AQUATIC BIOLOGY

BIOLOGY
COLLOQUIUM
1946

OREGON STATE CHAPTER OF PHI KAPPA PHI
OREGON STATE COLLEGE · CORVALLIS · 1946

Seventh Annual Biology Colloquium
Saturday, April 27, 1946

Aquatic Biology

OREGON STATE CHAPTER OF PHI KAPPA PHI
OREGON STATE COLLEGE · CORVALLIS · 1946

TABLE OF CONTENTS

FOREWORD

The Biology Colloquium is conducted in a spirit of informal discussion and provides opportunity for participation from the floor. The colloquium is sponsored by the Oregon State Chapter of Phi Kappa Phi with the collaboration of Sigma Xi, Phi Sigma, and Omicron Nu. Sigma Xi assumes special responsibility for the colloquium luncheon. Phi Sigma and Omicron Nu provide afternoon tea. The College Library arranges special displays of the writings of colloquium leaders and notable works on the colloquium theme.

Grateful acknowledgment is made of the cooperation and interest of the several faculties of Oregon State College that are concerned with biology, of those biologists contributing to the program, of Chancellor Frederick M. Hunter, President A. L. Strand, and other executives of Oregon State College.

The first Biology Colloquium was held March 4, 1939, with Dr. Charles Atwood Kofoid of the University of California as leader, on the theme "Recent Advances in Biological Science." Leaders and themes of succeeding colloquia have been: 1940, Dr. Homer LeRoy Shantz, chief of the Division of Wildlife Management of the United States Forest Service, theme "Ecology"; 1941, Dr. Cornelius Bernardus van Niel, Professor of Microbiology, Hopkins Marine Station, Stanford University, in collaboration with Dr. Henrik Dam, Biochemical Institute, University of Copenhagen, theme "Growth and Metabolism"; 1942, Dr. William Brodbeck Herms, Professor of Parasitology and Head of the Division of Entomology and Parasitology, University of California, theme "The Biologist in a World at War"; 1943, Dr. August Leroy Strand, Biologist and President of Oregon State College, theme "Contributions of Biological Sciences to Victory"; 1944, Dr. George Wells Beadle, Geneticist and Professor of Biology, Stanford University, theme "Genetics and the Integration of Biological Sciences." Because of wartime travel conditions, the 1945 Biology Colloquium was omitted.

Colloquium Committees
Seventh Annual Biology Colloquium

COLLOQUIUM COMMITTEE

- Vernon H. Cheldelin (chairman)
- G. V. Copson
- Ernst J. Dornfeld
- Margaret L. Fincke
- Delmer M. Goode
- Elmer Hansen
- Henry P. Hansen
- Rosalind Wulzen
- Margaret Jean Bennett
- Patricia Hackett
- Virginia Weimar

PHI KAPPA PHI EXECUTIVE COMMITTEE

- Mabel W. Winston (president)
- Georgena Samson Knapp (secretary)
- Carol L. Angerman (assistant secretary)
- Dan W. Poling (journal correspondent)
- Frank L. Henry (president elect)
- Donald D. Hill (past president)

SIGMA XI EXECUTIVE COMMITTEE

- Wallace H. Martin (president)
- E. L. Packard (vice president)
- Frank H. Smith (secretary)
- E. M. Dickinson (treasurer)

PHI SIGMA EXECUTIVE COMMITTEE

- Ernest Anderson (president)
- Ethel I. Sanborn (vice president)
- Bertha M. Dana (secretary-treasurer)

OMICRON NU EXECUTIVE COMMITTEE

- Betty C. Hamlin (president)
- Janelle Hostetter (vice president)
- Eleanor Swift (secretary)
- Beverly Osterman (treasurer)
- Georgia C. Bibee (adviser)

Robert C. Miller, Ph. D.
Leader of Seventh Annual Biology Colloquium

Seventh Annual Biology Colloquium

Theme: Aquatic Biology

Leader: Robert C. Miller, Ph.D., Director, California Academy of Sciences

Discussion Leaders:

Frederic F. Fish, Sc.D.
In Charge of Pacific Coast Fish-Cultural Investigations, U. S. Fish and Wildlife Service.

Trevor Kincaid, A.M., Sc.D.
Professor of Zoology, University of Washington.

Arthur Russell Moore, Ph.D.
Research Professor of General Physiology, University of Oregon.

Ivan Pratt, Ph.D.
Assistant Professor of Zoology, Oregon State College.

Arnie J. Suomela, M.S.
Master Fish Warden, Oregon State Game Commission.

Clinton L. Utterback, Ph.D.
Executive Officer, Department of Physics, University of Washington.

Chairmen of Sessions:

Vernon H. Cheldelin, Ph.D.
Associate Professor of Chemistry, Oregon State College (opening session).

Henry P. Hansen, Ph.D.
Associate Professor of General Science, Oregon State College (luncheon session).

James A. Macnab, Ph.D.
Professor of Biology, Linfield College (first afternoon session).

Ralph W. Macy, Ph.D.
Professor of Biology, Reed College (second morning session).

Cecil R. Monk, Ph.D.
Professor of Biology, Willamette University (second afternoon session).

Mabel W. Winston, M.A.
President of Oregon State Chapter of Phi Kappa Phi (evening session).

OPENING OF THE COLLOQUIUM

Dr. Cheldelin: On behalf of the committee on preparations for this event and as a member of Phi Kappa Phi, I welcome all of you to the 1946 Biology Colloquium. Before introducing the speakers on the scientific program, however, I am going to turn the meeting over to Dr. Gilfillan, Dean of the School of Science of Oregon State College.

Dean Gilfillan: Dr. Cheldelin and members of the colloquium, if we may unleash our imaginations for a few moments, we may well fancy that millions and millions of ages ago the great Architect of the Universe gave thought to His construction plans for this world and the other countless worlds that fill up the infinite space. We may think also, as He looked around for construction materials for the job, that things didn't look too auspicious. He had a bin full of protons, neutrons, and a few little electrons, but His job was one like trying to build a house out of marbles. So then He took a different line of thought. Taking these little protons and electrons, He hit upon the idea of putting them into larger building blocks. He coined hydrogen and then, with increasing complexity, built up ninety-two blocks from which He made His Universe. So He went ahead and built some eight or ten or twenty houses on our side of the street, and then on the other side and countless others that we know very little about, but of those which He built in our neighborhood, we think that He particularly favored our own residence. He took care of central heating, which has proved fairly satisfactory. He air-conditioned the earth, which He did not do for our neighbor satellite the moon, and lastly He provided us with a combination in His particular building block consisting of one atom of oxygen and two of hydrogen. This, of course, has made things possible on this planet that are not possible on some of the other houses on the street, such as Neptune and Uranus.

