at Los Alamos, three complete filter papers (obtained from the environmental air sampler) were placed in the center chamber of the electrodialysis cell. The samples were electrodialyzed for a period of 48 hours. The distance between electrodes was 2 cm. The voltage was maintained at 100 v. After the dialysis, the extract obtained was analyzed for Sr^{90} by the ion-exchange method (*3*). The filter papers were allowed to dry. They were then placed in a large porcelain crucible and heated slowly to 450°C and held at this temperature until they were ashed. The samples were allowed to cool to room temperature, then 10 ml of 72-percent perchloric acid was added to complete the digestion. The amount of Sr^{90} obtained by ashing the papers was determined by the ion-exchange method (*3*).

To study the effect of electrodialysis on the stability of the fallout collected by aircraft, approximately 2 cm^2 of the collector filter paper was placed in the dialysis cell and dialyzed for 48 hours. The conditions of dialysis were the same as those described above. The Sr^{90} of the dialysis extract and the portion remaining in the filter paper after dialysis were analyzed as described above. The results of the weathering studies of fallout are presented in Tables 1 and 2.

The results of this study show that the glassy pellets which fall in the area around the test site are resistant to weathering. They are so resistant that it is unlikely that more than 1 percent of their activity would enter into the biological cycle in any given year.

The samples collected at Los Alamos contained Sr^{90} in dialyzable and nondialyzable forms. This does not seem unreasonable since some of the glassy pellets are small enough to be transported by wind from the test site to Los Alamos.

The results of the study on the samples collected by aircraft flying through the cloud caused by the nuclear detonation suggest that electrodialysis could be used to evaluate the hazard associated with each type of detonation and that valuable information regarding the rate of entry into the biosphere could be obtained.

ELLIS R. GRAHAM*
Los Alamos Scientific Laboratory,
Los Alamos, New Mexico

References

1. H. Nishita and K. H. Larson, "Summary of Certain Trends in Soil-Plant Relationships Studies of the Biological Availability of Fallout Debris," *Univ. Calif. (Los Angeles) Publ. Biol. Med. No. UCLA-401.*
2. U.S. Regional Salinity Laboratory, Riverside, Calif., "Diagnosis and Improvement of Saline and Alkali Soils," L. A. Richards, Ed., *U.S. Dept. Agr. Handbook No. 660.*
3. E. R. Graham, *Soil Sci.*, in press.

* Present address: Department of Soils, University of Missouri, Columbia.

10 November 1958

Group Effort in Modern Physics Research

Abstract. In the *Physical Review* for the year 1957, as a sample, multiple authorship appears with greatest relative frequency in communications from government, academic, and industrial laboratories, in that order. For the three types, it appears that research is conducted on the average by groups and not by individuals. These conclusions are at variance with premises assumed recently by R. S. Uhrbrock (*1*).

For the planning and direction of scientific research, it is important to determine the elusive factors that enter into research productivity. The elements affecting the productivity of the *individual* have been studied recently by Shockley (*2*). However, current scientific periodicals show that articles with N authors, where N not infrequently is large relative to unity, are prevalent, whereas such papers were the glaring exception a decade or so ago. It is interesting to examine quantitatively the relative frequency of group and individual efforts in the physical sciences and to determine whether any correlations exist. This report summarizes initial conclusions for one science, physics, based on a sample consisting of all contributions that appeared in the *Physical Review* during the calendar year 1957 (volumes 105–108). This particular journal was selected because of its timeliness in the coverage of active areas of research in modern physics.

In the sample chosen, the names of laboratories of three general types (academic, government, and industrial) appear in the respective by-lines of the contributions (*3*). For each separate category the histogram given in Fig. 1 shows the total number (on a logarithmic scale) of papers and letters to the editor with N authors (*4*) as a function of N. The most striking feature revealed by Fig. 1 is that the number of communications with N greater than unity is relatively, as well as absolutely, greater for government and academic laboratories than for their industrial counterparts. This number is 64, 62, and 48 percent, respectively, of the total number of communications in the three categories, listed in the order given above. Thus, only for industrial laboratories are contributions from single authors not outnumbered by those of joint authorship.

An individual rank in its category was assigned to each laboratory, corresponding to the total number of communications from that laboratory in the sample. In the academic category, the University of California, Berkeley, ranks first, with 112 works; Bell Telephone Laboratories is the corresponding giant (47 works) in the industrial class. The histogram given in Fig. 2 shows the average number of authors per contribution from a laboratory as a function of rank for academic and industrial laboratories, up to rank 50 (three works) for the former. One sees immediately that for the laboratories under consideration, research is conducted, in general, by groups or teams and *not* by individuals. In fact, the mean number of authors per publication over the entire sample considered is 2.1, 2.1, and 1.7 for academic, government, and industrial laboratories, respectively. Comments by Temperley (*5*) indicate that a trend toward a similar situation exists in the United Kingdom.

