulum, exclusive of the pubic part of this bone. The fibers run cephalolaterad to the tendon of insertion on the greater trochanter of the femur just caudad of the tendon of insertion of gluteus minimus.

Laterally the muscle is crossed by adductor longus and the sciatic nerve.

Obturator externus rotates the thigh laterally. It is an antagonist of gluteus medius and gluteus minimus.

Obturator internus. Obturator internus (not shown in the figure) is an elongated oval muscle. It arises from the greater part of the medial surface of the ischium, the pubis and the membrane between these two bones. The fibers pass cephalad and end on a tendon which passes through the obturator foramen and which is inserted on the greater trochanter of the femur mediad of the insertion of obturator externus.

Since this muscle lies on the inner side of the bony pelvis, only its tendon is in contact with obturator externus.

Obturator internus assists obturator externus in lateral rotation of the thigh.

Gemellus. Gemellus (not sho'vn in the figure) is small and quadrilateral. It arises from the lateral side of the innominate bone close to the margin of the obturator foramen. The muscle is divided into two slips by the tendon of insertion of obturator internus. The fibers run laterad to the insertion on the caudal border of the greater trochanter of the femur just mediad to the tendon of insertion of obturator internus.

The muscle is concealed by the insertion of obturator externus.

Gemellus is a lateral rotator of the thigh.

The superficial muscles of the medial aspect of the hip and thigh (Fig. 4) are the following:

Musculus ambiens. This is a flat, superficial muscle on the medial side of the thigh. It has an origin of about 3.75 cm from the lateral margin of the cephalic end of the pubic bone. It extends toward the knee and tapers to a tendon which is 0.6 cm wide and 11.25 cm long. This tendon crosses the front of the knee joint in a groove on the patella and in a groove on the lateral side of the proximal one third of the fibula (Fig. 1). Then this tendon passes medially to the tendon of insertion of biceps femoris and joins the head of a leg muscle (flexor perforatus digitorum) which arises from the lateral side of the distal end of the femur. The part of the tendon that passes over the surface of the groove on the patella has a marked thickening.

On its deep side, musculus ambiens makes contact with gracilis. The part of the tendon of insertion that lies in the groove on the patella is concealed by the distal end of sartorius.

Musculus ambiens adducts the thigh and extends the leg.

Gracilis. Gracilis is a slender muscle that arises from the whole medial surface of the shaft of the femur. It inserts by a tendon on the medial side of the proximal end of the medial upper tibial crest.

This muscle lies between the origin of extensor cruris and the insertion of adductor magnus. The medial surface of the major part of it is covered by musculus ambiens.

Gracilis extends the thigh.

Adductor magnus. This is a large, thick muscle. It arises from the lateral side of the pubis, ischium and the membrane between these two bones for a distance of 9.37 cm from the obturator foramen to a point 1.25 cm distant from the cartilaginous tip of the pubic bone. The fibers pass transversely to the insertion on the caudal surface of the distal half of the femur. Some of the insertion is by a special tendon on the area just above the internal condyle of the femur. To this tendon some fibers of a leg muscle (gastrocnemius) are attached.

Laterally the muscle makes contact with adductor longus and crurococcygeus.

Adductor magnus adducts and extends the thigh.

Semimembranosus. Semimembranosus is a large, flat muscle. It has two heads of origin: pubic and abdominal. The pubic head arises from the following: (1) the lateral side of the distal end of the pubic bone, including a part of the cartilaginous tip of that bone; (2) the lateral side of the adjacent distal end of the ischium; and (3) the lateral side of the caudal end of the membrane between the pubis and ischium. The abdominal head arises from the lateral surface of the abdominal wall where it is attached to the aponeurosis of the abdominal muscles for a distance of about 12.5 cm running parallel to the long axis of the body.

The fibers of both heads of origin extend to a common insertion which is on the medial side of the medial upper tibial crest. This insertion is a linear one of 5 cm, with additional fibers at the cephalic end attached to the medial side of the patella.

Laterally the pubic head makes contact with crurococcygeus and semitendinosus. Cephalically it is in contact with adductor magnus.

Semimembranosus extends the thigh and flexes the leg.

SUMMARY

1. The morphology of the muscles of the hip and thigh of the emperor penguin, *Aptenodytes fosteri*, is very similar to that given by Watson for *Eudyptes chrysocome.* However, the muscle which he described as pectineus was found to be represented in *Aptenodytes fosteri* by only a ligament.

2. As suggested by Watson the possession of an abdominal head by semimembranosus is possibly a unique feature in the anatomy of penguins.

LITERATURE CITED

SHUFELDT, R. W. *Osteology of the penguins.* Journ. Anat. and Phy. **35.** 1901.

WATSON, M. *Report on the Spheniscidae.* Zool. Voy. *Challenger,* pt. 18. 1883.

ZOOLOGY—*Notes on* Mecistocephalus *in the Americas, with a redescription of* Mecistocephalus guildingii *Newport* (Chilopoda: Geophilomorpha: Mecistocephalidae). R. E. Crabill, Jr., U. S. National Museum.

(Received April 7, 1959)

Heretofore four centipede species properly referable to the genus *Mecistocephalus* have been reported from the tropics of the New World. These are: *maxillaris* (Gervais), 1837; *punctifrons* Newport, 1842; *guildingii* Newport, 1845; and *janeirensis* Verhoeff, 1938. Although I have never seen a neotropical specimen of the first, I do not doubt that it occurs in Central and South America: *maxillaris* is probably pantropical. Whether the true *punctifrons*, an Indian and southeast Asian form, is established in the Neotropics at all seems questionable, for there is reason to suspect that most or all of those neotropical specimens that have been called *punctifrons* are in fact referable to an historically obscure species, one which I believe may be peculiar to the New World Tropics. I submit that *guildingii* and *janeirensis* both refer to the same zoological entity and suggest further that it may be very widely distributed in the tropical and parts of the subtropical American continents. Indeed, it may very well prove to be as representative of the Americas as are *maxillaris* and *insularis* (Lucas), 1863, of the Old World tropics and subtropics.

This species was initially described as *guildingii* from the Antillean island of St. Vincent by George Newport in 1845 (p. 429). But inasmuch as the original characterization was quite superficial, the identity of *guildingii* has remained in obscurity until the present time.

Dr. Chamberlin we know synonymized *guildingii* under *maxillaris* (1920, p. 185), so that whenever he reported the latter in the Neotropics, as he did most recently from southern Florida (1958, p. 14), we may be sure that his specimens were either *guildingii* or *maxillaris*, and usually the former. In 1893 (p. 470) R. I. Pocock reported having seen specimens, which he called *guildingii* from the West Indies; he expressed the belief that they were not in any case conspecific with *punctifrons* and thereby disagreed with Meinert and Bollman who had thought they were. These men had seen specimens from St. Croix, Cuba, and Bermuda, and T. D. A. Cockerell had collected others on Jamica. It seems probable that all were referable to *guildingii*. Subsequently no topotypical material from St. Vincent was ever described, so that in his great monograph of 1929 (p. 156) the Count von Attems-Petzenstein was obliged to set aside *guildingii* pending clarification.

The first adequate description—it is, however, not without errors—of this centipede appeared in 1938 (p. 383) when Karl W. Verhoeff redescribed it from Rio de Janeiro, Brazil, as a new species, *janeirensis*. Topotypes of *janeirensis* from Rio de Janeiro that I have seen are, however, essentially indistinguishable from the St. Vincent topotype of *guildingii* described below. Equally similar to the St. Vincent topotype are: a series of Florida specimens recently acquired[1]; a specimen from the Panama Canal Zone; eight individuals from the island of Martinique lying in the Lesser Antilles not far to the south of St. Vincent. If it is true that (a) my topotype is really conspecific with the original cotypes, and (b) all are conspecific with the specimens cited above, then all must take the Newport name. What we understand of distribution in the genus and what we know about this particular case strongly suggest both inferences to be true.

Finally, in 1942 Wolfgang Bücherl reported the presence of *punctifrons* and *janeirensis* in Brazil, synonymizing *guildingii* under the former but admitting he had never seen a specimen of the latter. I suspect that all these specimens were actually referable to *guildingii*.

[1] I should like to express my thanks to Dr. Howard V. Weems, Jr., and to his colleagues of the State Plant Board of Florida at Gainesville for their kindness in placing these and many other specimens in my hands for study.

It seems to me that the evidence suggests: (1) that the representative and possibly endemic *Mecistocephalus* of the New World tropics is *guildingii*, and further; (2) that this species is very widely distributed from southern Florida, throughout the Caribbean and Central America, southward at least as far as southern Brazil.

The following description is based upon a single female topotype from St. Vincent. To the best of my knowledge it is the first such specimen known since the time of the original description of the Newport species in 1845. Unfortunately his original cotypical series cannot be identified in the British Museum collections today and so must be presumed to be unavailable.[2]

In the underlying description I have utilized a number of new characters and have attempted to refine some old ones. In both cases it has often seemed desirable to devise new terms to describe them, both to avoid imprecision and to propose an interlinguistic uniformity of unambiguous usage.

Imprecision of designation and the common failure of one worker to understand exactly what another meant by loose and variant usage have injected much confusion into our present, often jumbled heritage. We need to be exhaustive rather than merely minimally (and highly subjectively) analytical in describing typical material; we need to establish an unambiguous terminology and then abide by it. New terms and characters are signalized in the description and then are treated separately at the end of the paper: in addition all are illustrated in the labeled figures.

Mecistocephalus guildingii Newport, 1845

On the basis of published descriptions one could come to the conclusion either that (a) *insularis* and *guildingii* are conspecific, or (b) they are not, but are very similar to one another. On the basis of African material of *insularis* I suggest they are very similar but not conspecific. Briefly, they differ at least as follows. In *insularis* (compare with data on *guildingii* below): clypeal plagulae are as long as or somewhat longer than the anterior areolate clypeus; buccal spicula are deflected anteromedially and reach or nearly reach anterior head margin; body suffused with subsurface blackish-green pigment flecks and patches; basal plate not centrally sulcate; 1st pedal tergite not bisulcate; ultimate pedal tergite very long, sides regularly convergent, posterior margin narrowly rounded.

[2] I am indebted for this information to Dr. G. Owen Evans, who is in charge of the arachnid and myriapod collections at the British Museum.

Topotype: female. British West Indies, St. Vincent Island. (Exact locality, collector, and date are unknown.) U.S. National Museum Myriapod Collection 2546.

Introduction. Length, 33 mm. Pedal segments, 49. Body shape: anterior five-sixths of body approximately parallel sided, final fifth gradually narrowing. Color: head, prosternum, and prehensors orange-brown; antennae, basal plate, and first pedal tergite concolorous, lightly orange-brown; tergites and sternites of anterior body third white-yellow, becoming paler posteriorly; legs essentially white to very faintly yellow-white.

Antennae. Length, 3.7 mm in Hoyer's mountant. Distally slightly attenuate, each article distinctly longer than greatest width. First 4 slightly indented at outer basal corner, the remaining articles not so. First 7 clothed sparsely with very long setae, the 8th suddenly densely shortly setose as are those following. Ultimate article on outer and inner surfaces of distal half with elongate patches of short club- or spoon-shaped setae, these short and not set into depressions.

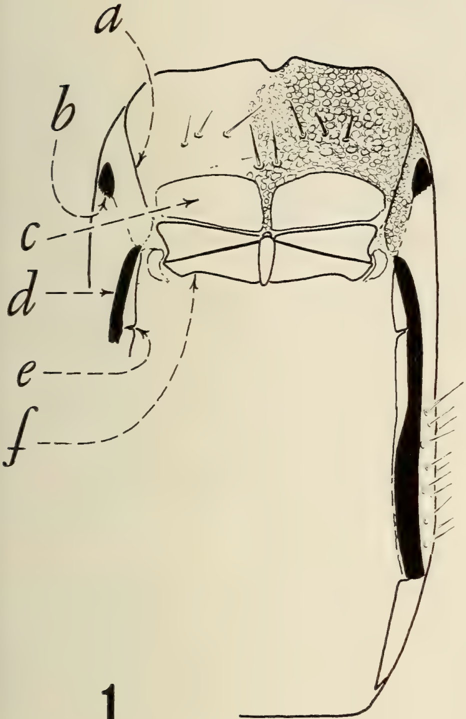
Cephalic Plate. Dimensions: length 1.16 mm, greatest width 0.62 mm, i.e., 1: 1.187. Shape: long and very narrow; sides straight but converging very slightly posteriorly. Frontal suture conspicuous, evenly curved posteriorly. From straight posterior margin two diverging setigerous sulci pass forward for about a third the length of the plate. Prebasal plate not detected.

Clypeus (Fig. 1). Paraclypeal sutures distinct, complete (Note D). Each bucca (Note B) anteriorly areolate but posterior to spiculum (Note H) smooth and consolidated; buccal spicula well developed, bluntly pointed; buccal stili (Note I) long and curved, anterior incisures (Note A) distinct, deep; approximately the anterior half of each bucca glabrous, as a group the long stiff setae fall far short of the labral area and the anterior incisures of the stili. A typical clypeal area absent, in its position the areolate figures are somewhat smaller and paler. Clypeal plagulae (Note F) much shorter than the anterior areolate clypeal portion; anterior margins rounded, not square; separated posteriorly from labrum by a thin membranous suture and from each other by a thin areolate strip; their surface nonporous, smooth except for small rugose posteromedial corner. Setae: posterior geminate setae (Note E) essentially paramedian and just anterior to plagulae, with large alveolate sockets; midclypeal setae long and stiff, three on each side, not set into sclerotized islands. LABRUM (Fig. 1). Midpiece not projecting below sidepieces, its sides very narrowly overlapped by sidepieces medially. Anterior division of each sidepiece separated by suture from adjacent plagula; posterior divisions each with a distinct indentation laterally on posterior margin; labral posterior margin smooth, not roughened or serrulate. MANDIBLE. With 6 pectinate lamellae and one membranous hyaline projection (an incipient pectinate lamella?); the comb-teeth of each lamella from 5 (on the first) to 11 (on one of the medials); all teeth hyaline, broad, about equal in length. FIRST MAXILLAE (Fig. 6). Coxosternum with a prominent midlongitudinal suture, this margined anteriorly by a few stout setae; each anterolateral corner extended into a blunt projection, posterior to each a prominent sinuous incisure or suture (Note C); lappets absent. Medial lobes slightly shorter than telopodites; both very long, curved; telopodite lappets absent. SECOND MAXILLAE (Fig. 6). Without medial suture or sign of division; coxosternum medially and posterolaterally coarsely areolate, anterolaterally smooth, essentially consolidated; most setae set into strongly sclerotized semialveoli confluent anteriorly with a large vacant or membranous lacuna. Telepodite first article very long, curved, bicondylic basally; apical claw straight, small, very sharply pointed. PROSTERNUM (Fig. 5). Without sclerotic lines; sparsely setose; shallowly areolate; midlongitudinally very shallowly sulcate. Anteriorly shallowly diastemate, with two pale small sharp denticles. Ventral condyles displaced far to each side. TELOPODITE (Fig. 5). Flexed, well surpassing front of head. First article with two rounded prominent denticles; femoroid and tibioid each with a rounded denticle; tarsungula with a minute pointed basal denticle. Ungular blades not serrulate. Poison calyx extremely long and thin, the digitiform appendices minute, beginning at the pigmented base of the ungula proper. Poison gland extending posteriorly to level midway between denticles of first article.

TERGITES (except ultimate pedal). Basal plate with a midlongitudinal elongate elliptical sulcus. First pedal tergite with a pair of deep paramedian sulci, these extending from posterior margin not less that three-fourths the distance to the anterior margin but not attaining it. Remaining tergites each deeply completely bisulcate. SPIRACLES. On anterior body third vertically broadly elliptical, thereafter gradually tending toward subcircular. LEGS. Dorsally very sparsely shortly setose, ventrally and laterally moderately setose, the setae long and straight. Pretarsi ventrally *evidently* not concave, at most flat basally; accessory claws acicular, not more than one-third as long as pretarsus. STERNITES (Figs. 2, 3). Rhachides (Note G) anteriorly bifurcate, subtended angles of first three or so approximately 90° when measured at base, thereafter widening slightly to subtend more than 90° (to approximately 110°); bifurcate rhachides detected on sternites 2 through approximately 25, these very weak posterior to the tenth. Sternites of about the anterior body third each with a very long metasternite extending far under the succeeding sternite.

ULTIMATE PEDAL SEGMENT (Fig. 4). Pretergite separated from each of its pleurites by a pronounced suture. Tergite with perfectly straight sides and an evenly rounded posterior margin; width to greatest length = 1:1.35. Presternite distinctly divided medially. Sternite subtriangular, the sides very strongly convergent, the posterior margin rounded and very densely clothed with fine setae, with very dense underlying, apparently glandular tissue; posterior

FIGS. 1–6.—*Mecistocephalus* (*M.*) *guildingii* Newport, topotype: 1, Clypeus and bucca; ventral. All setae shown; areolation of left side shown. *a*, Right paraclypeal suture. *b*, Right buccal spiculum. *c*, Right plagula. *d*, Anterior end of right buccal stilus. *e*, Anterior incisure of stilus. *f*, Indentation on right labral sidepiece. 2, Rhachis of third pedal sternite. 3, Rhachis of eighth pedal sternite. 4, Ultimate pedal and postpedal segments; ventral. All setae of sternite and left coxopleuron shown; those of postpedal segments deleted. 5, Prosternum and right prehensor; ventral. All setae deleted. Dashed outline of poison calyx shown inside that of poison gland. 6, First and second maxillae; ventral. All setae of left side shown; setal alveoli and lacunae of right side shown. Areolation of right side shown, those of left deleted. *a*, Anterolateral projection of first maxillary coxosternum. *b*, Right lateral incisure of first maxillary coxosternum. *c*, Setae with alveoli and lacuna *in situ* and enlarged.



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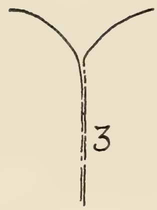

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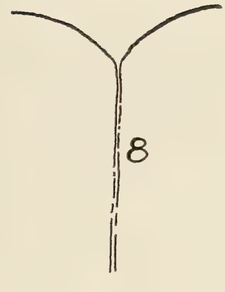

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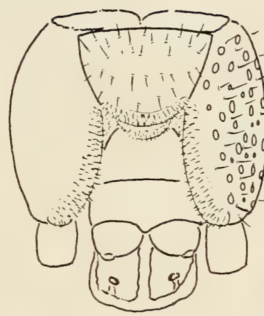

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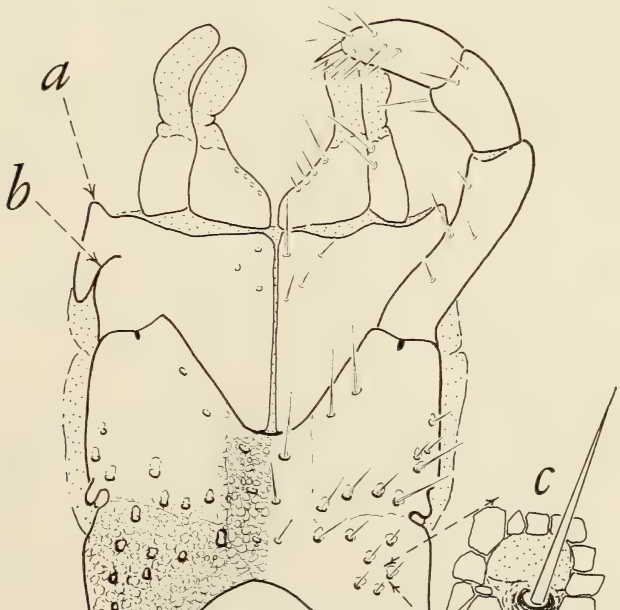


6

Figs. 1–6.—(See opposite page for legend).

rounded margin followed by a cushionlike mound, this also densely finely setigerous. Each coxopleuron swollen, not extending anteriorly beyond rear margin of penultimate pedal segment; pores large and slightly smaller, distributed uniformly but absent ventromedially, ventroposteriorly, dorsomedially, and dorsoposteriorly; ventromedial edge raised and swollen, densely finely setose and with dense underlying glandular tissue. Ultimate legs very thin and long, with long stiff setae; pretarsus represented by a microscopic terminal bristle. Postpedal segments (Fig. 4). Gonopods well separated; basal article broad and flat; second article minute, nipplelike, only indistinctly separated from the basal. Terminal pores conspicuous.

The other specimens that I have examined all agree very closely with one another and with the St. Vincent topotype. In the males the ultimate sternite seems somewhat broader and shorter, the coxopleura shorter than the corresponding parts of the females.

Lengths (in mm): 5 males: 19, 21, 29, 30, 33; 11 females: 27, 28, 28, 30, 30, 30, 32, 33, 33, 33, 36. Florida: Miami, South Miami, Rockdale, Key West. Panama Canal Zone: Frijoles. Martinique: Rivière Pilote. Brazil: Rio de Janeiro.

NOTES

A. Anterior Incisure (of the Stilus); New Character. The anterior cleft or break on the medial side of the buccal stilus, q.v. (Fig. 1e.)

B. Bucca; New Term (pl. = buccae, L. "cheek"). The so-called cephalic pleuron; that portion of the ventral head capsule bounded anteriorly by the paraclypeal sutures, q.v., and laterally by the folded lateral margin of the cephalic plate; a neutral descriptive term proposed to replace the morphologically implicative "pleuron" of authors. (See also stilus, spiculus, anterior incisure.) (Fig. 1.)

C. Lateral Incisure (of First Maxillae); New Character. The cleft on each side of the 1st maxillary coxosternum. Its presence, absence, development, and position are all significant systematically. (Fig. 6b.)

D. Paraclypeal Sutures; New Character. The sutures or grooves in most Geophilomorpha that pass from the antennal sockets shortly laterally, then ventroposteriorly usually to terminate in the vicinity of the outer end of each labral sidepiece. When present they may be taken to define the lateral limits of the clypeus and the anterior limits of each bucca, q.v. The degree of development, the course, the termination of these sutures all have significance. (Fig. 1a.)

E. Posterior Geminate Setae; New Term. The persistent pair of setae located posteriorly on the clypeal midline. (Fig. 1.)

F. Plagula (of the Clypeus); New Term (pl. = plagulae; L. "a small flat surface or area"). The so-called clypeal or preclypeal consolidated area(s), or in Mecistocephalidae the posterior clypeus; widespread in the order, though in many families much smaller in size. When present, so far as is known always paired and bilateral, each occupying a position just anterior to the labrum on the posterior part of the clypeus. (Fig. 1c.)

G. Rhachis (or Rachis); New Term (pl. = rhachides, rachides, G. "a ridge, axis, backbone"). In Mecistocephalidae the elongate, midlongitudinal sternital thickenings, especially characteristic of the more anterior sternites. The rhachis is apparently in reality a very narrowly inverted sternital fold whose surfaces, in any case, serve as areas of muscular attachment. Anteriorly the rhachis is bifurcate or not; if bifurcate, the size of the angle *subtended by the bases* of the anterior arms, within limits, has systematic significance. (Figs. 2, 3.)

H. Spiculum (of the Bucca); New Term (pl. = spicula, L. "a small spike or sharp point"). In Mecistocephalidae, the pigmented spikelike point on the anterior part of the bucca, q.v. (Fig. 1b.)

I. Stilus (of the Bucca); New Term (pl. = stili, L. "a pointed writing instrument"). The heavily sclerotized, elongate, usually blunt and thickened inner edge of the bucca; at midlength giving attachment to the maxillae. (Fig. 1d.)

REFERENCES

Attems, Carl. Das Tierreich **52**: 1–388. 1929.

Bücherl, Wolfgang. Mem. Inst. Butantan **15**: 1–372. 1941 (=1942).

Chamberlin, Ralph V. Can. Ent. **52**(8): 184–189. 1920.

———. Ent. News **69**(1): 13–14. 1958.

Newport, George. Trans. Linn. Soc. London **19**(4): 349–439. 1845.

Pocock, Reginald I. Journ. Linn. Soc. London **24**: 454–544. 1893.

Verhoeff, Karl W. Zool. Jahrb. (Syst.) **71**(4/6): 339–388. 1938.

ZOOLOGY—*A new species of* Haloptilus (*Copepoda: Calanoida*) *from equatorial and subtropical waters of the east-central Pacific Ocean*[1]. George D. Grice,[2] Woods Hole Oceanographic Institution, Woods Hole, Mass. (Communicated by Paul L. Illg.)

(Received April 3, 1959)

The new species of *Haloptilus* described below was found while examining a series of plankton samples which had been collected by the U. S. Fish and Wildlife Service as part of their oceanographical and marine biological studies in the Pacific Ocean.

Haloptilus austini, n. sp.

Figs. 1–18

Localities and materials.—Latitude 28°00′N., longitude 159°03′W. (U. S. Fish and Wildlife Service *Hugh M. Smith* Cruise 27, station 67, February 19, 1955, 100–0 m depth of tow, 1 female); latitude 00°11′S., longitude 119°58′W. (*Hugh M. Smith* Cruise 31, station 94-2, November 7, 1955, 146–72 m depth of tow, 2 females). Physical oceanographic and other data for Cruise 27 are summarized by McGary and Stroup (1958) and that for Cruise 31 by King, Austin, and Doty (1957).

Types.—All three specimens have been deposited in the U. S. National Museum. A female from Cruise 31 was selected as the holotype (U.S.N.M. no. 102742). Paratype numbers are as follows: U.S.N.M. no. 102744 (1 female, Cruise 31) and U.S.N.M. no. 102743 (1 female, Cruise 27).

Description.—Female (Figs. 1–18). The cephalothorax is much longer than the abdomen, the ratio of these two body parts being approximately 8 to 1 (Fig. 1). The head is rounded and considerably produced anteriorly (Figs. 1 and 2). A convex protrusion is present on each side at a point adjacent to the origin of the second antennae. The rostral filaments (Figs. 2 and 3) arise from two small elevations which are situated a short distance in front of the origin of the first antennae.

The abdomen (Figs. 4, 5, and 6) consists of 4 segments. The genital segment is longer than the combined lengths of the succeeding 3 segments.

[1] Contribution No. 116 Hawaii Marine Laboratory, University of Hawaii.

[2] Fellow of the John Simon Guggenheim Memorial Foundation, 1958–1959.

The first antennae of all three specimens are broken off at segment 22. When held against the body, segment 20 reaches to approximately the end of the caudal furcae. The endopod of the second antennae (Fig. 7) is a little less than twice the length of the exopod. The exopod consists of 7 segments. Segment 1 has 2 setae. Segments 2 through 6 are furnished with a single seta. There are 4 setae on segment 7. The first segment of the endopod has 2 setae situated just beyond the mid-point of this segment. The external lobe of the second endopodal segment has 6 large and 1 minute seta. The internal lobe has 8 setae, 4 of which are notably small.

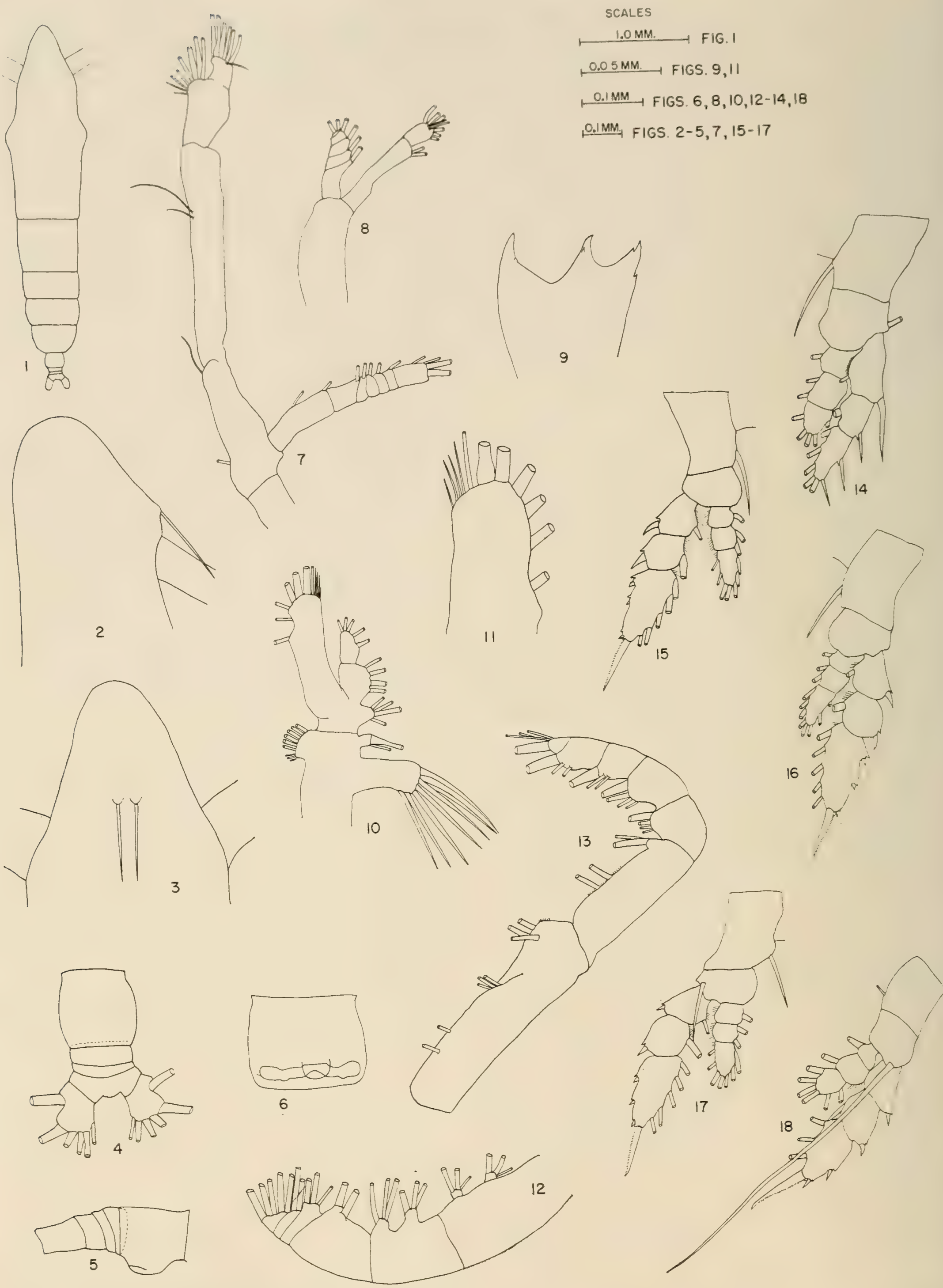
The exopod of the mandible (Fig. 8) is a little more than one-half the length of the endopod. The former apparently consists of 5 segments, the first 4 of which are furnished with a seta. The terminal segment has 2 setae. Segment 1 of the endopod has 2 setae distally, and segment 2 is provided with 8 terminal setae. The gnathal lobe of the mandible is shown in Fig. 9.

The first maxilla is shown in Fig. 10. The exopod is elongate and furnished with 11 setae. Four of the setae on the distal margin are quite small and slender (Fig. 11). The endopod carries 5 setae, and the second basal segment bears 4 setae. Inner lobes 1, 2 and 3 bear 7, 2 and 4 setae, respectively. The external lobe has 6 large and 3 small setae.

The second maxilla (Fig. 12) has 6 lobes. Lobes 1 through 4 and lobe 6 have 3 setae. Lobe 5 has 2 setae. The distal part of this appendage is furnished with 7 setae.

The maxilliped (Fig. 13) consists of 2 basal and 5 endopodal segments. The first basal segment has 2 setae near the proximal end, 3 setae near the center, and 3 setae near the distal end. The second basal segment is furnished with 2 setae near the center and 2 setae on the disto-lateral corner. Endopodal segments 1 and 2 have 4 setae and segments 3 and 4 have 3 setae. The fifth segment is furnished with 1 seta and 3 bristles.

The first to fourth pairs of swimming feet are



FIGS. 1–18.—*Haloptilus austini*, n. sp., female: 1, Dorsal; 2, forehead, lateral view; 3, forehead, ventral view; 4, abdomen, dorsal view; 5, abdomen, lateral view; 6, genital segment, ventral view; 7, second antenna; 8, mandibular palpus; 9, gnathal lobe of mandible; 10, first maxilla; 11, terminal part of exopod of first maxilla; 12, second maxilla; 13, maxilliped; 14, first foot; 15, second foot; 16, third foot; 17, fourth foot; 18, fifth foot. Fig. 11 drawn from paratype. All other figures drawn from holotype.

shown in Figs. 14 through 17. The first pair of feet is smaller than the succeeding 3 pairs. There is 1 seta on the internal margin of basipodal segment 1 and 1 seta on the external margin of basipodal segment 2. Both exopod and endopod consist of 3 segments. Segments 1 and 2 of the exopod have 1 long external spine and 1 internal seta. Segment 3 has 2 external spines and 4 internal and 1 terminal seta. Endopodal segment 1 has 1, segment 2 has 2, and segment 3 has 5 setae.

The second, third, and fourth pairs of feet are similar. Basipodal segment 1 has an internal seta. Basipodal segment 2 of the second and third feet is naked. This segment of the fourth feet is furnished with an external seta. Segments 1 and 2 of the exopod have a small external spine and a single internal seta. The third exopodal segment has a terminal, finely serrate spine. There are 3 small external spines and 5 internal setae on this segment. In the second and fourth pairs of feet, endopodal segment 1 has 1 seta, segment 2 has 2 setae, and segment 3 has 7 setae. In the third pair of feet the numbers of setae on these respective segments of the endopod are 1, 2, and 8.

The fifth pair (Fig. 18) of feet is smaller than the preceding 3 pairs. Basipodal segment 1 has 1 internal seta. Basipodal segment 2 is furnished with 1 seta which exceeds the tip of the terminal exopodal spine. Exopodal segment 1 has 1 external spine, segment 2 has 1 external and 1 internal spine, and segment 3 has 2 external and 1 terminal spine. Segment 3 is also furnished with 3 internal setae. Endopodal segments 1, 2, and 3 are provided with 1, 1, and 6 setae, respectively.

Total length of the three specimens is as follows: 3.33 mm (holotype), 3.16 mm (paratype, Cruise 31) and 3.06 mm (paratype, Cruise 27).

No male has been found.

Remarks.—This species resembles *H. chierchiae* (Giesbrecht) but may readily be distinguished from it by the shape of the head and the structure of the first maxillae and fifth pair of feet. The head of *H. austini* is considerably more produced anteriorly. In regard to the first maxilla of *H. austini,* the second basal segment has 4 setae, the exopod has 11 setae, and the endopod has 5 setae. The corresponding parts of the first maxilla of *H. chierchiae,* as figured by Giesbrecht (1892) and Sars (1924), have 5 setae, 8 setae, and 7 setae. The seta on the second basal segment of the fifth pair of legs of *H. austini* exceeds the tip of the terminal exopodal spine. In *H. chierchiae* this seta, as figured by Sars (1924), does not reach the distal end of the second exopodal segment. This new copepod is named in honor of Thomas S. Austin, oceanographer, Honolulu Biological Laboratory, U. S. Fish and Wildlife Service.

Acknowledgments.—The Honolulu Biological Laboratory, U. S. Fish and Wildlife Service, provided laboratory space during the course of the investigation. Dr. W. Vervoort has kindly read the manuscript.

REFERENCES

GIESBRECHT, W. *Systematik und Faunistik der pelagischen Copepoden des Golfes von Neapel und der angrenzenden Meeresabschnitte.* Fauna und Flora des Golfes von Neapel. Monogr. 19: 831 pp., 54 pls. 1892.

KING, J. E., AUSTIN, T. S., and DOTY, M. S. *Preliminary report on expedition EASTROPIC.* U. S. Fish and Wildlife Service Spec. Sci. Rep., Fisheries 201: 155 pp. 1957.

MCGARY, J. W., and STROUP, E. D. *Oceanographic observations in the central North Pacific, September 1954–August 1955.* U. S. Fish and Wildlife Service Spec. Sci. Rep., Fisheries 252: 250 pp. 1958.

SARS, G. O. *Copépodes particulièrement bathypélagiques provenant des campagnes scientifiques du Prince Albert ler de Monaco.* Res. Camp. Sci. Monaco **69:** text (1925), 408 pp., atlas (1924), 127 pls. 1924–1925.

They will tell you to try to prove you are right; I tell you to try to prove you are wrong.—LOUIS PASTEUR.

James Herbert Hibben

James H. Hibben, for 20 years chief of the chemical division of the U. S. Tariff Commission and one of the foremost chemical consultants in the United States, died suddenly on June 15, 1959, at George Washington University Hospital after a fall at his home.

Dr. Hibben, the son of Thomas E. and Jeanie Ketcham Hibben, was born in Indianapolis, Ind., on May 14, 1897. He attended public schools in Indianapolis; was a graduate of the University of Illinois, receiving his B. S. in 1920 and his M. S. in 1922; and of the University of Paris (1924) with the degree of D. Sc. He has been a fellow of the International Education Board at Paris (1924), a National Research Fellow at Princeton University (1925–27), consultant to the Bureau of Standards and to various chemical industries, and a member of the research staff of the Geophysical Laboratory of the Carnegie Institution of Washington (1928–1939). During World War I Dr. Hibben enlisted in the Army as a private and served with the A.E.F., being discharged in 1919 with the rank of sergeant. Decorations and awards: St. Mihiel and Marne Defense Sector.

Dr. Hibben was a member of the Washington Academy of Science (vice pres.); New York Academy of Sciences; the Cosmos Club; American Chemical Society; the Chemical Society of Washington (treas., sec., pres.; Hillebrand Prize award); Sigma Xi and Sigma Chi; and a former fellow of the American Institute of Chemists.

He was the author of several books and many papers. One of his best-known works was the book entitled *The Raman effect and its chemical application* (1939). This was one of the first definitive works on this subject. It brought together all the then known information on a new type of secondary radiation information by which the behavior of atoms within the molecules and the molecules themselves may be determined independently of their state of aggregation. Many applications of this effect have been made, both to physics and chemistry, and Hibben's "Raman Spectra" is still used as the starting point for much of this work.

At the Tariff Commission Dr. Hibben carried out many complex and important responsibilities which, by law or Executive order, the Commission is charged with making. He provided basic and authoritative information to the Commission, to top ranking officials of Government agencies, executives of industry, and, when necessary, to members and committees of Congress and the Office of the President on matters relating to United States tariffs and foreign trade pertaining to chemicals and chemical products. During World War II he was chairman or member of many intra agency committees and commissions. He was directly responsible for the organization and publication of the Tariff Commission's annual report on *Synthetic organic chemicals, U. S. production and sales.*

Dr. Hibben is survived by his wife, the former Louise Douglas of Indianapolis; a daughter, Mrs. Phyllisann Courtis; a granddaughter, Lisa; and two sisters, in Indianapolis.

FISHER AWARD

Dr. James I. Hoffman, chief, metallurgy division, National Bureau of Standards, is the recipient of the 1959 Fisher Award in Analytical Chemistry. This award is the highest recognition for work in analytical chemistry in the United States and Canada. It consists of $1,000 and an etching. Presentation of the award was on April 6, 1959, at the meeting of the Society in Boston.

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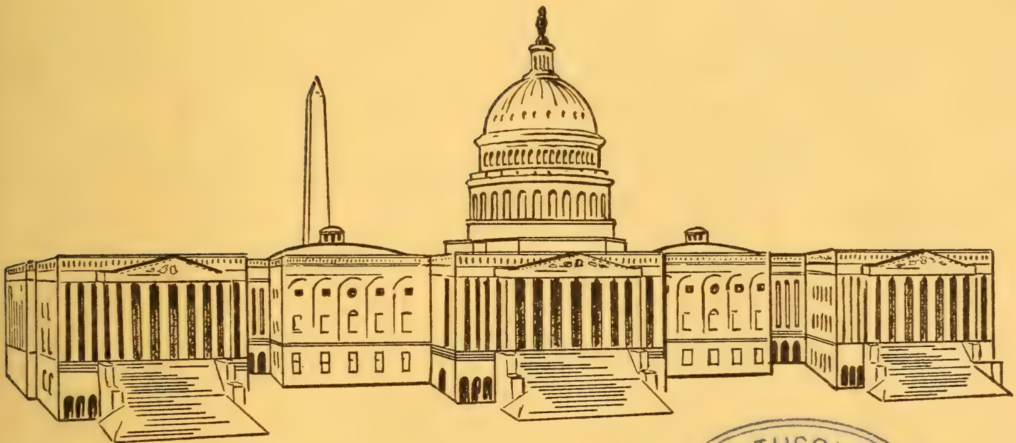

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SYMPOSIUM ON THE HISTORY OF AMERICAN GEOLOGY

* * *

Prefactory Statement

The papers published in this issue of the Journal were presented as a part of a Symposium on the History of American Geology at the Washington meeting of the American Association for the Advancement of Science, December 27 and 28, 1958. The Symposium was arranged by Edgar W. Owen, of the University of Texas, and was sponsored jointly by AAAS Section E (Geology and Geography), Section L (History and Philosophy of Science), and the Geological Society of America.

The Symposium aimed to examine the current state of investigation into the history of the science and its applications and to stimulate interest in the subject. Of the 224 American colleges giving majors in geology, only 18 offer courses in the history of geology. The scarcity of historical publications during the period when the science has undergone phenomenal development of its basic concepts and practical applications indicate the existence of a fertile field for mature and discriminating research.

The following papers, not made available for inclusion here, were also presented at the Symposium:

Dirk J. Struik, Massachusetts Institute of Technology: *Science in America before 1830.* Published in Science, April 24, 1959.

Kirtley F. Mather, Harvard University: *Geology, geologists, and the AAAS.* Published in Science, April 24, 1959.

F. C. MacKnight, University of Pittsburgh: *A university course in history of geology for seniors and graduates.*

Erwin F. Lange, Portland (Oregon) State College: *Dr. John Evans, U. S. geologist to the Oregon and Washington Territories.* Published by American Philosophical Society, 1959.

Herman R. Friis, National Archives: *Highlights in the history of the development and use of topographic maps as a base for delineating geological information by agencies of the Federal Government, 1800–1879.*

Notes on the Earliest Geological Maps of the United States, 1756–1832

By John W. Wells, *Cornell University*

Here I propose to consider briefly a still poorly understood aspect of American geology, that of the earliest geological maps. Published listings and accounts of these early maps are very few, and all are incomplete. The best are Jules Marcou's *Mapoteca geologica Americana* (1884) and Ireland's *History of the development of geologic maps* (1943). Important also is Leighton's *One hundred years of New York State geologic maps* (1910). There are a few notices of early maps in Merrill's *Contributions to the history of American geology* (1906). Stanton's *Evolution of the geologic map of the United States* (1934) mentions only two maps prior to 1843 (Maclure's maps of 1809 and 1817). At least 11 maps are known that show the geology of this country as it then was understood before 1843.

It is assumed that there is agreement on the essential characteristics of a geological map as contrasted with other types of maps. They are attempts to show symbolically the distribution of the different kinds of rock at or near the earth's surface. Thus, Lewis Evans's maps of 1749, 1751, and 1755 can not be considered as geological, although his *Analysis* of 1755 indicates that he could have produced a most creditable one.

In 1756, however, a genuine geological map of America appeared in France. This was in a memoir on the mineralogical comparison of Canada and Switzerland by the great French naturalist Jean-Étienne Guettard, who had never been in North America. This map has generally been dismissed as merely showing by various symbols the localities of some 39 kinds of "earths," rocks, minerals, and fossils, but it is truly a geological map, for like all geological maps it exhibits a generalization of the distribution of the rocks. By even modest standards it is a poor map, and while it is probable, as White (1951) has suggested, that Lewis Evans could have produced a better one based on extensive first-hand knowledge, he did not, and Guettard's effort must stand as the oldest geological map of the continent as well as one of the oldest of geological maps in general. It was as good in its time as many of the later ones, but unlike many of them it was almost wholly ignored, was never a source of information, and had not their wider distribution, especially in the land to which it referred. An English version appeared in the Literary Magazine, or Universal Review in 1757, which was reprinted later in Fuller's *Naval Chronicle* (1760) (Ireland, 1943, p. 1257).

Guettard's map developed from a memoir he read before the Académie Royale des Sciences in Paris in 1752, a date often quoted as its publication date. First based largely on information in Charlevoix's *Historie et déscription gênèrale de la Nouvelle France*, it was considerably augmented by the time it was first published in 1756; Comte de la Galissionère and M. Gautier, the latter King's Physician at Quebec, had in the meantime sent him specimens and notes. He may also have gotten some information from the *Jesuit Relations*. Guettard undertook the compilation from a desire to see if other countries showed the same systematic arrangement of rocks, minerals, and fossils that he had already made out for France, where he recognized three *terreins* or *bandes*. He thought he demonstrated this for Canada and Switzerland, and marked the extent of the *bandes* on his maps. He suggested that they could be traced into Mexico and into Greenland, and thereby be linked to their counterparts in England, probably the earliest attempt at intercontinental correlation. The first of his *bandes* was the *Bande Sableuse*: sands, marls, and sandstones that extended along the continental shelf from the Gulf of Mexico to Newfoundland and the Grand Banks. The *Bande Marneuse*, with limestones with no other metal than iron, is shown along the Gulf and Atlantic Coastal Plains, including eastern New York, New England, and eastern Quebec. The *Bande Schisteuse ou Métallique*, with shales, slates, sandstone, coal, marble, granite, etc., with many metals and hot springs but few fossils, covered all the continent then known westward from the *Bande Marneuse*, including the Maritime Provinces. On the map these three *Bandes* are labeled by name and the middle one is shaded.

Guettard regarded fossils as important, especially is showing the geological similarities of one continent with another. It may be noted is passing that the first figures of American Paleozoic (Ordovician) fossils appeared in his memoir.

This first attempt to map the geology of America and correlate it with Europe, based upon what were later developed anew as working principles when Wernerian concepts failed, deserves the premier place in the history of American geology in ways other than merely chronological.

Some 40 years later, Constantin-François Chasseboeuf, later Comte de Volney, traveled extensively for several years in the United States, and in 1803 he published his then famous but now almost forgotten *Tableau du climat et du sol des États-Unis d'Amérique*, an attempt to assess the relation of the soil and climate to the economy, politics, and viability of the new Republic. A year later two englished versions appeared in London and Philadelphia which have been the source of most references to Volney's geology. There were several later editions in French, one in German, and one in Italian. It is curious that this work should be so little known today, for it first brought an idea of American geology widely to the notice of Europeans.

Volney's ideas on American geology were not wholly original. His classification of the rocks was derived from that of Samuel L. Mitchill (1798–1802), who in turn owed much to Lewis Evans. He recognized five regions, each characterized by certain types of rocks: (1) a *Granitic region*, from Long Island to the mouth of the St. Lawrence and the Thousand Islands, separated by the Mohawk Valley from (2) the *Catskill Sandstone region* (Les grès de Katskill), extending west of the Hudson Valley as far as the "Genesee lakes," (3) a *Limestone region* in the "West or Back country," (4) marine sands of the coastal plain, and (5) the [Piedmont] region between the fall-line ("sillon d'isinglass," a term first used by Lewis Evans) and the sandstone or granite mountains.

An anonymous review, probably by Mitchill, of Volney's book appeared in that fascinating *omnium gatherum* of doings in American science, the Medical Repository, in 1804–05. It noted that Volney's terrains corresponded to Mitchill's, and that Volney "possesses a discriminating as well as generalizing mind" and "beheld with an observing eye the tracts over which he travelled" (p. 189). The geological eye-opener to the reviewer, however, was Volney's geologically colored map: "This is a beautiful and obvious manner of expressing the prevalence of any of the great strata of the earth, as over-spreading or underlaying [*sic*] an extensive tract of country. It is a pity that map-makers have not more generally observed it" (p. 411).

This appears to be the first and only published reference to the important fact that Volney's map, to us misleadingly titled *Carte des États-Unis de l'Amérique-Nord, pour servir au tableau du climat et du sol par C. F. Volney* (40 × 53 cm, lacking any geological legend), was geologically colored. And indeed in very few copies of the original French edition and in none of the later editions is the map colored, although all have geological indications such as the trace of the outcrop of the "Isinglass Vein" and the "Limestone Band" in Virginia. The only colored copy I have yet seen is William Maclure's large-paper copy which is now in the library of the Academy of Natural Sciences of Philadelphia, a small portion of which is shown in Fig. 1. But that the map was to be colored has always been obvious from this note printed on the *errata* page (p. 534) of the 1803 edition:

Avis au Lecteur

Dans la grande Carte qui est coloriée, le sol *calcaire* est designée par la couleur *verte*; le *granitique*, par la couleur *rouge*; et le *grès*, par le *bistre*; et dans la petite carte [climatic] l'*orange* marque le lit du vent; le *verd-d'eau*, indique le courant du Golfe.

Fig. 1.—Part of Volney's geological map of 1803. Dark band through "Ohio R." is green, the limestone terrain; dark area southwest from the "York" of New York is bistre, the Catskill sandstone terrain; and the dark stripes in the Appalachians, the coastal plain, and the New England coast are red, the granitic terrain. (From copy in Acad. Nat. Sci. Philadelphia, × 1).

This extraordinary synthesis, the second geological map of the United States and one of the very earliest of published colored geological maps, surely deserves as much respect as Maclure's attempt six years later.

A parenthetical note may be added here: Volney, who had visited Thomas Jefferson several times at Monticello, sent him a copy of the *Tableau*. Jefferson acknowledged it early in 1805 in a lengthy letter (Chinard, 1923, p. 171–175), in the course of which he sniffed at the geological part:

> Of the first [geological] part I am less a judge than most people . . . [not] having indulged myself in geological inquiries, from a belief that the skin-deep scratches which we can make or find in the surface of the earth, do not repay our time with as certain and useful deductions as our pursuits in some other branches.

So much for geology from the first of democrats!

The year 1809 is, of course, memorable for the appearance of William Maclure's map of the United States. While this is only the third, it is the earliest well-known geological map of this country, and Maclure has been overpraised as the "father of American geology" and the "William Smith of America." Many have taken his memoir and map as the starting point of our geology. Maclure introduced the Wernerian classification to American geology, a classification that was to dominate as well as to hinder its progress for two decades. Although Maclure certainly made observations in much of the country east of the Alleghenies, he was obviously greatly indebted—an unacknowledged debt[1]—to the published details and observations made earlier by Evans, Schoepf, Larochefoucauld-Liancourt, Mitchill, and especially to Volney as evidenced by the geological coloring of his map. His classification was hardly more than Mitchill's put in Wernerian terminology; and his almost total disregard of fossil evidence scarcely warrants his being placed even near William Smith. But his map was good, the best of its time considering the large area covered, especially since it reputedly represented the results of little more than a year's work. In 1809 Mitchill noted Maclure's forthcoming map in the Medical Repository and mentioned that Maclure had returned to the United States in 1808 (others say 1807) after 9 or 10 years in Europe (where he had been an agent of the United States government), that he had started working on American geology in the summer of that year, and that he had already delineated the principal strata on a map. It is entirely likely that Maclure already had his map outlined before he returned to this country and went into the field. Two bits of evidence suggest this. One is the sour comment of Gilbert Chinard (1923, p. 101, footnote) to the effect that Maclure, who had been in Paris in 1801 on affairs of the American government, obtained much unacknowledged information from Volney:

> Maclure fit autre chose que de recueillir des observations pour le compte du gouvernement américain; il receuillit auprès de Volney les matériaux pour ses *Observations on the geology of the United States. . . .*, et qui lui ont value la réputation d'être l'auteur de la première étude géologique sérieuse sur les Etats-Unis, ...

The second is found in the second version of Maclure's map, published in the Journal de Physique in Paris in 1811. This map was prepared in France from a colored map that Maclure had sent to J.-C. Delamétherie, editor of the Journal in 1809 together with his memoir. As published this map has the same color scheme as the 1809 map, colors different from those on the map sent to Paris. Most remarkable, however, is that the base map is Volney's 1803 map, with re-engraved title but retaining all other details including Volney's route trace and contact lines. Either Maclure sent Delamétherie a copy of Volney's map with his own geological coloring, or Delamétherie had Maclure's data transferred to pulls from the re-engraved plate of Volney's map. Also, the curious caterpillar bands of granitic or primary color in Canada, found on Volney's map but not on Maclure's 1809 map in the Transactions of the American Philosophical

[1] Maclure rarely referred to the work of others. His theory of the origin of the secondary rocks of the Mississippi basin in a vast inland sea or lake impounded behind the Appalachians, solemnly advanced so late as 1823, makes no mention of the fact that this had been previously elaborated by Mitchell and Volney, and according to White (1951) the idea can be traced back to Lewis Evans.

Fig. 2.—Geological map from Hinton's *History and topography of the United States*, 1832, × 2/5. Geology east of the Mississippi from Maclure; west of the Mississippi to the Chippewayan (Rocky) Mountains based on James.

Society, appear on the 1811 version. Were they added by Delamétherie from Volney's map or were they on the map Maclure sent Delamétherie?

A version of Maclure's map that has generally been overlooked, except by Marcou (1893, p. 6), appears in L. A. F. de Beaujour's *Aperçu des États-Unis* . . . , published in Paris in 1814 and englished the same year by William Walton. This is colored in Wernerian fashion only along the contact lines, and admittedly is based wholly on Maclure.

Two other versions of the Maclurean map appeared in the two editions of Parker Cleaveland's *Elementary treatise on mineralogy and geology*, 1816 and 1822. They were no improvement on Maclure and scarcely warrent mention except for their wide circulation of Maclure's work.

In 1817 and 1818 Maclure published revised editions of his memoir and map. The 1817 edition appeared as a book in Philadelphia; that of 1818 was published in the Transactions of the American Philosophical Society. The geology on both is essentially the same and these maps are generally listed as if they were the same. They were printed, however, on different bases and only the 1818 issue carries a geological legend. Geological details on both are only a slight improvement over the 1809 map. The base maps for both were very poor for the time. In a critical notice of Maclure's memoir and map of 1817 Rafinesque clearly pointed out the path to be followed:

> . . . We must especially collect and describe all the organic remains of our soil, if we ever want to speculate with the smallest degree of probability on the formation, respective age, and history of our earth. (1818, p. 43).

The eleventh and last map (Fig. 2) considered here is almost completely unknown, except for listing in two catalogues of the Library of Congress and mention by Ireland (1943, p. 1260). It appeared in John Howard Hinton's *History and topography of the United States*, published in London in 1832 and also in the same year in an *Atlas of the United States of North America*, published in London and Philadelphia. The atlas was made up of the maps from Hinton's *History* with condensed text. The geological map and sections and most of the other maps were not included in the several American editions of this popular work.

This map deserves particular notice, for it was the first to show anything of the geology west of the Mississippi Valley. The geology east of the Mississippi was obviously taken from Maclure's maps, and that of the region westward to the "Chippewayan Mountains" could only have been developed from Edwin James's geological results of Long's Expedition to the Rocky Mountains published in 1822–23. The plate following the map in both Hinton's book and the atlas is a copy of James's geological sections across the United States, and the legend on the map uses James's geological nomenclature. Although James did not publish a geological map, his route map has a few geological boundaries indicated for the western section, and might be considered a geological map of the western part of the United States. Unfortunately there is no indication in Hinton's work as to just who, among the "several literary gentlemen in America and England" who are mentioned as having contributed to the book, compiled the map and accompanying geological text. Both are skilfully done, evidently by someone who had some acquaintance with geology but who added little or nothing beyond information already published.

Eleven years after the appearance of this eleventh geological map of the United States saw the publication of James Hall's far better and more detailed map of the Northeastern States (1843). This was followed two years later by Lyell's beautifully executed map of the eastern half of the country. With these the pioneer era of American geological maps came to a close.

REFERENCES

BEAUJOUR, L. A. F. *Aperçu des États-Unis, au commencement du XIX^e siècle, depuis 1800 jusqu'au 1810 avec des tables statistiques:* 274 pp.; map, 17 tables. Paris, 1814.

CHINARD, G. *Volney et l'Amérique, d'après des documents inédits et sa correspondance avec Jefferson.* Johns Hopkins Stud. in Romance Lit. and Lang. **1:** 206 pp., portr. 1923.

CLEAVELAND, P. *An elementary treatise on mineralogy and geology, . . .:* xii, 668 pp., 5 pls., map. Boston, 1816. Second ed.: 2 vols., xii, pp. 1–480, 481–818, 5 pls., map, Boston, 1822.

EVANS, L. *An analysis of a general map of the Mid-*

dle British Colonies in America . . . : iv, 32 pp. Philadelphia, 1755.

Fuller, J. *The Naval Chronicle:* 3 vols. London, 1760.

Guettard, J.-E. *Mémoire dans lequel on compare le Canada à la Suisse, par rapport à ses minéraux.* Mém. Acad. Roy. Sci. (Paris), Ann. 1752: 189–220, pl. 7; 323–360, pls. 8–12; Addition, 524–538. 1756. Also: duodecimo edition, t.**2:** 281–328, pl. 7; 480–538, pls. 8–12. Amsterdam, 1761.

Hall, James. *Geology of New York. Part 4, comprising the survey of the Fourth Geological District:* 683 pp., map, 19 pls., 74 figs. Albany, 1843.

Hinton, J. H. *The history and topography of the United States: edited by John Howard Hinton, A.M., assisted by several literary gentlemen in America and England . . . ,* 2 vols. (Geology, vol. 2, p. 45–89, geological map opposite p. 45). London, 1832. See also: *An atlas of the United States of North America, corrected to the present period, . . . :* 58 pp., 16 maps, 1 pl. London (third map is geological). (The atlas sold for 2 guineas plain, 3 guineas colored.)

Ireland, H. A. *History of the development of geologic maps.* Bull. Geol. Soc. Amer. **54:** 1227–1280. 1943.

James, E. P. *Account of an expedition from Pittsburgh to the Rocky Mountains performed in the years 1819 and '20 . . . under . . . command of Major Stephen H. Long,* 2 vols. (1823), 503 pp.; 442, xcviii pp. Atlas (1822), 2 maps, 8 pls., pl. of sects. Philadelphia.

Leighton, H. *One hundred years of New York State geologic maps, 1809–1909.* Rep. Director New York State Mus. for 1908: 115–155, 1 map. 1910.

Lyell, C. *Travels in North America: with geological observations on the United States, Canada, and Nova Scotia,* 2 vols. London, 1845.

Maclure, W. *Observations on the geology of the United States, explanatory of a geological map.* Trans. Amer. Phil. Soc. **6:** 411–428, map (43.5 × 53.5 cm). 1809.

———. *Observations sur la géologie des États-Unis, servant à expliquer une carte géologique.* Journ. Physique **69:** 204–213. 1809.

———. *Suite des observations sur la géologie des États-Unis servant à l'explication de la carte ci-jointe.* Journ. Physique **72:** 137–165, pl. 1 (map, 40 × 52.7 cm). 1811.

———. *Observations on the geology of the United States of America . . . :* 127 pp., map (36.5 × 43.7 cm), plate of sections. Philadelphia, 1817.

———. *Observations on the geology of the United States of America . . .* Trans. Amer. Phil. Soc. (n.s.) **1:** 1–91, map (31.5 × 42.5 cm), plate of sections. 1818.

———. *Some speculative conjectures on the probable changes that may have taken place in the geology of the continent of North-America east of the Stoney Mountains.* Amer. Journ. Sci. **6:** 98–102. 1823.

Marcou, J., and Marcou, J. B. *Mapoteca geologica Americana, 1752–1881.* U. S. Geol. Surv. Bull. no. 7 (with supplement). 1884.

Marcou, J. *Second supplement to Mapoteca geologica Americana.* Amer. Geol. **11:** 95–99, 1933.

Merrill, G. P. *Contributions to the history of American geology.* Rep. U. S. Nat. Mus. for 1904: 189–734, 37 pls., 141 figs. 1906.

Mitchill, S. L. *A sketch of the mineralogical history of the State of New-York.* Medical Repository (N.Y.) **1** no. 3: 293–314 (1798); no. 4: 445–452 (1798); **3,** no. 4: 325–335 (1800).

———. *A sketch of the mineralogical history of the State of New-York.* Trans. Soc. Promotion Agriculture, Arts, and Manufactures (New York), pt. 4: 124–152. 1799. (Second edition, 1801.)

———. *Additional articles of my report to the Agricultural Society on the mineralogy of New-York.* Medical Repository **5:** 212–215. 1802.

———. (*Review of Volney's Climat et Sol des États-Unis.*) Medical Repository **8:** 172–196; 410–420. 1804–05.

———. *Maclure's geological enquiries.* Medical Repository **12:** 295–296. 1809.

Rafinesque, C. S. (*Review of Maclure's Observations on the geology of the United States of America, 1817.*) Amer. Monthly Mag. and Crit. Rev. **3:** 41–44. 1818.

Stanton, T. W. *The evolution of the geologic map of the United States* (abstract). Journ. Washington Acad. Sci. **23:** 485. 1934.

Volney, C.-F. Chasseboeuf, Comte de. *Tableau du climat et du sol des États Unis d'Amérique; suivi d'eclaircissemens sur la Floride, sur la colonie française au Scioto, sur quelques colonies canadiennes et sur les sauvages . . . ,* 2 vols., xvi, 300 pp.; pp. 301–534, ii, 4 pls., 2 maps, 1 section. Paris, 1803 (An. XII).

White, G. W. *Lewis Evans' contributions to early American geology, 1743–1755.* Trans. Illinois Acad. Sci. **44:** 152–158. 1951.

———. *Lewis Evans (1700–1756): a scientist in colonial America.* Nature **177:** 1055–1056. 1956.

Emergence of Geology as a Public Function, 1800–1879

By William Back, *U. S. Geological Survey*

The congressional act of March 3, 1879, that created the U. S. Geological Survey marked the acceptance of geology as a science having permanent value for and deserving permanent support from the American people. Even earlier, organization of the four western surveys which were consolidated by the act of March 3, 1879, demonstrated a change in the public attitude toward their national government. This change prompted Henry Adams (1918, p. 312) to refer to the congressional authorization for the exploration of the fortieth parallel as "almost its first modern act of legislation." In this paper I attempt to indicate some of the political and administrative attitudes that accounted for a delay of nearly 100 years after the Constitutional Convention before geology achieved this recognition. Part of the answer lies, of course, in the slowness of development of geology itself, because the growth and public support of a science progress concurrently. The science can not be actively supported until it develops, nor can it develop until it is actively supported.

Another reason for the delay was that during the Jeffersonian period, 1801–29, the climate of the time was not favorable to the extension of Federal Government functions and expenditures. The policy was stated by Jefferson in his first annual message: "Agriculture, manufactures, commerce, and navigation, the four pillars of our prosperity, are then most thriving when left most free to individual enterprise" (White, 1951, p. 23). It was a period of consolidation and growth but not of expansion. Jefferson's and Adam's interest in the appreciation of science was generally not shared by others who, through their political positions, could have facilitated the promotion of scientific studies.

Nor was the philosophical attitude as to the proper functions of the Federal Government significantly changed during the Jacksonian period of 1829–61. President Van Buren stated the underlying Democratic philosophy clearly and unequivocally in his message to Congress in 1837. "All communities," he declared, "are apt to look to government for too much . . . But this ought not to be. The framers of our excellent Constitution and the people who approved it with calm and sagacious deliberation acted at the time on a sounder principle. They wisely judged that the less government interferes with private pursuits the better for the general prosperity . . . its real duty . . . is . . . to leave every citizen and every interest to reap under its benign protection the rewards of virtue, industry, and prudence." Governmental policy followed this philosophy consistently (White, 1954, p. 6).

While the National Government was used by its citizens hardly more in 1860 than it was in 1800, the States and their subdivisions were actively pushing into new fields, unhampered by the constitutional doubts of statesmen on the national scene, although restrained in some measure by the dominant philosophy of laissez faire (White, 1954, Preface).

The movement for public education, inspired and led by Horace Mann, reflected the desire for more informed public opinion. A convention of organized workingmen meeting in Boston in 1833 resolved that no person would receive the votes of its members "but such as are known to be openly and decidedly favorable to a system of general education, by means of manual labor schools, supported at public expense, and open alike to the children of the poor as well as to the rich . . . " This resolution was symptomatic of the future, as Americans came to realize that government could make positive, constructive contributions to the needs of the people without necessarily creating either a threat to liberty or a drain on the Nation's resources (White, 1954, p. 10). Coming as it did in 1833, this resolution may be a manifestation of the same intellectual forces, the same general awakening of the desire for knowledge, that prompted the organization of the State geological surveys—17 of them during the period 1830–40 alone (Fig. 1).

As to more positive contributions by the Federal Government, however, it is doubtful that much could have been accomplished even if the prevailing attitude had been more favorable. The years of the Jacksonians, from 1829 to 1861, were years of almost uninterrupted excitement, tension, crisis, and apprehension. Nullification in South Carolina, the resolution censuring Jackson and its final erasure from the Senate Journal, the panic of 1837, the controversy with Great Britain over Oregon, the war with Mexico, the problem of slavery in the newly acquired territories leading to the Compromise of 1850, the moral and administrative crises precipitated by the Fugitive Slave Act, the panic of 1857, John Brown's raid—all these events gave neither the politicians nor the people any peace (White, 1954, p. 18). Congress and the administrators had little time for expanding the function of science in government.

Another reason, as we have said, is that geology was a young science which, at least so far as the Federal Government was concerned, had not yet proved its practical value and was considered theoretical and academic. The general intellectual environment in the United States was not conducive to active participation in theoretical sciences. We have the clearest description of the attitude of the times in Tocqueville's perceptive writings where he states (1900, vol. 2, p. 43), "In America the purely practical part of science is admirably understood, and careful attention is paid to the theoretical portion which is immediately requisite to application. On this head the Americans always display a clear, free, original, and inventive power of mind. But hardly anyone in the United States devotes himself to the essentially theoretical and abstract portion of human knowledge."

Thus we see that the political and administrative philosophy was not compatible with support of geology on the Federal level, and that whatever was to be done with public support necessarily became the responsibility of the State governments. The defeat of John Quincy Adams in 1828 marked the climax of his effort to use national power and resources for what he con-

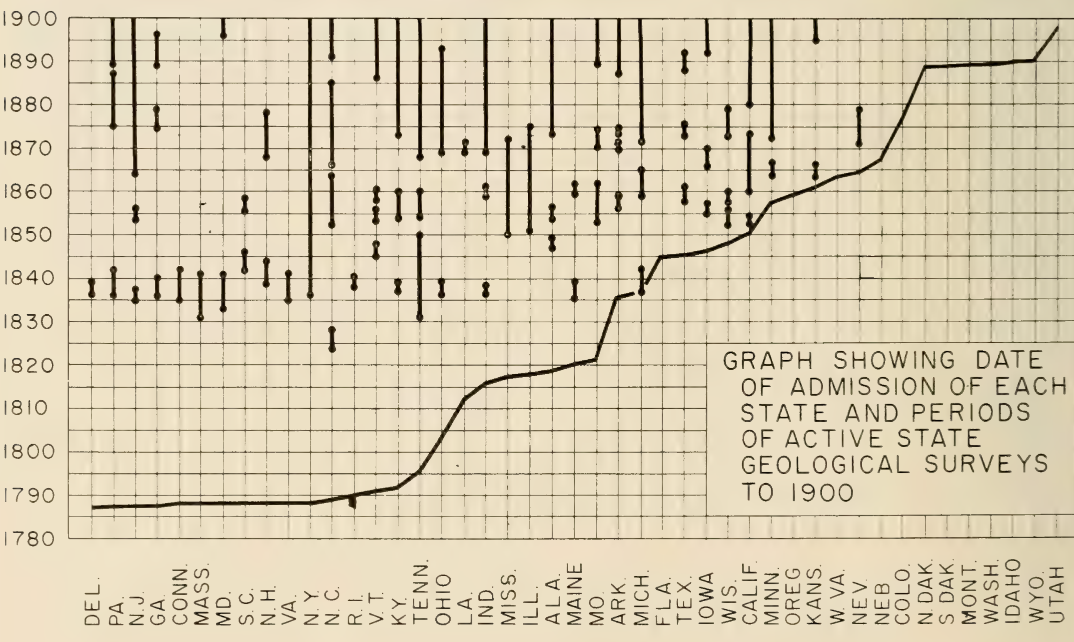

Figure 1

ceived to be national purposes. I think this may have brought about the general realization that the States would have to assume greater responsibilities, and it is particularly significant to geology in that it happened immediately before the first State surveys were formed in the 1830's.

This is not to imply that the Federal Government was completely inactive in geologic exploration but only that the States were taking the lead and dominating that part of geology supported directly by public funds. As we know, we had the expeditions of Schoolcraft, Lewis and Clark, Pike, Long, Wilkes, and Frémont; the Pacific Railway Survey; and others during the period 1803 to 1860. Geologic knowledge was gained from all these expeditions, but geology was not their primary purpose. The authorizations of the surveys of Featherstonhaugh in 1834–35 and of David Dale Owen in 1839 were the first Federal attempts to support geologic investigations.

It is interesting to speculate on the possible causes of the flourishing of the State surveys in the 1830's (Fig. 1). Of the 13 original States only two did not start a survey during the decade 1830–40; one of these, North Carolina, had had a token survey a few years earlier, and the remaining State, South Carolina, began its survey only two years after the end of this decade. (It is also of interest to note that the Geological Survey of Great Britain was organized in 1835.) Were these States only imitating Massachusetts and North Carolina, the early birds, or had geology truly become a science, as Smallwood suggests? He states (1941, p. 441), "Geology, the third large department of natural history, stands out in rather marked contrast to botany and zoology. During the period designated as 'the passing of the naturalist' (1830–40), in which the naturalist, after acquiring great influence, rather rapidly declined, geology became very prominent in the making of State surveys. The naturalists' emphasis was being replaced by the adoption of scientific criteria that any geologist could apply."

I think we cannot completely disregard the role of chance in the nearly simultaneous beginning of the surveys. That is to say, there was enough general activity in geology to permit this sudden development. The establishment of the American Journal of Science in 1818 and of the American Geological Society in 1819, the publication of Eaton's Index to the Geology of the Northern States in 1818, and the organization of the Geological Society of Pennsylvania in 1832 were significant items in bringing geology to the forefront.

Nor do I think we can overlook the role of individual personalities as contributing factors. We see the rise of strong leaders such as Edward Hitchcock, who was responsible for the conception and establishment of the first State geological survey, that of Massachusetts; the Rogers brothers, responsible for three of the early surveys; W. W. Mather, who made the Ohio and Kentucky surveys; C. T. Jackson, also responsible for three State surveys; David Dale Owen, who started the Indiana survey; and Amos Eaton, whose lectures to the New York State Legislature no doubt were the beginning of that State's survey.

Regardless of which of the several possibilities was dominant, we see from Fig. 1 that the early State surveys were short-lived, not only those that began during the early period but even those that began later. The short life of these surveys no doubt could be explained by many reasons, such as adverse economic conditions, internal political changes, or shortage of competent personnel. But I think none of these come as close to the truth as that suggested by the Federal Survey's Director Mendenhall in describing the tremendous task confronting the men who undertook the first survey of Pennsylvania: "An adequate study of 45,000 square miles of extremely varied and complex geology and the revelation of the wide variety of mineral resources that it contains, would tax the capacity of a large modern staff, trained according to modern standards, and equipped with complete modern maps. It couldn't be done promptly, of course, a century ago. Base maps were lacking; trained geologists were very few. Principles had to be established and methods devised as the work proceeded. The magnitude of the task was tremendous and dawned only slowly on the workers. Results came in slowly so that the State lost patience and in six years appropriations ceased" (Mendenhall, 1936, p. 17).

It was no doubt this same impatience that caused nearly continuous difficulty in establishing permanent State surveys. Tocqueville apparently recognized this characteristic of our society and in effect predicted the difficulty that activities such as State geological surveys would face in gaining general acceptance. He comments, "The man of action is frequently obliged to content himself with the best he can get, because he would never accomplish his purpose if he chose to carry every detail to perfection . . . The world is not led by long or learned demonstrations" (Tocqueville, vol. 2, p. 44).

Therefore, when geology did not yield results immediately capable of application to current wishes, the "men of action" saw no need for further support and the surveys ceased. As the reports were later published and use could be made of the geologic knowledge from the surveys, most of the States again organized surveys, the later ones generally being longer lived than the earlier ones. The State surveys continued to dominate the public activity in geology until the Civil War.

Although three States started surveys during the Civil War, this generally was a period of disruption in geology, lost records, and diversion of personnel. After the war we see a great increase in geologic interest and activity by the Federal Government. Merrill states, "The period of the Civil War had brought to light a considerable number of men . . . of great physical and moral courage. It was but natural, therefore, particularly when the necessity for military routes in the west and public land questions were taken into consideration, that such should turn their attention toward western exploration. Further, the surveys made in 1850's, in connection with routes for the Pacific railroads, and the work done by Evans, Hayden, and Meek in the Bad Lands of the Missouri had whetted the desires of numerous investigators. Willing workers were abundant and Congress not difficult to persuade into granting the necessary funds" (Merrill, 1924, p. 500).

This change in the attitude of Congress marks a significant step in the emergence of geology as a public function. Only a few years before, in 1852, Congress specified that no new geological surveys be undertaken unless authorized by law. I think this change in attitude may be attributed at least in part to a gradual shift in the point of initiation of new functions in the Government. In the early periods we see the President taking a very active role in developing new functions. For example, Thomas Jefferson wrote detailed instructions for Lewis and Clark to follow on their expedition. A few decades later Congress is perplexed with the problem of doing something constructive with Smithson's estate. The act creating the Smithsonian Institution was one of the earliest modern acts of Congress to take a positive and constructive attitude toward a new function. Still later, as the tasks and responsibilities of the Government increased, I believe we can see the initiation of new functions taking place in the newly organized and expanding departments. Here the debates are not among the members of Congress as much as between the Congress and the administrators. Therefore, as the potential leaders of western surveys sought Congressional appropriations, the logic of their arguments added force to governmental processes and facilitated the beginning of new functions. As these western surveys gained in strength and popularity it was only a step in the direction of more economical operation to create the U. S. Geological Survey by combining their purposes and personnel.

In summary, I have attempted to outline the political and administrative philosophy from about 1800 to 1879 as it bears on the emergence of geology as a public function. I have ignored almost entirely the force of geology itself. Nor have I considered the very significant contributions made by the land-grant colleges and other publicly supported educational institutions. Other items I have ignored, in deference to other papers in this symposium, are, for example, the role of the Smithsonian Institution, the activities of the AAAS, the effect of Darwinian concepts, the popularization of geology, and the development and use of topographic maps. Indeed, every contribution to the advancement of geology must be considered a part of the story of the emergence of geology as a public function.

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REFERENCES

Adams, Henry. *The education of Henry Adams:* 517 pp. Boston, Houghton Mifflin Co., 1918.

Mendenhall, W. C. *Establishment of Pennsylvania survey—an outstanding event in development of science in U. S.* Pennsylvania Dept. Internal Affairs Monthly Bull. **2**(1): 17–18. 1936.

Merrill, G. P. *The first one hundred years of American geology.* Yale University Press. 1924.

Smallwood, W. M. *Natural history and the American mind:* 445 pp. New York, Columbia University Press, 1941.

Tocqueville, Alexis de. *Democracy in America* **1**: 442 pp.; **2**: 399 pp. New York, Colonial Press, 1900.

White, L. D. *The Jeffersonians:* 572 pp. New York, Macmillan Co., 1951.

———. *The Jacksonians:* 593 pp. New York, Macmillan Co., 1954.

The United States Geological Survey and the Advancement of Geology in the Public Service

By Thomas B. Nolan, *Director, U. S. Geological Survey*

The Geological Survey will be 80 years old on March 3, 1959. It came into being that date in 1879, when President Hayes signed an appropriation bill that contained an item giving the Director of the Geological Survey the responsibility of administering a new organization, which was directed to classify the public lands and to examine the "geological structure, mineral resources, and products of the national domain."

This rather oblique method of creating the new organization was perhaps an appropriate conclusion to the struggle for support —especially financial support—by four predecessor exploratory surveys which were by this action combined into one. The union was accomplished largely through the acceptance by the Congress of the major recommendations of a committee set up by the National Academy of Sciences at its request. The infant bureau thus, at its inception, enjoyed the sponsorship of the leading scientific group of the country. It has been fortunate since that time to have had continued assistance in the selection of its directors, through recommendations by this same Academy.

The four predecessor surveys were each established in the years following the Civil War. They were to aid in developing the West, through the acquisition of additional knowledge of its geography and of its resources. Their objectives, and those of the young Geological Survey, were primarily the practical ones of exploring the geographic frontier, in part to learn about new or better routes by which it might be traversed; in part to discover and appraise the natural wealth of the new territory. Emphasis was, of course, laid upon the mineral wealth, but the soils, the water and forest resources, and even the scenic features had to come under scrutiny if the objectives were to be attained.

To achieve success in this sort of an exploration of a physical frontier, it is now apparent that it was necessary to develop both new concepts and new techniques. It was fortunate that the members of the early surveys and of the new Geological Survey had the capacity to do this; they were able, in a sense, to use the results of their exploration of intellectual frontiers in the attainment of their practical objective of delimiting the geographic one.

The record of the Survey in subsequent years seems to me to illustrate a continuing ability to utilize the products of intellectual curiosity in the solution of the practical problems that arise in our economy. The industrialization of the country, following the development of the West; participation in two World Wars; and currently the need to resolve difficult and perplexing problems in water and mineral supply have each been accompanied by reorientations in the research programs of the Survey, with concomitant applications of research results to the problems themselves.

I believe this ability to recognize, or anticipate, national needs and to use research results in their solution has been the most significant contribution by the Survey to the "advancement of geology in the public service."

With this preface, I should like to review very briefly the history and activities of the Geological Survey since its founding. Clarence King was the first director; he served for only two years, but in that brief period a staff of outstanding scientists was gathered, several geologic studies were begun, a chemical laboratory was set up in Denver, topographic surveys were begun in Nevada, the Survey's first geophysical work was started as part of the study of the Comstock Lode, and, in cooperation with the Census Bureau, the collection of statistics on yearly mineral production in the region west of the 100th meridian was begun. Thus, from the very beginning both practical and theoretical investigations, or applied science and basic research, were part of the Survey program.

Establishment of the Survey did not put an end to the controversy over the function of a Government bureau engaged in scientific activities. John Wesley Powell, who had been instrumental in the founding of the Survey and who had succeeded King as director, had as his goal the establishment of the Survey as a great scientific and technical bureau with emphasis on research in all its functions. Shortly after he assumed office, paleontological laboratories were established, a physical laboratory was set up for research on the effect of temperature, pressure, and related phenomena on rocks, and studies of metamorphism and the paragenesis of minerals were begun. In 1882 congressional authorization was given "to prepare a geologic map of the United States," thus leaving no doubt as to the national extent of the Survey's work; and to procure statistics in relation to mines and mining, thus placing on a permanent basis work that had been undertaken in cooperation with the Tenth Census. And the Survey was making a topographic map of the United States because, as Powell pointed out, sound geologic research is based on geography.

By 1884 this vigorous prosecution of work and rapid expansion of the Survey had provoked considerable discussion in both public and private circles, and a Congressional committee undertook an investigation of the several scientific bureaus to attain greater efficiency and economy in their administration. In his appearances before this committee Powell established a philosophy which has become the guiding principle of the Survey in later years that a Government research agency should promote the welfare of the people by investigations in those fields most vitally affecting the great industries in which people engage, should have the broadest possible territorial base, and its work should not be undertaken in those fields where private enterprise may be relied on for good and exhaustive work. The majority report was favorable, and Congress, by specific appropriation, endorsed the chemical, physical, and paleontologic work of the Survey.

In addition to its regular scientific work, three major problems in conservation occupied the Survey during the first third of its history. In 1888 Congress authorized the Survey to undertake a study of the arid regions where irrigation was necessary to agriculture. In 1894 and in subsequent years the Survey received appropriations for gaging streams and determining the water supply of the United States. When the Reclamation Act was passed in 1902, its administration was assigned to the Survey until the work changed from planning to construction. In 1907 the Reclamation Service became an independent bureau and the chief of the Geological Survey's Hydrographic Branch became its first director.

In the course of its geologic and topographic surveys, the Survey had gathered data related to forests, and in 1891 Congress authorized creation of forest reserves on the public lands. A comprehensive study of forest reserves was begun in 1897, and land classification maps were prepared to form the basis for regulations governing the reserves. In 1905 the Forest Service was established in the Department of Agriculture and took over the further examination and classification of forest reserves as well as the administration of regulations.

Mining geology and mining technology had been an important part of the Survey's work from the start. Beginning in 1883, an annual volume of statistics on the mineral resources had been prepared. Public interest in a separate division of mines to serve the needs of the mining industry developed fairly early. But it was some years later (1908) when the Survey was authorized to undertake an investigation of mine safety. These activities were somewhat outside the normal work of the Survey and were later transferred to the Bureau of Mines, which was established by congressional act of May 16, 1910, along with the Technologic Branch of the Survey, whose chief became the first director of the Bureau.

Meanwhile the regular geologic work of the Survey had progressed. Investigations had been undertaken in Alaska, Hawaii, Puerto Rico, and Cuba. Nearly a third of the country had been mapped topographically, at least in reconnaissance, geologic folios had been published, and some 400 reports had been published on such topics as Lake Bonneville, the Paleozoic fishes of North America, the glacial gravels of Maine, borax deposits in Death Valley, and tin in Alaska, on the chemical composition of igneous rocks, the form of sea level, earthquakes in California, and the compressibility of liquids. Its investigation in the Leadville district had shown the practical importance of geologic studies in mining, those in the Lake Superior region had an effect on discovery and development, and studies in the Appalachian coal field were pointing the way toward a scientific basis for development of natural fuel resources.

The middle third of the Survey's history is nearly coincident with the directorship of George Otis Smith. It was Smith's idea that a scientific bureau should collect and arrange facts upon which the Nation could base its plans for future development and should make its science useful to the public. Basic research was encouraged but there was increased emphasis on and a widening of the Survey's usefulness in applied science.

During his first decade in office the general public was in closer touch with the Survey and made more use of its scientific results than ever before. In one year it was reported that approximately 50,000 letters of inquiry were handled in the different scientific branches. In a special publication, Bulletin 599, entitled *Our mineral reserves*, the country's ability to meet emergency demand was summarized and the Survey offered to serve as an agent in bringing consumer and producer into touch with each other. In recognition of its responsibility to make its work intelligible to the layman, nontechnical descriptions of the physical features and their origin were printed on the backs of several topographic maps, and guides covering points of scenic or unusual geologic interest in some of the national parks and along several transcontinental routes were prepared.