The importance of water to life was recognized by the early Greeks who had their own ideas about the fact that life originated from the ocean. It is strange that this idea did not develop through the ages. In fact, it was not until 1872 that the first marine biological station was established at Naples. In 1888 the first marine biological station was established at Woods Hole in this country. Now we on the Pacific Coast enjoy having in our front yard the biggest of these bodies of water, and we are rather belatedly paying some attention to it. It is interesting to note at this meeting today devoted to aquatic biology that we have representatives from Oregon, Washington, and California, the three states that do have this great Pacific Ocean on our front doorstep.

On behalf of Oregon State College and President Strand, and on behalf of the School of Science, I welcome you researchers in aquatic biology. We hope that your stay will be pleasant, and we believe it will be profitable both to us and you mutually. Thank you.

DR. CHELDELIN: Thank you, Dean Gilfillan.

This is the seventh annual Biology Colloquium, as I am sure you have already noted from your program. During these seven years, two of the programs have been devoted to the role of biology in winning the war. This year, as the biologist turns his mind away from thoughts of military security, he can again attend to his "other loves." One of the most important of these is the enlargement and development of the fund of vital information that is available about living things. Organisms on this planet, and in the Pacific Northwest in particular, have a prior interest in water, as Dr. Gilfillan has said; it is on our front doorstep (and often on our roof). Because of the great value of water to our state and to the states adjacent to us, the Committee on Preparation for this year's colloquium has felt that it would be desirable to discuss aquatic biology in many of its ramifications.

An equally important reason for discussing aquatic biology at this time is that in our sister state to the south there is a man who is thoroughly and ably qualified to lead us. That man is Dr. Robert C. Miller, who is with us representing the California Academy of Sciences, of which group he is the director.

Dr. Miller was born in Pennsylvania and received his college education at Greenville College in Illinois. He came west to California where he received his doctor's degree. After teaching zoology at California, he went to the University of Washington and was associated with that institution in various capacities for fourteen years. In 1938 he resigned his position as professor of zoology to become director of the California Academy of Sciences, the position he now holds. He has held intermittent positions at the Hopkins Marine Station and at Lingnan University in China. He is a member of numerous scientific societies, both in this country and abroad. Dr. Miller is an expert on bird behavior and bird flight. He has published many works dealing with the biology of marine wood-boring organisms, oceanography, and photobiology. With this prologue, we now turn the meeting over to Dr. Miller, with our best wishes.

WATER AS AN EXTERNAL ENVIRONMENT

ROBERT C. MILLER

Mr. Chairman, Dean Gilfillan, members of this Biology Colloquium: I am distinctly pleased to have this opportunity to return to the Pacific Northwest, distinctly honored to be asked to lead this colloquium, and somewhat apprehensive regarding the responsibilities involved. I was reassured to learn that your first biology colloquium seven years ago was conducted by Professor Kofoid. I am pleased to bring you greetings from Professor Kofoid who recently celebrated his eightieth birthday. I attended a biology colloquium about twenty-three years ago this month, which was also conducted by Professor Kofoid, and the printed program carried the information that it was the final public examination of one Robert C. Miller for the degree of Doctor of Philosophy.

There was a feature of that colloquium which was very gratifying to me and was a matter of remark on the part of other persons present, namely, that whenever I was asked a question and paused or hesitated over the answer, the chairman of my committee, Professor Kofoid, promptly came to the rescue and answered the question himself. That is the sort of procedure I like to see followed at a colloquium, and I suggest the idea to my fellow participants on this occasion.

The committee in charge of this colloquium did a very efficient job. They offered certain suggestions to me which may work out for good or ill. One was that I should this morning introduce the general topic of the colloquium, and at the evening session say something tending to integrate the discussions of the day. Not having the prescience to know what my colleagues are going to say, I find both these assignments a little difficult. If my remarks this morning seem too general, you must remember that I am trying to set the stage for those who follow me and at the same time avoid transgressing on their topics.

Water constitutes the most important environment in the world. In support of what seems a rather sweeping statement, it may be pointed out that, in comparison with other biological environments, water is by all odds the most extensive. It covers more than seven-tenths of the surface of the globe today, and in times past has covered more. One may stand high up on the slopes of Mt. Whitney, or the Alps, or the Andes, or the Himalayas, and when he has sufficiently admired the view, may look down and find beneath his feet marine sediments. At altitudes he may reach only with utmost toil—10,000—12,000—in some cases even 19,000 feet—the geologist finds sedimentary rocks indisputably of marine origin, and the paleontologist may collect the fossil remains of the inhabitants of some ancient sea.

Few if any portions of the earth's surface have escaped this cosmic inundation. Even the shield-lands, those areas of highly metamorphosed Archaean rocks which form the nuclei of the continental masses, may well have been at times the bottom of shallow seas. Two of them even today are partly under water, the Baltic shield being well invaded by the Baltic Sea, and the Canadian shield being half submerged by Hudson Bay. Indeed, it may reasonably be doubted that there is a single square foot of the earth's surface that has been permanently above water since Archaean time.

If all the hills and all the valleys and all of the ocean depths were to be smoothed out, and the world to become as smooth as the proverbial billiard ball, the entire surface of the globe would be covered by water to a depth of nearly two miles.

These continents on which man lives and moves and has his being, and which in eighth grade geography we learned to enumerate and describe and to regard as permanent, extensive, and important areas, are really only small islands in a great world ocean. In the long view, we hold them in insecure tenure, like the natives of Bikini Atoll, and look out questioningly at the ocean from which we came and which ever threatens to engulf us.

