gists. The committee is taking this opportunity of reporting its work, so that it may acknowledge the help it has received from various organizations and publicly express its thanks. It hopes also that this report will encourage others to extend the program.

Subscriptions from society members have provided a total of some six hundred dollars, an amount which obviously cannot significantly reduce foreign shortages of literature or equipment. Real success, however, has been achieved in promoting good will. The present program in literature does not compete with the much more ambitious program now being organized by CARE, which should be supported to the fullest extent possible, but the society's program can still fill gaps and play a useful supplementary role.

In order not to dissipate its efforts over too large an area, the committee decided to limit its main activities to a few schools in countries in which the United States has particular interests. The selected medical schools are those in Salonika, Naples, Frankfurt, Würzburg, and Tohoku. Some additional help has gone to other schools, including help to China.

Reprints. Reprints of recent literature are very valuable. Considerable numbers (with multiple copies) have been sent to these schools, and are being lent in turn to other schools. The Japanese Physiological Society has even set up a "Loan Library with American Reprints" in Tokyo and arranged to lend such reprints by mail throughout the country. This effort should receive our full support. The International Exchange Service of the Smithsonian Institution is undertaking to forward such collections of reprints or other literature to foreign countries. Will any physiologists with supplies of recent reprints kindly send them to these schools.

Textbooks are also much in demand and copies of standard texts recently replaced by new editions would be welcomed abroad in all of the schools. They may be forwarded to the schools directly or through the Smithsonian Institution. The society is greatly indebted to publishing firms, which have sent abroad hundreds of obsolescent volumes. Our thanks are due to Saunders, Lea and Febiger, Appleton-Century-Crofts, Inc., Chemical Rubber Publishing Company, and particularly to the Year Book Publishers, which donated 105 copies of its current year books, and to Williams and Wilkins, which sent abroad a total of 215 volumes.

Journals published in the United States are badly needed; a few have been sent abroad by special subscriptions and others are being sent after the subscriber has used the current numbers. Thus, the *American Journal of Physiology* and the *Journal of Clinical Investigation* are being sent to Würzburg and used copies of *Biological Abstracts, Journal of Aviation Medicine, American Heart Journal, British Physiological Abstracts,* and *Proceedings of the Society for Experimental Biology and Medicine* to Salonika, Naples, or Nagoya. Up to the present time only single sets of these have been available, so that there is ample opportunity for physiologists to extend this list or to add new sets so that other schools can be supplied. The publication trustees of the society have also sent abroad some of the society's journals for the period when foreign subscriptions were unavailable and have donated excess stocks of other back issues.

Equipment. Very little equipment can be bought with the small funds available, which in the main are being used to pay transport costs. Two used metabolism machines have been sent to China from West Coast laboratories, and a considerable amount of obsolete teaching equipment has been sent to Naples from the University of Pennsylvania. Through a generous gift by the Aloe Company, new equipment valued at $1000 or more (made available during recataloguing) has been sent to Frankfurt, and requests for amino acids made by Frankfurt and Würzburg have been partially met by General Biochemicals, Inc. The A. H. Thomas Company has donated the assistance of skilled packers, and technicians at the University of Pennsylvania, including James Graham, the university glass-blower, have contributed time, labor, and glass equipment. For these aids we extend our thanks.

Reciprocity. The Italians and Japanese have shown their gratitude by presenting the society with current numbers of the *Bolletina della Societa Italiana di Biologia Sperimentale* and of the *Tohoku Journal of Experimental Medicine.* Any school with limited library facilities, which would like to receive these journals, may apply to the executive secretary of the society.

Needs. The University of Salonika needs a photoelectric colorimeter. Any such instrument, used or rebuilt (if in usable condition), will be welcome to the committee, which will pay for transport, or assume other costs within their means.

Reprints, books, or other material should be forwarded to the departments of physiology in the universities listed or, if for China, sent to the American Bureau for Medical Aid to China, 1790 Broadway, New York 19, New York. Large packages of literature for forwarding abroad to countries other than China, can be sent through the Smithsonian Institution, International Exchange Service, Washington, D. C. Carriage should be paid to Washington and the institution should be notified of the packages consigned. Reprints of biological papers for the Japanese Reprint Loan Library should be sent directly to Professor Kunizo Hukuda, Department of Physiology, Medical School, University of Tokyo, Hongo, Tokyo, Japan.