Efforts to assist in discovering and developing new oil reserves were intensified, field studies seeking a better understanding of the principles and conditions governing the origin, movement, and segregation of oil and gas were begun, and field investigations of the oil shale reserves were also under way. After Germany gained a monopoly of the potash supply, Congress directed the Survey to explore for domestic deposits, and intensive and ultimately successful exploration was carried out in the western States. Another notable contribution to geology in its broadest sense was the study by G. K. Gilbert of hydraulic mining debris in the Sierra Nevada which involved mining, agriculture, and navigation problems as well as geology.

With the advent of the first World War, scientific knowledge and methods were applied to the technology of weapons, and the need for basic raw materials brought to the Survey an important role in the war effort. Scientific data already available in the Survey formed the basis of special investigations of certain mineral deposits and an increased exploration for new deposits. The strategic minerals concept was first developed at this time, and a beginning was made in military geology as information on potential mineral and water resources of other countries was gathered.

The war had shown the need for increased development of power sources. During the war Survey hydraulic engineers had made a countrywide survey of the power situation to determine where water power could be substituted for steam-generated power. After the war a survey of sources of energy in the Washington-Boston area, the so-called Superpower Survey, was undertaken by congressional authorization. The Federal Coal Commission was set up in 1922 and took the director away from the Survey for a year; in 1924 he was appointed to a Federal Oil Conservation Board and to a naval oil supply commission; in 1925 he was delegate to the World Power Conference, and in 1930 the newly established Federal Power Commission took him permanently from the Survey.

The last third of the Survey's history has been one of relatively rapid and great changes and an even more intimate involvement of the Survey with the national development. During the depression years of the early 30's, appropriations were so reduced that many were forced to leave the Survey and many projects were suspended. Through allocation of funds from the Public Works Administration and other agencies some of the Survey programs, notably topographic mapping and investigations of mineral resources in the Southeastern States, were continued, and in 1936 increased appropriations made possible more normal operations.

In 1939, with the threat of approaching war, Congress authorized the beginning of strategic mineral investigations, and when the war started a high proportion of Survey men were shifted to this work. A military geology group was formed immediately after the United States entered the war and grew rapidly as its work became more and more useful to the armed services. Appraisals of characteristics of enemy terrain were made for use in strategic planning, and Survey scientists went into the war theaters to aid in planning tactical operations. An investigation of fissionable raw materials begun at the request of the Manhattan Engineer District was expanded after the war on behalf of the Atomic Energy Commission to a major program that involved both exploration and basic research in the geology of fissionable materials.

In the post-war years, also, engineering geologic investigations have been undertaken in support of the program of the Department of the Interior for river-basin development, and geologic mapping of fast-growing industrial areas has provided data needed in many types of engineering construction in expanding urban areas. Research has also been undertaken on geologic processes, such as the development of landslides, that affect the safety of engineering structures.

In the Survey's traditional fields of geologic mapping and appraisal of the mineral resources of the Nation there has been a constant awareness of the need for continual development of new exploratory tools and improvement of techniques as the expanding economy calls for ever-increasing amounts of raw materials and advancing technology creates demands for new materials. Geochemical prospecting methods have been developed to aid in the discovery of mineral deposits. New, rapid, sensitive, and inexpensive analytical methods suitable for use in the field have been developed, and geobotanical and hydrogeochemical techniques have been investigated. Geophysics has taken to the air, and magnetic and radioactivity surveys have been made of many thousands of square miles. Geologic mapping techniques are being improved notably by the development of photogeology to obtain greater coverage more rapidly and at less cost.

More than ever before we need to develop an understanding of the processes by which mineral deposits are formed in order to develop the scientific techniques required to guide the search for new sources. As part of a long-range minerals program, more and more data are being sought on the physical properties of rocks, on the nature of the ore-forming fluids, on the physical, chemical, and biochemical changes that take place in weathering.

Geologic facts and techniques are being used in an ever-increasing variety of problems. Airborne radioactivity surveys developed to aid in exploration for new sources of uranium are being adapted to monitoring the effects of nuclear explosions on atmospheric radioactivity, and both geophysical and geochemical methods are being used in a study of the relation of environmental factors to the development of cancer, and measurements of the temperature in frozen ground turn out to be significant in the design of buildings, roads, and other construction and the location of water supplies in our forty-ninth State.

This recital of activities and policies since 1879 is in part abridged from the excellent historical summary prepared by John and Mary Rabbitt on the occasion of the seventy-fifth anniversary of the Geological Survey; it was published in Science in 1954. The chronological recital alone, I think, records the very considerable contributions that the organization has made to the "advancement of geology in the public service." I should like, though, to further summarize by pointing out four broad categories in which these activities have been especially productive.

One might be categorized as the development or refinement of new fields or new principles. I believe that it is fair to say, for example, that mining geology as it is practiced today is very largely the product of Survey work. This began with Clarence King who, in addition to his own activities, sponsored the work of Becker in the Comstock and S. F. Emmons in Leadville, continued through the widespread activities and generalizations of Lindgren and the timely analysis of the newly developed porphyry copper deposits by Spencer and Ransome, and is operative to the present day through the field development of airborne and geochemical exploration methods, and the laboratory researches of the Geochemistry and Petrology Branch. An even stronger case might be made for the new field of groundwater hydrology with the early work of Mendenhall in southern California, the long period of development under Meinzer, and the more recent investigations by Sayre, Theis, and others.

Contributions to geologic thinking and to the development of principles are basically made by individuals, rather than organizations, but the latter can provide an environment in which individual contributions may flower. I believe this has been true in the Geological Survey; certainly our basic concepts in sedimentation and stream dynamics have been continuously influenced by the work of Gilbert, Rubey, and, most recently, by Leopold. Similarly, glacial geology has been influenced by Survey authors from T. C. Chamberlain through Alden and Matthes; structure, from Dutton to Gilluly, petrology from Hague through Cross to E. S. Larsen, Jr. The list could be greatly expanded.

Less glamorous, perhaps, but certainly of inestimable value to the profession have been the numerous new or improved tools or techniques that have resulted from the Survey's work. The *Bibliographies of North American geology*, *Lexicon of geologic names*, and *Data of geochemistry* are examples of published contributions that are invaluable to the practicing geologist, while a whole series of proposals or developments from the standardization of cartographic methods for geologic maps to the devising of the numerous instruments and methods of photogeology have made it possible for geologists to do their field work and write their reports more accurately and more effectively.

The third category has been alluded to in previous paragraphs. It might be called the recognition, and sponsoring, of new and desirable areas of endeavor in fields related to geology and earth science. The establishment of such Federal agencies as the Forest

Service, Bureau of Reclamation, Bureau of Mines, and the Grazing Service (now a part of the Bureau of Land Management) and the non-Federal Geophysical Laboratory, resulted directly from activities initiated in the Geological Survey. I suppose some may feel that the creation of additional Federal agencies is a dubious contribution, but I believe most thoughtful observers will concur in the belief that the part played by the Survey in the creation of professional agencies in the resource management field with the high standards that characterized the parent agency has been a significant contribution to the Nation's wellbeing.

Finally, I feel that the Survey has played a large and beneficial role in education in this country that is in addition to the contributions to geologic thinking that I have mentioned. In part this has been the result of its personnel policies and in part of its extensive publication program. In regard to the first, the bureau has from the beginning encouraged an interchange of personnel between its staff and that of university faculties in geology as well as in the summer employment, as field assistants, of advanced students in geology. This policy has led to the widespread use of the so-called "w. a.e." appointments; these are operative only when the individual, usually a university teacher, is actually employed—commonly during the summer field seasons. Among the earliest appointments recorded in the Survey archives are those of T. C. Chamberlain (who received the magnificent sum of "$10 per diem, paid only when actually employed"), J. P. Iddings, O. C. Marsh, and a number of others. Utilization of men such as these not only benefited the Survey through the individual skills thus made available but also inevitably contributed to the universities and to geologic education, by making available promptly as instructional material the results of field and laboratory work of not only the w. a. e. teachers but of the Survey staff with whom they were in contact. This interchange of personnel and the widespread utilization of "w. a. e." appointments is still a major element in Survey policy.

Possibly even greater assistance to geologic education has been provided by the several series of publications which record the results of the Survey's work. I suspect that directly, through the use of such classics as Gilbert's Lake Bonneville monograph, and indirectly, through the contributions of Survey material in textbooks and lectures, almost all of us in the geologic profession are indebted, more than we recognize, to this long series of reports on the Survey's field and laboratory work.

It is apparent that I believe the Geological Survey has contributed significantly to both the advancement of geology and the public service. To me the real and lasting contribution made by the Survey, and by the other Federal scientific agencies, is the part they have played in securing general recognition, throughout the country, not only that scientific and professional work of the highest quality is possible in the Federal Government, but that it has been one of the essential contributions to the development of this Nation to the international power that it is today.

I observed earlier in this paper that a transition from an exploration of a geographic frontier to an intellectual one characterized the early work of the Geological Survey. In recent months, some of our more inquisitive younger members have proposed various studies of the geography of the individual components of "outer space." Perhaps we are about to see the beginning of a new cycle in the history of the Geological Survey in the public service.

The Role of the Smithsonian Institution in Early American Geology

By Paul H. Oehser, *Smithsonian Institution*

The concern of the Smithsonian Institution with the science of geology began very early in its history. It was, indeed, inherent in its very foundation; for James Smithson, the Englishman who left his fortune to the United States of America "to found at Washington an Institution for the increase and diffusion of knowledge among men"—this disappointed, lonely man who had never been to America but somehow caught the vision of the potential of such an establishment on American soil—was himself something of a geologist. While still a young Oxford student he geologized through the British Isles and thereafter assembled a large collection of gems and minerals and made noteworthy studies of them. Today, on entering the beautiful new Hall of Gems and Minerals at the Smithsonian, one can read this label accompanying a colorful specimen of smithsonite (zinc carbonate):

"This mineral was named [by Beudant] in honor of its discoverer, James Smithson, distinguished English chemist and mineralogist and founder of the Smithsonian Institution. Despite the primitive chemical apparatus and crude reagents which Smithson had to use, he was able to achieve analytical results of the most creditable character and to enlarge our knowledge of many mineral species. Before his time zinc carbonate and zinc silicate were confused as a single mineral species under the name *calamine*, but his researchers distinguished the two minerals which are now known as smithsonite and hemimorphite."

When the Smithsonian Institution was finally established by act of Congress in 1846, on the basis of a broad interpretation of the provisions of Smithson's will, geology and mineralogy were included among the Institution's concerns. In fact, James Smithson's personal collection of minerals came as a nucleus of the great national collections in this field that have accumulated through the years.

The first Secretary of the Smithsonian was Prof. Joseph Henry. He was a "natural philosopher" and made his principal contributions to science in the field of electricity; but he began as a geologist in his native New York State in the days of Amos Eaton under whose influence he came. When, in 1820, Eaton was commissioned to conduct an agricultural and geological survey of Albany County, N. Y., he chose the 23-year-old Joseph Henry as an assistant. Six years later, Henry received an appointment as engineer on a survey for an east-west road through New York State, an assignment in which he notably acquitted himself. It is said that "his labors in this work were exceedingly arduous and responsible. They extended far into the winter, and the operations were carried on in some instances amid deep snows in primeval forests." He was offered the job of directing the construction of a canal in Ohio, but the vacant chair of mathematics at the Albany Academy beckoned, and this budding geologist-engineer abandoned canal-building for the classroom. His third published scientific paper, *Topographical sketch of the State of New York; designed chiefly to show the general elevations and depressions of its surface*, which appeared in the Transactions of the Albany Institute in 1829, capped this phase of this career. Henry too was a lifelong friend of James Hall, the eminent State geologist of New York, from whom he must have assimilated considerable geologic nourishment.

I dwell on Henry here because a few years later it was put into his power to organize and shape the destiny of the Smithsonian Institution, and there can be little doubt that his knowledge of geology and its methods and his understanding of the importance of the science of geology to the growth of the country had its impact on the course the Institution was to take. This knowledge and understanding were reflected particularly in two directions—exploration and publication.

Henry had as his Assistant Secretary a man as thoroughly trained in the natural sciences, particularly biology, as he himself was in the physical sciences—Spencer Fullerton Baird. Before Baird came to Washington, and up to the time the Smithsonian was founded, there had been at least half a dozen principal Western exploring expeditions, beginning with Lewis and Clark in 1804 and ending with Frémont's explorations of Oregon and California. But these were only the beginning. Soon the Bad Lands were being explored by Dr. John Evans and Thaddeus A. Culbertson. In 1849–50 Capt. Howard Stansbury led an exploring and surveying expedition to Great Salt Lake. Capt. Lorenzo Sitgreaves (1852) was exploring the Zuni and Colorado River region. The Mexican boundary survey was in progress (1854–56) under Maj. W. H. Emory. Several parties were in the field surveying for a railroad route to the Pacific. There were expeditions, also, to Chile, the La Plata region, the Amazon Valley, Greenland, and Bering Sea.

The Smithsonian's part in these efforts was considerable. In his 1854 annual report Baird described 26 important explorations undertaken during the preceding two years, including six Pacific Railroad surveys. "With scarcely an exception," he wrote, "every expedition of any magnitude has received more or less aid from the Smithsonian Institution. This has consisted in the supply of instructions for making observations in meteorology and natural history, and of information as to particular desiderata; in the preparation, in part, of the meteorological, magnetical, and natural history outfit, including the selection and purchase of the necessary apparatus and instruments; in the nomination and training of persons to fill important positions in the scientific corps; in the reception of the collections made, and their reference to individuals competent to report upon them; and in employing skillful and trained artists to make accurate delineations of the new and unfigured species. Much of the apparatus supplied to the different parties was invented or adapted by the Institution for this special purpose, and used for the first time, with results surpassing the most sanguine expectations."

All this represented the type of aid the Smithsonian rendered throughout the exciting decades of western exploration and expansion. It paid off in many ways, and all the natural sciences, including geology, benefited. The Nation benefited. Two spectacular instances are enough to mention.

On June 16, 1874, Maj. John Wesley Powell laid on the desk of Secretary Joseph Henry the manuscript of his *Exploration of the Colorado River of the West and its tributaries,* culminating Powell's explorations up to that time. The Smithsonian among others had aided the Powell expeditions in various ways, and it was the Smithsonian that sponsored the publication of the *Exploration.* With remarkable speed, it came off the press the following year. Its importance to American geology needs no recounting before this audience.

Another Smithsonian-nurtured venture of far-reaching significance was the Kennicott Expedition that in 1864 set out to explore Russian America for the Western Union Telegraph Co., which undertook to run a telegraph line to Europe by way of Alaska and Siberia after the failure of the Atlantic cable. Directing the scientific corps was the young Robert Kennicott, of the Chicago Academy of Sciences, who died of a heart attack near Nulato in May 1866. A geologist, William Healey Dall, was then put in charge. Soon afterward, Cyrus Field's Atlantic cable was assured and the Western Union dropped the whole project of an overland telegraph line, and the exploring party was disbanded. In their few months in the Far North, however, they had done remarkable work, penetrating territory never before seen or traversed by white men and gathering a wealth of natural-history data. Two of the party—Henry M. Bannister and Ferdinand Bischoff—had returned to Washington in 1867, about the time when the United States Congress was considering the purchase of Alaska from Russia. Their presence was most opportune, for they were probably the only persons in the Capital with firsthand knowledge of Russian America. Bannister, Bischoff, and Baird were called to testify before the Senate Committee on Foreign Relations. Their story of Alaska's wealth of furs, fish, and timber, gold and copper, its unbelievable mountains and glaciers and forests, must have been a thrilling one to hear. Bannister himself later remarked: "The annexation was ridiculed at the time, but we could testify that the country was worth the price asked. Time has sufficiently proved that we were right and I can safely say that we did not overstate anything . . . The project of the Western Union Telegraph Company . . . was a failure but its greatest result was the annexation of Alaska." Almost immediately another expedition was organized by the Treasury Department to obtain additional information concerning the new Territory of Alaska, and at the request of the Secretary of the Treasury the Smithsonian furnished instructions "for research into the physical and natural history of the country." Among these instructions the following is of special interest: "Full collections should be made of the rocks and minerals of the country at the different stopping points, as well as of any fossil remains that may be found to occur. Notes should accompany these specimens showing their relationship to each other and the country itself, and illustrated by diagrams indicating the number, inclination, and relative thickness of any strata that may be observed."

There was another aspect to the Smithsonian's role of catalyst whose importance should not be minimized. It was the atmosphere it provided young scientists in Washington for study and research. In those early days the Smithsonian's funds had to be spread thin. It could not build up a large staff of geologists, biologists, physicists, anthropologists. But it could provide some of them with facilities and even living quarters. The be-towered, owl-haunted Smithsonian Building, designed by the church-building architect James Renwick, was a mecca for them. Joseph Henry and his family occupied the east "apartments" of the building. Encouraged by both Henry and Baird, many a young hopeful was allowed to occupy some unused upper room in one of the towers. One group called itself the Megatherium Club, taking its name from the field of vertebrate paleontology. The geologist Fielding Bradford Meek lived in a north-tower room from the time he went to Washington in 1858 until his death in 1876, and within the Smithsonian walls were carried on his patient and conscientious labors "by which the paleontology of the United States was so greatly advanced." The visiting Louis Agassiz spent many a night in the building as a guest of the Henrys, and there still is circulated the probably not apocryphal story of how, one night, some of the resident "boys" loosened the slats of Agassiz's bed. It is not recorded just what effect this downfall had on the future career of the famous glaciologist.[1]

Two other geologists who were the beneficiaries of Smithsonian hospitality were William Healey Dall and Lester F. Ward. Neither, so far as I know, ever lived in the building or was ever on the payroll of the Smithsonian; but Dall, explorer, paleontologist, conchologist, spent a lifetime in the National Museum's division of mollusks; while Ward, the paleobotanist who finally became the patron saint of sociology, was similarly given the keys to the Institution and did some of his finest work under its aegis. A little later, Charles Doolittle Walcott became similarly attached to the Smithsonian, where he helped to build up its invertebrate collections, particularly the Cambrian. All this provided the kind of encouragement that scientific research always needs. Throughout the latter half of the nineteenth century the Smithsonian was perhaps its most generous dispenser; and certainly, as Prof. William North Rice long ago stated, until the time the U. S. Geological Survey was organized in 1879, the Smithsonian Institution was the headquarters of the geologists in the service of the Government. In geology, as in other fields, the Smithsonian created a salubrious climate for scientific work.

In 1846 when the Smithsonian was founded, there were few outlets for the publication of sizable scientific manuscripts.

[1] Dr. T. S. Palmer, biologist and necrologist who pervaded Washington scientific circles for many years until his death in 1955, tried to find out just which room in the Smithsonian Building "the bed fell with Agassiz." If he ever discovered this bit of esoterica, the secret died with him.

As Henry said, "The learned societies in this country have not the means, except in a very limited degree, of publishing memoirs which require expensive illustrations, much less of assisting to defray the cost of investigations by which the results have been attained." Henry felt, therefore, that the Smithsonian could make a real contribution to science by allotting a part of its income to such publication, and he provided for this in his initial program. "The publication of original memoirs and periodical reports," he said, "will act as a powerful stimulus on the latent talent of our country, by placing in bold relief the real laborers in the field of original research, while it will afford the best materials for the use of those engaged in the diffusion of knowledge." This program was immediately initiated, and Henry through the Smithsonian not only began a series of monumental publications but also organized a scheme (the International Exchange Service) by which scholarly publications in general could be distributed throughout the world.

Geology benefited tremendously, as did anthropology, astronomy, mathematics, biology, and other disciplines. The quarto volumes of the Smithsonian Contributions to Knowledge began to appear in the libraries and laboratories of the learned world, their large illustrations, ample print, and careful editing distinguishing them. Before 1860 there had appeared such pioneer works as Joseph Leidy's *Ancient fauna of Nebraska*; J. W. Bailey's *Microscopical examinations of soundings, made by the United States Coast Survey off the Atlantic coast of the United States*; and Edward Hitchcock's *Illustrations of surface geology*. There followed such works as Meek and Hayden's *Paleontology of the Upper Missouri* (1865); Charles Whittlesey's *On the fresh-water glacial drift of the Northwestern States* (1866); Raphael Pumpelly's *Geological researches in China, Mongolia, and Japan* (1866); J. G. Barnard's *On the internal structure of the earth* (1877); and many others.

The effect of these publications was indeterminable but pervasive, and over the years the Smithsonian's publications in geology, in all its branches, have constituted perhaps the greatest contribution of the Institution to that science. It did not, of course, end with the cessation of the Smithsonian Contributions to Knowledge in 1916, but has continued to the present day in other Smithsonian series, particularly the Smithsonian Miscellaneous Collections and the Bulletins of the United States National Museum.

One should mention here too, the free public lectures that Joseph Henry rather reluctantly inaugurated in the early days of the Smithsonian and which had their special heyday up to the time the Institution's lecture-room was destroyed by the fire in the Smithsonian Building in 1865. The best scientific and literary talent of the country was brought to Washington for these lectures, and geology was well represented. The very first lectures given in the Smithsonian Building were a series of six on *Geology*, by Edward Hitchcock, president of Amherst College. Other geological lecturers included the elder Benjamin Silliman and James D. Dana of Yale; Joseph LeConte, then of Georgia; T. Sterry Hunt, of Canada; Fairman Rogers, of Philadelphia; and Louis Agassiz, of Harvard. To quote again Professor Rice: "When science had scarcely naturalized itself in the country, these lectures in the national capital, and under quasi-authoritative auspices, served a most valuable purpose in stimulating public interest in scientific subjects."

The United States National Museum is the largest of the "bureaus" of the Federal Government administered by the Smithsonian. Its Department of Geology, housed in the Smithsonian's Natural History Building, is the Nation's great geological depository, and has been ever since 1846, when by act of Congress the custody of the National Cabinet of Curiosities was transferred to the Smithsonian Institution. The act stipulated that "all objects of natural history, plants, and geological and mineralogical specimens belonging or hereafter to belong to the United States," and which were then in the City of Washington, should be delivered to the Regents of the Smithsonian Institution and together with new specimens obtained by exchange, donation, or otherwise, should be so arranged and classified as best to facilitate their examination and study. An act of March 3, 1879, decreed that "all collections of rocks, minerals, soils, fossils, and objects of natural history, archeology, and ethnology, made by the Coast and Geodetic Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress, shall be deposited in the National Museum." By the operation of these authorities, augmented by the efforts of the National Museum's staff geologists, the national collections in geology have grown in all divisions—vertebrate paleontology, invertebrate paleontology, paleobotany, micropaleontology, petrology, mineralogy. Indeed, in some fields, such as Foraminifera, they are matchless anywhere in the world. Scientists from all over the world have studied these collections, and hundreds of technical papers based on them have been published, particularly in taxonomic paleontology. Many eminent geologists, such as William Henry Holmes, O. C. Marsh, Charles A. White, George Perkins Merrill, and Charles D. Walcott, have identified themselves with this Department of Geology of the Museum. The last-named, in fact, became the third Director of the United States Geological Survey and later the fourth Secretary of the Smithsonian Institution. His influence on American geology, both scientific and philanthropic, has been great and would make an interesting story in itself.

And another result of these Museum collections that we have been discussing is an educational one. The collections have been drawn upon through the years as the basis of geological exhibits that have been viewed by millions of people. Today this exhibition phase is being developed to a high level in the modernized and expanded displays that are being built, a most notable example being the new Gems and Minerals Hall opened to the public in July 1958. We surmise that James Smithson would be surprised but pleased if he could walk into this hall today, captioned by his name on a block of smithsonite. Perhaps, however, we are getting away from our limitation of "early American geology."

In summary, then, we should say that during the third of a century between the establishment of the Smithsonian Institution 1846 and the founding of the United States Geological Survey in 1879, the Smithsonian served as a focus, headquarters, and catalyst for geology in America. Its contribution to the science of geology was manifested along several lines: (1) the encouragement, stimulation, and facilities offered by the Institution to young scientists who gathered in Washington in those early days; (2) the publication and worldwide distribution of geological works at a time when expensive monographic publication was difficult to obtain; (3) aid that the Smithsonian rendered in the western explorations and surveys; (4) its promotion of the science of paleontology and its necessary concomitant, taxonomy; (5) the building up of the great geological collections in the U. S. National Museum; and (6) education in geology through the Museum exhibits emanating from these collections.

REFERENCES

Bassler, Ray S. *The Smithsonian: Pioneer in American geology.* Science **104** (2693): 125–129. 1946.

Gilmore, Charles W. *A history of the division of vertebrate paleontology in the United States National Museum.* Proc. U. S. Nat. Mus. **90:** 305–377. 1941.

James, James Alton. *The first scientific exploration of Russian America and the purchase of Alaska.* Northwestern Univ. Studies in Social Sci. **4:** 276 pp. 1942.

Merrill, George Perkins. *Contributions to the history of American geology.* Rep. U. S. Nat. Mus. for 1904: 189–733, illus. 1906.

Oehser, Paul H. *Sons of science: The story of the Smithsonian Institution and its leaders:* xvii + 220 pp., illus. New York, 1949.

Rice, William North. *Geology and mineralogy.* In "The Smithsonian Institution, 1846–1896: The History of its First Half Century," edited by George Brown Goode: 631–646. Washington, 1897.

Smithsonian Institution. *Annual reports of the Board of Regents,* 1847–1878.

United States Congress. *A memorial of Joseph Henry:* 528 pp. Washington, 1880. (Published also in Smithsonian Misc. Coll. **21:** 1879.)

Geology Plus Adventure: The Story of the Hayden Survey

By J. V. Howell, *Tulsa, Okla.*

The period 1840 to 1880 was one of expansion on a scale never before experienced in North America. Population density of the area east of the Missouri had reached a point at which the supply of cheap land was near exhaustion as a result of 250 years of exploration and settlement. Yet the desire for land and the spirit of adventure were in no wise diminished, and the stage was set for the explosive westward movement which, in 35 years, resulted in settlement of all that area from the Missouri River to the Pacific.

Transportation here was a problem vastly different from that in the eastern half of the country, where rivers, lakes, and mountain passes were readily traversed, wood was generally available for fuel, pastures were plentiful, and the Indians were soon conquered or driven to the northward and southward. But on the Western plains the streams were few and seasonal and flowed in the wrong direction. The Indian tribes were warlike and well mounted, and main trails were lacking. Nevertheless, the feat was accomplished, and in a remarkably short time.

First, as usual, came the fur traders and trappers; then the military explorations with their emphasis on wagon roads and railroad routes to the Pacific, and with them the geological and natural history surveys. In seeking a reason for their proliferation, one needs only to consider the temper of the people and the reasons cited above. Both government and its citizens were avid for news of the West.

Alone of all the various explorations of the period, the Hayden Survey and its immediate predecessors, staffed by Ferdinand V. Hayden and a handful of assistants, have failed to receive full recognition and adequate description. Meanwhile, those of King, Powell, Frémont, Gunnison, Marcy, Long, and others have produced a spate of books. For this there are many reasons, none of which seems wholly justified. The last four were Army expeditions, each assigned to the search for a major route to the Pacific. Geology and natural history were secondary to pathfinding, the civilian scientists being strictly subordinates. King's Survey of the 40th Parallel gained prestige and acclaim not only by reason of its undisputed geological results but also because of its colorful, articulate leader. That of Powell became famous first through the impact of the Grand Canyon Voyage, the adventurous character of which largely overshadowed its very real geological discoveries. Hayden, on the other hand, had little flair for personal publicity and depended on a workmanlike job, prompt publication of results, and an efficient liaison with the newspapers to publicize his expeditions.

Ferdinand V. Hayden was born in Westfield, Mass., on September 7, 1829, to Asa and Melinda Hawley Hayden, and he lived there until his twelfth year. At this time his parents separated, the father moving to Rochester Depot, Ohio, and the mother to Rochester, N. Y. Each remarried and each had children by the second spouse. Ferdinand lived with an uncle at Rochester Depot, and at the age of 18 entered Oberlin College, 15 miles distant, from which he was graduated in the spring of 1850. He then entered Albany Medical College where he came under the influence of James Hall and of Dr. J. S. Newberry, who combined the practice of medicine in Cleveland, Ohio, with the study of paleobotany.

It should be mentioned here that only through a medical course could the student of that day obtain an adequate training in science. Hayden seems to have had no urge to practice medicine and never did so, except during the Civil War, when he served as a surgeon in the Union Army. Shortly before graduation in 1853, Hayden, sponsored by James Hall, made a trip up the Missouri Riven in search of vertebrate fossils in the Badlands. In this venture he was joined by F. B. Meek, and thus began an association that ended only with Meek's death in 1876.

The complete story of Hayden and the Hayden Survey has never been told and is beyond the scope of this paper. But an appraisal of the work is possible, and many hitherto unemphasized features will be pointed out. Previous authors, concerned with Hayden's rivals, have been careless in their statements, and some of these, too, will be refuted.

After their first trip up the Missouri, an expedition financed by James Hall and by Pierre Chouteau, Jr., Alex Culbertson and J. B. Sarpy of the American Fur Co., Meek and Hayden returned in late autumn and spent the winter at Albany, preparing their collections and writing a report.

In the spring of 1854, Hayden again ascended the Missouri under the auspices of the American Fur Co. and Maj. A. J. Vaughan, the Indian agent for the Upper Missouri tribes. This time he remained through the winter, living at Fort Pierre and making trips as weather permitted. During this period he was able to visit the posts at Forts Sarpy, Benton, and Union, returning to St. Louis on November 5, 1855.

In 1856, attached to the exploring party of Lt. G. K. Warren, Hayden again ascended the Missouri, traveling upriver by steamer, and visited the valley of the Yellowstone, part of the time in company with the famous guide Jim Bridger.

Again in 1857, he accompanied Lieutenant Warren to the Black Hills and for the first time discovered their domal structure. Writing to Prof. S. F. Baird from Fort Laramie on August 21, he said, "Success has attended all our efforts, but we have had a hard time. My discoveries in a geological way are wonderful," and "I have got the key to the mountain area," and "I am making good use of it, so that this trip will not by any means be a failure."

The following year, 1858, under the auspices of the Department of the Interior (General Land Office), and with an appropriation of $5,000, Hayden made a survey of western Kansas, traveling by wagon and on horseback. In 1859–60 he was attached to the expedition led by Col. W. F. Raynolds to the headwaters of the Missouri and Yellowstone Rivers. This party wintered at Deer Creek, Wyoming (½ mile southwest of Glenrock), and under the guidance of Jim Bridger made an unsuccessful attempt to reach the geyser area of the Yellowstone. Bridger had been with the party during most of its travels, and there is no doubt that Hayden was well acquainted with the "tall tales" of that famous raconteur. Certain it is that on the 1871 expedition the route taken to the Park area followed that of the 1860 attempt which had been foiled by the deep snow in the mountain passes.

The Civil War brought to a close all Western explorations, and Hayden entered the Army as acting assistant surgeon, was advanced to surgeon of volunteers, and was discharged with the rank of brevet lieutenant colonel on June 22, 1865. His Army service involved duty in hospitals at Beaufort, S. C.; West Philadelphia, Pa.; and Winchester Field Hospital at Winchester, Va.

Immediately after his discharge from the Army, Hayden again headed for the Upper Missouri, this time with one assistant and under the auspices of the Academy of Natural Sciences of Philadelphia. Starting from Fort Randall, S. Dak., on August 3, he made a circuit of 650 miles in 52 days, his party consisting of James Stevenson, a guide, an Indian hunter, and a military escort of five troopers.

The years 1867–68, Hayden, under auspices of the General Land Office, devoted to a survey of Nebraska Territory and eastern Wyoming, but he was able to make trips into North Park, Colorado, and westward along the Union Pacific Railroad almost to Salt Lake City and to spend two weeks in the San Luis Valley. All this travel was on foot or on horseback.

In the year 1869, again under the General Land Office, Hayden traveled from Cheyenne southward along the foothills to Santa Fe, returning through South, Middle, and North Parks. As a result of this trip he was able to state for the first time that (1) the main range of the Rockies is a huge anticlinal; (2) the Tertiary Lignite beds from New Mexico to Canada are parts of one basin, interrupted by uplifts; (3) the Rocky Mountains are Post-Cretaceous in age; and (4) the lower ranges are monoclinal, descending toward the plains in steps.

By this time he had seen much of the present States of Montana, North and South Dakota, Wyoming, Kansas, Nebraska, and northeastern Utah. A "Grand Plan" was now shaping up, which involved the mapping of these States as a unit, embracing the mountains and plains, and studying the relationships between them. With the reconnaissance completed, detailed study and mapping were now the object of his efforts.

In 1870 there was created, under the Department of the Interior, the U. S. Geological and Geographical Survey of the Territories with Hayden as director. The work of the first year was in Wyoming, the starting point Cheyenne, and, with an appropriation of $25,000, it was possible to utilize 12 assistants, 8 teamsters and cooks, and sufficient horses and wagons. In this season Hayden first described and named the Dacota, Fort Pierre, and Fox Hills units of the Cretaceous.

The next year, 1871, the expedition took the field at Ogden, Utah, to which the tracks of the Union Pacific Railroad had then been extended. An appropriation of $40,000 permitted an increase in personnel to 32 and included the photographer W. H. Jackson and the artist Thomas Moran, and the summer was spent in what is now Yellowstone Park. Paintings and photographs resulting from their work were widely circulated and certainly aided greatly in obtaining increased support for the succeeding year. Incidentally, the edition of 12,000 copies of the 1871 report was exhausted by 1874.

The season of 1872 was spent in the Yellowstone Park area where two large parties totaling 56 men, 117 horses and mules, and 5 guests were able to explore thoroughly the valleys of the Yellowstone, Gallatin, Madison, and Snake Rivers and the Teton Mountains. There is little doubt that the photographs and reports of this year did much to cause the establishment of the Park.

Indian troubles in Wyoming led the War Department to forbid geological work there in 1873, and so attention was directed to Colorado, where three divisions covered Middle Park, South Park, and the San Luis Valley. In this year also triangulation and topography were begun under James T. Gardiner, previously associated with Dr. J. D. Whitney on the Survey of California. Again in 1874, 1875, and 1876 work was continued in Colorado and resulted in the great Atlas of the geology of that State, published in 1877, as well as the usual annual reports.

In general, Hayden's relations with the Indians were good, but the large Survey parties on occasion proved an irresistible temptation. Thus in 1872 a party had some difficulty with Bannocks near Fort Hall. In 1875 a party under J. T. Gardiner lost most of their animals and equipment near the Sierra La Sal after holding off an attack for several hours and finally escaping during the night. Meanwhile, W. H. Holmes lost his animals to a band of Utes on Montezuma Creek in southwestern Colorado. Holmes and his packer, Tom Cooper, pursued the Indians and recovered their stock on Recapture Creek, so named by Holmes in commemoration of this episode.

Again in 1877, A. D. Wilson's party in the Yellowstone area lost all their stock, apparently to Chief Joseph's band, while in the final year of 1878 a topographical party in the Teton area lost all its animals and part of its equipment. Several other minor attacks were repelled and no losses occurred, but diaries and letters of the period 1870–78 indicate that all parties posted guards each night in strict military fashion. Incidentally, a goodly number of the packers and guides were familiar with the Indian type of warfare, and a considerable number of packers, cooks, geologists, and topographers were veterans of the Civil War; and pictures, letters, and diaries agree that Hayden was the only one who habitually went unarmed.

In 1877, work again was in Wyoming, Utah, and Idaho but was rudely interrupted in September by the depredations of Chief Joseph. Next season an attempt was made to conclude the work in the Wind River and Yellowstone areas, and the personnel numbered 68. Despite loss of all the horses of the Yellowstone party, much was accomplished, particularly by A. C. Peale and W. H. Holmes in the Park area.

On June 30, 1879, the Hayden Survey ended. Hayden himself moved to Philadelphia where he owned a home, where his wife's family lived, and where there was access to library facilities then superior to those in Washington. Here he closed out the Survey affairs and completed his 2-volume final report. By now his health had begun to fail, and although in the summers of 1883–1886 he made several trips to Montana with his close friend Peale, his condition grew rapidly worse, and he died in December 1887.

It may be of interest to note that on December 30, 1930, six surviving members of the Hayden Survey, W. H. Holmes, George B. Chittenden, Ernest Ingersoll, W. H. Jackson, Story B. Ladd, and Frederick D. Owen, met in Washington to unveil a memorial to the Survey. This took the form of a bronze plaque located in the ground-floor lobby of the new Washington Evening Star Building, at the corner of Eleventh Street and Pennsylvania Avenue, NW., site of the old Star Building on whose third floor were the offices of the Survey from 1870 to 1875.

An institution should be judged by the quantity and quality of its work, and in this respect the Hayden Survey and its director have not received adequate recognition. One may look well at the "firsts" attributed to them, as follows:

1. Developed the plan of having topographer and geologist work together, a method carried over to the U.S.G.S. and continued down to the recent past.
2. First reported the domal structure of the Black Hills.
3. Made the first scientific exploration of the Yellowstone Park.
4. First determined age of the Rocky Mountains.
5. First reported presence of Potsdam sandstone west of the Missouri.
6. Made the first geological map of the Black Hills.
7. First to report thrusting in the Rockies.
8. First to delimit and name 29 stratigraphic units of the Cretaceous and Tertiary of the Western United States, which are still valid and used in their original sense.
9. First to recognize and explain the terraces in the Salt Lake Basin (in 1869).
10. First to recognize and explain laccoliths (but not to name them).
11. First to point out the anticlinal structure of the Main Range of the Rockies.
12. First to make extensive use of photographs to illustrate geologic features.
13. First to show the existence of the great Tertiary basin extending from Mexico to Canada.

Other features that should be noted include Hayden's invariable custom of publishing the report of one season's work before taking the field for the following year. No backlog of manuscripts was allowed to accumulate. And here it may be well to point out that the Survey during the nine years of its existence published 21,142 pages of reports, while Hayden alone, or with F. B. Meek, published a grand total of 1,306 pages bearing his name.

During these same 25 years from 1853 to 1878 there were employed 14 geologists (including Hayden) whose total man-years of field work were 55 in number. The area mapped by all Hayden expeditions and colored on the final map of 1882 included 417,000 square miles, which indicates an output of 7,582 square miles per man—per year. Admittedly, this was largely reconnaissance, but the work was good to excellent and shows everyone was working.

Other statistics concerning personnel may be of interest also. Of 219 members of Hayden's various expeditions, 38 are listed in Who Was Who, Dictionary of American Biography, and American Men of Science. Approximately 70 streams, mountains, towns, lakes, and gulches were named for Survey members. At least 10 men wrote books other than technical reports, and one became a Congressman. Eighteen employees, after the Survey closed, joined U.S.G.S. or other Government departments.

Here may be mentioned a feature of the personnel which was much criticized by his opponents. This pertained to Hayden's employment each season of a few "general assistants" who were sons, nephews, or protegees of Senators and Congressmen. Recalling that there was then no Civil Service, that Hayden's relations with Congress were generally good, and that most of these assistants were college students or graduates and did a man's work, in addition to having a great adventure, one cannot be too critical. Besides, what else could Hayden do if, as is shown by the record, one application was signed by 32 Senators and Congressmen! Incidentally, this young man wrote a very creditable book for boys detailing his experiences of that summer. It is entitled *In the trail of the pack-mule*, and the author is Sid H. Nealy, who was an assistant in 1872 and 1873.

The Hayden Survey, its members and Hayden himself, left behind a vast store of nearly 12,000 unpublished letters, diaries, and journals, scattered widely. No full biography of Hayden, or a history of his Survey, has yet been published. However, Dr. F. M. Fryxell and the writer, after many years of searching, have brought all this together on microfilm or photostatic copy; and they hope eventually to write the detailed history which the man and his Survey deserve. The story is one that will require a large volume, and in this brief paper only a glimpse can be given of geology plus adventure as revealed by the participants themselves.

A History of the Popularization of Geology in America: A Bibliographical Survey

By Mark W. Pangborn, Jr., *U. S. Geological Survey*

The history of the public relations aspects of our science reveals that in this country, during the 1830's and 1840's, geology held a high position in public esteem, that our profession lost that position by default, and that, by the same token, it is reestablishing geology as a subject worthy of strong public support and interest, and that an effective and abundant popular literature plays a large role in such a rennaissance.

During the Colonial and early Federal periods the study of geology was largely limited to the educated aristocracy. Such public figures as Jefferson and Gallatin were considerable students of geology, and their interests were often parlayed into worthy public enterprises, such as the explorations of Lewis and Clark, Pike, and Long.

It was in the 1830's and 1840's, however, that geology really came into its own. This was the great age of the lyceum, or public lecture series, that so impressed Agassiz when he arrived in Boston in 1846. Geology rode high on the wave of self-culture and interest in natural history that got under way about 1820, propelled by the ardent proselyting activities of a sizable percentage of the most prominent geologists, including Eaton, Silliman, H. D. Rogers, Lyell, and Agassiz. Amos Eaton alone made 3,000 lectures outside the classroom, and it was in part due to the boundless enthusiasm of such men that a number of State legislatures were inspired to finance early surveys.

The layman's literature of the time was largely that used by the geologists themselves. Concepts were still simple, and the specialized geological terminology of 1840 was limited to a few hundred words. The textbooks of Eaton (1), J. D. Dana (2), Hitchcock (3), and Lyell (4) sold well among those hungry for learning, and Mantell's *Medals of creation* (5) and Hugh Miller's *Old Red Sandstone* (6) were vastly popular informal books. The volumes of the early State surveys were also well received by laymen. Yet even this enlightened age had its share of potboilers by nongeologists, and we must admit that the works of S. G. Goodrich (Peter Parley) are horrible examples of the genre.

Public interest in geology declined during the period from the Civil War to the turn of the century, despite interest in the great bonanzas and in Western exploration. Part of the decline may be blamed on the fact that during this period geologists began to use their special and often unnecessary technical terms, a trend which continues to the present day and renders unacceptable, to the layman, far too much of the professional literature. Equally significant was the very sharp decline in the proportion of geologists interested in popularizing their science.

Some of the most famous exceptions were, of course, John Wesley Powell and Clarence King. *Exploration of the Colorado* (9) and *Mountaineering in the Sierra Nevada* (8) went through many editions and helped to keep alive the tradition of Western scientific exploration. Perhaps the biggest selling book was Darwin's *Origin of species* (7), which caused almost as much uproar and intellectual ferment in this country as it did in England. Other geologist-writers included J. D. Dana, whose easier texts, like *The geological story briefly told* (12), were fine for high school and layman's use, and N. S. Shaler, who turned out a number of nontechnical introductions to physiography, such as *Aspects of the earth* (10) and *Sea and land.* Another gifted popularizer was Alexander Winchell, whose vividly written *Walks and talks in the geological field* (11) was, for many years, on the reading list of the Chautauqua Association, an organization whose subscribers numbered 5 million in the year 1900. Among nongeologist writers, the best was probably H. N. Hutchinson, a liberal English clergyman whose books *Extinct monsters* (13) and *Creatures of other days* were free of the theological controversy of earlier times.

From 1900 to World War II, it is no coincidence that geology and physiography all but disappeared from the high schools at the same time that interest in popularization all but disappeared within our profession.

On the credit side, between 1910 and 1930 the U. S. Geological Survey undertook a modest public education program, publishing guidebooks (14) covering some of the western railroad routes, and some booklets on the national parks, by men like Arnold Hague, M. R. Campbell, and W. T. Lee. François Matthes, in his *Geologic history of the Yosemite Valley* (17), proved that a scientific classic could be written in plain English. The National Park Service became a potent educational force in the 1920's as its public education program began to develop. Some State surveys, notably New York, Pennsylvania, and Kentucky, began to issue popular publications, as did the American Museum of Natural History. Popular interest in mineral collecting, to become so strong in the 1950's, began to revive with the founding of the journals Rocks and Minerals, in 1926, and Mineralogist, in 1933.

Among the few layman's books that sold well were F. B. Loomis's *Field book of common rocks and minerals* (15) and astronomer W. M. Reed's *The earth for Sam* (16). Two other authors, who are still turning out big sellers, were Roy Chapman Andrews, whose books on dinosaur hunting (19) were well received, and Carroll Lane Fenton, who was establishing his reputation as a popularizer with works like *Our amazing earth* and *The rock book* (18).

Since World War II, the outlook for popularizing geology has become generally brighter. Geology courses are being reintroduced into a number of high schools, and school libraries, by now rather common, feature the better-known geological texts and popular works, as well as such fine journals as Natural History and Scientific American. Some States have stepped up their educational and publishing programs, including California (22), Kansas, Oklahoma, and Illinois, and the U. S. Geological Survey now prints geological descriptions on the backs of its National Parks maps (23).

The National Park Service remains preeminent as the great popularizer of geology in the country. Perhaps 10 million young people of school age see geological wonders first hand every year, and take home scores of thousands of earth science books from park concessions.

Interest in caves has burgeoned since 1941, when the National Speleological Society was formed; now its 1,700 members and perhaps 15,000 other young spelunkers spend their weekends underground. Even more spectacular has been the spread of interest in mineral collecting and cutting; H. C. Dake authoritatively estimates the minimum number of devotees at 250,000.

With the publication of the successful new Merit Badge pamphlet on geology (27), the Boy Scouts have become an important agent for promoting the earth sciences. Over 50,000 copies of this pamphlet have been sold since introduction in 1953, and geology badges earned have risen from 300 to 3000 per year. Geology month among the Scouts, October 1957, featured "The biggest show on earth," during which 4,000 geologists assisted 38,000 scout units to make it by far the largest public relations program ever put on by our profession.

Geology now has an over-all public relations organization in the American Geological Institute, founded in 1948. Its publications include a career booklet, of which a modest 18,000 copies have been given away, and a layman's guide to the nontechnical literature (29). Yet A.G.I.'s operations are still on a small scale compared with those of the American Petroleum Institute and of certain oil companies, which distribute free career materials and teachers' pamphlets by the millions.

In the past few years there has been a noticeable increase in the sales of popular geology books, both absolute and in relation to other technical subjects; only aviation and rocketry attract more young readers now than do the earth sciences. The Fentons' *Rock book*, for example, has been selling twice as well since 1945 as it did when published in 1940, and Zim and Shaffer's new *Rocks and minerals* (30) is the runaway leader in the fabulously successful Golden Guide series.

In addition to established names like Andrews (25) and the Fentons (31), a new group of outstanding popularizers is now at work. Among them are journalist Ruth Moore (28), physicist George Gamow (21), geologists O. P. Jenkins (22) and F. M. Fryxell, paleontologists G. G. Simpson and E. H. Colbert (20), and mineralogists R. M. Pearl (26) and F. H. Pough (24).

Although lack of objective data makes it difficult to contrast the status of popular geology in recent years with its status in the 1840's, it is clear that in 1840 a high percentage of the most prominent geologists participated in public lectures and similar services; by 1940 surely no more than one or two percent of our profession lectured, counselled, or wrote for the public.

I am glad to say, however, that since World War II an increasing number of geologists have become aware that geology must be brought to the layman if public interest and support for geological enterprises are to grow, and if a supply of future geologists is to be assured. Let us hope that our profession fills the gaps in the popular literature. New illustrating and publishing techniques promise more attractive books, and new marketing methods are providing far wider audiences. If our geologists themselves can engender the proselyting enthusiasm of Amos Eaton and Agassiz, and are willing to grant their popularizations the same care that they put into their professional work, then geology will indeed hold the American public's interest and approval.

BIBLIOGRAPHY

1. Eaton, Amos. *Geological text book, prepared for public lectures on North American geology . . . :* 63 pp. Webster and Skinners, Albany, 1830.
2. Dana, James Dwight. *A system of mineralogy:* 144 pp. Durrie & Peck, New Haven, 1837.
3. Hitchcock, Edward. *Elementary geology,* ed. 2: 346 pp. Dayton & Saxton, New York, 1841. (Went through 30 editions in 20 years; Hitchcock tried to reconcile the Bible and geology.)
4. Lyell, Charles. *Elements of geology,* 1st American ed. James Kay, Philadelphia, 1839. (Lyell's numerous textbooks went through many editions.)
5. Mantell, Gideon Algernon. *The wonders of geology,* 2 vols. A. H. Maltby, New Haven, 1839. (This and *Medals of creation* were intended for the layman.)
6. Miller, Hugh. *The Old Red Sandstone.* Edinburgh, 1841.
7. Darwin, Charles Robert. *Origin of species,* 1st American ed.: 432 pp. Appleton, New York, 1860. (Appleton issued this book in the face of hundreds of threatening letters; it was a best seller for years.)
8. King, Clarence Rivers. *Mountaineering in the Sierra Nevada.* J. R. Osgood, Boston, 1872.
9. Powell, John Wesley. *The exploration of the Colorado River of the West . . . :* 291 pp. Government Printing Office, Washington, 1875.
10. Shaler, Nathaniel Southgate. *Aspects of the earth:* 344 pp. Scribner, New York, 1889.
11. Winchell, Alexander. *Walks and talks in the geological field:* 329 pp. Chautauqua Press, New York, 1886.
12. Dana, James Dwight. *The geological story briefly told:* 302 pp. American Book Co., New York, 1895.
13. Hutchinson, Henry Neville. *Extinct monsters . . . :* 254 pp. Appleton, New York, 1892.
14. Lee, Willis Thomas. *Guidebook of the Western United States, Part B, The Overland route . . . :* 244 pp. Government Printing Office, Washington, 1915. (U.S. Geol. Surv. Bull. 612.)
15. Loomis, Frederic Brewster. *Field book of common rocks and minerals:* 352 pp. Putnam, New York, 1923. (100,000 copies of this steady best seller have been printed over the years.)
16. Reed, William Maxwell. *The earth for Sam:* 390 pp. Harcourt Brace, New York, 1930. (52,000 copies in print.)
17. Matthes, François Emile. *Geologic history of the Yosemite Valley:* 137 pp. Government Printing Office, Washington, 1930. (U.S. Geol. Surv. Prof. Paper 160.)
18. Fenton, Carroll Lane, and Fenton, M. A. *The rock book:* 357 pp. Doubleday, New York, 1940. (Over 40,000 copies sold.)
19. Andrews, Roy Chapman. *Under a lucky star; a lifetime of adventure:* 300 pp. Viking, New York, 1943. (Sold 30,000.)

20. COLBERT, EDWIN HARRIS. *The dinosaur book:* 156 pp. American Museum of Natural History, New York, 1945. McGraw-Hill, 1951. (Nearly 25,000 copies of this model popularization have been bought.)
21. GAMOW, GEORGE. *Biography of the earth:* 194 pp. Viking, New York, 1948. (8,000 of the hard cover edition and a quarter million paperbacks have been sold.)
22. JENKINS, OLAF PITT. *Geologic guidebook along highway 49—Sierran gold belt ...:* 164 pp. San Francisco, 1948. (California Div. Mines Bull. 141. Leads all state-issued publications with 20,000 copies sold.)
23. U.S. GEOLOGICAL SURVEY. *Topographic map of the Denver mountain area,* scale 1:190,680. Washington, 1948. (Top seller among Park maps which have a geological text on the back; over 3,000 per year.)
24. POUGH, FREDERICK HARVEY. *A field guide to rocks and minerals:* 333 pp. Houghton Mifflin, Boston, 1953. (Like Loomis, a tremendous seller.)
25. ANDREWS, ROY CHAPMAN. *All about dinosaurs:* 146 pp. Random House, New York, 1953. (A leader even in the highly successful "All-about" series of children's books, with sales over 160,000.)
26. PEARL, RICHARD MAXWELL. *How to know the minerals and rocks:* 192 pp. McGraw-Hill, New York, 1955. (Another title which has passed the quarter million mark, in all editions.)
27. BOY SCOUTS OF AMERICA. *Merit badge series: geology,* ed. 2: 35 pp. New York, 1956.
28. MOORE, RUTH. *The earth we live on:* 416 pp. Knopf, New York, 1956. (This history of geology has had a fine reception.)
29. PANGBORN, MARK W., JR. *Earth for the layman; a list of nearly 1400 good books ...,* ed. 2: 68 pp. Washington, 1957. (American Geol. Inst. Report no. 2.)
30. ZIM, HERBERT SPENCER, and SHAFFER, PAUL. *Rocks and minerals:* 160 pp. Simon & Schuster, New York, 1957. (Numerous sales outlets, high quality, and low price enable this title to sell at the rate of half a million copies per year, surely the all-time high for a science book.)
31. FENTON, CARROLL LANE, and FENTON, M. A. *The fossil book:* 496 pp. Doubleday, New York, 1958. (Prepublication orders of this expensive book totalled nearly 4,000, a phenomenon that could hardly have been conceived a few years ago.)

Asa Gray and American Geology

BY A. HUNTER DUPREE, *University of California*

American geologists as a group did not occupy a theoretical position which could help them much to understand what was happening when the *Origin of species* broke over them in 1859. In spite of their number and the quality of the precise stratigraphical work which they were doing, their theories were as crude as they were hotly contested within the group itself. As examples, the brothers William Barton Rogers and Henry Darwin Rogers will serve as well as any. They were able geologists, but their theories, depending heavily on such cataclysms as sudden floods, were far-fetched. Louis Agassiz had imported the idea of a glacial epoch to North America, but his ideas of organic development were dominated by an extreme idealism. Even the acclaim of Europe was not sufficient to establish his glacial hypothesis firmly in America, where many geologists still talked of icebergs as the main depositors of the drift. Virtually the only general theoretical agreement in American geology in 1859 was a propensity to catastrophism. The one man with the stature to resolve these difficulties and to bring American concepts into line with Darwinian theories, James Dwight Dana, did not perform this expected role both because his own thoughts on species were distinctly idealistic and because his health broke in 1859, preventing him from even reading the *Origin of species* for several years.

Within 15 years, or at the very most 20 years, the picture had changed completely. Not only did American geology stand near the forefront in its accomplishments, glorying and suffering in the great age of paleontology with O. C. Marsh and E. D. Cope, the glacial theories of T. C. Chamberlain, and the Great Basin studies of able men such as G. K. Gilbert. Whatever theoretical difficulties remained, though they were formidable, were those which faced the men at the frontiers of the science rather than those of provincials caught in a backwater. Who was responsible for this sudden clearing of the ground, this rapid assimilation of descent with modification on the organic side of the geologic scale as required by Darwinian theory? Who dethroned the great catastrophist Louis Agassiz from the pinnacle of American geology in the very period that his glacial hypothesis was winning the vindication of overwhelming evidence? The answer to these questions is the name of a man who had the distinct advantage of knowing very little geology—the botanist Asa Gray.

While Gray's role as the protagonist of Darwin in America is widely if uncritically recognized, the specific contribution which he made toward adapting geologic phenomena to a Darwinian sequence of life forms has often been overlooked. And the implications which his work had for the reorganization of geologic theory among Americans have been almost totally ignored.

Gray began his scientific life in the late 1820's, when the old-style naturalist still had a place in the upstate-New York intellectual milieu in which he lived. Hence he collected, in addition to plants and insects, trilobites and minerals. His first paper in the American Journal of Science concerned the mineralogy of St. Lawrence County, N. Y. But Gray was a good example of a most important change which came across American science in the 1830's—the trend toward specialization. The old-style naturalist was vanishing, Gray becoming increasingly identified with the science of botany. Soon after he went to Harvard as Fisher Professor of Natural History he donated to the College his mineral collection in an almost symbolic act of renunciation.

That he had withdrawn from active research in any phase of geology made it easier for him to adopt general views of the subject without entering the controversies which raged among the professional geologists. Thus when Sir Charles Lyell lectured before the Lowell Institute in Boston in 1845, Gray attended regularly even though he considered Lyell "not a good lecturer at all." But he spoke of an Englishman "occupying—though under a rather different aspect the ground I am to take up . . . on Geographical Botany." Thus effortlessly and without fanfare Gray absorbed Lyell's point of view even if he did not use his opportunities to become a friend and correspondent of the British geologist.

Undoubtedly the arrival of Agassiz in America in 1846 stimulated Gray to a friendly reception of the Swiss scientist's glacial theory as well as his views on natural history. The two cooperated cordially to combat the idea of *Vestiges of the natural history of creation*, which had a considerable vogue in America as well as Europe. Yet even in 1846, subtle differences showed up between the thought of the two men, and Gray never assented either to Agassiz's idealistic views of species as "a thought of the Creator" or to his catastrophism.

By 1855 Gray was aware of a fundamental antagonism between his whole view of nature and that of Agassiz. Although the zoologist dominated the scene in America and commanded an overpowering European reputation, the quiet botanist had unusual facilities for tapping those minds of Europe who were shaping the coming revolution. He, and not Agassiz, was collaborating with Joseph D. Hooker and Alphonse De Candolle in creating a science of the geography of organisms on a world scale. Through Hooker he was brought into the circle of Charles Darwin, who might most aptly be described in 1855 as a geologist of first importance who had also prepared an admirable monograph on the barnacles. But behind the sharp questions concerning the world distribution of plants which Darwin put to Gray seemed to lurk a consistent set of doctrines. The trend of these doctrines, as they gradually became apparent in Darwin's letters, reinforced Gray's belief in the law of genetic connection among all the members of a species. They not only resembled one another, they were also the actual descendents from a single pair and had radiated from a single center of creation. Agassiz, on the other hand, maintained that species had been created in great numbers, occupying essentially the same geographic areas throughout their existence. Thus he denied both a genetic connection among the members of the same species and among similar organisms which occurred in different geologic strata. Gray increasingly felt dissatisfied with Agassiz's formulation, but until 1858 he bided his time, hoping to assemble a specific case with which to challenge his renowned colleague.

Gray found his facts with which to construct a challenge among the botanical collections coming in to him in large quantity from the American exploring expeditions, which were the characteristic research organizations of the 1850's. Disjunct distributions, that is, plants peculiar to two widely separated geographical localities, had been among the favorite arguments of those who believed in multiple as well as special creation. Gray found a large number of plants in the first collections to come in from Japan in 1857 and 1858 which were to be found also in eastern North America and nowhere else. To assume that a *Philadelphus*, say, which was reported only in Japan and the southern Appalachians, had been created in those two localities independently, seemed to Gray to answer the problem only by preventing its being posed. If he could, on the other hand, come up with a material connection between the two similar plants found half a world away, he would have a case which fairly refuted Agassiz's whole conception of biology.

The key to Gray's solution of the problem of disjunct distributions between eastern Asia and eastern North America lay in geology, and here his own ignorance placed him in the hands of others. Consulting both James Dwight Dana and Charles Darwin, he came up with a conception of geologic history which would explain the present distribution of plants. In the Tertiary period a temperate flora had extended all the way around the North Pole. With the glaciation of the Pleistocene epoch this flora had been pushed far southward, its remnants forming the disjunct distributions which Gray's evidence should. Thus a flora continuous across the Bering Strait area in the Tertiary provided a material and genetic connection between the plants with which Gray hoped to refute Agassiz. Gray had no fossil evidence of this Tertiary flora, and precious few indications of the climate, but his reasoning established an unbroken chain of events.

That his paper on this subject was intended as a full-scale assault on Agassiz and not a fragmentary report on collections from Japan is clear from the dramatic circumstances of that meeting of the American Academy of Arts and Sciences in Boston early in 1859, many months before the publication of the *Origin of species*. Agassiz was present in person to contest and rebut Gray's effort at every point. Yet the very construction of Gray's argument bears the marks of the debate. His strategy avowedly was to "hoist Agassiz on his own petard." At three points especially, this strategy led Gray to make choices momentous for American geology.

In the first place, he was one of the first Americans to accept publicly and unqualifiedly Agassiz's conception of the Ice Age. An ice sheet which spread generally over both the old and the new worlds was the agent which Gray needed to accomplish his distributions. It could not at the same time serve, however, as the catastrophe which Agassiz required. The very completeness of Gray's acceptance is a landmark in the history of glacial theory in America which must have infuriated Agassiz by its very cordiality.

In the second place, Gray was well aware that Agassiz, who believed that no Tertiary species existed in the present, would take advantage of Gray's lack of fossil evidence for a circumboreal temperate flora in the Tertiary. Agassiz had also made much of the length of time during which present species had remained unchanged. Therefore Gray, in choosing geologic advice, rejected that of Darwin in favor of Dana, who advocated a very warm period after the Pleistocene glaciation. Gray could thus postulate a second mingling of his species across the Bering Strait area after the Pleistocene as well as before, establishing a material connection even if one accepted with Agassiz the catastrophic nature of the Ice Age.

In the third place, Gray pointed out, besides the identical species which followed his pattern of distribution, a number of genera which did the same. Thus genera peculiar to Eastern Asia and Eastern North America which were represented only by distinct species in the two places, suggested to Gray that the vicissitudes of geologic history had produced sufficient modifications in the pristine stock to lead to distinct species which nevertheless had descended from a single pair. This was descent with modification through geologic time, and lest anyone misunderstood the general bearing of his theories, he pointed to the Linnaean Society publication of 1858 which first presented Darwin and Alfred Russel Wallace to the world.

Agassiz never effectively answered Gray, despite his continued eminence in American science. When the *Origin of species* appeared, Gray introduced it to the American scientific public in a review in the American Journal of Science, speaking not for himself but for the whole board of editors, which included both Dana and Agassiz. When Gray retired as president of the American Association for the Advancement of Science in 1872 he presented his theories in new and elegant form in *Sequoia and its history,* which extended the formulation to Western North America. Before the end of his life in 1888 he was able to point to the research of Oswald Heer, Saporta, and others as providing fossil evidence from Arctic Tertiary flora to support his hypothesis.

Thus Gray, a botanist who knew little geology but only understood its implications, provided a secure base for a Darwinian geology in America even before the publication of the *Origin of species.* He ranged descent with modification in the organic scale alongside the geologic record and found in their coincidence a key to the present distribution of organisms. That Agassiz's whole conception of nature disappeared so promptly from American science, even among his own students, must be credited largely to Gray. At the same time, the equally rapid triumph of Agassiz's Ice Age theory received from the botanist a marked impetus. The Darwinian way of looking at the relation of geology and biology became common coin in America among geologists who never cited Gray in their publications. The very pervasiveness of this fundamental shift made it more anonymous.

Lest this sweeping conclusion be set down as the circumstantial adulation of a biographer, let me call your attention to a significant piece of contemporary evidence.[1] Of all those who commented on Gray's career at the time of his death in 1888, the one who most fully plumbed the significance of his introduction of organic evolution into geology was Lester Ward. As a paleobotanist, Ward is under a professional shadow because he spent so much of his time and intellect on sociology. But in 1888 Ward was speaking from the headquarters of American geology. As paleobotanist at the U. S. Geological Survey he was the fellow worker of John Wesley Powell, Gilbert, Clarence Dutton, and the rest.

Ward felt that "history will doubtless fully bear out the statement that, whether we look at England or to the United States, no man has done as much to remove apprehension from, and inspire respect for Darwinism, and therefore really to help its triumphal march, as the modest American botanist, Dr. Asa Gray." Concerning Gray's *Sequoia and its history,* Ward was even more specific. "Although possessed of scarcely any of the abundant facts of paleontology now known in support of his views, he saw with unerring ken and portrayed with a precision which had defied subsequent criticism, all the steps in the weary pilgrimage of these giant denizens of the Sierras, as they were driven southward by the advancing ice sheet, or lured northward by the return of cosmical summer . . . and he saw how, in this protracted and unequal struggle with the elements, this grand race of beings . . . had been gradually decimated in number and circumscribed in habitat . . ."

The idealist and catastrophic views of Agassiz, although not the influence of his magnetic personality, had so completely disappeared by 1888 that only a few could recognize in Gray a major actor at a crucial juncture in the history of science, a deft and able theoretician who with one thrust of his polished stiletto of a pen—the phrase is Darwin's—deflated one view of nature and aided in the substitution of another.

[1] WARD, LESTER F., *Asa Gray and Darwinism.* New Monthly Mag., August 1888: 85–92.

Darwinian Natural Selection and Vertebrate Paleontology

BY JOHN A. WILSON, *University of Texas*

The close correlation between form and function as seen by the vertebrate paleontologists in North America prevented the adoption of Darwin's proposal of natural selection as the primary operating force in evolution. This resulted in a schism between paleontologists and neontologists that did not close until the 1940's. Cope in the immediately post-Darwin period led in the formation of a Neo-Lamarckian school to which most North American vertebrate paleontologists belonged. All the members of this school were enthusiastic supporters of evolution and their contributions furnished an enormous amount of the paleontologic evidence for evolution. But it was this paleontologic evidence consisting of oriented sequences of mammalian phylogenies that prevented their accepting the randomness of Darwinian natural selection as the primary operating force.

A few quotations will, I hope, substantiate my thesis.

In North America Joseph Leidy was the most prominent vertebrate paleontologist in the Darwinian period. The *Origin of species* did not fall on infertile ground; Leidy had already in 1848 expressed earlier a general belief in evolution:

> The study of the earth's crust teaches us that very many species of plants and animals became extinct at successive periods, while other races originated to occupy their places. This probably was the result, in many cases, of a change in exterior conditions incompatible with the life of certain species and favorable to the primitive production of others . . . There appears to be but trifling steps from the oscillating particles of inorganic matter to a bacterium; from this to a vibrio, thence to a monas, and so gradually up to the highest order of life! The most ancient rocks containing remains of living beings indicate the contemporaneous existence of the more complex as well as the simplest of organic forms; but, nevertheless, life may have been ushered upon the earth, through oceans of the lowest types, long previously to the deposit of the oldest paleozoic rocks as known to us.

It will be seen from this quotation that Leidy certainly had a concept distinctly above that of the "scale of nature." He believed in the extinction of forms, of course, and plainly expresses the germ of evolution, even the development of living matter from nonliving matter.

Leidy, one of the most competent vertebrate paleontologists North America has produced, confined most of his paleontological writing to the description of new types. While he firmly believed in the doctrine of descent, he refrained from theorizing as to the manner in which such descent came about. In many ways this is understandable, since Leidy's period of work coincides with the beginning of the discovery of the vertebrate paleontological treasures of the West. The vast tonnages of specimens and the discovery of the sedimentary sequence of the Tertiary did not come until Marsh and Cope took over the field. At any rate, Leidy did not theorize or speculate in print concerning the Darwinian proposal of natural selection.

Of his two successors Marsh and Cope, the latter became the leader of a group which until quite lately had survivors known as the Neo-Lamarckists. Of the two Cope wrote more extensively and expressed his ideas on natural selection more freely than did Marsh. However, from the few statements on this subject made by Marsh it is quite obvious that he was a member of the same school. In Marsh's vice-presidential address before the American Association for the Advancement of Science meeting at Nashville, Tenn., on August 30, 1877, he says:

> As a cause for many changes of structure in mammals during the Tertiary and Post-Tertiary, I regard as the most potent, *natural selection,* in the broad sense in which that term is now used by American evolutionists. Under this head I include not merely Malthusian struggle for life among the animals themselves, but the equally important contest with the elements and all surrounding Nature. By changes in the environment, migrations are enforced, slowly in some cases, rapidly in others, and with change of locality must come adaption to new conditions, or

extinction. The life history of Tertiary mammals illustrates this principal at every stage, and no other explanation meets the facts.

I think it very likely that Marsh herein referring to "natural selection, in the broad sense in which that term is now used by American evolutionists" is referring to the Neo-Lamarckian school as conceived by Cope, but about this I cannot be certain.

In Marsh's retiring presidential address before the same organization at Saratoga, N. Y., August 28, 1879, Marsh is not even as explicit as he had been the previous year. He states:

> Just 20 years ago, science had reached a point when the belief in "special creations" was determined by well established facts, slowly accumulated. The time was ripe. Many naturalists were working at the problem, convinced the Evolution was the key to the present and the past. But how had Nature brought this change about? While others pondered, Darwin spoke the magic word—"*Natural Selection,*" and a new epoch in science began.

A little farther along in the address Marsh continues:

> The publication of Charles Darwin's work on the "Origin of Species," November, 1859, at once aroused attention, and started a revolution which has already in the short space of two decades changed the whole course of scientific thought. The theory of "Natural Selection," or as Spencer has happily termed it, the "Survival of the Fittest," had been worked out independently by Wallace, who justly shares the honor of the discovery. We have seen that the theory of evolution was proposed and advocated by Lamarck, but he was before his time. The anonymous author of the "Vestiges of Creation," which appeared in 1844, advocated a somewhat similar theory which attracted much attention, but the belief that species were immutable was not sensibly affected until Darwin's work appeared.

Beyond Marsh's magnificent contributions to the documentation vertebrate paleontology furnishes to evolution these are the only two short statements in which he appears to give forth his views concerning natural selection. Neither is sufficiently complete to furnish any great light concerning Marsh's view on the mechanics of evolution, and although he does lip service to natural selection the telling remark in the first quote: "natural selection, in the broad sense in which that term is now used by American evolutionists," seems to make him a follower of the Neo-Lamarckists school.

Cope, on the other hand, left absolutely no question concerning his views on the mechanics of evolution. More than 50 titles concerning evolution are cited by Osborn in his biography of Cope. From these it is necessary to choose only one as illustrative of the later concepts of Cope with regard to natural selection. I quote from *The primary factors of organic evolution*, 1896, on p. 474:

> That natural selection cannot be the cause of the origin of new characters, or variation, was asserted by Darwin[1]; and this opinion is supported by the following weighty considerations:
>
> 1. A selection cannot be the cause of those alternatives from which it selects. The alternatives must be presented before the selection can commence.
>
> 2. Since the number of variations possible to organisms is very great, the probability of the admirably adaptive structures which characterized the latter, having arisen by chance, is extremely small.
>
> 3. In order that a variation of structures shall survive, it is necessary that it shall appear simultaneously in two individuals of opposite sex. But if the chance of its appearing in one individual is very small, the chance of its appearing in two individuals is very much smaller. But even this concurrence of chances would not be sufficient to secure its survival, since it would be immediately bred out by the immensely preponderant number of individuals which should not possess the variation.
>
> 4. Finally, the characters which define the organic types, so far as they are disclosed by Paleontology, have commenced as minute buds or rudiments, of no value whatever in the struggle for existence. Natural selection can only effect the survival of characters when they have attained some functional value.
>
> In order to secure the survival of new character, that is, of a new type of organism, it is necessary that the variation should appear in a large number of individuals coincidentally and successively. It is exceedingly probable that this is what has occurred in past geologic ages. We are thus led to look for a *cause* which affects equally many individuals at the same time, and continuously. Such *causes* are found in the *changing physical conditions* that have succeeded each other in the past history of our planet, and the *changes of organic function necessarily produced thereby.* (Italics mine.)

Cope and Marsh were shortly followed by Scott and Osborn as leaders in the field of vertebrate paleontology in the United States. Scott in 1926 in his book entitled *The theory of evolution* (from the Westbook Lectures delivered before the Wagner Free

[1] *Origin of species*, ed. 1872, p. 65.

Institute of Science, Philadelphia) on page 151–152 has this to say:

> Of late years, a host of experiments have been performed upon animals, the larger number of them with the object of determining whether new characters, acquired during the lifetime of the parents, can, under any circumstances, be transmitted to the offspring. This is one of the most hotly disputed questions of modern biology and our whole conception of the efficient factors which have brought about evolution hinges upon the answer to this question. The same experiments are interpreted in diametrically opposite senses by different writers according to their predisposition and general point of view. At the present time, it is probable that a very considerable majority of zoologists and botanists, especially in this country, are inclined to deny the hereditary transmission of characters acquired in the post-embryonic life of the parents, but the problem is still far from definite solution. Important as this problem is in an attempt *to explain* evolution and the manner in which it has been effected, it has no bearing upon the question which I have been endeavoring to answer in these lectures, as to the probable truth of the evolutionary theory. That theory is held quite as strongly by those who affirm the transition of acquired characters. Whatever interpretation be put upon the significance of the experiments, presently to be mentioned, as to the problem of acquired characters, they do, at all events, show that hereditarily transmissible modifications may be artificially produced in both animals and plants.

Scott proceeds in pages following this quotation to enumerate experimental evidence of the inheritance of acquired characteristics as Cope had done before. In Scott's revision of *The history of land mammals in the Western Hemisphere* of 1937 his discussion of evolution is somewhat modified:

> While the theory of evolution is accepted by naturalists with substantial unanimity, there is great divergence of opinion among them concerning the efficient causes of the marvelous transformations which the fossils reveal. Darwin's theory of Natural Selection does offer an explanation, though he himself was far from attributing to that agency the exclusive importance which his modern followers ('Neodarwinians') ascribed to it. He also attached much significance to the direct action of the environment and to the effects of use and disuse and, toward the end of his life, he was inclined to the belief that he had underestimated these factors and overestimated Natural Selection. According to the modern version of Darwin's theory, random variations supplied the material from which Natural Selection picks the favorable ones, just as does the breeder of animals or plants in establishing a new variety. Natural Selection, in Darwin's view, was the exact analogue of the breeders artificial selection.
>
> This is not the place to present the arguments, *pro* and *con*, over this famous theory, which is still upheld by many high authorities, further than to say that, in the writer's opinion the observed facts of parallelism and convergence are fatal to it. The chances than random variations should bring about the astonishing likeness between the marsupial *Thylacosmilus*, the carnivore *Eusmilus*, and the ungulate *Uintatherium*, or the conversion of hoofs into claws in three unrelated groups, are mathematically *nil*. Few paleontologists have felt that the direct, unswerving, step-by-step development of the ammonites studied by von Waagen and Neumayr, or of the many mammalian series, which have been described in the preceding chapters, were satisfactorily accounted for by Natural Selection. In giving up this theory, it must be admitted, there is nothing to put in its place. Darwin's theory does offer an explanation of the evolutionary process and this no other theory does, but the question remains: is it an adequate explanation?

The answer to Scott's question so far as the vertebrate paleontologists were concerned was no. It was certainly inadequate for Osborn because he proposed a further alternative, aristogenesis, which was vitalist in its essential form although Osborn denied this.

Vertebrate paleontology is an observational and descriptive science, and the North American workers were busily observing and describing the spectacular material discovered with the opening of the West. Genetics, an experimental science, was born a little later, and during the 1920's and 1930's its workers were busily acquiring experimental proof of the mechanics of evolution. During this period of the marshaling of the evidence in both fields the chasm between them grew.

The turning point when the chasm began to narrow goes back, in my opinion, only to the publication of J. Huxley's *Evolution: The modern synthesis* in 1942. The chasm closed, so far as vertebrate paleontologists are concerned (with some exceptions) only in 1944 with the publication of G. G. Simpson's *Tempo and mode in evolution*. Within the synthesis Darwinian natural selection has been modified somewhat. With this modification both the oriented and random aspects of evolution are satisfactorily explainable, at least for the present.

Impact of the Development of Photogrammetry upon Geology

By David Landen, *U. S. Geological Survey*

The modern specialized scientist, immersed in the particular problems of his own field, needs to raise his head at opportune times and see what is going on in other fields. What he sees when he looks about is a vast complex of progress in many scientific disciplines. This progress offers both a challenge and an opportunity. The scientist can often save himself costly and tedious work by discovering the useful tools scientists have already developed in other fields and adapting them to his special purposes.

In the marriage of the disciplines of photogrammetry and geology, we have an excellent illustration of this point. Scientists, operating in the specialized field of geology, have recognized the challenge of photogrammetry and have seized the opportunity to espouse it. The linking of photogrammetry, the science of making reliable measurements by means of photographs, to the science of geology was for many years a slow process; only in the last decade has it experienced a rapid acceleration.

EARLY USE OF PHOTOGRAPHY FOR RECORDING SCIENTIFIC DATA

As far back as 1853, a famous scientific expedition, under the leadership of Col. John C. Frémont, employed a photographer to obtain reliable records of geologic and geographic features encountered on a route of exploration. This expedition set out from Westport, Mo., with the objective of crossing the Rocky Mountains near the thirty-eighth parallel, in quest of a direct route to California. A key member of Frémont's party was Solomon N. Carvalho,[1] a daguerreotypist and artist from Baltimore, who was the first official photographer to accompany a Western expedition. In his account of the journey, *Incidents of travel and adventure in the Far West* (New York, 1858), Carvalho describes the intricate process of mixing chemicals and preparing daguerreotype plates while standing waist deep in snow with the thermometer registering 20° below zero.

Between 1854 and 1860 at least four more exploration parties employed photographers, with varying degrees of success. The outbreak of the Civil War halted expeditionary photography for the duration. Following the cessation of Civil War hostilities, several separate Government-organized geological-survey expeditions were created to further knowledge concerning national resources in the West. The most important of these were the Hayden, King, Wheeler, and Powell surveys; each of these parties included a photographer. The photographic work of these survey expeditions was considerably more successful than that of the earlier expeditions, owing largely to three factors: the superiority of the wet-plate process over the daguerreotype process, the availability of commercially prepared collodion, and the experience acquired by the photographers during the Civil War years. An important product of these surveys, made between 1865 and 1880, was the large amount of accurate geologic and geographic data collected, which were represented largely in the form of maps, with photographs serving to illustrate geologic features in detail. Robert Taft gives a list of photographers of this period.[2]

The growing recognition of the value of photography in recording scientific data such as that gathered by the early western surveys led to the formation, in 1890, of a Committee on Photographs of the Geological Society of America. In the first report of this committee[3] we see the first known reference to a new activity: photogeology. The object of the new movement, according to the committee report, was "to make a photo-geologic survey, and to secure for the

[1] Wallace, E. S., *The great reconnaissance:* 126–137. Little, Brown & Co., 1955.

[2] Taft, Robert, *Photography and the American scene:* 308. 1938.

[3] Geol. Soc. Amer. Bull. **2:** 616–6–30. 1890.

Society a national collection of photographs illustrating the geology of the country." The stated uses for such a collection were "first, to furnish to teachers better illustrations in teaching geology, and second, to furnish to investigators material for comparative study."

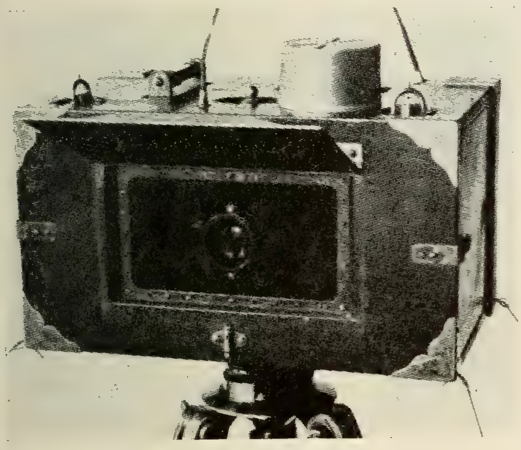

Fig. 1.—Panoramic camera. The first panoramic camera used by the Geological Survey was constructed by C. W. Wright and F. E. Wright in 1904. Later, beginning in 1910, J. W. Bagley improved this camera and extended its use in a program for producing topographic maps.

PHOTOTOPOGRAPHIC SURVEYS

To understand properly the intensive mapping activities by field parties interested primarily in geology, it is important to realize that mapping was considered to be a means to an end. The object was to facilitate the understanding of geology; maps were needed as a base on which geologic data could be plotted.

In 1904, two members of the U. S. Geological Survey staff, C. W. Wright and F. E. Wright,[4] pioneered the use of photogrammetric methods for the development of topographic maps needed specifically as a base for geologic studies. The Wrights, operating in an area of Alaska completely devoid of maps, devised a spring-driven, revolving, panoramic camera (Fig. 1) which afforded a very large field of view. Level bubbles and scales fitted to the camera provided a basis for photogrammetric measurements. Beginning in 1910, James W. Bagley, a topographic engineer of the Geological Survey, developed and improved the panoramic camera with the object of extending its use to the Survey's regular program of producing general-purpose topographic maps. Bagley also designed a panoramic photoalidade (Fig. 2) which enabled the operator to use the photograph for the determination of directions and elevation differences in the same manner in which a topographer operates the telescopic alidade on a plane table in the field. This afforded a basis for drawing planimetry and contours in the construction of a map.

Meanwhile, the use of photographs for mapping had been stimulated by two important advances: (1) the discovery in 1892 by F. Stolze,[5] in Germany, of the principle of the stereoscopic floating mark, and its practical development later, and (2) the advent of the airplane. The floating mark principle offered a satisfactory method of making measurements in the three-dimensional "model" observed when overlapping photographs are viewed stereoscopically. The airplane offered an excellent platform on which a camera could be moved rapidly from exposure station to exposure station; furthermore, aerial photography offered a practical means of obtaining a vertical view of the terrain, with its inherent superiority over terrestrial photography, for mapping purposes. These events opened the way to the widespread use of aerial photographs in stereoscopic plotting equipment; maps could now be produced by continuous plotting instead of the old tedious point-by-point methods. The two advances also accelerated the development of a large number of accurate stereoscopic plotting instruments for mapping. Eventually, it was found that, in general, maps of comparable accuracy could be obtained at lower costs with the new aerophotogrammetric techniques than with the older ground methods.

In 1916, after studying the work of Scheimpflug, the Austrian inventor of a multiple-lens camera, Bagley and another mem-

[4] Landen, David, *History of photogrammetry in the United States.* Photogrammetric Eng. **18**(5): 857. December 1952.

[5] Von Gruber, O., *Photogrammetry:* 163. American Photographic Publishing Co., Boston, 1932.