The conclusions given above are not at all what widely held preconceptions might suggest. It is true that the choice of a different journal of physics would alter conclusions with respect to details (the papers of Fig. 1 with an extremely large multiplicity of authors are all on nuclear physics). Clearly, however, the ubiquity of group effort is the ineluctable concomitant of the explosive growth of

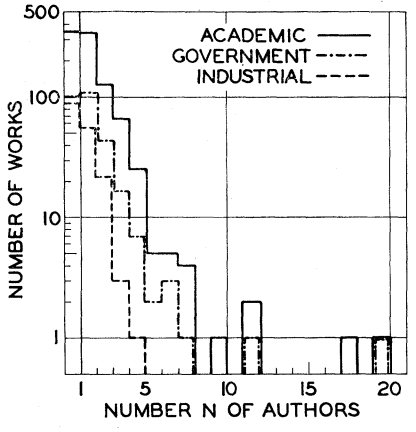

Fig. 1. Number of research communications with N authors in the sample, as a function of the number, N, of authors (the vertical scale is logarithmic).

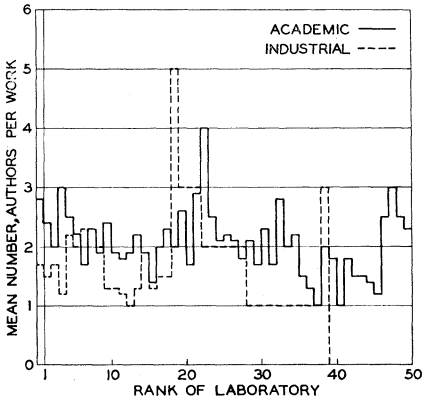

Fig. 2. Mean number of authors per research communication from a laboratory, as a function of the laboratory's rank in research productivity. (Results for government laboratories have been omitted for the sake of simplicity.)

science in recent times, with its consequent dependence on the services of specialists and the functioning of large (sometimes vast) complexes of equipment. An interesting question which has not been explored is the secular dependence of multiple authorship on time; are the papers today with 20 or so authors, as indicated in Fig. 1, merely the precursors of papers with 50 or 100 authors that will appear some decades hence?

A guest editorial by Uhrbrock (*1*) in *Science* is germane to the results of this study. Uhrbrock's conclusions are based on the following premises: (i) Research in industrial laboratories is conducted mainly by teams of investigators, and (ii) investigation by teams is in some sense inimical to the proper ends of science and to the best interests of the individual investigator. At least for the sample studied in this report, it is clear that premise (i) is not restricted to industrial laboratories but is valid a fortiori for academic and government laboratories, on the logical assumption that any number of authors in excess of one constitutes a team (the dictionary definition). In view of the stature of the *Physical Review* in its field, it would appear, further, that premise (ii) is not valid in general. Uhrbrock's conclusion is that the prospective investigator in an industrial laboratory should protect himself against the danger of the team by means of a written statement obtained before employment. However, the correlation with joint effort of rank of institution in research productivity, as implied in Fig. 2, suggests the possibility that in many laboratories such a step might defeat its own end. Without examining the numbers involved, Shockley (*6*) has taken issue on essentially the same grounds with views of Miessner (*6*) similar to those of Uhrbrock.

Contrary to a possible implication in Uhrbrock's discussion, 172 communications in the sample studied attest to a basic willingness on the part of industrial laboratories to publish research results. At least in the laboratory with which we are affiliated, approval of the patent department (approval which has never been denied) is the only requirement for submission of a finished piece of work for publication (as against the time-consuming and uncertain security clearance required in many government laboratories and research enterprises conducted by universities and institutes) (*7*).

J. J. GILVARRY
H. K. IHRIG

Research Laboratories,
Allis-Chalmers Manufacturing Company,
Milwaukee, Wisconsin

References and Notes

1. R. S. Uhrbrock, *Science* **128**, 747 (1958).
2. W. Shockley, *Proc. I.R.E.* (*Inst. Radio Engrs.*) 45, 279 (1957).
3. The designation *government* includes laboratories operated by a national government or operated for it by universities or industrial contractors. Foreign "institutes of physics" were classed as academic.
4. In cases where the names of laboratories of more than one category appeared in a by-line, prorated fractions were assigned to the number of communications from each category for that value of *N*. In Fig. 1, the resulting numbers were rounded to the closest integer above.
5. H. N. V. Temperley, *Science* **124**, 355 (1956).
6. B. L. Miessner and W. Shockley, *Proc. I.R.E.* (*Inst. Radio Engrs.*) 45, 409 (1957).
7. We wish to acknowledge discussions with Dr. W. Zeit of the School of Medicine of Marquette University, and to thank Miss H. Pandow for the computational work.