Man seldom stops to realize the importance of water in the world—the vastness, the power, and permanence of the sea—the beauty of floating clouds, the beneficence of gentle rain, the fury of storms, the devastation of floods, the grinding force of ice, the continuous hydraulic mining of streams. These forces operate with a large indifference to man—sometimes to his benefit, sometimes to his destruction—but always to the end of wearing down the land and submerging it again beneath a cosmic sea.

Life itself is predominantly aquatic, not terrestrial. As pointed out by Quinton nearly half a century ago, the vast majority of living animals are marine. This is undeniably true, as regards numbers of individual organisms, as anyone who has ever hauled a plankton net can testify. Nowhere on land, unless it be in an anthill or a swarm of bees or locusts, do we find a concentration of organisms equal to that normally present in the surface waters of the sea. It is true also as regards numbers of species if we make the single exception of insects.

According to a recent (1946) tabulation of Mayr, the total number of species of animals known to science approximates one million. Of this number, three-fourths or 750,000 are insects and 40,000 are arachnoids and myriapods. Of the remainder we find in the following groups, which are predominantly aquatic and, in a majority of cases marine, 18,000 fishes, 25,000 crustacea, 88,000 mollusks, 10,000 coelentrates and ctenophores, 5,000 sponges, 15,000 protozoa, and 25,000 miscellaneous invertebrates including Annelida and several minor phyla. In contrast to these large numbers, we find only 3,500 mammals, 8,600 birds, and 5,500 reptiles and amphibians.

With reference to the striking predominance of insects in this picture it needs to be remarked that this is in some measure due to the intensity with which this group has been studied. Any planktologist is well aware that our knowledge of the species of plankton organisms is only fractional, and the same is true of various aquatic groups. And even if we admit that, as now seems probable, insect species are in fact more numerous than any others, it must be remembered that many groups of insects have aquatic larvae, and belong at least as much to the water as to the land.

We live in an aquatic world, in which the continents are hardly more than accidents of diastrophism, and the effort to people them with higher vertebrates appears as a precarious experiment. We do not yet know how it is going to turn out. To any reflective organism, the safest place in the world is obviously at the bottom of the sea.

Let us now examine some of the characteristics of water which make it so important as an environment for living organisms.

The first and most obvious character of water is its wetness—the characteristic which caused a disillusioned poet to write:

> The sea is cold, and wet, and rough;
> They do not keep it warm enough.
> It seems a pity that they can't
> Equip it with a heating plant. . . .
> The sea is wet, and full of fish
> And you can have it, if you wish.

This same characteristic, which may be unpleasantly familiar to a shivering swimmer or a duck hunter who has fallen out of his boat, or a person caught in the rain, is a very satisfying aspect of such processes as taking a bath or drinking a refreshing draught of cool water, or of keeping mucous membranes in a healthy, functional state. The ability of water to wet most substances with which it comes in contact is one of the most important factors in its role as a biological medium.

A second property of water that is pretty obvious is its fluidity. It is this property which allows tides to ebb and flow, and waves to roll up on the beach, and currents to rotate in majestic vortices in all the oceans, and which allows brooks to trickle, and waterfalls to tumble from cliffs with crash and spray, and rivers to find their courses to the sea. We need only to consider for a moment the inconvenience of being subjected to a rain of some less fluid medium, like molasses, to appreciate the fluidity of water.

Fluidity is the reciprocal of viscosity. It is important to note that water is not completely fluid, but has a measurable viscosity, which decreases with rising temperature and increases with increasing salinity. The viscosity of water is important in reducing turbulence (consider for a moment the alarming state of the ocean if water were as turbulent as air); it is important in the swimming of aquatic organisms, in the movement of ships, and particularly to the flotation of plankton organisms, many of which have long slender spines or filaments which retard the rate at which they sink in water.

Other characteristics of water fundamental to its role as a biological environment are its peculiar density relations, its high specific heat, and its function as a universal solvent. No effort here is made to list the properties of water in order of their importance. They are listed rather in the order in which they come to mind. It is, in fact, impossible to assign any order of importance to properties all of which are essential to water considered as a medium for living organisms.

Water is unique in having its maximum density at 4° C—in other words 4° above its freezing point. It is this fact which permits ice to float instead of sinking to the bottom, thus preventing fresh-water lakes and streams in colder climates from freezing solidly from top to bottom, and avoiding the accumulation of tremendous quantities of ice at the bottom of polar and even temperate seas. If water had its maximum density at its freezing point, large portions of the aquatic environment—both fresh and salt—would be unsuitable for organic life.

There is, it is true, a reverse side of the coin. When organisms are subjected to freezing, it appears to be the expansion of water on freezing, rupturing cells and tissues, that is a primary cause of disaster, preventing the resumption of normal functioning when the tissues are thawed out.

The expansion of water at temperatures above that of its maximum density is, of course, the basis of convection, and hence both the cause of thermal stratification and the autumnal overturn in fresh-water lakes and ponds, and of the motive power of ocean currents. These last are augmented, it is true, by prevailing winds, which are themselves, however, the result of convection in a different medium.

The high specific heat of water, coupled with its abundance, its wide distribution, and its tendency to move about—whether by convection, wind-driven currents, evaporation, or other causes—make it the world's most important thermoregulator. Of all the factors affecting the welfare of organisms, temperature is one of the most critical. Few organisms are able to survive long in a temperature either higher or lower than the one to which they are adapted. The life zone concept of the distribution of terrestrial plants and animals is based on the temperature gradient, from lower to higher latitudes, or from lower to higher altitudes, as the case may be. In the distribution of animals in the sea, temperature is even more convincingly a determining factor.

The ability of water to hold heat, to take it up slowly, and to give it off slowly, provides the uniform temperature conditions which most aquatic animals require.

Water is, moreover, an important regulator of temperature over the adjacent land. The differences in winter temperatures between Portland and Minneapolis, or the differences in summer temperatures between San Francisco and St. Louis, afford convincing evidence of the effect—not to say the advantages—of proximity to the Pacific Ocean (I refrain from specifying the California Current).

The effects of the sea on terrestrial climate are in fact very considerable and extremely diverse. Proximity of a relatively warm ocean to a relatively cool land mass—as occurs along the Pacific Coast from Alaska to central California—results in a mild, uniform climate, with much fog and rain. Proximity of a warm land mass to a cooler ocean has quite a different effect. The moisture-laden air from over the ocean has its relative humidity lowered as its temperature increases, and it becomes a drying wind instead of a bringer of rain. In several parts of the world—as in northwest Africa, western Australia, and the west coast of South America—we have the interesting phenomenon of deserts close to the sea.