Fig. 2.—Panoramic photoalidade.

ber of the Geological Survey, J. B. Mertie, undertook the task of developing a tri-lens camera (Fig. 3). Meanwhile, another colleague, F. H. Moffit, designed a transforming printer (Fig. 4) as a companion piece to the camera. After Bagley was commissioned a major in the Engineer Reserve Corps, in 1917, he continued his interest in phototopographic mapping. The first aerial photographs taken with the tri-lens camera were made at Langley Field in 1917–1918 with the cooperation of the Air Service. This event marks the actual beginning of aerial surveying in the United States; the tests led to a program of producing aeronautical charts of the terrain between flying fields. Multiple-lens cameras are in use for obtaining mapping photography to this day, notably the nine-lens camera of the U. S. Coast and Geodetic Survey which has been in use since 1936. For the great majority of modern photogrammetric mapping projects,

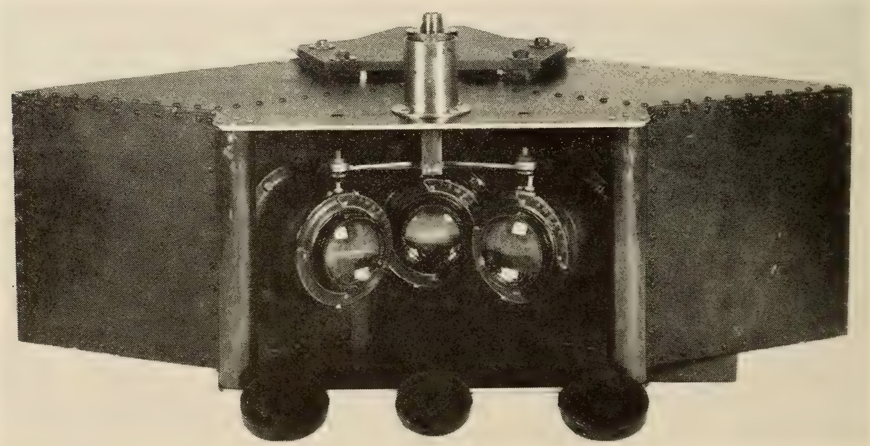

Fig. 3.—Tri-lens camera. Designed in 1916–17 by J. W. Bagley, with the assistance of J. B. Mertie and F. H. Moffit, and developed by the Corps of Engineers, U. S. Army. Later, cameras of this general design were built with 4- and 5-lens combinations.

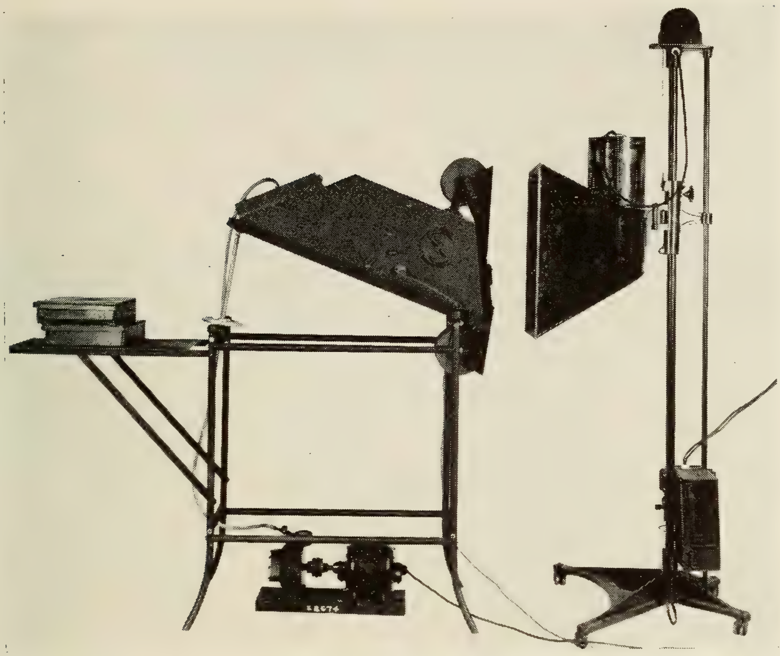

Fig. 4.—Transforming printer. Designed by F. H. Moffit in 1916–17, this transforming printing-camera was used to project the side negatives of the tri-lens camera so as to bring the photographs to the same plane and scale of the center photograph.

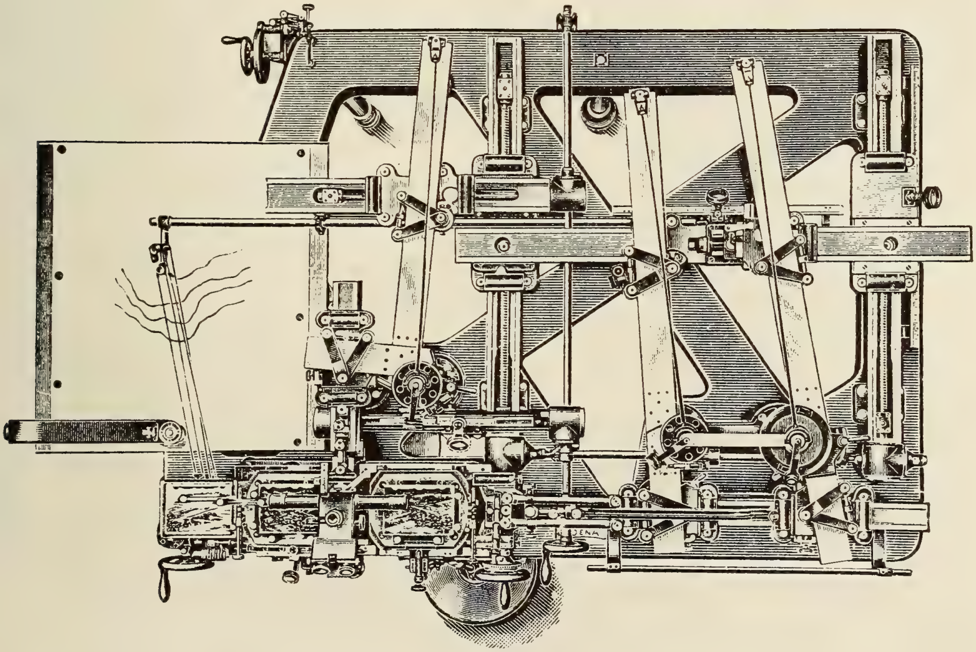

Fig. 5.—Plan view of the stereoautograph.

however, aerial photography is obtained with a single-lens camera or a combination of single-lens cameras.

AMERICAN USE OF STEREOSCOPIC MAPPING INSTRUMENTS

In the early 1920's the Brock and Weymouth Co. of Philadelphia designed and built the first American stereoscopic plotting equipment, and in 1923 they compiled the first topographic map produced commercially on such a machine in the United States.

Meanwhile, in 1921, a semiautomatic plotting machine, the stereoautograph (Fig. 5), was received (on loan) from Germany for testing by the Geological Survey's newly established Section of Photographic Mapping. This instrument employed terrestrial photographs only, and while workable, did not prove to be economical. A second instrument, the Hugershoff aerocartograph (Fig. 6), was imported from Germany by the Geological Survey in 1927; this was the first precise stereoscopic plotting instrument utilizing aerial photography to be owned by the United States Government.

Although the aerocartograph produced satisfactory contour maps, its initial cost was high and it was mechanically complex. The multiplex aeroprojector, manufactured by Zeiss in Germany, overcame these disadvantages, and in 1935 the Geological Survey purchased its first multiplex equipment. (See Fig. 7, Principle of multiplex.) Once the value of the multiplex was demon-

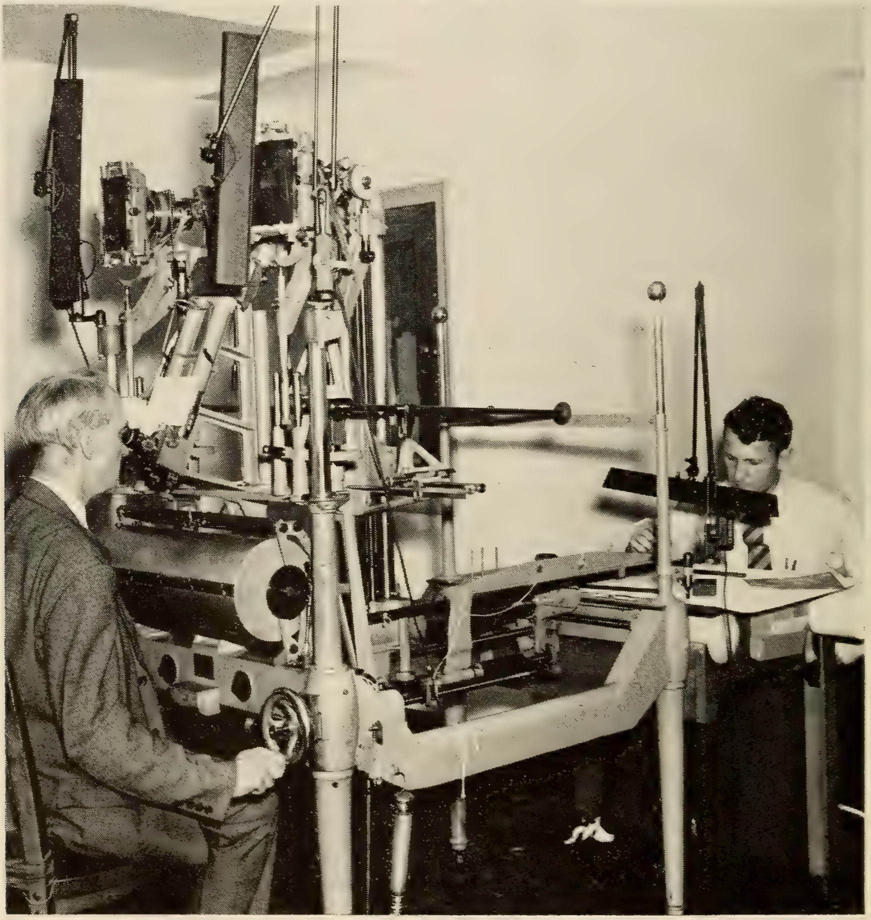

Fig. 6.—The Hugershoff aerocartograph. The (German) aerocartograph is a complex stereoplotting instrument using the optical-mechanical projection principle. While it is capable of producing good maps from either vertical or terrestrial photographs, its use, together with narrow-angle photographs is now considered obsolete, as it was replaced by more modern wide-angle plotting instruments.

strated, it was put into widespread use, first in topographic mapping in the Tennessee River Valley, then in the topographic mapping of other areas throughout the country. During World War II this equipment was used in carrying out formidable strategic mapping assignments of high importance.

Following World War II, two important new plotting instruments were developed by the Geological Survey: the Kelsh plotter (Fig. 8) and the ER-55 plotter (Fig. 9). Both of these instruments embody the general principle of the multiplex but have features which result in greatly superior per-

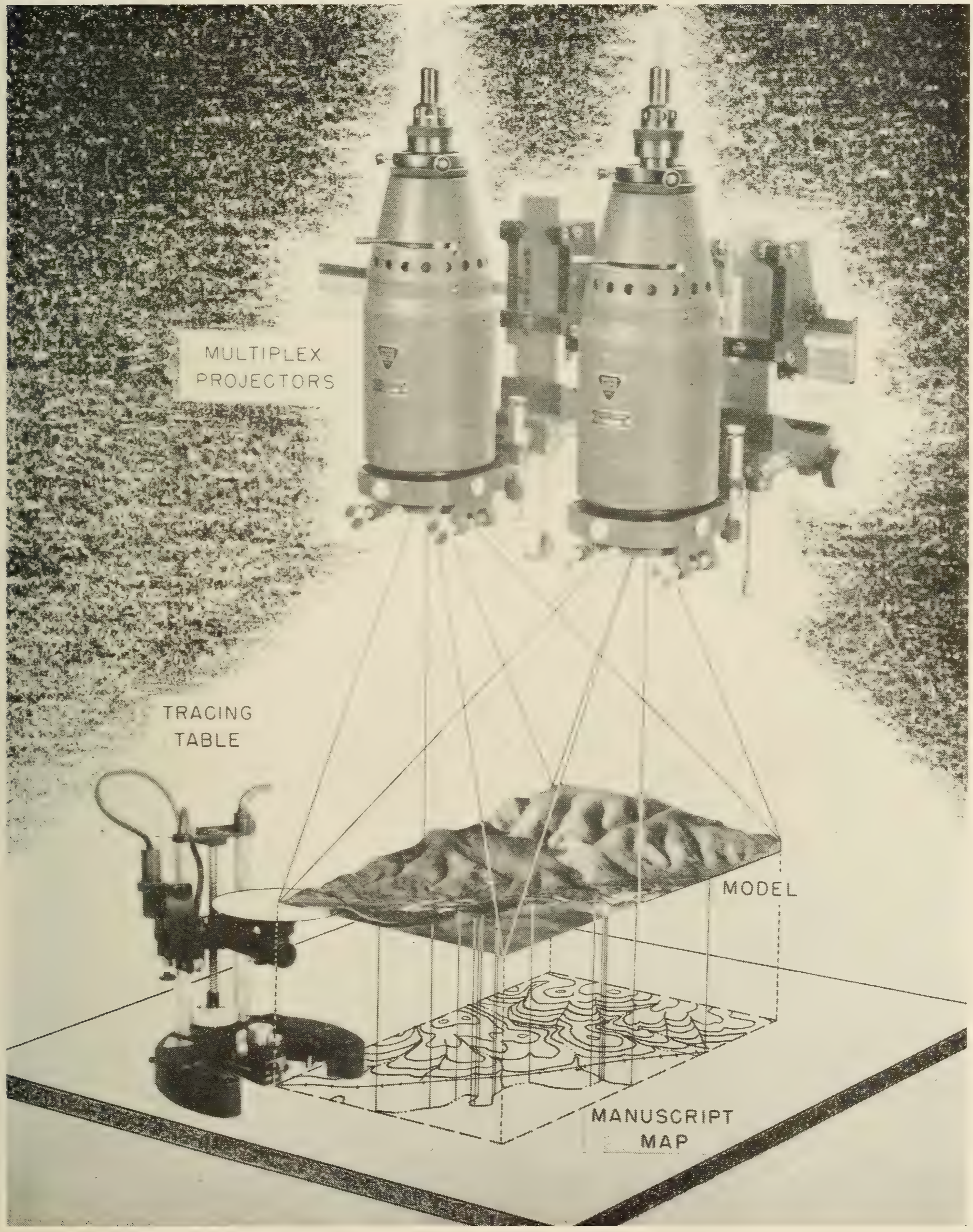

Fig. 7.—Principle of multiplex.

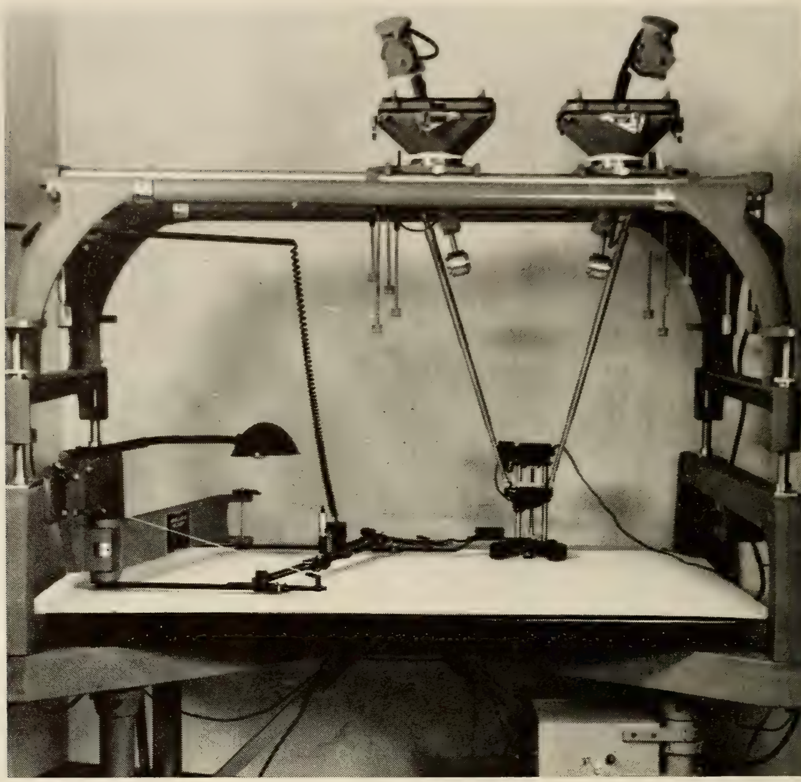

FIG. 8.—Kelsh plotter. Conceived by H. T. Kelsh in 1943, the Kelsh plotter was developed by him in 1947 and later by members of the Geological Survey technical staff. The main advantages of this plotter over previous double-projection plotters are the swinging light source; correction, when necessary, of camera lens distortion by means of an arm-and-cam arrangement; and contact (negative) size diapositive plates.

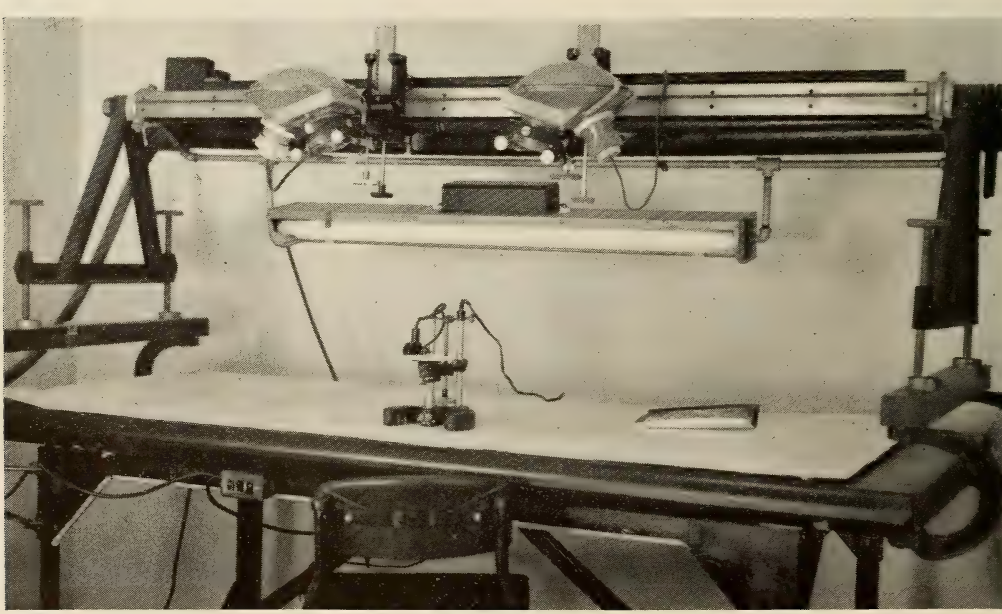

FIG. 9.—ER-55 plotter. Two ER-55 optical projectors are shown mounted on a standard multiplex supporting frame. The projectors are arranged for convergent photography.

formance. Commercial versions of these two instruments are now the leading American-made instruments of this type on the American market.

In addition to the American-made instruments, numerous foreign-made instruments are to be found in use for high-precision topographic mapping in this country. (See Fig. 10, Wild plotter.) Among these are numerous instruments made by Zeiss Aerotopograph (Germany), Henry Wild (Switzerland), Officine Galileo (Italy), and Ottica Mecanica Italiana (Italy). Despite their complexity and high first cost, these instruments find an important use because of their versatility and increased capability.

RATE OF PROGRESS OF THE UNITED STATES MAPPING PROGRAM

In view of the need for good topographic maps on which to plot geologic data, the rate of progress of the United States mapping program is of vital importance to the geologic profession. The lack of a suitable map of the area of interest can delay a geologist's operations by weeks or months.

Fortunately, Congress has recognized the vital importance of the national topographic mapping program and has, in recent years, appropriated the funds needed to permit an increase of several times in the annual map output as compared to that of a decade ago. At the current rate, about 100,000 square miles of U.S.G.S. quadrangle maps at the scales of 1:24,000 and 1:62,500, are completed annually.

As of 1958, the Geological Survey distributes some 20,000 separate topographic maps produced by Federal agencies. These maps are published at various scales ranging from 1:24,000 to 1:250,000 (see Fig. 11, Status of topographic mapping).

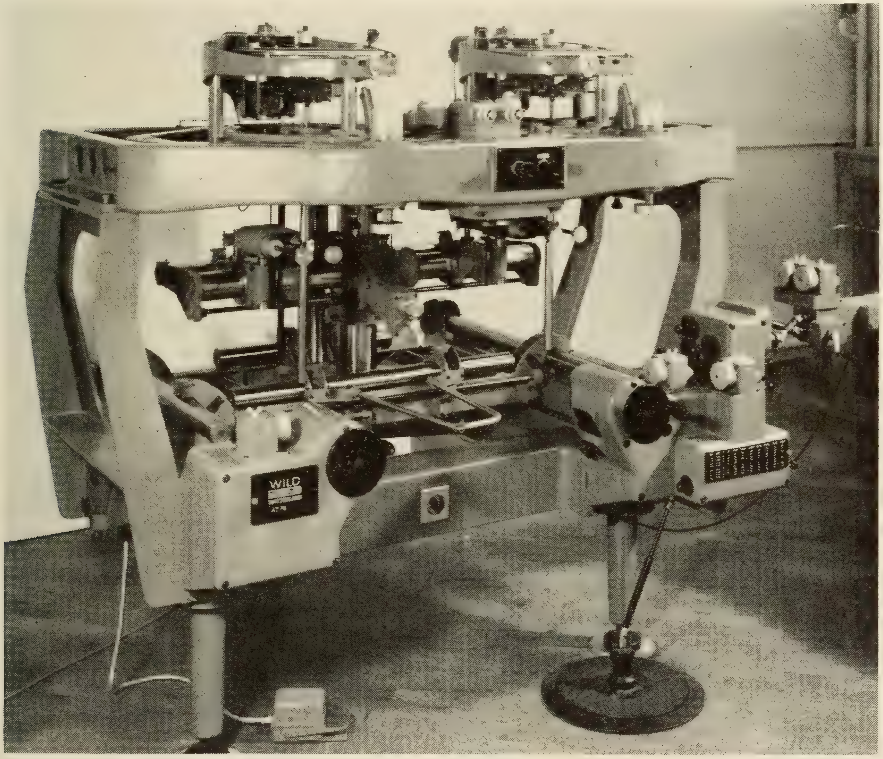

FIG. 10.—Wild autograph A-7 (Swiss). The autograph is a complete stereoplotting instrument of the mechanical projection class. The instrument can be used for control extension by aerotriangulation as well as for map compilation. Despite the initial high cost and complexity, its versatility and high order of accuracy make it suitable for a wide range of special projects, with long-range economies in operation.

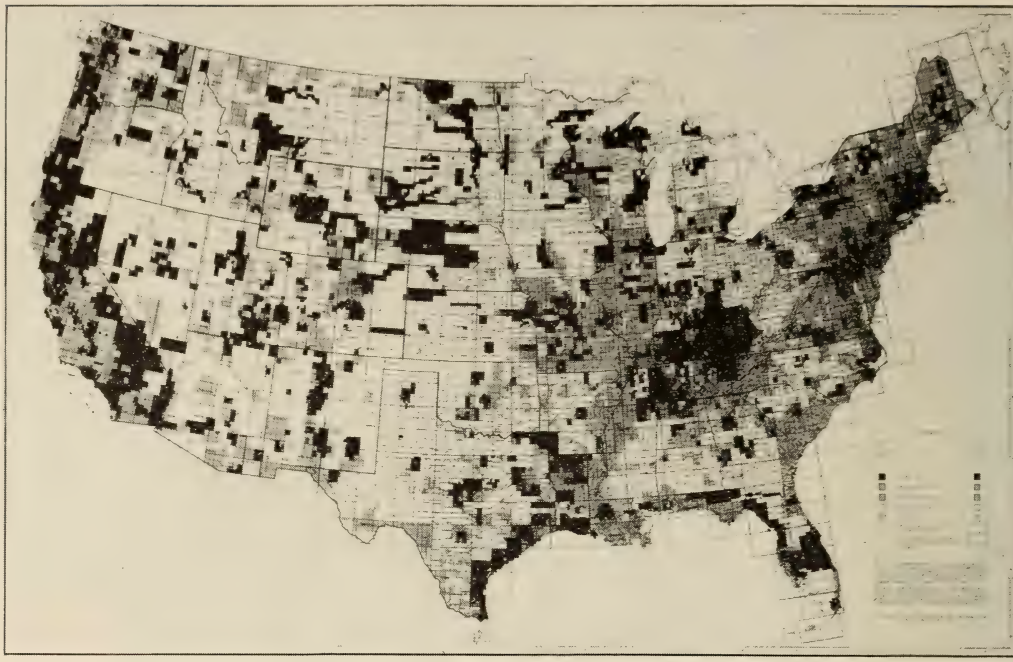

FIG. 11.—Status of topographic mapping (at scales ranging from 1:24,000 to 1:250,000) (January 1958).

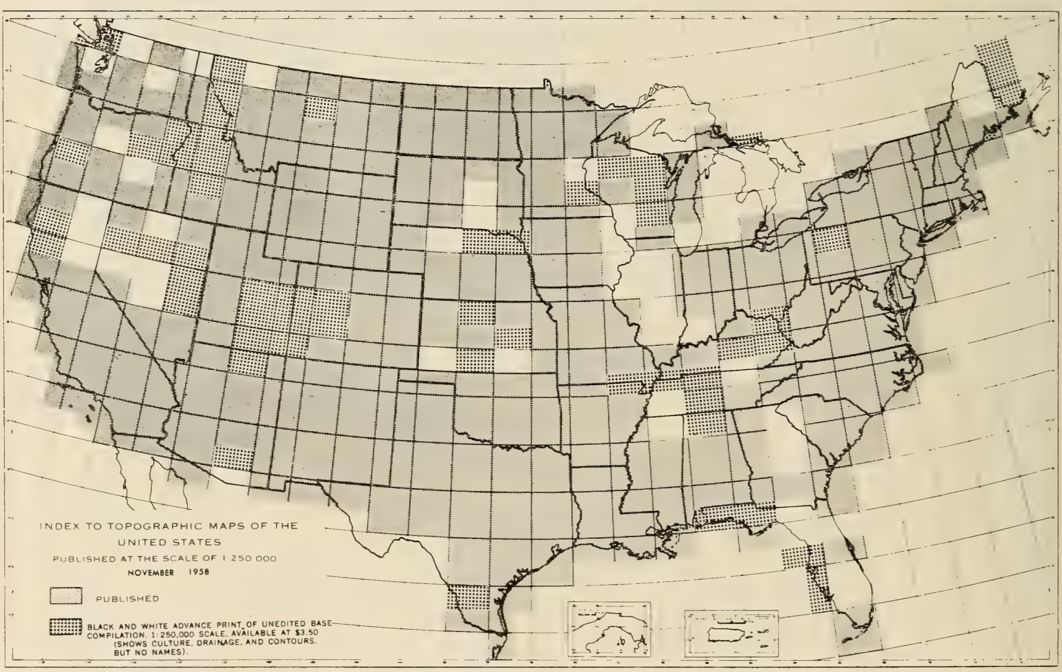

FIG. 12.—Index to topographic maps of the United States, published at the scale of 1:250,000 (November 1958).

Quadrangle maps at a scale of 1:250,000 are also available, in a preliminary series, for the entire State of Alaska. In addition, more detailed mapping of a type that may be termed "adequate" is already available for about 29 percent of Alaska's tremendous land area. When Arizona, the last State to be admitted previously, entered upon statehood in 1912, only 1 percent of its area was adequately mapped.

The new series of 1:250,000-scale topographic maps of the United States, originally prepared by the Army Map Service, but now being published in civilian editions by the Geological Survey, is of particular interest because it provides nearly complete coverage of the country. (See Fig. 12, Index to 1:250,000-scale maps.) In addition to the 1:250,000-scale maps themselves, geologists have access to the rather recent high-altitude aerial photography and other source materials used in preparing the maps. These materials, obtainable from the Geological Survey, may provide detailed information in areas of interest not covered by larger-scale quadrangle maps. Much of this topographic mapping is a result of the use of high-altitude aerial photography flown at heights as high as 36,000 feet.

PHOTOGRAMMETRY AND ACCURACY STANDARDS

Not only does photogrammetry provide a means of increasing the rate of topographic mapping but it also provides the means whereby accuracy standards can be established on a practical basis for maps of all types of terrain.

The practical value of geologic information, however well catalogued, may be seriously limited if the location of the items described is not accurately known. It is therefore quite important to the geologist that he recognize the characteristics of the topographic map on which geologic data is to be plotted, with respect to the accuracy of the positions and elevations of features shown on the map.

The idea of producing topographic maps conforming with specified standards of accuracy has long been known, and indeed many maps meeting rigid specifications have been prepared over the years, by classical methods, where such procedure was economically justified. It was not until the advent of photogrammetric techniques and parallel advances in related field-survey procedures, however, that attainment of standard accuracy in nearly all of the quadrangles of the National Topographic Map series became economically feasible. Since the early 1940's, most topographic maps produced by or for the Federal mapping agencies have been prepared to comply with standard specifications for horizontal and vertical accuracy. Maps made in accordance with these specifications are so designated by the following statement printed on the bottom of the sheet: "This map complies with National Map Accuracy Standards." This statement assures the geologists, forester, engineer, or other user that the map has been made under carefully controlled conditions and that the information given can be relied on within the provisions of the accuracy specifications.

SPECIAL-PURPOSE MAPS

The general-purpose topographic maps produced by the Federal agencies cannot be expected to meet all the specialized requirements of all the map users with respect to scale, contour interval and map content. To meet such requirements, photogrammetry offers a valuable means for producing special-purpose maps at relatively low cost.

Several government agencies, having specialized map requirements for studies in geology, forestry, agriculture and other fields, maintain their own photogrammetric facilities for producing the needed special-purpose maps. Likewise, a number of commercial organizations, such as oil companies, operate photogrammetric installations for producing needed geologic and other scientific data.

The organization or individual that needs special-purpose maps but is not in a position to operate photogrammetric facilities may wish to consider the services of the various commercial firms that are equipped to perform such tasks. Firms of this type are to be found in all parts of the United States; in general, they operate their own photographic aircraft and photogrammetric plotting equipment.

SOME EXAMPLES OF SPECIAL-PURPOSE MAPPING

Some representative examples of the use of photogrammetric techniques in geology are shown by the following illustrations:

a. A structure contour map (Fig. 13)

b. An isopachous map (Fig. 14)

c. A compilation of photogeology and surface geology is shown in Fig. 15—a photogeologic map of the Notom-15 quadrangle, Garfield County, Utah. The only available control information was outside the area mapped, and all the photogeologic data was derived from photographs. The structure contours shown are based on measurements obtained with a multiplex plotter.

Two additional examples of large-scale special-purpose mapping further illustrate the use of photogrammetry for the solution of scientific and engineering problems:

d. A beach-erosion study (Fig. 16). A large-scale map of a heavily eroded beach at Gay Head, Massachusetts, was compiled from aerial photographs flown at 1,500 feet above ground. The scale of the required map was 1:600 (50 feet to the inch). Two-foot contours were plotted with the Kelsh plotter. It is planned to remap the area chronologically on a yearly basis to record the rate of erosion and its relation to the topography and resistance of surficial materials.

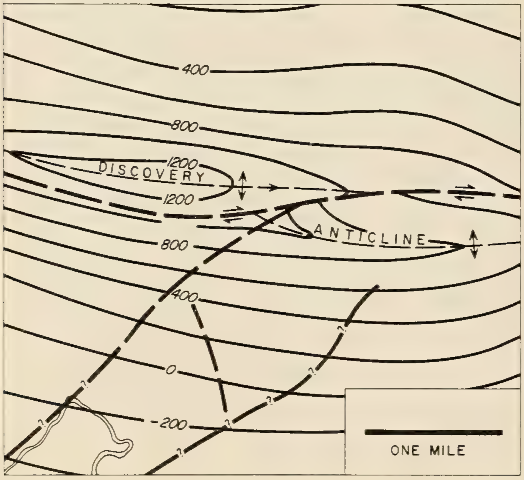

Fig. 13.—Portion of a structure contour map. This figure shows an enlarged portion of a structure contour map of Discovery Anticline in northern Alaska (U. S. Geol. Surv. Spec. Rep. 42, pl. 1, 1:40,000 scale). Measurements that were used to develop the structure contours were made from aerial photographs with a stereometer. (A structure contour is a contour line drawn through points of equal elevation on a stratum, key bed, or horizon, in order to depict the attitude of the rocks.) The contour interval is 200 feet, and the reference datum is approximately sea level.

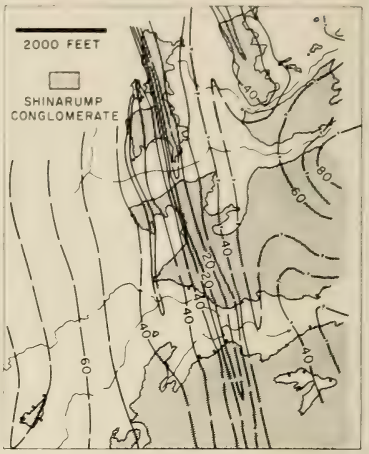

Fig. 14.—Example of isopachous map. Portion of an area in Monument Valley, northeastern Arizona, showing isopach intervals of 10 feet. (Isopachous line are contour lines which show the thickness of a formation.) A Kelsh plotter was used to measure the thickness of the formation and to plot the location of these measurements on a base map.

e. Photogrammetric mapping of sand beds in a hydraulic test flume[6] (Fig. 17). In connection with a wide range of studies of phenomena relating to the problems of water shortages and soil erosion, an unusually large-scale map was made of sand dune configurations, resulting from flowing water in a hydraulic test flume. Contour maps (Fig. 18) were prepared at 1:2 scale (half-size) with a contour interval of 0.01 foot, from photographs taken at a height of 65 inches (5.4 feet). A Wild A-8 plotter was employed. The cyclical recurrence of ridges and depressions in the sand dune pattern is plainly evident. Wavelengths and amplitudes of the configuration can be easily determined. This map was tested and was found to comply with standard-accuracy specifications.

SOME EXAMPLES OF PAPER-PRINT PLOTTERS

Many of the less-exacting tasks required in the plotting of data compiled on or from photographs can be performed with less

[6] Thompson, M. M., *Photogrammetric mapping of sand beds.* Photogrammetric Eng. **24**(3): 468–475. June 1958.

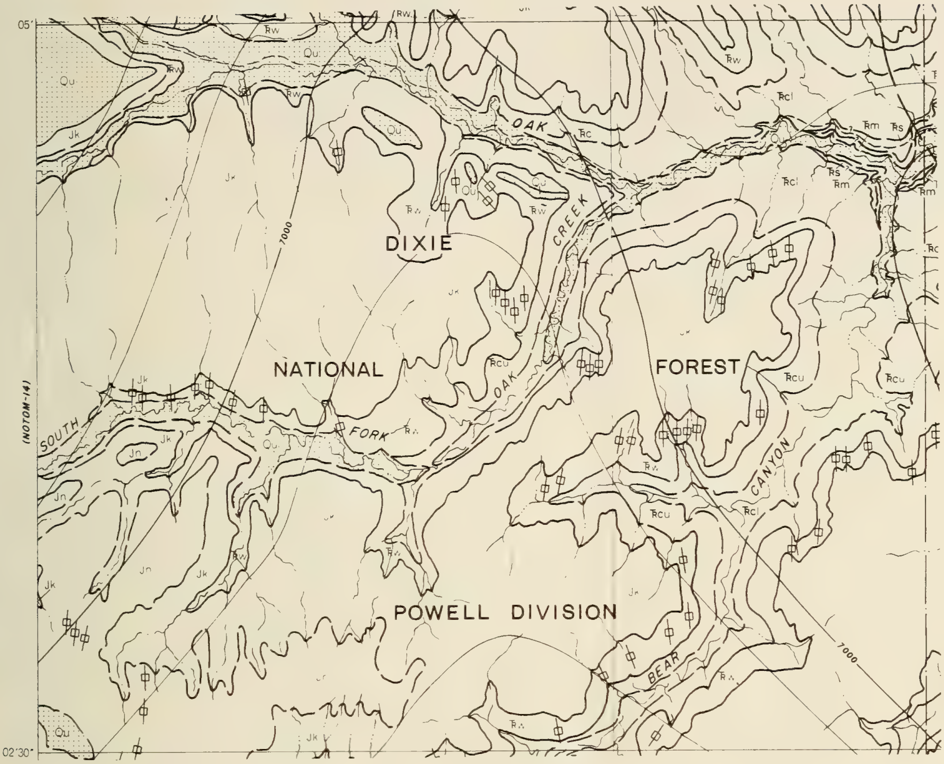

FIG. 15.—A compilation of photogeology and surface geology. Portion of Notom-15 quadrangle, Garfield County, Utah.

costly and less complicated instruments than those required for high-precision topographic mapping. These instruments are generally characterized as "paper-print plotters," as contrasted with the precision mapping plotters which invariably use glass-plate diapositives (positive photographs printed on glass instead of on paper). Among the more popular paper-print stereoscopic plotters are the Kail radial planimetric plotter, the K.E.K. Plotter, and the Ryker-Wernstedt-Mahan plotter. (See Fig. 19, K.E.K. plotter.)

Another simple instrument, the sketchmaster, based on the camera lucida principle, permits the transfer of detail from the photograph to the map. (See Fig. 20, Vertical sketchmaster.)

Until recently, the paper-print plotters constituted the prevailing type of instrument for use in photo-geologic operations. Lately, however, there has been an increasing use by geologists of modern precision stereoplotting instruments, such as the Kelsh plotter, for making quantitative measurements, for transferring geologic data from the photographs to the map, and for photointerpretation.

SOME EXAMPLES OF SPECIAL-PURPOSE PHOTOGRAMMETRIC INSTRUMENTS FOR MAKING QUANTITATIVE MEASUREMENTS

In addition to providing a variety of general-purpose and special-purpose maps, photogrammetry has already provided a large number of special instruments for making quantitative measurements that are useful in scientific studies. Geologic mapping, for example, employs basic measurements such as distance, elevation, or direction, as intermediate steps in the solution of some larger problem. Some of the instruments described herein can be used to obtain measurements such as dips, strikes, thickness of beds, profile elements and the like; measurements heretofore largely made on the ground. The forester, for example, can use photogrammetric measurements for obtaining heights of trees; the hydrologist can make use of these instruments for watershed and gradient studies; the engineer, for example, makes use of these measurements in highway design and construction, etc. A few of these special-purpose photogrammetric measuring instruments are described below:

The parallax-bar, or stereometer (Fig. 21) is both the oldest as well as the most simple photogrammetric instrument available. It is used for measuring parallax differences.

FIG. 16.—Large-scale map for beach erosion study, Gay Head, Mass. Scale 1:600; contour interval 2 feet. Made with Kelsh plotter.

(The parallax of an object is its apparent displacement due to its being viewed from two different viewpoints.) By measuring the horizontal separation between individual dots placed at the bottom of an object to be measured, then measuring the separation, or parallax, at the top of the object, the difference between the two parallax readings can be directly related to the height of the object. With the stereometer shown parallax can be measured to hundredths of a millimeter.

The photogrammetric dip angle indicator (Fig. 22) is a device for making direct measurement of dip, or angle of slope, in the

FIG. 17.—Photogrammetric mapping of sand beds in a hydraulic test flume. (The white spots are heads of tacks used as vertical accuracy test points.)

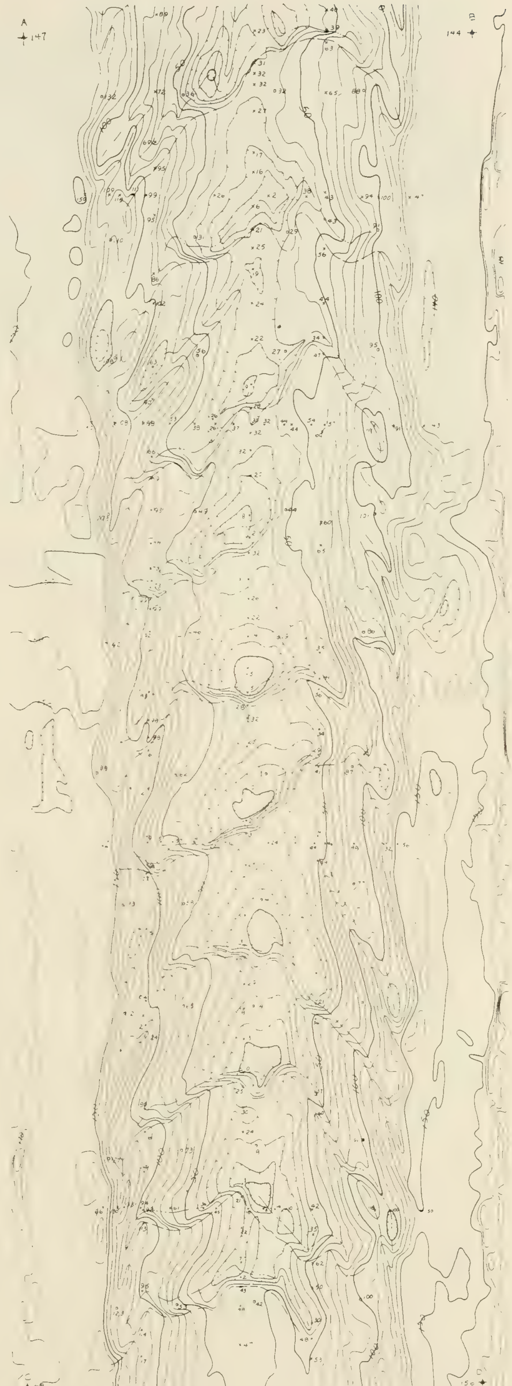

FIG. 18.—Contour map of sand beds compiled on Wild A-8. Contour interval, 0.01 foot.

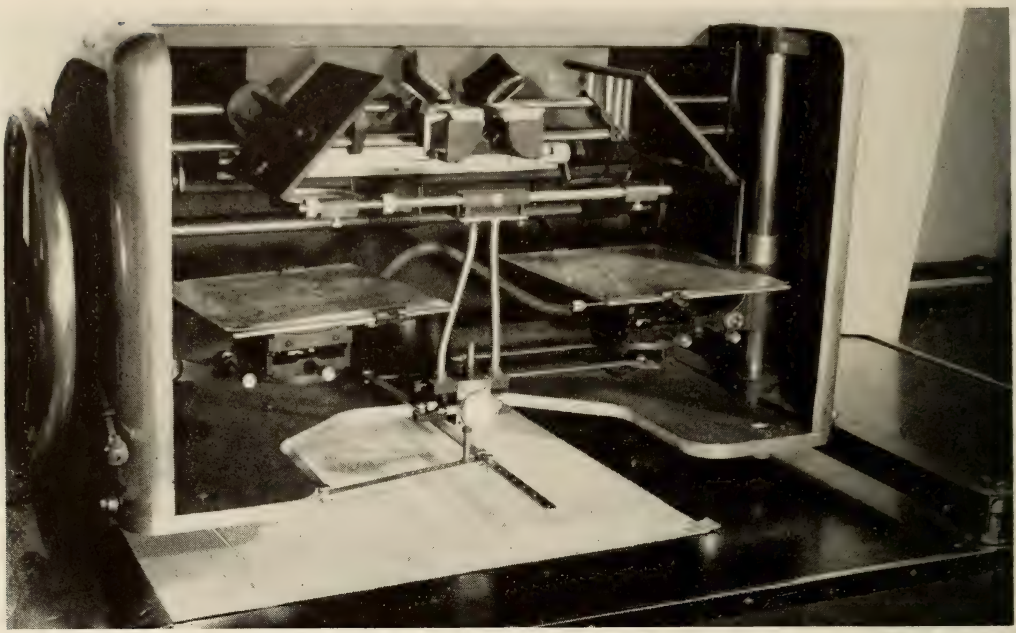

FIG. 19.—KEK (Kail, Elliot, King) plotter. The KEK plotter consists of a stereoscope for viewing a pair of photographs mounted upon two tables, a pair of floating marks scribed on glass disks, and a plotting device attached to a pantograph. By raising or lowering the plate-carriers the floating mark is placed in contact with the ground in the stereoscopic model so that planimetric detail can be plotted on the map. Elevations are read on a drum scale linked to the plate-carriers. The floating mark can be set to any desired contour interval and permits contouring when the photographs are well controlled. Since the instrument is based on certain approximations and does not produce a geometrically true model, it is not intended for precision work.

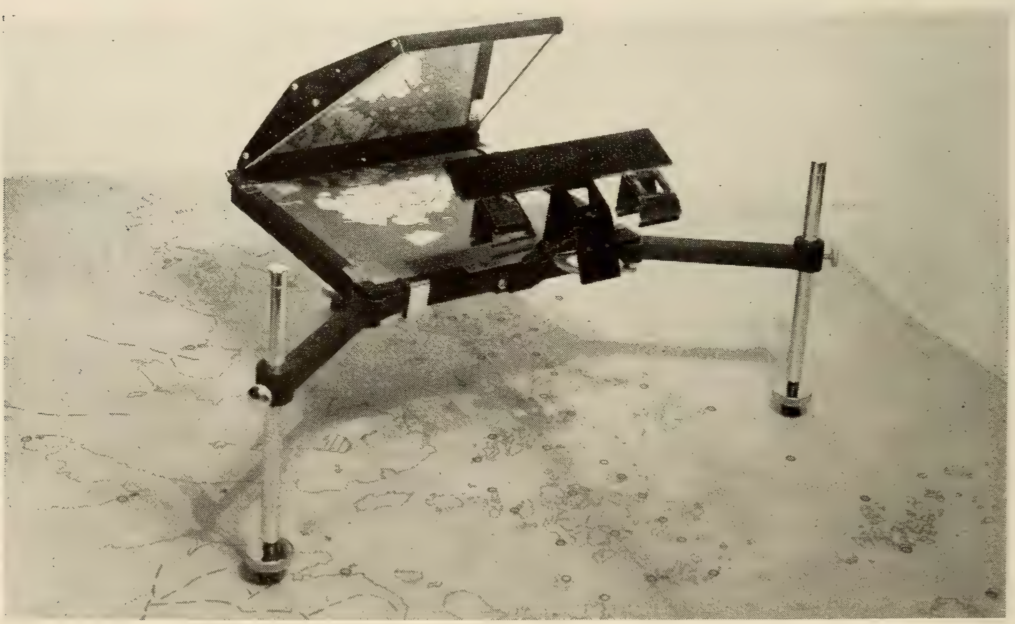

FIG. 20.—Vertical sketchmaster. This portable instrument based on the camera-lucida principle was designed by J. L. Buckmaster of the U. S. Geological Survey in 1931. By means of a mirror arrangement, the sketchmaster permits the photograph and the plotting sheet to be viewed simultaneously, thus making possible the transfer of detail from the vertical photograph to the plotting sheet. Adjustments are provided for scale changes and approximate tilt correction.

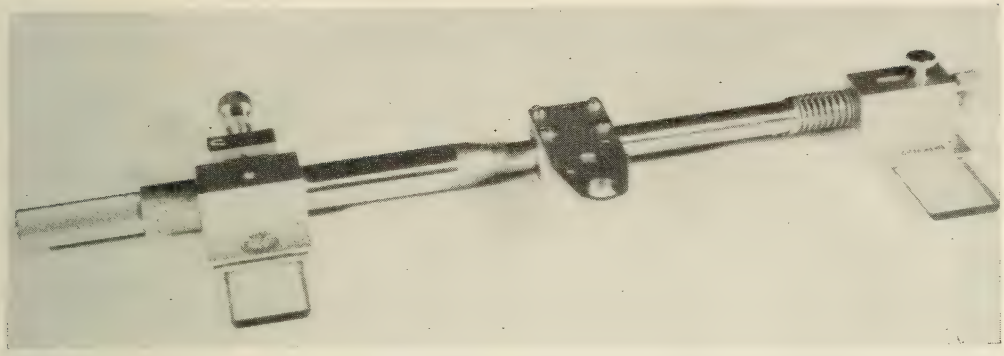

Fig. 21.—The parallax-bar, or stereometer.

stereoscopic model of a double projection plotter. The surface of the platen shown is gridded with suitable stereoscopic floating marks. A vertical angle arc, passing through a slot in the platen, is used for making direct measurements of angles of slope. A strike line can be plotted graphically, at right angles to the plotted direction of dip.

A photogrammetric profile plotter[7] (Fig. 23) is an instrument for plotting profiles directly from multiplex-type stereoplotting equipment. Profiles are often used, in combination with geologic data, to show geographically the inclination, structural relations and thickness of rock units at the surface or subsurface of the ground. The profile plotter plots the profile directly upon a sheet of graph paper mounted in a vertical plane.

ORTHOGRAPHICALLY RESTITUTED AERIAL PHOTOGRAPHS

One of the important problems of the geologist working with aerial photographs is how to relate, or transfer, information from the photograph which is in a perspective form, to a map which is in an orthographic, or plan, projection.

A new photographic material that has aroused much interest is the orthographically restituted aerial photograph. This new photographic material is called an orthophotograph and the photogrammetric machine which produces it is called an orthophotoscope.[8]

[7] Landen, D., *A photogrammetric profile plotter for geologic use.* Photogrammetric Eng. **22**(5): 953–956. December 1956.

[8] Southard, R. B., *Orthophotography.* Photogrammetric Eng., June 1958.

The orthophotoscope (Fig. 24) employs the anaglyphic principle to form a stereoscopic model under a double-projection stereoplotter. The model is mechanically scanned in contiguous strips by a moving aperture which is controlled by an operator to rise and fall while in stereoscopic contact with the terrain being viewed. Photographic detail, located by the intersection of homologous optical rays in true orthographic position, is rephotographed upon a new sheet of film placed directly under the moving aperture and rising and falling with it. The film is sensitive only to the blue light of the red and blue rays forming the anaglyph. After the scanning is complete, the film is removed and orthographic paper prints are made (Fig. 25).

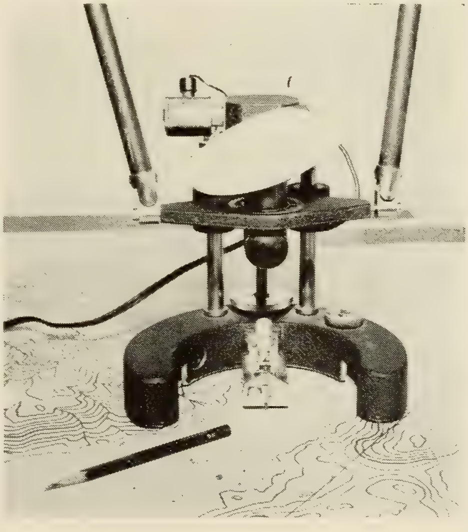

Fig. 22.—Photogrammetric dip (or slope) indicator.

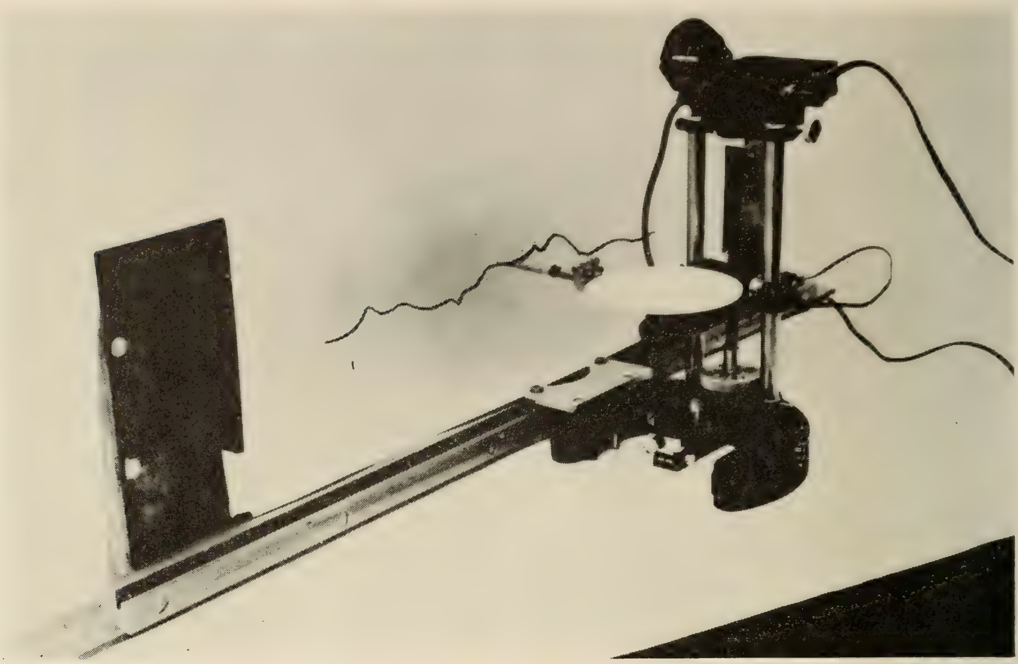

FIG. 23.—Photogrammetric profile plotter.

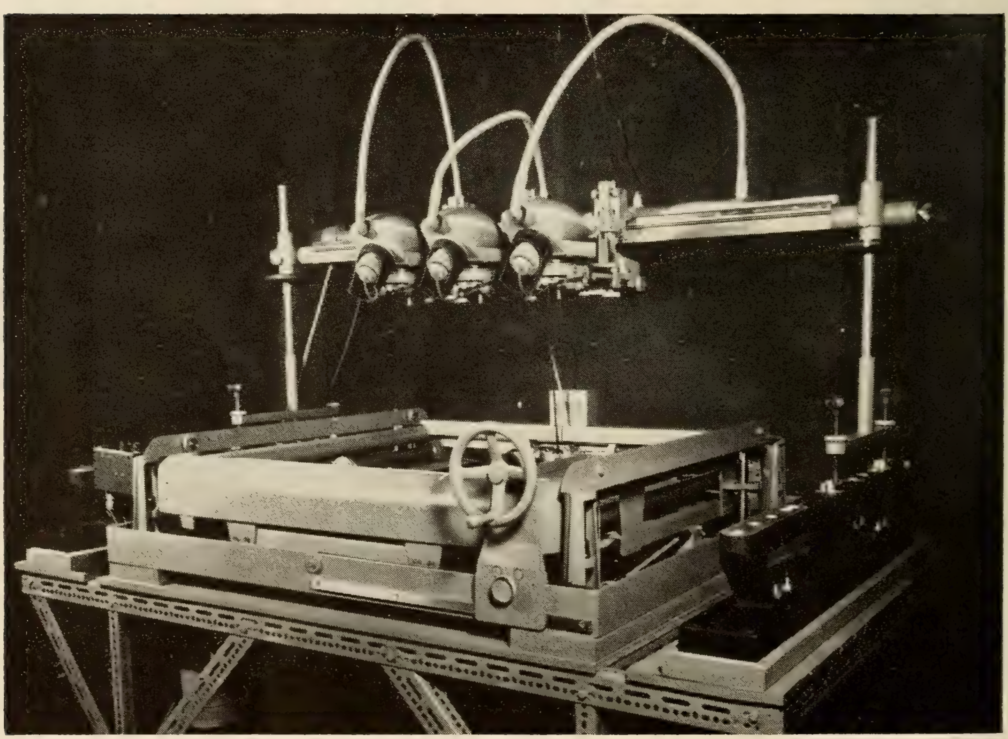

FIG. 24.—1956 model orthophotoscope with ER-55 projectors. The orthophotoscope, developed in the research laboratory of the Geological Survey, under the direction of R. K. Bean, is an apparatus for converting perspective photographs to the equivalent of orthographic photographs.

FIG. 25.—Corresponding portions of a perspective photograph (left) and an orthophotograph (right). In the perspective photograph the powerline appears to be crooked, while in the orthophotograph it is shown in its true, straight alignment.

Experience with orthophotographs by geologists shows that the photographic detail is uniformly in position within nominal accepted tolerances. The orthophotograph facilitates the transferring of geologic details from photograph to map. This can now be done in a simple fashion by tracing; or, the orthophotograph itself can be used as a map.

A somewhat related photographic product is called the photo-contour map.[9] This product provides a topographic map whereon elevations are shown by contours, while planimetry is shown by photographic detail.

[9] Mahan, R. O., *The photo-contour map*. Photogrammetric Eng. **24**(3): 451–457. 1958.

CONCLUSION

We have seen how photographs and photogrammetry, over a period of a hundred years, have made and continue to make a profound impact on the science of geology. This development has improved the work of the geologist, through its effect in two fields. One was an indirect effect, that of improving the availability, quality, and variety of photo-topographic maps. The other was a direct effect, that of making available in photographic form, a vast amount of quantitative and interpretative data relating to the earth's surface. Geologists have been alert to the possibilities of applying this sister science to the solution of their own problems.

Development of Geologic Thought Concerning Ulster County, New York

By Jules Friedman, *U. S. Geological Survey*

In the history of American geology, certain areas have been outstanding in the role they have played in the development of geologic thought. Such an area is Ulster County, N. Y., situated west of the Hudson River and halfway between the igneous and metamorphic highlands of the Hudson and the limestone Helderberg escarpment of the Capitol District. Although more widely known for the geology of its Catskill Mountains, the county also includes part of the Shawangunk Mountains and the Rondout and Wallkill Valleys.

The geomorphic setting of the area, known three centuries ago as the Esopus territory, has exposed it to geologic speculation since the earliest colonial days. By the late nineteenth century, geologic thinking in America was concerned with several stratigraphic problems—the real boundaries of the Ordovician, Silurian, and Devonian systems—for which rock exposures in Ulster County provided many of the problems and some of the solutions. After several mid-nineteenth century developments in mining and quarrying, technological advances opened the way, though inadvertently, for stratigraphic and structural field investigation. During the present century, the area has served as a training ground in Paleozoic stratigraphy for hundreds of American geologists.

Settlement of the Esopus territory of the seventeenth century was controlled largely by geographic factors. The fertile Rondout and Wallkill Valleys, colonized and farmed by the Huguenot French and Dutch, had been occupied by Minsi and Delaware Indians in earlier times. That these Algonkian Indians were as least as aware of their geologic environment as the first European settlers is suggested by their recognition and use of Pleistocene glacial deposits of the Rondout Valley for military strongpoints and for burial grounds, by scores of Indian place names derived from and incorporating rock and landform names, and by their recognition of landforms and drainage in the alignment of their trails. The original inhabitants may also have discovered the sphalerite-galena ore bodies emplaced in the Shawangunk conglomerate. William Mather, in 1843, wrote, "There are traditions that lead ore has been cut out of Shawangunk Mountain in many places by the Indians and hunters of former days with their hatchets, and melted to make their bullets. Traditions of this kind," continued Mather, "are said to have led to the discovery of the lead ores at Ellenville."

Settlement of the old Indian lands and rapid growth of the sparse population occupied several decades after the American Revolution, and then, in 1828, the Delaware and Hudson Canal was completed between the newly opened anthracite mines near Honesdale, Pa., and Kingston, on the Hudson. Ten miles southwest of Kingston, at the village of High Falls, dark beds of a previously unknown limestone formation were exposed during excavation for the canal. The discovery of these natural cement beds, now recognized as part of the Rondout limestone of Silurian age, made possible the development of a natural cement industry unparalleled elsewhere in the United States. Throughout the remainder of the nineteenth century the industry was concentrated at Rosendale and Rondout. By 1892 more than a dozen major plants produced nearly 3,000,000 barrels of cement annually—90 percent of all cement consumed in the United States at that time. But just before the close of the century the introduction of the portland process caused the natural cement industry to decline and then all but disappear. Ironically, as the old quarries and kilns at Rosendale fell into disuse, the new portland cement industry thrived in northern Ulster County, where nonmagnesian, crystalline limestones of Devonian age, the Alsen and Becraft formations, as well as the Coeymans and Manlius limestones, were exploited.

The Rosendale area, nevertheless, had influenced the development of a standard section for the Silurian and Devonian systems in North America. When the four geologic districts of New York State were delimited in the 1830's, Ulster County was included in the First District, and William Mather was chosen to report on the geology of this area, including the cement belt. His *Geology of the First Geological District*, published in 1843, but preceded by several preliminary reports, is the first comprehensive work concerned with the stratigraphy of Ulster County. The rocks of Mather's New York system, his classification of the Paleozoic of southeastern New York, are well displayed in the Rosendale segment of the Rondout Valley. The New York System corresponds to parts of the Devonian, Silurian, and Ordovician systems of the present day. Despite this work, the structure of the cement belt was not to be unraveled until the cement industry itself had declined after 1893. The geology of the Rondout-Whiteport-Rosendale region had drawn geologists by the score, and the stratigraphic positions of the Silurian and Devonian limestones were eventually worked out in detail by Darton, Van Ingen and Clark, Grabau, Hartnagel, and many others at the close of the century. By 1910, faunal lists had been published for

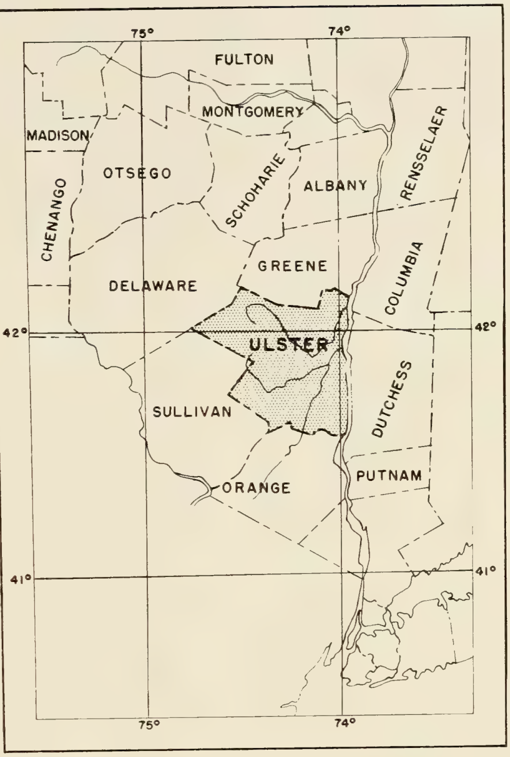

FIG. 1.—Index map of southeastern New York showing the location of Ulster County.

nearly all the fossiliferous formations, and the top boundary of the Silurian system in North America was drawn at the top of the Manlius limestone and below the overlying Coeymans limestone, the base of the Devonian system in Ulster County.

As commercial interest switched to the structurally complex belt between the Catskill escarpment and the Hudson River north of Kingston, so did the interests of contemporary geologists; the first geologic maps published on U. S. Geological Survey topographic base maps for this area were prepared by George Chadwick and Rudolf Ruedemann in the early 1940's for the Catskill and Kaaterskill quadrangles which include part of northern Ulster County. With a few notable exceptions, all the detailed geologic maps painstakingly done in the cement belt south of Kingston during the nineteenth century have either been lost or have never appeared on adequate topographic base maps. It was not until R. M. Logie restudied the natural cement limestones in detail in the 1930's that the internal stratigraphy of the Rondout limestone was deciphered, but this study has not been published and large-scale geologic maps of the cement belt are still lacking.

Construction of the Ashokan Reservoir and Aqueduct for the water supply system of the City of New York provided the incentive for Charles Berkey's *Geology of the New York Aqueduct*, the first work on the valleys of the upper Rondout and Esopus to use modern stratigraphic terminology and to base structural interpretations on diamond drill core measurements. It was published as a New York State Museum Bulletin in 1911. Again, technological requirements had preceded and initiated an advance in geologic techniques.

Before the 1920's, very little information was published on the Silurian Shawangunk conglomerate below the cement limestone sequence; moreover, a clear structural description of the intricately deformed Ordovician clastic rocks below the Ordovician and Silurian unconformity was unavailable. In 1929, however, Bradford Willard provided stratigraphic evidence suggesting that the Taconic disturbance occurred during the interval represented by the unconformity below the Shawangunk conglomerate; in the following year C. K. and F. M. Swartz traced the Tuscarora and Clinton units of Swatara Gap, Pa., eastward and found that they merged into the Shawangunk conglomerate at the Delaware Water Gap, and that the conglomerate continued without interruption into Ulster County. They concluded that the age of the formation was early Middle Silurian and reinforced the concept that a major hiatus exists below the base of the Silurian system in much of eastern New York.

In 1932, Charles Schuchert and Chester Longwell summarized structural and stratigraphic facts from Kingston and the Catskill cement belt, indicating at least two episodes of deformation, Taconic and Acadian, during Paleozoic time in the mid-Hudson Valley region. It became clear, indeed, that a single orogeny at the close of the Paleozoic could not have been responsible for all northern Appalachian structures and that there was a series of smaller orogenic disturbances distributed throughout Paleozoic time. It also was learned that the disturbances were possibly not correlative with similar events in Europe, Asia, and Africa.

Between 1930 and 1945, stratigraphic publications by Winifred Goldring, G. A. Cooper, Rudolf Ruedemann, Rousseau Flower, George Chadwick, and several other geologists clarified much of the older work and prepared the way for a new and more realistic understanding of the lower Paleozoic section of eastern New York.

Since 1945, synthesis and mild revision have characterized the most recent work. Detailed studies by W. A. Oliver, Jr., have enhanced our knowledge of the facies relationships of the Onondaga limestone. Various workers have divided the Shawangunk conglomerate into three or even five members. Lawrence Rickard, Jean Berdan, and other contemporary stratigraphers have new evidence that several long-recognized stratigraphic units, e.g., the Manlius and Coeymans limestones, each transgress time lines so sharply that they may actually be, at least in part, facies of each other. This new work is reminiscent of the studies published by G. A. Cooper and George Chadwick in the 1930's in which they demonstrate the importance of facies relationships in the Middle and Upper Devonian rocks of eastern New York. If facies changes are as marked in the Lower Devonian and Silurian part of the section as in the Upper Devonian, the recognized contact between the Silurian and Devonian systems may be invalidated, i.e., the Manlius limestone may actually be the base of the Devonian system. The base of the Silurian system, the lowest member of the Shawangunk conglomerate, also may be of different age in different places, suggesting the possibility of several different ages for the Taconic orogeny even within Ulster County.

Since Ruedemann's death, however, published papers on the deformed Ordovician rocks below the Taconic unconformity in the area have been few; it is in this subject that work for the future could be most profitable.

In retrospect, the most recent work in geology in Ulster County, as elsewhere in America, indicates the need for more complete information on tectonic history as an aid to stratigraphic correlation. It suggests, moreover, the necessity for critically reviewing some of the most widely held concepts of American geology.

REFERENCES

Berkey, C. P. *Geology of the New York Aqueduct*. New York State Mus. Bull. 146. 1911.

Chadwick, G. H. *Revision of "the New York series."* Science, new ser., **28**: 346–348. 1908.

———. *Catskill formation*. Bull. Geol. Soc. Amer. **42**(1): 242–243. 1931.

———. *Great Catskill Delta*. Pan-Amer. Geol. **60**(2): 91–107. 1933a.

———. *Hamilton red beds in eastern New York*. Science, new ser., **77**: 86–87. 1933b.

———. *Upper Devonian of the New York region*. Bull. Geol. Soc. Amer. **44**: pt. 1: 177. 1933c.

———. *Geology of the Catskill and Kaaterskill quadrangles*. New York State Mus. Bull. 336, pt. 2. 1944.

Clarke, J. M. *Classification of New York series of geologic formations*. New York State Mus. Handbook 19: 29 pp. 1903.

——— and Schuchert, C. *The nomenclature of the New York series of geological formations*. Science, new ser., **10**: 874–878. 1899.

Cooper, G. A. *Stratigraphy of the Hamilton group of New York*. Amer. Journ. Sci., ser. 5, **19**: 116–134. 1930.

———. *Stratigraphy of the Hamilton group of eastern New York*. Amer. Journ. Sci., ser. 5, **26**: 537–551. 1934.

Darton, N. H. *Preliminary report on the geology of Ulster County*. New York State Mus. Rep. 47. 1894.

Davis, W. M. *The nonconformity at Rondout, New York*. Amer. Journ. Sci., ser. 3, **26**: 389–395. 1883.

Goldring, W. *Geology of the Coxsackie quadrangle, New York*. New York State Mus. Bull. 332. 1943.

——— and Flower, R. H. *Restudy of the Schoharie and Esopus formations of New York State*. Amer. Journ. Sci. **240**: 673–694. 1942.

Hartnagel, C. A. *Notes on the Siluric or Ontaric section of eastern New York*. New York State Mus. Bull. 107: 39–54. 1907.

———. *Classification of the geologic formations of the State of New York*. New York State Mus. Handbook 19. 1912.

Mather, W. W. *Geology of New York: Report on the First District*. 1843.

Mencher, E. *Catskill facies of New York State*. Bull. Geol. Soc. Amer. **50**(11): 1761–1793. 1939.

Oliver, W. A., Jr. *Stratigraphy of the Onondaga limestone in eastern New York*. Bull. Geol. Soc. Amer. **67**: 1441–1474. 1956.

Ruedemann, R. *Geology of the Catskill and Kaaterskill quadrangles. Pt. 1*. New York State Mus. Bull. 331: 7–188. 1942.

Schuchert, C. *Silurian formations of southeastern New York, New Jersey, and Pennsylvania*. Bull. Geol. Soc. Amer. **27**: 531–534. 1916.

——— and Longwell, C. R. *Paleozoic deformations of the Hudson Valley region, New York*. Amer. Journ. Sci., ser. 5, **23**: 305–326. 1932.

Swartz, C. K., and Swartz, F. M. *Silurian of the central Appalachians*. Bull. Geol. Soc. Amer. **51**(2): 148–149. 1929.

———. *Age of the Shawangunk conglomerate of eastern New York*. Amer. Journ. Sci., ser. 5, **20**: 467–474. 1930.

Van Ingen, G., and Clark, P. E. *Disturbed fossiliferous rocks in the vicinity of Rondout, New York*. New York State Mus. Bull. 69: 1176–1227. 1903.

Willard, B. *The age and origin of the Shawangunk formation*. Journ. Paleont. **1**(4): 255–258. 1928.

———. *Stratigraphic aspect of Taconic disturbance*. Pan-Amer. Geol. **51**(2): 93–96. 1929.

Remarks on the History of American Petroleum Geology

By Edgar W. Owen, *University of Texas*

These remarks do not pretend to constitute a history of petroleum geology. They are merely an attempt at a perspective which seems to have been elusive.

The year 1859 may well be considered the beginning of modern times. Petroleum activated a new period of power and maneuverability for man at the same time that Darwin's *Origin of species* freed his mind from the shackles of dogma. The Drake well at Oil Creek, Pa., was completed in August 1859, producing 25 barrels per day at a depth of 69 feet. It is generally recognized as the beginning of the oil industry, although petroleum had long been used in many parts of the world. The American origin of the industry is anomalous, as western Europe was much more industrialized and had greater familiarity with the occurrence, character, and uses of oil.

Many of the basic concepts of petroleum geology were stated during the first decade after the Drake discovery. In 1860 Henry D. Rogers noted the occurrence of gas and oil on anticlines. In the same year Alexander Winchell recognized the role of reservoir porosity. In 1861 T. Sterry Hunt and E. B. Andrews emphasized the significance of anticlines, and Andrews began working as an exploration consultant while teaching at Marietta College. H. D. Rogers in 1863 advanced a carbon-ratio theory as a criterion of oil habitats. In 1865 Hunt elaborated the anticlinal theory and Briggs explained underground fluids mechanics. These concepts are basic to petroleum geology, but their enunciation did not add up to a workable doctrine for oil exploration. E. DeGolyer has stated the case admirably: "The anticlinal theory of the first half-century of the oil industry was a speculative generalization, determined empirically upon misunderstood and inadequate data."

Organization of geological observations into a disciplined science of petroleum geology has come slowly. In 1885 I. C. White, after an important consulting job for Forest Oil Co., restated the anticlinal theory clearly enough to establish it as a guiding exploration principle, but little practical application was made of it for a quarter century. Edward Orton published classic reports on the *Oil sands of southwestern Ohio* in 1886 and on *The Trenton limestone as a source of petroleum* in 1887. M. J. Munn in 1909 made a major contribution to our understanding of the migration of oil.

Following the organization of the American Association of Petroleum Geologists and the employment of thousands of professional geologists by the oil industry, our concepts of the origin, migration, and accumulation of oil and gas advanced rapidly from 1918 to 1926. During those years hundreds of important descriptive studies were published and major contributions to the philosophy of the discipline were made by Alex. W. McCoy, E. G. Woodruff, L. F. Athy, John L. Rich, F. M. Van Tuyl, R. C. Beckstrom, R. Van A. Mills, W. H. Emmons, and others. More than 50 years after its basic principles were first stated, petroleum geology had finally grown into a fairly mature discipline, with an organic literature of comprehensive observations and usable working hypotheses.

Some of the most important later scientific milestones were: 1929, E. Russell Lloyd's exposition of the nature and role of reef limestones; 1932, Parker D. Trask's work on source sediments; 1934, W. E. Wrather and F. H. Lahee, editors, *Problems of petroleum geology*; 1927–1941, A. I. Levorsen's work on stratigraphic traps; 1942, Wallace Pratt's spacious concept of *Oil in the earth*; and 1940–1950, M. King Hubbert's studies in the mechanics of fluid movement. No major contribution to the science of geology has been the creation solely of its author. All these important works were syntheses, incorporating the observations and ideas of many other workers.

The employment of geology in petroleum exploration and exploitation has been consonant with the development of the science. Although I. C. White, E. B. Andrews, and a few others were employed briefly by oil operators in the last century, the first organized geological department in the oil industry was established by E. T. Dumble for the Southern Pacific Railroad in 1897. W. W. Orcutt formed a department for Union Oil Co. of California in 1898. A. C. Veach was a full-time geologist for Houston Oil Co. in 1901 and 1902, and H. B. Goodrich did pioneer consulting work during 1899 to 1902 in many areas from New Brunswick to Texas and Mexico. In 1907 and 1908 F. G. Clapp, Ralph Arnold, W. T. Griswold, and C. A. Fisher resigned from the U. S. Geological Survey to do commercial geological wark. In 1909 several able American geologists were doing phenomenally successful work in Mexico. They were associated with Europeans who had gained experience in foreign areas, where oil companies had employed geology more actively than in the United States. By 1912 several other men were engaged in consulting practice. This tardy application of known, effective scientific techniques to the costly and hazardous operations of oil exploration and development is beyond understanding. But suddenly geology became fashionable. Most of the major American oil companies established geological departments between 1913 and 1915. These were greatly expanded in 1916 and have grown at an irregular rate ever since.

As an art, petroleum geology has responded more quickly to technological developments than to new abstract scientific concepts. Its practices and methods have undergone constant transformaiton as geologists have applied, improved, and even initiated a wide variety of new techniques. Direct surface indications were the dominant guide to oil prospecting until about 1910 and were used by geologists as well as by the wildcat drillers who scorned geology. These consisted of surface seepages, unusual topographic features, drainage anomalies, "creekology," and directional trends from known fields. Surface structure mapping was the dominant exploration method from 1910 to 1925. It had been used as early as 1883 when I. C. White surveyed with a spirit level. W. T. Griswold introduced the more efficient alidade in 1901. Every petroleum geologist who worked between 1910 and 1925 had an intimate acquaintance with the rocks on the ground and with the amiable qualities of the telescopic alidade. Unfortunately, surface mapping went into almost total disuse by the oil companies after 1925. The use of aerial photographs in the field, and laboratory photogeology, have revived some of the dignity of the surface geologist in recent years.

Petroleum geology is essentially a subsurface inquiry. J. F. Carll was studying well cuttings and plotting sample logs for the Pennsylvania Geological Survey in 1875. F. W. Minshall published cross sections of the Burning Springs anticline as early as 1878. Orton's Trenton Lime report of 1887 would be a creditable subsurface study by today's standards. But the oil companies did not begin organized subsurface work until 1917, when Alex. McCoy initiated the first program for the Empire Gas & Fuel Co. Other companies adopted the methods promptly, and core-drilling was introduced in 1919 to obtain additional subsurface information. The early emphasis was on structural attitude, and stratigraphy was mainly a means to that end. The first general recognition of the importance of subsurface stratigraphic studies resulted from the publication in 1921 of two classic papers by Fritz Aurin, Glenn Clark, and Earl Trager and by Luther White and Frank Greene. Recognition of the economic importance of stratigraphic traps resulted in rapid expansion of the studies. Since World War II several large research departments have grown up in the oil industry, and their attention has turned increasingly to stratigraphy.

The seismograph dominated petroleum exploration from its successful application on the Gulf Coastal Plain in 1924 until recent diminishing economic effectiveness has forced its more efficient integration with other geological techniques. It was introduced almost simultaneously by Alex. Deussen, L. P. Garrett, and E. DeGolyer for their respective companies, quickly followed by most other operators. The refraction method of Mintrop was used until it was largely supplanted by the reflection method perfected by J. C. Karcher in 1926. Seismograph surveys have now covered almost every acre of prospective areas in the United States; some areas have been surveyed many times. Gravity methods have also had an important, but lesser, role. The magnetometer has had wide use for rapid reconnaissance. Many other geophysical techniques have been tried without much success, but new methods are constantly under study. Geophysical instruments are used in petroleum exploration only as tools to obtain subsurface geological data. The interpretation of their data has been left largely in the hands of the technicians, whose knowledge of geological structure and of the formations they were exploring was only rudimentary. The results of geophysical exploration have been phenomenal in spite of this costly absurdity, but continued success will be measured largely by the degree of coordination with other information.

The principal effort of the petroleum geologist has always been directed to obtaining new data on earth science. His demand for information is insatiable and often exceeds his ability to assimilate it. The most reliable source of information, as well as the ultimate test of his ideas, has always been the drilling well. He soon replaced the drillers' well logs of early days with sample logs of his own making. The rotary drilling rig, which had been introduced in the Corsicana field in 1895, gradually supplanted the cable tool rig, which had furnished him rather clean cuttings from the bottom of the hole. By 1906 the rotary had reached California and in 1918 moved into Oklahoma. It reduced drilling time of individual wells from years to days, but only the concerted efforts of many geologists, engineers, and drillers supplied the inventions of tools and techniques which converted it into a satisfactory medium for getting geological data. The core barrel in 1921, later the wire-line core barrel, the side-wall core, and the drill-stem test tool, became direct sampling devices. Use of the shale shaker, and control of drilling mud viscosity, pump pressure, and other physical factors made the cuttings more intelligible samples. Introduction on a commercial scale of Schlumberger electrical logging into the United States in 1932 began a new cycle of data collection.

Instrumental logging of wells has become universal practice, conducted simultaneously with drilling, or run at the time of completion of the well. A wide range of physical characters has been recorded directly or measured indirectly by recording the response to various induced impulses. No less than a dozen logging methods have been developed and widely applied. The resulting accumulation of accurate, detailed measurements of multiple characters in billions of feet of geological section in hundreds of thousands of deep wells has exceeded the capacity of all employed geologists, engineers, and technicians to analyze and interpret them.

Application of the acquired information to problems of petroleum exploration has required the use of many scientific procedures in addition to standard geological and geophysical field methods. Micropaleontology was first applied by E. T. Dumble in 1920. It was originally used for correlation purposes in mapping subsurface structure, but broadened into environmental and ecological studies. Macropaleontology, both invertebrate and vertebrate, has been used consistently in surface work and sparingly in subsurface. The usual orthodox petrologic methods have recently been supplemented by more sophisticated techniques which are still in an early stage of development. Late discoveries in physical chemistry have had some attention, and isotope geology has been applied to some of the broader problems of geologic dating. Almost every recent advance in geology and related sciences has found some application to petroleum geology.

The contributions of petroleum geologists to the basic science of geology have been surprisingly meager, although their informal impact on the philosophy of the science has been far greater than is usually appreciated. Several reasons account for this deficiency. The requirement for immediate economic employment of their studies usually prevents definitive completion of their work. Many of their results must remain confidential until after the interest of the worker and his contact with the work have subsided. For most other scientists the literature of their science is their sharpest tool; with petroleum geologists it is the most neglected. Until recently, the bachelor's degree was considered adequate for the professional training of many petroleum geologists; it is not sufficient preparation for the science of today.

The abundance of the data which the petroleum geologists have accumulated has passed their ability to marshal it, and will require new statistical and electronic sorting techniques for satisfactory analysis. Petroleum geologists generally command a more comprehensive three-dimensional view of large segments of the earth than do any other scientists. Their detailed knowledge of the character of thick sections of the geologic column is unique. Many of their concepts are far in advance of anything published. Many of the ideas in the current geological literature relating to sedimentation, stratigraphy, structure, geologic history, and physiography look silly in the light of their information. But their neglect of effective communication has resulted in continual duplication of basic studies. No scientists are more liberal in the informal sharing of their knowledge by oral discussion, but no others have made as small contributions per capita to the literature of their science. The neglect, or even disdain, of the data of petroleum geology by geologists outside the oil industry is equally indefensible. The efficient employment of the accumulated geological information and the optimum advancement of the science await a vast improvement in the means and habits of communication. As the cost of oil finding in the United States has increased to almost prohibitive levels this need has assumed critical economic importance.

The role of the petroleum geologist has changed continually with the development of the oil industry and of the general economy. The imposition of conservation measures and State control of production during and after the depression changed petroleum exploration from a gambling game to an orderly business. The growth of many large oil operators and their tenacity in acquiring and holding leases in prospective oil territory have now made acreage acquisition the limiting factor in every new exploration campaign. Diversity of ownership in small tracts has magnified both the problems and the costs. Unitization of drilling activities, elimination of excessive drilling, and cooperation in exploration have become more pressing needs than improved technological efficiency.

The role of petroleum geologists in the building of the massive and complex modern economy has been so great as to receive general recognition. But the great impact of these men on the world's ethical climate has been little appreciated. Into the traditionally selfish morals of the marketplace has been injected the influence of thousands of men educated in an idealistic atmosphere and dedicated to scientific discipline. Most of them had become geologists because of an inherent adventurous and pioneering spirit. They entered industry at a time when operational control of most big corporations was passing into the hands of trained, professional management. Their energy and the practical experience of their active, strategic profession carried many of them quickly into positions of authority in the industrial world. Their success and that of their companies came to be as closely related to the degree of their integrity and the support and cooperation which they commanded as to their technological ability. In a single generation, under their leadership and that of other men of similar training, the United States has evolved a pattern of business ethics superior to any the world has ever seen. Although piracy and rapacity are by no means extinct, and we shall never be able to dispense with the policeman, no man today can afford ethical practices inferior to the standards of his industry or profession. There even appears the anomalous suggestion that, over the long term, self interest is best served by unselfishness. Fortunately this ethical transformation has coincided with the phenomenal growth of modern industry, if it has not in fact been largely responsible for that growth. This has come to be a day of bigness, big business, big labor, government, science, even big universities. Great power without strong checks and balances and high ethical restraint is unendurable. But in the United States, if nowhere else yet in the world, there is hope that for the first time in history we need not be afraid of bigness for its size alone. If that hope is realized the credit will belong to the teachers of this new generation of leaders.

Columbus alleged as a reason of seeking a continent in the West, that the harmony of nature required a great tract of land in the western hemisphere, to balance the known extent of land in the eastern; and it now appears that we must estimate the native values of this broad region to redress the balance of our own judgments, and appreciate the advantages opened to the human race in this country, which is our fortunate home. The land is the appointed remedy for whatever is false and fantastic in our culture. The continent we inhabit is to be physic and food for our mind, as well as our body. The land, with its tranquillising, sanative influences, is to repair the errors of a scholastic and traditional education, and bring us into just relations with men and things.—Ralph Waldo Emerson.