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Education and Training for Oceanographers[1]

The shortage of scientists is general. Two circumstances combine, however, to exaggerate the present need for men trained in oceanography. Revolutionary developments in the military techniques of the late war created an unprecedented demand for knowledge of the sea and for trained oceanographers. Knowledge of the sea can contribute to the solution of peacetime as well as military problems. Thus, the state of the postwar world makes it

[1] Contribution No. 519 from the Woods Hole Oceanographic Institution and contribution from the Scripps Institution of Oceanography, New Series, No. 463.

only too clear that the food resources of the sea must be exploited to the utmost. Oceanographers are needed to lay foundations for technological advances in military techniques, in transportation and communication across the sea, and in the expansion of sea fisheries. Yet no increase of effort in the investigation of the sea is possible, since all trained oceanographers are now employed.

Three factors must be considered in connection with oceanographic training: (a) What positions may students look forward to after receiving their oceanographic education? (b) What distinguishes oceanography as a separate scientific discipline requiring a special combination of skills and interests? (c) How can such skills be obtained within the usual academic pattern, or what special modifications and additions does this pattern require?

Opportunities for employment in oceanography exist primarily in the federal government and in university or associated research laboratories. Within the federal government the Hydrographic Office, the Coast Guard, the Geological Survey, the Coast and Geodetic Survey, the Office of Naval Research (including the Naval Research Laboratory), the Bureau of Ships (including the Navy Electronics Laboratory and the U. S. Navy Underwater Sound Laboratory), the Naval Ordnance Laboratory, the U. S. Engineers, and the Beach Erosion Board, are the principal agencies interested in physical oceanography. The Fish and Wildlife Service of the Department of the Interior, the conservation agencies of many maritime states, and various international fisheries commissions are interested in oceanography from the biological standpoint. Private interests in oceanography include the oil companies now engaged in an extensive search for new oil reserves under continental shelves.

Two well-established oceanographic laboratories are maintained by universities: the Scripps Institution of Oceanography of the University of California (including the Marine Physical Laboratory) and the Oceanographic Laboratories of the University of Washington. A third laboratory, the Chesapeake Bay Institute, has been established recently at The Johns Hopkins University. The Woods Hole Oceanographic Institution, an independent foundation, provides facilities for investigators from other institutions and maintains its own professional staff as well. The other institutions represented have included Harvard, Brown, Yale, Columbia, Rutgers, Princeton, New York, and Queens Universities, the Massachusetts Institute of Technology, the Universities of Chicago and of Maine, and Amherst, Wellesley, Barnard, and Rhode Island State Colleges.

Marine research involving oceanography is conducted by the Bingham Oceanographic Foundation at Yale, the Department of Engineering of the University of California at Berkeley, the Department of Geology at Columbia, the University of Southern California, Harvard University, New York University, the University of Miami Marine Laboratory, and other biological laboratories. Research closely akin to oceanography is being done on the Great Lakes and on smaller lakes throughout the country, most notably at the Universities of Wisconsin, Michigan, and Chicago and at Ohio State and Northwestern Universities.

Although these lists suggest a rather extensive interest in oceanography on the part of government and educational institutions, the number of persons in the profession is small. A recent survey of manpower available for research in oceanography lists 448 persons, and only 223 of them are reported to be doing independent research or to have done it recently. The number of graduate students now in training is about 80. There is an immediate need for 30–40 oceanographers throughout the governmental and other oceanographic institutions of the U. S., and when the present large demand levels off it is believed that ten or more newly trained oceanographers will be required each year to take care of normal replacements and expected growth. As in many other fields of science and engineering, needs exist both for highly trained men capable of carrying on oceanographic research independently or under very little supervision, and for men of less advanced training, for positions involving oceanographic engineering, surveying, or reducing and compiling of data. In addition, special provision should be made for the training of officers of the Department of Defense, who should profit greatly from intimate contact with the techniques of a field science such as oceanography, even though their professional responsibilities are primarily administrative.

The present professional oceanographers in the U. S. have received their training for the most part in physics, chemistry, biology, or geology. Until recently, organized training in oceanography as such has been available only at the University of Washington and at the Scripps Institution at La Jolla. Courses in oceanography are also given as part of various curricula at Harvard, Columbia, St. Louis, Clark, Brown, Cornell, and New York Universities, at the Agricultural and Mechanical College of Texas, and at the Universities of Chicago, California (at Los Angeles), and Southern California. Amherst College has pioneered in offering instruction in oceanography as a part of the liberal arts curriculum where it shows the value of the basic sciences for interpreting the phenomena of the natural world.