But it is not my purpose to digress to the subject of weather and climate. I desire only to illustrate the importance of the ocean in affecting conditions of life even of terrestrial organisms.

Perhaps the most extraordinary characteristic of water is its function as a universal solvent. Water dissolves practically everything. When we say that a substance is insoluble in water we mean only that it dissolves very slowly. We cannot keep water in bottles without altering its character, because it takes up substances from the glass. If by some magic we could suspend a drop of absolutely pure water in mid-air, in a few moments it would cease to be pure water and contain measurable amounts of both oxygen and carbon dioxide taken from the atmosphere. Even gold and silver, which we are prone to regard as completely immune to the solvent action of water, occur in the sea in an aggregate amount that would make the wealth of Midas seem but a pittance. The figure is of the order of hundreds of millions of tons, and persons whose cupidity has been aroused will be further excited to know that Nodak in 1940 found exactly twice as much gold in sea water (.008 mg./m^3) as Haber found in 1928 (.004 mg./m^3). Interesting to note, the concentration of gold appears to be higher in waters rich in plankton, suggesting that man is not the only organism with an affinity for this curious metal.

Forty-nine elements are known to occur in sea-water and four others (titanium, thallium, germanium, and antimony) have been detected in marine organisms. It is likely that nearly all of the elements will ultimately be found in the sea. The search for these minor constituents is an interesting one, and there is always the exciting possibility that some substance present in seemingly negligible amounts will prove to play some major role in biological processes.

For the moment, however, we are interested in the major constituents of sea-water—especially the salts of sodium and to a lesser degree those of magnesium, calcium, and potassium, which are responsible for the "saltness" of the sea as we know it. These salts are present in so much greater abundance than any other substances that for what we may call "bulk consideration" we may disregard the others—you may forget now those hundreds of millions of tons of gold—and think of the salt content of the ocean as made up of the chlorides or carbonates or sulfates of the metals named. Sea-water may be roughly described as a 3.5 per cent solution of these salts. If through some cataclysm of nature the oceans were to evaporate completely, there would remain on the bottom of the desiccated seas a layer of salt averaging about 200 feet in thickness (5×10^{16} metric tons). More than 4/5 of this would be sodium chloride. Less than one per cent would be made up of substances other than salts of sodium, magnesium, potassium, and calcium.

But let us hasten to redissolve this great desert of salt and get our ocean back. In the process of solution, we get dissociation into positive ions of the salts mentioned, with their corresponding anions—chlorides, sulfates, carbonates. We also get in some degree dissociation of the water itself, with the release of hydrogen ions and hydroxyl ions. With hydrogen ions and carbonate ions in the same solution, we immediately have the carbonate equilibrium set up. By the simple process of putting sea-salts in water, we have established a solution that is a good electrolyte, has a high osmotic pressure, has a pH a little on the alkaline side of neutrality, and a good buffer effect, so that it can absorb carbon dioxide, for example, without seriously disturbing its properties. In other words, we have a solution which is an excellent milieu for organic life. At this point we are ready to turn it over to the other participants in this colloquium.

DR. CHELDELIN: Thank you, Dr. Miller. Ladies and gentlemen, the California Current is running very strong. Would anybody like to take a dip?

DR. BOLLEN: Mr. Chairman, there are a number of remarks which the speaker made on which I should like to offer a few comments. In the first place, as to the wetness of water: There are some bacteria which are not wet by water. Those are the mycobacteria or the organisms which cause tuberculosis. They have a waxy coating around them, and when put in water, they float; when mixed with water and oil, they pass spontaneously into the oily layer. Now this, of course, is a very unusual type of organism, but it does bring up some considerations as to how they can possibly carry on growth and metabolism. How do they exchange their food and waste products within the medium in which they live? Molasses, for example, certainly does not have much fluidity. Certain bacteria live in a relatively dry atmosphere. Although bacteria in general can be regarded as aquatic organisms since they cannot grow or multiply without water, some bacteria not only will grow in molasses where the water content is low, but will even grow and multiply on dry sugar, getting the necessary moisture from the atmosphere. There are others which will grow only on dry salt, again getting their moisture from the atmosphere. Such bacteria grow on salted hides, deteriorating their quality.

Regarding organisms at the bottom of the sea at great depths: Water as we know it is not a simple liquid or a simple substance. It consists not only of H_2O molecules, but a polymer of H_2O taken twice and in some places taken three times. Fresh, still water is made up of H_2O while steam is made up chiefly of H_2O taken twice, and ice is made up largely of H_2O taken three times. Pressure tends to deoxygenate water. So at the bottom of the sea where there is tremendous pressure, these organisms must not be existing in the presence of ordinary water as we know it, but rather in water that is more characteristic of steam. Our recent experiments have shown that such water is definitely antagonistic to protozoa and to certain bacteria. That means the organisms which live on the bottom of the sea are not influenced in a similar manner, perhaps because of their having overcome the water's toxicity.

The discussion of temperature brings to mind some of the extremes in temperature over which organisms have grown, and again I have had to refer chiefly to bacteria and to other micro-organisms. There are bacteria which live and multiply in the polar waters at a temperature slightly below zero. As the temperature is raised ten degrees, most reaction rates are increased about three times. Certain biological reactions, however, are affected to a very much greater extent, so that instead of the customary threefold increase, it may be three hundredfold. Of course, as the temperature approaches zero, the rate becomes very, very low. That brings out some interesting speculations as to how these organisms change and multiply below the freezing point and are able to carry on metabolic action rapidly enough to effect growth. Actually, they do grow very slowly.

At the other extreme we find thermal organisms which multiply as no ordinary bacteria. They develop in water which is hot enough to boil an egg. For example, changes develop in hot springs at a temperature of 80° C. Certainly they must live at a very rapid rate, and the cell must have some unusual protective controls.

DR. MILLER: Bacteria are certainly the most versatile organisms in the world. There is no other group that can occupy the wide variety of habitats and exist under the severe conditions that bacteria seem to manage. I think some very important problems of the relation of living organisms to the physical environment can be solved by bacteriologists, although I will say that the study of the physiology of bacteria requires as great ingenuity as any other field of human inquiry.