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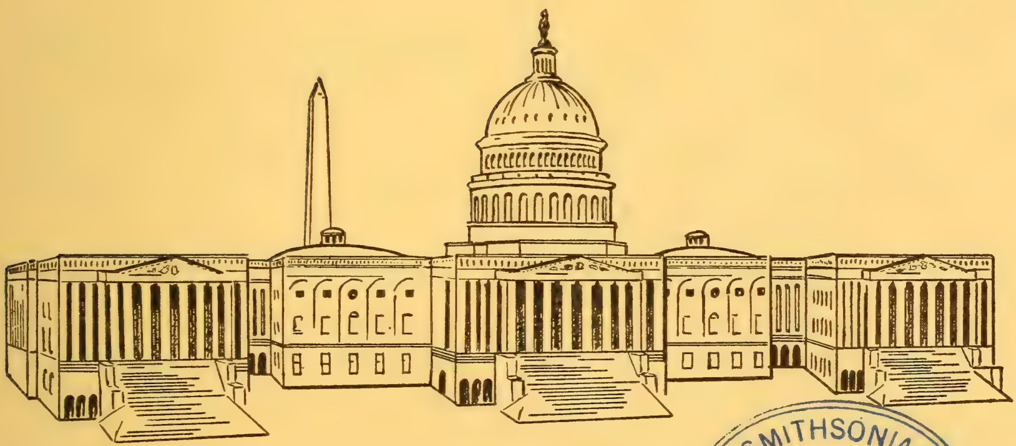

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BOTANY.—*Adventitious bud and stem relationship in apple.* Haig Dermen, Crops Research Division, U. S. Department of Agriculture, Beltsville, Md.

(Received May 12, 1959)

Under a title as of the present article some details relating to adventitious bud development on the stem of apple were reported at the 1956 meeting of the Botanical Society of America. The following note on this subject appeared in the mimeographed "Abstracts" assembled for the abstracts of the papers presented at the meetings of the General Section of the Botanical Society: "In early March of this year 10 one-year-old apple trees of the variety Maiden Blush were cut back to about 12″, planted in 10″ pots and disbudded to induce adventitious bud development on the stem. A number of buds developed endogenously on the stems adjacent to scars of cut-off buds as well as in internodal regions. Buds were examined by making serial tangential cuts under them. Under the normal buds, three leaf traces and a bud trace could be followed into the stem pith but *no* trace of any nature was observed in the stem behind the adventitiously induced buds. Adventitious buds which developed near normal bud scars had no connection with any leaf or bud trace. The results reported here verify and extend conclusions made previously with similar material."

General information on the subject here discussed appeared in earlier publications (Dermen, 1948, 1951a, 1955a). Some additional details with illustrative material are presented here. This article will also formalize the note quoted from the mimeographed abstract.

Fig. 1-*A* shows a 1-year-old tree of Maiden Blush apple disbudded to induce development of adventitious buds on the stem. Round scars along the stem mark the nodal regions where normal buds were cut off. Arrows *a* and *b* point to two adventitious buds that developed several weeks after normal buds were excised. The same two buds are shown in the enlarged photograph in Fig. 1-*B* indicated by arrows. The same portion of the stem, shown in Fig. 1-*C* from side view in respect to the buds, shows the upper bud already grown into a shoot and the lower one barely grown through the bark.

Fig. 2 shows an adventitious bud (indicated by an arrow) from another tree of Maiden Blush lifted from the stem with a piece of bark attached and sectioned by the free-hand method with a razor blade. The bud was still inside the bark when lifted from the stem and the bark over the bud was barely cracked. In Fig. 2 the centrally located darkened region, appearing irregularly inside the bark, is where the bulk of the adventitious bud had developed. The curved portion at the upper side of the endogenous growth indicated by the arrow is the shoot apex of the bud. Sometimes from such endogenously proliferating growth more than one shoot emerged.

At the stage of adventitious growth shown in Fig. 2 no mark of any sort was detectable on the wood surface at the point of the adventitious bud growth when the bark was lifted; whereas behind all true nodal buds there were clearly visible marks of vascular tissue connection between leaf and bud at a node and the wood under the bark.

Figure 3-*A* shows an enlarged view of the scar of a normal bud. Figure 3-*B* shows vascular tissue markings on the wood of the stem when the bark at the bud scar (Fig. 3-*A*) is lifted from the stem. In this view there are on the stem four major vascular connecting points. Three vascular points marked *a*, *b*, and *c* are in a straight line; they indicate the three points of vascular connection between a leaf and the stem. The point of vascular connection between an axillary bud and the stem, marked *d*, is indicated by an arrow. The four markings in Fig. 3-*B* (*a*, *b*, *c* and *d*) are transverse views of traces of vascular tissue bundles from a leaf and a bud at a node of the apple stem extending through the wood to the pith of the stem. The few small dots around trace *d* are trace marks of scales and young leaves of the axillary bud.

Figure 4-*A* shows the view of the area of the shoot grown from the adventitious bud *a* in Fig. 1-*C* after the bark of the area was lifted. Arrow *a* points to the scar in the wood where a piece of fresh wood tissue had pulled off when the bark with the shoot was lifted, indicating the amount of wood tissue which had grown on the stem since the adventitious bud *a* (Fig. 1-*A* and *B*) had grown into the shoot in Fig. 1-*C*. In Fig. 4-*A* arrow *b* points to the central middle trace of the leaf at the node. Arrow *c* points to the left trace of the leaf. The right leaf trace cannot be seen in the view of the stem shown. Arrow *d* points to the main axillary bud trace. The small trace at the left of the main bud trace is one of the traces of the axillary bud scales.

Figure 4-*B* shows the stem at the same position in Fig. 4-*A*. Here is shown what re-

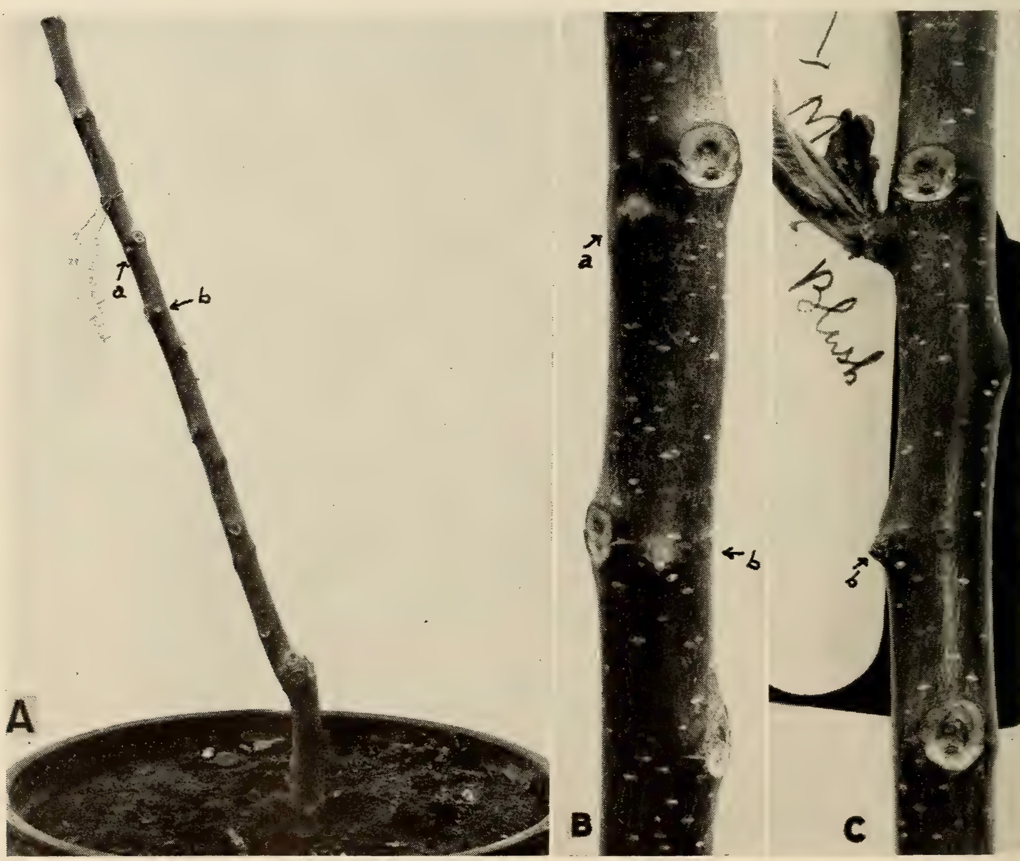

Fig. 1.—Two adventitious buds on the stem of a one-year-old tree of variety Maiden Blush apple. *A*, Two adventitious buds are indicated by arrows *a* and *b*. × ⅓. *B*, Enlarged view of the portion of stem of the same tree with the two adventitious buds. × 1½. *C*, Upper adventitious bud grown into a shoot, lower one barely emerged through the bark. × 1½.

FIG. 2.—A highly enlarged view of cross section of bark with an adventitious bud or buds developing inside of it. × about 30.

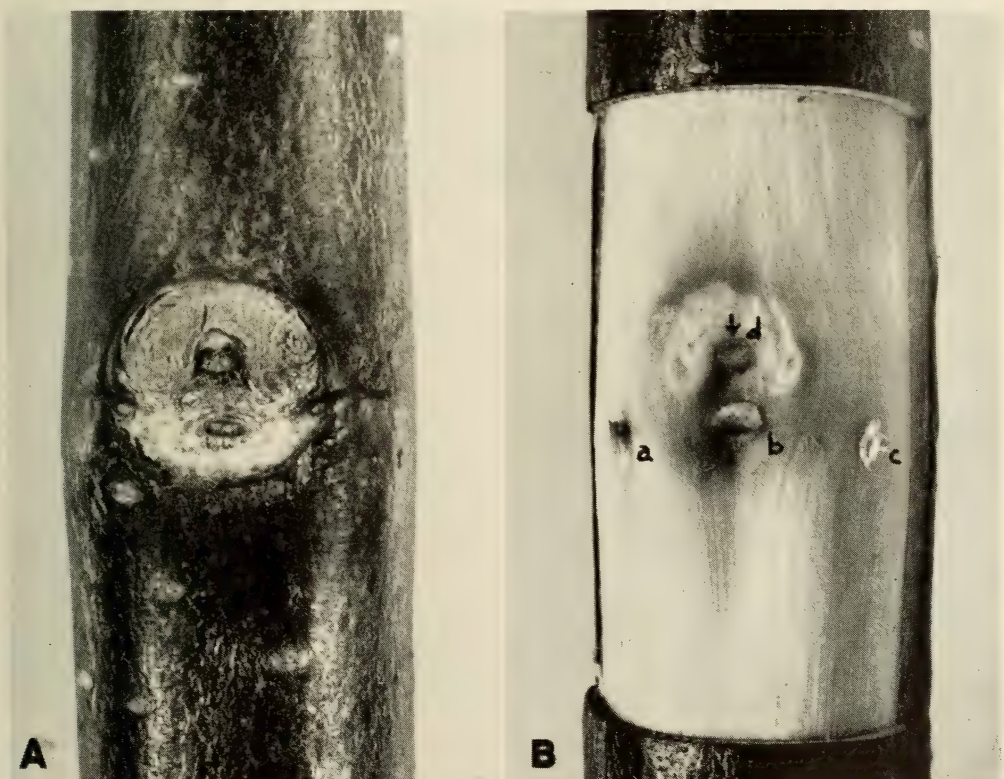

FIG. 3.—*A*, Large scar at a stem node after nodal bud was excised. *B*, The same node region as in *A* with the bark removed; *a*, *b*, *c* indicate transverse view of three vascular traces of leaf; arrow at *d* indicates transverse view of the vascular trace of the axillary bud. × 5.

mains when the wood in the area marked by arrows *a* and *c* in Fig. 4-*A* was shaved off with a razor blade. There was no vascular trace connection beyond the depth of the scar on the wood. In contrast to the situation just described, there was present the vascular trace of the leaf trace at arrow *c*. The traces of the leaf and the normal axillary bud could be followed through the wood tissue to the stem pith.

The adventitious bud *b*, shown in Fig. 1, was examined similarly. Figure 5-*A* shows the region of bud *b* after the bark was lifted. There was hardly any mark on the wood underneath the bud *b*. The location of bud *b* is indicated by an arrow on the back of the lifted piece of bark (Fig. 5-*B*). Other marks are those of the three leaf traces and that of the axillary bud trace. In Fig. 5-*C* the arrow points to the right trace of the leaf. No other markings could be found in the vicinity of the leaf

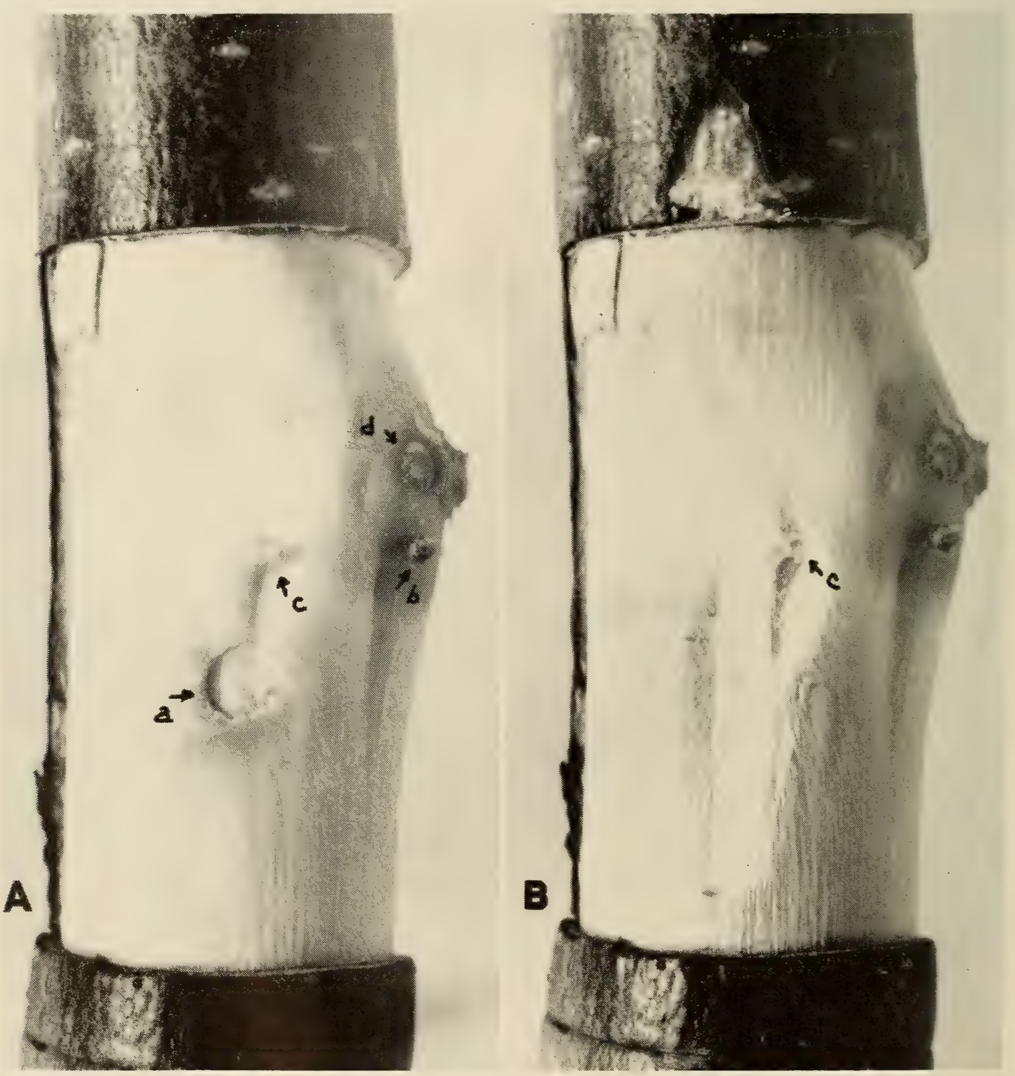

FIG. 4.—*A*, Area of adventitious bud *a* in Fig. 1-A and B. Arrow at *a* indicates the place from which a piece of wood tissue was pulled when bark and with it the shoot which had developed from bud *a* was removed. Arrows at *b* and *c* point to two vascular traces of the leaf at the node. Arrow at *d* points to the vascular trace of the axillary bud. *B*, The same area as in *A*. In *B* the area at *a* and *c* was shaved off. The figure shows the vascular trace at *c* is present, but there was *no* trace of vascular tissue back of the region *a*. × 5.

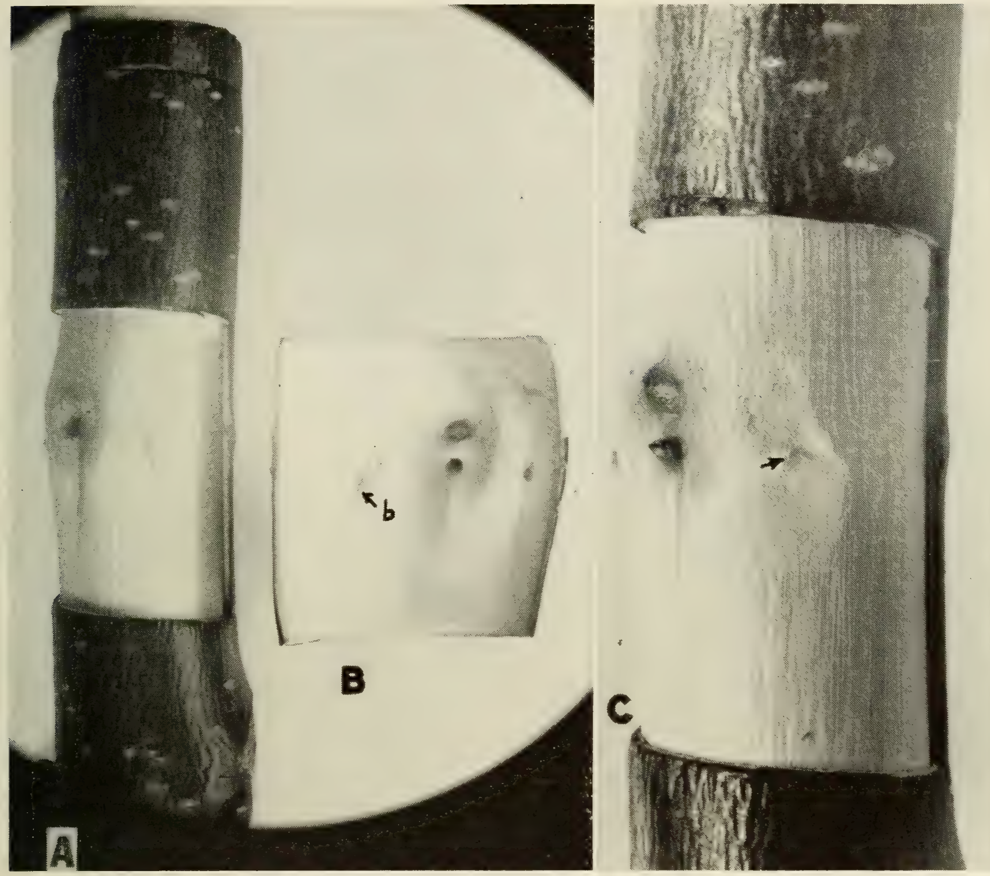

Fig. 5.—Illustration of absence of vascular trace behind adventitious bud *b* in Fig. 1. Other details in text. *A* and *B* enlarged × 2½; *C*, × 4½.

trace which would have indicated connections with the adventitious bud *b*.

The features just described give further evidence that bud development on the apple stem previously reported was truly of adventitious and endogenous origin and that such buds were not latent buds which could have been forced into shoot growth by heavy pruning (MacDaniels, 1953).

The method here followed to demonstrate whether a bud is of adventitious or of normal origin is useful and reliable, but not the only method, as results previously reported (Dermen 1951a, 1955a) indicated. Occasionally buds may originate in the nodal area where a scar has resulted from disbudding operation to induce adventitious bud growth. In such cases cuts in the scar area tangential to the stem surface would not reveal whether the vascular traces present were those of an adventitious bud or those of the axillary bud and the leaf which had been removed. If a bud appears in the scar region resulting from a cut carefully made, or in close proximity to a scar, and it has appeared in the manner described previously (Dermen, 1948, 1951a, 1955a) weeks or months after the disbudding operation, it surely must have originated adventitiously and endogenously through meristematic activity of cells of the callus tissue forming after a cut.

A tree of Winesap apple variety was determined to have a cytochimeral complex in which at the shoot growing point the two outermost cell layers, designated as L-I and L-II, were diploid ($2x$) and inner cell layers tetraploid ($4x$). This kind of chimeral plant is designated as 2-2-4 (diploid, diploid, tetraploid) type and functions sexually as diploid (Dermen, 1951b). Some twigs and branches of this Winesap apple tree were found to have reverted to a completely diploid condition (Dermen, 1951b).

A number of attempts were made to obtain a completely tetraploid form of Winesap apple, along with some other varieties, by the adventitious budding method but failed (Dermen, 1955a). In previous experiments as many as two dozen trees had been used. Hoping that eventually success might be achieved with the chimeral Winesap, the number of experimental plants was increased to 60 one-year-old trees. Even then not a single adventitious bud growth occurred on the internodal regions of any of the trees. However, on many of them a large mass of callus grew in the scarred areas at the nodes from where normal buds had been cut. One such callus growth is shown in Fig. 6-*A*. The growth reached the size shown in 6 months, at the end of which two shoots

FIG. 6.—*A*, Large callus formation at a node of stem of Winesap apple with 2-2-4 type chimeral complex. Arrow at calloused region points to a swelling suspected of being an adventitious bud. × 2. *B*, Two diploid shoots from the calloused region. × about normal.

FIG. 7.—*A*, At the lower calloused node arrow points to bud developed adventitiously at the node of a stem of 2-2-4 chimeral Winesap tree. *B*, Shoot growth from adventitious bud. *C*, A leafy shoot growth from the adventitious bud; the shoot *was entirely tetraploid*. *A*, Slightly enlarged; *B* and *C*, normal size.

had begun to emerge (Fig. 6-*B*). The arrow in Fig. 6-*A* points to one adventitious bud with a smooth layer of tissue over it. On cytological examination both shoots were found to be homogeneously diploid.

One shoot also developed on another of the 60 disbudded trees. It also developed in a callused nodal region. In Fig. 7-*A* the arrow points to a swelling suspected of being an adventitious bud and growing into a shoot. In Fig. 7-*B* is shown a young shoot developed from the "bud" in Fig. 7-*A*, and in Fig. 7-*C* is shown the leafy shoot; *it was totally tetraploid* (Dermen, 1955c). This was the only instance in all the experiments that a tetraploid shoot was isolated from a 2-2-4 chimeral type of plants by the disbudding method (Dermen, 1955a).

SUMMARY AND CONCLUSION

When tangential cuts are made behind the normal buds at the stem nodes, there are found in the wood a definite number of markings which are easily recognizable; these are the three vascular traces of a leaf and one major vascular trace of the axillary bud at a node seen at transverse sections. These markings represent cross-sectional views of vascular tissue bundles which connect a leaf and a bud at a node with the wood tissue. These traces can be followed through the wood tissue to the pith of the stem as cuts transverse to the traces are made successively. Similar tangential cuts were made into the wood behind what were judged to be adventitiously originating buds. There were no such marks of vascular traces in the wood behind any of the adventitious buds. A bud or branch trace was present only in the amount of wood tissue grown after the adventitious buds have started growing into shoots. The present study confirms earlier reports concerning initiation of adventitious bud on the stem of apple by following disbudding method previously described. This study also makes it obvious that other methods followed demonstrating the nature of the adventitious buds developed on some apples were reliable. It is concluded that when 1- to 2-year-old apple trees, potted in 10- to 12-inch pots, are cut to stumps about 10 to 12 inches high and all the buds at all the nodes are removed, adventitious buds may appear either along the internodal space on the stem or near or in the nodal region. In the internodal and near the nodal regions adventitious buds originate in phloem tissue. In the nodal region they originate in the callused tissue. They appear as small swellings with a smooth surface. The smooth surface is ruptured and a shoot slowly grows from such an endogenously developed bud. The appearance of the swellings and emergence of a bud and its growth into a shoot may take weeks or months. Buds appearing in the manner just described are truly adventitious. Wellensick (1952) obtained adventitious bud growth on apple, pear, beech, birch and oak. MacDaniels (1953) failed to obtain such buds on the apple. At the base of a propagated shoot there are normal small buds close together, and some of them are difficult to see with naked eye. Bud and shoot growth from these buds which normally remain latent should not be confused with the true adventitious buds. When such buds show growth into shoots following disbudding of stems they should be destroyed so that they will not interfere with the initiation of adventitious growth.

LITERATURE CITED

Dermen, Haig. *Chimeral apple sports and their propagation through adventitious buds*. Journ. Hered. **39**: 235–242. 1948.

———. *Tetraploid and diploid adventitious shoots from a giant sport of McIntosh apple*. Journ. Hered. **42**: 144–149. 1951a.

———. *Ontogeny of tissues in stem and leaf of cytochimeral apples*. Amer. Journ. Bot. **38**: 753–760. 1951b.

———. *Three additional endogenous tetraploids from giant apple sports*. Amer. Journ. Bot. **42**: 837–841. 1955a.

———. *A 2-4-2 chimera of McIntosh apple*. Journ. Washington Acad. Sci. **45**: 324–327. 1955b.

———. *A homogeneous tetraploid shoot from a 2-2-4 type chimeral Winesap apple*. Journ. Hered. **46**: 244. 1955c.

MacDaniels, L. H. *Anatomical basis of so-called adventitious buds in the apple*. Cornell Univ. Agr. Exp. Stat. Mem. **325**: 3–22. 1953.

Wellensick, S. J. *Rejuvenation of woody plants by formation of sphaeroblasts*. Proc. Nederl. Akad. Wetensch. Amsterdam C. **55**(5): 567–573. 1952.

It is the creatures which have their independent emotional life that give us the great lesson of our kinship with the lower stages of living. This lesson is sorely needed. I have known famous naturalists who had never come by either an intellectual or emotional understanding of their place in the chain of intelligence, and without this a man remains a stranger in this world.—Nathaniel Southgate Shaler.

BOTANY.—*New chiropterophilous Solanaceae from Colombia.* JOSÉ CUATRECASAS, U.S. National Museum, Smithsonian Institution.

(Received May 27, 1959)

Dr. Stefan Vogel, accompanied by the entomologist Dr. Helmut Sturm, both from the University of Mainz, Germany, spent one year, from 1955 to 1956, in northern South America (Colombia and Panama) conducting ecological research on pollination in the field. The main topic of the investigation was the pollination of flowers by bats. On this kind of fertilization there existed at the time positive information on about 20 genera, mostly of South Asian plants, but only scarce data were available from the American tropics. Before Dr. Vogel's studies, the existing reliable observations on fertilization by bats in the New World were limited to *Crescentia cujete* by Porsch in Central America and to *Eperua falcata* and *Bauhinia megalandra* by Hart in Trinidad; Porsch had quoted several genera, the flowers of which were supposedly visited by bats.

During his stay in Colombia and Panama, Dr. Vogel checked the visiting of flowers of about 17 species by long-tongued vampires of the subfamily Glossophaginae. He obtained on infrared film an amazing and fine documentation on the subject clarifying many details concerning the performance of bats. The species of Glossophaginae which were observed are: *Glossophaga soricina, Lonchophylla concava,* and *Anoura geoffroyi peruana.* The chiropterophilous plants and flowers studied by Vogel mainly were Bignoniaceae (*Kigelia aethiopica, Crescentia cujete*), Solanaceae (*Trianae, Markea*), Gesneriaceae (*Campanea*), Gentianaceae (*Symbolanthus*), Polemoniaceae (*Cobaea*), Melastomataceae (*Purpurella*), Papilionaceae (*Mucuna*), Bombacaceae (*Ochroma*), Cucurbitaceae (*Cayaponia*), Marcgraviaceae (*Marcgravia*), Lythraceae (*Lafoensia*), and Capparidaceae (*Cleome anomala*).

A detailed and illustrated report on his research has been published by Dr. Vogel, which is recommended to the reader interested in this subject: *Fledermausblumen in Suedamerika,* Oesterreich. Bot. Zeitschr. **104** (4/5): 491–530, 10 figs. 1958.

Among the Colombian collections of chiropterophilous plants made by Vogel and Sturm, which I received for identification, three of the Solanaceae proved to be new taxa. Their descriptions follow. The illustrations are originals of Dr. Vogel.

Markea vogelii Cuatr., sp. nov.

Frutex epiphyticus caudice tuberculato lignoso ramis scandentibus prodeunti. Rami ramulique griseo-virides glabri.

Folia alterna integra crassiuscula chartacea. Petiolus glaber 4–8 mm longus semiteres tantum basi paulo incrassatus. Lamina oblongo-ovata vel oblongo-elliptica velsubelliptica basi rotundata vel obtusa apice attenuata acuminataque acutissima, margine sublaevis plana vel paulo revoluta, 5.5–9 cm longa 3–4.5 cm lata; supra in sicco griseoviridis glabra sed minute papillosa costa filiformi nervis secundariis paulo visibilibus venulis obsoletis; subtus viridulis costa eminenti nervis secundariis 6–8 utroque latere tenuibus prominentibus ascendentibus prope marginem arcuate-anastomosatis, venulis obsoletis parcissimis minutis pilis sparsis vel glabra, leviter papillosula.

Inflorescentia simplicissima floribus solitariis axillaribus ad terminationem ramulorum pendulorum. Pedicelli 1–1.5 cm longi glabri apicem paulatim incrassati cum brevi pedunculo articulati. Calyx crasse membranaceus circa 4 cm longus glaber prismatico-tubulosus supra medium lobatus lobis triangularibus acutis, tubo prismatico circa 2 cm lato comissuris sepalorum angulatis apparente carinatis; sepalis ovato-oblongis acutis uninervis 12–16 mm latis. Corolla luteo-viridis glabra crasse membranacea companulata basi tubulata in totidem 6.5–7.5 cm longa, tubo crasso circa 1.8 cm longo 0.8–1 cm diamitenti, limbo campanulato circa 3 cm diamitenti lobis oblongo-ovatis obtusis 1.5–1.8 cm longis latisque reflexis; petalis trinervis venulis laxi reticulatis inconspicuis. Stamina 5 filamentis apice teneris basim versus incrassatis robustisque basi barbulatis reliquis glabris 2.5–2.8 cm longis

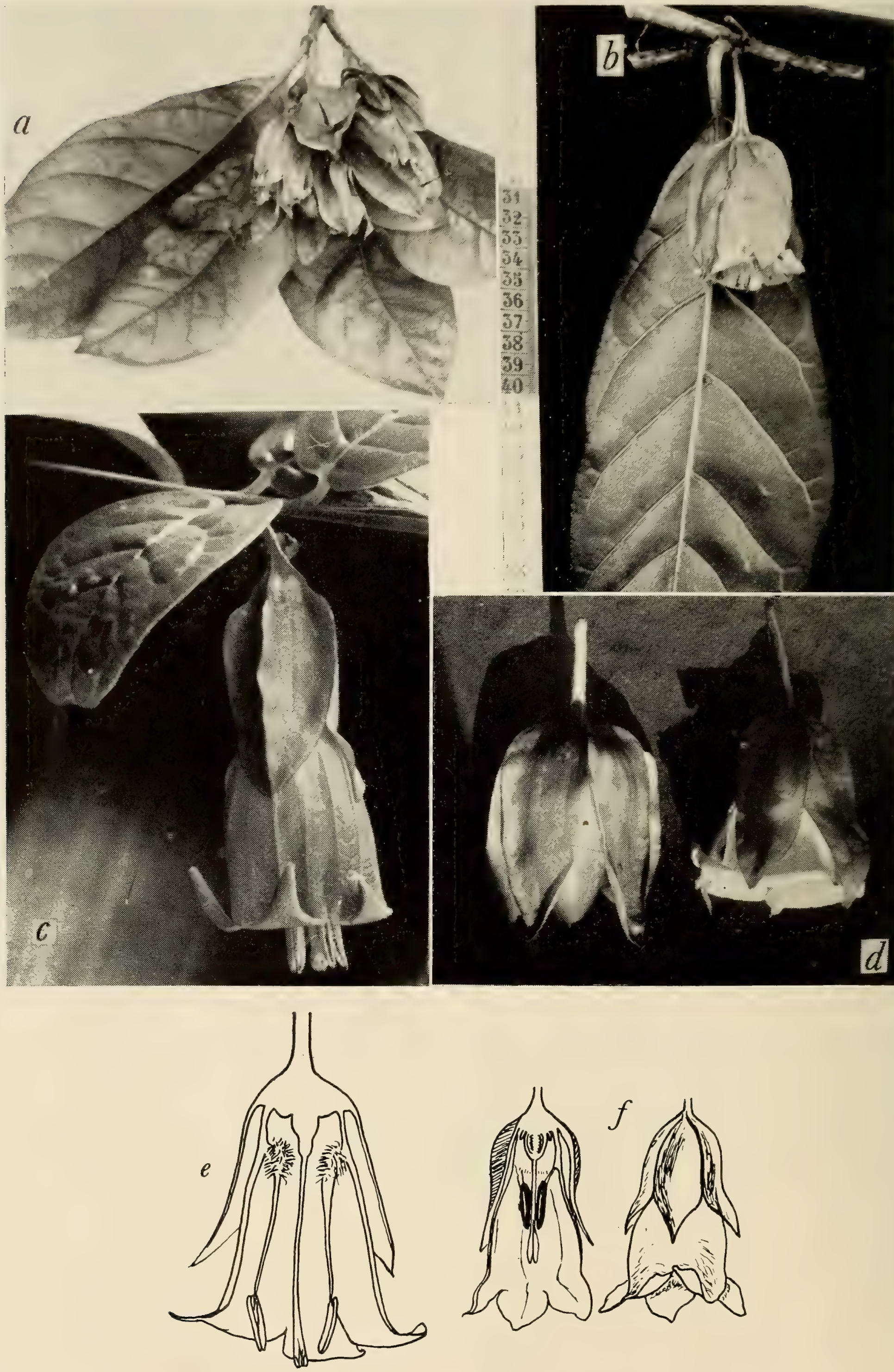

FIG. 1.—*a*, *b*, *d*, *e*, *Trianaea spectabilis* Cuatr. var. *brevipes* Cuatr., var. nov.; *c*, *Markea vogelii* Cuatr., sp. nov.; *f*, *Markea sturmii* Cuatr., sp. nov.

ad faucem corollam (apicem tubi) insertis; antheris basifixis pendulis crassis oblongis 1.6–1.8 cm longis circa 3 mm crassis birimosis usque ad basin dehismentibus. Discus crassus planus. Ovarium oblongo-ovoideum glabrum biloculare multiovulatum. Stylus circa 5.5 cm longus crassiusculus erectus apice 2 stigmatibus bilobatis decurrentibus.

Typus: Colombia, Cundinamarca: Cordillera Oriental, forests 1,800 m alt. above Monterredondo, between Guayabetal and Limoncito, 13-X-1956, *Stefan Vogel 159*. Holotypus US.

Markea vogelii, because of its life form, rather large flowers, and greenish corolla, is in some way closely related to *M. viridiflora*, but its tubulous-campanulate corolla is more similar to that of *M. venosa* and *M. neurantha*. The new species could be placed near numbers 6 and 7 in my key of the genus *Markea* (Feddes Repertorium Sp. Nov. **61:** 83. 1958), differing by its subchartaceous or submembranaceous leaves, its glabrescence, the shape and size of the calyx and corolla, and the yellow-greenish color of the corolla.

Markea sturmii Cuatr., sp. nov.

Frutex epiphyticus ramis tortuosis cortice pallido-griseo corrugato rhitidomatoso ramulis ultimis angulatis tenuibus glabris.

Folia alterna integra crassiuscule membranacea glabra. Petiolus subteres leviter incrassatus 3–4 mm longus. Lamina elliptico-lanceolata vel oblongo-lanceolata basi attenuata obtusa vel subacuta apicem versus angustata longe acuteque acuminata vel caudata margine laevi, 6.5–12.5 cm longa 1.8–4 cm lata, acumine 2–20 mm longo; supra sublaevis tantum costa filiformi notata reliquis nervis inconspicuis; subtus costa prominenti angusta nervis secundariis 6–8 utroque latere tenuibus prominulis patulis prope marginem arcuatis anastomosatisque leviter conspicuis venulis obsoletis reliqua superficie laevi.

Inflorescentiae pauciflorae ad ramulos pendulos ex axillas foliorum supremum, pedunculo 6–8 cm longo valde teneri sed rigidulo angulato glabro subapicem brevem ramulum orienti, ad apicem et in ramulo paulo incrassato 3–4 flores sessiles ferenti. Pedicelli in specimine absenti. Calyx crasse membranaceus viridis glaber subprismatico-campanulatus circa 1.8 cm longus 5-lobatus, lobis oblongo-ovatis subacutis uninervis 8–9 mm longis 6–7 mm latis (ad basim), tubo prismatico comissuris sepalorum angulatis carinata-prodeuntibus, venulis laxe reticulatis inconspicuis. Corolla crassiuscula viridis campanulata basi tubulosa in totidem 3–3.5 cm longa; tubo circa 7 mm longo 4–5 mm diamitenti; limbo late campanulato circa 1.5 cm diamitenti apice lobis reflexis ovalibus vel subrotundatis 7–9 mm longis latisque, petalis uninervis (costis) et laxe obsoleteque reticulato venosis, intus fauce (apice tubi) sparsissime pilosula reliqua omnino glabra. Stamina 5, filamentis crassis 1.5–2 mm longis subapicem tubi insertis parcis minutis pilis praeditis; antheris inclusis erectis crassis oblongis conniventibus 6 mm longis glabris 2-rimosis usque ad basim dehiscentibus. Discus crassus obtuse pentagonus fere planus. Ovarium ovato-conicum glabrum circa 3 mm longum, biloculare loculis multi-ovulatis. Stylus erectus glaber 1.2–1.3 mm longus apice stigmatibus duobus oblongis decurrentibus. Fructus ignotus.

Typus: Colombia, Huila: ridge of the Cordillera between Guadalupe and Florencia, forests 1700 m alt., 9-VI-1956, *Helmut Sturm 178*. Holotypus US.

M. sturmii belongs to the section *Merinthopodium* (D. Smith) Cuatr. and differs from all other species essentially by its very short staminal filaments. The size and shape of the calyx and corolla and the thin, rather small and lanceolate leaves also are unique. Although the thin peduncles of the inflorescences are not flexuose, these are pendant, because the terminal branchlets which bear them, are more or less flexuose and pendulous.

Trianaea spectabilis Cuatr. var. **brevipes** Cuatr., var. nov.

Frutex epiphyticus caudice tuberculato ramis scandentibus elongatis. Lamina foliorum late ovato-elliptica vel obovato-elliptica 20–29 cm longa, 9–13 cm lata. Stamina circa 8 mm supra basim corollae inserta. Stigmata 5 oblonga conniventia basim coalita. Ovarium 8–10 loculis. A species typica pedicelli tantum 3.5–6 cm longi differt.

Typus: Colombia, Cundinamarca: Monterredondo between Guayabetal and Limoncito, Cordillera Oriental, forests 1,800–2,100 m alt., 6-XII-55. "Vermutlich epiphytisch aehnlich *Markea* wachsend mit grosser verholzter Knolle. An Baeumen von dieser Knolle aus lange kletternde verholzte, bis 15 m. hoch steigende Triebe ausbildend. Blueten einzeln, axillaer, haengend, oder gehaeuft am Ende beblaetterter Sprosse. Bisweilen Tetramerie meist pentamer. Wasserkelche. Blueten bei dieser Art die Kelchzipfel nur wenig ueberragend, Kronlappen spitz, Farbe gruenlich gelb. Blaetter lederartig. Unreife Fruechte beerenart." *Stefan Vogel 6*. Holotype, US; isotype, M.

These specimens are cited by S. Vogel in his extremely interesting studies on chiropterophilous flowers (p. 506, fig. 4–I). The only difference I can find between these and the regular typical *Trianaea spectabilis* are the short pedicels of the Vogel plants; this feature is remarkable, because the long flexuose pedicels are characteristic of the genus.

Trianaea was described from flowering specimens. Recently I received for study other collections with developed fruits which gave me the opportunity to study the seeds. These prove to be reniform, minutely alveolate and with a curved semicircular embryo. This character excludes the genus *Trianaea* from the tribe *Cestreae* and indicates that it belongs to the *Datureae*. (See also Cuatrecasas, J. *Notes on American Solanaceae,* Feddes Repertorium **61**: 83. 1958.)

FORMER ACADEMY PRESIDENT MEMORIALIZED

A bust of Dr. Aleš Hrdlička (1869–1943), world-famous anthropologist who was associated with the Smithsonian Institution for 40 years, was recently presented to the Smithsonian's National Museum by Dr. Miloslad Ruzek, Ambassador of the Czechoslovak Republic to the United States. The gift was made on behalf of several educational and cultural groups of Czechoslovakia as a memento of the recent observances in that country marking the 15th anniversary of Hrdlička's death and the 90th anniversary of his birth.

The bust is the work of the Czech sculptor Milan Knobloch, based in part on a death mask of the scientist made by Andreas J. Andrews, Smithsonian sculptor. The original of the bust was unveiled last September in the entrance of the school that now bears Hrdlička's name in Humpolec, Czechoslovakia, the town where he was born.

Hrdlička came to America with his father in 1882. He studied medicine in New York and anthropology in Paris, and in 1903 was called to Washington to set up a division of physical anthropology in the U. S. National Museum. Here he spent the rest of his life and built up the collections in that department to rival those anywhere else in the world. He was founder and first editor of the American Journal of Physical Anthropology, and founder and first president of the American Association of Physical Anthropologists. He encouraged anthropology in Czechoslovakia, especially at Charles University, Prague, by gifts of books and money, one result of which is the Hrdlička Museum in the Anthropological Institute of that institution. He served as president of the Washington Academy of Sciences in 1929.

HONORARY MEMBERSHIP

D. E. Parsons, chief, Building Technology Division, National Bureau of Standards, has been elected to honorary membership in the American Society for Testing Materials, "in recognition of long and distinguished service to the Society in both technical and administrative work, and for eminent leadership in the field of building materials and building technology involving both research and standardization."

ZOOLOGY.—*Three new cave amphipods from the West Indies.* Clarence R. Shoemaker,[1] U. S. National Museum.

(Received March 27, 1959)

During the Smithsonian-Bredin Caribbean Expedition of 1958, caves of several of the Lesser Antilles were investigated. The first two of the new amphipods described below were collected by Desmond Nicholson, captain of the Expedition's vessel, *Freelance,* from a fresh-water stream in Dark Cave, Barbuda, on April 25, 1958. The third new species, the type of a new genus, was collected by Gilberto Silva Taboado during his investigations of the fauna of Cueva Grande, a large cave in Las Villas Province, Cuba.

Family Bogidiellidae Hertzog, 1936

Genus ***Bogidiella*** Hertzog, 1933

Bogidiella bredini,[2] n. sp.

Fig. 1

Material examined.—Two specimens, a male and a female, from Dark Cave, Barbuda.

Description.—Female: Side lobes of head prominent and distally rounding; eyes absent. Antenna 1 less than half the length of the body; first joint of peduncle a little stouter and longer than second; second joint twice as long as third; flagellum about equal in length to the peduncle, and consisting of about 12 joints; accessory flagellum of 3 or 4 joints and reaching a little beyond the second joint of primary flagellum. Antenna 2, a little shorter than 1; gland-cone prominent; third joint half the length of the fourth; fourth joint a little stouter and a little longer than the fifth; flagellum shorter than fifth peduncular joint and consisting of 5 joints which decrease in length consecutively.

Mandible, cutting-edge with few teeth; accessory plate well developed, broad distally, without teeth, but with crenulate distal margin; 5 spines in spine-row; molar low and conical with a very small triturating surface which is armed with several slender teeth and a long seta; palp, 3-jointed, the second joint the longest. Maxilla 1, inner plate broad and bearing 2 plumose setae; outer plate with 7 spine-teeth which are nearly simple; palp 2-jointed, second joint bearing 3 slender terminal spines. Maxilla 2, inner plate a little wider but shorter than outer plate and armed with 7 spines; outer plate with 5 spines. Maxilliped, inner lobe reaching little beyond base of outer lobe, and armed distally with 3 slender spine-teeth and 3 setae; outer lobe reaching only to base of second joint of palp, armed distally with 3 spine teeth and 1 seta, on the inner margin with 4 setae; palp 4-jointed, fourth joint well developed, with a comb of fine spinules on inner surface, and bearing a slender nail having a spine and a seta at its base. Upper lip symmetrical. Lower lip with inner lobes poorly developed; side lobes short and blunt.

Gnathopod 1, longer and stronger than 2; second joint rather short, not as long as the sixth, somewhat, expanded for the greater part of its length; third joint short; fourth joint about as long as the fifth and with a brush of fine setae on lower margin; fifth joint produced below into a narrow lobe carrying a few spines; sixth joint very large and strong, widest proximally and converging to a narrow apex, rear margin short; palm very oblique and without defining angle, slightly convex, on the outside armed with about 20 short slender submarginal branched spines, and with a group of 3 slender spines at center, a row of 10 rather stout branched spines beginning on the rear margin of the joint and extending a short distance into the palm, each of these spines having a slender spine springing from its base; on the inside of palm there is a groove into which the seventh joint fits, defined by a row of 3 stout spines and a group of slender spines, below which is another row of 4 spines (Fig. 1, *l*); seventh joint long, ending in a short nail, on the inner margin are 2 short spinules distally and 1 spinule near the center, on the outer margin are 2 short setae. Gnathopod 2, second joint not as much expanded as that of gnathopod 1, and about as long as the sixth joint; fifth joint half the length of the

[1] Mr. Shoemaker died on December 28, 1958, leaving this manuscript nearly completed. It was prepared for publication by Thomas E. Bowman, U. S. National Museum, who added Fig. 2, *j*, to those drawn by Mr. Shoemaker.

[2] Named in honor of J. Bruce Bredin, sponsor of the Expedition.

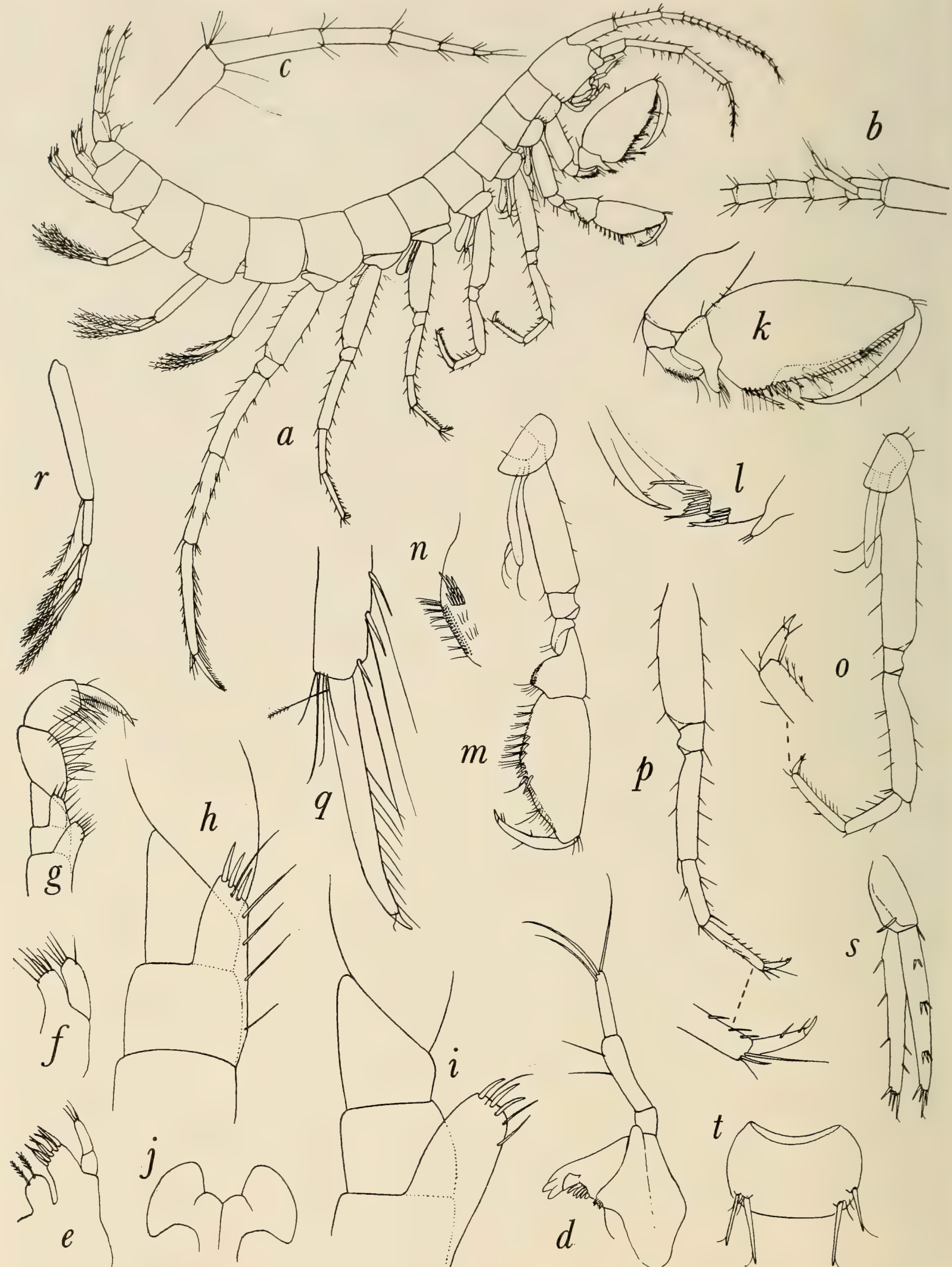

FIG. 1.—*Bogidiella bredini*, n. sp., female holotype: *a*, Entire animal, lateral; *b*, antenna 1, showing accessory flagellum; *c*, antenna 2; *d*, mandible; *e*, maxilla 1; *f*, maxilla 2; *g*, maxilliped; *h*, maxilliped enlarged, showing outer lobe; *i*, maxilliped enlarged, showing inner lobe; *j*, lower lip; *k*, gnathopod 1; *l*, gnathopod 1, sixth joint, inside of palm; *m*, gnathopod 2; *n*, gnathopod 2, inside rear margin of sixth joint; *o*, peraeopod 1; *p*, peraeopod 3; *q*, peraeopod 5, distal end; *r*, pleopod 1; *s*, uropod 3; *t*, telson.

sixth, with the lower lobe rather broad and carrying a few spines and a brush of fine scales or setae on rear margin; sixth joint widest in the middle, rear margin with 7 groups of spines; palm about as long as the rear margin of joint, very oblique, slightly convex, without defining angle, but having a row of 5 or 6 spines where the palm curves into the rear margin of joint; on the outside of the palm is a row of 15 or 16 slender curved bifurcate submarginal spines extending almost the entire length of the palm, and a group of 3 long slender spines near the center; on the inside of the palm near its juncture with the rear margin of the joint are 3 rows of spines, the first or distal of group consisting of 3 spines, the second group of 4 spines, and the third of 5 spines, below these spines are 2 groups of slender spines (Fig. 1, *n*) and a narrow brush of fine setae adjacent to the rear margin of the joint; seventh joint fitting palm, and resembling that of gnathopod 2.

Peraeopods 1 and 2 are alike and carry rather few spines. Peraeopod 2, second joint much longer than any of the following joints and little expanded; fourth joint not quite as long as the fifth and sixth combined; seventh joint short, nearly straight, with a spinule on the inner margin, and bearing a small nail with a seta at its base. Peraeopod 3, about as long as 2, but shorter than 4; second joint little expanded and much longer than any of the succeeding joints; fourth joint not quite as long as the fifth and sixth combined; seventh joint like that of peraeopods 1 and 2 but a little longer and having 2 spinules on inner margin. Peraeopod 4, like 3, but longer; seventh joint broken, so the number of spinules could not be determined. Peraeopod 5 very much like 4, but much longer and with longer and more numerous spines; second joint about as long as the fourth, which is about equal in length to the fifth; fifth joint a little shorter than the sixth; seventh joint nearly half as long as the sixth, slender, with 8 slender spinules on inner margin, a sensory seta on outer margin, and having a small nail with a seta at its base.

Uropods 1 and 2 reaching back about the same distance. Uropod 1, much longer than 2; peduncle nearly twice as long as the subequal rami, a spine on lower margin near the proximal end, and a spine at the distal end of the outer and inner margin; rami without lateral spines, but with distal spines. Uropod 3, very long, peduncle not half as long as the subequal rami, and bearing a spine on the upper outer margin and one at the distal end of the lower margin; outer ramus with 3 groups of lateral spines, and a group of terminal spines; inner ramus with 3 spines on inner margin, 2 on outer margin, and a group of terminal spines. Telson short, broader than long, sides convex, rear margin nearly straight and with 2 spines and 2 setae at either side.

Pleopods alike, but the third is the shortest. Pleopod 1, peduncle much longer than outer ramus, which consists of 3 joints, each consecutively shorter, and each bearing 2 plumose setae; inner ramus reduced to a very small single joint bearing a long terminal plumose seta. Pleopod 2 is like pleopod 1. Pleopod 3 is like 1 and 2, but shorter.

The coxal plates are all shallow and are as shown in Fig. 1, *a*. The metasome segments are as shown in Fig. 1, a. The branchiae occur on gnathopod 2 and peraeopods 1–4, and are rather narrow simple sacs. Marsupial plates occur on gnathopod 2 and peraeopods 1–3. The marsupial plates are narrow and rather short, and carry very few setae. Length of animal from front of head to the end of uropod 3, about 7 mm.

Male: Length 5.8 mm. Its characters agree closely with those of the female, but several peraeopods are missing. A pair of small genital papillae is present on the ventral surface of the seventh peraeon segment; to the right one is attached a slender filament, coiled distally. Under high magnification the filament is seen to be made up of minute granules, which appear to be spermatozoa.

Types.—Holotype, female, U.S.N.M. no. 102418. Allotype, male, U.S.N.M. no. 102419.

Two species of *Bogidiella* have been described from the Americas, *B. neotropica* by Sandra Ruffo (1952) from a small brook, tributary to the Rio Cupari, Brazil, and *B. brasiliensis* by Rolf Siewing (1953) from Bahia and Ilhabela, Brazil. *B. neotropica*, described from a single specimen about 3 mm in length, is the largest species heretofore described, but it is much smaller than the present species which measures about 7 mm. In some of its characters *B. bredini* is much like *B. neotropica*, and whether the disagreements which occur are due to greater maturity of *B. bredini* or differences in sex, cannot be determined from the known material. The pleopods of *B. neotropica* have only one ramus each, while in *B. bredini* each has a well-developed outer ramus and a very much reduced inner one. In *B. neotropica* the accessory flagellum has 2 well-developed joints and a smaller terminal joint, while in *B. bredini* there are 3 well-developed joints and a smaller terminal joint. No spines or setae are shown on the dactyls of the peraeopods of *B. neotropica,* but in *B. bredini* all of the dactyls have them, the last having as many as eight. *B. brasiliensis,* while less than 2 mm in length, has two rami to the pleopods, with the inner ramus much less reduced than in *B. bredini.* The telson is long in proportion to its width, and has a small median lobe distally. The first antenna is nearly twice as long as the second, and bears a unisegmental accessory flagellum.

Of the remaining three species of *Bogidiella,* only *B. skopljensis* (Karaman, 1933) from Skoplje, Yugoslavia, has biramous pleopods, and it differs markedly from *B. bredini* in the form and armature of the antennae, peraeopods, and telson.

Family Gammaridae

Genus ***Metaniphargus*** Stephensen, 1933

Metaniphargus nicholsoni,[3] n. sp.

Figs. 2, 3, *a–o*

Material examined.—Thirty specimens from Dark Cave, Barbuda, collected during the Smithsonian-Bredin Expedition. Also, more than 100 specimens collected in Dark Cave by G. A. Seaman in November 1955 and donated by him to the U.S. National Museum.

Description.—Male: Head and antennae are as shown for the female (Fig. 2,*a*), but possibly the antennae are a little longer in the male; accessory flagellum as long as the first joint of the primary flagellum and consisting of one long joint and a very short terminal joint. Eyes not present.

Upper lip symmetrical. Mandible, cutting-edge toothed; accessory plate strong, 3-pronged; spine-row of 2 stout plumose spines and several slender spines; molar strong, triturating surface narrow with a tuft of setae at the front end and a long plumose seta at the rear end; palp 3-jointed, first joint over half the length of the second, which is about equal in length to the third; third joint is pectinate on the lower margin and carries a distal group of long spines. Maxilla 1, inner plate broad and carrying about 20 long plumose setae on its straight outer margin; outer plate armed with 11 strong pectinate spine-teeth; palp 2-jointed, and armed distally with 6 strong spine-teeth and one long slender seta. Maxilla 2, outer plate wider, but a little shorter than the inner; inner plate carrying a diagonal row of closely-set plumose setae, besides the distal and marginal spines. Maxilliped, inner plate reaching beyond the middle of the outer plate, armed distally with 3 rather stout spine-teeth and a row of subdistal plumose setae which continues part way down the inner margin; outer plate reaches to about two-thirds the length of the second joint of the palp, armed distally with 3 long plumose spines, and on the inner margin with a row of about 11 stout spine-teeth and a submarginal row of slender spines; palp 4-jointed, fourth joint about two-thirds the length of the third, armed with a nail and carrying a diagonal row of 5 closely set ridges or setae on the inner surface. Lower lip without inner lobes, and with short blunt side lobes.

Gnathopod 1 (Fig. 2, *f*), shorter than 2; second joint expanded, a little longer than the fifth joint, a few short spines on front margin, 4 groups of long spines of 2 spines each on rear margin, and 3 long backward-directed submarginal spines near the proximal end of rear margin. Third and fourth joints short and rather stout, the fourth with a brush of setae on lower margin; fifth joint much longer and a little wider than the sixth, lower margin bearing 5 or 6 groups of spines, some of which are bifurcate at apex; front margin with a group of spines near the middle and a distal group; sixth joint about two-thirds as long as the fifth, widest in the middle, front margin slightly convex and bearing an apical and a subapical group of spines, rear margin straight and bearing three groups of spines, the longer of which are bifurcate at apex; palm transverse, slightly convex, smooth, defined on the outside by 3 slender bifurcate spines, with 3 shorter straight submarginal spines between these and the hinge of the seventh joint, and a curved spine just before the hinge, at the defining angle on the inside of palm are 2 short, stout bifurcate spines, 2 straight spines near the middle and a curved distal spine; seventh joint fitting palm, bearing a nail, which is about one-third the length of the joint, at the base of which are a forward-pointing tooth and a seta, inner margin with a submarginal seta, outer margin of joint with a forward-curving seta. Gnathopod 2 (Fig. 2, *h*) a little stouter and much longer than 1, second joint expanded, about as

[3] Named in honor of Desmond Nicholson, captain of the Expedition's vessel, *Freelance,* who collected the amphipods here described.

Fig. 2.—*Metaniphargus nicholsoni*, n. sp., *a–e*, *g*, *i–l*, female; *f*, *h*, male: *a*, Anterior end, lateral; *b*, mandible; *c*, maxilla 1; *d*, maxilla 2; *e*, maxilliped; *f*, gnathopod 1; *g*, gnathopod 1; *h*, gnathopod 2; *i*, gnathopod 2; *j*, distal end of gnathopod 2; *k*, peraeopod 2; *l*, peraeopod 3.

long as the sixth, with a small spine on front margin, and 5 groups of 2 spines each on rear margin; third and fourth joints short and stout; fifth joint a little shorter and a little wider than the sixth, widest distally, outer margin with a small median spine and a distal group, rear margin convex, with a brush of fine spinules or setae and 10 or 11 groups of spines, the longest member of each being bifurcate at apex; sixth joint long and narrow, widest in the middle, both front and rear margin slightly convex, front margin with 2 short spines and a distal group, inner margin with a brush of 5 setae and 4 groups of spines, some of which are serrate and the longest one in each group is serrate and bifurcate at the apex; on the inside of the sixth joint are 6 groups of spines near the front margin; palm very oblique, nearly as long as the rear margin of joint, nearly straight, smooth, without defining angle, grooved along its length, the edges of the groove bearing a series of blunt spines, a group of long setae at either end of the groove; seventh joint fitting palm, with a seta on the outer margin near the proximal end, inside margin of joint has what appear to be a number of slender forward pointing teeth, but they are so closely appressed to the margin that at first they appear to be part of the cuticle.

Peraeopods 1 and 2, slender and about equal in size and form. Peraeopod 2, second joint not much expanded and as long as the fourth and fifth joints combined, front margin bearing about 6 short spines, rear margin with 4 short spines on lower half and 3 long spines on upper half; fourth joint scarcely at all expanded and a little longer than the fifth; fifth and sixth joints not expanded and equal in length; seventh joint short and bearing a short nail with a spinule and a seta at its base. Peraeopod 3, much longer than 2; second joint considerably expanded, about four-fifths as wide as long, front margin convex and armed with about 11 spines, rear margin nearly straight, with an upper and lower lobe; fourth joint little expanded and a little shorter than the fifth; fifth joint very little shorter than the sixth; fourth to sixth joints bearing groups of spines on their front and rear margins; seventh joint short and like that of the second peraeopod. Peraeopod 4, second joint considerably expanded, nearly as wide as long, front margin less convex than in 3 and armed with 10 spines, rear margin slightly convex and with an upper and lower lobe; the third to seventh joints are like those of peraeopod 3, but longer and a little stouter. Peraeopod 5 (Fig. 3, *f*), second joint narrower in proportion than that of 3 or 4, about three-fourths as wide as long, front margin a little convex and armed with 7 spines, rear margin a little convex and with an upper and lower lobe, the upper lobe being not as pronounced as in peraeopod 3 or 4, and the spines in the serrations being stouter than in 3 or 4; the third to seventh joints are like those of peraeopod 4, but are a little stouter.

Uropod 1 and 2 extending back about the same distance; uropod 3 extending back much farther. Uropod 1, peduncle a little longer than the inner ramus, upper outer margin with 2 lateral and 2 distal spines, the lower of which is the stouter, inner margin with 2 lateral spines and one distal spine, lower margin with one spine; outer ramus without lateral spines but with a terminal group; inner ramus with one lateral spine and a terminal group. Uropod 2, peduncle as long as the inner ramus, without spines on upper outer margin, and with one distal spine on the upper inner margin; outer ramus shorter than the inner and without lateral spines but with a terminal group; inner ramus with one lateral spine on outer and one on inner margin and a distal group. Uropod 3, peduncle much shorter than outer ramus, but about two-thirds as long as the inner ramus, upper outer margin with 2 distal spines, and inner margin with one; outer ramus with a small second joint, first joint with 3 groups of spines on the outer margin, inner margin with 6 groups of spines, 2 in each group being short and stout, and one longer and plumose, distal margin with a group of spines; second joint short, narrow and conical, with a lateral spinule and 2 apical spinules; inner ramus slender, about half as long as outer ramus, and with sides converging to a sharp apex, outer margin with one lateral spine and a very small spinule near the apex; inner margin with 3 spines. Telson short, extending to about the end of the peduncle of uropod 3, divided to its base, each lobe converging to a narrow, sharp apex, outer margin of each lobe with one spine, inner margin of each lobe with 2 lateral spines and 2 apically, all spines being branched at apex (Fig. 3, *o*).

Coxal plates 1–5 are deeper than their body segments. Coxal plate 1, front margin convex and rear margin concave, with a few spines on the front and lower margin. Coxal plate 2 like that of 1, but a little wider and deeper. Coxal plates 3 and 4 much alike, a little deeper than 2, and with lower margin evenly rounding. Coxal plate

5 is the largest and deepest, the front lobe is twice as deep as the rear lobe and extends down about two-thirds the length of the second joint of the peraeopod (Fig. 3, *b*). Coxal plate 6 with a small front lobe (Fig. 3, *e*). Coxal plate 7 is as shown by Fig. 3, *f*. Metasome segments are as shown for the female by Fig. 3, *h*.

Urosome segment 1 with a single small spinule on either side of the rear dorsal margin, and urosome segment 2 with 2 spinules similarly placed. Pleopods all well developed. There does not appear to be any unusual character at the base of the outer ramus of the third pair, such as occurs in *M. curasavicus*. The branchiae occur on gnathopod 2 and peraeopods 1–4, and are large, oval, simple and attached to the limb by a peduncle. Length of the male about 7 mm.

Female: The female is very much like the male and differs only in detail. All of the figures here given of the female or of a fully developed ovigerous specimen. The head, antennae and front part of the female are shown by Fig. 2, *a*. Gnathopod 1 is proportionately shorter and stouter than in the male; fourth joint with a brush of fine setae on lower margin; the palm of the sixth joint is transverse, smooth, with 3 short median spines, a curved spine at the base of hinge, and 3 short stout bicuspid spines on the outside at the defining angle, and on the inside at the defining angle are 3 long slender spines which appear to have 3 apical branches; the seventh joint has on the outer margin a sensory seta, and on the inner margin one or 2 small teeth or spines proximally, and a long nail with a forward-pointing tooth and a seta at its base. Gnathopod 2 is a little stouter than that of the male.

Peraeopods 1 and 2 very much like those of the male. Peraeopod 3 much like that of the male; longer than peraeopod 2, but shorter than 4, which is about as long as 5; the front lobe of its coxal plate is even larger in proportion than that of the male. Peraeopods 4 and 5 much like those of the male, but the second joint is longer and narrower in proportion, and that of 4 has the upper rear lobe more developed. The metasome segments are as shown by Fig. 3, *h*. The first urosome segment has one dorsolateral spinule on either side, and the second segment has 3 on either side (Fig. 3, *i*). The pleopods are like those of the male.

Uropods 1 and 2 are alike in both sexes. Uropod 3 is like that of the male, but is somewhat less spinose. The telson is very similar to that of the male; outer margin of each lobe with 2 marginal spines, inner margin with one lateral spine and one just below the apex, all the spines being branched apically (Fig. 3, *n*). The branchiae are like those of the male, and occur on gnathopod 2 and peraeopods 1–4. The marsupial plates are narrow, and carry few setae (Fig 2, *i*, *k*). The female reaches a length of 7.5 mm.

Types.—Holotype, male, U.S.N.M. no. 102424; allotype, female, U.S.N.M. no. 102425; and 28 paratypes, all from Dark Cave, Barbuda, collected by Desmond Nicholson, April 25, 1958.

M. nicholsoni is very similar to *M. beattyi* Shoemaker, 1942, from slightly brackish water in a deep well, St. Croix, Virgin Islands.[4] It differs in details of the armature of the appendages and most obviously in the shape and armature of the telson. In *M. beattyi* the telson is relatively shorter and broader; each lobe bears two apical spines and a single spine on the distal part of the outer margin; there are no spines on the margins of the cleft as in *M. nicholsoni*. In *M. curasavicus* Stephensen, 1933, however, the armature of the telson is more similar to that of *M. nicholsoni*.

Paraweckelia, n. gen.

Head with prominent lateral lobes, and without eyes. Antenna 1 longer than antenna 2, with a 4-jointed accessory flagellum. Upper lip symmetrical. Mandible with toothed cutting-edge, strong accessory plate, well-developed molar, and a 3-jointed palp. Maxilla 1 with a row of plumose setae on inner plate, 9 spine-teeth on outer plate, and a 2-jointed palp. Maxilla 2 without a diagonal row of spines or setae on inner plate. Maxilliped with inner and outer plates well developed, and with a 4-jointed palp. Lower lip with inner lobes. Gnathopod 1 smaller than 2; both subchelate. Gnathopod 1 with fifth joint longer than the sixth; palm of sixth joint only slightly oblique. Gnathopod 2 with fifth joint much shorter than sixth and with a rear lobe. Peraeopods 3–5 with expanded second joint. Coxal plate 4 incised in rear. Pleopods normal, not reduced. Uropods normal and with all rami well developed. Uropod 3 with 2-jointed outer ramus. Branchiae simple, not attached by a pedicel. Marsupial plates narrow, with few setae. Telson cleft to base. Type, *P. silvai*, n. sp.

[4] Stephensen (1948) considered *M. beattyi* to be identical with *M. curasavicus* Stephensen, 1933, from Aruba, Curaçao, and Bonaire. It has not been possible to determine from Mr. Shoemaker's notes whether he agreed with Stephensen.—T. E. Bowman.

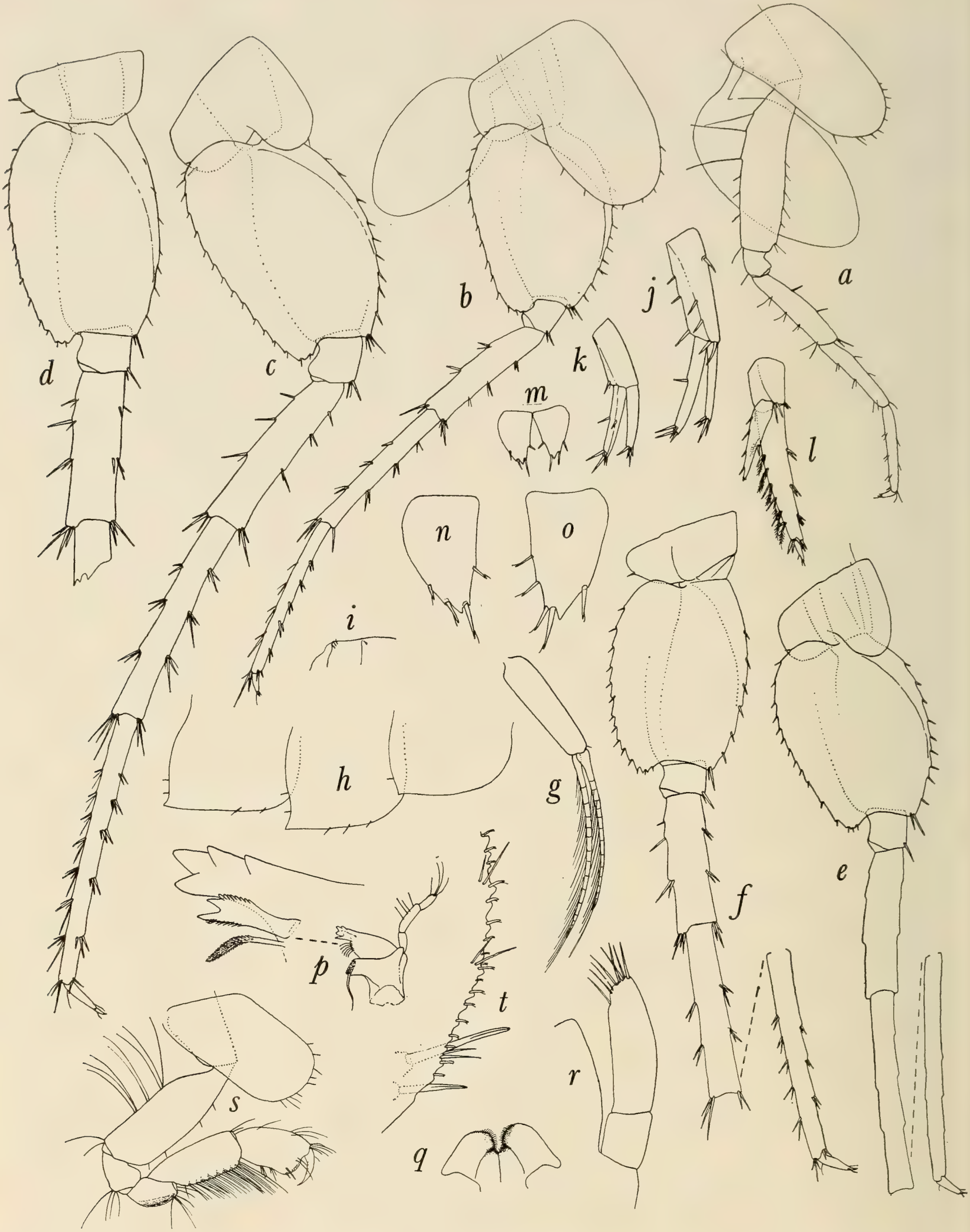

FIG. 3.—*a–o*, *Metaniphargus nicholsoni*, n. sp.: *a*, Peraeopod 2, male; *b*, peraeopod 3, male; *c*, peraeopod 4, female; *d*, peraeopod 5, female; *e*, peraeopod 4, male; *f*, peraeopod 5, male; *g*, pleopod 1, female; *h*, metasome segments, lateral, female; *i*, urosome segments, lateral, male; *j*, uropod 1, female; *k*, uropod 2, female; *l*, uropod 3, female; *m*, telson, female; *n*, left half of telson, female; *o*, right half of telson, male. *p–t*, *Paraweckelia silvai*, n. sp., female: *p*, Mandible; *q*, lower lip; *r*, maxilla 1, palp; *s*, gnathopod 1; *t*, palm of gnathopod 2.

***Paraweckelia silvai*,**[5] n. sp.

Figs. 3, *p–t*; 4

Material examined.—Ten specimens, collected by Gilberto Silva Taboada in a fresh-water lake, Lago Martí, in Cueva Grande, the largest of the Caguanes Caves, a group of five caves located in Punta Caguanes, north coast of Las Villas Province, Cuba, February 1958.

Description.—Female: Head with prominent rounding lateral lobes. Without eyes. Antenna 1, longer than 2; first joint equal in length to the second; third joint nearly half the length of the second; flagellum composed of about 30 joints; accessory flagellum of 4 joints. Antenna 2, first joint nearly circular and very prominent, gland-cone prominent; third joint about one-third as long as the fourth, which is equal in length to the fifth; flagellum not as long as the peduncle and composed of about 12 joints, the first of which is the longest.

Upper lip, symmetrical. Mandible, cutting-edge toothed, accessory plate, strong, armed with 2 distal teeth, a row of smaller teeth on outer margin and a brush of setae on inner margin (Fig. 3, *p*); spine-row of seven spines; molar prominent, its base produced forward into a narrow prominent process which extends beyond the base of the palp; triturating surface rather long and narrow and carrying a long plumose seta; palp 3-jointed, second joint longest, first and third being equal in length, second and third joints with very few spines. Maxilla 1, inner plate with 7 plumose setae; outer plate with 9 toothed spine-teeth; palp 2-jointed, and armed distally with 8 slender spines. Maxilla 2, inner and outer plate about the same size and length and each carrying very few spines; inner plate without diagonal row of spines. Maxilliped, inner plate reaching to about the base of the second joint of the palp and armed distally with 5 slightly curved spine-teeth and a row of plumose spines or setae which extends part way down the inner margin; outer plate not extending to the middle of the second joint of palp, armed distally with several spines, inner margin armed with rather stout spine-teeth and a few slender spines; palp, with 4 joints, the second of which is much the longest; fourth joint almost as long as the third, with a comb of fine setae or spinules on inner surface, and with a small nail. Lower lip with broad outer lobes, narrow inner lobes, and with short blunt lateral processes.

Gnathopod 1, smaller than 2, second joint expanded and not quite as long as the fifth and sixth combined; fourth joint with a brush of setules and a few spines on rear margin; fifth joint longer than the sixth and with about 9 groups of long spines on rear margin; sixth joint widening distally, front margin with a few spines, rear margin with 2 groups of spines, palm convex, very finely toothed throughout, defined by a spine with a long thin branch, armed with about 7 submarginal branched spines, and with a curved spine just before the hinge of the seventh joint; inside of palm with a group of 5 spines at the defining angle, and with about 12 submarginal branched spines; seventh joint fitting palm, a sensory seta on the outer margin and 3 setules on inner margin. Gnathopod 2, second joint not much expanded and not as long as the sixth; fourth joint with rear margin produced forward rather sharply; fifth joint, front margin with one median spine, lower margin with a few spines; sixth joint very large, widest through the center, front margin with a few scattered spines and a distal group, rear margin with 4 groups of spines, palm convex, longer than the rear margin of the joint, crenulate, armed with about 18 short branched spines and defined by a long spine on the outside and one on the inside, each of which has a long slender branch (Fig. 3, *t*); seventh joint fitting palm, and apparently unarmed.

Peraeopods 1 and 2 slender and nearly equal in form and length. Peraeopod 1, second joint very little expanded, as long as the fourth and fifth combined; fourth joint very little expanded and about as long as the sixth; fifth joint shorter than the sixth; seventh joint about a third as long as the sixth, with a spinule on inner margin, and with a curved nail. Peraeopod 3, longer than 1 or 2, but shorter than 4, second joint expanded, front margin convex and spinose, rear margin almost straight, slightly serrate, spinose, and with a lower lobe; fourth joint little expanded and not as long as the fifth; fifth joint not as long as the sixth; seventh joint about a fourth as long as the sixth joint, and much like that of peraeopod 1. Peraeopod 4, shorter than 5; front and rear margins of second joint convex and spinose, rear margin with a rather shallow lower lobe; fourth, fifth, and sixth joints proportionately

[5] Named in honor of Gilberto Silva Taboada, who collected the new species and donated them to the U. S. National Museum.

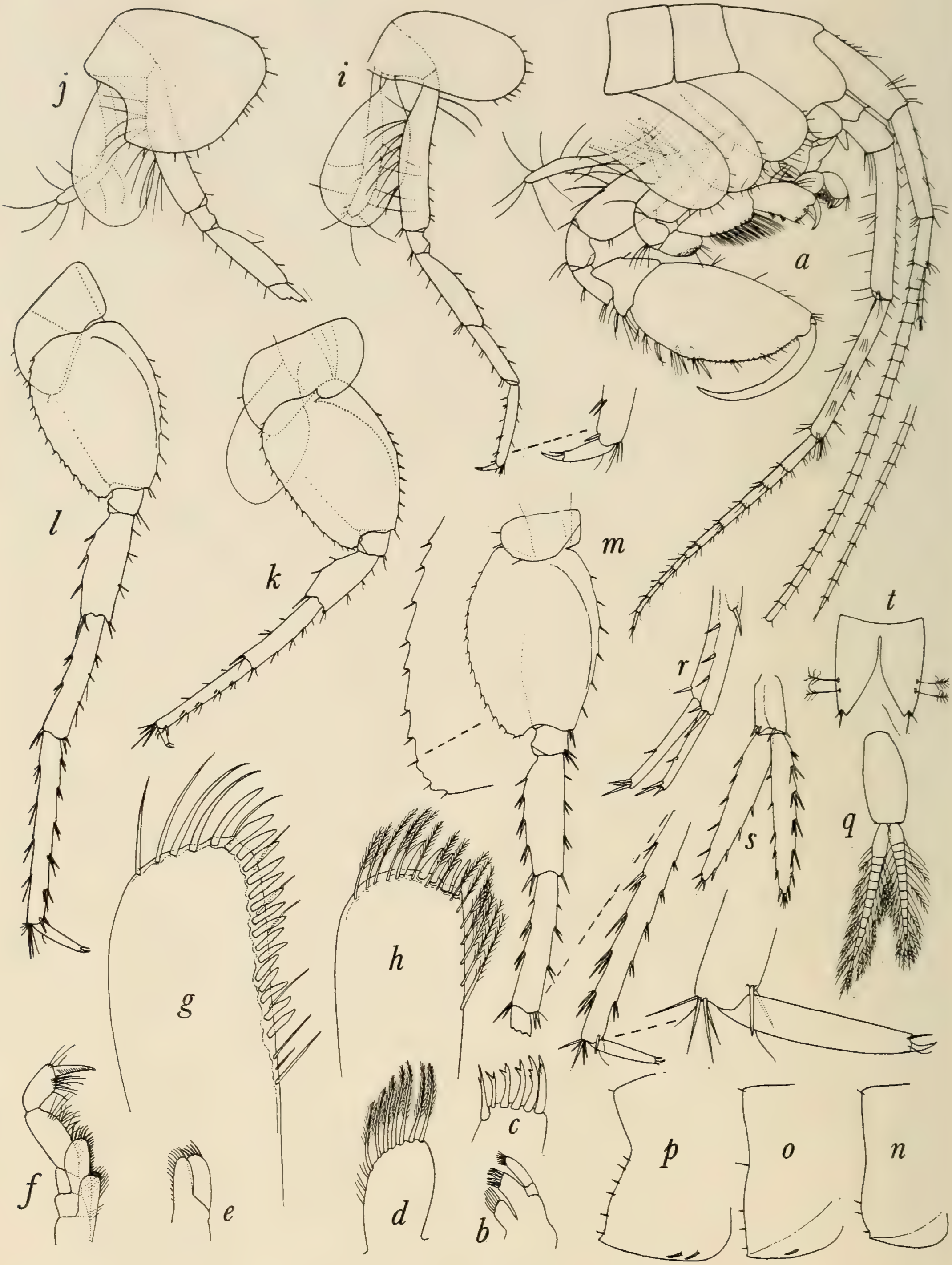

FIG. 4.—*Paraweckelia silvai*, n. sp., female: *a*, Anterior end, lateral; *b*, maxilla 1; *c*, maxilla 1, apex of outer plate (only 6 of the 9 spines shown); *d*, maxilla 1, inner plate; *e*, maxilla 2; *f*, maxilliped; *g*, maxilliped, outer plate; *h*, maxilliped, inner plate; *i*, peraeopod 1; *j*, peraeopod 2; *k*, peraeopod 3; *l*, peraeopod 4; *m*, peraeopod 5; *n*, *o*, *p*, metasome segments 1, 2, and 3, respectively, lateral; *q*, pleopod 3; *r*, uropod 1; *s*, uropod 2; *t*, telson.

as in peraeopod 3, but longer; seventh joint about a third as long as the sixth. Peraeopod 5, proportionately much like 4, but longer; second joint with upper rear margin straight; seventh joint straight, about a third as long as the sixth, and is as shown by Fig. 4, *m*.

Coxal plates 1–4 deeper than their body segments, the first three with evenly rounding spinose lower margins. Coxal plate 4 much broader than the preceeding, rear margin deeply incised. Coxal plate 5, with a shallow front lobe. Coxal plates 5–7 as shown in Fig. 4, *k, l, m*.

Branchiae are simple oval sacs, without pedicels, and occur on gnathopod 2 and peraeopods 1–4. The marsupial plates are narrow, carry few setae and are attached to gnathopod 2 and peraeopods 1–3. The metasome segments are as shown by Fig. 4, *n, o, p*. Metasome segments 1–3 and urosome segment 1 each has two posteromedian dorsal setae, and urosome segment 2 has a small spine on either side of the posterodorsal surface.