Oceanography acquires its unity because it deals with everything taking place in a limited geographical subdivision of the earth—its watery envelope. Problems in oceanography fall rather definitely into two groups, those of geophysics and those of ecology. Their solutions require the various techniques of physics, chemistry, geology, and biology. It is pertinent to ask whether oceanography has its own peculiar disciplines or whether it is merely a collection of those parts of these other sciences which happen to deal with the phenomena of the seas.

In order to answer this question it is necessary to consider briefly the intellectual content and methods of oceanography. Oceanography may be defined as the study of the ocean in all its aspects, including the interrelationships between marine organisms and their environment and between the ocean and its boundaries—the atmosphere, the sea bottom, and the shores. In contrast to the exact sciences, it deals with the investigation of condi-

tions and processes as they exist on a large scale in nature rather than with the conduct of controlled experiments in the laboratory. The conditions in the sea cannot be controlled; moreover, they are characterized by a high degree of complexity, great geographical diversity, and variability with time. The nature of oceanography is determined by these characteristics as well as by the large dimensions involved and by the fact that the fluid nature of the medium results in widespread interrelationships.

The oceanographer is concerned primarily with the elucidation of the individual processes in the sea which together produce the observed conditions. In general, two or more processes oppose each other and are balanced in such a way that a state of approximate equilibrium is maintained. The principle of dynamic equilibrium may be thought of as a unifying principle of oceanography, in much the same way that the principle that the present is the key to the past underlies and unifies geology. The problems of oceanography require analysis of observed conditions that represent the integration of several processes so as to differentiate and describe the individual processes that are at work. Two methods are commonly employed for this purpose: (a) All possible parameters in a given situation are measured and processes are deduced which explain the observed relationships between these parameters in terms of physical, chemical, and biological principles; (b) Comparative studies are made of variations in certain parameters in many situations. These studies can be facilitated in some instances by model experiments in tanks, in which individual processes can be controlled. Statistical correlations are then carried out to obtain empirical relationships, or preferably a simplified theoretical model is constructed and shown to correspond in essential features to the complex reality.

Although no individual method or principle of oceanography is unique, it is believed that the combination of principles and methods just described forms a distinct discipline which requires special training.

When the diverse quality of the disciplines on which oceanography depends is considered, together with the present limited opportunities for professional employment, it appears doubtful whether there is need for new organizations for specialized training in oceanography. What is required, rather, is the establishment of professional standards for oceanographic training. These can largely be met within the existing academic pattern of universities that recognize the special training requirements. Since oceanography comprises such a wide variety of problems no individual can become fully competent in all its departments. Depending on his interests and aptitudes, a student must specialize in the physical, biological, geological, or chemical aspects of oceanography. It is essential, however, that each worker understand the concepts and the language of the entire subject. In a field with limited outlets for employment it is important that the basic training be broad enough to equip students for jobs in related branches of geophysics, geology, or biology. Such breadth of training will give a wider base for the later development of a professional career and greater opportunities for intellectually satisfying research. There is need in the field sciences for research workers whose education has followed the pattern proposed herein.

With this objective in mind, we have prepared a list of subjects recommended for the basic training of a student who anticipates a professional career in oceanography. Clearly, the quality of the student's general education, and the extent to which he has been infused with scientific curiosity and the research spirit, are of primary importance in the training of any scientist. We have limited ourselves here, however, to technical aspects of basic training of special value for oceanographers.