DR. MOTE: As an entomologist, I should like to put in a word for the insects—their ability to exist in oil and water, and to multiply in molasses, etc.

DR. MILLER: I still question whether insects can live in as wide a variety of habitats as bacteria. The bacterium finally gets the insect in any case.

DR. CHELDELIN: Are there any other questions or comments?

I have one question. I am sure we all appreciate the shearing effect which water has on protoplasm. I wonder if you can give us any ideas about what might have happened to biological life during the recent seismic disturbance in the western Pacific.

DR. MILLER: Anything that I might say on that would be a guess. I doubt whether the effect would be very important except right at the source of the disturbance. The tidal wave was produced by a major dislocation of the sea bottom, and the disturbance at that point must have been very great. The sudden dislocation of the sea bottom over a considerable area might seriously disturb many organisms. In the case of a submarine earthquake there are two effects produced. The first is a shock which is the direct transmission of the earthquake through the water. Mariners passing over seismic disturbances are often startled by a shock that makes them think they have hit a rock. A shock of that intensity might be fatal to some organisms. But the tidal wave as it affects man some distance from the point of origin of the quake is quite a different phenomenon. It is a large oscillation of the water. A tidal wave may on occasion be fifty to a hundred feet high and have a wave length of many miles. It moves through the ocean with a speed of as much as three to four hundred miles an hour. It sounds very terrifying, and is destructive when it piles up on a shore; but if you were out there in a ship you would go over it quite easily. So I don't think the tidal wave itself would seriously affect organisms, but the immediate shock at the epicenter of the earthquake might.

DR. CHELDELIN: Our schedule calls for a ten-minute intermission at this point. Dr. Ralph Macy of Reed College will be chairman of this next session for the rest of the morning, and in the afternoon Professors J. A. Macnab of Linfield College and Cecil Monk of Willamette University will preside.

SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF NATURAL WATER BODIES OF THE PACIFIC NORTHWEST

Clinton L. Utterback

Dr. Macy: After the splendid opening by Dr. Miller, it is very fitting that we now hear from a physicist about the characteristics of water which relate to the environment of living organisms. The next talk will be by Dr. Utterback, representing the University of Washington. Dr. Utterback was born in Indiana, took his first degree at Purdue and then did graduate work at the University of Washington and the University of Wisconsin. He has been head of the Physics Department since 1941 at the University of Washington. He is a member of the American Association for the Advancement of Science, of the American Physical Society, and of the American Geophysical Union. We will now hear from Dr. Utterback on some physical and chemical characteristics of water bodies of the Pacific Northwest.

Dr. Utterback: Dr. Macy, Dean Gilfillan. I was very glad a moment ago to hear some member protest a statement that Dr. Miller made, because last night when Dr. Miller told me what he was going to discuss, I said to him, "If you cover all those things, what shall I talk about?" He said, "I am going to talk first, so you may take up what I forget to mention." I felt that I had the rather bad position of a newspaper reporter who had to follow another reporter in the proceedings of a very famous murder trial. His assignment covered the very end of the trial, and in an effort to put some glamor into it, he wrote a note to the editor: "I shall try to make the hanging as pleasant as possible."

The physical character of water and its ability to supply a high multiplicity of needs of marine organisms were pointed out in the introductory paper by Dr. Miller.

It has long been recognized that marine life and the distribution of marine life are determined by the physico-chemical character of the environment. Of the many properties of water, temperature, absorption of radiant energy, salt content, and electrical properties which determine the dissociation of inorganic salts are among the most important. Since these were but briefly mentioned by Dr. Miller, this paper will discuss them in a little more detail.

First, it may be noted that our idea of water has been altered by the small amounts of heavy hydrogen which exist in natural water bodies. A number of observers have found that water distilled from sea water has a density slightly greater than water distilled from tap water. Each of these observers collected sea water from a particular locality. In 1939 Wirth, Thompson, and Utterback analyzed water from various depths from the Mediterranean Ocean, the Red Sea, and the Indian Ocean. With the exception of one sample taken at 4,000 meters in the Indian Ocean, all the waters showed a density differing from tap water by the order of 1.38×10^{-6} gms per milliliter. Also a number of samples taken from the Pacific from the surface to 2,000 meters showed density differences which averaged 1.47×10^{-6}. Samples from a region in the San Juan Archipelago, noted for its abundant flora and fauna, yielded very low density differences which were of the order of 0.8×10^{-6}.

It has been found that many of the physical properties of natural waters depend on three variables, namely temperature, pressure, and chlorinity. Also experience shows that many marine processes may be modified considerably by the presence and distribution of suspended matter and by the conditions of motion of the water. Vapor pressure, osmotic pressure, refractivity, and electrical conductivity are examples of those properties which are determined by the temperature and the soluble salt content.

The coefficient of viscosity, the coefficient of heat conduction and diffusion are not the same in the turbulent motion in the sea as are found in the laboratory. Values of these coefficients depend on a particular state of motion and hence are not quantities that can be determined with the same certainty as vapor pressure, refractive index, etc. Each of these coefficients is a measure of a specific transport phenomenon in the sea. Since turbulence is a state of random motion of various masses of sea water, usually superimposed upon some directed flow, it is obvious that the transport of momentum, mass, and energy is greater than that which would exist in a simple type of directed motion.

The most noticeable and probably the most important effect of suspended matter is the scattering of radiation of all wave lengths. This causes differences in the length of light paths through layers of equal thickness and hence a difference in the rate of absorption of solar energy.

Of the many properties of water, which depend on temperature and salinity, details of two, electrical conductivity and refractivity, will be discussed.

Conductivity

In addition to its application to the study of the physical chemistry of the oceans, electrical conductivity has important practical applications. It has been used for the determination of salinity, and suitable apparatus has been employed by the United States Coast Guard on the last cruises of the *Carnegie*. When used with adequate temperature control, conductivity measurements furnish a method of high accuracy for the indirect determination of the total salt content of natural water bodies.