Pleopods, normal and well developed, outer ramus the shorter.

Uropod 1 reaches back a little farther than 2, and uropod 3 much farther than 1. Uropod 1, peduncle much longer than inner ramus, which is longer than the outer; the armature of spines is shown by Fig. 4, *r*. Uropod 2, much like uropod 1, but there are no spines on the peduncle except the distal one. Uropod 3, peduncle about a third as long as the outer ramus, which has small, narrow second joint; inner ramus a little shorter than the outer, and the spine arrangement of the uropod is shown by Fig. 4, *s*. Telson reaches back to about the end of the peduncle of uropod 3, about as broad as long, cleft nearly to its base, each lobe converging to a narrow indented apex containing a spine and a seta, and each outer lateral margin bearing 2 plumose setae. Length from front of head to end of uropod 3, about 12 mm.

MALE: The male is like the female, and can be distinguished only by the absence of marsupial plates and the presence of male genitalia. The males in the present lot are about the size of the females except the male type which measures about 15 mm.

Types.—Holotype, male, U.S.N.M. no. 102461. Allotype, female, U.S.N.M. no. 102462, and eight paratypes.

The new genus, *Paraweckelia,* is closely related to the genus *Weckelia* Shoemaker, 1942, containing the single species *W. caeca* (Weckel) from Modesta Cave, near Cañas, Cuba. The most important difference is in the structure of the mandibular palp, which consists of the usual three joints in *Paraweckelia,* but is reduced to a single small joint in *Weckelia.* In addition, the oblique row of setae on the inner plate of the second maxilla of *Weckelia* is absent in *Paraweckelia.*

LITERATURE CITED

HERTZOG, LOUIS. Bogidiella albertimagni *sp. n., ein neuer Grundwasser amphipode aus der Rheinebene bei Strassburg.* Zool. Anz. **102**: 225–227. 1933.

———. *Crustacés des biotopes hypogées de la Vallée du Rhin d'Alsace.* Bull. Soc. Zool. France **61**: 356–372. 1936.

KARAMAN, STANKO. *Über zwei neue Amphipoden,* Balcanella *und* Jugocrangonyx, *aus dem Grundwasser von Skoplje.* Zool. Anz. **103**: 41–47. 1933.

RUFFO, SANDRO, Bogidiella neotropica *n. sp., nuovo Anfipodo dell' Amazonia.* Riv. Svizzera Idrologia **14**: 129–143, 1952.

SHOEMAKER, CLARENCE R. *Notes on some American fresh-water amphipod crustaceans and descriptions of a new genus and two new species.* Smithsonian Misc. Coll. **101** (9): 1–31. 1942.

SIEWING, ROLF. Bogidiella brasiliensis, *ein neuer Amphipode aus dem Küstengrundwasser Brasiliens.* Kieler Meeresforschungen **9** (2): 243–247. 1953.

STEPHENSEN, KNUT. *Fresh- and brackish-water Amphipoda from Bonaire, Curaçao, and Aruba.* Zool. Jahrb. (Abt. Syst.) **64** (3/5): 415–436. 1933.

———. *Amphipods from Curaçao, Bonaire, Aruba and Margarita.* Studies on the Fauna of Curaçao, Aruba, Bonaire and the Venezuelan Islands **3** (11): 1–20. 1948.

ZOOLOGY.—Antrogonodesmus, *a new chelodesmoid genus from Cuba, and a redescription of* Amphelictogon dolius *Chamberlin* (*Polydesmida, Chelodesmidae*).

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(Received June 16, 1959)

So far less than 80 species of Diplopoda have been recorded from Cuba, a small number which reflects inadequate collecting rather than an impoverished fauna. More than half of the known species have been taken in the mountains of Oriente Province, and it seems reasonable to presume that attention to other parts of the island will greatly augment our knowledge of the millipeds of Cuba. The first large contribution to this general subject was made in 1918, when R. V. Chamberlin described a considerable number of Cuban species (unfortunately without illustrations), the majority of which are still known only from the original types. In recent years H. F. Loomis has added a large number of new species to the list, and redescribed some of the older ones.

Two separate collections of Cuban diplopods, received by the U. S. National Museum and kindly transmitted to me for study by Dr. Ralph E. Crabill, are of exceptional interest. One includes a remarkable new genus of the Chelodesmidae without close relatives elsewhere in the family; the other contains male specimens of *Amphelictogon dolius*, a species originally based on females and not subsequently rediscovered.

Family Chelodesmidae Cook

The status of this name has been the subject of much dissention ever since its proposal in 1895, but with the recent discovery that the type genus is subjectively synonymous with the older name *Eurydesmus*, plus the latest (Copenhagen, 1953) decisions concerning the formation of family names, there can hardly be any doubt that it is the correct name for the group of genera which has long been called the family Leptodesmidae by most European workers. A detailed study of classification within the limits of this huge group and its satellite families is in preparation at this time, and should settle the question of how much ground should be covered by the name Chelodesmidae in a stricter sense than now employed.

On the basis of work completed to date, it can safely be said that of the two genera here discussed, at least *Amphelictogon* is very closely related to both *Eurydesmus* and *Leptodesmus*, falling in the same family with the former and in the same subfamily or tribe with the latter genus. This association is made on the basis of comparison with material of species strictly congeneric with the type species of the three genera named, including newly-found characters of antennal structure, form of the 2nd leg pair, body shape and proportion, paranotal configuration, and formation of the male genitalia. Less can be said concerning the status of *Antrogonodesmus* although it is obviously a member of the Chelodesmidae in a restricted sense.

Antrogonodesmus, n. gen.

Type species.—*Antrogonodesmus curiosus*, n. sp.

Diagnosis.—A remarkable chelodesmid genus differing from all other known genera by the form of the gonopods. The coxae are normal for the family in shape, mode of connection, and presence of a long coxal process, but the prefemora are greatly enlarged and impressed on the ventral side into a deep cavity densely beset with long macrosetae. The prefemoral process is short and distally biramous, one of the divisions forming a shield for the solenomerite. The latter is short and laminate, slender, unmodified, largely concealed by the prefemoral process and by a femoral process which is somewhat expanded and functioning as a solenophor.

Body form chelodesmid, e.g., with the anterior four of five segments broadest and the following paranota becoming gradually reduced in size in going caudad and well separated from each other by the large prozonites which are only partly included by the preceeding metazonites. A distinct interzonal furrow in the segmental constriction. Pore formula normal, the pores opening near the end of slender elongate peritremata. Tergites, pleurites, and sternites all smooth and glabrous, without any surficial modifications. Legs long and slender, virtually glabrous, those of the male sex with distinct tibial pads extending back as far as the eighth segment.

Antrogonodesmus curiosus, n. sp.

Figs. 1–4

Type specimens.—Male holotype and female paratype, U. S. Nat. Mus. (Myriapod Type no. 2581), from San Vicente, Pinar del Río Province, Cuba, collected in June 1956, by N. L. H. Krauss.

Diagnosis.—With the characters of the genus. Specific characters probably are reflected in the size, color pattern, and gonopod configuration.

Description.—Male holotype: an elongate, slender, caudally attenuate chelodesmoid, the paranota of segments 2–4 rather broad, transverse, almost horizontal, subrectangular, those following gradually decreasing in size. Length, approximately 34 mm., widths of selected segments as follows:

Collum	5.1mm
2d	5.2
3d	5.1
4th	5.0
6th	4.6
10th	4.5
16th	4.1
18th	3.2

Body chiefly tan to a light testaceous-brown, the intersegmental constriction more darkly pigmented across dorsum. Caudolateral corners of paranota, *the entire collum,* and large middorsal spots on the 2d and 3d segments chalky white. Antennae, legs, and underparts light tan to nearly colorless.

Head convex, smooth, polished, the vertigial groove very distinct and extending down to middle of interantennal isthmus. latter broad, twice length of first antennal article. Frons and clypeus with numerous scattered setae, these extending laterad well onto the genal surfaces, latter only slightly convex without flattened margins, a little sinuate. Labrum with about 28 stout setae, the series merging into the 3 large genal marginal setae on each side.

Antennae moderately long (5.0 mm) and slender, reaching back to 3rd segment; all of the articles moderately setose but vestiture increasing distally; article 7 cylindrical, apically rounded, the free margin inturned between and separating the 4 sensory cones, outer (dorsal) side of article with a small rounded sensory area. Relative lengths of antennal articles, in decreasing order: 2-3-4-5-6-1-7 (perhaps abnormal).

Collum broader than head, smooth, convex, anterior margin an even arc, almost a semicircle; median fourth of caudal margin rather deeply concave. Anteriolateral edge of set off by a fine groove extending dorsad as far as base of mandibles. Lateral corners almost rectangular. A row of six widely spaced submarginal microsetae along the rear edge of the segment.

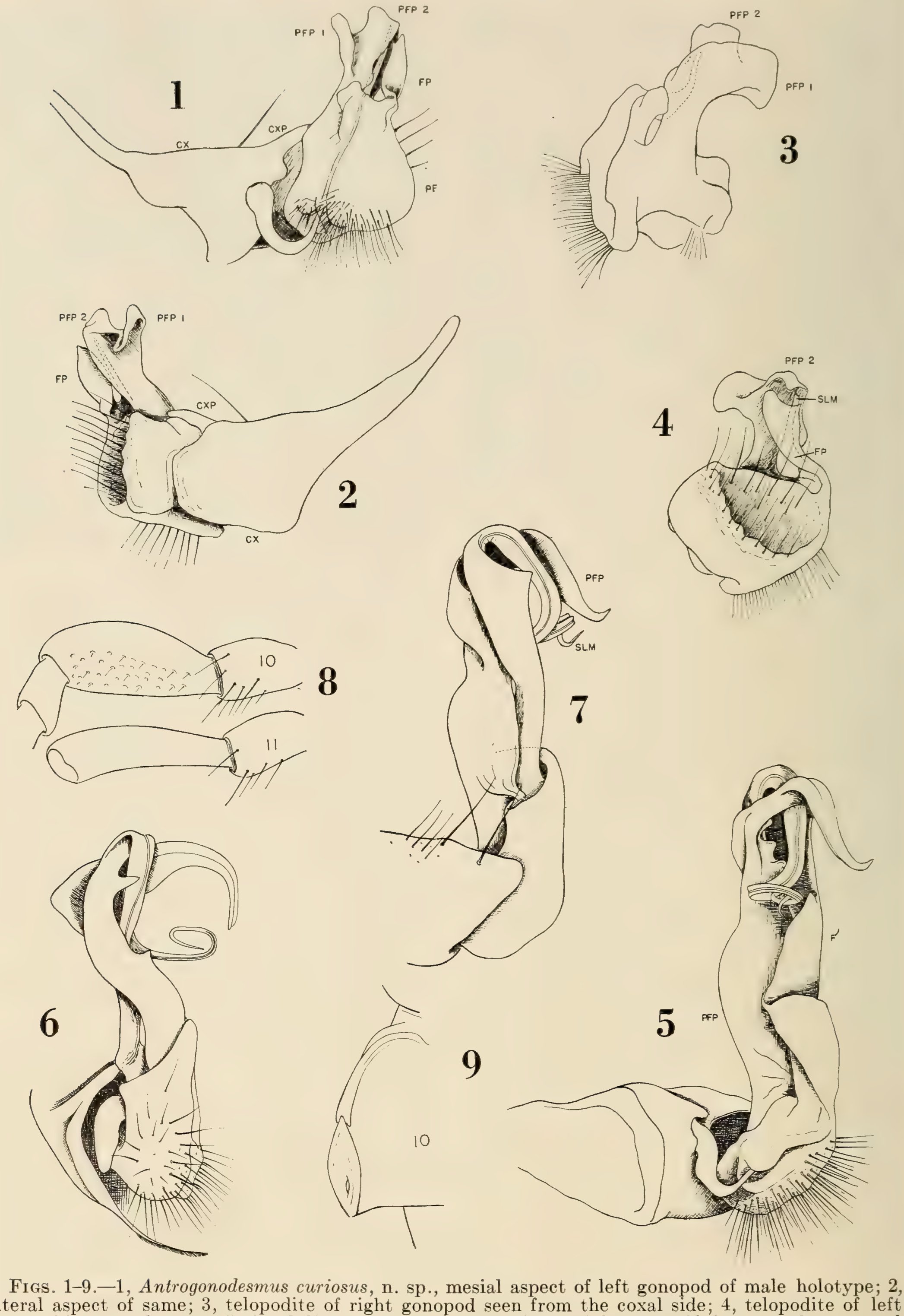
Second segment slightly broader than the others, the paranota broad and only slightly depressed, not tilted cephaloventrad; the paranota margined only on anterior edges, lateral and caudal edges continuous with dorsal surface. Segments 2–4 with small but distinct scapular dentations, these segments all essentially similar in size and shape. In going caudad from 5th segment the paranota become increasingly reduced, the anterior corners become more oblique and the posterior more acutely produced. On all poriferous segments the peritremata are elongate and slender, the pores opening dorsolaterally almost at their posterior ends.

Prozonites and metazonites of equal size, separated by a broad, smooth, interzonal furrow in the convexity of a distinct intrasegmental constriction. Surface of segment smooth and polished, without granulations or perceptible setal sockets.

Paranota of 19th segment rudimentary lobes just large enough to carry the pores, scarcely extending beyond caudal margin of the segment. Anal segment small, the epiproct short, bluntly conical, bent slightly ventrad. Anal valves smooth, with a median setiferous convexity, the mesial edges produced as raised rims, the marginal setiferous tubercules small, set quite high on the valves, and separated from the marginal rims. Hypoproct large, subcircular, the median projection broad and low but distinct between the small paramedian tubercules.

Pleural areas entirely smooth, unadorned; stigmata small and opening almost flush with the surface just above and in front of the coxae. Sterna broad, glabrous, unmodified, the legs inserted into an abruptly elevated podosternum, this not produced into subcoxal spines or knobs, but distinctly notched between the coxae on each side and with the caudal side deeply concave between the last legpair of each segment.

Legs long and slender, the joints virtually glabrous except for a ventral macroseta on each coxa and prefemur, and some microsetae on the following three joints. Tarsus sparsely invested with fine slender setae, these distinctly procum-



FIGS. 1–9.—1, *Antrogonodesmus curiosus*, n. sp., mesial aspect of left gonopod of male holotype; 2, lateral aspect of same; 3, telopodite of right gonopod seen from the coxal side; 4, telopodite of left gonopod in ventral aspect; 5, *Amphelictogon dolius* Chamberlin, mesial aspect of left gonopod; 6, ventral aspect of right gonopod; 7, lateral aspect of right gonopod; 8, ventral aspect of basal two joints of tenth and eleventh leg pairs; 9, left paranotum of tenth segment. (Abbreviations: CX, coxa; CXP, coxal process; F, femur; FP, femoral process; PF, prefemur; PFP, prefemoral process; SLM, solenomerite.)

bent. Pretarsus small, short, slightly curved. Leg joints in decreasing order of length: 3-6-5-2-4-1.

Tibiae of legs 1–10 with extruded arthrodial subtarsal pads, apparently a few others behind the 10th can be extruded also. Seminal processes of second coxae rudimentary, they open through a low conical swelling of the coxae. Sterna of anterior segments broad and without any trace of subcoxal knobs or processes. Anterior pretarsi also small and similar to the others.

Pleurae of segments 2–7 modified by a distinct groove from the caudal margin of the segments, curving cephaloventrad to form an arc just above the coxae, thence fading out toward the interzonal furrow. The low ridge formed by this groove is entirely smooth.

Gonopod aperture quite small, broadly transversely oval, about three times as wide as long, its edges produced distally into a complete circumgonopodal rim of moderate height. Aperture entirely confined to the metazonite of the seventh segment, not infringing even onto the course of the interzonal furrow.

Telopodites of gonopods, seen in situ, very small, not extending beyond prozonite of segment although the coxae of normal size for the bulk of the animal. Coxae attached by a very small, elongate sternal remnant, and with long slender apodemes, produced on the cephalic surface into an elongate subconical coxal process (CXP). Prefemora greatly enlarged especially on the ventral surface, which is largely occupied by a deep subcircular cavity, lined with long setae (Figs. 2 and 3), unlike anything now known in other chelodesmids. In mesial aspect, prefemora are short and broad, with a straight seminal groove proceeding distad to the base of the solenomerite. A large prefemoral process (PFP), distally expanded and divided into two subequal laminate lobes, the outer of which is terminally reflexed and curved to form a hoodlike structure covering the solenomerite (PFP 2) as seen in ventral aspect, Fig. 3. Two other gonopod processes, probably postfemoral in structure, are the solenomerite (SLM), a simple, slightly curved, mostly concealed blade carrying the seminal groove, and the femoral process (FP), which originates near the base of the solenomerite, and shields it on the ventral side.

Female paratype: similar to the male in most structural details, but the body somewhat larger with wider sterna and narrower paranota, and with the interzonal furrow more deeply impressed. The antennae are longer (5.8 mm), with articles 2–6 almost identical in size and shape. The color pattern is identical except that the 3rd segment lacks the median spot. The body form is less attenuated caudally. Length, 35.0 mm, widths of selected segments:

2d	5.0mm
10th	4.9
16th	4.9
18th	3.8

Remarks:—Heretofore two chelodesmoid genera have been known from Cuba: *Amphelictogon* and *Cubodesmus*, both abundantly represented by species from the eastern half of the island. *Antrogonodesmus* is perhaps endemic to the western part of the island, geographically vicariating for the other two, but apparently not closely related to either of them. There is, in fact, no known genus with which it can be compared. The large prefemoral cavity is unique, and the relationship of the terminal processes almost so.

As regards body forms and details, *Antrogononodesmus* seems to have no close ties with Central American forms such as the dominant chelodesmid genus *Chondrodesmus*. Tibial pads on the male legs occur in numerous genera of South America, but the systematic significance of these structures has yet to be proven at least as regards tracing affinities of genera so provided.

With most of the collecting which has been done in Cuba restricted to the mountains of Oriente, it would be premature to speculate on the likelihood of a distinctive endemic fauna in the hills of Pinar del Río, yet such is suggested by the discovery of an unusual chelodesmid. Perhaps the intervening lowlands of Cuba have been largely submerged through the Tertiary to enhance the development of two distinct faunas. Further exploration west of Havana is certainly much to be desired.

Genus **Amphelictogon** Chamberlin

Amphelictogon Chamberlin, 1918, Bull. Mus. Comp. Zool. **62:** 224.—Loomis, 1938, Bull. Mus. Comp. Zool. **82:** 460.—Attems, 1938, Das Tierreich **68:** 157; 1940, *ibid.* **70:** 552.—Loomis, 1941, Psyche **48:** 35.

Type species.—Amphelictogon cubanus Chamberlin, by orthotypy.

Diagnosis.—Amphelictogon is characterized primarily by the structure of the gonopods, which are rather small and project from a strongly modified sternal aperture. The coxae are connected by a small but distinct, attenuate sternite, and are produced into a triangular projection partly concealing the lateral face of the prefemur. The telopodite projects directly distad from the prefemur as a rather straight stalk which, however, is bent abruptly retroproximad, strongly attenuated, and drawn out into a long coiled flagellum. Prefemoral process set off by a distinct articulation, extending distad as far as the geniculum of the telopodite, where it normally curves proximad as a slender falcate blade, occasionally with a terminal expansion or a subterminal accessory process.

Body form slender, collum and second segment widest, segments posterior to 4th becoming gradually narrower to end of body. Paranota widely separated by the large exposed prozonites, the two subsegments separated by a well defined interzonal furrow. Prozonite of 7th segment of males complete, not reduced in front of the gonopod aperture. Legs long and slender, without tibial pads, the pretarsi short and slender, unmodified. Pore formula normal, peritremata usually specialized and set off from margin of paranota.

Coloration variable, the dorsum dark brown with spots or bands or red, yellow, or white.

Species.—22, most of them from Oriente Province, Cuba, one from the Bahamas and one from Isle of Pines.

Amphelictogon dolius Chamberlin

Figs. 5–9

Type specimens.—Female holotype and paratypes, M. C. Z. nos. 5024–25, from Punta de Judas, 40 miles east of Caibarién, Santa Clara Province, Cuba, collected by Thomas Barbour in 1917–18.

Diagnosis.—The color pattern alone sets this species off from the other known species of *Amphelictogon.* On the basis of the gonopods, *dolius* is allied to *bidens* Loomis and *strumosus* Loomis in having the prefemoral process distally arcuate and slender and the telopodite femur with two marginal teeth. It differs from both in details of gonopod structure as well as color pattern.

Description.—Male: body elongate, slender, widest across collum and attenuate caudally; outline of body strongly moniliform, the prozonites large and broadly separating the metazonites. Paranota set high on sides and nearly horizontal. Length of specimen approximately 30 mm., widths of selected segments as follows:

Collum	4.5mm
5th	4.2
10th	4.0
17th	3.5

Segments rich chestnut-brown, head and antennae lighter brown; legs brownish pink, becoming reddish distally. Dorsum of paranota and adjacent part of the metatergites as well as tip of epiproct chalky white, each white spot wider than the brown of the intervening middorsal area.

Head capsule normal in appearance, convex, smooth; median groove of the vertex well defined. Clypeal region set with numerous long fine setae, the upper edge of the area limited by a transverse row of larger setae, above which only a few scattered setae occur on the lower frons. A pair of subantennal setae, and two pairs on the vertex is a transverse row, the setae of each pair set close together. Labrum fringed with about 40 long setae, intercalated with much shorter ones. Genae rather flat, evenly convex.

Antennae long (5.8 mm) and unmodified, articles 2–6 similar in size and shape, 1 very short, 7 subhemispherical, its distal edge turned in mesially between each of the 4 sensory cones and almost completely separating them; dorsal (outer) side of article 7 with a small rounded convex sensory area.

Collum broadly transverse, wider than head, surface evenly arched and smooth. Anterior margin evenly rounded through almost a half circle, posterior margin strongly bisinuate, i.e., with a median and two paramedian emarginations, the latter emphasizing the lateral corners of collum. Both edges set off by a submarginal groove, deepest at the lateral ends and obsolete across middorsum.

Second, third, and fourth tergites subsimilar in appearance but narrowing in width, paranota broadly transverse; anteriorly the margins are evenly rounded and set off by a distinct ridge, posteriorly the margins are bisinuate and set off with a fine ridge; caudolateral corners distinctly produced. Surface of metatergites smooth and polished, of prozonites finely shagreened, the two subsegments separated by a deep sharply defined interzonal furrow.

Segments 5 through 19 narrower than the preceeding, the anterior paranotal corners increasingly reduced along with width of the paranota, the prozonites proportionately more conspicuous along middle of body. Lateral margins of segments 17–19 scarcely divergent from median body axis, paranotal angles directed caudad, abruptly smaller on segment 19. Poriferous segments (5, 7, 9, 10, 12, 13, 16–19) similar to others except for the strongly differentiated peritremata, these elongate pyriform, the upper surface flattened, pore directed dorsolaterad (Fig. 9). Caudal edges of paranota margined, but none produced into marginal dentations.

Epiproct subconical in dorsal aspect with a small cylindric truncate apex beyond the terminal whorl of macrosetae; lateral tubercules of both whorls large and interrupting the curve of the sides. Disc of anal valves convex, smooth, surface of basal third of valves vertically striate, mesal edges very strongly compressed, each valve with an oblique secondary ridge projecting from about the basal sixth and extending cephaloventrad to near the lateral ends of the hypoproct. Latter about twice as wide as long, with the ends acutely rounded and the distal edges nearly straight, and with a large and distinct median terminal lobe. Setiferous tubercules small and removed from the edges.

Pleural and ventral surfaces smooth and nearly glabrous, the former without pleural carinae or other modifications. Interzonal furrow continues well-defined around the segments in a strong constriction between prozonites and metazonites.

Legs inserted upon a distinctly elevated podosternum, which is not produced into subcoxal processes, and glabrous except for a row of 10–14 setae across the anterior surface above the interzonal furrow and a few scattered setae in general located near the coxal sockets. Legs long (up to 5.2 mm) and slender, the joints in decreasing order of length: 3-6-5-4-2-1. Basal two joints glabrous except for a few long ventral macrosetae, distally the joints are increasingly setose. Most legs are similar in proportion except the 9th and tenth pairs, the femora of which are conspicuously enlarged with the ventral surface flat or subconcave, ornamented with numerous flat tubercules each of which bears a tiny curved seta (Fig. 8).

Anterior legs smaller than the others but similar in form, without tibial pads or other modifications. Seminal ducts open flush with the surface of the 2d coxae. Sterna between the 3d legs (4th segment) produced into two contiguous elongate mounds; sterna between fourth legs produced into 2 low subconical knobs; the other sterna unmodified. Pretarsi short, slightly curved, somewhat compressed.

Prozonite of seventh segment not infringed upon by the small aperture of the gonopods and generally similar to adjoining segments. The aperture with the edges produced distad forming a circumgonopodal sheath, the rim of which is flared and recurved toward the body. Gonopods large, extending cephalad onto the 6th segment, not in contact mesially or but slightly so; the coxae joined by a small elongate sternal remnant, without a coxal process, but extending somewhat behind the prefemora on the lateral side.

Prefemora rather small, densely setose. Prefemoral process elongate, as large as main part of telopodite, terminating distally in a slender, simple, attenuated curved process, the inner edge of the process provided just beyond the midlength with three rounded projecting lobes. Femora short, flat, glabrous, separated from the more distal part of the telopodite by a deep (flexible?) groove or cingulum. Postfemur elongate, slender, the basal half with two acute projections along the mesial edge; just beyond the distalmost projection the telopodite is abruptly reflexed proximad and drawn out into a long coiled flagellum (Figs. 5–7).

Female: similar in structure to the male but somewhat larger, the tergites wider (4.6 mm at tenth segment, 5.0 mm at second). Color pattern similar to that of male except that the collum is completely ringed with white.

Remarks.—This species has heretofore been known only from the type locality. The material described originated at the Cueva de Colon, in Matanzas Province, Cuba, extending the known range about 130 miles to the west.

Amphelictogon dolius appears to be remarkable for the enlargement of the femora of legs 9 and 10. Whether such modification is unique in this species or merely overlooked in others I cannot guess. In the form of the gonopods *dolius* is very much like Loomis's species *bidens* and *strumosus*, but differs so much in color pattern from both that subspecific status seems unlikely. Probably actual comparison of specimens of the three will provide various points of difference not apparent from the published descriptions.

REFERENCES

Chamberlin, R. V. *The Chilopoda and Diplopoda of the West Indies.* Bull. Mus. Comp. Zool. **62**(5): 149–262. 1918.

———. *Notes on West Indian Millipeds.* Proc. U. S. Nat. Mus. **61**(10): 1–19, pls. 1–6. 1922.

Loomis, H. F. *New and noteworthy millipeds from Cuba, collected by Dr. P. J. Darlington in 1936.* Bull. Mus. Comp. Zool. **82**(6): 427–480, figs. 1–27. 1938.

ICHTHYOLOGY.—Bathypterois pectinatus, *a new bathyal iniomous fish from the eastern Pacific.* GILES W. MEAD, United States Fish and Wildlife Service.[1]

(Received May 29, 1959)

The holotype of the distinctive species described below has been available during my review of the western Atlantic fishes of the family Bathypteroidae. It was compared with all known north Atlantic species (Mead, 1959: 369); with the type or syntypes of the Pacific *Bathypterois ventralis* Garman, *B. pectoralis* Garman, and *B. antennatus* Gilbert; with specimens representing *B. longipes* Günther and several variations of the cosmopolitan but poorly-understood groups of species now known as *B. antennatus* and *B. atricolor*. The study of a second specimen, caught by the *Vema,* has shown clearly that this form is not an extralimital subspecies or variant of the Atlantic *B. quadrifilis* Günther but a distinct although related species.

Bathypterois (Bathypterois) pectinatus, n. sp.
Fig. 1

Holotype.—A specimen 142.1 mm in standard length caught by the U. S. Fish Commission steamer *Albatross* at station D. 4654, 24 miles off Aguja Point, Peru (lat. 05°46′ S., long. 81°32′ W.) on November 12, 1904, at a depth of 1,036 fathoms. U. S. National Museum no. 150029.

Paratype.—A 123.0-mm specimen taken by the R. V. *Vema* of the Lamont Geological Observatory from L.G.O. Biotrawl no. 122, Panama Bay (lat. 07°25′ N., long. 79°23′ W.) on November 14, 1958, at a depth of 956 fathoms (corrected). American Museum of Natural History no. 20401.

Diagnosis.—Posterior ventral procurrent caudal ray modified into a hook or notch. Upper prolonged and stiffened pectoral rays fused basally but divided from one another at a point anterior to the origin of the dorsal fin; these upper strong rays followed by at most one rudimentary pectoral ray. Base of lowermost pectoral fin ray about as thick as that of the adjacent ray. Scales beneath proximal part of pectoral fin strongly pectinate. Body black and without pattern; the edges of the scale pockets white. Caudal fin white; dorsal, anal, and ventral fins dusky.

Bathypterois pectinatus is closely related to *B. quadrifilis*, a species known from the western Atlantic (off Brazil, in the Gulf of Mexico and the western Caribbean, and off Grenada and St. Vincent in the British West Indies) at depths from 470 to 655 fathoms. It differs from *B. quadrifilis* in the thickness of the lowermost pectoral ray, by its colorless caudal fin and dusky dorsal and anal fins (all are black in *B. quadrifilis*), by its less-deep body, and in the extent of the scaly covering over the proximal part of the caudal fin (this covering extends out on to the caudal lobes in *B. quadrifilis* but is restricted to the area over the bases of the caudal rays in *B. pectinatus*).

Description.—The following counts and measurements (expressed in percent of standard length) are those of the holotype (142.1 mm) followed, in parentheses, by those of the paratype (123.0):

D.—14 (14). A.—9 (9). P. (upper part)—2,0/2,1 (2,1/2,1). P. (lower part)—9/9 (9/9). V.—8/9 (9/9). C.—I-16-II. Gill rakers (first arch)—12 + 1 + 29 (12 + 1 + 30). Branchiostegal rays —4 + 8 (5 + 8). Scales in lateral line—about 62. Vertebrae—59.

Length of head 21.3 (21.3), of snout 7.1 (6.7), of upper jaw 13.6 (13.3). Diameter of eye 2.0 (2.4); width of bony interorbital 7.9 (8.3). Greatest depth of body 14.6 (14.4), depth at origin of anal fin 10.6 (10.7), least depth of caudal peduncle 7.1 (7.0). Greatest width of body 8.2 (8.1). Snout to origin of dorsal fin 40.1 (41.3), to origin of anal fin 55.4 (55.7), to insertion of pectoral fin 18.3 (19.4), to insertion of ventral fin 35.5 (37.3). Base of last dorsal ray to insertion of adipose fin 23.7 (22.6); insertion of adipose fin to dorsal procurrent caudal ray 21.5 (22.2); base of last anal ray to ventral procurrent caudal

[1] One of the specimens on which this account was based was caught by the 1958 eastern Pacific cruise of the *Vema,* research vessel of the Lamont Geological Observatory, Columbia University, and was made available by Dr. Robert J. Menzies of that laboratory through Dr. Vladimir Walters of the American Museum of Natural History. Partial support for this cruise of the *Vema* was obtained from the U. S. Navy, Office of Naval Research, the Bureau of Ships, and the National Science Foundation. This paper constitutes contribution no. 363 of the Lamont Geological Observatory and no. 11 of the Biology Program.

ray 33.8 (32.6); insertion of ventral fin to anus 13.0 (11.8); anus to origin of anal fin 6.8 (7.6). Length of base of dorsal fin 13.2 (13.7), of anal fin 8.2 (8.1). Length of longest pectoral fin ray 89.6 (96.0), of longest ventral fin ray 32.2 (28.1).

Body compressed, snout depressed. Body deepest at origin of dorsal fin, this depth 1.5 in length of head. Depth at origin of anal fin 2.0 in head; least depth of caudal peduncle 3.0 in head. Greatest width of body, anterior to dorsal fin, 1.8 in greatest depth.

Cheeks, top of head posterior to eye, and body covered with scales. Most body scales cycloid; those beneath anterior end of lower part of pectoral fin strongly pectinate and more adherent than most body scales. Body scales extend onto caudal fin; all other fins scaleless. One or two lateral line scales on caudal fin above the midcaudal ray.

Head 4.7 in standard length, depressed and slightly convex above and before eye. Snout 3.0 to 3.2 in length of head. Sensory pores of head well developed, 4 to 6 in the horizontal series below the eye, about 8 along the lower outer surface of the mandible, and about 4 in each longitudinal series on top of head. Olfactory organ slightly closer to eye than to tip of snout, the nostrils separated by a thin membrane which bears a short flap.

Eye minute but larger than that of several other bathypteroid species, its greatest diameter equal to or greater than the combined width of the upper jaw bones (maxillary and supramaxillary) at their widest point. Pupil elliptical, but not keyhole-shaped. Interorbital broad and convex, 2.5 to 2.7 in length of head.

Branchiostegal membrane extending posteriorly beyond operculars, supported by 12 or 13 branchiostegal rays of which four or five originate on the epihyal. The membranes overlap anteriorly and are covered by a thick transverse gular fold. Gill rakers on all four arches, of the usual lathlike shape, spiny, and moderately long. Those near the angle of the first arch are about twice as long as the opposite gill filaments. No pseudobranchiae.

Maxillary broad and flat posteriorly, extending beyond posterior end of the premaxillary and surmounted by a slender supramaxillary which extends forward nearly or quite to beneath the posterior edge of the eye. Teeth on premaxillary minute, mostly depressible, and in a single band which is broader anteriorly than posteriorly. Symphysis of upper jaw without teeth. A patch of minute teeth on each side of the vomer, and a row of smaller teeth on each palatine. Mandible broad and heavy, with a bony toothless boss at the symphysis, the anterior half not included within or opposed to the upper jaw when the mouth is closed. Teeth in mandible small but larger than those in upper jaw, depressible and forming a band which is broader anteriorly than posteriorly. No teeth on the small tongue.

Dorsal fin inserted well behind axil of ventral fin, the length of its base 1.6 in length of head. Predorsal distance 2.4 or 2.5 in standard length. First two dorsal rays unbranched, the rest branched, the last divided to its base. Adipose

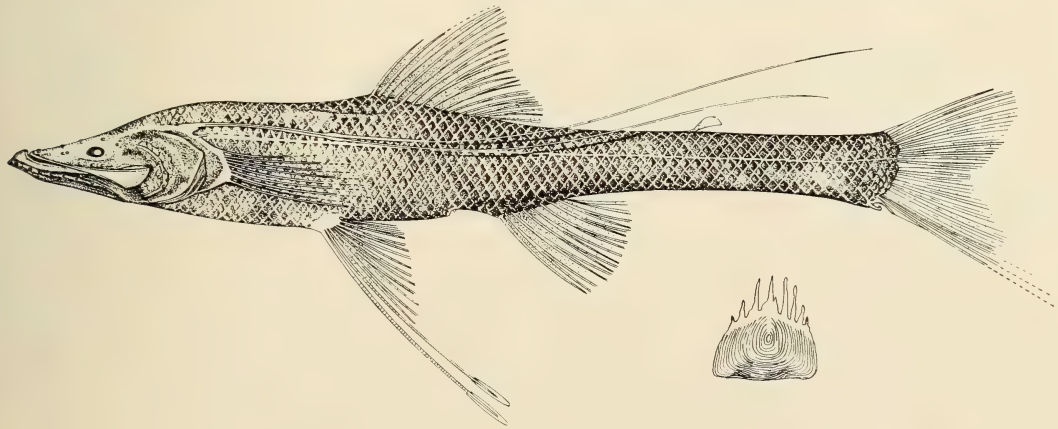


FIG. 1.—*Bathypterois* (*Bathypterois*) *pectinatus*, holotype, U.S.N.M. no. 150029. The figured scale was taken from beneath the anterior third of the lower part of the pectoral fin. (Drawn by Mildred H. Carrington.)

dorsal fin located about midway between posterior end of base of dorsal fin and first dorsal procurrent caudal fin ray, or slightly closer to end of base of dorsal fin. (The position of the adipose fin is variable in several bathypteroid species.) Preventral distance 2.7 or 2.8 in standard length, the length of the fin 3.1 to 3.6 in length of fish. Ventral fin normally with nine rays, but one side of the type has but eight. (The number of ventral rays is constant in the western Atlantic species.) The outer two ventral rays are simple, the rest branched. Base of second ventral ray about the same thickness as that of the third. Origin of anal fin behind a vertical from end of base of dorsal fin, the preanal distance 1.8 in standard length. First anal ray unbranched, the rest branched, the last divided to its base. (All fins except the ventrals and the adipose are broken in both specimens.) Upper two pectoral fin rays stiffened and elongate and fused basally, separating from one another anterior to the origin of the dorsal fin and extending beyond end of base of dorsal fin nearly to base of caudal. One or no rudimentary rays below these two fused and prolonged upper pectoral rays. All rays in lower part of pectoral fin broken.

Anus located about midway between insertion of base of inner ventral ray and origin of anal fin. A small urogenital papilla present, preceded by the ovopore.

Body black and without pattern. Edges of scale pockets white. Caudal and adipose fins white. All other fins, snout and under surface of lower jaw dusky.

LITERATURE CITED

Mead, Giles W. *Three new species of archibenthic iniomous fishes from the western North Atlantic*. Journ. Washington Acad. Sci. **48**: 362–372. 1959.

Happy is he who has knowledge
That comes from inquiry. No evil he stirs
For his townsmen, nor gives himself
To unjust doings,
But surveys the unaging order
Of deathless nature, of what it is made,
And whence, and how.
In men of this kind the study
Of base acts never finds a home.

—Euripides.

Editor's Note.—The August and September numbers of the Journal are combined in one issue, as will also be the October and November numbers. Only 10 issues will be published in Volume 49.

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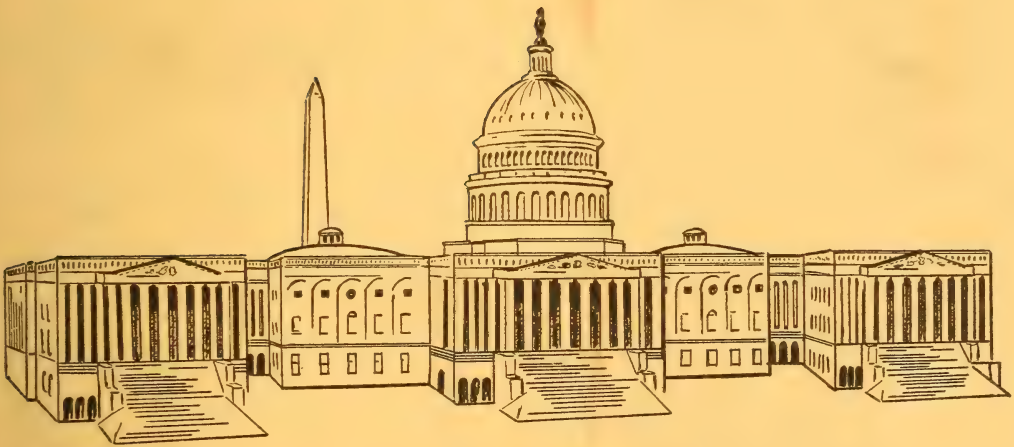

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EDUCATION.—*Education for the Age of Technology.*[1] S. B. Ingram.[2] (Communicated by F. L. Campbell.)

I have chosen for a title around which to organize the thoughts I wish to put before you today *Education for the Age of Technology.* I should like first to talk about our technical manpower needs and then go on to some implications that these have for our American educational system.

THE AGE OF TECHNOLOGY

The first point I wish to make is that today is indeed the Age of Technology in which educated, technically trained people are at a premium as never before. The impact of science upon our civilization has been so great that it is the controlling factor, whether we like it or not, in our culture. The technological character of our civilization has the profoundest effect on our politics, on our international relations, on our economic institutions, on our daily lives and finally, our particular interest here today, on our educational system.

The rate of social progress is paced by the rate of technological progress. Within our own country we experience the stresses and strains of trying to adjust our social structure to the rapid changes which have occurred in our material way of life. Externally, we find ourselves caught up in a contest between two competing ideologies. We know that the laurels will ultimately go to the side that can establish and maintain the greatest rate of technological advance, and we know that this is true whether the goal of the contest is the peaceful one of providing the highest standard of living for all the people of a nation or the grim one of military victory in the ultimate struggle of modern nuclear and electronic war.

Education plays a key role in determining the rate of technological advance because it is through our educational system that we develop the abilities of those members of society whose numbers and quality are critical in this determination, our scientists and engineers. Less and less is the work of the world done by unskilled and semiskilled labor. More and more are highly skilled and highly trained people needed by our society. Our greatest need has shifted from manpower to brainpower, and since we are concerned with the rate of technological progress our need is more and more for technological brainpower.

POTENTIAL OF TECHNOLOGICAL MANPOWER

The second point I wish to make is that our potential of technological manpower has a very definite limit, and we are not far from reaching this limit at the present time. I shall illustrate the point specifically by some figures with respect to our capacity to produce people trained in engineering, since the same line of reasoning can be applied with equal force to those trained in other technological fields like science and architecture.

At the present time only about 9 percent of our college entrants or 15 percent of our male college entrants have the interest, the aptitude, and the necessary preparation to embark on engineering courses and only about half of these graduate. Engineering educators estimate that only those young

[1] Presented at a meeting sponsored by the D.C. Council of Engineering and Architectural Societies and the Washington Academy of Sciences on Engineers, Scientists, and Architects Day at Washington, D. C., on February 25, 1959. Published jointly with the Journal of Engineering Education.

[2] Director of education and training, Bell Telephone Laboratories, Inc., Murray Hill, N. J., and vice-chairman, Engineering Manpower Commission of Engineers Joint Council.

people scoring above 120 on the Army General Classification Test are capable of successfully completing engineering training. This is about 17 percent of the age group. Now this does not mean, by any stretch of the imagination, that all these 17 percent may be regarded as potential engineers. Far from it. In the first place, half of these are women, and while experience has shown that we can get a small number of scientists and a smaller number of engineers from this group, barring a social revolution, we can not count on them to contribute in substantial numbers to our reservoir of potential engineers. This brings us from 17 percent down to 8½ percent. Now we have to consider that this remainder has to supply not only the engineers we have in our society but also members of the other professions and occupations which make the same high demands on intellectual capacity that engineering does. In the past, engineering has succeeded in getting about one-fourth of these. It is a question of how much higher this figure can go. We certainly can not put all our highly intelligent people in engineering, and very many of them would not be successful at it even if they tried. It takes a lot of other things besides intelligence to be an engineer. It takes a mathematical mind. It takes an interest in physical things and physical phenomena. Engineering does not give an adequate outlet for some of the other basic aptitudes and interests which intelligent people have. Many a successful lawyer, journalist, or social scientist would be wasted as an engineer, and besides our society needs these people in those fields into which their aptitudes and interests properly channel them. So if we assume that we will not be able to increase this fraction of one-fourth substantially, we conclude that about one-fourth of the 8½ percent or about 2 percent of the 2,200,000 young people coming of college age each year is our potential capacity for the production of engineering graduates. This number is 44,000. It is not far above the 35,000 engineers we graduated last year. Even this 2 percent figure does not represent ultimate additions to our national engineering force because it takes no account of losses of trained engineers to other occupations. Dael Wolfle (*1*) reports a study made in 1953 on a large sample of college graduates of the classes of 1930, 1940, and 1951. Of this group of engineering graduates, only 64 percent were doing professional engineering work as of 1953. We thus lose about one-third of those we graduate as engineers from our engineering schools and in return we gain comparatively few to the profession from other sources. A more realistic figure then for our capacity to add to the engineering segment of our labor force is 1⅓ percent, and this, I believe, is one we can hope to exceed only with considerable difficulty.

NEED FOR TECHNOLOGICAL MANPOWER

My third point is that our need for technically trained people has increased continuously in the past and may be expected to do so in the foreseeable future. A National Science Foundation study on our scientific personnel resources (*2*) traces the growth in the percentage of our population engaged in professional work in science and technology over an 80-year period from 1870 to 1950. This percentage was, in 1870, 1910, and 1950, 0.03, 0.2, and 0.7, respectively. The basis for this steady increase, of course, has been the continuous growth in the complex technological nature of our civilization over this 80-year period. Certainly, we can say that this growth has continued over the decade since 1950. I know of nobody, certainly no responsible spokesman for science, who is willing to predict any cessation in this trend. It, therefore, seems a valid procedure to extrapolate this curve upward.

PERMANENT SHORTAGE OF TECHNOLOGICAL MANPOWER

My fourth point, which is a corollary of my points 2 and 3, is that our needs for technically trained people, which we have always been able to satisfy in the past, may shortly be expected to outrun permanently our ability to satisfy them. This means that our shortage of scientists and engineers has become chronic.

It is interesting to compare the 0.7 percent figure, which I just quoted, and which since 1950 may well have increased to nearly 1 percent with the 1⅓ percent figure for our capacity to produce engineers, which I cited previously. The figures are not directly comparable since the first one includes not only engineers but also all professional technical people, and the second one is our rate of production of engineers and not their total number. Nevertheless, I believe, that with a more careful analysis of these figures than I am prepared to make here, one can satisfy himself that we will very shortly reach the point where we will always need more scientists and engineers than we are able to produce. This does not say that in times of business recessions, like last year, there may not appear to be temporary easing of the shortage, but this is a transient market condition associated with the business cycle and we should not be misled by it. When business turns upward again, the engineer and scientist shortage will be back with us once more and in a more acute form than ever.

IMPLICATION FOR EDUCATIONAL SYSTEM

So much for our needs for technically trained people in the Age of Technology. What are the implications of the Age of Technology for education? Actually, it has implications for every phase and at every level of our educational system.

To begin with, in assessing our educational system, it is important to do so with respect not to the world of today but to that of tomorrow. For it is in tomorrow's world that the school children and the college students of today will take their places as contributors to our society. Education must, therefore, take a long range point of view. Specifically, what can we do to educate adequate numbers of scientists and engineers to fill the needs which, I hope I have convinced you, exist today and are going to grow more acute as time goes on? How long it takes to observe any noticeable change in our output of engineers, after we take specific action to increase it is illustrated by an experience only too fresh in the minds of many of us. Between World War II and the Korean War we misjudged our technological manpower needs. Official government sources, as well as general public opinion, supported the view that our needs for engineers were amply provided for and that opportunities in the engineering profession were limited. It was not until after the outbreak of hostilities in Korea in 1950 that we awoke to the fact that we were facing an engineer shortage instead of an engineer surplus. Although the nature of the shortage immediately became obvious to employers of engineers, to placement officers of engineering colleges and to those in Government concerned with manpower problems, it was not until six years later, in 1956, that the curve of engineering graduates turned upward. It took two years of market stimulation, government-backed publicity, and strong public leadership to overcome the inertia of the public attitude toward the profession and its opportunities, plus four more years, the length of an undergraduate college course, before any effective increase in the rate of production of engineers could be observed. In other words, the lead time for the production of engineers is at least six years.

Since we must be looking at least 6 years ahead it is obvious that we should not allow ourselves to fall into the trap of responding to the short-term fluctuations of the business cycle. As far as national policy is concerned, we can hope for a basic enough understanding of the problem on the part of those who determine it to prevent this, but unfortunately, we do not determine as a matter of national policy, as for example they do in Soviet Russia, how many high-school graduates enter engineering school in a given year. This is done by the high-school graduates themselves. There is some recent disturbing evidence that they may be very sensitive to the immediate state of the market. The first Russian sputnik went up in October 1957. Something like a near panic gripped the nation. Science and engineering and their national importance were brought into the focus of public attention as never before. General expectation was that engineering freshman enrollments which had been slowly and steadily increasing in recent years would take a sudden spurt upwards in the fall of 1958. What happened? They actually turned downward. The United States Office of Education tells us *(3)* that freshman engineering enrollment decreased 11.1 percent below that of 1957, whereas total college first-time enrollments increased 7.0 percent. What turned the graduates away from engineering? Nobody has the answer for sure, but among the various possible answers the most likely one seems to be that it was the result of the recession of 1957–58 and the wide publicity that attended the slight easing of the tight market for engineering talent that had prevailed continuously since 1950.

In the guidance of these young students, the high-school teachers of science and the high-school guidance counsellors play a vital role. The teachers can stimulate the interest of the promising students in scientific careers and direct them into the right courses to prepare them adequately for college entrance in engineering or science. The counsellor can make the students aware of the opportunities in these fields. The actual beginning of a career in science is in the early years of high school. A mathematics or science course, not taken then, may bar the student from the college science course he may wish to elect later. There is a trend in the engineering colleges toward raising admission standards. Too often in the past, the colleges have had to make up deficiencies left by inadequate high school preparation. The pressures on the modern engineering curriculum are great and there is no room in the college curriculum for high school mathematics. This puts the responsibility squarely where it belongs—on the high school.

ELEMENTARY AND HIGH SCHOOL

Actually the conditions of the Age of Technology will require, I believe, in the long run, a reorientation of the objectives of our system of free public education. For many years, the emphasis has been on personality development and social adjustment of the school child. Little has been done to stimulate, intellectually challenge and develop the gifted child. We will not much longer be able to tolerate the waste involved in moving all of our students through the same curriculum at the same pace, the gifted along with the dull.

Particularly is this true at the high-school level. Personality development and social adjustment may well be the most important considerations in the early grades of elementary school, but when we come to the high-school level, in my opinion, the primary function of the school should be to teach subject matter, and we should make much greater demands on the scholarship of the students than we do today. Academic standards should be strictly maintained and there should be greatly increased emphasis on mathematics and science. Opportunities should be provided for the better students to progress at a more rapid rate in separate classes and their subject matter should be greatly extended. We simply cannot afford to spend four years of the precious time of those members of society who form our most critical national resource coasting along in academic low gear as we do now.

HIGHER EDUCATION

Turning now to higher education in science and engineering, we find that the engineering schools, being very close to the technological developments of recent years and in many cases playing an important role in them, as partners with government and industry, have responded much more quickly to changing educational needs than have the high schools. The result is that in the case of undergraduate engineering education the reorientation toward new objectives is already far along. Our American engineering education has traditionally been one of schooling the young engineer heavily in engineering practice. The new trend is to give him a good solid foundation of mathematics and pure and engineering sciences as a base for his later work in engineering practice. Engineering practice changes rapidly and soon becomes obsolete in the complex and rapidly developing technology of today. Furthermore, the multiplicity of the specific fields of engineering practice is great. The young engineer cannot be trained in all of them while he is in college, and if he is trained in one he quite probably will end up working in another. Finally the engineering colleges are not in a good position to train in engineering practice, because the seat of knowledge of engineering practice is in industry and not in the colleges. It is more important for the engineering student to gain a comprehensive understanding of the laws of nature and a facility in the use of the mathematical and scientific tools by which engineering problems are attacked than to master their detailed application in a specific field. Experience shows that it is not possible for him to do both in the short span of a four-year undergraduate course.

Along with the changes occurring in undergraduate engineering education has come a greatly increased emphasis on graduate work. A 4-year college training is inadequate in depth to equip an engineer to undertake successfully much of the work he is called upon to perform in the Age of Technology. This is particularly true in the creative work of research and development, which now absorbs the efforts of over 30 percent of our total professional technological force. The shortage of engineers is acute, but that for engineers trained to the graduate level is doubly so. In this area the pure sciences are far ahead of engineering, the number of doctorates granted annually in physics alone approximately equalling those granted in all fields of engineering. Much is being done by the fellowship and loan programs of the Federal Government and others as well as by the provision of opportunities for part-time employment during graduate study to enable qualified engineering students to continue for graduate work. The kernel of the problem here is to support our institutions of higher education so that they may attract adequate numbers of highly qualified faculty members in competition with private industry.

EDUCATION IN INDUSTRY

The final segment of the educational system is the newest part of our formal educational structure, education in industry. It is a segment which might have been ignored as recently as a few decades ago, but which certainly cannot be ignored today. It is one which may be expected to expand rapidly in the future. It is a phenomenon of the Age of Technology.

Formal technical educational programs in industry have grown up in response to two needs. The first is that of industry to train its own employees in its own technology. I have already noted that the engineering schools are now emphasizing fundamental science at the expense of engineering practice. Where then does the young engineer learn his engineering practice? The answer is in industry. Employers today accept the need for training their new engineering employees as a necessary step in the development of their engineering staffs. There is no clamor that I can detect to persuade the colleges to relieve them of this burden. The reason is that they prefer to give their own employees their own kind of training in their own field.

The second need which brings educational programs into being in industry is the need to keep engineering staffs up to date. In today's rapidly developing technology, we know that our physical equipment will become obsolete soon enough. What we should be concerned about is the obsolescence of our engineers and scientists. Obsolescence is the fate of any engineer or scientist who allows his own field of technology to pass him by or who allows himself to be outflanked by a competing technology. The preventive is continuing education. No engineer can afford to neglect his continuing education. Industry and the nation faced in the future, as I hope I have convinced you, with a chronic shortage of engineers and scientists cannot afford to neglect it either. An engineer kept in technological midstream by continuing education rather than being swept into the eddy of obsolescence may not increase our technological nosecount, but he certainly does increase our technological potential. Quality counts as well as quantity.

By no means all this industrial educational effort is vocational in nature or is specific training in engineering practice. Particularly in the second area, that of continuing education, the great need is for the upgrading of long service technical personnel in the fundamentals which have come into the engineering curriculum since they went to school. Here the universities can be of great service and here too a reorientation of our thinking in higher education is called for. Our present higher educational system is largely built on the assumption that once a student is educated to a certain level and has received certification for this in the form of a degree, that he is equipped for life with a level of technical competence corresponding to the degree. Nothing could be further from the truth. A master's degree of 1940 is not the equivalent of a master's degree of 1960, unless a lot has gone on in between in the form of continuing education. Whole new fields of knowledge and whole new technologies have grown up. The typical engineer or scientist has specialized and kept up through his own efforts with the new developments in his own specialty. But increasingly, he finds himself less and less able to understand what goes on about him outside of that specialty. When called upon to change his field, as he sooner or later probably will be, he finds himself in a poor competitive position with respect to the younger men with more modern educations. This is a problem in which we have only begun to scratch the surface. I predict that as our present technological labor force whose age distribution is now so heavily peaked at the younger years, ages and as the shortage of technical manpower becomes more acute, we are going to have to do much more about it than we do now. Training programs in industry, not for new employees, but for longer service ones, cooperative programs with universities for older technical employees, I feel sure will see a great growth in future years. These will often be nondegree programs, and when done by universities industry will be prepared to foot the bill. I can cite you several examples of such programs taken from our own company which are in existence at the present time. In Bell Telephone Laboratories we have an extensive program of out-of-hours courses taught by the members of our own technical staff, as well as tuition refund plans to encourage and facilitate the continuing education of our employees at universities. Each year the operating telephone companies of the Bell System send to us about 50 young engineers to learn the latest developments of the communications art. The New York Telephone Co. and the Southern Bell Telephone & Telegraph Co. have joint programs with Cornell University and Clemson College to which their engineers are sent to be brought up to date in the fundamentals underlying the technology of telephone transmission. The Bell Telephone Co. of Pennsylvania has a program with similar objectives, but does it for itself. The Western Electric Co., the manufacturing arm of the Bell System, sends its experienced engineers at intervals, to training centers, where with the help of universities, it offers them courses in the fundamentals underlying important new areas of technology. Other Bell System companies and other companies outside the Bell System are also active in this field. Industry will move to solve its own problems as they become acute, but I think there is little appreciation in university circles of the magnitude of this field of education and the part that they are going to be called upon to play in it. Coming on top of the foreseeable demands on them for supplying undergraduate education, resulting from the population bulge following World War II and the need for great expansion in graduate engineering education, this educational responsibility will not be easy to discharge and yet, I believe, is one which it is proper for our system of higher technical education to assume.

CONCLUSION

These are exciting times in which we live. Perforce we are all gamblers because the one thing we can be sure of in the Age of Technology is change—rapid change. Statesmanship, business management, educational administration, have become largely a matter of trying to anticipate the direction and rate of this change. I have made bold to try to look into the future in several directions which seem to me to be of importance to some who may be in this audience. If I am right, I hope that what I have said may be useful. If I am wrong, I hope that at least it has not been dull.

REFERENCES

(1) Wolfle, Dael. *America's resources of specialized talent:* 332 pp. Harpers, 1954.

(2) National Science Foundation. *Scientific personnel resources:* 86 pp. Washington, 1955.

(3) U.S. Department of Health, Education, and Welfare, Office of Education, Circular 554. December 1958.

GEOLOGY.—*The Wolfcamp Series (Permian) and new species of fusulinids, Glass Mountains, Texas.*[1] Charles A. Ross, Peabody Museum, Yale University. (Communicated by Herbert H. Ross.)

(Received May 29, 1959)

INTRODUCTION

The Wolfcamp Series in the Glass Mountains, Tex., is represented by a sequence of diverse lithologies and includes a regional unconformity. A detailed study of these strata reveals that two formations can be recognized in the field and that both units are within the "Zone of *Pseudoschwagerina*" (Fig. 1). Each formation has a distinct and characteristic fusulinid fauna. The Nealranch formation embraces the upper part of beds originally called Wolfcamp by Udden (1917) in the Wolf Camp Hills and is renamed to retain this widely used name for the time-stratigraphic unit, the Wolfcamp Series. The Lenoxhills formation unconformably overlies the Nealranch formation and is the upper formation of the Wolfcamp Series in the Glass Mountains. It was in part included in the Wolfcamp formation of King (1931), where it crops out in the western Glass Mountains and is now known to be present across the southern escarpment of the eastern Glass Mountains, and is the lower 200 to 300 feet of the Hess formation of Udden (1917). The correlation of these stratigraphic units with strata in other regions is determined on the basis of their fusulinid faunas.

The exact placement of the top of the Pennsylvanian system in the Glass Mountains has long been a major controversy. Fusulinid faunas of Cisco (Virgil) age are known from strata as high as the "grey limestone" of King (1931 and 1937). In the Wolf Camp Hills the Nealranch formation (300 to 470 feet thick) unconformably overlies the "grey limestone" and contains the oldest *Schwagerina* and *Pseudoschwagerina* faunas thus far discovered in the Glass Mountains. The boundary between the Permian and Pennsylvanian systems is taken at this unconformity. The Nealranch formation is truncated and has been removed for some distance east of the Wolf Camp Hills by pre-Lenoxhills erosion. At Gap Tank, about 10 miles east of the Wolf Camp Hills, 90 feet of Nealranch strata have been preserved from pre-Lenoxhills erosion in a faulted syncline which formed before Lenoxhills deposition.

In the western part of the Marathon Basin at the foot of the Lenox Hills, 6 miles west of Marathon, faulted and folded strata locally contain *Pseudoschwagerina uddeni* (Beede and Kniker), *Schwagerina puguncu-lus*, n. sp., and *Triticites uddeni* Dunbar and Skinner. Thus the Nealranch formation was deposited in the western part of this area prior to the last major tectonic pulse of the Marathon orogenic belt.

The Wolf Camp Hills, Gap Tank, the foot of the Lenox Hills, and probably the base of the Hess ranch horst have the only known outcrops of the Nealranch formation in the Glass Mountains.

The Lenoxhills formation unconformably overlies the Nealranch, Gaptank, and older strata of the Marathon orogenic belt. The type section of the Lenoxhills formation is in the Lenox Hills west of Marathon, where it is composed of 130 feet of conglomerate at its base succeeded by 160 feet of sandstone, clastic limestone, and shale. To the southwest in the Lenox Hills the entire formation changes facies into conglomerate. Further to the southwest at Dugout Mountain, the conglomerate changes facies into sandstone and shale (150 feet thick) and finally into limestone and shale. Throughout the Glass Mountains the Lenoxhills formation is marked by a persistent basal conglomerate, but the strata above change facies within short distances.

Northeast of the Lenox Hills, the formation changes into a shale facies and is thin (120 feet) just west of Iron Mountain. At Leonard Mountain the Lenoxhills formation forms the southern and eastern facies. Here the shale units intertongue eastward into

[1] From a dissertation submitted to the Department of Geology, Yale University, in partial fulfilment of requirements for Ph.D.

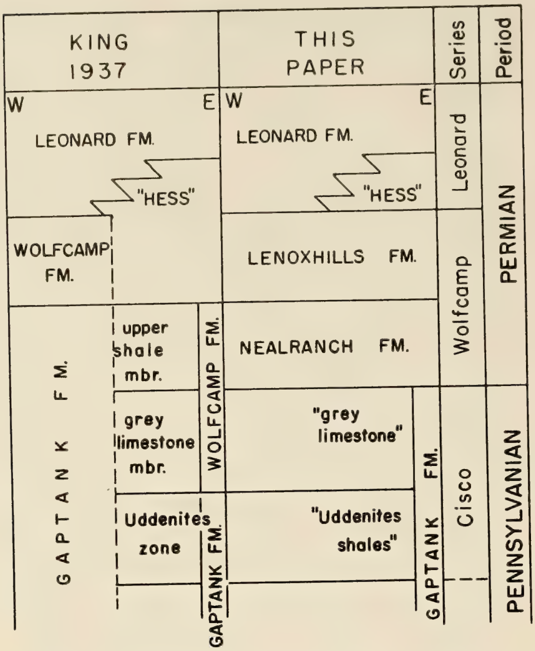

Fig. 1.—Stratigraphic terminology as used by King (1937) and in this paper. In the table W represents the western Glass Mountains and E the eastern Glass Mountains.

biohermal limestones which form the eastern face. Farther to the east from the Hess ranch house to the vicinity of the Wolf Camp Hills these biohermal strata intertongue into silty thin-bedded limestones, 200 to 300 feet thick. Eastward from the Wolf Camp Hills, the thin-bedded limestones of the Lenoxhills formation intertongue with red and varicolored shales, and green cross-bedded sandstones of the marginal marine facies. Throughout much of this eastern area the basal conglomerate of the Lenoxhills formation fills valleys cut into the limestone beds of the Gaptank formation.

The Leonard formation unconformably overlies the Lenoxhills formation in the western Glass Mountains. Locally pre-Leonard erosion has removed most of the Lenoxhills formation and as at the southwest end of Dugout Mountain and in the northern part of the Lenox Hills the base of the Leonard formation rests on the truncated edges of the folded and faulted beds of the Marathon orogenic belt. In the eastern part of the Glass Mountains the Leonard formation overlies the limestone and shale of the Lenoxhills formation with no apparent unconformity, being rather a sharp change in facies into thick units of thin bedded limestone.

The "grey limestone" of King (1931) contains the youngest Pennsylvanian fauna in the Wolf Camp Hills and includes *Triticites comptus* n. sp., *T. ventricosus* (Möller), *T. pinguis* Dunbar and Skinner, and *T. koschmanni* Skinner (Fig. 2).

The fusulinids which characterize and are restricted to the Nealranch formation in the Wolf Camp Hills include: *Triticites uddeni* Dunbar and Skinner, *Schwagerina emaciata* (Beede), *S. pugunculus*, n. sp., *Pseudoschwagerina uddeni* (Beede and Kniker), *Paraschwagerina acuminata* Dunbar and Skinner, and *P. gigantea* (White). In addition the following species range into the Nealranch formation: *Triticites ventricosus* (Möller), *T. pinguis* Dunbar and Skinner *T. koschmanni* Skinner, *Pseudoschwagerina beedei* Dunbar and Skinner, and *P. texana* Dunbar and Skinner.

Fusulinids which characterize and are restricted to the Lenoxhills formation in the western Glass Mountains are: *Schwagerina extumida,* n. sp., *S. lineanoda,* n. sp., *S. dispansa*, n. sp., *S. laxissima* Dunbar and Skinner, *S. bellula* Dunbar and Skinner, *Pseudoschwagerina tumidosus*, n. sp., and *P. robusta* (Meek). In addition the following species range into the Lenoxhills formation: *Schwagerina compacta* (White), *S. tersa*, n. sp., *S. crebrisepta*, n. sp., *S. nelsoni* Dunbar and Skinner, *S. knighti* Dunbar and Skinner, *S. diversiformis* Dunbar and Skinner, *Paraschwagerina plena*, n. sp., *Pseudoschwagerina beedei* Dunbar and Skinner, *P. texana* Dunbar and Skinner, *Parafusulina linearis* (Dunbar and Skinner), and *P. schucherti* Dunbar and Skinner.

Descriptions of the new species mentioned above follow.

Triticites comptus, n. sp.

Pl. 1, figs. 1–3, 5

Description—This elongate, subcylindrical species commonly reaches a length of 9.2 mm and a diameter of 2.0 mm in six to seven volutions. The tightly coiled compact early whorls, regularly and highly folded septa, rudimentary

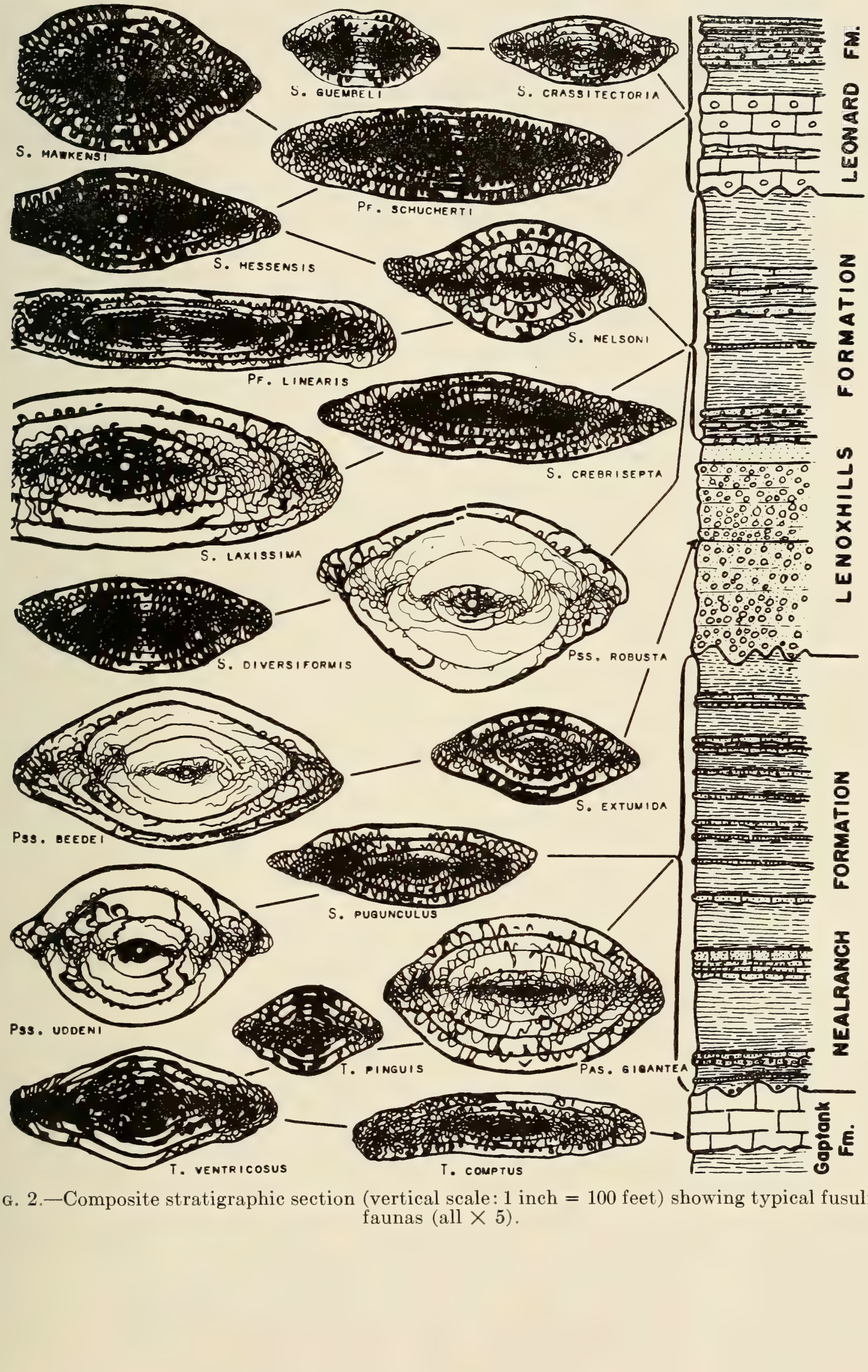

Fig. 2.—Composite stratigraphic section (vertical scale: 1 inch = 100 feet) showing typical fusulinid faunas (all × 5).

chomata, and curved axis of coiling are distinctive of this species (Pl. 1, figs. 1, 5).

In specimens examined the proloculi are small, averaging 0.10 mm outside diameter. The first two or three volutions are tightly coiled and elongate, attaining form ratios of 2.5 to 3.2. Succeeding volutions are higher and become greatly extended along the curved axis of coiling; the form ratio in the sixth or seventh volution generally exceeds 4.5. The long polar extremities are narrow and unevenly rounded and overlap irregularly the preceding half volution (Pl. 1, figs. 2, 5). The chambers increase slightly in height laterally away from the midplane. The shape of the lateral slopes is regular but tends to be convex in most volutions.

The wall is composed of a thin tectum and a thin, indistinct keriotheca. The wall thickness gradually increases from 0.005 mm in the proloculus to 0.05 mm in the sixth or seventh volution. The wall thickness remains nearly constant from the midplane to the polar extremities.

The septa are thin and highly fluted into closely spaced, nearly regular folds, which extend laterally across the entire chambers (Pl. 1, fig. 5). As seen in the sagittal section (Pl. 1, fig. 3), the septa are extremely numerous per volution and are inclined steeply from the antetheca towards the floor of the chamber. The folds often reach the top of the chamber and have steep nearly parallel flanks and acutely rounded crests.

The tunnel, narrow in the first three or four whorls, expands gradually in later whorls. The tunnel angle measures 18° in the first volution, 25° in the third, and 40° in the fifth or sixth whorl. The tunnel is well defined by either low chomata or breaks in the closely spaced, highly folded septa throughout all but the outer volution (Pl. 1, figs. 1, 5). The path of the tunnel includes the midplane of the shell. The antetheca beneath the tunnel is often thinner than the antetheca on the lateral slopes and apparently has been slightly resorbed by the tunnel. Chomata are rudimentary in the shell and form as thin, high deposits connecting adjacent septal folds of the successive chambers (Pl. 1, fig. 3). Secondary axial deposition, common in the first two or three whorls, gives this portion of the shell a dense, dark appearance. These deposits form as septal thickening in the lateral regions of the early whorls.

Discussion.—*Triticites comptus*, n. sp., is similar in shape and general internal structures to *T. joensis* Thompson, *T. osagensis* Newell, *T. tenuis* Merchant and Keroher, *T. plicatula* Merchant and Keroher, *T. ohioensis* Thompson, and *T. collus* Burma. From these species *T. comptus* differs in lacking well-defined chomata and having more regularly and highly folded septa across the shell.

The stratigraphic occurrence of this highly specialized species of *Triticites*, *T. comptus*, indicates that it is probably similar to the undescribed species mentioned by Thompson (1957, p. 300) from the lower Virgil of the Midcontinent region. The species takes its name from the Latin *comptus*, meaning ornamented, elegant, refer-

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20550	20551	20555	20554	20552
radius vector	0	.05mm	.05mm	.06mm	.04mm	.05mm
	1	.07	.08	.11	.08	.10
	2	.10	.12	.19	.12	.16
	3	.20	.20	.30	.20	.23
	4	.31	.30	.48	.30	.32
	5	.53	.48	.70	.47	.47
	6	.77	.70	1.00	.65	.62
	7	—	.98	—	.90	.88
half length	1	.19mm	.19mm	.28mm	.12mm	12*
	2	.30	.38	.45	.38	16*
	3	.57	.62	1.00	.65	22*
	3	1.15	1.01	1.90	1.20	23*
	5	2.40	2.00	3.40	1.40	27*
	6	3.60	2.40	5.30	1.90	32*
	7	—	4.60	—	3.90	29*
form ratio	1	2.7	2.4	2.5	1.5	
	2	3.0	3.2	2.4	3.2	
	3	2.8	3.1	3.3	3.2	
	4	3.3	3.3	4.0	4.0	
	5	4.5	4.2	4.9	3.0	
	6	4.7	3.4	5.3	2.9	
	7	—	4.7	—	4.3	
tunnel angle	1	26°	18°	—	—	
	2	28	24	24°	18°	
	3	30	26	30	20	
	4	32	29	44	24	
	5	—	39	45	28	
	6	—	43	—	20	
	7	—	—	—	—	
wall thickness	0	.003mm	.007mm	.02mm	.007mm	
	1	.003	.009	.005	.008	
	2	.005	.01	.007	.01	
	3	.01	.01	.01	.01	
	4	.02	.02	.005	.01	
	5	.02	.03	.01	.02	
	6	.05	.04	.03	.06	
	7	—	.05	—	.05	

* Number of septa.

ring to the close, regularly folded septa seen in thin-section.

Occurrence.—Upper part of the Gaptank formation in the Wolf Camp Hills, at Leonard Mountain, and in the syncline four miles west of Marathon, Tex.

Holotype.—YPM 20551, Yale Peabody Museum, illustrated Pl. 1, fig. 5, Gaptank formation, Wolf Camp Hills.

Schwagerina crebrisepta, n. sp.

Pl. 4, figs. 1–3, 5

Description.—This large, elongate species commonly reaches 13 mm in length and 3 mm in diameter in seven volutions. In thin section specimens show a marked division between early and late growth patterns; the young shell is tightly coiled with secondary deposits and the adult shell is loosely coiled with secondary deposits in irregular patterns along the axis.

The proloculus of the holotype (Pl. 4, fig. 3) is 0.10 mm outside diameter and is spherical. The size of the proloculi in other specimens examined is remarkably consistent averaging 0.10 mm in diameter with little variation. The first three to four volutions are tightly coiled and growth during this stage is mainly along the axis. Form ratios of 3.0 to 4.0 are common in the first four volutions. The fifth volution shows a distinctive increase in chamber height as well as a considerable increase in length. The form ratio remains constant or decreases slightly in this volution, but in later volutions it increases reaching as much as 4.3 in the seventh one. The chamber height in the adult whorls increases gradually in the center of the shell, but in the lateral and polar extremities the height increases greatly giving the shell a subcylindrical shape.

The wall is thin in the proloculus, 0.005 to 0.01 mm thick, and in the early whorls reaches only 0.03 mm. The adult whorls thicken gradually to about 0.10 mm in the last whorl.

The septa are thin and highly folded (Pl. 4, fig. 3). These folds have steep sides, reach to the top of the chambers, and are rounded to subacute at their crests in the adult whorls. In the early whorls the folds are flattened across their crests. Throughout the shell, the closely spaced folds show a regular pattern, each septum having folds of uniform height. The septa form parallel to the axis of coiling.

The tunnel angle ranges between 15° and 25° in young shells, but increases gradually to a width of 30° in the sixth volution and is one-third the height of the adult chambers. The tunnel path deviates as much as 10° out of the midplane of the shell. Chomata are rudimentary in the early whorls and completely lacking in the adult whorls. Secondary deposits fill the young volutions except near the midplane and in the first three adult whorls these deposits fill the axial extremities. The septa in the remaining portions of the shell show evidence of secondary deposition at the crests of their folds. False walls are common in the specimens examined; however, they are not present in whorls with axial fillings.

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20634	20632	20631	20630
radius vector	0	.05mm	.05mm	.05mm	.05mm
	1	.12	.11	.09	.09
	2	.19	.20	.12	.11
	3	.30	.32	.20	.21
	4	.52	.51	.32	.40
	5	.80	.86	.60	.70
	6	1.15	1.20	1.00	1.10
	7	1.50	1.50	1.40	1.45
half length	1	.25mm	.22mm	.11mm	.10mm
	2	.65	.50	.38	.20
	3	1.15	1.10	.52	.50
	4	2.10	1.95	.90	1.15
	5	3.10	2.80	1.85	2.15
	6	4.65	4.00	3.40	2.80
	7	6.40	5.75	4.20	4.70
form ratio	1	2.0	2.0	1.2	1.1
	2	3.4	2.5	3.2	1.8
	3	3.8	3.4	2.6	2.4
	4	4.0	3.8	2.8	2.9
	5	3.9	3.3	3.1	3.1
	6	4.0	3.3	3.4	2.5
	7	4.3	3.8	3.0	3.2
tunnel angle	1	20°	18°	15°	24°
	2	20	17	18	28
	3	25	22	28	28
	4	30	25	24	25
	5	30	21	17	23
	6	29	28	23	30
	7	—	—	—	—
wall thickness	0	.01mm	.01mm	.01mm	.005mm
	1	.01	.01	.008	.005
	2	.01	.02	.01	.008
	3	.02	.03	.01	.01
	4	.04	.05	.03	.03
	5	.09	.08	.03	.09
	6	.11	.12	.06	.11
	7	.10	.12	.08	.10

Discussion.—*Schwagerina crebrisepta* is similar in general internal structure to *S. franklinensis* Dunbar and Skinner but has distinct young and mature regions, a larger size per volution, and notable axial deposition. *S. complexa* Thompson is similar in size and ontogeny but has greater inflation in the adult chambers, less tightly and less regularly folded septa, and is more fusiform. The specific name *crebrisepta* from the Latin, many septa, refers to the abundant septa seen in thin sections of this species.

Occurrence.—Lenoxhills formation in western Glass Mountains, Tex., reworked specimens in lower part of the Leonard formation.

Holotype.—YPM 20634, Yale Peabody Museum, illustrated Pl. 4, fig. 3; from Lenoxhills formation, north of Hess ranch horst.

Schwagerina dispansa, n. sp.

Pl. 2, figs. 7–12

Description.—The shell of this species commonly attains a length of 9.5 mm and a diameter of 3.5 mm in seven to eight volutions. The outer two or three whorls are greatly extended along the axis and give the shell long winglike projections. The inner whorls are shorter and more loosely coiled. The regularly folded septa, early globose volutions and later extension of the shell along the axis, and medium to small size distinguish this species.

In specimens examined, the proloculi are aspherical to spherical and range in size from 0.04 to 0.16 mm outside diameter. As shown in Pl. 2, fig. 8, the initial whorl is often highly inflated and irregular, with a form ratio of 2.0. The succeeding two or three volutions have thick fusiform outlines and increase in height and length proportionally, retaining form ratios of 2.0. In the outer two or three whorls the chambers extend laterally along the axis as long extended polar extremities, and the form ratio increases to 3.0 (Pl. 2, fig. 7, 12). The poles of these mature volutions are evenly rounded and the lateral slopes concave. The chambers in the early whorls are nearly constant in height from the center to the poles, but in later whorls they show a great increase in height in the extended polar extremities.

The wall is composed of a tectum and a thick, coarsely alveolar keriotheca. The wall remains constant in thickness from the center of the shell to the polar extremities. It is commonly 0.01 mm thick in the proloculus and gradually increases to 0.10 mm thickness in the last volution. In specimen YPM 20628 (Pl. 2, fig. 7) the wall in the minute proloculus is 0.003 mm thick.

The septa are strongly and regularly folded throughout the shell. The folds are symmetrical with nearly straight sides and rounded crests and they are evenly spaced across the entire chambers. The basal margin of folds of one chamber generally touches the opposing folds in adjacent chambers. Cuniculi are not observed in these shells, but as shown in specimen YPM 20627 (Pl. 2, fig. 10) the formation of the tunnel results in resorption of the base of the septa and this gives the impression of one well-developed cuniculus on each side of the tunnel.

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20628	20629	20625	20626
radius vector	0	.04mm	.12mm	.16mm	.14mm
	1	.09	.20	.27	.27
	2	.10	.39	.47	.41
	3	.19	.70	.72	.65
	4	.30	1.15	1.10	.90
	5	.52	1.55	1.35	1.30
	6	.95	1.80?	—	1.70?
	7	1.35	—	—	—
	8	1.60	—	—	—
half length	1	.09mm	.45mm	.45mm	.65mm
	2	.20	.85	.72	.90
	3	.32	1.50	1.35	1.30
	4	.60	2.55	2.00	1.90
	5	1.00	3.65	2.95	2.95
	6	1.60	5.35	—	4.30
	7	2.80	—	—	—
	8	4.90	—	—	—
form ratio	1	1.0	2.2	1.7	2.4
	2	2.0	2.2	1.5	2.2
	3	1.7	2.2	1.9	2.0
	4	2.0	2.2	1.8	2.1
	5	1.9	2.4	2.2	2.3
	6	1.7	3.0?	—	2.5
	7	2.1	—	—	—
	8	3.1	—	—	—
tunnel angle	1	28°	17°	21°	22°
	2	30	27	23	27
	3	32	24	17	27
	4	32	31	—	36
	5	24	—	—	—
	6	29	—	—	—
	7	38?	—	—	—
wall thickness	0	.003mm	.01mm	.007mm	.02mm
	1	.003	.01	.02	.02
	2	.008	.03	.02	.03
	3	.01	.03	.07	.03
	4	.02	.10	.08	.06
	5	.04	.15	.08	.08
	6	.07	.10	—	.09?
	7	.09	—	—	—
	8	.10	—	—	—

The straight tunnel is of medium width, the tunnel angle is 20° in the first whorl with a gradual increase to 35° in the fourth or fifth whorl. The septa are resorbed to about one-half chamber height to form the tunnel. Chomata are rudimentary and are present only on the outer surface of the proloculus. Secondary deposits occur in about two-thirds of the specimens examined, and may be thick in the axial region or thin coatings on the septa throughout the shell. Falsewalls are common in shell chambers which lack axial fillings (Pl. 2, fig. 7, 12).

Discussion.—*Schwagerina dispansa* is a rare species that is seemingly closely related to *S. knighti* Dunbar and Skinner. *S. knighti* is much larger and has several more highly globose volutions than does *S. dispansa,* but variation within *S. knighti* is poorly known. Axial deposits when present in *S. dispansa* are apparently distinctive. *S. dispansa* is similar in shape to *S. nelsoni* Dunbar and Skinner but is smaller when mature and has a considerably different ontogeny.

The species takes its name from the Latin *dispansa,* meaning stretched out, and refers to the extended polar extremities in the mature shell.

Occurrence.—Lenoxhills formation in western and central Glass Mountains, Tex.