23 January 1959

I have no desire to prolong the discussion of the effects of team membership on the scientific careers of individuals employed in industrial laboratories. Gilvarry and Ihrig have presented data showing that multiple authorship is increasing in the field of physics. Smith [*Am. Psychologist* **13**, 596 (1958)] reported a similar trend in psychology. These studies show that (i) team research is being conducted on an increasingly large scale in governmental, academic, and industrial laboratories, and (ii) *some* teams are reporting their results, listing two to 20 persons as collaborators.

We have no evidence about the number of teams in existence at any one time or any indication of the proportion of completed projects reported. Young scientists should be aware of the trend toward team research and should consider its possible effect upon their individual careers. The time to ask questions is before accepting employment. That, as simply as I can state it, is the point I wish to emphasize.

RICHARD S. UHRBROCK
College of Arts and Sciences,
Ohio University, Athens

6 February 1959

Enchytraeus fragmentosus, a New Species of Naturally Fragmenting Oligochaete Worm

Abstract. A new species of enchytraeid (Oligochaeta) worm has no sex organs, but reproduces solely by fragmentation.

In April 1956 I received from R. A. Didriksen of Iowa State College some fresh enchytraeid worms, believed to be *Enchytraeus albidus*. Careful investigation, whole-mount and serial section studies, revealed that the culture was a mixture of two species, the one being *Enchytraeus fonteinensis* Michaelsen (1927), the other of uncertain classification. The separate cultures have been going for over 2 years, the *E. fonteinensis* reproducing from cocoon to cocoon about every 10 days, the other species reproducing by fragmentation in about the same length of time.

The amazing thing about the second species is the phenomenon of fragmentation. Fully mature worms break into from 3 to 11 fragments, usually of about five segments each. Each portion fully regenerates in a period of about 10 days. There is every reason to believe that full regeneration of vital structures results from changes of undifferentiated tissues of the body; I have not undertaken such an investigation, but have noted unusual, large "formative" cells in the body cavity.

Since the material lends itself to a great number of investigations—for example, regeneration processes; gradients, polarity and reversal of polarity; radiation experiments; possible mutations; pharmacological investigations—I offer to supply living material at postage cost to any applicants.

Enchytraeus fragmentosus n. sp. Because these worms have no sex organs, the usual criteria for determination of species, other characteristics will have to be adduced for diagnosis. Before I was aware of the unusual reproductive method in this worm (to my knowledge it is exceptional for all oligochaete worms), I regarded the worm as an immature specimen of *E. albidus*. The peptonephridia come from a dorsal pouch in segment III and divide into two sac-like masses passing caudad and ventrad in segment IV as in *E. albidus*. There are, however, a number of twigs off the main sacs in segment IV. There is one outstanding difference in the new species—namely, the possession of four pairs of septal glands instead of the usual three pairs. The type specimen is in my collection.

Diagnosis: Color white; length 10 to 16 mm in crawling; segments about 50 when fully developed; diameter 0.25 mm; setae straight, two only per fascicle; no special glands; no clitellum; prostomium rounded; head pore at 0/I. Brain nearly round, concave anteriorly and indented posteriorly, 65 μ wide and long. Pharynx in segment III with typical high palisade cells in roof; oesophagus widens gradually, no oesophageal pouches; peptonephridia arise in segment III from a dorsal pouch and branch into two elongated sacs in segment IV, with a number of terminal twigs. Chloragog cells large without granules. Septal glands (pharyngeal glands) lie on septa IV/V, V/VI, VI/VII, and VII/VIII. Dorsal vessel arises in segment XIII. Coelomocytes (lymphocytes) with clear, loose cytoplasm and large nucleus; circular; 15 to 20 μ in diameter; appear to be amoeboid in the living. Nephridia with small preseptal (20 μ long, 10 μ wide); postseptal larger (50 μ long, 20 μ wide) with terminal duct. No sex organs: reproduction solely by fragmentation.

A. W. BELL
Life Sciences Department, Los Angeles City College, Los Angeles, California

17 December 1958