While several measurements of conductivity have been made on a limited number of water samples over limited temperature ranges, Thomas, Thompson, and Utterback determined the conductivity at five-degree intervals from 0° C to 25° C inclusive over the entire range of concentrations of sea water found in nature. Chlorinity was measured by the Volhard method. Conductivity was measured by means of a bridge using a vacuum tube oscillator as a source of alternating potential. Samples of water were obtained from various depths and various sections of the Pacific Ocean, the Indian Ocean, the Mediterranean Sea, the Gulf of Alaska, and various inshore waters of the Pacific Northwest. Each of the chlorinity values used in the results was the mean of three determinations which checked to within 2 parts per million. Deviations of the individual values of chlorinities were not greater than 0.01 per cent. From a great many determinations, the data were analyzed and the following interpolation formulas derived:

$$0^\circ\ \mathrm{C}\ \ \mathrm{L} = 1.7875 \times 10^{-3}\,Cl - 2.9596 \times 10^{-5}\,Cl^2 + 1.127 \times 10^{-6}\,Cl^3 - 1.902 \times 10^{-8}\,Cl^4$$

$$5^\circ\ \mathrm{C}\ \ \mathrm{L} = 2.0818 \times 10^{-3}\,Cl - 3.6859 \times 10^{-5}\,Cl^2 + 1.449 \times 10^{-6}\,Cl^3 - 2.520 \times 10^{-8}\,Cl^4$$

$$10^\circ\ \mathrm{C}\ \ \mathrm{L} = 2.3749 \times 10^{-3}\,Cl - 4.1334 \times 10^{-5}\,Cl^2 + 1.554 \times 10^{-6}\,Cl^3 - 2.643 \times 10^{-8}\,Cl^4$$

$$15^\circ\ \mathrm{C}\ \ \mathrm{L} = 2.7009 \times 10^{-3}\,Cl - 5.1390 \times 10^{-5}\,Cl^2 + 2.097 \times 10^{-6}\,Cl^3 - 3.829 \times 10^{-8}\,Cl^4$$

$$20^\circ\ \mathrm{C}\ \ \mathrm{L} = 3.0191 \times 10^{-3}\,Cl - 5.6253 \times 10^{-5}\,Cl^2 + 2.181 \times 10^{-6}\,Cl^3 - 3.804 \times 10^{-8}\,Cl^4$$

$$25^\circ\ \mathrm{C}\ \ \mathrm{L} = 3.3524 \times 10^{-3}\,Cl - 6.2481 \times 10^{-5}\,Cl^2 + 2.371 \times 10^{-6}\,Cl^3 - 4.049 \times 10^{-8}\,Cl^4$$

The low chlorinities were obtained by diluting the various samples of ocean water with distilled water. Hence the density, at low chlorinities, will not correspond exactly to direct determination of densities of natural water of the same chlorinity.

Refractive index

The same samples described above were used to determine the relation between the refractive index and chlorinity. The refractive index was measured at five-degree intervals from 0° C to 25° C inclusive by means of a Bausch and Lomb refractometer. The accuracy of this instrument is three in the fifth decimal and as a difference of three in the fifth decimal between two samples can be measured, comparison of the index of one sample of sea water with that of another can be made with considerable precision. The results of the measurements are given in the following equations of the type $n_o = n'_t + b \cdot Cl$:

$$n_0 = 1.33402 + 3.54 \times 10^{-4}\,Cl$$
$$n_5 = 1.33391 + 3.46 \times 10^{-4}\,Cl$$
$$n_{10} = 1.33370 + 3.41 \times 10^{-4}\,Cl$$
$$n_{15} = 1.33340 + 3.35 \times 10^{-4}\,Cl$$
$$n_{20} = 1.33301 + 3.30 \times 10^{-4}\,Cl$$
$$n_{25} = 1.33250 + 3.28 \times 10^{-4}\,Cl$$

The values of n'_t were chosen from the results of various observers for the index of refraction of pure water for the sodium line 5893Å.

Absorption of solar radiation

Of the properties of water which depend upon suspended matter, absorption of solar radiation will be discussed.

When a parallel beam of radiation of wave length λ travels through water, the intensity of the beam decreases along the beam according to

$$I_x = I_o e^{-kx}$$

where I_x is the intensity after the beam has traveled a distance x, I_o is the initial intensity, and k, which is a function of the wave length, is called the absorption coefficient. When solar radiation enters the surface of the ocean, however, it is scattered by suspended matter and the beam does not retain its incident character. Since considerable interest is manifested in the rate of decrease of the downward traveling radiation, this rate of decrease can be defined by an equation exactly like that above. In this equation k is called an extinction coefficient. The name indicates that the decrease in intensity is due to many causes, the principal ones of which are absorption by ocean water, selective and general absorption by micro-organisms and suspended matter, and selective and general scattering which results in a longer light path for a layer of given depth.

To oceanographers, the study of submarine illumination affords a means of computing the rate at which solar and sky radiation is absorbed and converted into heat in the uppermost layers. The extinction coefficients give information as to the optical purity of the water and therefore the amount of suspended matter.

To biologists, the main interest afforded by such studies is in relation to the photosynthesis of plants, that is, the potential food supply, going on in the sea. Also the vertical migration of zoöplankton, and indirectly of fishes preying upon this for food, appears to be largely influenced by light conditions.

Quantitative measurements of submarine light have been made possible through the development of the photoelectric cells and the barrier layer cells. Those of the latter type are more satisfactory as accelerating potentials are not needed for their operation. These cells have a relative sensitivity response similar to that of the eye. This response can be made nearly to coincide with the eye by means of suitable filters.

Narrow spectral bands of solar and sky radiation can be selected by means of a series of color filters which can be made to cover the cell in any predetermined order. In this manner the intensity of light in the various parts of the spectrum is measured at various depths in the ocean with the cell submerged. The resulting cell current is read on suitable instruments on board the ship. Extensive measurements of submarine illumination have been made in this manner by Atkins and Poole of the Plymouth Laboratories in England, Petterson in Göteborg, Sweden, and the present author.

Several hundred stations in the Pacific and the inshore waters of the Northwest have been occupied for observation of the annual variations, seasonal variations, diurnal variations, variations with tidal conditions, and many other variations of submarine illumination. As is to be expected, the transparency of inshore waters is determined by such local conditions as plankton growth, land drainage, etc. In general the inshore waters are not very transparent. There is a definite and marked increase in the transparency as one goes from inshore waters to coastal waters and finally to the open ocean. In the open ocean the maximum transparency is in the blue portion of the spectrum. This is in contrast to the inshore waters, where the maximum transparency is in the green range.