Holotype.—YPM 20628, Yale Peabody Museum, illustrated Pl. 2, fig. 7; from the Lenoxhills formation, north of the Wolf Camp Hills.

Schwagerina extumida, n. sp.

Pl. 3, figs. 4–7, 9

Description.—This thickly fusiform species commonly attains a length of 9 mm and a diameter of 4 mm in seven to eight volutions. The form of the early whorls is globose and chamber height increases proportionally faster than axial elongation until the fifth volution. The later whorls become more elongate and have concave lateral slopes in the seventh and eighth volutions. The poles are small and acutely rounded. The wall in the outer whorls is extremely thick for shells of this size but it changes thickness appreciably from a maximum near the center to a minimum near the poles, a distinctive feature in this species (Pl. 3, fig. 6).

The proloculi are subspherical and in specimens examined range between 0.14 and 0.18 mm outside diameter. The first two whorls are low and in most specimens have a form ratio of 2.4 in this portion of the shell. The third, fourth, and fifth whorls increase notably in height but relatively little in length, giving form ratios of about 1.8. The chamber height remains constant, or nearly so, across the entire shell in these volutions. The sixth, seventh, and eight whorls show a considerable increase in length. The height of these chambers increases toward the poles to give the lateral slopes a slight concave outline (Pl. 3, figs. 6, 7).

The spiral wall is composed of a well-defined tectum and a thick, coarse keriotheca. In the center of the shell the wall thickness increases notably in the last two whorls to a maximum of 0.19 mm. In the lateral regions, the wall thins evenly toward the poles.

The septa are regularly and highly folded throughout the shell. They are closely folded in

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20648	20649	20646	20650
radius vector	0	.07mm	.09mm	.08mm	.09mm
	1	.12	.17	.12	.19
	2	.21	.31	.23	.38
	3	.36	.52	.45	.59
	4	.57	.70	.70	.90
	5	.71	1.20	1.00	1.30
	6	1.21	1.70	1.40	1.60
	7	1.65	2.00	—	—
half length	1	.20mm	.25mm	.25mm	.45mm
	2	.45	.50	.50	.80
	3	.65	.75	.70	1.20
	4	.95	1.20	1.30	1.75
	5	1.35	2.00	2.10	2.65
	6	2.15	3.30	—	3.80
	7	3.10	4.60	—	—
form ratio	1	2.4	1.5	2.1	2.4
	2	2.1	1.6	2.2	2.1
	3	1.8	1.4	1.6	2.0
	4	1.7	1.7	1.8	1.9
	5	1.9	1.7	2.1	2.0
	6	1.8	1.9	2.0	2.4
	7	1.9	2.3	—	—
tunnel angle	1	15°	20°	25°	22°
	2	15	20	25	22
	3	15	20	20	20
	4	20	20	20	20
	5	20	20	20	—
	6	15	—	—	—
	7	—	—	—	—
wall thickness	0	.008mm	.01mm	.007mm	.01mm
	1	.009	.015	.008	.03
	2	.015	.02	.012	.06
	3	.025	.07	.03	.07
	4	.080	.09	.08	.09
	5	.110	.15	.11	.12
	6	.180	.17	.14	?
	7	.190	.19	—	—

the first five volutions but the folds are spaced slightly farther apart in the outer whorls where the axis becomes elongate. Also the septa are somewhat farther apart in the outer whorls (Pl. 3, fig. 6) and the center of the septa lags behind the lateral portions during growth.

The tunnel is narrow throughout the shell. The tunnel angle reaches 25° in only one specimen examined, the average is about 20°. The tunnel is well defined by secondary deposits on the basal margin of the septa (pseudochomata) and occasionally as minor axial fillings (Pl. 3, fig. 9).

Discussion.—The rapid thinning of the wall toward the poles and the placement and type of secondary deposits make this species distinct from most other species of *Schwagerina*. *S. hessensis* Dunbar and Skinner is similar, however the large proloculus, elongate form, and nearly constant wall thickness of that species are distinctly different. *S. hawkinsi* Dunbar and Skinner is larger, more globose throughout the shell, and has secondary deposits reinforcing the septa throughout the entire shell. White (1932, Pl. 6, fig. 6) illustrates a form which is similar to this species and calls it *Triticites plummeri*, however that form is smaller, has well-developed chomata in the early whorls and is only superficially similar to *S. extumida*. Species derives its name from the Latin *extumida*, meaning swelled up.

Occurrence.—Lower part of the Lenoxhills formation in Hess ranch horst.

Holotype.—YPM 20649, Yale Peabody Museum, illustrated Pl. 3, fig. 9; Lenoxhills formation; Hess ranch horst.

Schwagerina lineanoda, n. sp.

Pl. 2, figs. 1–6

Description.—This small, subcylindrical species commonly reaches a length of 7.5 mm and a diameter of 2.5 mm in six volutions. The shape of the shell remains nearly constant during growth with only a gradual elongation along the axis of coiling. The poles are bluntly rounded and succeeding whorls form smoothly rounded poles without over hanging lips.

In specimens examined the proloculi are commonly aspherical and range in size from 0.16 to 0.24 mm outside diameter. The early whorls are low and establish the general shape of the shell by the second volution. The succeeding volutions increase gradually in height. The chambers, however, show an increase in height toward the polar extremities which causes gradual elongation of the shell along the axis and gives the shell a more cylindrical form in the outer volutions. The lateral slopes are convex throughout the shell. The form ratio increases from about 2.0 in the first or second whorl to about 3.0 in the sixth.

The wall is fairly thick for shells of this size and increases from 0.009 mm thick in the proloculus to 0.06 mm in the sixth volution. The wall is composed of a tectum and a finely alveolar keriotheca. It remains constant in thickness from the center of the shell along the lateral slopes to poles.

The septa are thick and tightly fluted into close, regular folds. In thin sections these folds are subcircular in outline, the greatest width of the folds being slightly above the floor of the chamber (Pl. 2, figs. 1–4). In axial section the folds appear as series of knots aligned on the floor of the chamber. The septal folds lap over

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20677	20675	20676	20674
radius vector	0	.12mm	.07mm	.11mm	.08mm
	1	.22	.20	.19	.12
	2	.33	.30	.29	.20
	3	.48	.48	.42	.30
	4	.72	.72	.70	.50
	5	1.00	.95	.95	.65
	6	1.20	1.20?	—	—
half length	1	.55mm	.30mm	.40mm	.20mm
	2	1.00	.70	.70	.45
	3	1.60	1.00	1.35	.80
	4	2.50	1.70	2.15	1.15
	5	3.30	2.45	2.80	1.60
	6	3.90	3.10	—	—
form ratio	1	3.3	1.5	2.1	1.7
	2	3.0	2.3	2.4	2.3
	3	3.3	2.1	3.2	2.7
	4	3.5	2.4	3.1	2.3
	5	3.3	2.6	2.9	2.5
	6	3.2	2.6	—	—
tunnel angle	1	28°	30°	28°	33°
	2	29	34	30	35
	3	29	35	35	32
	4	30	33	32	—
	5	—	—	—	—
	6	—	—	—	—
wall thickness	0	.008mm	.009mm	.009mm	.01mm
	1	.01	.02	.01	.01
	2	.03	.02	.02	.02
	3	.05	.04	.03	.04
	4	.07	.05	.07	.06
	5	.05	.07	.05	.07
	6	.06	.06	—	—

one another in the lateral regions of the early whorls, but this is not so in the central region. Cuniculi have not been observed. Although the septa touch each other (Pl. 2, fig. 5), the septal wall apparently is not resorbed at the point of junction. In the fourth and later whorls, the septa are widely spaced in many specimens and do not always touch one another.

The tunnel is wide in this species, 28° in the first volution, and gradually increases to about 35° in the third or fourth. Beyond the fourth whorl where the septa become widely spaced, the tunnel is difficult to trace in thin sections. Rudimentary chomata are common on the outer surface of the proloculus and in the first whorl, but are lacking in the rest of the shell. Secondary thickening of the septa in the axial region is common in adult specimens, but generally lacking in immature specimens (compare Pl. 2, fig. 1, with fig. 4, both specimens from the same sample).

Discussion.—*Schwagerina lineanoda,* n. sp., is similar to *S. crassitectoria* Dunbar and Skinner, but is more elongate, has more rounded septal folds, and a thicker spiral wall. *Parafusulina linearis* (Dunbar and Skinner) is more elongate, has heavier axial fillings, and more regularly folded septa.

The morphologic position of *S. lineanoda* between *Parafusulinea linearis* and *S. crassitectoria* suggests the three species are more closely related than previously suspected. The name, *lineanoda* from the Latin, having lined knots, refers to the appearance of the subround septal folds in thin section.

Occurrence.—Lenoxhills formation at Dugout Mountain and north of the Wolf Camp Hills, Tex.

Holotype.—YPM 20675, Yale Peabody Museum, illustrated Pl. 2, fig. 3; Lenoxhills formation, north of Wolf Camp Hills.

Schwagerina puguneulus, n. sp.

Pl. 1, figs. 8, 9, 12, 13

Description.—This large, fusiform species reaches a length of 11 mm and a diameter of 4 mm in six to seven volutions. The flat lateral slopes, small pointed poles, and highly folded septa are distinctive (Pl. 1, fig. 13).

The proloculi in specimens examined range between 0.12 and 0.26 mm outside diameter and are generally spherical. The first two or three volutions have low, long chambers which give form ratios between 2.0 and 3.7 depending on the individual specimen. The succeeding volutions become elongate along the axis of coiling. The chamber height increases markedly from the midplane toward the poles, and the lateral slopes are straight or slightly convex; in YPM 20777, however, one slope is slightly concave in the last volution. After the third whorl the volutions expand evenly and slowly having an early tightly coiled portion and late more loosely coiled portion that gives the shell a zoned appearance.

The wall gradually thickens from 0.01 mm in the proloculus to 0.10 mm in the seventh volution. It is composed of a tectum and well developed keriotheca with coarse alveoli. The keriotheca thins gradually toward the poles and is almost completely lacking around the poles.

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20719	20716	20777	20718
radius vector	0	.06mm	.07mm	.13mm	.11mm
	1	.12	.12	.21	.17
	2	.28	.26	.38	.30
	3	.50	.48	.65	.50
	4	.80	.62	1.00	.80
	5	1.15	1.10	1.42	1.20
	6	1.45	1.60	1.75	—
	7	—	1.90	—	—
half length	1	.30mm	.45mm	.45mm	.35mm
	2	.60	.80	.75	.70
	3	1.10	1.30	1.45	1.20
	4	2.20	1.80	2.20	2.15
	5	3.10	3.00	3.50	3.00
	6	5.20	4.50	5.00	—
	7	—	5.50	—	—
form ratio	1	2.5	3.7	2.0	2.1
	2	2.1	3.0	2.0	2.3
	3	2.2	2.7	2.2	2.4
	4	2.8	2.9	2.2	2.7
	5	2.7	2.7	2.5	2.5
	6	3.6	2.8	2.8	—
	7	—	2.9	—	—
tunnel angle	1	15°	15°	17°	23°
	2	15	17	21	19
	3	15	21	24	20
	4	17	19	25	32
	5	—	27	—	—
	6	—	—	—	—
	7	—	—	—	—
wall thickness	0	.01mm	.01mm	.02mm	.01mm
	1	.01	.02	.03	.02
	2	.02	.04	.03	.03
	3	.04	.08	.07	.03
	4	.07	.09	.10	.06
	5	.10	.10	.09	.09
	6	.10	.11	—	—
	7	—	.10	—	—

The septa are thick and are highly fluted from pole to pole (Pl. 1, fig. 12, 13). The sides of the folds are steep and nearly parallel along their basal margins. The crests of the folds are acutely rounded and extend to the top of the chambers. Small septal pores are common and are evenly distributed over the septal face.

The tunnel angle ranges between 15° and 32° in specimens examined and seems to expand gradually from a narrow beginning to its greatest width in the fourth or fifth volution. The path of the tunnel is slightly irregular, varying about 5° out of the midplane. Rudimentary chomata are common on the outer surface of the proloculus and in the first and second whorls. Slight secondary deposition is common along the axis as septal thickening which generally does not completely fill the chambers. False walls are not observed.

Discussion.—This species is similar in general size and form to *Paraschwagerina gigantea* (White) but lacks the tightly coiled juvenarium of that genus. *Schwagerina pugunculus* is similar in size to *S. hessensis* Dunbar and Skinner but lacks the thick walls, closely spaced, dense septa, and the early inflated whorls of that species. *S. pugunculus* differs from *S. diversiformis* Dunbar and Skinner, *S. compacta* (White) and *S. crassitectoria* Dunbar and Skinner by the lack of heavy axial deposits and differences in ontogeny.

S. thompsoni Needham is smaller and more inflated in its later volutions than is this species, but in other respects these two species appear closely related. At a given volution *S. elkoensis* Thompson is about half the size of *S. pugunculus*. *S. complexa* Thompson, which is similar in size and shape to *S. pugunculus*, has more highly inflated early adult chambers, more irregularly folded septa, less pointed poles and is smaller per volution.

Study of the Dunbar and Skinner collection shows that Dunbar and Skinner refer specimens of this species from the Nealranch formation (at Wolf Camp) to *S. franklinensis* Dunbar and Skinner. However, *S. franklinensis* is more slender and delicate in appearance and has a different ontogenetic growth. (*S. franklinensis* is present in the Glass Mountains but considerably higher in the stratigraphic section.) The species takes its name from the Latin *pugunculus*, short dagger, and refers to the short daggerlike appearance of the lateral slopes.

Occurrence.—Nealranch formation in the Wolf Camp Hills and at the base of the Lenox Hills, Tex.

Holotype.—YPM 20716, Yale Peabody Museum; illustrated Pl. 1, fig. 13; Nealranch formation, Wolf Camp Hills.

Schwagerina tersa, n. sp.
Pl. 1, figs. 4, 6, 7, 10, 11

Description.—This small, fusiform species commonly attains 7.5 mm in length and 2.5 mm in diameter in six to seven volutions. Throughout the shell the shape is ellipsoidal, the poles gently rounded, and lateral slopes convex.

In specimens examined, the proloculi range in size from 0.08 to 0.16 mm outside diameter, and the first two whorls are low and extend rapidly along the axis of coiling. After the shell has reached a length of 0.8 mm, the next volution increases markedly in height giving the shell the appearance of two growth stages. The lateral slopes are convex throughout the shell and the chambers remain constant in height from the center to the pole. Succeeding volutions overlap at the poles, but without forming a prominent lip; instead the underside of the whorls joins with and continues the profile of the preceding half volution (Pl. 1, fig. 4, 6, and 11).

The wall is composed of a tectum and a coarsely alveolar keriotheca. The wall in the proloculus is 0.007 mm thick and increases gradually to 0.09 mm in the sixth or seventh volution, and shows little or no decrease in thickness laterally away from the center of the shell.

The septa are highly fluted into closely spaced folds which extend to the top of the chambers (Pl. 1, fig. 4, 6, 11). The folds have steep flanks and gently rounded crests. Septal folds of one chamber overlap opposing folds of the preceding chamber only near the poles.

The tunnel is of medium width in the early whorls and gradually expands in later whorls; it measures 25° in the first volution and 40° in the fourth. The path of the tunnel follows the midplane of the shell with little deviation. Chomata, if present, are found only in the first and second volutions and on the outer surface of the proloculus, and are always rudimentary. Other secondary deposits are apparently lacking in this species.

Discussion.—*Schwagerina tersa* is a nondescript species which has all the characteristics of an idealized primitive *Schwagerina* species. These features include the medium to small size,

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20685	20684	20680	20682
radius vector	0	.07mm	.08mm	.08mm	.04mm
	1	.11	.13	.19	.09
	2	.19	.27	.32	.13
	3	.30	.43	.55	.24
	4	.48	.67	.80	.46
	5	.70	.95	1.10	.71
	6	.90	1.35	—	1.00
	7	—	—	—	1.35
half length	1	.23mm	.30mm	.42mm	.20mm
	2	.50	.55	1.10	.45
	3	.70	1.20	1.70	.55
	4	1.35	1.90	2.10	.95
	5	2.20	2.95	3.35	1.45
	6	3.20	3.70?	—	2.20
	7	—	—	—	2.95
form ratio	1	2.1	2.3	2.2	1.8
	2	2.6	2.8	3.4	3.5
	3	2.3	2.8	3.1	2.3
	4	2.8	3.1	2.6	2.1
	5	3.1	2.7	3.0	2.0
	6	3.6	?	—	2.2
	7	—	—	—	2.2
tunnel angle	1	25°	24°	26°	27°
	2	31	29	45	28
	3	29	34	48	?
	4	38	30	46	29
	5	55?	—	—	—
	6	—	—	—	—
	7	—	—	—	—
wall thickness	0	.008mm	.006mm	?	.006mm
	1	.008	.009	.01mm	.008
	2	.01	.01	.02	.01
	3	.02	.02	.03	.01
	4	.04	.05	.06	.03
	5	.06	.07	.08	.04
	6	.07	.08	—	.08
	7	—	—	—	.09

the even, elliptical outline of the volutions, the regularly folded thin septa, and the wide tunnel. It is similar to *S. emanciata* (Beede) but is larger, lacks well developed chomata, and has more closely and regularly folded septa. *S. grandensis* Thompson and *S. colemani* Thompson are about the same size and shape as *S. tersa,* but the walls of the early whorls in those species are thicker and the septal folding less intense. *S. vervillei* Thompson is similar in general shape, size, and interior structure but is notably smaller per volution.

This species incorporates a number of closely similar specimens from a thick stratigraphic sequence.

Occurrence.—Lenoxhills, Leonard and Word formations, Tex.

Holotype.—YPM 20684, Yale Peabody Museum, illustrated Pl. 1, fig. 6; from Lenoxhills formation, southwestern side of Leonard Mountain, Glass Mountains, Tex.

Pseudoschwagerina tumidosus, n. sp.
Pl. 3, figs. 1–3, 8

Description.—This large elongate species reaches a length of 11 to 14 mm and a diameter of 5 to 8 mm in six volutions. The apices of this form are rather acutely pointed for a *Pseudoschwargerina* and lack the knobs common in some of the more highly inflated forms.

The proloculus is relatively large (Pl. 3, figs. 1–3, 8) and average outside diameter is 0.25 mm. YPM 20761 (Pl. 3, fig. 2) from a different locality, has a smaller proloculus of 0.18 mm, outside diameter. YPM 20760 (Pl. 3, fig. 8) has an irregular proloculus but other specimens have near spherical proloculi. The juvenarium has three to four volutions and a form ratio of 2.2, but the adult shell inflates within a quarter volution to a form ratio of 1.6 to 1.7. The form ratio gradually diminishes to 2.4 in the last volution. The height of the last volution is considerably lower than those of the early adult volutions (Pl. 3, fig. 1, 3, 8).

The spiral wall is 0.03 to 0.09 mm thick in the juvenarium, decreases in thickness slightly in early adult whorls, but finally attains a thickness of 1.1 to 1.2 mm in the last volution. It is finely alveolar throughout the shell.

The septa are numerous, highly folded, and thick (probably as a result of secondary deposition) in the juvenarium (Pl. 3, fig. 8). In the early adult whorls they are thinner, irregularly folded, but commonly overlap one another, especially away from the center of the shell. The lower margins of the septa in the early adult region are folded slightly up to one-half chamber height and the septa do not always parallel the axis of coiling. In the last volution the septa are more numerous, more tightly folded and overlap each other across the shell. Septal pores are commonly seen in slightly oblique sections and are distributed evenly over the entire septal face (Pl. 3, fig. 2).

The tunnel is narrow in the juvenarium (tunnel angle 17°), where it is well defined by chomata. In later volutions it is not possible to trace the tunnel with any degree of accuracy but it apparently widens, having angles of 25° or 30°.

Discussion.—*Pseudoschwagerina tumidosus* is

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20760	20759	20761	20758	20757
radius vector	0	.12mm	.13mm	.09mm	.13mm	.11mm
	1	.20	.21	.18	.30	.45
	2	.38	.35	.30	.55	.70
	3	.64	.90	.60	.80	1.55
	4	1.12	2.00	1.10	2.00	2.20
	5	1.85	2.60	1.90	3.10	—
	6	2.30	—	—	—	—
half length	0	.20mm	.13mm	.09mm		
	1	.40	.20	.35	11	17
	2	.70	.70	.60	24	20
	3	.90	1.20	1.20	*27	19
	4	1.80	2.00	2.50	19	18
	5	3.50	3.40	4.25	20	18
	6	5.50?	4.50?	7.00	—	29
form ratio	1	2.0	1.0	2.0		
	2	1.8	2.0	2.0		
	3	1.4	2.2	2.0		
	4	1.6	2.2	2.3		
	5	1.9	1.7	2.2		
	6	2.4	1.7	2.8		
tunnel angle	1	17°	17°	15°		
	2	17	18	20		
	3	25	22	—		
	4	30	—	—		
	5	—	—	—		
	6	—	—	—		
wall thickness	0	.03mm	.03mm	.03mm		
	1	.04	.03	.03		
	2	.06	.09	.09		
	3	.08	.10	.09		
	4	.09	.09	.04		
	5	.10	.08	.10		
	6	.10	.09	.12		

rare in my collections from the Glass Mountains but those specimens examined suggest it is a distinct species from others in the collections. This species compares most closely with *P. texana* var. *ultima* Dunbar and Skinner but differs in certain important aspects. The inflation after the juvenarium is more pronounced and the septa are more irregularly folded in the early adult whorls in this species than in *P. texana* var. *ultima.*

P. beedei Dunbar and Skinner, and *P. texana* Dunbar and Skinner are smaller and less elongate than this species. *P. uddeni* (Beede and Kniker) and *P. robusta* (Meek) are more inflated and have smaller juvenaria. *P. convexa* Thompson is similar in respect to the juvenarium, but differs markedly in the adult stages by having more regularly, tighter, and more highly folded septa and a less pronounced inflation.

YPM 20759 and YPM 20760 differ from YPM 20761 in the septal folding in the early adult region, mature form ratio, and the size of the proloculus. As these may represent slight genetic differences in a population, these specimens are included in this species. Certainly the general form of these shells suggests a close taxonomic relationship and their stratigraphic distribution suggests an approximate age equivalence. This species takes its name from the Latin, *tumidosus,* meaning swollen, and refers to the shape of shell.

Occurrence.—Lenoxhills formation in the western Glass Mountains, Tex.

Holotype.—YPM 20760, Yale Peabody Museum, illustrated Pl. 3, fig. 8; Lenoxhills formation, Dugout Mountain, Tex.

Paraschwagerina plena, n. sp.

Pl. 4, figs. 4, 6–8

Description.—This inflated species commonly attains a length of 10 mm and a diameter of 5 mm in six volutions. The highly inflated central portion of the shell and the nearly straight lateral slopes tapering toward acutely rounded to pointed poles are characteristic of this species (Pl. 4, fig. 4, 7, 8).

In specimens examined the proloculi are spherical and small, ranging between 0.04 to 0.06 mm outside diameter. The first two or three whorls are greatly elongate along the axis of coiling and have form ratios of 3.3. After the shell reaches a length of 0.09 or 1.00 mm, it rapidly expands for two volutions with form ratios decreasing to 1.7. The last one or two volutions show a decline in chamber height and a slight elongation along the axis, this increases the form ratio to 2.0. Each chamber is nearly constant in height and shows little change laterally toward the poles. The lateral slopes are generally highly convex in the inflated portion of the shell and become either straight or slightly concave in the extended portion of the mature region.

The wall is composed of a tectum and a well-defined coarse keriotheca and increases gradually from 0.005 mm thick in the proloculus to 0.10 mm in the sixth whorl. The wall remains of constant thickness from the center of the shell nearly to the poles. The septa are strongly folded throughout the shell. The early or juvenile whorls have high septal folds reaching to the top of the low chambers. The inflated whorls show high but irregular septal folds and the outer one

TABLE OF MEASUREMENTS

YPM specimens

	Volution	20725	20723	20722
radius vector	0	.04mm	.05mm	.06mm
	1	.09	.09	.11
	2	.13	.15	.25
	3	.40	.32	.75
	4	.95	.94	1.40
	5	1.60	1.70	2.00
	6	2.30	—	2.50?
half length	1	.12mm	.20mm	.29mm
	2	.42	.50	.65
	3	.95	.80	1.20
	4	1.70	1.70	2.20
	5	2.90	2.95	3.70
	6	4.50	—	5.00
form ratio	1	1.3	2.1	2.6
	2	3.2	3.3	2.6
	3	2.4	2.5	1.6
	4	1.8	1.8	1.6
	5	1.8	1.7	1.8
	6	2.0	—	2.0
tunnel angle	1	35°	28°	29°
	2	38	32	—
	3	—	—	—
	4	—	—	—
	5	—	—	—
	6	—	—	—
wall thickness	0	.005mm	.007mm	.009mm
	1	.004	.009	.008
	2	.008	.02	.01
	3	.01	.04	.01
	4	.04	.07	.04
	5	.08	.11	.10
	6	.10	—	—

or two mature whorls indicate a return to closely spaced, regular septal folds.

The tunnel is wide in the juvenarium, measuring 30°, but it cuts few septa in the inflated and mature portions of the shell and can not be traced in this outer region. Rudimentary chomata in the juvenarium are thin and may be lacking in a few specimens. The rest of the shell lacks chomata. Secondary deposition is apparently rare in this species; Pl. 4, fig. 8, shows secondary deposition on the septa only in the mature region; other specimens show no deposition.

Discussion.—Paraschwagerina plena, n. sp., is structurally between a typical *Paraschwagerina* and a typical *Pseudoschwagerina.* The inflation of the chambers in the early adult shell and their reduction in height in the late adult shell compare favorably with *Pseudoschwagerina.* However, the elongate juvenarium with closely folded septa and only rudimentary chomata, and the well-developed although irregular septal foldings in the adult shell are more suggestive of *Paraschwagerina. P. plena* is similar to *P. yabei* (Staff), but *P. plena* has highly folded septa throughout the shell and differs in size and shape. Both of these species occur in rocks younger than Wolfcampian and apparently are the aberrant continuation of this lineage into the Middle Permian. *Paraschwagerina acuminata* Dunbar and Skinner is less inflated with more evenly folded septa throughout the shell; *P. kansasensis* (Beede and Kniker) is more globose and has more regularly folded septa; and *P. gigantea* (White) is longer and less inflated and has more regular septal folds in comparison to *P. plena.*

The species takes its name from the Latin *plena,* full or plump, and refers to the greatly inflated volutions of this species.

Occurrence.—Lower part of the Leonard formation in the Lenox Hills and the Lenoxhills formation in the Hess ranch horst.

Holotype.—YPM 20722, Yale Peabody Museum; illustrated Pl. 4, fig. 8; from lower part of Leonard formation, Lenox Hills.

REFERENCES

DUNBAR, C. O., and SKINNER, J. W. *The geology of Texas* **3** (pt. 2), *Permian Fusulinidae of Texas.* Texas Univ. Bull. 3701: 517–825, 1937.

KING, P. B. *The geology of the Glass Mountains, Texas, pt. 1.* Texas Univ. Bull. 3038: 1–167. 1931.

———. *Geology of the Marathon region, Texas.* U.S. Geol. Survey Prof. Pap. 187: 1–148. 1937.

THOMPSON, M. L. *Northern midcontinent Missourian fusulinids.* Journ. Paleont. **31:** 289–328. 1957.

UDDEN, J. A. *Notes on the geology of the Glass Mountains.* Texas Univ. Bull. 1753: 3–59. 1917.

WHITE, M. P. *Some Texas Fusulinidae.* Texas Univ. Bull. 3211: 1–104. 1932.

EXPLANATION OF PLATES

All figures × 10

PLATE 1

FIGS. 1–3, 5.—*Triticites comptus*, n. sp., Gaptank formation:
1. Axial section, "grey limestone," Wolf Camp Hills, YPM 20555.
2. Axial section, 5 miles northeast of Wolf Camp Hills, YPM 20550.
3. Sagittal section, "grey limestone", Wolf Camp Hills, YPM 20552.
5. Axial section, holotype, "grey limestone," Wolf Camp Hills, YPM 20551.

FIGS. 4, 6, 7, 10, 11.—*Schwagerina tersa*, n. sp., Leonard and Lenoxhills formation:
4. Axial section, southwestern end of Dugout Mountains, YPM 20680.
6. Axial section of holotype, 2½ miles west of the Wolf Camp Hills, one-third the distance up the slope, YPM 20684.
7. Axial section, 2½ miles northeast of Wolf Camp Hills, YPM 20681.
10. Sagittal section, 2½ miles west of Wolf Camp Hills, one-third the distance up the slope, YPM 20679.
11. Axial section, 2½ miles northeast of Wolf Camp Hills, YPM 20682.

FIGS. 8, 9, 12, 13.—*Schwagerina pugunculus*, n. sp., Nealranch formation, Wolf Camp Hills:
8. Axial section, YPM 20721.
9. Sagittal section, YPM 20720.
12. Axial section, YPM 20719.
13. Axial section of holotype, YPM 20716.

PLATE 2

FIGS. 1–6.—*Schwagerina lineanoda*, n. sp., Lenoxhills formation:
1. Axial section, southwest end of Dugout Mountain, YPM 20677.
2. Axial section, north of Wolf Camp Hills, YPM 20676.
3. Axial section of holotype, north of Wolf Camp Hills, YPM 20675.
4. Axial section, north of Wolf Camp Hills, YPM 20674.
5. Tangential section, north of Wolf Camp Hills, YPM 20673.
6. Sagittal section, north of Wolf Camp Hills, YPM 20678.

FIGS. 7–12.—*Schwagerina dispansa*, n. sp., Lenoxhills formation north of the Wolf Camp Hills:
7. Axial section of holotype, YPM 20628.
8. Axial section, photographed with oblique lighting, YPM 20629.
9. Sagittal section, YPM 20624.
10. Tangential section showing a single false cuniculus resorbed by tunnel, YPM 20627.
11. Axial section, YPM 20625.
12. Axial section, YPM 20626.

PLATE 3

FIGS. 1–3, 8.—*Pseudoschwagerina tumidosus*, n. sp., Lenoxhills formation.
1. Oblique section, Hess ranch horst, YPM 20751.
2. Slightly oblique section, Hess ranch horst, YPM 20761.
3. Axial section, Dugout Mountain, YPM 20759.
8. Axial section of holotype, Dugout Mountain, YPM 20760.

FIGS. 4–7, 9.—*Schwagerina extumida* n. sp., Lenoxhills formation, Hess ranch horst.
4. Sagittal section, YPM 20651.
5. Axial section, YPM 20650.
6. Axial section, YPM 20648.
7. Axial section, YPM 20646.
9. Axial section, holotype, YPM 20649.

PLATE 4

FIGS. 1–3, 5.—*Schwagerina crebrisepta*, n. sp., Lenoxhills formation in the Lenox Hills:
1. Axial section, YPM 20632.
2. Axial section, YPM 20631.
3. Axial section, holotype, YPM 20634.
5. Sagittal section, YPM 20633.

FIGS. 4, 6–8.—*Paraschwagerina plena*, n. sp., lower part of the Leonard formation, Lenox Hills:
4. Axial section, YPM 20723.
6. Oblique section, YPM 20726.
7. Axial section, YPM 20725.
8. Axial section, holotype, YPM 20722.

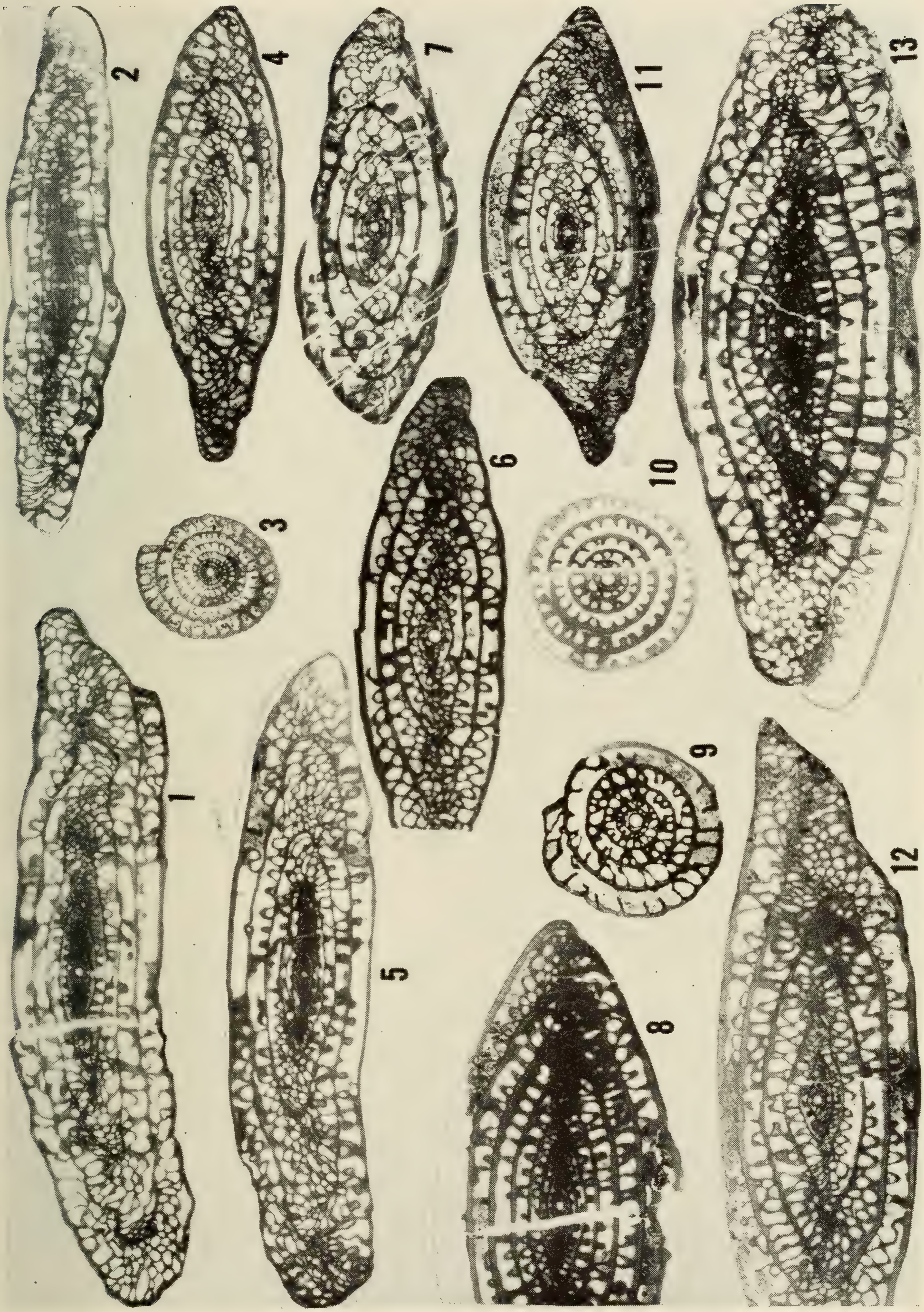

Plate 1.—(For explanation see p. 312).

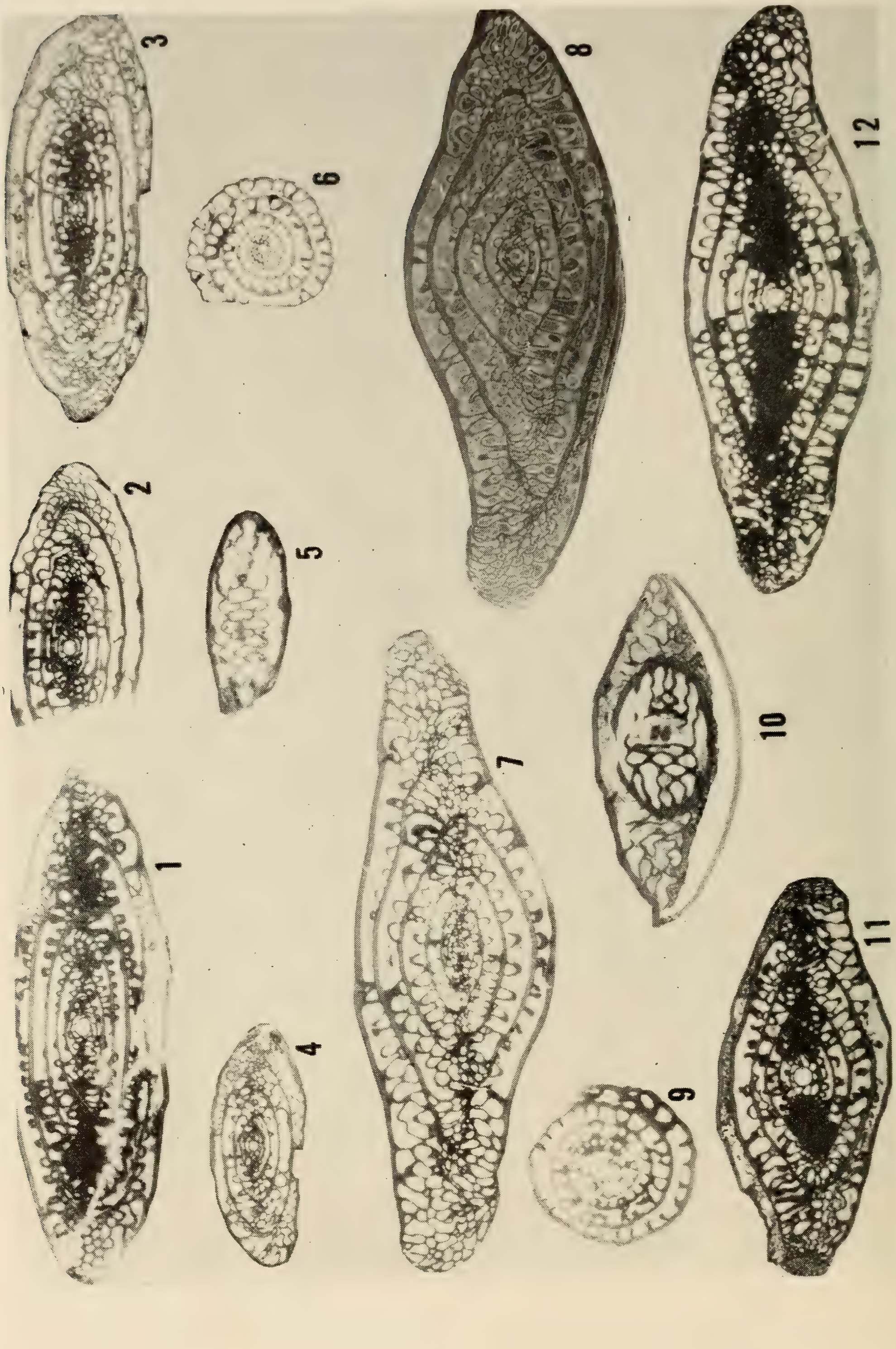

PLATE 2.—(For explanation see p. 312).

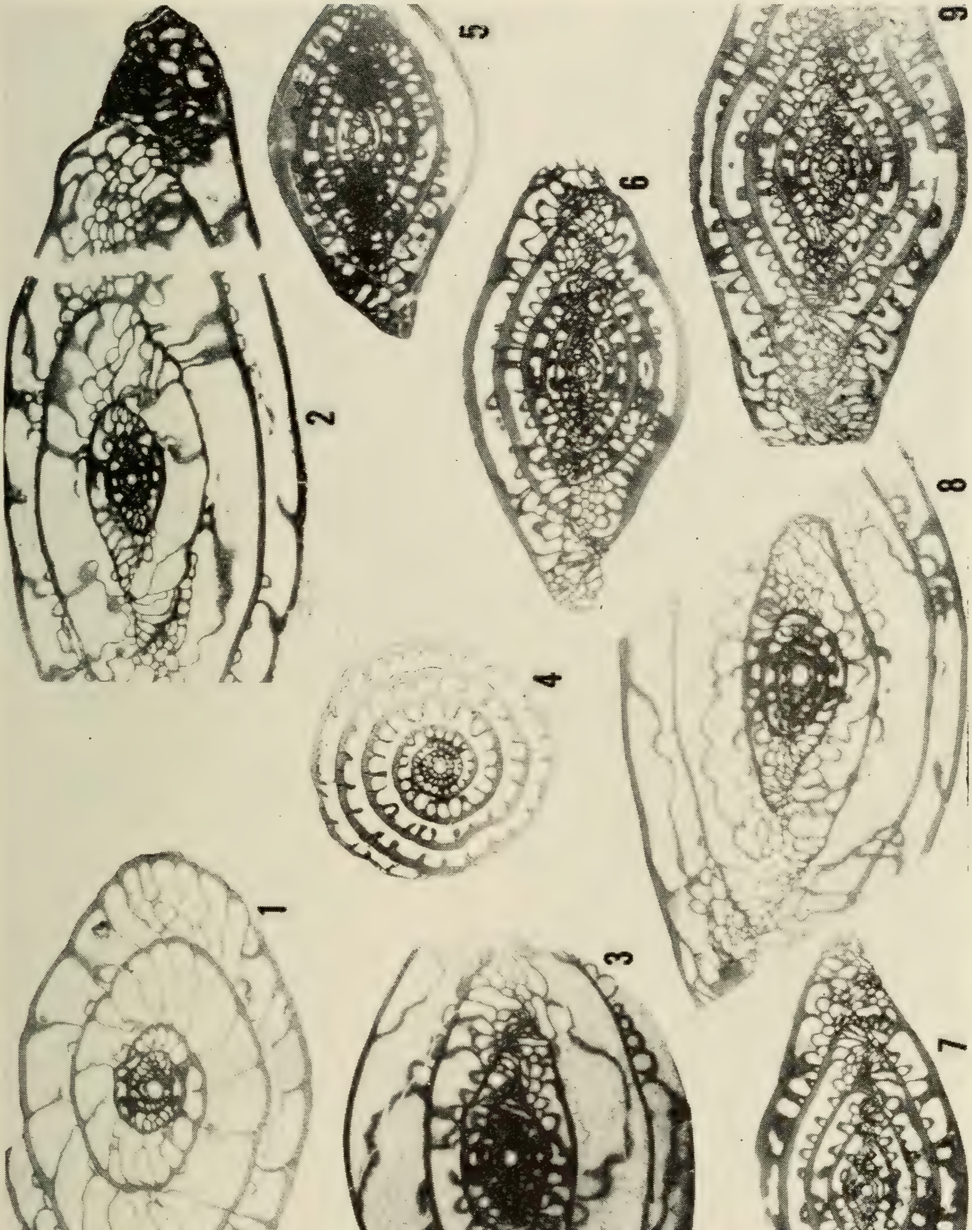

Plate 3.—(For explanation see p. 312).

PLATE 4.—(For explanation see p. 312).

PLANT PHYSIOLOGY.—*Responses of certain fungi, particularly* Trichoderma *sp., to light.*[1] Ida P. Bjornsson,[2] University of Maryland. (Communicated by Harry A. Borthwick.)

(Received June 16, 1959)

The importance of light for growth and development of fungi is evident from the widely scattered observations in the literature and the increasing number of recent studies. Its importance for processes other than photosynthesis is well demonstrated for higher plants (Hendricks and Borthwick, 1955) and has also been demonstrated for ferns (Mohr, 1956) and algae (Finkle, Appleman, and Fleischer, 1950; Killam and Myers, 1956). Owing to fundamental differences in structure and development among these groups of plants, their responses to light are expressed quite differently. Despite the differences, careful studies of the way light acts to induce each response can show whether the same or different photoreactions are involved.

The purpose of the present study was to explore the types of response of several fungi to light and to study in detail the response of one of them which appeared to be best suited for this type of investigation—viz., *Trichoderma* sp.

MATERIALS AND METHODS

Potato-dextrose-agar was generally used as the culture medium, and the cultures were grown at 21° C. Test tubes were used as culture vessels, except for *Trichoderma* sp., which was grown in petri dishes. The cultures were standardized by starting each from a single spore when possible—otherwise from a hyphal tip. For qualitative observations, photographic records and visual estimations were made. For the quantitative determinations, spores were counted or percent transmissions of light by the spore suspensions were determined with a spectrophotometer.

Cool, white, fluorescent tubes, at distances of 48 or 100 cm, gave illuminances of 78 or 34 f.c., respectively. For isolation of blue and red wavelength regions, two layers of blue or two layers of red cellophane were used with these tubes or with blue or red fluorescent tubes at the same distances when higher energies were desired. The fluorescent tubes were used as blue and red sources because they emitted very little of the far-red wavelengths (7,000 to 8,000 Å). The far-red wavelength region from four incandescent-filament lamps (125-watt) was isolated by a filter consisting of two layers each of blue and red cellophanes (Piringer and Heinze, 1954). Radiant energy from such lamps was rich in the far-red wavelengths. Radiant energy was varied either by varying the distance of the cultures from the source of light or by interposing neutral filters consisting of different numbers of layers of cheesecloth. The action spectrum for *Trichoderma* sp. was determined with the spectrograph described by Parker, Hendricks, Borthwick, and Scully (1946).

RESULTS

Twelve species of fungi were grown in light and in darkness and examined for responses, such as production of sexual and asexual fruiting bodies, growth of mycelium, and formation of pigments. Cultures of one of these species, *Mucor* sp., formed a mat of mycelium in the dark and under all conditions with light, but it did not fruit under any condition. Lack of fruiting suggested that there was lacking in the culture medium some compound necessary for the further development of the fungus. The other 11 species, including *Trichoderma* sp., which is discussed in detail in the last part of this section, showed one or more responses to light.

Stemphylium sp. (a yellow mycelial strain) did not sporulate in 4 weeks in darkness. This finding verified earlier work on other species or isolates of *Stemphylium*

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(Weber, 1930; Hannon and Weber, 1955) which also required light for sporulation. When cultures were grown on potato-sucrose-agar at 21° C., maximal spore production was obtained when light was given 26 to 72 hours after inoculation with a single spore. For sporulation, darkness prior to exposure to light was apparently unnecessary and, once initiated, spores apparently matured in light or darkness. After 50 hours of growth of the cultures in darkness, the shortest period of continuous white fluores-

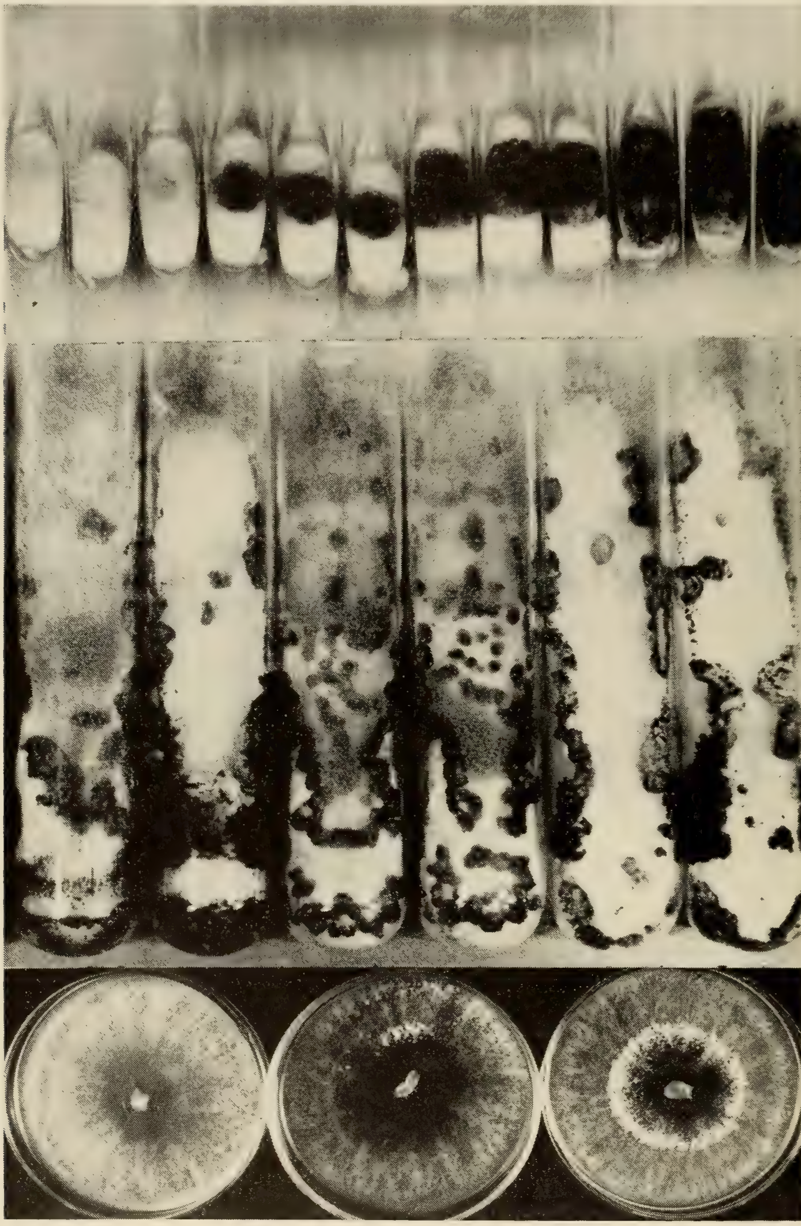

FIG. 1.—Top row: Sporulation of *Stemphylium* in response to various durations of white fluorescent light of 78 f.c. intensity. From left to right groups of three tubes received no light, 48 hours, 72 hours, and continuous light. Middle row: Formation of sclerotia in cultures of *Botrytis gladiolorum* in response to blue (first tube), far-red (second tube), red (third and fourth tubes), and darkness (fifth and sixth tubes). Bottom row: Sporulation of *Trichoderma* sp. in response to darkness (left), 1-minute exposure of sector at top of culture (center), and 1-minute exposure of whole culture (right) to 34 f.c. of white fluorescent light.

cent light (34 f.c.) that induced sporulation was 18 to 23 hours and the number of spores increased with duration (Fig. 1, upper row) and intensity of light. The least amount of white fluorescent light (78 f.c.) that induced spore formation, when given in daily cycles, was 1 hour per day for 4 or 5 days. With continuous white fluorescent light, saturation for sporulation was obtained in 7 days. During that period the intensity of the light was alternated (500 f.c. for seven hours and 78 f.c. for 17 hours). Red and far-red wavelengths were ineffective or much less effective for inducing sporulation than were the shorter wavelengths of the visible spectrum.

Mycelial growth of *Stemphylium* was stimulated by about 5 f.c. of continuous white fluorescent light at 21° C., but was retarded at 28° C. All wavelengths of the visible spectrum appeared to be effective for mycelial growth. In darkness the culture medium and the mycelium were yellow. In light there was a negative correlation between the number of spores and the intensity of yellow color; in no case was an irradiated culture as deep a yellow as those grown in the dark. The concentration of the yellow pigment in the medium was high under conditions unfavorable for spore formation—exposure to red, far-red, or low-intensity white light, increase in sugar concentration of the medium, or a temperature of 28° C. The pigmentation of the mycelium and medium might have been directly dependent on light or indirectly dependent through the action of light on growth and sporulation of the organism.

Cultures of *Botrytis gladiolorum* Timmerm. showed three responses to light—sporulation, ridging, and formation of sclerotia. The number of spores formed in response to exposure to white fluorescent light (78 f.c.) increased with duration of exposure from 7 to 70 hours. Mycelial ridges, consisting of aggregations of erect, aerial, spore-bearing hyphae, alternating with areas of sparse, prostrate hyphae bearing few spores, occurred in cultures exposed to certain daily alternations of 34 or 78 f.c. of white fluorescent light and darkness which followed not more than 3 days of darkness. Ridges were formed in cultures that received at least eight but not more than 23 hours of light in 24-hour cycles for 4 or 5 days. Ridges were not formed in cultures in continuous light or darkness. Continuous light resulted in a dense uninterrupted layer of spores and darkness resulted in a thick layer of nonsporulating mycelium. Blue light promoted spore formation and ridging.

Sclerotia did not form in cultures in continuous white fluorescent light (78 f.c.), but a few formed in continuous darkness. The best conditions for the formation of sclerotia were provided by a 30-minute irradiation with white fluorescent light after the cultures had grown in darkness 4 days. The cultures were returned to darkness and observed 8 days later. In three experiments, that tested the relative effectiveness of red and blue lights, more sclerotia were formed in cultures exposed to red light; the response to blue light was about the same as to darkness (Fig. 1, middle row). A promotive effect of red light has not been previously reported, but blue light has been observed to be inhibitory for sclerotium formation by *Botrytis cinera* (Reidemeister, 1909), five species of *Aspergillus* (Tatarenko, 1954), and *Verticillium alboatrum* (McClellan, Borthwick, Bjornsson, and Marshall, 1955).

Sporulation of *Curvularia tribolii* (Kauff.) Boed. and a dark mycelial strain of *Stemphylium* sp. was promoted in cultures exposed to continuous white fluorescent light (78 f.c.) as compared with that of cultures in darkness.

Penicillium gladioli McCull. et Thom. produced an abundance of aerial mycelium but no spores in continuous far red or in darkness. Cultures grown in continuous red light formed a few spores but considerable aerial mycelium; those grown in blue light formed an abundance of spores but no aerial mycelium. These results agree with earlier reports on several species of *Penicillium* (Tatarenko, 1954).

Stromatinia gladioli (Drayton) Whez. formed a greater number of sclerotia when grown in continuous white fluorescent, blue, or red light for 4 weeks than in continuous darkness. Blue light appeared to be the most promotive.

Rhizoctonia carotae Rader produced sclerotiumlike bodies when grown in continuous white fluorescent light (34 f.c.) either unfiltered or filtered with two layers of blue or red cellophane, but did not form these structures in the dark.

Diplodia sp. from cotton did not form pycnidia during 27 days in the dark, but produced these structures under all light treatments. Cultures in red light formed fewer, larger, and longer-necked pycnidia than did those in either blue or white fluorescent light (78 f.c.).

Rhizopus sp. formed sporangia abundantly when exposed continuously to unfiltered white fluorescent light or filtered blue light from blue fluorescent tubes, but both of these kinds of light depressed sporangiophore elongation. Cultures in red light or darkness formed long sporangiophores, only a few of which developed sporangia. Cultures grown in an alternation of eight hours of white or blue fluorescent light and 16 hours of darkness produced fewer sporangia but somewhat longer sporangiophores than did cultures in continuous light.

Lenzites trabea (Fr.) Fr. did not form basidiocarps during 12 months in darkness. Cultures, each started from a hyphal tip and grown in continuous white light for 4 weeks, also failed to produce fruiting bodies. However, if such cultures were given an additional 6 weeks in the light, small, incompletely developed basidiocarps were formed during an additional 4 weeks in darkness. They were also formed when filtered red or blue fluorescent light—but not far-red—was used. Cultures grown on malt agar gave the same results. Cultures left in darkness for 4 or 6 weeks prior to an exposure to filtered blue fluorescent light for 11 days or 4 weeks produced larger and better-developed basidiocarps than did cultures in filtered red fluorescent or unfiltered white fluorescent light (78 f.c.). An 11-day exposure to light was as efficient as a 4-week exposure; 4 weeks of darkness prior to and subsequent to treatments with light were sufficient for the response. Ten minutes, 60 minutes, 24 hours, 7 days, or 14 days of high-intensity blue, red, or unfiltered white fluorescent light given after 3 weeks of darkness did not induce basidiocarp formation, but 14 days of blue light after 6 weeks of darkness effectively induced their formation. *L. trabea* apparently requires 4 to 6 weeks of growth to reach the stage of greatest sensitivity to light for basidiocarp formation. An exposure to high-intensity blue light for at least 11 to 14 days is required for this induction.

An isolate of *Trichoderma* sp. was obtained from Raymond Lukens, Department of Botany, University of Maryland. Its growth and coloration were the same in light and in darkness. Cultures sporulated abundantly in light but did not produce spores during 96 hours in the dark. The growth rate of the mycelium increased with increasing temperatures above 4.5° C. until at 32° C. the mycelium became atypical. Growth at 21° C. proved satisfactory and that temperature was used for the experiments with light. Alternation of temperature induced sporulation of certain species of fungi, but sporulation was not induced in cultures of *Trichoderma* grown in darkness at 21° C. by exposing them to 2° C. for one-half hour to 6 hours at the time of their greatest responsiveness to light. A pretreatment at 2° or 27° C. of one-half hour to 6 hours in the dark did not affect the number of spores produced at 21° C. during a subsequent exposure to light. Cultures started from small uniform-size pieces of agar with vegetative mycelium or single spores reached the stage or size for maximal response when the colony had a diameter of about 1.5 cm. This was attained after 26 or 40 hours, respectively, at 21° C. With a

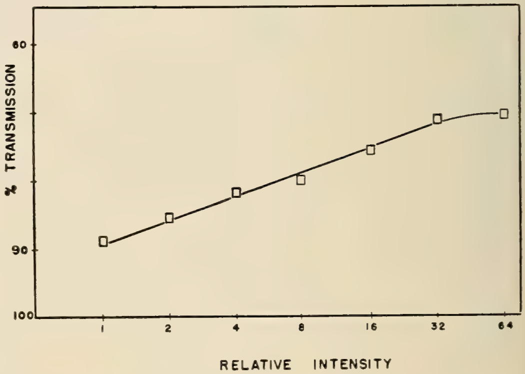

Fig. 2.—Sporulation of *Trichoderma* sp. as a function of different relative energies (value of 1 = 1.5 f.c.) of white fluorescent light given for 1 minute. Sporulation expressed in terms of percent transmission of light by spore suspension.

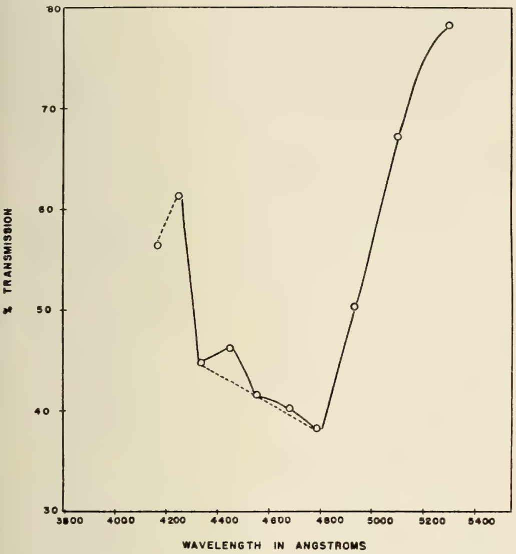

Fig. 3.—Action spectrum curve for sporulation of *Trichoderma* sp. at energies of 6 × 10^4 ergs/cm^2. Sporulation expressed in terms of percent transmission of light by spore suspension.

1-minute exposure to light, the number of spores increased linearly with a logarithmic increase in intensity from 1.5 to 50 f.c. of white fluorescent light (Fig. 2). At least 100 times as much energy was required for cultures of 1.0-cm diameter as for those of 1.5-cm diameter. Twenty-four hours after exposure to light the first visible sign of sporulation was the occurrence of a white ring of swollen hyphal tips 0.6 cm wide. The outer edge of the ring corresponded to the periphery of growth of the culture at the time the light was given. In an additional 24 hours this ring took on the characteristic blue-green of fully developed spores. With exposure times above saturation for sporulation, the spores matured earlier. If a portion of the ring of hyphal tips was exposed to light, sporulation was localized to those tips actually receiving light and the stimulus was not translocated to the unexposed but otherwise receptive hyphal tips (Fig. 1, lower row). Localized responses have been reported for the light-stimulated formation of pycnidia of *Physalospora obtusa* (Fulkerson, 1955) and the initiation of fruiting of *Coprinus lagopus* (Madelin, 1956).

Other workers reported that blue light was more effective than red for spore production in cultures of *Trichoderma lignorum* (Lilly and Barnett, 1951) and one isolate of *Trichoderma* sp. (Krietlow, 1938). Preliminary experiments with cellophane filters demonstrated the ineffectiveness of the red and far-red wavelengths, and this ineffectiveness was verified with the spectrograph. The action spectrum (with incident energies of 6 × 10^4 ergs/cm^2) showed that the most effective wavelengths for inducing sporulation were 4,300 to 4,900 Å. A sharp break occurred near 4,800 Å and sporulation was not induced by wavelengths longer than 5,200 Å (Fig. 3).

DISCUSSION

Numerous reports in the literature clearly show that fungi, although heterotrophic, require light for control of many features of their growth and reproduction. The widespread sensitivity of fungi to light is emphasized by the results of this study, in which 11 of 12 species exhibited one or more responses to light. These organisms, moreover, were selected at random as far as prior knowledge of their sensitivity to light was concerned and they were not subjected to a wide range of conditions during their culture.

The stage of development, age, or size of the fungus colony required for maximal response to light, as well as the total energy needed for a response, appears to vary with type of response and species. The amount of energy required for asexual sporulation in *Trichoderma,* for example, differed strikingly from that required for the same response in *Stemphylium, Botrytis* and *Penicillium. Trichoderma* sporulated after a short exposure to low-intensity light, and the reaction was easily saturated. These results resemble those reported for fruiting of *Coprinus lagopus* (Madelin, 1956). On the other hand, spore formation by *Stemphylium* sp. increased with increase in duration of exposure to relatively high-intensity light and saturation was difficult to attain. Blue light was the most effective for sporulation of both *Trichoderma* and *Stemphylium*—indicating that a similar pigment or pigment system absorbs the energy. The difference in the total energy requirement might be the result of differences in concentration of the absorbing pigment, different pathways of metabolism, or still other factors.

Sporulation of the above-mentioned fungi did not require a dark period prior to exposure to light. Responses of certain of the others appeared to be preconditioned by a dark period. For example, *Botrytis gladiolorum* responded differently depending on its age or stage of development when exposed to light. Sclerotia were not formed in cultures exposed continuously to light, but continuous light ultimately induced the greatest number of spores. Sclerotia were formed in the greatest number if, starting from a single spore, cultures received five or six days of darkness prior to a 30-minute exposure to light. It is not known whether the formation of sclerotia was preconditioned by the dark period or the dark period served to suppress the other responses and this suppression permitted the formation of sclerotia.

Ridging of *Botrytis* cultures in response to daily cycles of light and darkness occurred only when more than one cycle was used. Reports on this kind of response are rare for fungi (Sagromsky, 1952b). Such a response resembles photoperiodism in higher plants. Photoperiodic responses of higher plants, however, are controlled by red and far-red wavelength regions of the spectrum, whereas cyclic phenomena of fungi appear to be elicited by blue light.

Except for sclerotium formation in *Botrytis,* which was stimulated by red light, all responses of these fungi were promoted best by the blue region of the spectrum. The action spectrum for sporulation of *Trichoderma* showed a peak in the blue wavelengths and a sharp cutoff near 5,000 Å. These features are similar to those of other action spectra reported for fungi, such as conidiophore elongation in several isolates of *Penicillium* and *Verticillium* (Sagromsky, 1952a; Sagromsky, 1952b), sporophore elongation (Bünning, 1953) and trophocyst formation (Page, 1956) in *Pilobolus kleinii,* giant conidiophore formation in *Aspergillus giganteus* (Gardner, 1955), formation of macroconidia in *Sclerotinia fructigena* (Sagromsky, 1952b), fruiting of *Coprinus lagopus* (Borris, 1934; Madelin, 1956), and carotenoid production in *Neurospora crassa* (Zalokar, 1955). The action spectra resemble the action spectrum of phototropism and the absorption spectra of carotenoids and riboflavins. Several pigments from both of these groups, along with other pigments, have been reported in various species of fungi. Recent works (Bünning, Dorn, Schneiderhöhn, and Thorning, 1953; Zalokar, 1955), especially those on metabolic inhibitors (Page, 1956) and mutants (Cantino and Horenstein, 1956), appear to favor a flavoprotein as the absorbing pigment for such reactions to light.

Further research is required in this field to establish similarities and dissimilarities between fungi and other groups of plants, but fungi appear to have pigment systems absorbing mainly in the blue wavelengths, whereas green plants appear to possess these, for nonphotosynthetic reactions, as well as pigment systems absorbing in the red and far-red wavelengths.

SUMMARY

Light elicited the following responses in certain species of fungi: Spore production, mycelial growth and coloration, and coloration of the medium in cultures of a yellow mycelial strain of *Stemphylium* sp.; spore production, ridging and formation of sclerotia by *Botrytis gladiolorum*; and spore production by *Curvularia trifolii, Penicillium gladioli,* and a dark mycelial strain of *Stemphylium* sp.; formation of pycnidia by *Diplodia* sp.; basidiocarp formation by *Lenzites trabea*; formation of sporangia by *Rhizopus* sp.; formation of sclerotia by *Stromatinia gladioli*; and, the formation of sclerotiumlike bodies by *Rhizoctonia carotae.*

Spores were not formed by *Trichoderma* sp. within a 96-hour period of growth in darkness, but they were formed after a 1-minute exposure to white fluorescent light (1.5 f.c.). Alternation of temperatures neither induced sporulation nor increased the number of spores produced upon subsequent exposure to light. Spores were localized to that portion of the ring of hyphal tips exposed to light. Spore production increased linearly with a logarithmic increase in intensity from 1.5 to 50 f.c. of white fluorescent

light. The action spectrum for sporulation showed a peak of response to wavelengths of 4,300 to 4,900 Å, a sharp break near 4,800 Å, and ineffectiveness of wavelengths longer than 5,200 Å.

With a possible exception of red-light-induced sclerotium formation in *Botrytis gladiolorum,* these responses were induced with the shorter (less than 5,200 Å) wavelengths of the visible spectrum.

These findings corroborate the researches of other workers concerning the greater effectiveness of the shorter wavelengths of the visible spectrum and the widespread importance of light in the life cycle of fungi.

ACKNOWLEDGMENTS

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REFERENCES

BORRIS, H. *Über den Einfluss ausserer Faktoren auf Wachstum und Entwicklung der Fruchtkorper von Coprinus lagopus.* Planta **22:** 644–648. 1934.

BÜNNING, E. *Entwicklungs und Bewegungsphysiologie der Pflanze,* ed. 3. Berlin, 1953.

BÜNNING, E., DORN, L., SCHNEIDERHÖHN, G., and THORNING, I. *Zur Funktion von Lactoflavin und Carotin beim Phototropismus und bei lichtbedingten Wachstumsbeeinflussungen.* Ber. Deut. bot. Ges. **66:** 333–340. 1953.

CANTINO, E. C., and HORENSTEIN, E. A. *The stimulatory effect of light upon growth and CO_2 fixation in* Blastocladiella. I, *The S.K.I. cycle.* Mycologia **48:** 777–799. 1956.

FINKLE, B. J., APPLEMAN, D., and FLEISCHER, F. K. *Growth of* Chorella vulgaris *in the dark.* Science **111:** 309. 1950.

FULKERSON, J. F. *The relation of light to the production of pycnidia by Physalospora obtusa.* Phytopathology **45:** 22–25. 1955.

GARDNER, E. B. *Conidiophore elongation in* Aspergillus giganteus: *in the influence of temperature, light intensity and light quality.* Trans. New York Acad. Sci. (ser. 2) **17:** 476–490. 1955.

HANNON, C. I., and WEBER, G. F. *A leaf spot of tomato caused by* Stemphylium floridanum *sp. nov.* Phytopathology **45:** 11–16. 1955.

HENDRICKS, S. B., and BORTHWICK, H. A. *Photoresponsive growth.* In: Rudnick, D., ed., "Aspects of Synthesis and Order in Growth," pp. 146–169. Princeton, N. J., 1955.

KILLAM, A., and MYERS, J. *A special effect of light on the growth of* Chorella vulgaris. Amer. Journ. Bot. **43:** 569–572. 1956.

KRIETLOW, K. W. *The effect of quality of light on the growth of certain fungi and bacteria.* Thesis, Louisiana State University, 1938.

LILLY, V. G., and BARNETT, H. S. *Physiology of the fungi.* New York, 1951.

MADELIN, M. F. *The influence of light and temperature on fruiting of* Coprinus lagopus Fr. *in pure culture.* Ann. Bot., n.s., **20:** 467–480. 1956.

MCCLELLAN, W. D., BORTHWICK, H. A., BJORNSSON, IDA, and MARSHALL, B. H. *Some responses of fungi to light.* Phytopathology **45:** 465. 1955. (Abstr.)

MOHR, H. *Die Abhängigkeit des Protonemawachstums und der Protonemapolarität bei Farnen vom Licht.* Planta **47:** 127–158. 1956.

PAGE, R. M. *Studies on the development of asexual reproductive structures in* Pilobolus. Mycologia **48:** 206–224. 1956.

PARKER, M. W., HENDRICKS, S. B., BORTHWICK, H. A., and SCULLY, N. J. *Action spectrum for the photoperiodic control of floral initiation of short-day plants.* Bot. Gaz. **108:** 1–26. 1946.

PIRINGER, A. A., and HEINZE, P. H. *Effect of light on the formation of a pigment in the tomato fruit cuticle.* Plant Physiol. **29:** 467–472. 1954.

REIDEMEISTER, W. *Die Bedingungen der Sklerotienringbildung von* Botrytis cinera *auf künstlichen Nährboden.* Ann. Mycologici **7:** 19–44. 1909.

SAGROMSKY, H. *Der Einfluss des Lichtes auf die rhythmische Konidienbildung von* Penicillium. Flora (Jena) **139:** 300–313. 1952a.

———. *Lichtinduzierte Ringbildung bei Pilzen. II.* Flora (Jena) **139:** 560–564. 1952b.

TATARENKO, E. S. *Effect of light on the development of molds.* Mikrobiologia **23:** 29–33. 1954. (In Russian.)

WEBER, G. F. *Gray leaf spot of tomato caused by* Stemphylium solani *sp. nov.* Phytopathology **20:** 513–518. 1930.

ZALOKAR, M. *Biosynthesis of carotenoids in* Neurospora. *Action spectrum of photoactivation.* Arch. Biochem. Biophys. **56:** 318–325. 1955.

ZOOLOGY.—*A new Floridan* Pectiniunguis, *with re-appraisal of its type species and comments on the status of* Adenoschendyla *and* Litoschendyla (*Chilopoda: Geophilomorpha: Schendylidae*). R. E. CRABILL, JR., U.S. National Museum, Smithsonian Institution.

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In 1889, the year of his untimely death, Charles Harvey Bollman proposed a new genus, *Pectiniunguis,* for the reception of two species, one of which had been collected at Pichilinque Bay,[1] near La Paz, at the southern end of Baja California; he called his new centipede *Pectiniunguis americanus* and declared this species to be the type of the genus. This was only the second generic name referable to a group subsequently to be recognized as a family and called Schendylidae.

The Bollman species was reported for the second time in 1889 when O. F. Cook collected what he took to be *americanus* on the Florida Keys; subsequent workers until the present time have accepted the validity of his identification. It was, however, in error, as a recent comparison of the rediscovered Bollman type with the Cook material reveals. Final confirmation was possible following the study of a series of fresh specimens generously donated to the U.S. National Museum by Dr. H. V. Weems, Jr., of Gainesville, Fla. These specimens constitute the typical series of the new species described below.

Pectiniunguis (as it is defined here) may be distinguished from other schendyline genera by its possession of the following characters: Each coxopleuron has two gland pits of the heterogenous type; sternital porefields present; second maxillary claw bipectinate, the coxosternites not fused posterolaterally and posteriorly with the postmaxillary sclerites; ultimate pretarsus is either absent or minutely tuberculate. In 1912 Broelemann and Ribaut in a splendid monograph employed the same diagnostic features and added their own discovery that specimens so characterized display two kinds of labra. Some of the species, including *americanus,* they believed, have medial labral undulations instead of true alveolate, rooted and discrete teeth. They ascribed the possession of true medial teeth to other species to which they assigned (1911) a new generic name, *Adenoschendyla; geayi* is the type species (by subsequent monotypy).

Following an extended discussion (1912, p. 69), they summarized the differences between the two labral types as follows: "Arc médian à ondulations superficielles, appuyé à des pièces latérales peu dévelopées en avant..." for *Pectiniunguis*; versus "Arc médian composé de dents tuberculeuses presque individualisées et munies d'une racine appuyé à des pièces latérales plus or moins distinct de la zone prélabiale..." for some others including *Adenoschendyla.* In 1923 Professor Chamberlin, in the belief that *americanus* has true medial labral teeth, showed that *Adenoschendyla* must fall as the junior synonym of *Pectiniunguis* and that this action would leave the species with midlabral undulations without a generic name. For them he proposed a new name, *Litoschendyla,* designating *insulanus* (Broelemann and Ribaut) as its type species. In his monograph of 1929 Attems accepted the Chamberlin resolution, and the matter was apparently closed. The case seems simple and convincing; however, the recent examination of Bollman's type and of the six types of the present new species provides a basis for doubt which is implicit in two questions. (1) Since the *only* intergeneric character is said to be the labral one described by the French workers and accepted by Chamberlin and Attems, is it really significant and, if so, practical; that is, does it represent an intergroup repeatable difference *in kind* as the French authorities maintained (and if so will it assist rather than confuse the generic assignment of species), or, on the other hand, does this character represent a difference *in degree* which is quite variable among closely similar species and even intraspecifically (and if so

[1] The type locality was originally given as "Pichiliungue Bay," a misspelling for Pichilinque Bay.

would its use weaken the function of the genus as a collective category)? (2) And in case the labral character is really significant intergenerically, then to which of the two labral types is *Pectiniunguis americanus* assignable, for the resolution of this question determines the zoological content and the nomenclatural disposition of all three generic names.

It cannot be denied that in some species, e.g., *geayi*, there are some, or is at least one, specimen with relatively long, discrete medial teeth, and that in other species the medial teeth are blunter, lower, wholly or partly fused with each other, e.g., *insulanus, halirrhytus*, n. sp. On the other hand, two factors cannot be avoided, interpretative subjectivity and inter- or intraspecific variability. The labrum is normally directed ventroposteriorly, so that looking down upon it one sees it at an angle and not in perfect, flat outline; consequently the interdental fissures can appear shorter than they are, or absent when they are present, or they may not even be recognized as fissures. Therefore one person might decide that the teeth are labral undulations that are connected with each other or continuous; another, seeing the same specimen but under different conditions of preparation and magnification, could report quite a conflicting impression. The character, then, is capable of being interpreted in quite a highly subjective manner. Secondly, in my series of *halirrhytus* I have observed considerable labral variability, ranging from a typically "undulate" condition to one in which the medial structures seem typically toothlike, being discrete and apparently rooted. Yet five of the six specimens were collected at the same time from the same pile of seaweed, and all agree most minutely in other significant respects. I suggest that the labral difference, at least in some species and conceivably in many or in all, is one of degree, not of kind; that is, in some species (A) the teeth are long and tend to be or are well separated (e.g., *geayi*), whereas in some others (B) the teeth are shorter, blunter and are discrete or quite variously fused (e.g. *insulanus, halirrhytus*). Given a suitable series of any species, considerable variability *within* each of these two categories, A and B, might reasonably be anticipated. It seems most significant to me that, guided by the Broelemann-Ribaut criteria as applied to *halirrhytus*, one could, *if he had only one specimen at his disposal and not a series,* assign the holotype to *Litoschendyla,* some paratypes to *Pectiniunguis* and feel quite uncertain of the allocation of some others. If it is really the case that this labral character is a concomitant of supraspecific, e.g. generic, grouping, then either it is not now sufficiently refined, or else no degree of refinement can make of it a reliable indicator of supraspecific affinities. The reasonable solution seems provisionally to be to unite both kinds of species within one genus, defining the labral characters rather broadly and characterizing them as involving midlabral teeth that are either (A) low, blunt, nodular, separated or variously fused; or (B) longer, more or less well defined, essentially or clearly discrete. This is not to suggest that two monophyletic groups, genera let us say, are not actually involved, only that if they are, existing criteria seem inadequate for distinguishing them in a satisfactory manner. For practical purposes of preliminary classification it seems best for the time being to include all under the senior generic name.

The second question concerns the affinity of *americanus,* the type species of *Pectiniunguis.* Without any question its midlabral area is much more like that of *insulanus* and *halirrhytus* than that of *geayi.* Its midlabral teeth are low, rather nodular, some have interdental fissures but some do not (Fig. 5). The very distinct fissures separating the most central teeth from those adjacent seem to be artifacts owing their existence to the fact that the greatly arched labrum was crushed perfectly flat in the preparation of the microscopic slide by Cook or Collins. Therefore the present opinion is that careful scrutiny at high magnifications (450 ×) favors the original arrangement of Broelemann and Ribaut, so that if future studies provide new support for a division of *Pectiniunguis* into two genera, like that of 1912, one would be *Pectiniunguis* Bollman, 1889, type species *americanus*

Bollman, 1889 (teeth nodular, short, variously fused); the other, *Adenoschendyla* Broelemann and Ribaut, 1911, type species *geayi* Broelemann and Ribaut, 1911 (teeth longer, more or less discrete, typically dentiform rather than nodular): *Litoschendyla* Chamberlin, 1923, type species *insulana* (Broelemann and Ribaut), 1911 (teeth nodular or undulate, interdental fissures obscure or absent), would then fall as a junior subjective synonym of *Pectiniunguis*.

Pectiniunguis halirrhytus, n. sp.

On the basis of the limited evidence in the literature and the direct evidence derived from study of the type of *americanus*, it seems probable that the new species is most like the Brazilian *geayi* (Broelemann and Ribaut), the Colombian *chazaliei* (Broelemann), the Cuban *insulanus* (Broelemann and Ribaut), the Guianan *gaigei* (Chamberlin), and the Lower Californian *americanus* Bollman. In all, the leg-pair range is roughly similar, and the sternital porefields are undivided and extend in an unbroken series to one of the latter body segments.

In both *geayi* and *gaigei* the basal prehensorial article bears a tiny denticle, the porefields are subcircular or circular on all sternites, the midlabral teeth are, at least in the types, relatively long, narrow and apparently typically dentiform; at least *geayi* lacks a clypeal area: in *halirrhytus* no prehensorial article has any denticle whatever, the porefields are transversely elliptical to subtriangular becoming subcircular only on the rear sternites, the midlabral teeth are in some specimens typically dentiform but in others crenulate or undulate, in all they are nodular, short and broad. Like the new species, *insulanus* and *chazaliei* have short, broad midlabral teeth, but in both there are four mandibular dentate blocks, whereas in *halirrhytus* there are consistently only three. Moreover, in *chazaliei* the clypeus is not separated from the buccae by (paraclypeal) sutures, but in *halirrhytus* these sutures are prominent and complete, so that clypeus and buccae are separated; in *insulanus* the porefields are absent on the last four sternites, but in *halirrhytus* there is a tiny poregroup on the penult sternite.

Perhaps Bollman's *americanus* is most like *halirrhytus*; though the two are quite similar in many respects, they also differ rather strikingly in certain characters. In *americanus*: there is prominent subsurface dark pigmentation manifestating itself dorsally as a geminate longitudinal band, ventrally and laterally as dark blotches; the pretarsal accessory claws are equal in length and are not more than half as long as the claw proper which is robust, rather blunt and only slightly curved; the legs' femora and tibiae ventrally are only sparsely setose and are not more setose than the other articles; the ultimate sternite is relatively broader and shorter; the ultimate pretarsus is small but evidently discrete and distinctly tuberculate. In *halirrhytus*: there is in the typical series[2] no dark subsurface pigmentation whatever; the pretarsal accessory claws differ markedly in length, the larger of the two being more than three-fourths the length of the claw proper which is quite thin, well curved and pointed apically; the legs' femora and tibiae ventrally are clothed very densely with fine setae but the other articles are not; the ultimate is relatively longer and narrower; the ultimate pretarsus is intimately fused with the tarsus (or else it is absent) but in any case is not discrete and typically tuberculate. It seems unlikely that there are pleural differences too. The Cook and Collins representation of the pleural region of *americanus* (their Fig. 3) shows 4 gamma to be absent, but a re-examination of the Bollman type shows that it is present, just as it is in *halirrhytus*.

Holotype:—female. Florida: Monroe County, Big Pine Key; in beach seaweed; December 30, 1957, H. V. Weems, Jr., leg. In U.S. National Museum Myriapod Collection, no. 2548.

INTRODUCTORY. Total length, ca. 49 mm. Pedal segments, 59. Body shape: anterior quarter of body slightly attenuate, posterior third more conspicuously so. Color: head antennae and prehensorial segment pale orange-yellow; tergites,

[2] In 1899 Cook reported that some of his Florida Key specimens of what he called *Pectiniunguis americanus* had dorsal dark geminate bands. Having re-examined his material, I find that apart from the specimens of *halirrhytus*, all pale in color, there are at least two other species, the banded *Polycricus marginalis* (Meinert), and another species of *Pectiniunguis* which is weakly banded but whose identity is quite questionable owing to the extremely poor condition of the material. These specimens seem rather like the true *americanus*; however their present state of preservation precludes a confident assignment to that or any other species.

pleurites paler yellow; legs and sternites varying from very dilute yellow to white; body entirely without subsurface dark bands or blotches of pigmented cells.