RECOMMENDED SUBJECTS FOR OCEANOGRAPHIC TRAINING

Mathematics
- Algebra and trigonometry
- Analytical geometry
- Differential and integral calculus
- Differential equations
- Statistics
- Advanced mathematics, including vector analysis and Fourier integrals

Physics
- Basic physics, including mechanics, heat, sound and light, and electricity and magnetism
- Wave theory and acoustics
- Electronics laboratory
- Hydrodynamics or fluid mechanics
- Advanced mechanics or theoretical physics

Chemistry
- General inorganic chemistry
- Analytical chemistry
- Organic chemistry
- Physical chemistry
- Colloid chemistry
- Microchemical analytical techniques

Biology
- Elementary biology
- Invertebrate zoology
- Physiology
- Biochemistry
- Microbiology
- Ecology or limnology
- Advanced biology
- Biophysics, including applications of nuclear physics
- Summer work in marine biology

Geology
- Physical geology
- Historical geology
- Paleontology
- Introductory mineralogy and petrology
- Crystallographic and optical mineralogy
- Sedimentology or marine geology

Geophysics
- Principles of oceanography—physical, biological, chemical, and geological
- Exploration geophysics—magnetic, electrical, gravity, and seismic
- Summer field course in oceanography
- Physical and dynamic meteorology
- Synoptic meteorology
- Climatology
- Advanced physical oceanography
- Theoretical geophysics

These are the scientific subjects that are of direct value in oceanographic training, arranged more or less in their sequence of advancement. In Table 1, a selection is made among these subjects to indicate the relative distribution of effort considered desirable for basic training in the several fields of specialization. The programs of study outlined in Table 1 would require ordinarily about 13

course years, or about 70 to 80 semester hours. Allowing for the usual university requirements for courses in the humanities, languages, English composition, and the like, completion of one of the programs would probably require five years, particularly if the student did not start on the program at the beginning of his college career. Normally, these suggested programs would lead to the master's degree. Additional graduate courses, special seminars in oceanography, and appropriate research would be required for those who work toward the Ph.D. degree.

The listed subjects are fundamental, so that a student could proceed after the first two or three years of study into almost any other field of science without retracing his steps. At their completion the specialist in physical or geological oceanography would be well prepared for advanced work in any aspect of geophysics should he be unable or unwilling to continue in oceanography. The specialist in biological or chemical oceanography would have a better training than is usual among college graduates, for continued studies in ecology, limnology, physiology, or biochemistry. Conversely, students thoroughly trained in geophysics may find excellent opportunities in geological oceanography, and students well trained in biochemistry may make important contributions in biological oceanography.

TABLE 1

DISTRIBUTION OF SUBJECTS IN BASIC TRAINING FOR SPECIALTIES IN OCEANOGRAPHY: COURSE YEARS

	Physical oceanography	Geological oceanography	Biological oceanography	Chemical oceanography
Mathematics	3	2½	2½	2½
Physics	3½	2	2	2
Chemistry	3	3	3	4*
Biology	1	1	3	2
Geology	1	3	1	1
Oceanography	1	1	1	1
Meteorology	½	1	1	1
Summer field work at oceanographic laboratory	x	x	x	x
Summer course in marine biology			x	

* To include biochemistry.

The programs proposed would be adequate for students contemplating an "engineering" career in oceanography and would bring the student who plans to take an advanced degree to the point where his training should become individualized. For each of the four specialties of oceanography, an advanced student should master many more of the subjects listed in Table 1 that are related to his specialty. In physical oceanography, for example, he should try to cover all courses listed in mathematics, physics, and geophysics. In the end he would be fitted for research or teaching in nearly any aspect of geophysics.

Although these basic training programs involve a minimum of specialization, they all include a year's course in the methods and principles of oceanography and a summer of work and study at one of the major oceanographic research institutions. This introduction to oceanography should be experienced as early in college as possible, in order to arouse the interest and enthusiasm of enough students to screen out those without special aptitude for a field science, and to give concrete meaning and purpose to the other more general subjects included in the curriculum. Prerequisites for a general course in the principles of oceanography should include mathematics through differential and integral calculus, a basic course in physics, and an elementary knowledge of chemistry, biology (including taxonomy), and geology. It would therefore not be possible to take this course before the junior year. It should preferably be followed by the summer's field work in oceanography, between the junior and senior years.

A course in the principles of oceanography would be useful to biologists, geologists, and geophysicists, as well as to oceanographers. It would also have general educational value in demonstrating the application of scientific principles and methods to the phenomena of the real world—for example, in exploiting the food and mineral resources of the oceans to help solve problems created by overpopulation.

The general science courses required for basic training in the specialties of oceanography are offered in many universities—what is lacking is basic training in oceanography itself. Any university can institute a program in oceanography if it is prepared to add these introductory courses and provide for advanced study in one of the specialties. Graduate training should, of course, include some experience in research at sea, for which adequate facilities already exist at the established oceanographic institutions.

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