The following table shows the percentage of radiation of different parts of the spectrum transmitted by a meter of sea water. The values are averages of a great many observations.

Water	Wave lengths in Angstrom units				
	4,600	4,800	5,153	5,300	6,000
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Coastal	69.66	71.70	75.92	76.40	65.12
Ocean	91.80	92.65	92.42	91.50	75.78

Observations in the open ocean have yielded an experimental equation which represents with considerable accuracy the dependence of the extinction coefficient on wave length of light. The equation is

$$k = 2.463 - 2.930\lambda^{-1} + 1.373\lambda^{-2} - 0.3597\lambda^{-3} + 0.05355\lambda^{-4}$$

This equation was determined from observations at eight stations in the Pacific which were occupied for three consecutive years. These extended from 47° 26′ N—126° 26′ W to 49° 22′ N—129° 29′ W.

The following table illustrates the differences in the transparency of natural water bodies. Hulbert's data on distilled water are given for reference.

COMPARISON OF EXTINCTION COEFFICIENTS

Observer	Total vertical extinction coefficient per meter						
	$\lambda =$ 4,600	$\lambda =$ 4,800	$\lambda =$ 5,150	$\lambda =$ 5,300	$\lambda =$ 5,650	$\lambda =$ 6,000	$\lambda =$ 6,600
Hulbert 0-4 meters Spectrophotometer	.0166	.0154	.018	.024	.052	.165	......
Utterback and Jorgensen Average of deep sea stations	.085	.073	.069	.079	.100	.253	.503
Utterback and Jorgensen Station 49° 25′-127° 09′	.104	.093	.106	.093	.122	.279	.574
Atkins and Poole International Hydrographic Station E-1	.143	.146	.154	.157	.163	.224	......
Utterback and Jorgensen Thatcher Pass, San Juan Islands	.336	.316	.258	.256	.288	.441	.593
Ericson Gunflint Lake, Minnesota	.820	.610	.437	.390	.321	.330	......
Utterback Crater Lake, Oregon	.033	......	......	.060	......	.311	......

Radioactive elements in the sea

The amount of some of the radioactive elements, particularly radium, in marine sediments has been determined by a few observers. These are of interest because of the high radium content of pelagic sediments and because of the possible speculations of the mechanism of the concentration of radium in sediments taken from the floor of the ocean. While insufficient data are available to determine such mechanism, it has been determined that Pacific Ocean sediments vary from 2×10^{-12} grams of radium per gram of sample to 14×10^{-12} g/g, while inshore sediments average about 0.3×10^{-12} g/g with the exception that all sediments taken from glacier-fed bays average about 1×10^{-12} g/g. Interesting and valuable information will result from further studies of the content of radioactive elements in ocean water and sediments.

DR. MACY: Thank you, Dr. Utterback. This paper deserves lengthy discussion, but I do not believe there is sufficient time. Perhaps, however, someone has a question.

QUESTION: Dr. Utterback, I was quite interested in the data about Crater Lake. Crater Lake is quite transparent as a body of water and some particularly green mosses have been uncovered from depths of about four hundred feet. This is quite unusual, and I wonder if you are acquainted with it.

DR. UTTERBACK: We made a biological study of it, but I do not recall the details at this time. I should be very pleased to forward you a reprint of the published report.

BIBLIOGRAPHY

B. D. Thomas, T. G. Thompson, and C. L. Utterback
J. du Conseil International ***IX, 1,*** 28 (1934).

C. L. Utterback, T. G. Thompson, and B. D. Thomas
Ibid. **IX, 1,** 35 (1934).

C. L. Utterback and Wilhelm Jorgensen
Ibid. **IX,** 2, 197 (1934).

W. R. G. Atkins, G. L. Clarke, H. Petterson, H. H. Poole, C. L. Utterback, and A. Angstrom
Ibid. **XIII, 1,** 37 (1938).

C. L. Utterback. *A Symposium on Hydrobiology*
University of Wisconsin Press **45** (1941).

H. E. Wirth, T. G. Thompson, and C. L. Utterback,
J. Am. Chem. Soc. **57,** 400 (1935).

L. A. Sanderman and C. L. Utterback,
J. Marine Research **IV, 2,** 132 (1941).

C. L. Utterback, L. D. Phifer, and R. J. Robinson,
Ecology **23, 1,** 97 (1942).

THE USE OF MARINE ORGANISMS IN THE STUDY OF PHYSIOLOGICAL THEORY

ARTHUR R. MOORE

DR. MACY: We are to be favored now with an address by Dr. Arthur Moore. He has done extensive work in the physiology of organisms. He took his first college degree at the University of Nebraska, his Ph.D. at California, and then served successively with the staffs of California and Rutgers universities. He was head of the Department of Physiology at Rutgers when he came to the University of Oregon in 1926. He has since seen intermittent service at Oregon State and at Stanford University.

Dr. Moore will now address us on the use of marine organisms in the study of physiological theory.

DR. MOORE: Dr. Macy, ladies and gentlemen: The material which I am about to present consists largely of pictures, with a few explanatory remarks.

[Dr. Moore's presentation consisted principally of projected slides and a cinema record of the locomotion and righting of starfishes, both normal and after cutting the circumoral nerve ring.]

DR. WULZEN: I should like to point out the real artistic quality, the beauty, and the high scientific value of the work with these lower animal forms which live in the ocean and in the fresh water. The approach is a most vital one. Dr. Moore has spent his life at it. He is following in the footsteps of many before him, and we congratulate him on the intrinsic value and high quality of his scientific achievements.

A HALF CENTURY OF BIOLOGICAL SCIENCE

Trevor Kincaid

Dr. H. P. Hansen: Think back to what you were doing in 1894—fifty-two years ago. That is when Dr. Kincaid came to the University of Washington, and since then he has been extremely active in all phases of biology. I have heard it said at various times that if you wish information about a plant or an animal, you would ask a botanist or a zoologist; but if you have one about both, you ask Dr. Kincaid. Certainly I think that he can tell us more about biology in the Pacific Northwest than any other person in this region.