Antennae. Length (in Hoyer's mountant), 4.9 mm. Shape: distally very slightly attenuate; each article but the first slightly longer than wide. Setae (dorsal aspect): first 4–5 articles with few short setae, each with 2 circlets of long setae; articles 5 or 6 through 14 each densely finely setose. Special sensilla: fourteenth article with an elongate patch of spatulate setae on outer distal half (these absent on medial surface); a dorsal patch of short stiff special setae on articles 14, 9, 5, (2?). Cephalic Plate (Fig. 12). Length, 1.3 mm; greatest width, 1.2 mm. Shape: dorsal surface inflated or domed, not flat; anterior margin essentially rounded; sides very slightly incurved and distinctly convergent posteriorly; posterior margin straight. Setae very few, these moderately long. Areolation: coarse and deep on anterior dorsal lateral third, approximately the dorsal and lateral two-thirds smoothly shallowly areolate. Frontal suture entirely absent; with two essentially parallel paramedian sulci passing from posterior margin of plate forward for about half its length. Prebasal plate exposed for its entire width, very narrowly laterally, widely at middle. Clypeus. Paraclypeal sutures conspicuous, wide, complete from antennal sockets to outer edge of each labral fultura (Kommandibulares Gerüst). Surface swollen ventrally especially in region of labrum. Each bucca (pleuron of some authors) glabrous, well defined, with a prominent transbuccal suture running perpendicular to long head axis at level of fultura. Clypeus anterocentrally with a large, well-defined but essentially elongate ovate to flask-shaped clypeal area, this identified by its smaller, much paler areolate figures between which minute glandular pores open (seen only at 450 ×). Without areas of consolidate areolation (plagulae). Setae: postantennals, 2; posterior geminate setae (just anterior to labrum), 2, minute; midclypeals rather robust, 9 on each side, in two poorly defined transverse rows on anterior quarter of clypeus, the two medialmost setae occupying the aforementioned clypeal area. Clypeus adjacent to labrum swollen, the areolation here heavier, darker. Labrum (Fig. 7). *In situ* its free margin is strongly directed posteroventrally, the lateral ends bulging laterally, cleft, heavily sclerotized. Central arc separated from clypeus by a narrow membranous suture, with 4 low, irregular, blunt, nodular teeth, some of these not distinctly separated from each other, vaguely anchored to clypeus, the 4 nodular teeth flanked on each side by one weakly pointed tooth. Lateral part of labrum on each side indistinctly separated from central arc but fused without suture to adjacent clypeus and continuous with it, each side of labrum with about 7 teeth, each tooth firmly anchored, broad, essentially separated from the one adjacent, each with a relatively long and very sharp medially directed extension. Mandible (Fig. 1). Dentate lamella in 3 distinct, heavily sclerotized blocks, dentition 2-3-3, the innermost block (*in situ*, ventralmost) partly overlapped by the row of simple hyaline teeth, these numbering some 23, each sharply pointed. First Maxillae (Fig. 10). Coxosternum coarsely areolate, without medial sulcus or suture; setae as shown. Coxosternal lappets thick, short, mostly concealed, reaching level of base of second telopodite article; areolate, not fibrous or squamulate. Medial lobes subtriangular, without apical nipples, distal half membranous. Telopodite biarticulate, broad, apical rounded; lappets concealed, thick, curved, areolate, not fibrous or squamulate, not exceeding end of telopodite. Second Maxillae (Figs. 6, 10). The coxosternites very broadly joined by an isthmus, this medially narrowly continuous with 1st maxillary coxosternum. Postmaxillary sclerites (pleura of some authors) separated from posterior outer corners of maxillae by a broad membranous suture on each side; inner corner not reaching metameric pore opening, outer part not surpassing level of aforementioned suture. Telopodite: 1st article basally with a ventral and a dorsal condyle, inner and outer margins essentially parallel; third article much longer than second; apical claw robust, very long, distally strongly attenuate and apically incurved, with a dorsal and a ventral comb of long thin flat hyaline teeth. Prosternum (Fig. 11). Anteriorly broadly diastemate, not denticulate; entirely without midlongitudinal sulcus. Pleura very broad; pleuroprosternal suture strongly oblique, the adjacent prosternal margin thickened as shown; sclerotic lines absent. Setae few and moderate in length. Anterolateral corners smoothly areolate, the remainder coarsely deeply so. Prehensorial Telopodite (Fig. 11). When closed, not exceeding front margin of head. 1st article rather short and broad, without a denticle; second and third articles without denticles; tarsungula basally with a typical denticle but with a broad pale fold somewhat resembling a denticle; claw relatively long and curved, neither its dorsal nor ventral edges serrulate. Poison calyx extremely long and thin, the lower end abruptly deflected laterally; poison gland long and pointed, terminating posteriorly near base of trochanteroprefemur.

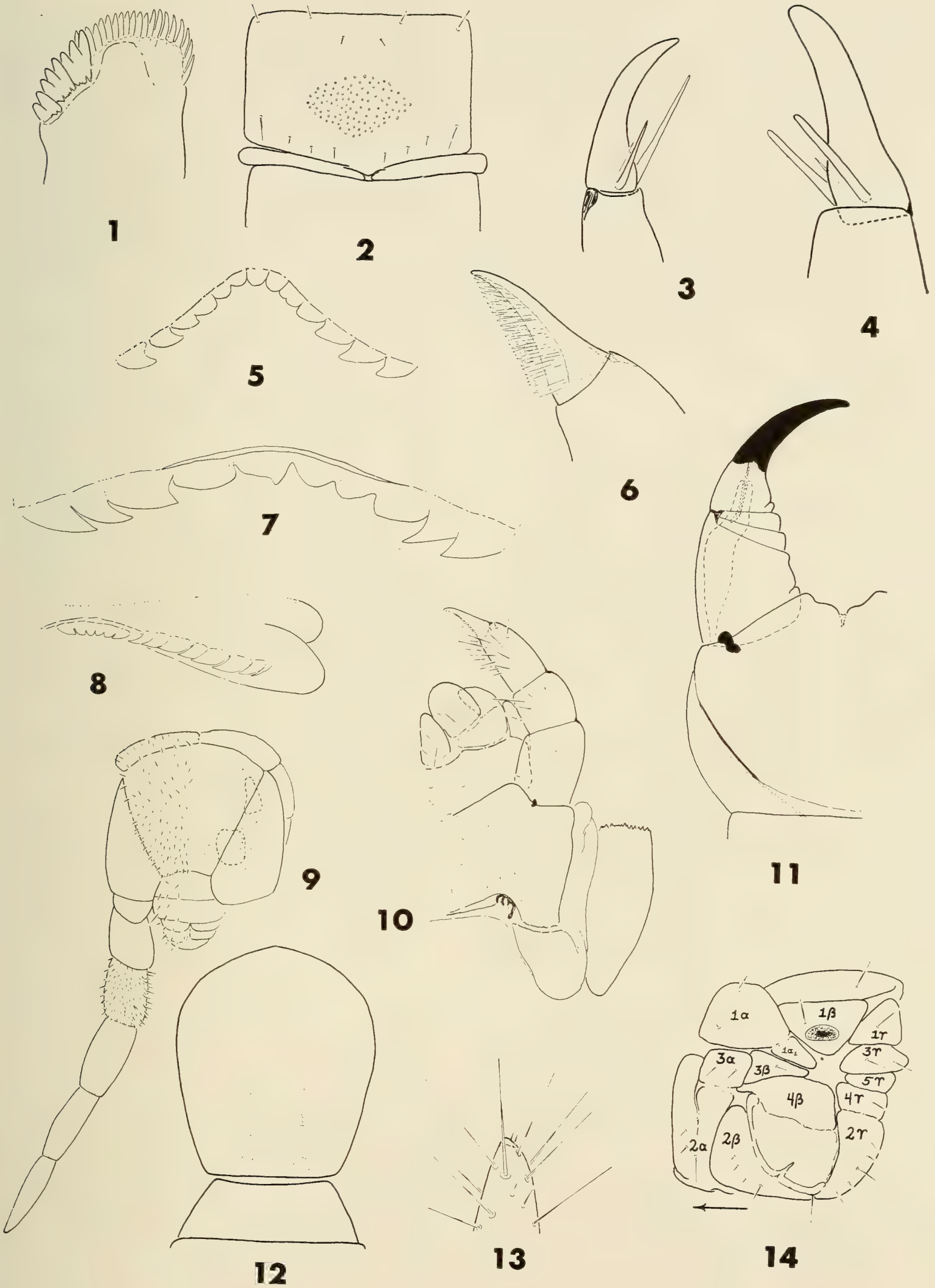
TERGITES. Basal plate centrally neither foveate nor sulcate; peripherally darker yellow, the areolation smoother, centrally whiter, the areolation coarser and deeper. Remaining pedal tergites (except the ultimate) each shallowly but distinctly bisulcate, sparsely setose. PLEURITES (Fig. 14). Coarsely areolate, very sparsely setose. All spiracles strongly elliptical, their axes horizontal. Series 1, 2, and 3 complete; 1 alpha is divided; 4 alpha evidently not discrete (i.e., not present); 4 gamma and 5 gamma are present, conspicuous. Legs (except ultimate) (Fig. 3). Ventral vestiture: femora and tibiae of legs 3 through penults very densely, finely setose; setae of remaining articles long and notably fewer in number. Posteriorly the legs become progressively thinner and longer. Pretarsi very thin (compressed side-to-side), distally strongly curved and apically sharply pointed; anterior accessory claw very long, at least three-fourths as long as claw proper, posterior accessory claw conspicuously shorter than the anterior, both accessory claws robust and pointed. STERNITES (Fig. 2). Porefields absent on the first but present on pedal sternites 2 through penultimate; last two porefields minute, each consisting of a few pores; porefields all undivided, those of anterior body third subelliptical to subtriangular, becoming wider side-to-side and developing rather pointed lateral ends, on posterior body third becoming rounder and smaller. Ventropleural subcoxal sclerites without porefields. Sternites of anterior one-third to one-half of body each with a very shallow transverse depression.

ULTIMATE PEDAL SEGMENT (Figs. 9, 13). Pretergite concealing anterior portion of coxapleuron; broadly fused with its pleurites, laterally not suturate. Tergite much broader at midlength than long; sides essentially straight and strongly convergent posteriorly; rear margin truncate. Presternite distinctly sulcate medially. Sternite width at midlength about equal to greatest exposed length; sides essentially straight, rear margin broadly evenly excavate; whole surface considerably swollen; rather densely clothed with short stiff setae, especially posteriorly, as shown. Coxopleuron as seen above exposed posterolaterally; the whole structure slightly swollen; posterior ventral half densely setose, the anterior lateral and dorsal parts with many fewer setae; each coxopleuron with 2 large ventral, concealed glandular pits, each pit with a large concealed exit and internally with numerous inclusive canals and glands (heterogenous type). Ultimate leg with 6 articles distal to coxopleuron; tarsus biarticulate, the articles thin and long; pretarsus either absent or so intimately fused with tarsus as to be indistinguishable; femur and tibia slightly flattened dorsally and moderately swollen ventrally; all articles dorsally with moderate vestiture but trochanter, prefemur, femur and tibia ventrally very densely finely setose, setae of tarsi long and less numerous.

POSTPEDAL SEGMENTS (Fig. 9). Gonopods uniarticulate, flat, wide, medially contiguous. Terminal pores absent.

Allotype:—male. See collection data for holotype. The male allotype agrees closely with the holotype but differs significantly as follows.

FIGS. 1–14.—Holotype (HT) and paratype (PT) of *halirrhytus* and holotype (HT) of *americanus*: 1, *halirrhytus* (HT): mandible. 2, *halirrhytus* (HT): sixth pedal sternite. All setae shown. 3, *halirrhytus* (HT): representative pretarsus from anterior third of body. 4, *americanus* (HT): representative pretarsus from anterior third of body. 5, *americanus* (HT): central portion of labrum. Ventral aspect. 6, *halirrhytus* (HT): left claw of second maxillae. 7, *halirrhytus* (HT): central portion of labrum. Ventral aspect. 8, *hallirrhytus* (PT): left half of labrum. Ventral aspect. 9, *halirrhytus* (HT): ultimate pedal segment and postpedal segments. Ventral. Setae shown only on right presternite, sternite, postpedal segments, and femur. Hidden glands and gland pits shown in dashed lines. 10, *halirrhytus* (HT): first and second maxillae with postmaxillary sclerite and adjacent cephalic plate; left side. All setae of maxillae shown. 11, *halirrhytus* (HT): right prehensor and right side of prosternum; ventral aspect. Setae deleted. Poison calyx and poison gland outlined in dashes within prehensor. 12, *halirrhytus* (HT): cephalic, prebasal, and basal plates. Cephalic paramedian sulci shown in stipples. Setae and antennae deleted. 13, *halirrhytus* (HT): tip of second tarsal article of ultimate leg. 14, *halirrhytus* (HT): left pleural region of tenth pedal segment. All setae shown.



Figs. 1–14.—(See opposite page for legend).

Length, 49 mm. Pedal segments, 55. Clypeus: midclypeal setae 9 + 10; posterior geminate setae absent. Labrum: medial arc wider, with 8–9 nodular undulate teeth, the interdental fissures between some absent, between others very vague, the suture separating the central arc from clypeus proportionately longer; lateral teeth about 5 on each side. Ultimate pedal segment: all leg articles conspicuously swollen ventrally and laterally, the prefemur, femur and tibia markedly flattened dorsally; all articles very densely finely clothed ventrally with stiff setae. Postpedal segments: gonopods biarticulare, long, projecting well beyond rear of body, basally widely separated.

The following paratypes differ from the holotype in the significant characters cited:

Paratype A: female. See collection data for holotype. Length, 62 mm. Pedal segments, 57. Prebasal plate very broadly exposed. Midclypeal setae right 12, left 7; posterior geminate setae present, minute. Labrum: central arc with 7–9 blunt, low broad teeth, these sharply separated from each other by deep, narrow interdental fissures; each lateral part with 8–10 broad, weakly pointed teeth. Mandibular dentate blocks 3, dentition 2-3-3.

Paratype B: male. See collection data for holotype. Length, 52 mm. Pedal segments, 57. Prebasal plate very narrowly exposed. Midclypeal setae right 7, left 7; only one minute posterior geminate seta present. Labrum: central arc with 8–10 blunt low teeth, these with short, narrow but distinct interdental fissures: each lateral labral part with about 8 teeth, some with long apical points, some lacking them. Mandibular dentate blocks 3, dentition 3-3-3. Coxopleural pits fully exposed, not concealed.

Paratype C: female. See collection data for holotype. Length, 42 mm. Pedal segments, 55. Prebasal plate very narrowly exposed, nearly concealed. Milclypeal setae 9 + 9; only one posterior geminate seta present and this seems vestigial. Labrum: 8 teeth on central arc, these with shallow interdental fissures, blunt, low, broad; lateral teeth about 7 on each side. Mandibular dentate blocks, 3, dentition 2-3-3 (left), 3-3-3 (right).

Paratype D:—female. Florida: Monroe County, Flamingo; May 3, 1958; R. S. Swanson and C. F. Dowling, leg. Length, 64 mm. Pedal segments, 57. Prebasal plate well exposed. Midclypeal setae right 11, left 9; with two minute posterior geminate setae. Labrum: central arc with 4–5 blunt broad teeth, the interdental fissures very shallow or else absent (Fig. 8); lateral teeth strongly pointed, 9–10 on each side. Mandibular dentate blocks 3, dentition 2-3-3.

REFERENCES

Attems, C. graf. Das Tierreich, Lief. **52:** 1–388. 1929.

Bollman, C. H. Proc. U.S. Nat. Mus. **12:** 211–216. 1889.

Broelemann, H., and Ribaut, H. Bull. Soc. Ent. France no. 8: 191–193. 1911.

———. Ibid. no. 10: 219–222. 1911.

———. Nouv. Arch. Mus. Hist. Nat. Paris (5)**4:** 53–183. 1912.

Chamberlin, R. V. Proc. California Acad. Sci. **12**(18): 389–407. 1923.

Cook, O. F. Proc. Ent. Soc. Washington **14**(3): 303–312. 1899.

Cook, O. F., and Collins, G. N. Proc. U.S. Nat. Mus. **13:** 383–396. 1891.

The beliefs which we have most warrant for, have no safeguard to rest on, but a standing invitation to the whole world to prove them unfounded. If the challenge is not accepted, or is accepted and the attempt fails, we are far enough from certainty still; but we have done the best that the existing state of human reason admits of; we have neglected nothing that could give the truth the chance of reaching us: if the lists are kept open, we may hope that if there be a better truth, it will be found when the human mind is capable of receiving it; and in the meantime we may rely on having attained such approach to truth, as is possible in our day. This is the amount of certainty attainable by a fallible being, and this is the sole way of attaining it.—John Stuart Mill.

R. E. SNODGRASS HONORED

The Smithsonian Institution has recently published a volume, *Studies in invertebrate morphology*, in honor of Dr. Robert Evans Snodgrass, one of the world's leading insect morphologists, on the occasion of his 84th birthday, which occurred last July 5. Longtime entomologist of the Bureau of Entomology of the U. S. Department of Agriculture, Dr. Snodgrass officially retired in 1945, but he has continued his scientific work at the U. S. National Museum, holding the position of honorary collaborator of the Smithsonian. He has been active in the scientific life of Washington for more than half a century and was one of the prominent contributors to this Journal's predecessor, the Proceedings of the Washington Academy of Sciences.

The Festschrift just published contains a biographical account of Dr. Snodgrass written by Dr. Ernestine B. Thurman, who also compiled his bibliography, covering the years from 1896 to 1958. These are followed by contributions from 17 of the some of world's most eminent scholars in the field of invertebrate morphology.

One outstanding chapter in the series, for example, is by Prof. C. S. Carbonell, of the Universidad de la República, Uruguay, who describes the anatomy of the South American grasshopper *Marella remipes*. This strange insect, at least from an evolutionary viewpoint, in the process of changing from a land to a water animal. It has acquired, chiefly through changes in body structure, ability to swim easily both on or under the surfaces of ponds and stagnant streams. It passes considerable time totally submerged among aquatic plants, to whose stems it clings to avoid floating back to the surface. Its eggs are laid under water, where they adhere to the under surfaces of floating leaves. Thus far specimens of this water grasshopper have been found in Argentina, Uruguay, eastern Peru, British Guiana, and Surinam, and it probably is actually much more widely distributed but ordinarily would not attract notice. It is normally an air-breathing creature which lives on the floating leaves of water lilies. It eats these leaves from the flat surfaces—never from the edges as would be characteristic of most grasshoppers. The peculiar aspect of the partially eaten leaves is so characteristic as to betray the presence of the insects before they actually can be seen, Dr. Carbonell says. From an anatomical viewpoint, he says, the creatures show notable adaptations to locomotion in water, especially in the structure of the hind legs which are "oar-shaped." Other changes from the conventional grasshopper form are less striking, but all are in the direction of adaptation to aquatic life.

Another noteworthy contributor to the Snodgrass volume is Dr. K. D. Roeder, of Tufts University. His thesis is that insects can not afford to "learn," that there is not room in their bodies for the spare nerve cells that apparently are essential for learning—that is, modification of behavior due to individual experience. Hence their quite limited nervous systems are constructed for extremely rapid, quite stereotyped innate responses to avoid predators or to capture their own prey. Admittedly, Dr. Roeder says, there is little understanding of the neurological basis for the process known as learning in higher animals. It is generally believed, however, that it involves the capacity for a very great number of combinations, or interactions, between neurons, the basic units of the central nervous system. The number of such interactions which is theoretically possible must depend to a great extent on the actual number of nerve units which are available. There must be a very great number of these in organisms with a high learning capacity.

The insect, however, apparently has no neurons to spare. It must depend on an all-or-none response to a stimulus. Dr. Roeder compares it with the ringing of an alarm bell in a fire station. The firemen do not know whether it is a big fire or a little fire. They spring to action at once. Their behavior is modified later, of course, by the kind of fire—a blaze in a trash barrel or the conflagration of a city block. They have "learned" from experience.

Notable in the insect anatomy are giant nerve fibers—considerably larger than any individual fibers found in mammals or birds—leading from the outside of the body to the brain. Such an "axon" can transmit only one impulse at a time. In higher animals a nerve transmitting "wire" is made up of many much finer fibers, each of which can carry its own message. But the insect does not need a lot of description of the cause of its alarm. It does not need to know color, shape, size, odor, etc. It is recognized, says Dr. Roeder, that a single large fiber transmits a nerve impulse more rapidly than a bunch of fibers. In the insect nervous system abundance of information has been sacrificed for speed of response. The response itself is built into the nervous system of the particular insect race, presumably the result of millions of generations of evolution. It is, by and large, invariable after the nerve impulse is received. The insect need not think what to do. This would take time, measured in thousandths of seconds. This the insect cannot afford, for in its world the difference of a millisecond may be the difference between destruction and survival.

KATMAI AREA DESCRIBED

Nearly half a century ago a large Alaskan valley was covered completely with the debris and hot ashes of one of history's greatest volcanic eruptions. All vestiges of life were consumed by fire. At the most, a bare trace of vegetation in a few sheltered spots may have survived. Thus was created an area believed quite comparable to the ancient surface of the earth before the most primitive forms of plant life first appeared. Plants presumably constituted the base from which has been built through a billion or more years the great pyramid of terrestrial life. The steaming, smoking, lifeless valley offered scientists an opportunity to observe firsthand an obviously telescoped re-enactment of the fundamental phenomenon of replacement of life on the planet. The area was the Valley of Ten Thousand Smokes, now part of the Katmai National Monument in southwestern Alaska.

The progress through half a century is recorded in a report recently published by the Smithsonian Institution of a systematic biological survey of the region by Victor H. Cahalane, former chief biologist of the National Park Service, and now Assistant Director of the New York State Museum. It results from a survey of the Katmai area by the National Park Service, starting six years ago and financed largely by the Office of Naval Research. One of the important objectives of the survey was to gather data on useful or poisonous plants, dangerous animals, and other information that might serve military needs from the survival aspect.

The first surveys, started about five years after the volcanic eruption, were carried on by a series of National Geographic Society expeditions. It was found that in this relatively brief period life had started to reassert itself amid the smoking desolation. The National Geographic Society explorers found in favorable spots patches of the quite primitive form of mosses known as liverworts. Through successive expeditions up to about 20 years ago these liverworts and a few other quite primitive plant forms expanded luxuriantly as the ashes cooled.

For the next two decades the progress was not followed by scientific observers. Mr. Cahalane and his associates resumed where the former explorers had concluded their work. They found, according to the Smithsonian report, that the ancient mosses had almost completely disappeared. The gradual cooling of the soil presumably had produced a condition unfavorable for their survival. But higher plants, including some flowering species, have gained a precarious foothold. Altogether 35 species were collected, including several grasses, dwarf willows, and the lovely Arctic poppy and dwarf fireweed. Most of these, according to the report, apparently are holding their own. From year to year conditions presumably will become more favorable for them.

In most cases, it is likely, seeds were blown in from outside the area. The investigator, however, found several "plant islands." These are in areas that presumably were slightly protected from the fall of hot ashes and may be survivals of the original vegetation of the region, concerning which nothing is known.

Henceforth the re-vegetation of the valley will be followed from year to year. Plots, each with its own limited plant growth, have been staked out and will afford bases for observing the development under the varying conditions which now obtain.

The animal life present before the eruptions was unable to survive them, but since then the area has been increasingly re-invaded by the same species from nearby areas. In due time it may be expected to show once more a faunal picture more or less like the original one. So far as human beings were concerned, the report says, there could have been at the most only a few scattered Eskimo villages farther away, the inhabitants of which had sufficient warning of the coming catastrophe so that they were able to escape.

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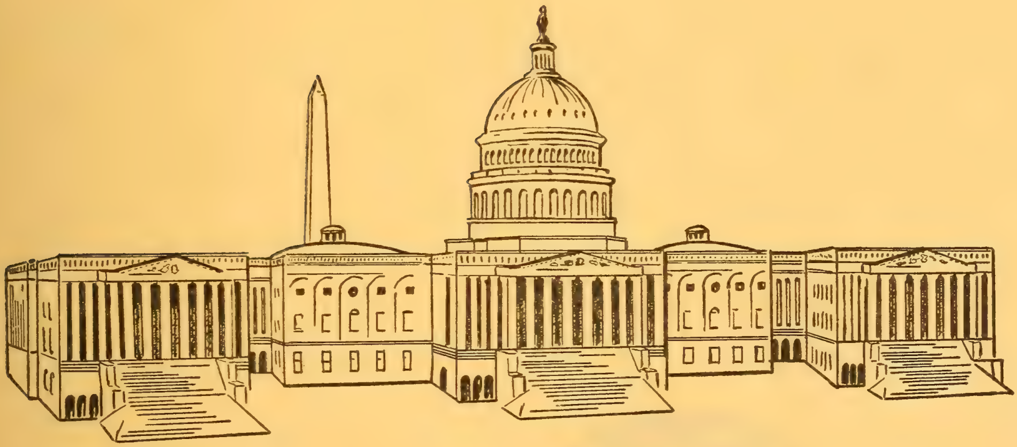

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ASTRONOMY.—Cepheid variables and the period-luminosity relation.[1] C. PAYNE-GAPOSCHKIN, Harvard College Observatory. (Communicated by Charles M. Herzfeld.)

The period-luminosity relation has almost reached its fiftieth anniversary. Today it is being studied more actively than ever, and its observed complexities and theoretical implications are still far from exhausted. In fact I hope to show that what we know and understand at present about the period-luminosity relation is far less than what remains to be discovered and interpreted.

Introduction.—The diagram derived by Miss Leavitt (*1*)[2] from 25 Magellanic Cepheids, reproduced in Fig. 1, already shows several of the features of current interest: the linear relationship between the apparent magnitude and the logarithm of the period, the scatter of the points about the curve, and the variety of amplitudes. Each, as I shall describe, has been verified and amplified by later work.

The earlier work of Bailey (*2*) on the variable stars in globular clusters laid the foundation for the recognition of an equally striking relationship between period and apparent brightness within any one globular cluster. Although the variables with periods shorter than a day showed no marked correlation between period and brightness, the few with longer periods were always brighter. On the simple assumption that all the short-period variables were of similar luminosity, Shapley (*3*) constructed a period-luminosity curve from the data for all globular clusters that contained variables with periods longer than a day, and concluded that it had the same slope as the relation for the Magellanic Cepheids.

If the identity of the two period-luminosity relationships is granted, the conversion from apparent to absolute magnitude can be effected by the establishment of absolute magnitude for some one contributor to the curve. The short-period variables in globular clusters were identified with the RR Lyrae stars of the galactic field, many of which have periods and light curves exactly like those of the cluster variables. Accordingly the absolute magnitudes of the RR Lyrae stars were intensively studied, and the generally accepted value 0.0 was used to fix the zero point of the period-absolute magnitude relation.

The immediate application of this conclusion by Shapley led to his epoch-making study of the dimensions of the galaxy. Later revisions of this work have resulted from improvements in the scale of apparent magnitudes and from corrections for obscuration, not from revisions in the zero point of the absolute magnitudes.

The upper part of the period-luminosity curve was used to derive the distances of the Magellanic Clouds, and when Hubble (*4*) discovered Cepheids in NGC 6822, Messier 33, and Messier 31, the distances of these galaxies were similarly derived. These applications of the period-luminosity curve depended on the original working assumption that the relationships among the stars in globular clusters and those in the Magellanic Clouds and other galaxies were not only parallel but identical. That this assumption is not justified was shown by Baade (*5*) in his study of the Andromeda galaxy. The zero point of the period-lumi-

[1] The 28th Joseph Henry Lecture of the Philosophical Society of Washington, delivered before the Society on May 22, 1959.

[2] Italic numbers in parentheses refer to the Bibliography, pp. 349–350.

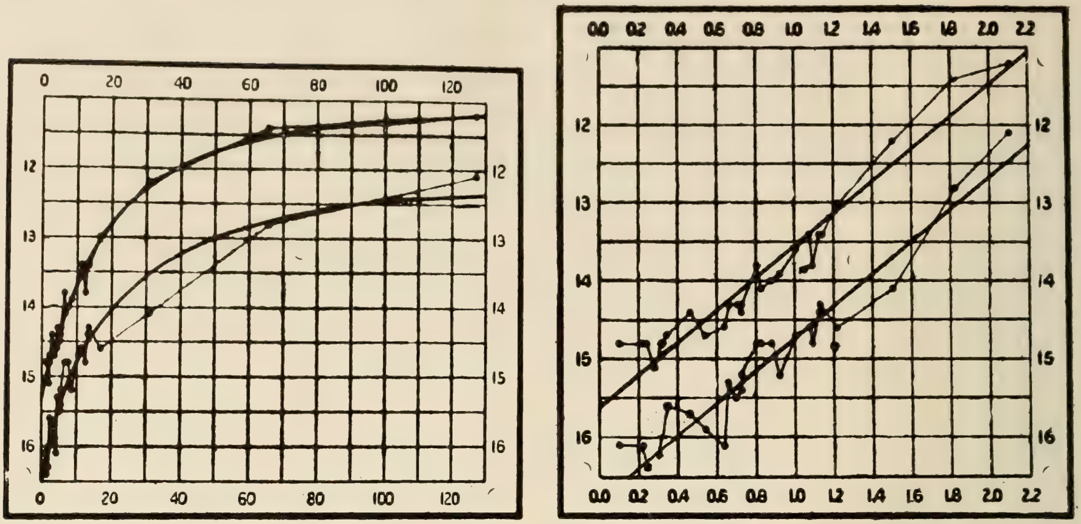

FIG. 1.—Miss Leavitt's period-luminosity relation (maximum photographic magnitude above, minimum below). Left: period plotted against magnitude; right, logarithm of period plotted against magnitude. From Harvard Circular 173. 1912.

nosity curve for classical Cepheids was thus revised upward by about 1.5 magnitudes, and all distances derived by the use of the upper part of the curve were accordingly also revised upward.

Within any one globular cluster there is very little correlation between the apparent magnitude and period of the RR Lyrae stars, but the photographic (though not the photovisual) magnitude has been shown for example by Roberts and Sandage (*6*) to be slightly brighter for the variables of shortest period in Messier 3. That the absolute magnitudes of RR Lyrae stars may differ slightly in different globular clusters is suggested by Sandage (*7*) and the possibility that the accepted absolute magnitude of RR Lyrae stars may require downward revision is discussed by Arp (*8*).

The period-luminosity relations for variables in globular clusters and for Cepheid variables have been convincing separated by the work that has been briefly sketched in the preceding paragraphs. Another equally striking correlation that might well have pointed in the same direction many years ago is the Hertzsprung relationship between the periods and the forms of the light curves (*9*). The classical Cepheids of the galaxy show a progression in the form of a light curve (*10*), such that stars of the shortest periods show a smooth rise and fall, at longer periods (about 5 days) a hump appears on the declining side, and becomes more pronounced up to periods between 8 and 9 days. Between 9 and 10 days the curves abruptly become more symmetrical, with a more or less well-marked hump between two shoulders, and generally small amplitude. At rather longer periods the light curve has a more abrupt and asymmetrical rise, with a small hump just preceding the main brightening, and at the longest periods the curve is again found to be smooth and uncomplicated. The light curve thus runs through one complete cycle of changes between the shortest and longest periods. Cepheids in the Magellanic Clouds also display the Hertzsprung relationship (*11*).

An analogous relationship between period and light curve is shown by the short-period variable stars in globular clusters: in any one cluster, the stars of shortest period have light curves that are almost sine curves, and there is a rather abrupt transition at some longer period (not the same in all clusters) to a highly asymmetrical light curve, usually with a small hump before the main rise. Stars of the longest periods (less than a day) have less asymmetrical light curves. This relationship was pointed out by Bailey, who designated the curves by the letters c, a, b, in order of increasing period.

The Hertzsprung relationship for galactic classical Cepheids and RR Lyrae stars is illustrated in Fig. 2.

The globular cluster stars with periods over a day do not conform to the Hertzsprung relationship; those with periods between 10 and 20 days show a broad maximum or a hump on the downward slope (*12*). A few galactic variable stars of simi-

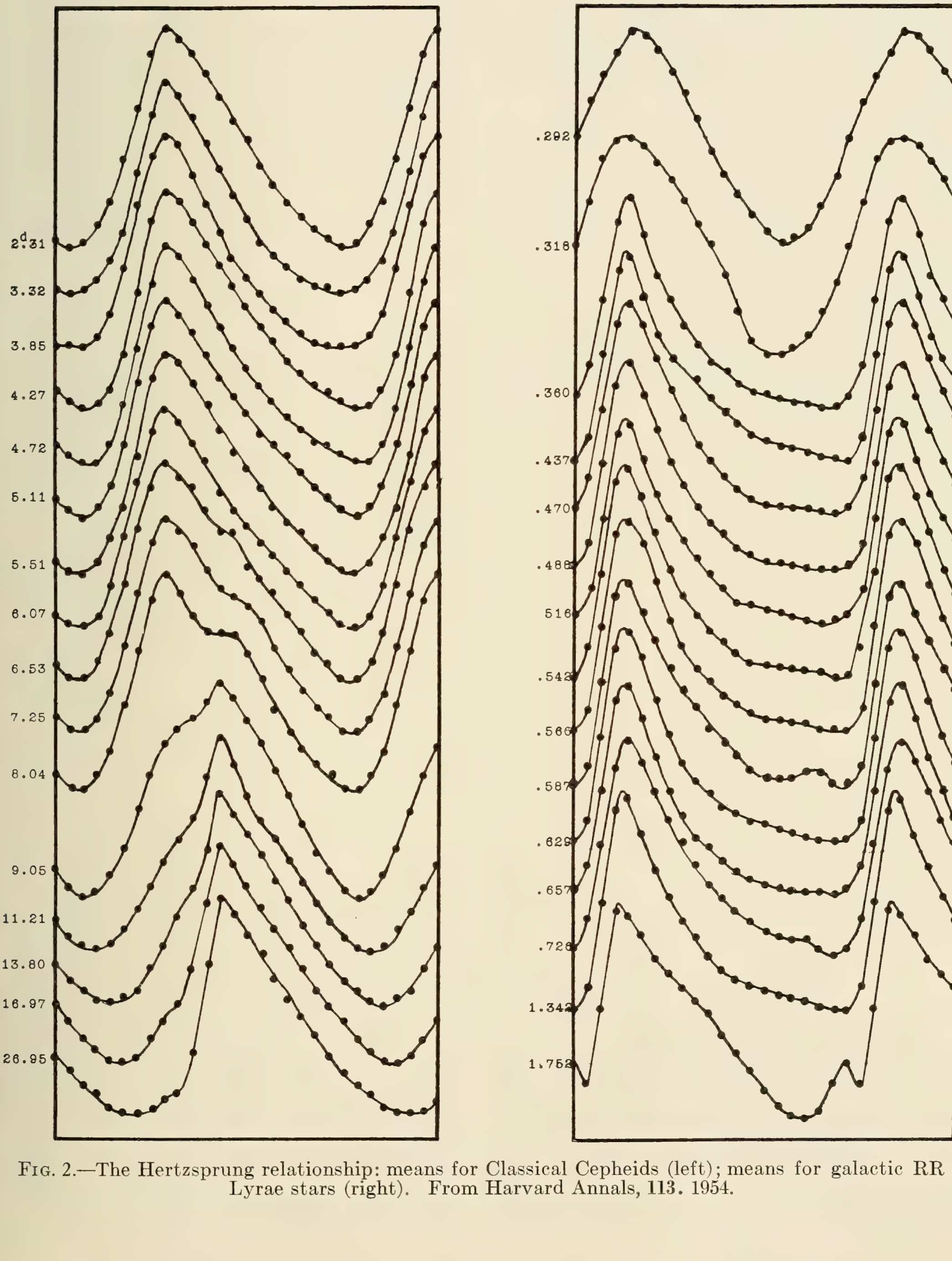

Fig. 2.—The Hertzsprung relationship: means for Classical Cepheids (left); means for galactic RR Lyrae stars (right). From Harvard Annals, 113. 1954.

lar period, which differ from classical Cepheids in lying far from the galactic plane, in motion, and in other ways, show similar light curves. In particular, a group of Cepheids associated with the galactic center shows a period-light curve pattern similar to that of the stars in globular clusters (*13*). These galactic variable stars are clearly to be associated, like those in globular clusters (*14*), with Population II, whereas the classical Cepheids are members of Population I (*15*).

The period - luminosity relationship.—Miss Leavitt's period-luminosity relationship showed considerable scatter about the mean curve, and all later studies of the variables in a single system (the Magellanic Clouds, Messier 31, and so forth) also show a dispersion. As the periods are determined with adequate accuracy, it is usual to consider whether the observed dispersion can be a result of factors that have affected the magnitudes. Shapley (*16*) enumerated possible contributors: errors of the magnitudes, effects of unresolved doubles, effects of general background brightening, obscuration within the system, galactic obscuration, Eberhard effect. Erroneous periods would produce the same effect, but their contribution is certainly negligible.

In the early days of the application of the period-luminosity relation, there was a tendency to assume that a great part of the dispersion was due to observational causes and that the stars actually lay very close to the curve. Recent work by Arp (*17*) on the Small Magellanic Cloud leads him to the conclusion that most Cepheids lie within a range of one magnitude at any one period, which implies that most of the observed dispersion is intrinsic. Sandage (*18*) contemplates the even larger range of 1.2 magnitudes at a given period.

Hitherto I have spoken in terms of observed quantities only. Further progress cannot be made without some very elementary theoretical assumptions: first, that the relationship $P\sqrt{\rho} = C$ is accurately fulfilled; second, that Cepheids conform to the mass-luminosity relationship. Granted these premises, then if there is a dispersion in magnitude at a given period, three conclusions follow:

1. At a given period there is:
   - (a) a dispersion in color, the bluest stars being of highest luminosity
   - (b) a dispersion in luminosity, the brightest stars being the bluest
2. At a given luminosity, there is:
   - (a) a dispersion in period, stars of longest period being the reddest
   - (b) a dispersion in color, the reddest stars being of longest period
3. At a given color, there is:
   - (a) a dispersion in period, stars of longest period being brightest
   - (b) a dispersion in luminosity, the brightest stars being of longest period

These three conclusions are shown graphically in Figs. 3, 4, and 5, which have been drawn for a range of magnitude of 1.0 at a given period, and for a range of color of 0.2 at a given magnitude.

The relation between mean color and absolute magnitude is not implicit in the assumptions, but can be shown to be plausible. The existence of a mean period-spectrum relation for Cepheids has long been recognized, and the data given by Code (*19*) define it accurately. If all Cepheids were of the same color, they would all have the same surface temperature. But the more luminous Cepheids would then have somewhat earlier spectral classes on account of lower surface gravity. Since the opposite is observed, we can infer that bright Cepheids are somewhat redder than fainter Cepheids and that the difference of color between two Cepheids is greater than the difference found between two stars of comparable luminosities and identical spectral class.

Data on the accurate colors of Cepheids in other galaxies are needed, both to test the qualitative statements just made and to provide quantitative material from which consistent period-magnitude-color arrays may be constructed. However, the effect of obscuration also enters into such colors, and even if all Cepheids in a system were of the same true color at a given period, obscuration and extinction would conspire to make the most reddened stars the faintest. The size of the effect in our own system may be judged from the diagram of maximal color index against logarithm of period reproduced by Walraven, Muller and Oosterhoff (*20*). The diagram contains a few points for the two Magellanic Clouds, from measures by Gascoigne; these, and the few colors

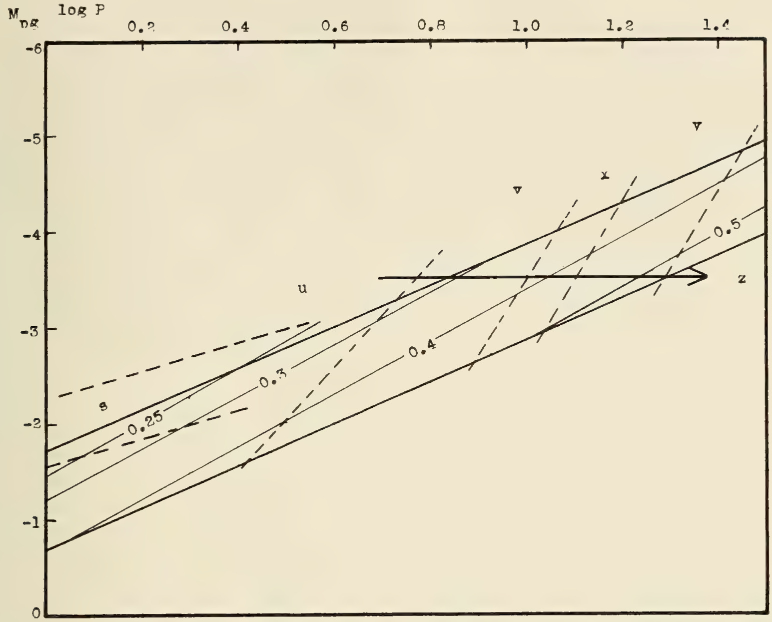

FIG. 3.—Relation between period and absolute magnitude (schematic); light lines show equal colors; broken lines separate the domains of different curve types. The arrow shows the possible course of Cepheid development.

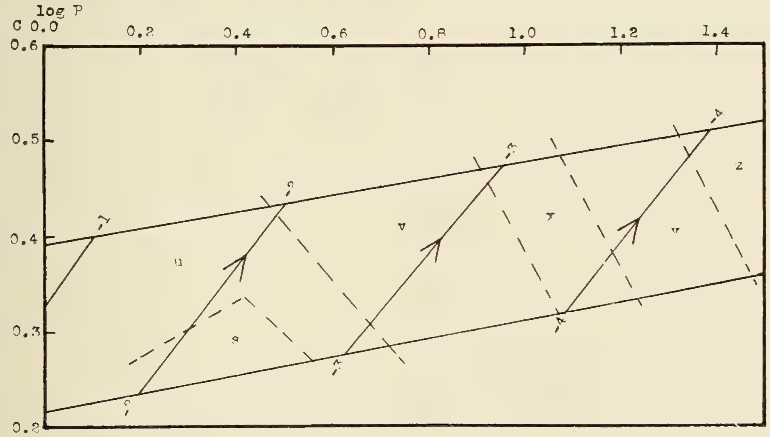

FIG. 4.—Relation between period and color (schematic). Light lines show equal absolute magnitudes; broken lines separate the domains of the different curve types. Arrows show the possible course of Cepheid development.

published or discussed by Gascoigne and Kron (*21*), Gascoigne (*22*), and Gascoigne and Eggen (*23*) are not inconsistent with the view here expressed. Gascoigne and Eggen act on the belief that the evidence for identity in color between galactic and Magellanic Cepheids, though not conclusive, is encouraging. Opinion has long been divided on this matter, and I will state my own view—that the colors of the galactic and the Magellanic Cepheids are essentially similar, and that the dispersion of color is as decribed above in simplified terms.

The Hertzsprung relationship.—The relation between the period, luminosity, and light curve of a Cepheid must next be con-

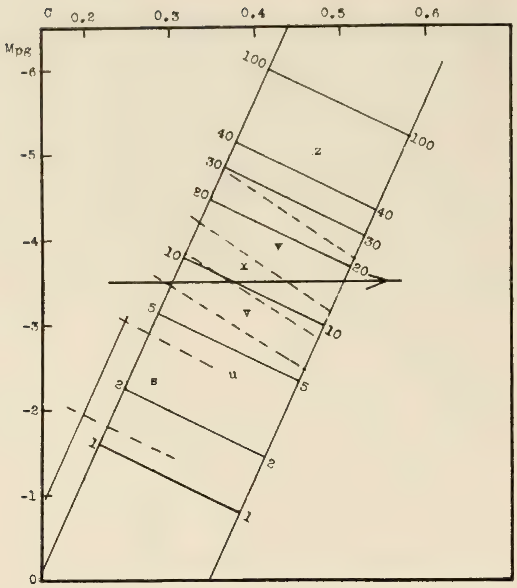

FIG. 5.—Relation between color and absolute magnitude (schematic). Light lines show equal periods; broken lines separate the domains of the different curve types. The arrow shows the possible course of Cepheid development.

sidered. The fact that averaged light curves for several stars with a small range of period display the Hertzsprung relation shows clearly that form of light curve is closely related to period. If the period-luminosity curve has a dispersion, then, if stars of a given period should have identical light curves, stars of a given absolute magnitude should have light curves that differ systematically with period.

The Cepheids in the Small Magellanic Cloud furnish information on this point. In order to present the data something must be said about the classification of light curves. The Bailey types a and c for the variables in globular clusters are excellent criteria, unambiguous and mutually exclusive. Type b, however, grades into type a and today is usually combined with it. In the classification of light curves, as in other matters (period frequencies, absolute luminosities of RR Lyrae stars) a globular cluster appears, so to speak, to lack a dimension in comparison to a system like the Small Cloud. This dimension is very likely mass: stars on the horizontal branch of a globular cluster must all be of almost the same mass. The Cepheids in a large system also differ in the time dimension. Methods of analysis and classification that give clear-cut results for globular clusters will not necessarily do so when applied to more complex groups. This statement, obvious in regard to color-magnitude arrays, is no less true of the classification of light curves. Methods that suffice for RR Lyrae stars are not flexible enough for Cepheids.

The first photoelectric light curves of Cepheids confirmed the variety and complexity of the light curves and color changes. Eggen (*24*) first defined groups A, B, C to represent the light curves, on the basis of relationships between period and amplitudes of light and color. Whether or not is was intended, the names suggested a parallel with the Bailey types, which has no physical justification. In a later paper, the definitions for types A, B, and C have been modified: a star is of type C if the light curve is symmetrical ($M - m = 0.37\,P$), of type B if a hump is present, of type A if no hump is observed (*25*).

To me it has always seemed that the Hertzsprung relationship is fundamental in describing the light curves of Cepheids, and that three classes are not enough to cover its complexities. My own classes have been defined as follows (*26*)

u: smooth, asymmetrical (δ Cephei)
v: smooth rise, hump on decline (η Aquilae)
w: saddle-shaped curve (S X Velorum)
x: central peak, shoulder on each side (Z Lacertae)
y: sharp rise, preceded by small rise (S Z Aquilae)
z: smooth, asymmetrical (U Carinae)
s: sine curve (G H Carinae)

Eggen's type C covers types s and x, his B covers v and w, and his A covers u, y, and z.

The period-luminosity curve for minimal photographic brightness in the Small Magellanic Cloud is shown in Fig. 6, which embodies a great deal of unpublished material kindly made available by Dr. Shapley, for over 600 stars. The magnitudes are on the uncorrected Harvard scale; Arp's photoelectric work has shown that the range of magnitudes should be increased.

The points corresponding to stars with different curve types have been plotted with distinctive symbols, and I have indicated by

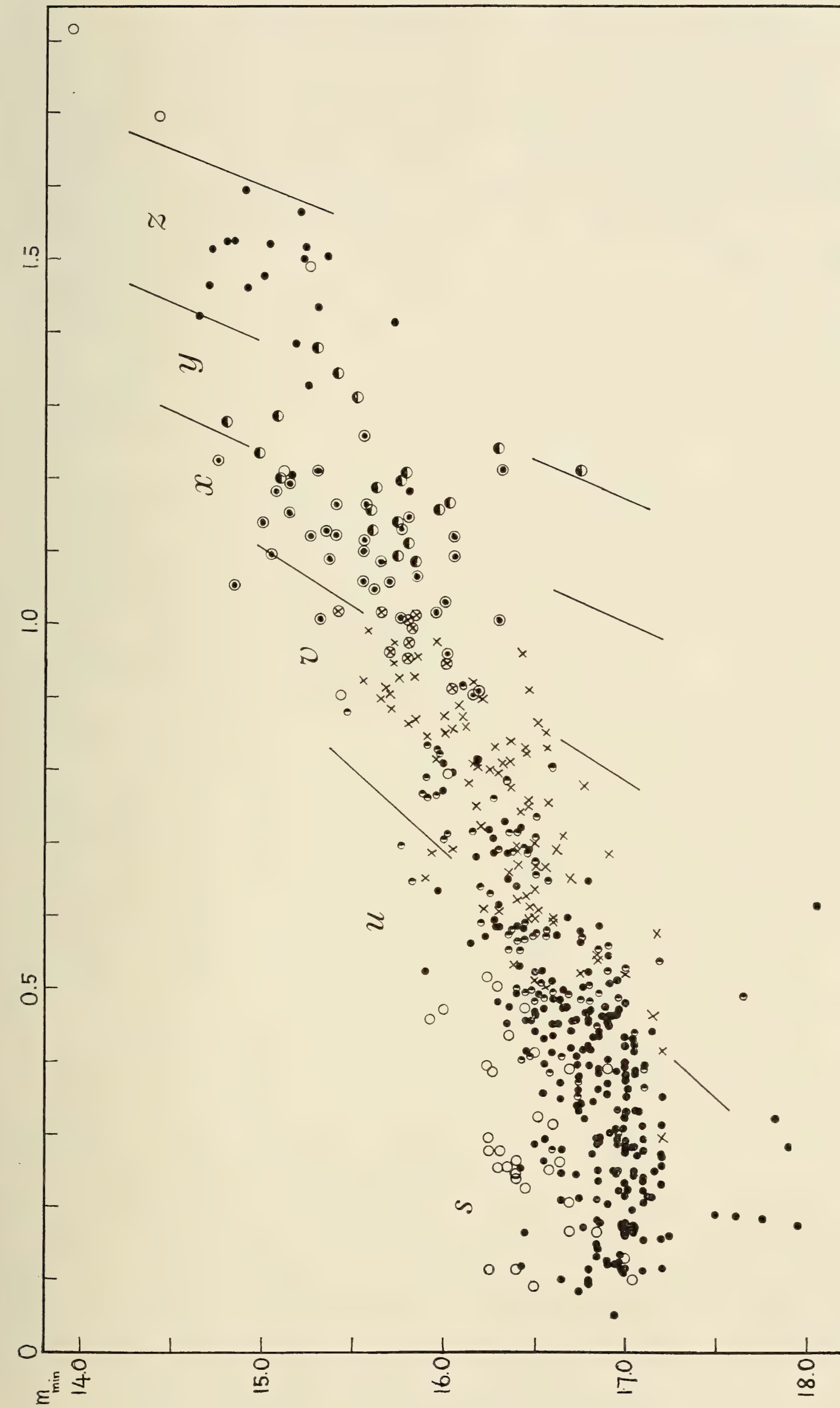

FIG. 6.—Relation between logarithm of period and apparent minimal magnitude for Cepheid variables in the Small Magellanic Cloud. Stars with various types of light curve are shown as follows: type s, circles; type u, dots; type u-v, half-filled dots, vertically divided; type v, crosses; type w, circled crosses; type x, circled dots; type y, circles horizontally divided; type z, dots (= type u). Light lines separate the domains of the various curve types.

broken lines the approximate domains occupied by light curves of different types.

An earlier diagram of the same kind (*26*) made with about a hundred stars from both clouds shows the effect more clearly. This is in part because the light curves were better determined, in part because the stars were selected for freedom from obvious obscuration. The reality of the dependence of curve type on luminosity as well as on period was verified by means of the χ^2 test. Points for curve type u could not be included in the discussion on account of incompleteness at faint magnitudes.

A feature of Fig. 6 that does not run parallel to the other curve types is the group of symmetrical curves for stars of short period. These small-range curves seem to follow a period-luminosity spread parallel to the main one, and overlapping it slightly. These stars are of such interest that they must be examined critically to see whether their small range, and comparatively high luminosity for their period, could result from the presence of unresolved companions. They seem to be too numerous for this to be a likely interpretation. Moreover, they have counterparts in our galaxy (GH Carinae, FF Aquilae, DT Cygni).

Cepheids of similar curve type, therefore, are not aligned precisely with Cepheids of similar period. In Figs. 3, 4, and 5, the domains of similar curve type are separated by broken lines. These domains cut lines of equal period (mean density), equal luminosity, and equal color, at various angles, so curve type is not primarily determined by any of these properties of the star.

Development of RR Lyrae stars.—The place of the RR Lyrae stars in stellar development has been deduced from their well-defined position in the H-R diagrams of globular clusters. They are evidently members of the horizontal branch; the continuity of star counts through the variable star domain, in variable-rich clusters, suggest that they move *along* the horizontal branch (*27*). The correlation of period and color found in Messier 3 by Roberts and Sandage implies that an RR Lyrae star changes its period as it crosses the gap, and makes an abrupt transition to or from "overtone" pulsation as it crosses the interface between the type a and c curves. Changes of period are not (and are unlikely to be) large enough to indicate which way the RR Lyrae star travels in the H-R plane although one can infer that many writers think in terms of progress from long to short period, from fundamental to overtone, from right to left in the HR plane.

If the method of mapping empirical evolutionary tracks employed by Sandage (*28*) is valid, the distribution of stars along the horizontal branch might give a clue to the rate at which a star crosses the variable gap, or at least the relative rate at which different parts of the path are traversed. As Arp (*29*) has pointed out, a strongly populated horizontal branch goes with a large variable star population, but there are variable-poor clusters such as Messier 2 in which only one side of the variable star gap is well populated. Within the gap itself, however, the variable stars are not distributed uniformly with period. In ω Centauri, for example, numbers of stars within equal limits of log P are as follows:

log P	0.4 to 0.5	0.5 to 0.6	0.6 to 0.7	0.7 to 0.8	0.8 to 0.9	0.9 to 1.0
Number of stars	6	31	15	38	25	10

These numbers do not change uniformly, as might be expected for steady progress across the gap; rather they suggest acceleration-deceleration-acceleration as the gap is crossed. For classical Cepheids the situation is even more complex. In any one globular cluster there is a very small dispersion of absolute magnitude at any one period, but in a large stellar system such as the Magellanic Clouds and Messier 31, the dispersion in magnitude at one period adds at least one dimension to the problem.

Development of Cepheids.—It has long been recognized that the Cepheid variables lie within the Hertzsprung gap in the HR plane. Although the true colors of galactic Cepheids, and their dispersion, are extremely difficult to determine, as has already been mentioned, it seems very likely that all Cepheids with a given luminosity lie within a restricted range of color (about 0.2 magnitude), and that no other stars lie within this range. The Population II Cepheids seem to occupy a similar domain, probably somewhat to the blue of the domain for classical Cepheids. The situation as I see it is shown in Fig. 7. The variable supergiants appear to lie on either side of the Cepheid domain (*30*).

The picture has been refined by the discovery of a few Cepheid variables in galactic clusters (*31*). The well-established members are tabulated below.

Cluster	Cepheid	Period d	Light curve	
			Eggen	This paper
NGC 6664	EV Sct	3.09	C	s
NGC 7788	CE Cas a (*32*)	4.45		
	CF Cas	4.87	AB	u
	CE Cas b	5.13		
Messier 25	U Sgr	6.74	AB	v
NGC 129	DL Cas	8.00	C?	s?
NGC 6087	S Nor	9.75	C	x

The suggestion of Bidelman that UX Persei (4^d.57), UY Persei (5^d.37), VX Persei (10^d.90) and SZ Cassiopeiae (13^d.60) are members of the Perseus I association should be mentioned (*33*). The Burbidges regard SZ Cassiopeiae as "probably a member of the cluster." The apparent magnitudes of all four stars are correlated with their periods.

The stars in the table are all as bright as, or brighter than, the brightest main sequence stars in the clusters (*34*); the four possible members of the Perseus cluster are fainter than the bright B stars and M stars in the Perseus double cluster. These data suggest that the age of a Cepheid in a galactic cluster can be determined:

Star	Cluster	Age of cluster years	Age of Association years	*Ref.*
EV Sct	NGC 6664	2×10^8		(*33*)
CE Cas a, CF Cas, CE Cas b	NGC 7778	10^8		(*33*)
U Sgr	Messier 25	10^8		(*33*)
DL Cas	NGC 129	10^8		(*33*)
S Nor	NGC 6087	10^8		(*33*)
SZ Cas	h, χ Persei	10^6		(*35*)
	Perseus I		4×10^6	(*36*)

The Cepheids in galactic clusters evidently lie within the Hertzsprung gap, and it is rather clearly indicated that a star becomes a Cepheid as it reaches a certain critical color as it crosses the gap. Analogy with globular clusters, where nonvariable stars are found on both side of the gap, might suggest that it emerges on the other side of the gap and becomes a red giant, and at least in NGC 6664 there is clear evidence of red giants (*31*). If SZ Cassiopeiae is a member of the Perseus Association, it again is associated wtih red giants, and ER Carinae has been suggested as a possible (though unverified) member of NGC 3532, which is very rich in red giants. We note also that the lower limit of the classical Cepheids is not far from the place (between NGC 752 and Messier 67) where the Hertzsprung gap has narrowed and disappeared. The general picture is shown in Fig. 8, which amplifies Sandage's well-known diagram by the addition of material for the Orion I association (*37*) and the Magellanic Clouds (*38*).

The three Cepheids in NGC 7778 display a rather small range of periods and magnitudes. The bright "galactic" cluster NGC 1866 in the Large Magellanic Cloud is an example of a cluster that contains many Cepheids, most of them in a restricted range of period (*39*). The following table gives the names, periods, and approximate mean magnitudes; stars within 10′ of the center of the cluster are marked with asterisks.

HV	Period d	Mean m_{pg}	HV	Period d	Mean m_{pg}
12206*	2.506	16.1	12194*	3.205	16.0
12208	2.604	16.2	12205*	3.210	15.9
12199*	2.639	16.51	12189	3.246	16.4
12200*	2.725	16.4	12187	3.287	15.8
12209	2.930	16.21	12204*	3.439	15.6
12188	2.934	16.31	12201*	3.444	15.8
12211	2.940	16.21	12193	3.465	16.3
12203*	2.954	16.4	12198*	3.523	16.2
12202*	3.101	16.2	12207	4.566	15.8
12196*	3.113	16.4	12211	5.083	15.9
12197*	3.144	16.01	12186	12.24	15.0
12195	3.190				

Most of the Cepheids in NGC 1866 lie within the limits 0.40 and 0.55 in log P, and there is a trend toward brighter magnitudes for longer periods. The picture is like that presented by nearby galactic clusters, except that NGC 1866 is much richer in

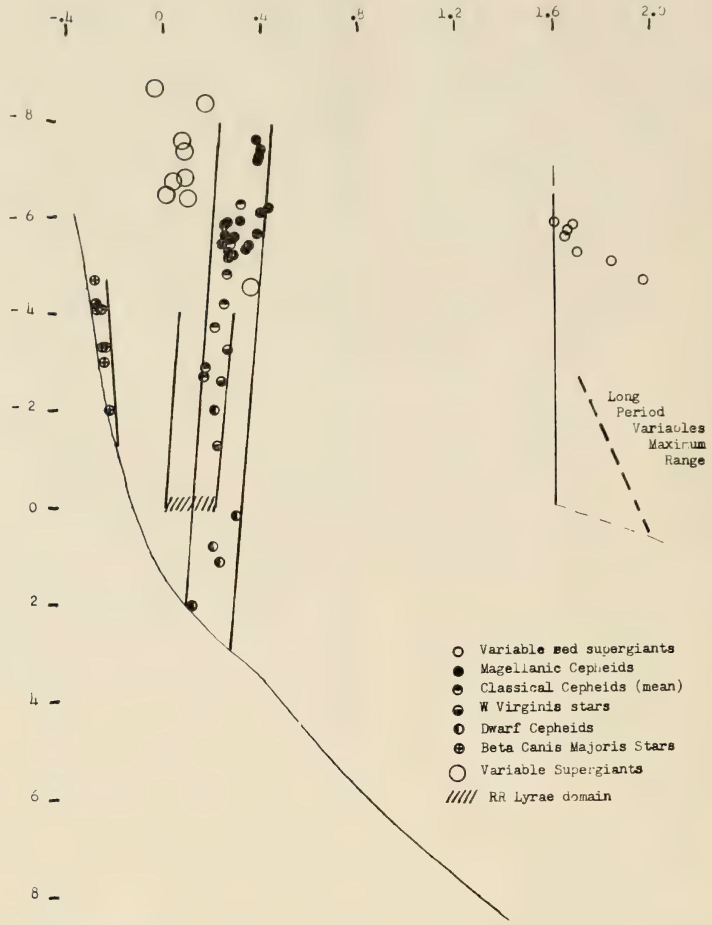

FIG. 7.—Domains of the several types of variable stars in the color-magnitude array. The original main sequence is sketched as a light line.

Cepheids. Details of its color-magnitude array will be of extreme interest. If there is a detailed analogy with galactic clusters, we can infer an age comparable with that of EV Scuti from the average period of the Cepheids. With the anticipated discovery of more Cepheids in Magellanic clusters, we can look forward to verification and extension of the dating procedure.

Galactic clusters provide suggestive qualitative information about the course of development of a Cepheid; among other things they suggest that the Cepheids follow a route like that of stars of mass over 2.5 suns, and move more or less horizontally across the HR plane, rather than rising sharply after leaving the main sequence, like stars of solar mass and less. This is the justification for the earlier assumption that Cepheids conform to the mass-luminosity relation.

In a globular cluster, there is a strong correlation between the amplitudes and periods of the RR Lyrae stars, which we have mentioned as probably traversing the horizontal branch across the variable gap: as we go from long to shorter period, the amplitude rises to a maximum, and then falls abruptly at the transition between curves of type a and type c. In NGC 1866 we note that four stars of amplitude 1.2 magnitudes and more lie between $\log P = 0.5$ and 0.54, but there are also two stars of large amplitude with $\log P = 0.41$, one of them within 10′ of the center of the cluster. The numbers of stars within equal limits of $\log P$ are:

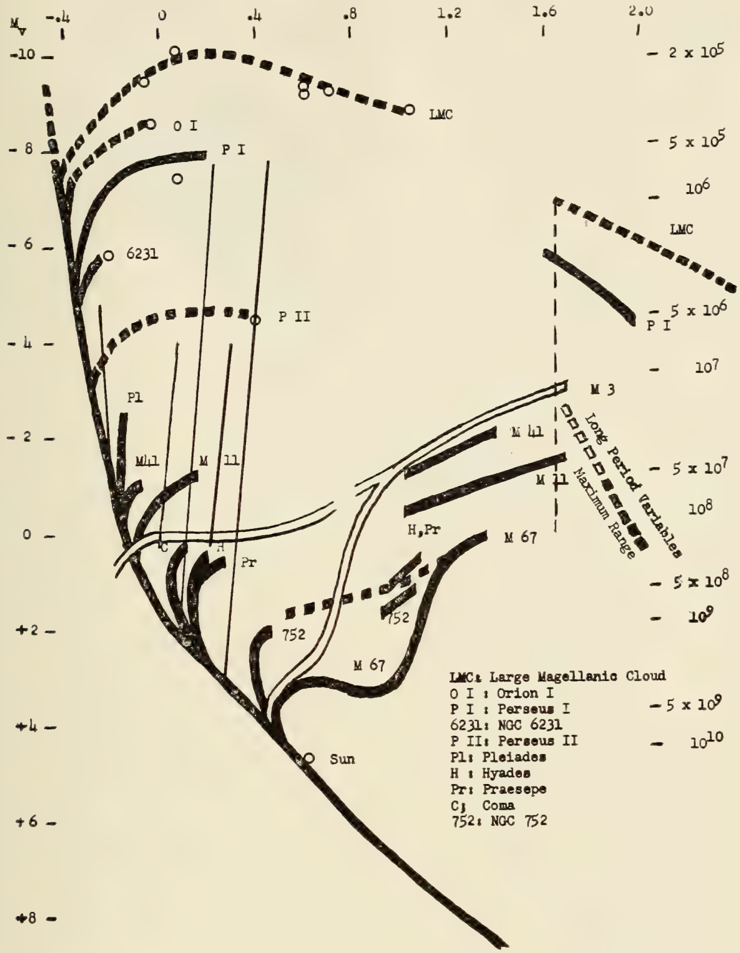

FIG. 8.—The Cepheid variable domain as related to the color-luminosity arrays of galactic clusters and associations.

log P	0.4 to 0.45	0.45 to 0.5	0.5 to 0.55	0.65 to 0.7	0.7 to 0.75	over 1.0
Number of stars	4	7	9	1	1	1

Thus the greatest concentration of periods coincides with a maximum of amplitude. Here again there is no indication of steady progress through the gap, but of a slowing-up in the neighborhood of log $P = 0.525$.

A single cluster presents a simpler picture than the Cepheids in a larger system; its stars may be regarded as having dispersion in mass, but do not differ appreciably in age. It is not surprising that the Small Cloud displays no simple relation between period, luminosity and mean amplitude. Fig. 9 shows a contour map of mean amplitudes in the period-luminosity plane. Small amplitudes are characteristic of periods between 8 and 10 days and apparent magnitude 15.4 (about absolute magnitude -3.6), and also of the strip to the short-period edge of the diagram for apparent magnitudes less than 16.0. These latter small amplitudes correspond to the type s light curves of Fig. 6. The fact that they are associated with the shorter periods speaks against the possibility that they are caused by unresolved companions, for there is no reason why unresolved companions should have a preference for particular *periods*; they should be equally common at all periods for a given apparent magnitude. Large amplitudes show an even more striking distribution. They occur, as is well

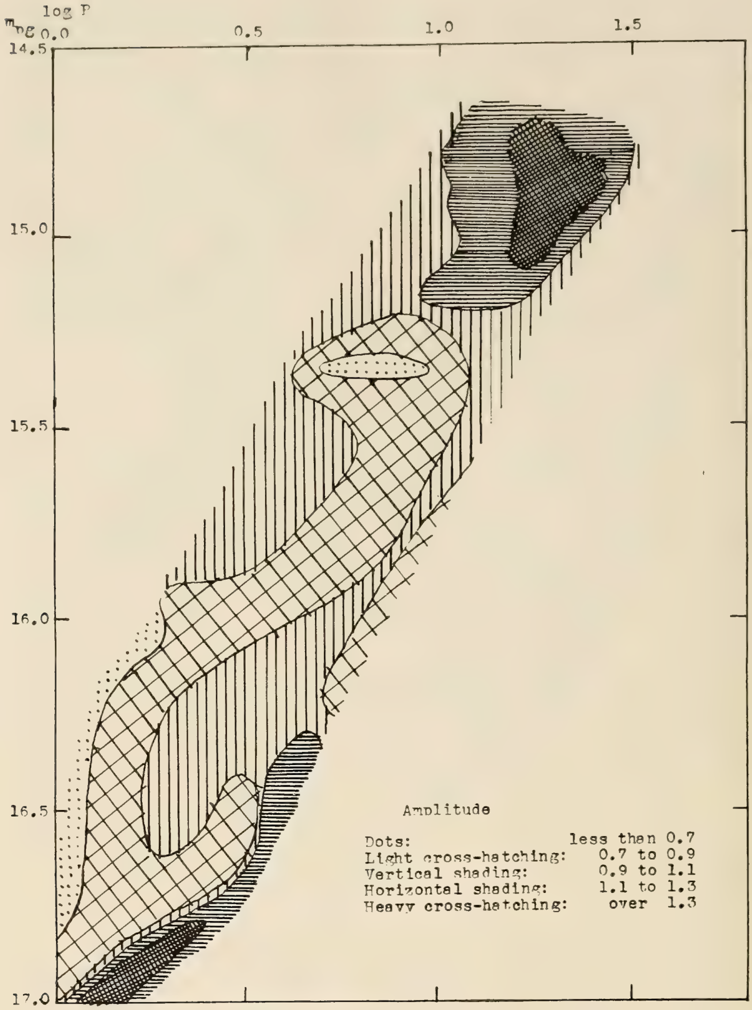

FIG. 9.—Mean amplitudes of the Cepheids in the Small Magellanic Cloud (schematic contour diagram).

known, for the more luminous stars, but they also occur at the low-luminosity, long-period edge of the period-luminosity array. The occurrence of large amplitudes among the fainter Magellanic Cepheids has been noted by Arp and is undoubtedly a real phenomenon.

If the path of any one Cepheid is a horizontal track across the period-luminosity plane, we might be able to trace the changes that a star undergoes by examining the changes in light curve at any one apparent (and therefore absolute) magnitude with changing period. Figs. 10, 11, and 12 show such series of light curves at seven different apparent magnitudes, and are typical for the whole available material. At brighter magnitudes, the light curve shows systematic changes and shifts of one prevalent pattern, which recall the Hertzsprung relationship, and illustrate the angle at which light curves of different types cross the average period-luminosity relation. For fainter magnitudes, however, the stars of shortest period tend to have small-amplitude, symmetrical light curves (type s), which recall the type c light curves for RR Lyrae stars in globular clusters.

If it is accepted that a Cepheid travels from left to right in the HR plane, and if

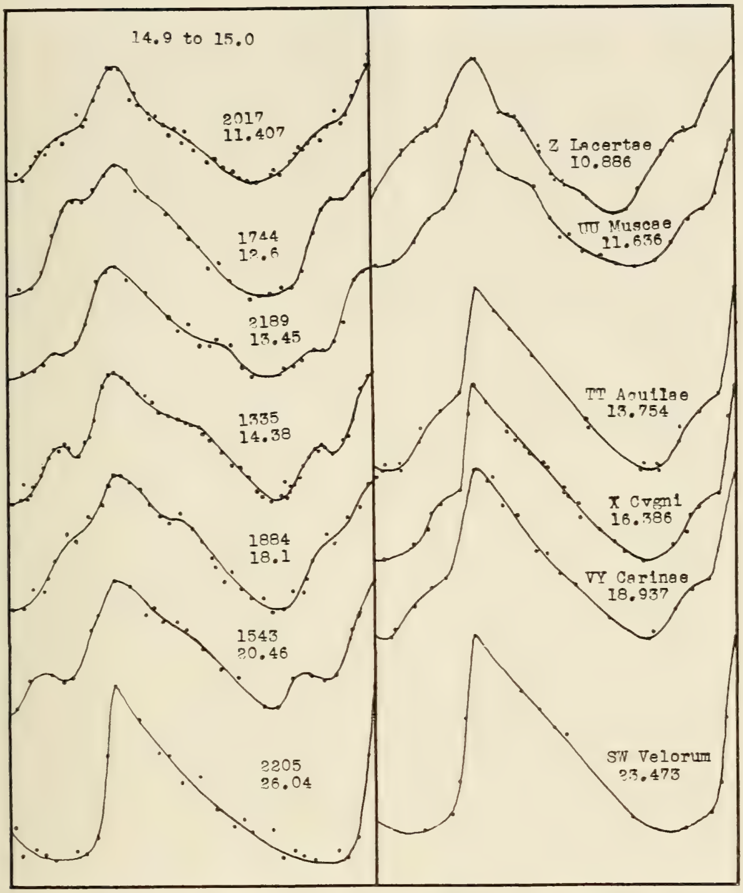

FIG. 10.—Light curves of Cepheids in the Small Magellanic Cloud, mean apparent photographic magnitude 14.9. Harvard Variable number and period are indicated for each. On the right, for comparison, several galactic Cepheids (photoelectric light curves by Eggen, except, for UU Muscae, Harvard photographic light curve).

the type s light curves represent overtone pulsations (as Sandage has suggested for the very similar Eggen type c curves), must we suppose that the developing Cepheid proceeds in the direction overtone to fundamental, short to long period?

With this possibility in mind we can reexamine the amplitudes of the Magellanic Cepheids. Instead of drawing a contour diagram of mean amplitudes, we draw contour diagrams of the frequencies of amplitudes less than $0^{m}.7$ and greater than $1^{m}.0$ (Fig. 13). The picture is now greatly simplified, and suggests that the complexities of Fig. 9 are a consequence of two overlapping distributions. This possibility cannot be profitably explored further until accurate photoelectric amplitudes are available.

Finally, let us compare the frequency of periods of stars in different parts of the period-luminosity plane. The results derived from over 600 Cepheids in the Small Cloud are shown as a contour diagram in Fig. 14. The division into two groups is very evident. If, again, we suppose that a Cepheid moves from left to right across the diagram, then we can infer that its progress is not uniform.

The rate of development might be expected to be a function of the mass (i.e., the luminosity), faster for more luminous stars. It should also be a function of the time: for constant mass, log P should increase as 3/2 log R, where R is the star's radius. Thus, if the radius increased in proportion to the time, log P should in-

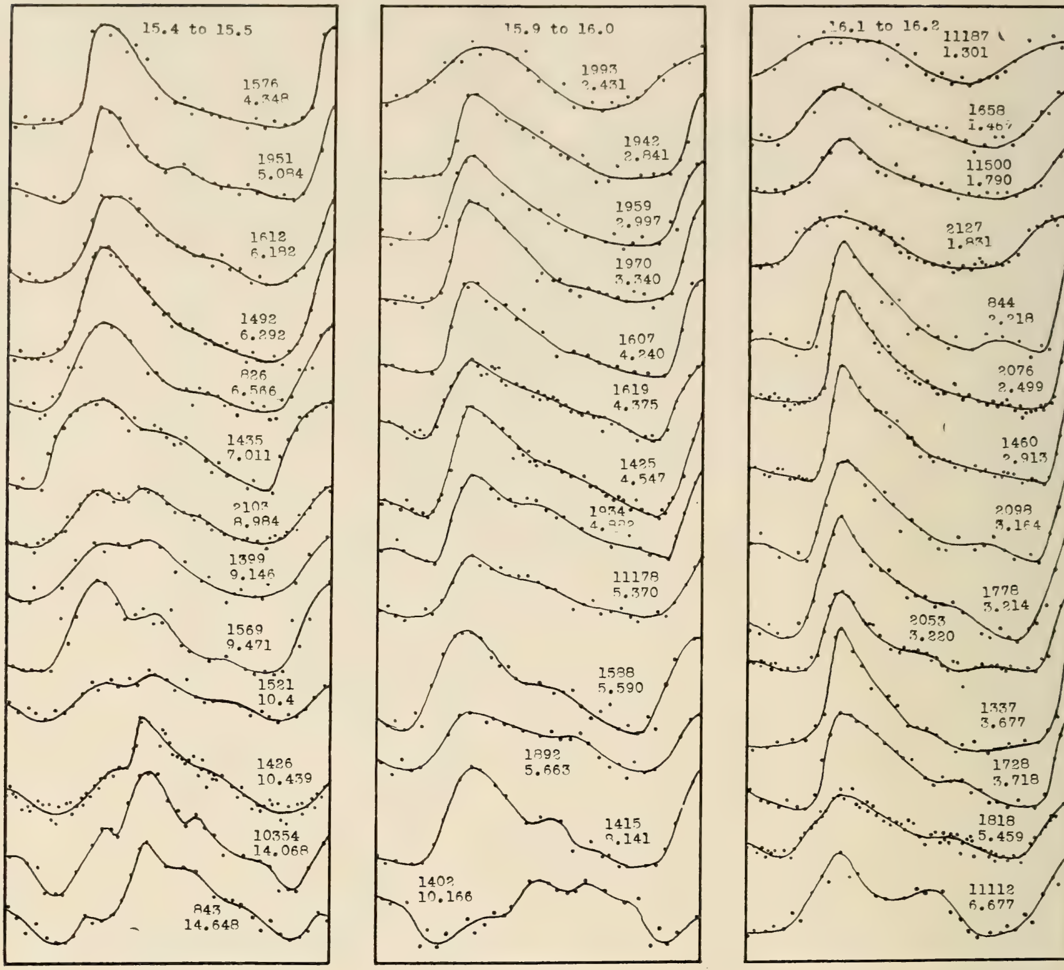

FIG. 11.—Light curves of Cepheids in the Small Magellanic Cloud, mean apparent photographic magnitudes 15.4, 15.9, and 16.1. Arrangement as in Fig. 10.

crease at an accelerated rate, and the greatest number of Cepheids at any one luminosity should occur for the shortest periods. However, it seems probable from analogy with the earlier development of massive stars, that R itself increases at an accelerated rate with time, so the concentration of Cepheids at the shortest periods would be enhanced even more. Fig. 14 is not consistent with these expectations. There are two maxima of period-frequency for all stars at and below magnitude 16. A similar situation has already been noted for the RR Lyrae stars in ω Centauri. The observations indicate that if a Cepheid moves across the period-luminosity plane, its development slows down in the neighborhood of two periods, different for each magnitude level.

If the two sets of contours refer respectively to the overtone and the fundamental, however, they also refer to different values of R at a given period. In this case, in order to convert Fig. 14 into a contour diagram representing frequency of *mean density,* we must shift the lower-period distribution to the right by an appropriate amount. If the two frequency distributions are thus combined, we obtain Fig. 15, which strongly suggests a single distribution, and also raises the question whether a given star passes through the Cepheid domain with overtone pulsation, or fundamental pulsation, or both successively. Here again we

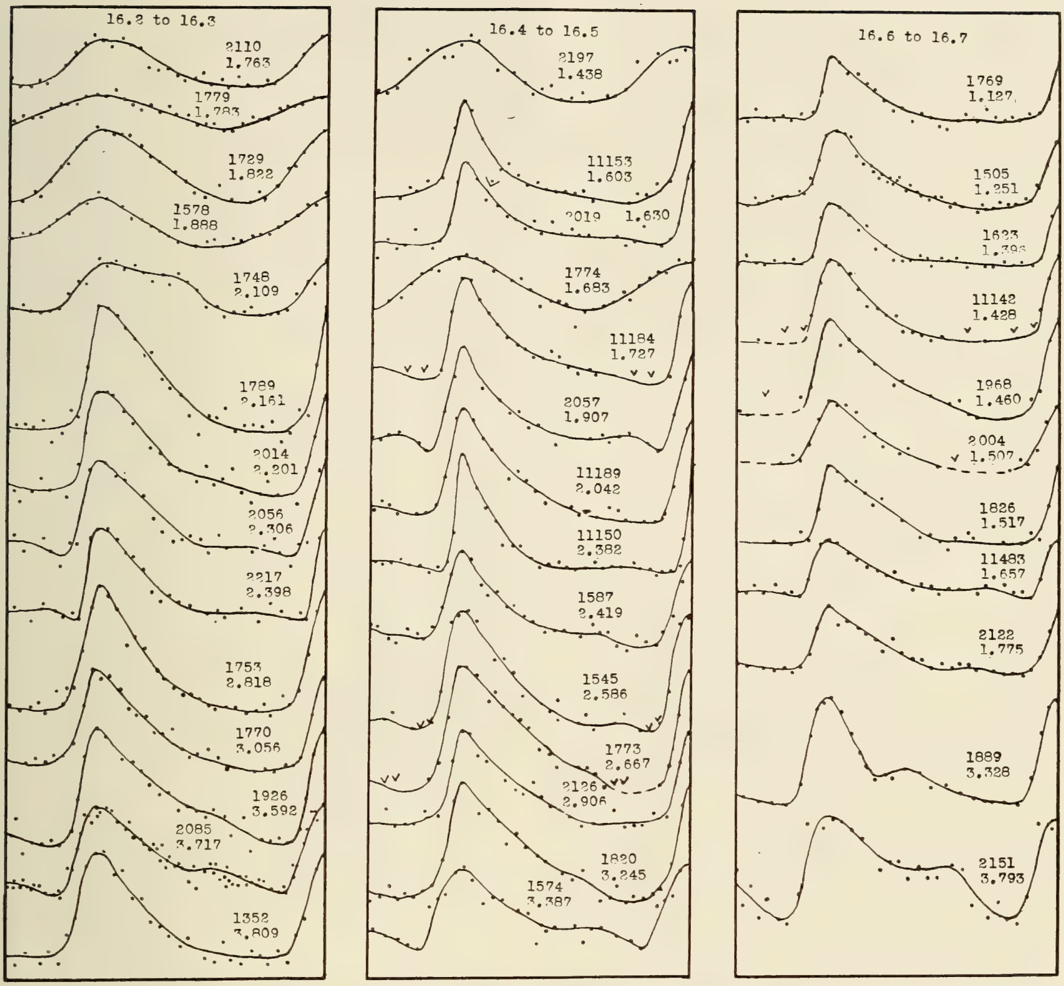

FIG. 12.—Light curves of Cepheids in the Small Magellanic Cloud, mean apparent photographic magnitudes 16.2, 16.4, and 16.6. Arrangement as in Fig. 10.

need accurate light curves and colors in order to clarify the picture. A diagram like Fig. 15 might prove to be the most fundamental representation of the relation between luminosity and mean density, and we note that its slope in the lower part is greater than that of the period-luminosity relation.

The question of the rate at which an individual Cepheid traverses the HR plane leads immediately into the wider question of the significance of the frequency of periods. The large number of Cepheids of short period in the Small Cloud, as compared with our own galaxy, has been discused by Shapley and McKibben (*40*), who regard the difference as real. Indeed, it is difficult to suppose that selection and obscuration could have cut down the numbers of galactic Cepheids with periods less than three days by a factor of ten; down to a given apparent magnitude, the Cepheids of longer period are at a greater disadvantage.

If all stars that leave the main sequence and move to the right in the HR diagram become Cepheids at some stage, we might (if their progress was uniform or followed a known law) predict the number of Cepheids per cubic parsec by means of the Salpeter "creation function." However, as we have argued above, a uniform progression does not seem to fit the known facts. We

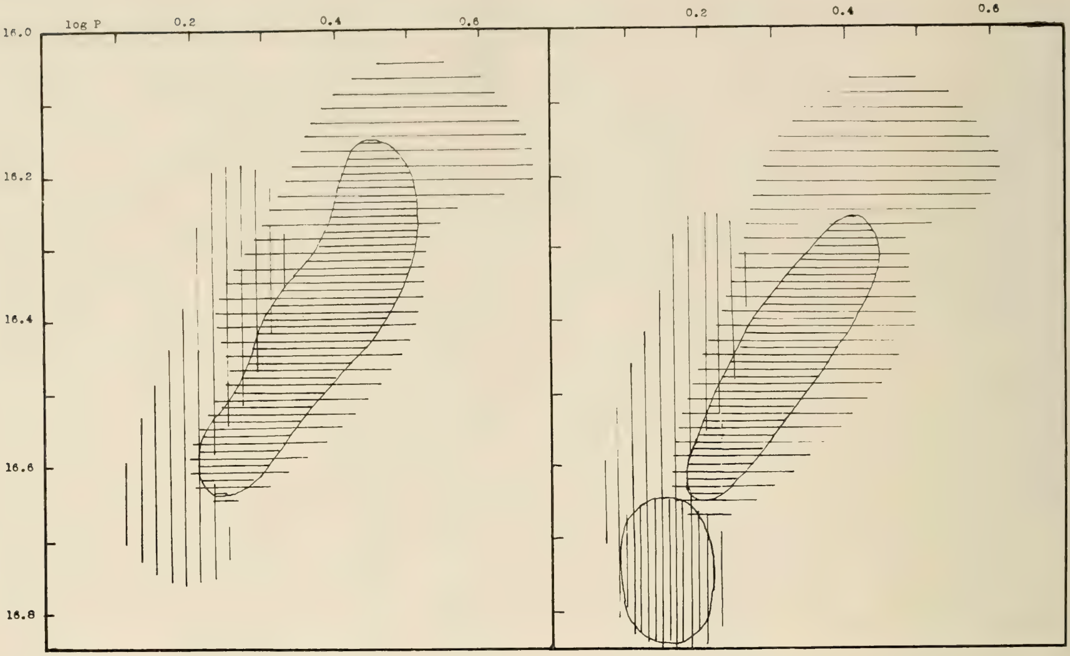

FIG. 13.—Distributions of amplitudes for Cepheids of average photographic magnitude 16.0 and fainter in the Small Magellanic Cloud. Left side: light shading, over 4 stars between limits of 0.1 in log P and in m_{pg} ; heavy shading, over 6 stars. Horizontal shading: amplitude over $1^m.0$; vertical shading: amplitude less than $0^m.7$. Right side: light shading: over 6 per cent of Cepheids in given magnitude interval; heavy shading: over 10 per cent of Cepheids in given magnitude interval. Horizontal and vertical shading have the same meaning as on the left.

could invert the argument, and, assuming that Cepheids follow the period-luminosity law exactly, use the number of observed Cepheids at each period to calculate the duration of the Cepheid stage at that period. This procedure is so uncertain that I shall not presume to make a numerical application of it; it predicts an increasing number of Cepheids per cubic parsec down to periods of about a day, since all stars down to this luminosity presumably rate as massive stars, and may be thought to move nearly horizontally across the HR diagram.

However, the data can be used in another way, to examine the source of the difference between the period distribution in the Small Cloud and in our own galaxy. If the Cepheids are strictly comparable in the two systems, their rate of progress at a given absolute magnitude should be the same, and if the distribution of periods is as different as it appears to be, the only conclusion that can be drawn is that the "birth function" in the Small Cloud differs from that in our galaxy, and increases more steeply with decreasing luminosity, at least down to absolute magnitude −1.5. Information on the observed luminosity function in the Small Cloud is very indefinite, but this is an observational datum that could readily be obtained. It is possible, as Arp has suggested, that Cepheids in the Small Cloud (and, by inference, the Small Cloud itself) may differ from their galactic counterparts in chemical composition. A difference in chemical composition would, if large enough, have a noticeable effect on the mass-luminosity relation (*41*), and perhaps on the luminosity function itself.

In conclusion, I can summarize my opinion concerning the present status of the period-luminosity relation. The preliminary task of determining its average course has been completed, and we are nearing a consensus concerning the colors of Cepheids, and the relation of mean color to period. Future work must be concerned with the dispersions of the period-luminosity rela-

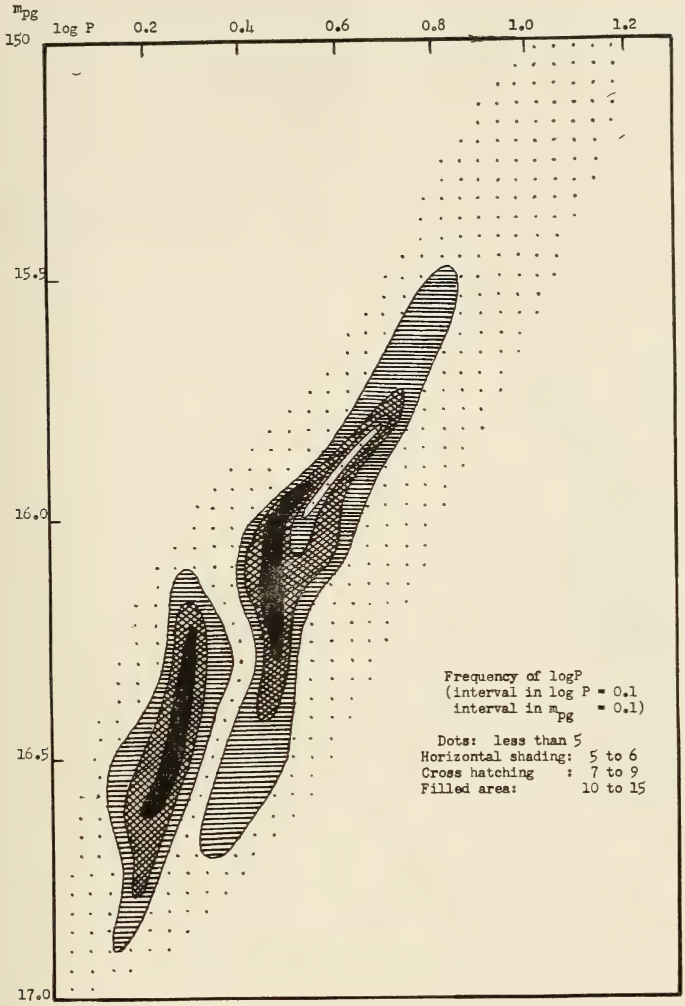

FIG. 14.—Contour diagram showing frequency of log P in the period-luminosity plane.

tion, the period-luminosity-color relation, and the period-luminosity-light curve relation. The part played by the Cepheid stage in stellar development will stimulate studies of the relation of period-frequency to the local birth function and to the rate of progress of a star through the variable stage. These last problems are intimately tied up with the study of stellar interiors, and the machine computation of evolutionary tracks. In this area, speculation is worse than valueless, and the greatest service that can be rendered by the student of variable stars is the provision of data that are accurate and complete—in other words, the systematic discovery of variable stars in carefully selected systems, accurate studies of brightness, light curve and color, and determination of luminosity functions.

REFERENCES

(1) PICKERING, E. C. Circ. Astr. Observ. Harvard Coll. 173. 1912.
(2) BAILEY, S. I. Ann. Astr. Observ. Harvard Coll. **38.** 1902.
(3) SHAPLEY, H. *Star clusters:* 125. 1930.
(4) HUBBLE, E. P. Astrophys. Journ. **62:** 409. 1925; **63:** 17. 1926; **69:** 145. 1929.
(5) BAADE, W. Trans. Int. Astr. Union **8:** 397. 1954; Publ. Astr. Soc. Pacific **68:** 1. 1956.
(6) ROBERTS, M., and SANDAGE, A. R. Astr. Journ. **59:** 190. 1954.
(7) SANDAGE, A. R. *Stellar populations:* 52. Vatican Observatory, 1958.

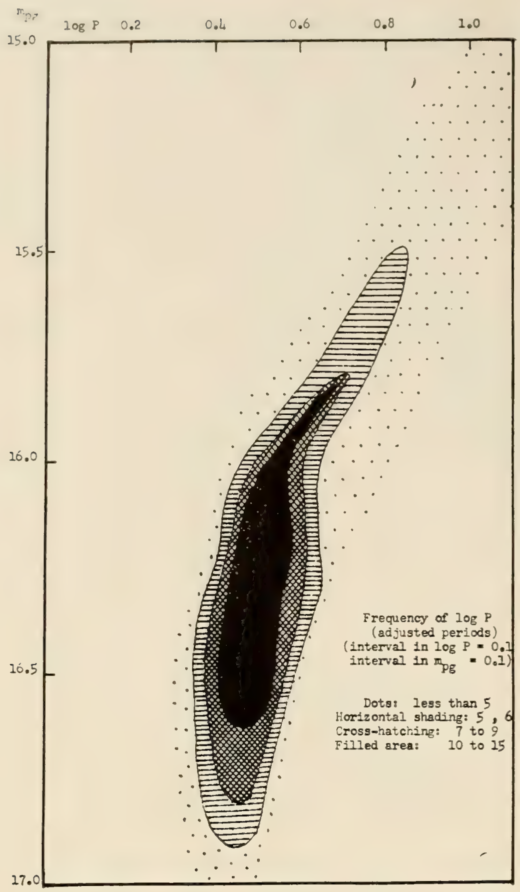

Fig. 15.—Contour diagram showing frequency of logarithm of adjusted period (see text) for the material of Fig. 14.

(8) Arp, H. C. Handb. der Phys. **51**: 118. 1958.

(9) Hertzsprung, E. Bull. Astr. Inst. Netherlands 96. 1926.

(10) Payne-Gaposchkin, C. Ann. Astr. Observ. Harvard Coll. **113**: 173. 1954.

(11) Shapley, H., and Nail, V. McK. Proc. Amer. Phil. Soc. **92**: 310. 1948.

(12) Payne-Gaposchkin, C. *Variable stars and galactic structure*: 42. 1954.

(13) Payne-Gaposchkin, C. Astr. Journ. **52**: 218. 1947.

(14) Payne-Gaposchkin, C. *Vistas in astronomy*: 1142. 1956.

(15) Payne-Gaposchkin, C. *Variable stars and galactic structure*: 13. 1954.

(16) Shapley, H. *Star clusters*: 132. 1930.

(17) Arp, H. C. Astr. Journ. **63**: 45. 1958.

(18) Sandage, A. R. Astrophys. Journ. **127**: 513. 1958.

(19) Code, A. Astrophys. Journ. **106**: 309. 1947.

(20) Walraven, Th., Muller, A. B., and Oosterhoff, P. Th. Bull. Astr. Inst. Netherlands 484. 1958.

(21) Gascoigne, S. C. B., and Kron, G. E. Publ. Astr. Soc. Pacific **64**: 196. 1952.

(22) Gascoigne, S. C. B. Australian Journ. Sci. Suppl. 1957.

(23) Gascoigne, S. C. B., and Eggen, O. J. Monthly Notices Roy. Astr. Soc. **117**: 423. 1957.

(24) Eggen, O. J. Astrophys. Journ. **113**: 367. 1951.

(25) Eggen, O. J., Gascoigne, S. C. B., and Burr, E. J. Monthly Notices Roy. Astr. Soc. **117**: 423. 1957.

(26) Payne-Gaposchkin, C. *Variable stars and galactic structure*: 34. 1952.

(27) Burbidge, G. R., and Burbidge, E. M. Handb. der Phys. **51**: 186. 1958.

(28) Sandage, A. R. Astrophys. Journ. **126**: 326. 1957.

(29) Arp, H. C. Handb. der Phys. **51**: 110. 1958.

(30) Abt, H. A. Astrophys. Journ. **126**: 138. 1957.

(31) Irwin, J. B. Proc. Nat. Sci. Found., Charlottesville. 1956.
Kraft, R. P. Astrophys. Journ. **126**: 225. 1957; **128**: 161. 1958.
Arp, H. C. Handb. der Phys. **51**: 99. 1958; Astrophys. Journ. **128**: 166. 1958.
Sandage, A. R. Astrophys. Journ. **128**: 150. 1958.

(32) Starikova, G. A. Variable Stars (U.S.S.R.) **7**: 124. 1949.

(33) Burbidge, G. R., and Burbidge, E. M. Handb. der Phys. **51**: 208. 1958.

(34) Irwin, J. B. Proc. Nat. Sci. Found., Charlottesville. 1956.

(35) Sandage, A. R. *Stellar populations*: 41. Vatican Observatory, 1958.

(36) Hoerner, S. von. Zeitschr. für Astrophys. **42**: 273. 1957.

(37) Johnson, H. L. Astrophys. Journ. **126**: 134. 1957.

(38) Thackeray, A. D. *Stellar populations*: 195. Vatican Observatory, 1958.

(39) Shapley, H., and Nail, V. McK. Astr. Journ. **55**: 249. 1951.

(40) Shapley, H., and Nail, V. McK. Proc. Nat. Acad. Sci. **26**: 105. 1940.

(41) Hoyle, F. *Stellar populations*: 223. Vatican Observatory, 1958.

PALEONTOLOGY.—*Paleontologic record of the primary differentiation in some major invertebrate groups.* DAVID NICOL, GEORGE A. DESBOROUGH, and JAMES R. SOLLIDAY, Southern Illinois University, Carbondale, Ill.

(Received July 9, 1959)

A table of the geologic ranges of the principal animal phyla, prepared by Shrock and Twenhofel (1953, p. 11), should be of interest to all students of evolution. According to their data, the animal phyla with a good fossil record, those having hard parts that are readily preserved, all appeared by about 450 million years ago, and most of them are still older. In other words, according to present knowledge of the fossil record, the major differentiation of the animal kingdom was completed by about the end of the Cambrian period. Probable exceptions to this, which would now appear to be few in number, would be of two kinds—animal phyla with poor or no fossil records and extinct phyla which are not recognized as such now. At the present state of knowledge it can be said that only many lesser groups—classes, orders, families, and genera—first appeared in time less than 450 million years ago.

This would seem to support the assertion of Willis (1940, p. 186):

> It is clear that the tests give a very strong evidence indeed in favour of the theory of differentiation or divergent mutation, according to which the course of evolution is in the opposite direction to what has hitherto been supposed, and by mutations which tend to diminish as time goes on, but go in the direction family-genus-species. The organism that first represents the family is, of course, at the same time its first genus and species, but these are of different rank from genera and species in a larger family. By further mutations this will then give rise to further genera and species. The first new genus formed will usually be widely divergent from the parent genus of the family, even if the family be quite small, e.g. of two genera only. Later formations will be less and less divergent on the whole, but will show some of the characters of divergence of their first parents. The main lines of divergence are therefore given by the latter, and later genera fill them in, as shown by a good dichotomous key.

This is the main theme in Willis's book, and he repeats it many times in various ways. In another place Willis (p. 191) states: "Evolution goes on in what one may call the downward direction from family to variety, not in the upward, required by the theory of natural selection." Willis attributes the idea of divergent mutation to H. B. Guppy and claims that it was adumbrated by St. Hilaire. More recently James Small (1951, p. 131) has stated the same idea: "The general factual picture of evolution is now one of progressive evolution by apparently large steps for the phyla, combined with diversification of genetic patterns *downwards* from phyla to families, genera, species and lower categories." Schindewolf (1951, p. 139) has stressed divergent mutation, too, as shown by this paragraph:

> Palaeontological evidence suggests that the beginning of each phylogenetic cycle, irrespective of the systematic category concerned, is marked by an intensification of evolution. In the later phases, the rate of evolution is much smaller and the ability to change decreases. An instructive example is the evolution of the placental mammals in the early Tertiary. In the upper Cretaceous the Insectivora appear, initiating the evolutionary cycle of the Eutheria. At the boundary of Cretaceous and Tertiary, and in the early Paleocene all other known placental orders become differentiated from the original group. Twenty-five orders, representing the entire morphological range of the subclass, appear in the relatively short period of 10–15 million years, whilst during the subsequent, post-Paleocene, period of 60 million years not a single new order is added.

Other workers who have favored the theory of early primary divergence could be cited, but the ones either mentioned or quoted herein should suffice to show that this is not a new idea nor is it without its adherents today. The thesis of these workers is that the major subdivisions of a group (e.g., classes of a phylum or orders of a class) generally originate early in its history, whereas new subdivisions of lesser rank (e.g., genera and species) may arise at any time throughout the group's geologic history.

For this paper the writers have taken 13 major invertebrate groups with a good paleontologic record and have recorded the geologic ranges of their primary subgroups. In the case of a phylum, the geologic ranges of its classes were plotted; in the case of a class, the geologic ranges of its orders were recorded; and so on. With these data we hope to show whether the basic pattern of evolution is like that described by Willis and others who claim that primary divergent mutation occurs early in the history of a major group or is like that described by other workers who contend that primary divergences occur as a gradual and steady process throughout the geologic history of each group. The latter idea is conventionally considered the more logical pattern in evolution. Except for some work by Schindewolf almost no analyses of this sort have been attempted by invertebrate paleontologists.

COMPILATION AND PRESENTATION OF DATA

Thirteen examples are presented, all taken from invertebrate groups with a good fossil record. The writers have purposely avoided groups like the Trilobita and the Porifera because so much of the history of their divergence ranges back to the base of the Cambrian that a long pre-Cambrian history might be postulated for both of them even though the direct evidence of the fossil record is scanty or absent. We have avoided groups where the basic classification is not well understood or where the fossil record is rather poor. Our examples are drawn from the following phyla: Protozoa (1), Coelenterata (3), Bryozoa (1), Brachiopoda (1), Mollusca (2), Arthropoda (1), Echinodermata (3), and Protochordata (1). These, we believe, give us a reasonably large sample of the invertebrate phyla, although additional examples could have been obtained.

Another way by which we have attempted to avoid a bias of the data is to exclude the declining phase of a group's evolution—i.e., the phase in which it approaches extinction. For example, we have used only the Paleozoic history of the orders of nautiloids and the superfamilies of articulate brachiopods because the possibility of the occurrence of a primary divergence in a group approaching extinction is remote. However, in the case of the graptolites we have included data on the final stage of the group's existence because the complete geologic history, from inception to extinction, illustrates a typical pattern of rapid evolution.

The first appearance of a particular group is the most important part of the data presented here. No attempt was made to show the phylogenetic relationships of the various groups to each other, for two reasons. The first is that this information is unimportant for our purposes in this paper. Secondly, many of these relationships are not well understood and are a matter of conjecture. The writers do not claim to be experts on the phylogeny of the groups used as examples.

In the presentation of the data concerning the time of origin, only the primary divergences or largest subdivisions of a particular group have been used. In other words, for the phylum Mollusca we have considered only the classes; for the subclass Nautiloidea we have used only the orders.

We are well aware that scientists differ in their opinions concerning the classes which should be included in a particular phylum, the orders which should be included in a particular class, and, in some cases, the question of whether a certain group should be ranked as a class or an order or whether another group should be ranked as an order or a family. For this paper we have excluded aberrant groups for which the allocation is questionable and have sought to avoid excesses of classificational splitting and lumping. In deciding which primary subdivisions to include in each of our major groups we have relied on either the consensus or the latest authority. We have also done this for the data regarding the time of the first appearance of each primary subdivision, in some cases taking the majority opinion from standard textbooks on paleontology and zoology and in others using the most recent authoritative work. Only in the latter cases have we specifically cited the references from which our data were taken.

There is no exact agreement on the time

span, in millions of years, of the various periods of geologic history. We have used the same time scale as was used by Knight (1952, p. 7) with the exception of dividing the Carboniferous into Mississippian and Pennsylvanian periods and combining the Tertiary and Quaternary periods by using the Cenozoic era. Knight stated that his data were taken from *Report of the measurement of geologic time of the Division of Geology and Geography*, National Research Council, for 1949–1950, p. 18. The writers have not seen this latter reference. The chart used by Knight is here reproduced, with few modifications:

Era or period	Duration, millions of years	Occurrence, millions of years ago
Cenozoic	60	0–60
Cretaceous	70	60–130
Jurassic	25	130–155
Triassic	30	155–185
Permian	25	185–210
Pennsylvanian	25	210–235
Mississippian	30	235–265
Devonian	55	265–320
Silurian	40	320–360
Ordovician	80	360–440
Cambrian	80	440–520

DISCUSSION OF COMPILED DATA

The sequence in which the examples are presented is from the groups of organisms that are structurally simpler to the more complex ones. The first example (Fig. 1), therefore, comprises four families of planktonic Foraminifera as compiled by Loeblich and collaborators (1957). These families are generally considered by most micropaleontologists to be phylogenetically related, although there are a few planktonic Foraminifera not included in these four families. In preparing this figure the writers arbitrarily assigned the same amount of time to each of the Cretaceous stages, there being 12 of them if the Danian is excluded as was done by Loeblich and his collaborators. The first family, the Orbulinidae, appeared at the beginning of the Hauterivian stage, approximately 120 million years ago, and continues to the present. At the beginning of the Aptian stage, approximately 12 million years later, two more families emerged—the Globorotaliidae and the Hantkeninidae. These two families also have living representatives. Finally, at the beginning of the Turonian stage, the last of the families arose, the Globotruncanidae, only 30 million years after the first-appearing of these four families. The Globotruncanidae were a relatively short-lived family that became extinct at the end of the Cretaceous. To summarize: within 12 million years three of the four families made their appearance, and within approximately 30 million years all of them had emerged. Thus, all the basic differentiation took place within a time span of 30 million years and no new families have appeared in the last 90 million years.

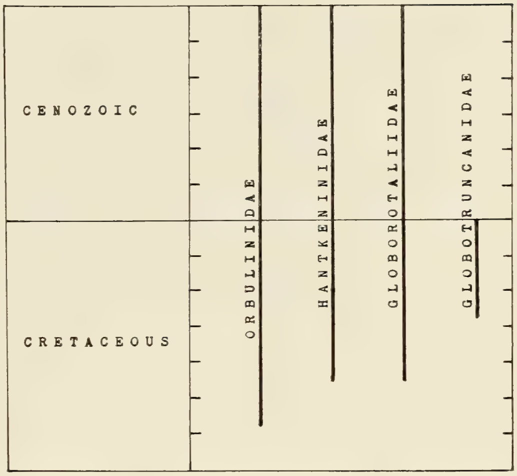

FIG. 1.—Periods of existence of four related families of planktonic Foraminifera. Data taken from Loeblich and collaborators, 1957. Horizontal stubs demark 10-million-year intervals.

The next example (Fig. 2) comprises the families of tabulate corals (data taken from Hill and Stumm *in* Moore, 1956). The first two families of the Tabulata, the Chaetetidae and Syringophyllidae, appeared almost simultaneously at the beginning of the middle Ordovician. Two more families, the Heliolitidae and Halysitidae, made their appearance during the upper part of the middle Ordovician no more than 20 million years later. At the beginning of the late Ordovician the Auloporidae and Favositidae arose; this was no more than 30 million years after the first two families of tabulate corals began their existence. Thus, in approximately 30 million years the basic di-

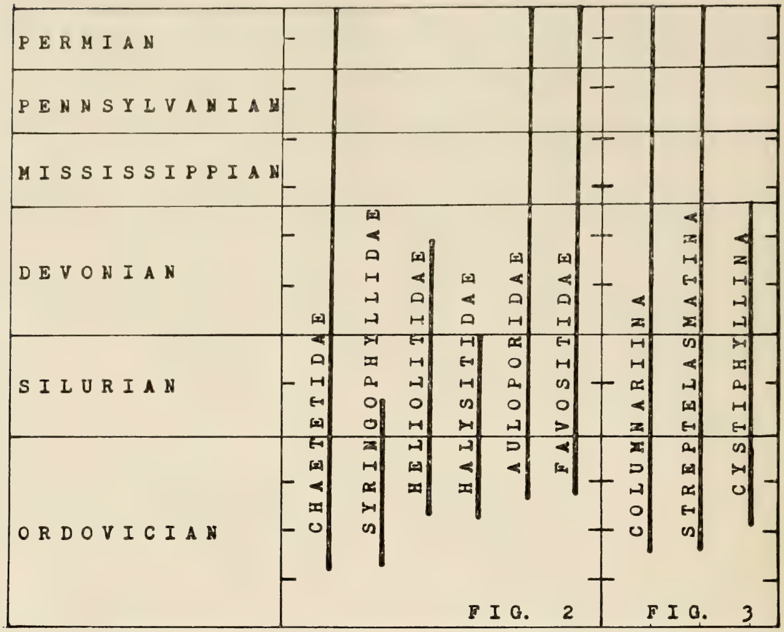

FIG. 2.—Paleozoic history of the families of tabulate corals. Data taken from Hill and Stumm *in* Moore, 1956. Horizontal stubs demark 20-million-year intervals.

FIG. 3.—Periods of existence of the suborders of rugose corals. Data taken from Hill *in* Moore, 1956. Horizontal stubs demark 20-million-year intervals.

vergence of the Tabulata was completed, and no new families appeared throughout the remaining 200 million years of the Paleozoic era.

Many of the major groups studied have included subgroups which existed only briefly, usually early in the history of the major group. For example, the Syringophyllidae, Heliolitidae, and Halysitidae appeared within the first 20 million years of tabulate existence. The Syringophyllidae were extant for about 70 million years, the Heliolitidae for less than 120 million years, and the Halysitidae for about 80 million years. The occurrence of short-lived subgroups is common enough that it should be considered an important phenomenon, although it has been left unexplained in theories on the basic causes of evolution.

The suborders of the rugose corals (Fig. 3) (data taken from Hill *in* Moore, 1956) provide another illustrative example of rapid primary divergence. All three suborders of the Rugosa emerged within about the first 10 million years of the order's beginning in the middle Ordovician. No new suborders appeared during the remainder of the Paleozoic, a span of 220 million years, although many families and groups of lesser rank did arise after all of the suborders had been established.

Another interesting example (Fig. 4) is that of the primary divergence in the scleractinian corals (data taken from Wells *in* Moore, 1956). Three of the five suborders appeared almost simultaneously in the middle Triassic. About 25 million years later the fourth suborder arose in the early Jurassic. Some 80 million years after that, or about 105 million years after the scleractinians began, the last suborder originated in the late Cretaceous. No new suborders have appeared during the 70 million years since. Most of the basic divergence in the scleractinian corals took place within the first 25 million years, and only one new suborder appeared in the last 150 million years of scleractinian history.

Many scientists, particularly in the field of genetics, would expect evolution to be a

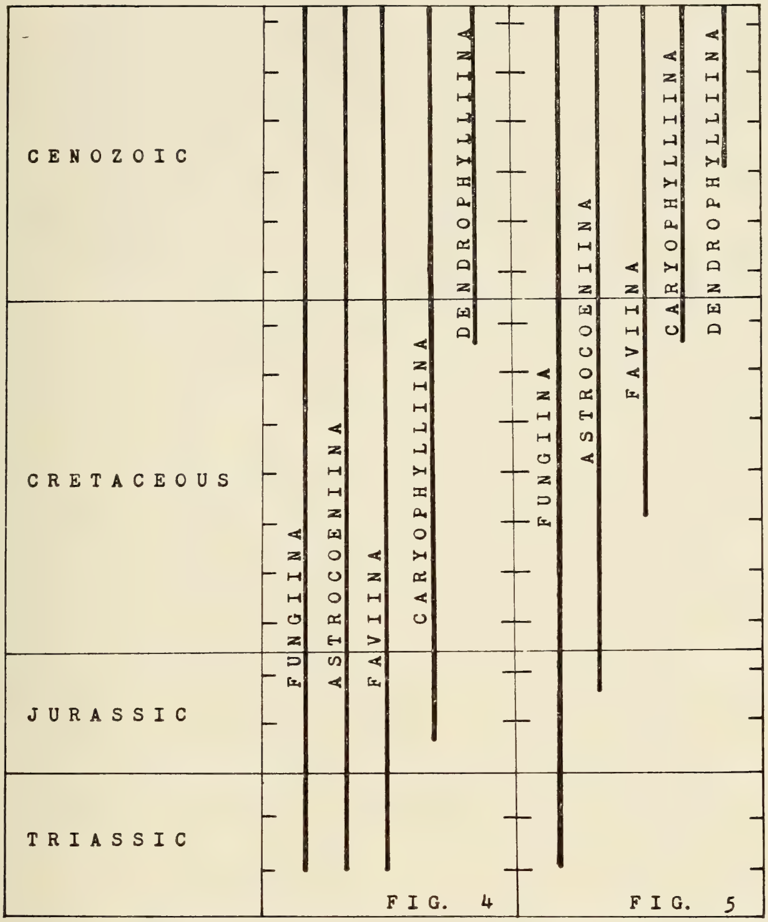

FIG. 4.—Periods of existence of suborders of scleractinian corals. Data taken from Wells *in* Moore, 1956. Horizontal stubs demark 10-million-year intervals.

FIG. 5.—Hypothetical periods of existence of suborders of scleractinian corals. If evolution were a slow, gradual, and steady process, with primary divergences occurring at regular intervals throughout geologic history, new suborders of scleractinian corals would have arisen at 35-million-year intervals. Cf. Fig. 4.

relatively steady and gradual process, with primary divergences occurring one by one at regular intervals throughout the history of a major group. We digress here in order to compare the actual paleontologic record of the suborders of the scleractinian corals with the theoretical record which would have been established if this hypothesis were true (cf. Figs. 4 and 5). Assuming that the scleractinian corals have existed for 175 million years, the first suborder having originated at the beginning of the middle Triassic, one might expect the other four suborders to appear thereafter one at a time at 35-million-year intervals (and a new suborder would be due to arise soon). Thus, according to the "regular interval" theory, one suborder would have originated at the base of the middle Triassic, one in the middle Jurassic, one in the early middle Cretaceous, one in the late Cretaceous, and one near the middle Cenozoic. In actual fact, however, the record is remarkably different.

It should be pointed out that the foregoing comparative example is based on a group that evinces little or no indication of decline in evolutionary vigor at the present time. Similar comparisons between actual and theoretical evolution are presented in

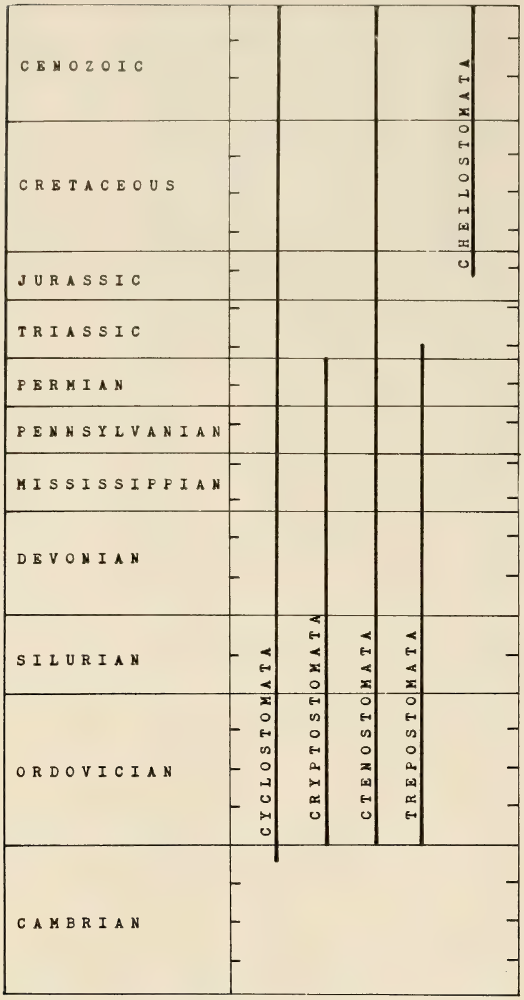

Fig. 6.—Periods of existence of classes of Bryozoa. Horizontal stubs demark 20-million-year intervals.

Figs. 8 and 9, the classes of the Mollusca, and Figs. 12 and 13, the classes of the Echinodermata. These phyla also show no tendency toward extinction at the present time. In all three examples it is clear that major divergences have not occurred gradually or at regular intervals throughout the history of each group.

Returning to the presentation of the basic data, we cite another good case of early rapid divergence: the five classes of the phylum Bryozoa (Fig. 6). Within probably 10 million years during late Cambrian and early Ordovician times, four of the five classes appeared. Not until 310 million years later did the fifth class, the Cheilostomata, make its debut during the late Jurassic. No new classes of the Bryozoa have appeared within the past 140 million years. In other words, most of the basic divergence in the Bryozoa occurred during a brief span of 10 million years; for the past 450 million years, little primary divergence has occurred within the phylum.

The superfamilies of the Paleozoic articulate brachiopods (Fig. 7) also provide a good example of rapid primary divergence. The data were taken from Cooper and Williams (1952, part of fig. 6, p. 332). At the beginning of the Cambrian the Orthacea emerged. No more than 20 million years later, still in the early Cambrian, three more superfamilies began their existence. Two of these, the Rustellacea and the Kutorginacea, were short-lived and became extinct within about 35 million years. Then there was a lag of nearly 80 million years, or 100 million years after the beginning of the Cambrian, before more divergent mutation took place. The Triplesiacea and the Atrypacea appeared almost simultaneously in the middle of early Ordovician time. About 10 million years later two more superfamilies emerged in the late early Ordovician. Some 15 million years after that, five more superfamilies appeared; this was accomplished by middle Ordovician time. During the late Ordovician one more superfamily arrived on the scene, the Productacea. Thus, within a part of the Ordovician period spanning less than 60 million years, 10 new superfamilies appeared. By the middle part of the early Silurian the last two superfamilies began their existence. It took more than 170 million years for all 16 of the superfamilies to emerge. In the remaining 165 million years of the Paleozoic era, no new superfamilies of articulate brachiopods appeared, and, with one possible exception, none arose during the articulate brachiopods' period of decline in evolutionary vigor, the 185 million years represented by the Mesozoic and Cenozoic eras.

The time lag of 80 to 100 million years between the appearance of the first articulate brachiopod superfamilies and the time of rapid divergence which began in the early Ordovician is analogous to the time lag between the inception and the period of rapid

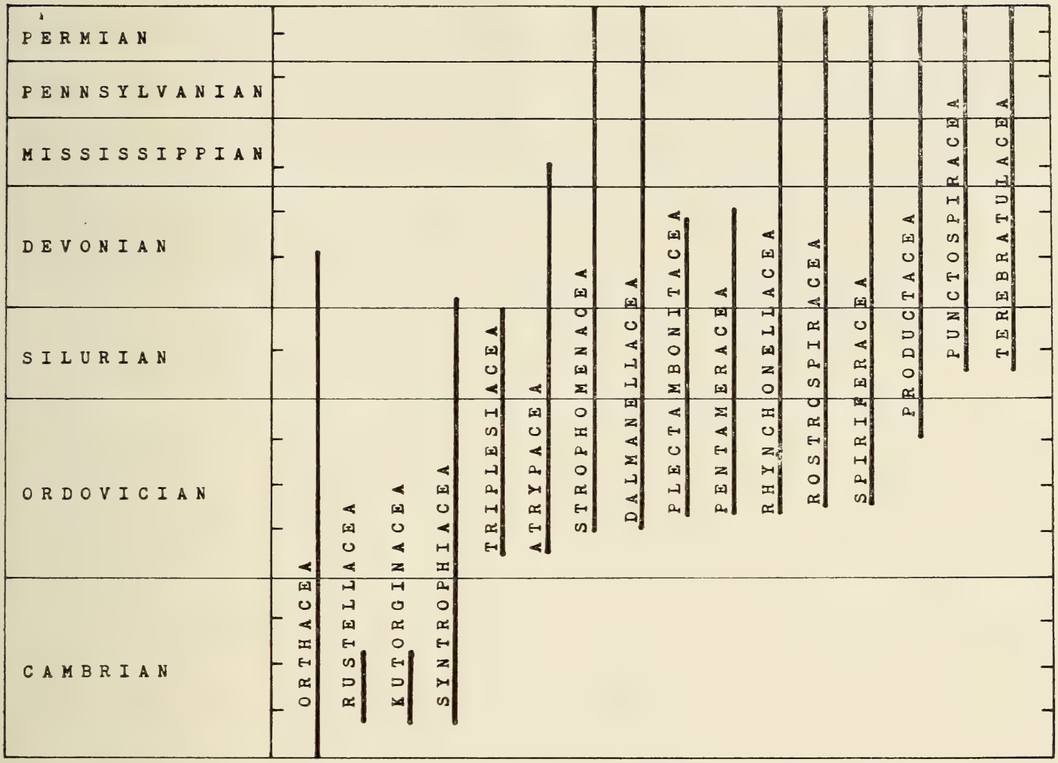

Fig. 7.—Paleozoic history of superfamilies of articulate brachiopods. Data taken from Cooper and Williams, 1952, part of fig. 6, p. 332. Horizontal stubs demark 20-million-year intervals.

emergence of the mammalian orders. As in the case of the mammals, the postponement of rapid divergence of the articulate brachiopods may have been due in part to competition from another group—in this instance the inarticulate brachiopods which flourished first. Another possibility is that the Cambrian seas may have been more suitable for animals with chitinophosphatic shells (e.g., most, but not all, of the inarticulate brachiopods), whereas a favorable environment for animals with calcareous shells (e.g., the articulate brachiopods) did not develop until later. This possibility seems to be confirmed by the fact that many calcareous-shelled animals originated in the early and middle Ordovician (Raymond, 1939, p. 42); examples are the pelecypods, the rugose and tabulate corals, and the bryozoans. Possibly these two factors together may have caused the postponement of rapid primary divergence of the articulate brachiopods.

The classes of the Mollusca (Fig. 8) originated early in the history of the phylum. The gastropods began at the base of the Cambrian. About 60 million years later, in the late Cambrian, the Cephalopoda and the Amphineura appeared. Twenty million years after this latter event, at the beginning of the Ordovician, the Pelecypoda began their existence. Finally, the Scaphopoda emerged at the base of the Silurian, 160 million years after the beginning of the Cambrian, or 80 million years after the appearance of the Pelecypoda. No new classes of Mollusca have emerged during the 360 million years since the beginning of the Silurian. In other words, most of the primary divergence within the Mollusca was accomplished in no more than 80 million years, and it all occurred within a span of 160 million years. All the known classes of the Mollusca are long-lived.

Once again the authors digress, this time to compare the actual history of the ap-

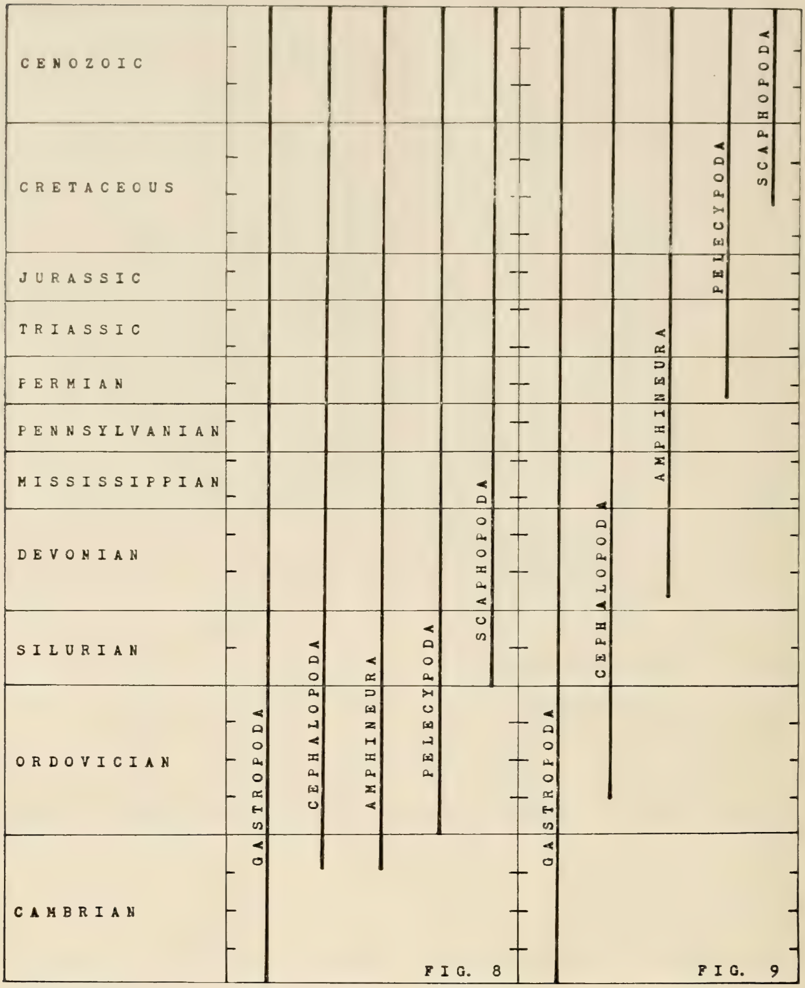

Fig. 8.—Periods of existence of classes of Mollusca. Horizontal stubs demark 20-million-year intervals.

Fig. 9.—Hypothetical periods of existence of classes of Mollusca. If evolution were a slow, gradual, and steady process, with primary divergences occurring at regular intervals throughout geologic history, new classes of Mollusca would have arisen at 104-million-year intervals. Cf. Fig. 8.

pearance of the molluscan classes, based on the paleontologic record, with a hypothetical sequence of divergences based on the idea that the classes should appear at approximately regular intervals throughout the entire history of the phylum. If the time from Cambrian to Recent is taken as 520 million years and the first class originated at the base of the Cambrian, then the next four classes should have emerged one by one at approximately 104-million-year intervals and a new, or sixth, class could be expected to appear soon. Accordingly, one class should have arisen at the beginning of the Cambrian, the next one in the early middle Ordovician, the third near the beginning of the Devonian, another at about the base of the Permian, and the last known one in the middle Cretaceous. That the actual record is sharply different from the hypothetical is illustrated by a comparison of Figs. 8 and 9.

Another case of early rapid divergence (Fig. 10) is seen in the orders of the nautiloids (data taken from Flower and Kummel, 1950, with slight modifications). During the late Cambrian the first order of nautiloids, the Ellesmeroceratida, appeared. Beginning at the base of the Ordovician and extending to the middle Ordovician, a tremendous

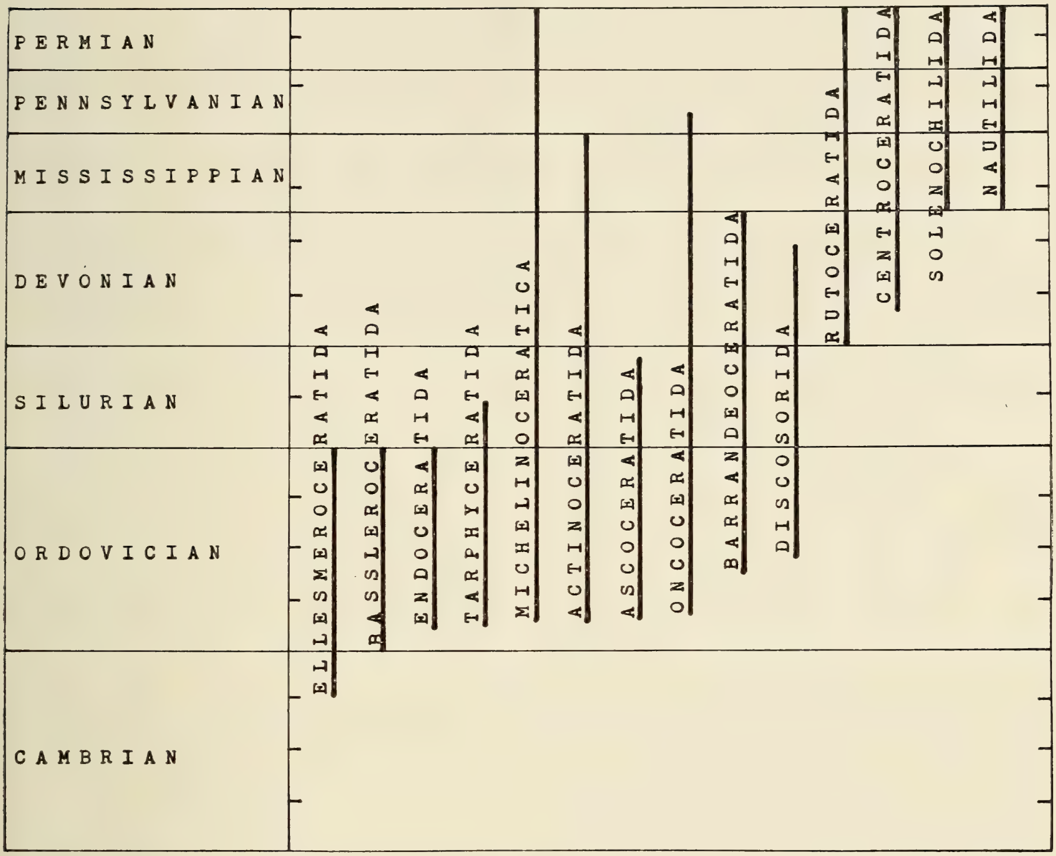

Fig. 10.—Paleozoic history of orders of nautiloid cephalopods. Data taken from Flower and Kummel, 1950, with slight modifications. Horizontal stubs demark 20-million-year intervals.

burst of divergent mutation occurred: within a span of no more than 40 million years, and within about 60 million years of the first appearance of the nautiloids, nine new orders emerged. Several of these were relatively short-lived, having existed for about 100 million years and in a few cases even less. Between 80 and 90 million years later, in the early Devonian, two more orders appeared. Finally, the last two orders arose in the early Mississippian about 195 million years after the beginning of nautiloid history. No new orders of nautiloids emerged during the final 80 million years of the Paleozoic, nor did any appear during the Mesozoic and Cenozoic eras when the general trend of the nautiloids was toward extinction. It is noteworthy that five-sevenths of the nautiloid orders originated within the first one-seventh of the nautiloids' period of existence. In other words, most of the major groups (10 of 14) appeared between the late Cambrian and middle Ordovician. This corresponds well with the time of rapid divergence of many other organisms that had calcareous shells. In the last 400 million years of nautiloid history only four new orders emerged, and even they all began within the first 135 million years of that span of time.

The first superfamily of Paleozoic ostracodes (Fig. 11) emerged at the beginning of the Ordovician period. In the early Ordovician, also, and about 15 million years later, two more superfamilies appeared. About 190 million years after that, the fourth and last superfamily originated; this was at the base of the Pennsylvanian period. During the remainder of the Paleozoic era, 50 million years, no new superfamilies of

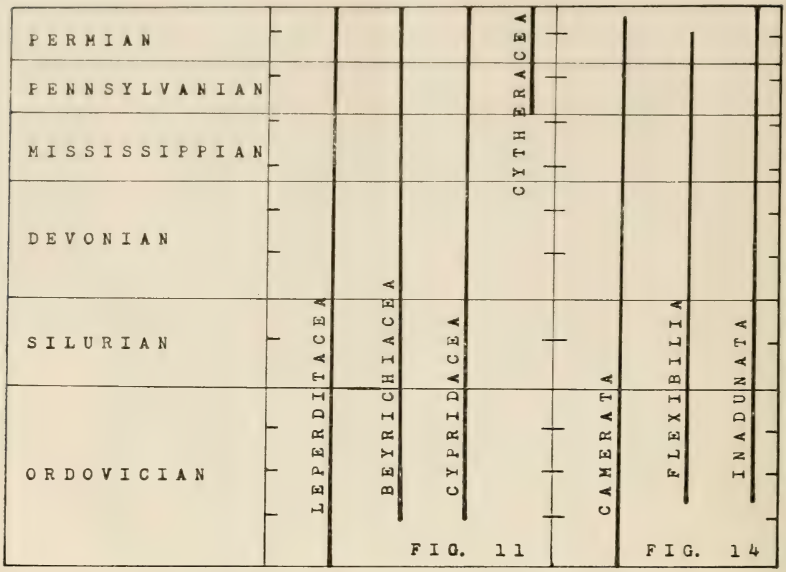

Fig. 11.—Paleozoic history of four superfamilies of ostracodes. Horizontal stubs demark 20-million-year intervals.
Fig. 14.—Paleozoic history of three subclasses of crinoids. Horizontal stubs demark 20-million-year intervals.

ostracodes emerged. Thus, three of the four major groups of ostracodes arose within a span of 15 million years during the early Ordovician, and only one new superfamily appeared during the remaining 240 million years of the Paleozoic era.

In regard to early divergent mutation, perhaps the most illustrative and interesting group studied comprises the classes of the phylum Echinodermata (Fig. 12). The data, collated from several different sources, represent a concensus of authorities. A few questionable groups were not included, as for instance the Bothriocidaroida, which is considered a separate class by Moore (Moore, Lalicker, and Fischer, 1952, p. 577) but not by others, and the classes Cyamoidea and Cycloidea, which are aberrant short-lived middle Cambrian groups and are discussed only by Shrock and Twenhofel (1953, pp. 694–696). If these groups had been included in the present study, the depiction of early divergent mutation among the echinoderms would have been even more striking.

Near the beginning of the Cambrian the Edrioasteroidea appeared, and about 25 million years later, in the middle Cambrian, the Eocrinoidea made their debut. Also in the middle Cambrian, and about 10 million years after the appearance of the Eocrinoidea, the Carpoidea emerged. For the remainder of the Cambrian, about 40 million years, no new classes of echinoderms appeared. At the beginning of the Ordovician, however, three more classes arose. Within the next 40 million years, and no later than middle Ordovician, the Paracrinoidea, Cystoidea, Echinoidea, and Blastoidea made their debut. The Holothuroidea originated in the middle Devonian, no more than 110 million years later than the middle Ordovician. No new classes appeared after the middle Devonian, or for the past 290 million years. Except for the holothuroids, all the classes of echinoderms emerged within the first 120 million years (roughly the first quarter) of the history of the phylum. The most rapid divergence took place within the first 40 million years of the Ordovician period, coinciding again with the time of rapid divergent mutation of many major groups of animals with calcareous skeletons. It is interesting to note here that several of the echinoderm classes were short-lived, having originated and expired early in the history of the phylum.

The writers have chosen the classes of the

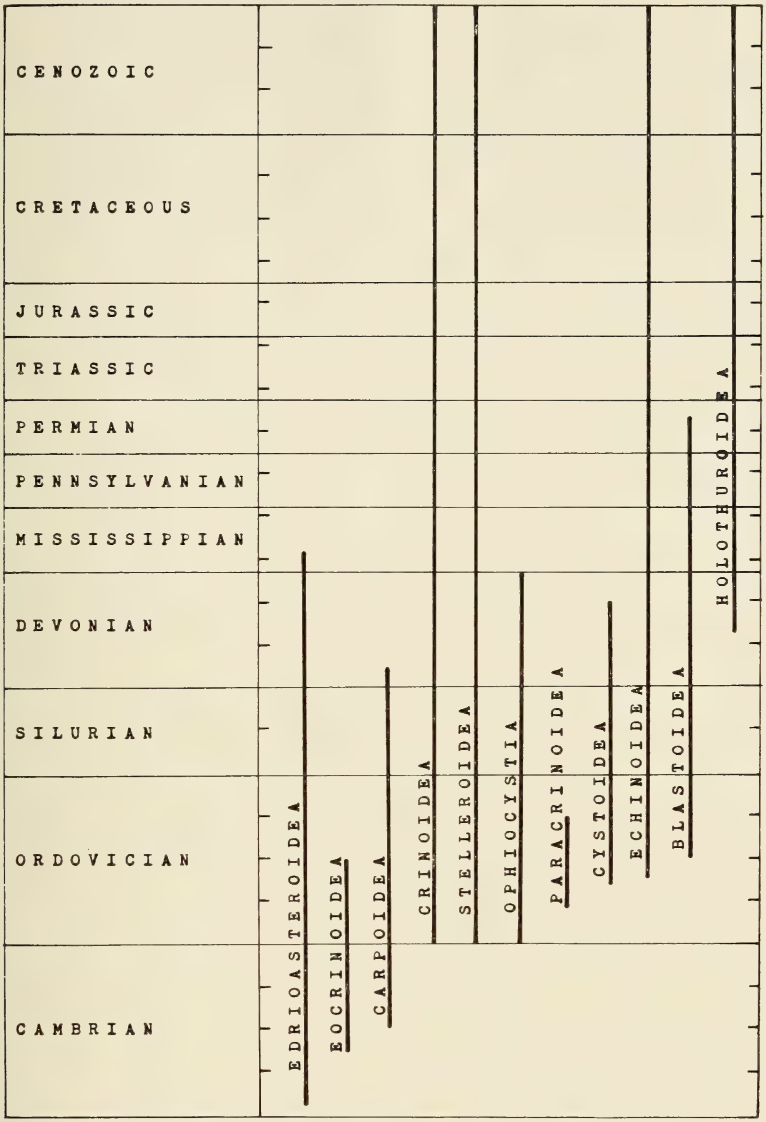

Fig. 12.—Periods of existence of classes of Echinodermata. Horizontal stubs demark 20-million-year intervals.

phylum Echinodermata, a group that shows no evidence of becoming extinct, for presentation of another example of the difference between the actual and hypothetical records of primary differentiation. If we assume that the phylum's history from early Cambrian to Recent spans 520 million years and if we theorize that evolution is a relatively steady and gradual process, the 11 classes of echinoderms should have originated one by one at about 47-million-year intervals. Hence, their individual emergences should have occurred in the (1) base of the Cambrian, (2) middle Cambrian, (3) early Ordovician, (4) late Ordovician, (5) late Silurian, (6) late middle Devonian, (7) latest Mississippian, (8) late Permian, (9) middle Jurassic, (10) middle Cretaceous, and (11) early Cenozoic. The theory appears fallacious, however, when one examines the actual record, which shows that three classes originated before the Ordovi-

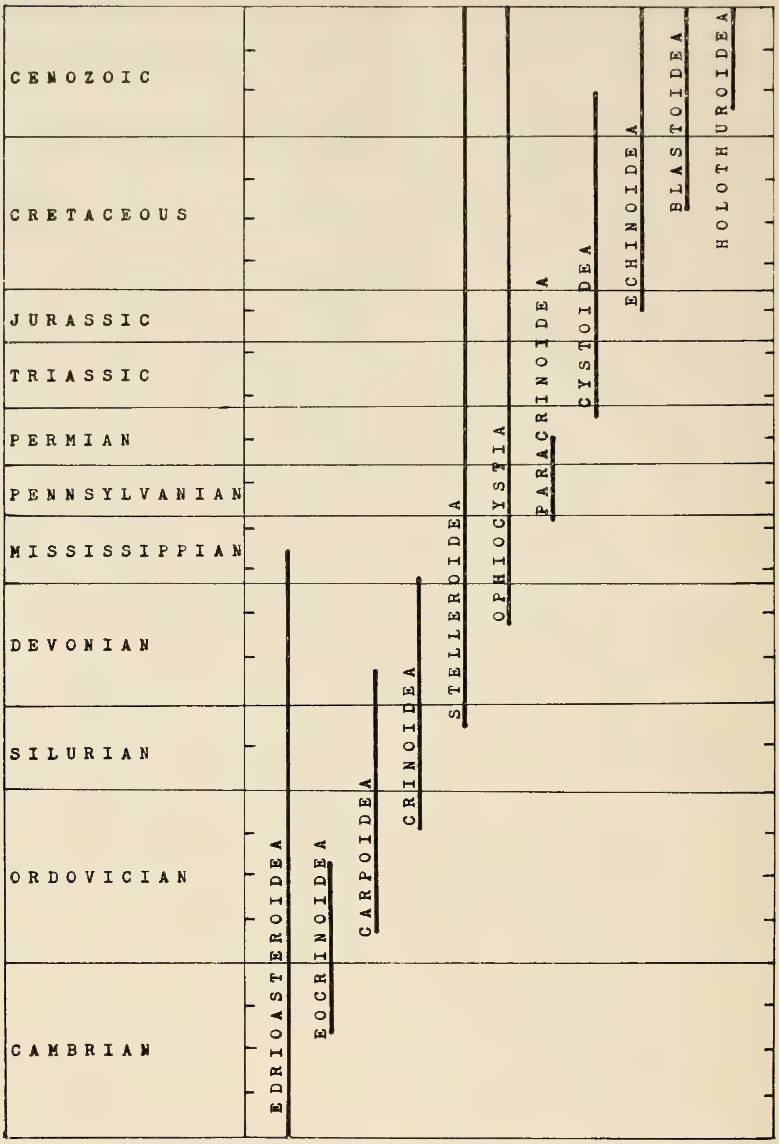

FIG. 13.—Hypothetical periods of existence of classes of Echinodermata. If evolution were a slow, gradual, and steady process, with primary divergences occurring at regular intervals throughout geologic history, new classes of Echinodermata would have arisen at 47-million-year intervals. Horizontal stubs demark 20-million-year intervals. Cf. Fig. 12.

cian, seven during the Ordovician, and only one thereafter. To facilitate comparison we present the actual and theoretical records in Figs. 12 and 13.

The first subclass of Paleozoic crinoids (Fig. 14), the Camerata, appeared at or near the beginning of the Ordovician. No more than 30 million years later, in the early middle Ordovician, the other two subclasses made their debut. Once again we see the early and middle Ordovician as a period of rapid emergence of animals having calcareous shells. For the remainder of Paleozoic time, about 225 million years, no new subclasses of crinoids arose.

The orders of the irregular echinoids are an excellent case of adaptive radiation and rapid divergent mutation (Fig. 15). As soon as the echinoids developed the ability to thrive on a sandy or muddy substrate, they

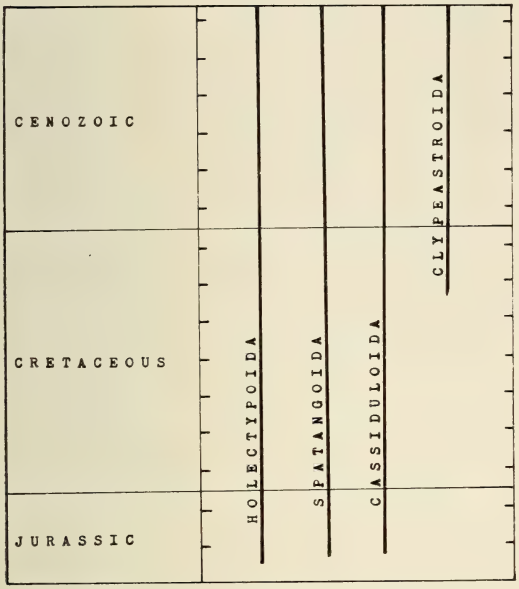

Fig. 15.—Periods of existence of orders of irregular echinoids. Horizontal stubs demark 10-million-year intervals.

evolved quickly. The first order, Holectypoida, appeared in the early Jurassic. Two more orders sprang into existence almost simultaneously in the early Jurassic, probably no more than two million years later. The last order, the Clypeastroida, did not emerge until the late Cretaceous, about 70 million years later. For the past 80 million years no new orders of irregular echinoids have arisen. Most of the primary divergent mutation occurred within the first two million years of the existence of the irregular echinoids; only one new order arose during the subsequent 150 million years.

The five orders of graptolites (Fig. 16) give an excellent and typical picture of the entire history, from inception to extinction, of a rapidly evolving group of organisms. The Dendroidea appeared first in the middle Cambrian. About 25 million years later, in the late Cambrian, the Graptoloidea arose; and approximately 10 million years after that, at the beginning of the Ordovician period, the other three orders began their existence. Two of the latter three orders were short-lived, existing for less than 30 million years. All of the basic divergence within the graptolites was accomplished in about 35 million years. In the remaining 185 million years of graptolite existence, no new orders appeared.

The history of the graptolites can be divided into three phases such as Schindewolf (1951, p. 139) has depicted for other groups of animals. The first phase of rapid divergent evolution (typogenesis) occurred in the graptolites from middle Cambrian to the beginning of the Ordovician—approximately 35 million years—and was characterized by the origin of all of the orders. The second phase (typostasis), or the acme of development of graptolites from the standpoint of numbers of families, genera, and species, occurred during the Ordovician and Silurian periods, or in about 120 million years. This second phase was marked not only by the origins of new families, gen-

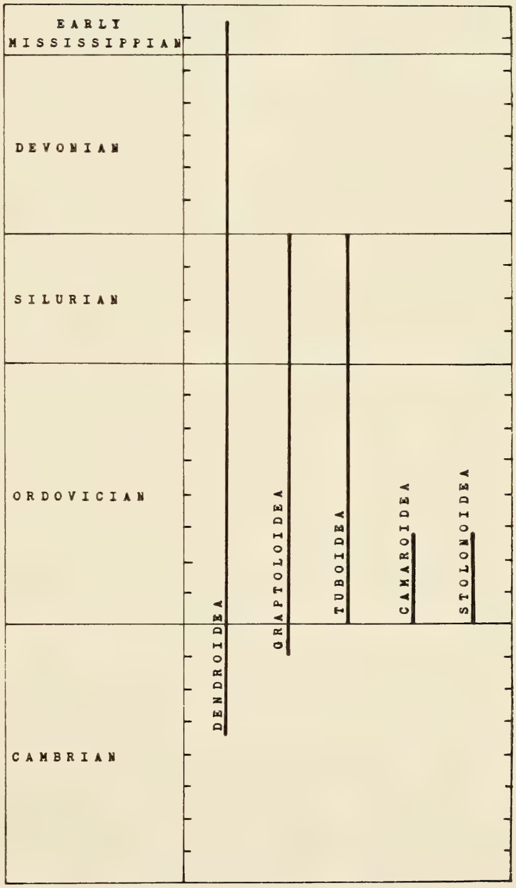

Fig. 16.—Periods of existence of orders of graptolites. Horizontal stubs demark 10-million-year intervals.

era, and species but by the extinction of others. Finally, in the third phase (typolysis) the numbers of lesser subgroups declined and the graptolites became extinct. This last phase occurred during the Devonian and early Mississippian and spanned 65 million years. The senior author (1954, p. 24) has shown that a similar cycle of development, on a much smaller scale, occurred in the long-lived pelecypod species *Glycymeris americana* with regard to its populations and variations.

INFERENCES AND CONCLUSIONS

Believing that the 13 examples used in this study are representative of major invertebrate groups, the authors observe that primary divergent mutation typically occurs early in a group's history, as diagrammed by Schindewolf (1950, p. 239). Thus, the origin of a phylum is closely followed by the origin of all its classes; the inception of a class is soon followed by the inception of all its orders; and a new order is quickly completed in terms of its families. An occasional major divergence may occur much later than the others, but this is rather exceptional. These observations are at variance with the theory that primary differentiation occurs gradually and at regular intervals throughout the history of a given group. That the latter contention is fallacious is graphically demonstrated by a comparison of Fig. 4 with 5, 8 with 9, and 12 with 13, depicting the actual and theoretical histories of the suborders of the scleractinian corals and the classes of the Mollusca and Echinodermata.

One possible explanation for early primary divergent mutation within a major group of animals is alluded to in a somewhat different aspect by Simpson, Pittendrigh, and Tiffany (1957, p. 588). In discussing the appearance of the amphibians they have this to say:

> It is characteristic of evolution that the amphibians did not evolve from late, specialized, progressive or perfected osteichthyans, such as the teleosts, but from primitive forms that lived near the beginning of osteichthyan history. It has usually been true that when a radical adaptive change occurs and a new major group arises, it originates from primitive and not from advanced members of the ancestral group. With progressive adaptation to any one way of life, there often comes a time when the adaptation seems to become irrevocable—a special aspect of the irrevocability of evolution in general. Then change to a radically different way of life becomes, if not impossible, at least extremely improbable.

For example, suppose that the Cephalopoda arose from the Gastropoda: this must have occurred, if at all, early in gastropod history, while the gastropods were still primitive and relatively unspecialized, because later representatives of a major group are generally too specialized to give rise to another group of equal rank. The actual case is that the Cephalopoda did emerge in the first one-eighth of gastropod history, during the time that the gastropods still had primitive or unspecialized representatives.

A fairly common phenomenon is the occurrence of aberrant short-lived subgroups such as two orders of graptolites, several classes of echinoderms, three families of tabulate corals, several superfamilies of articulate brachiopods, and several orders of nautiloids. In most, but not all, cases these short-lived subgroups were among the earlier divergences of their respective groups. If the taxonomic rank assigned to these subgroups is correct on the basis of morphology, then several interesting inferences can be drawn. First: knowing that extinction of families, orders, and classes is not uncommon, one might reasonably assume that extinction of phyla is also not uncommon. The type of geologic history could be the same, in which case extinct phyla may well be more numerous than paleontologists have heretofore acknowledged. Thus, when dealing with aberrant groups which can be only doubtfully allocated to extant phyla, perhaps taxonomists would be more accurate in assuming that they represent extinct phyla. With little confidence and less evidence, paleontologists have allocated aberrant groups such as the conulariids, stromatoporoids, labechiids, receptaculitids, and pleosponges to phyla which still have living representatives; but the fossil groups are sufficiently different from modern groups that such allocations may be erroneous and the extinct groups may actually represent extinct phyla.

It should be stressed, however, that not all extinct groups do represent extinct phyla, no matter how difficult their proper allocations to extant phyla may be. A class of fossil animals having structurally simple hard parts may be so lacking in distinctiveness that its phyletic assignment is dubious; and yet, if the soft parts were available for examination, all doubt would be removed. Moore (Moore, Lalicker, and Fischer, 1952) makes an excellent point when he states (pp. 273–274): "The scaphopods hold unquestioned status as members of the Mollusca in good standing, but if they were known only as fossils, it is certain that they would be put on an *incertae sedis* (uncertain classification) list."

Let us further explore the possibility that extinct phyla may be fairly numerous. The extinction of a phylum of course implies the extinction of all its classes. Conversely, the survival of other phyla implies the survival of at least some of their classes and occasionally the inception of new classes. Considering extinctions, survivals, and new inceptions, one is led to wonder whether there were more phyla and classes of living invertebrates at any one time in the past than there are today. In the case of the echinoderm and bryozoan classes, to cite but two examples, there is no doubt. One has only to look at Figs. 6 and 12 to see that these phyla had more classes of living representatives in the Paleozoic era than in the present. Yet these phyla do not appear to be approaching extinction. That is to say, despite a net reduction in the number of classes, the echinoderms and bryozoans are still flourishing and may actually have more genera and species today than at any other moment of history.

Although they may represent fewer classes and phyla, we would be inclined to believe that there are as many species, genera, families, and possibly orders of animals and plants living on the earth today as at any specific time in the geological past. When one considers the ecological relationships among plants and animals, one realizes that the appearance of a new species generally provides another ecological niche or habitat for one or more additional species as commensals, symbionts, or parasites. The development of grasses provided impetus to the evolution of mammals; the origin of flowering plants promoted the development of insects; more fundamentally, the emergence of land plants was followed by rapid evolution of terrestrial animals. Furthermore, most non-parasitic animals have parasites living inside or outside their bodies, and many of the parasites are peculiar to one or, at most, a few species of host; and so the origin of a new host species encourages the origin of new parasites. Of course, it follows that the extinction of a species may lead to the extinction of some or all of its commensals, symbionts, and parasites; but we strongly suspect that in the general trend of geologic history the proliferation of some genera has fully offset the decline of others. Accordingly, while there may have been a net decline in the number of major living groups (phyla and classes), there has probably been no net decline in the number of minor living groups (genera and species).

Commenting on extinctions, survivals, and new inceptions of major and minor groups, Simpson, Pittendrigh, and Tiffany (1957, p. 754) state:

> Since the Ordovician innumerable groups have died out, but as they disappeared their places were simply taken over by other groups, generally of more recent origin. Among animals and animal-like protists that are at all likely to leave a fossil record, there are only 12 phyla and 31 classes in the present seas. That actually represents a slight decrease from the 13 phyla and 33 classes known for late Ordovician seas. The recent phyla are the same as those of the Ordovician. Several of the classes are of later origin and have replaced extinct classes present in the Ordovician. Replacement has been more and more complete at lower levels of the hierarchy of classification.

Why have some of the major groups become extinct? In assembling the data for this paper we have observed the following facts. It seems that several different basic patterns of morphology arose among the groups which, early in their history, had a number of short-lived primary subgroups, as for example the classes of the Echinodermata and the orders of the Nautiloidea. In each case, the "successful" pattern of morphology was exhibited only by the long-lived subgroups and was characterized by the development of numerous genera and species flourishing over a wide geographic area for a long period of time. Once the basic pattern had been established, subsequent modifications were relatively minor but numerous. In contrast, the basic morphologic patterns adopted by the short-lived subgroups (and a few of the long-lived ones) exhibited very few minor modifications and never became "successful" in the sense of being characterized by large numbers of genera and species and broad geographic range.

Completing our summary, we call attention to the fact that many groups of animals with calcareous skeletons show primary divergence most rapidly during the latest Cambrian and early and middle Ordovician. Exemplifying this phenomenon are the echinoderms, the tabulate and rugose corals, the bryozoans, the articulate brachiopods, the mollusks, the nautiloids, and the Paleozoic crinoids. Raymond (1939, pp. 34, 38–40, 42) noted that the Ordovician was a period of rapid development and evolution of calcareous-shelled animals, and our data confirm his assertions.

LITERATURE CITED

COOPER, G. ARTHUR, and WILLIAMS, ALWYN. *Significance of the stratigraphic distribution of brachiopods.* Journ. Pal. **26** (3): 326–337, 12 figs. 1952.

FLOWER, R. H., and KUMMEL, B., JR. *A classification of the Nautiloidea.* Journ. Pal. **24** (5): 604–616, 1 fig. 1950.

KNIGHT, J. BROOKES. *Primitive fossil gastropods and their bearing on gastropod classification.* Smithsonian Misc. Coll. **117** (13): 56 pp., 2 pls., 10 figs. 1952.

LOEBLICH, ALFRED R., JR., and COLLABORATORS. *Studies in Foraminifera.* U. S. Nat. Mus. Bull. **215:** 323 pp., 74 pls., 30 text figs. 1957.

MOORE, RAYMOND C. *Treatise on invertebrate paleontology: Part F, Coelenterata:* 498 pp. University of Kansas Press and Geological Society of America, 1956.

MOORE, RAYMOND C., LALICKER, CECIL G., and FISCHER, ALFRED G. *Invertebrate fossils:* 766 pp. McGraw-Hill, New York, 1952.

NICOL, DAVID. *Growth and decline of populations and the distribution of marine pelecypods.* Journ. Pal. **28** (1): 22–25, 2 figs. 1954.

RAYMOND, PERCY E. *Prehistoric life:* 324 pp. Harvard University Press, 1939.

SCHINDEWOLF, OTTO H. *Grundfragen der Paläontologie:* 506 pp. E. Schweizerbart, Stuttgart, 1950.

———. *Geologische Zeit und organische Entwicklung.* Proc. Linn. Soc. London **162** (2): 134–140, 2 figs. 1951.

SHROCK, R. R., and TWENHOFEL, W. H. *Principles of invertebrate paleontology:* 816 pp. McGraw-Hill, New York, 1953.

SIMPSON, G. G., PITTENDRIGH, C. S., and TIFFANY, L. H. *Life: an introduction to biology:* 845 pp. Harcourt, Brace, New York, 1957.

SMALL, JAMES. *Discussion on time-rates in evolution.* Proc. Linn. Soc. London **162** (2): 130–134. 1951.

WILLIS, J. C. *The course of evolution by differentiation or divergent mutation rather than by selection:* 207 pp. Cambridge University Press, 1940.

BOTANY.—*The Danthonia-Lichen-Moss community in Washington, D.C., and vicinity.*

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The purpose of this paper is to describe a Danthonia-Lichen-Moss community as it exists in Washington, D.C., and vicinity and to discuss its possible role in ecological succession. This community, heretofore undescribed, is ecologically interesting as it seems to be confined to disturbed places and is found in woodland clearings, along the periphery of woods, and on eroding areas. It consists chiefly of the poverty oat-grass, *Danthonia spicata*,[1] the lichens, *Cladonia cristatella* and *C. subtenuis*, and a variety of mosses.

PROCEDURE

Six stands of the Danthonia-Lichen-Moss community in different locations in and near Washington, D.C., were analyzed during March and April 1959. The greatest distance between stands was 7 miles.

The vegetation was analyzed by means of 2-decimeter-square quadrats placed at regular intervals through the center of each stand (except in stand 3 where intense erosion and degradation of the community necessitated selection of quadrat areas for study). Ten quadrat samples were studied in each of the six stands. Cover estimates of the vegetation were made using the Hult-Sernander scale modified by Hanson (1953) where a cover of 6 is assigned a species with vertical projection of its living parts covering 3/4 to 4/4 of the quadrat, 5—1/2 to 3/4, 4—1/4 to 1/2, 3—1/8 to 1/4, 2—1/8 to 1/16, 1—less than 1/16, x—rare, vitality low. From tabulated data on each stand the average cover and per cent constancy of each species were computed (see Table 1).

Soil samples from 0 to 1 inch and 1 inch to 3 inch depths were taken and analyzed for texture by the Bouyoucos (1951) hydrometer method, pH according to the colorometric system using bromcresol green indicator, and color designation with the Munsell color charts (Soil Survey Staff, 1951).

[1] Nomenclature follows Gleason (1952).

The first study area was located on the west side of U.S. Highway No. 1 on top of a hill south of the business section in University Park, Md. (Fig. 1). It consisted of a small irregular area (106 by 30 feet at its greatest dimensions) in a gravelly clearing among pines (*Pinus virginiana*). The degree of slope and other pertinent data for this and each of the other stands are listed in Table 1.

The second stand of this study was located at the edge of an open white oak woods near St. Paul's College, Fourth Street, NE., Washington, D.C. The woods here appears to have been artificially cleared, as there were no tall shrubs and only a few scattered forbs near the *Danthonia*, lichen, and moss vegetation which grew on a slight north-facing slope just above a three foot bank bordering the street sidewalk. A rectangular area 24 by 13 feet was chosen as representative of the Danthonia-Lichen-Moss community here.

The third and most poorly developed community considered in this study was at 3900 Harewood Road, Washington, D.C., situated on a northern slope in an open stand of oak, pine, and tulip trees. The community components occurred in irregular patches along the hillside which showed evidence of severe frost action and erosion.

A fourth stand 65 by 20 feet was studied near Sisters' College on the Catholic University campus, Washington, D.C. This community covered an open, nearly level area adjoining a pine (*Pinus virginiana*) stand and was subject to occasional mowing.

The fifth and most thriving community was located on the north side of Edgewood Road just off U.S. Highway No. 1, half a mile south of the Plant Industry Station, Beltsville, Md. The stand 60 by 12 feet was on a level area from northwest to southeast between a pine (*Pinus virginiana*) woods and an old field invaded by the bluestem broomsedge, *Andropogon virginicus*. Across the road from stand 5 north of a pine woods, stand 6 comprised a rectangular area 75 by 12 ft.

OBSERVATIONS

The soils supporting these communities in the various areas of study ranged in texture from sandy loam to loam with a clay loam "B" layer in stands 3 and 6. They varied greatly in the percentage of gravel present with some soils showing a 40 to 60 percent gravel content, while others contained little or no gravel. Variation was also noted in color. The "A" soil layers ranged from dark gray through dark red-brown to yellowish brown. The "B" layers exhibited more uniformity, most of them being yellowish brown. A striking similarity in pH was observed among the various soil samples all of which were acid with about a pH 4.5 reaction except for one pH 5.4 reading in the top soil of stand 3.

Regardless of the differing conditions in which the community was found (difference in intensity of erosion, frost action, degree and exposure of slope, etc.), the three chief components of this community, *Danthonia*, lichens, and mosses, show a high degree of constancy (see Table 1). No single species of moss, however, is regularly associated with the *Danthonia spicata-Cladonia cristatella-Cladonia subtenuis* communities observed in this study. In stands 1 and 4 *Ceratodon purpureus* was the chief moss while *Pohlia nutans* and *Dicranella heteromalla* were most frequent in stand 2. The former moss was again frequent in stand 4 with scattered cushions of *Leucobryum albidum*. *Dicranella heteromalla* appeared infrequently again in stands 3 and 4 and frequently in stand 6. *Polytrichum commune* was found in part of stand 5. Generally where lichen cover was high, moss cover

Table 1.—Association of Danthonia-Lichen-Moss Communities

Analysis number	1	2	3	4	5	6	Average cover	Average frequency (percent)
Date, 1959	3–13	4–3	4–6	4–8	4–10	4–10		
Number of 2dm² samples	10	10	10	10	10	10		
Slope, degrees	NE, 5–10	N, 4	N, 20	NW, 5	NE, 0	W, 5		
Cover, percent	71.8	71.3	54.5	84.5	93.5	88.5		
Stones or bare ground	3.6	1.5	2.3	1.1	.4	.8	1.6	75
Debris	2.1	3.1	3.2	2.4	3.6	3.0	2.9	100
Total number of species	9	11	5	14	11	13		
Danthonia Spicata	1.8	3.4	2.8	2.0	3.1	2.9	2.7	97
Lichens*	4.2	1.4	3.2	3.0	3.9	2.4	3.0	97
Mosses	.9	3.6	1.1	.9	1.8	2.8	1.9	80
Agrostis hyemalis						.2	.03	2
Andropogon virginicus				1.0	.1	.3	.2	17
Anthoxanthum odoratum		.1		.6			.1	8
Aristida dichotoma				.2	x	.2	.07	8
Digitaria sanguinalis							x	x
Juncus tenuis						x	x	2
Luzula campestris		.1					.02	2
Panicum albomarginatum	.1				.3		.07	7
Triodia flava						.2	.03	3
Antennaria plantaginifolia		.2					.03	3
Aster sp.	x						x	2
Cassia chamaechrista						.4	.07	5
Duchesnea indica				x			x	2
Liatris graminifolia						.2	.03	3
Lonicera japonica			.5				.08	8
Potentilla canadensis	x			.2	.1	.1	.07	10
Solidago nemoralis			.5	.2			.1	15
Pinus virginiana					.2	.1	.05	5
Quercus seedling						.1	.02	2

* Lichens: *Cladonia cristatella* Tuck. (common), *Cladonia subtenuis* (des Abb.) Evans (frequent), *Baeomyces roseus* Pers. (rare). Mosses: *Ceratodon purpureus* (Hedw.) Brid. (common), *Dicranella heteromalla* (Hedw.) Schimp. (frequent), *Pohlia nutans* (Hedw.) Lindb. (frequent), *Eurhynchium hians* (Hedw.) Jaeg. (infrequent), *Leucobryum albidum* (Brid.) Lindb. (infrequent), *Polytrichum commune* Hedw. (infrequent), *Dicranella heteromalla* var. *orthocarpa* (Hedw.) Par. (sparse), *Ditrichum pallidum* (Hedw.) Hampe (sparse).

Fig. 1.—Stand No. 1. A Danthonia-Lichen-Moss community in a scrub pine opening. Goldenrod is scattered. University Park, Md. April 26, 1959.

was low. In two such instances the *Danthonia* cover was also low.

In stand 5 the pink-earth lichen *Baeomyces roseus* mingled with the *Cladonia subtenuis* and rated about equal in cover. It is interesting to note that this pink-earth lichen is a soil stabilizer of wide distribution in eastern United States and is most often found on new road cuts (Hale, 1959, personal communication). The level terrain of stand 5 and the presence of this lichen along a poorly defined footpath through the center of the community may account for the high cover (93.5 percent) observed here.

The 17 percent degree of constancy noted for the broomsedge grass indicates that where it occurs adjacent to *Danthonia* communities it readily invades when a certain degree of stability is maintained by the *Danthonia*, lichens, and mosses. The other species listed in Table 1 are of such infrequent occurrence and low cover that they appear to be accidental and do not essentially belong to this community-type.

DISCUSSION AND CONCLUSIONS

It appears that disturbance such as clearing a forest, scraping off the top soil, trampling, and erosion favor the establishment of this community of *Danthonia*, lichens, and mosses. *Danthonia spicata* has a high tolerance for the infertile "raw" soil in such sites. It not only propagates by seeds in panicles, but also by large basally borne seeds called "cleistogenes" (Hitchcock, 1950). Some species of *Cladonia* and mosses are likewise hardy pioneers in these bare areas. The *Danthonia* seeds germinate in the soil, especially where some deposition is occurring in cracks of the lichen mat and in moss cushions. The mosses grow mostly during late winter and early spring and produce sporangia before the end of April if moisture is available for a sufficiently long time. Moisture and shade also apparently favor the continuance of this community, but dry weather causes cracking and breaking up of the lichen mat, thus accelerating erosion. Freezing in cold weather in a number of places causes heaving, loosening of the soil, severing the attachment of plants to the soil and increases erosion. When erosion has started, parts of the stand disintegrate rapidly, usually leaving a gravelly surface on which invasion takes place again. In some spots it appears that a cycle of invasion, growth, and degradation may be repeated several times before other species such as *Andropogon virginicus* or *Pinus virginiana* invade and cause the disappearance of most of the lichens. Similar cracking of lichen mats, especially those formed by *Diplochistes scruposus* (Schreb.) Norm., followed by erosion has been noted by the junior author in Colorado. Churchill and Hanson (1958) mention the drying and breaking of the lichen mat in the initiating of the downgrade series of cyclic changes in vegetation in the Arctic (cf. Watt, 1947).

Reduced light intensity, such as is found in openings and along edges of woods, and soil that remains wet for a considerable time after rains, is favorable for the best expression of this community. *Danthonia* does occur in open sunlight, but the lichen and moss components are poorly developed or lacking in such areas. *Danthonia* can also survive in areas where deposition is actively occurring, but mosses and lichens cannot.

As in other communities an excessive or deficient supply of plant requirements may prove limiting to the establishment and continuance of the vegetation. Too severe frost action and erosion in stand 3 may account for the poor condition of the community here. Schramm (1958) points out that soil heaving by frost action can easily occur in soil with a clay component as high as that found in this stand. The lichen mats and moss cushions are lifted by this action and offer little resistance to rain and runoff. The undermined *Danthonia* clumps soon erode away also. The most flourishing community was found in loam soil in stand 5 where the ground was level. The winds and high temperature of a Washington summer may further limit this community by causing drying of the moss and early disintegration of the lichen mats. An excessive amount of litter and debris in the form of pine needles, twigs, branches, and leaves also interferes with the growth of the plants, particularly the lichens and mosses.

The soil type in general did not seem to limit the community except where clay soils favored frost action and eliminated the pink-earth lichen, a sand-adapted species according to Nearing (1947). The *Cladonia* species and *Danthonia* appear to have a wide tolerance for different kinds of substrates. The mosses, however, seem to flourish best in the loam of the oak woods in stand 2.

From the study of these six communities it appears that the Danthonia-Lichen-Moss community is characteristic of disturbed areas in the vicinity of Washington, D.C. It occurs on a variety of soils as a pioneer in the revegetation of waste places. It is not known at present how widespread this community is. It appears important as a transitional stage in succession by stabilizing the soil and is followed by invasion and establishment of less tolerant grasses, particularly *Andropogon virginicus*, shrubs, and tree seedlings. If this invasion does not occur, the lichen mat breaks up, erosion and frost action may occur and the community is likely to deteriorate even to the bare ground stage. Thus a cyclic series of downgrade and upgrade vegetational changes may be initiated. As invasion of other species, however, does occur in time, this community performs a useful soil-stabilizing service in nature's economy in the revegetation of disturbed areas.

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LITERATURE CITED

Bouyoucos, G. J. *A recalibration of the hydrometer method for making mechanical analysis of soils.* Agron. Journ. **43**: 434–438. 1951.

Churchill, Ethan D., and Hanson, Herbert C. *The concept of climax in arctic and alpine vegetation.* Bot. Rev. **24**: 127–191. 1958.

Gleason, H. A. *The new Britton and Brown illustrated flora of the northeastern United States and adjacent Canada:* 3 vols. New York Botanical Garden, New York, 1952.

Hanson, Herbert C. *Vegetation types in northwestern Alaska and comparisons with communities in other Arctic regions.* Ecology **34**: 111–140. 1953.

Hitchcock, A. S. *Manual of the grasses of the United States:* 1051 pp., Washington, 1950.

Nearing, G. G. *The lichen book:* 648 pp. Ridgewood, N. J., 1947.

Schramm, J. R. *Mechanism of frost heaving of seedlings.* Proc. Amer. Phil. Soc. **102** (4): 333–350. 1958.

Soil Survey Staff. *Soil survey manual.* U.S. Dept. Agr. Handb. 18: 503 pp. Washington, 1951.

Watt, A. S. *Pattern and process in the plant community.* Journ. Ecol. **35**: 1–22. 1947.

ACADEMY NEWS

Dr. Jacob Rabinow, president of the Rabinow Engineering Co., Inc., of Washington, D.C., has been awarded a Longstreth Medal of the Franklin Institute for his work on the magnetic fluid clutch.

Dr. Walter Ramberg, president of the Academy in 1952 and head of the Mechanics Division at the National Bureau of Standards until this year, is now scientific attache at the American Embassy in Rome, Italy.

Dr. Francis B. Silsbee, president of the Academy in 1951, retired as head of the Electricity and Electronics Division, NBS, this year.

The successful career and pleasant associations in this country of Dr. Shan-Fu Shen of the University of Maryland were featured this summer in U. S. Information Office releases to the Far East. He was the recipient of the Academy's Engineering Sciences Award at the Annual Dinner this year.

Dr. Herbert P. Broida, of the Free Radicals Research Section, National Bureau of Standards, left in September to spend a year in Cambridge, England.

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