Dr. Kincaid: When I was called on by the sponsors of the present colloquium to present a history of the biological sciences in the Pacific Northwest, with emphasis on aquatic phases, I was at first inclined to hesitate for several reasons. For one, I felt that I was perhaps not historically minded. Many of us are carried along by the stream of passing events without attempting to maintain any sort of record of what is transpiring, and with the passage of time we find it increasingly difficult to reconstruct in a logical manner the march of events presenting themselves like a complicated sequence in a vast kaleidoscope. Also, I was reminded that we have in our department of the university a man who has a gift for organizing historical material, and I was inclined to delegate to him the task that confronted me. I refer to Dr. Melville H. Hatch. He has organized out of what seemed a hopeless mass of material a fairly consistent story of the sequence of events over the years. In view of the fact, however, that I am perhaps the only living witness of many of the events taking place fifty years ago, I thought I would attempt to set down what seem to me to be the more salient events of the half century intervening between my arrival on the campus of the University of Washington in 1894 and the time of my retirement in 1944.

In the time allotted to me this afternoon, only the broadest outline can be presented. As suggested by the committee, I shall confine my attention to the major fields of aquatic biology, the marine and fresh-water aspects of our science.

To orient ourselves into the main current of events, let us take a glance at the situation at the period when my story begins, in the summer of 1894. At that time the University of Washington occupied a small frame building in what is now the central business district of the city of Seattle. All of the science work of the institution was conducted in two rooms on the second floor of the building. The larger room was provided at one end with several tables which were used for laboratory exercises, while at the other end were a blackboard and seats for ordinary classroom work. The smaller room, which was little larger than an ordinary kitchen, was devoted to chemical experiments. A few cases along the wall in the larger room contained meager equipment for the demonstration of experiments in physics. A case of stuffed birds ornamented the hallway. The staff consisted of a single person, the professor of Natural Science, Charles Hill, who had been trained under Jacob Reighard of Michigan. He was truly a one man army to spearhead what was to come in the years ahead. He had been brought in to replace Professor Orson Bennett Johnson, who was nominally in charge but who had become crippled by a disabling disease and was confined to his home. Hill had to teach not only his own subjects in the biological sciences, but also chemistry and physics, all of which, strange to say, he did surprisingly well.

At this period the library of the University was housed in a small room at the rear of the assembly hall, little larger than a closet. The collection consisted mainly of government documents together with a miscellaneous lot of books which apparently had been donated in a casual manner by friendly citizens.

Professor Hill was not interested in field work, nor in the collection and identification of animals. He was primarily a morphologist, and eventually published some very creditable papers on the development of embryonic structures in the lower vertebrates. He had, however, while a student at Michigan, done some work on the fresh-water group of Crustacea, the Cladocera, and he turned over to me a set of excellent drawings he had made of these animals. He also taught me to use a small plankton net which he had brought with him, and trained me in the technique of staining and mounting these small animals. The interest developed through this contact with fresh-water life was in time destined to develop into a rather extensive program in limnological research. Hill was also a skilled technician, and he gave me my first training in sectioning and staining tissues.

Previous to this time the activity in natural history was centered in an organization known as the "Young Naturalists' Society," originally founded in 1879 by a group of young men with a mutual interest in the various branches of natural history in vogue at that time. This organization was given new life through the arrival in the city of Professor Johnson, who had been brought from his home in Oregon to take charge of the science work in the small struggling state university, and who shaped the policy of the institution along these lines for many years. Professor Johnson spent a number of years in Forest Grove and in Salem before coming to Seattle. A full account of his career has been assembled by Dr. M. H. Hatch, but up to this time the material has not been published.

Johnson, although he was not a technically trained biologist, was a man of abounding energy with a potent personality. Although he had worked in an isolation that was almost a vacuum he had built up an extraordinary fund of information, and had developed skill in collecting and preparing natural history specimens that was of the first order. Through his efforts money was raised to construct a three story frame building on what was then the campus of the university; it was located about where the Cobb Building now stands. On the ground floor of this building was located the meeting room and library of the organization with a work room in the rear. The collection of books included a range of well selected material including some quite extensive sets. The second floor was used for a museum, and included the usual assemblage of stuffed birds, birds eggs, shells and marine specimens, with a sprinkling of archaeological material as well as a valuable collection of pressed plants prepared by C. V. Piper, who at that time had in hand the organization of the biological departments of the State College at Pullman. In the third story was an auditorium designed for use in giving public lectures, which the society sponsored from time to time in an effort to stimulate interest in science and build up their organization.

Although Johnson was primarily an entomologist, he was vitally interested in the marine life of the region, and before his health failed he was accustomed to organize summer camps on the shores of Puget Sound, usually at Rocky Point in Kitsap County. He was particularly interested in the Crustacea, and assembled a fine series of identified species handsomely mounted which now forms part of the collection in the State Museum on the present campus. He may well be regarded as having laid the foundation for marine zoology in this region.

Among the members of the Young Naturalists' Society who had maintained an interest in their original program was a man named P. Brooks Randolph, who was an enthusiastic conchologist. He had inherited an ancient and decrepit tugboat, bearing the name of *Maud*, which burned driftwood in her ancient boilers. In this strange craft I was inducted into the mysteries of dredging in offshore waters. The two of us would cast off our moorings on Friday afternoons, steam out into the Sound at a rate of three or four miles per hour, and cruise at will until we were forced to return to terra firma on Sunday afternoon. A boat dredge, worked from a winch attached to the rear of the vessel, brought on board masses of material, the sorting of which provided an endless and altogether delightful task for the embryo zoologist.

By his own efforts and through exchange with collectors in other parts of the world, Randolph built up a very extensive and interesting series of marine Mollusca. He also included in his studies both fresh-water and terrestrial forms. Several species of molluscs, including the *Pecten randolphi*, were named in his honor.

To return to the scene in 1894: that scholastic year represented a turning point in the history of the University of Washington and in the development of the scientific branches of the institution. Denny Hall, the first of the buildings to be constructed on the present campus, was being prepared for occupancy, and in the fall of 1895 the old campus down town which had seen the embryonic stages of the institution, was deserted. The hammers of the carpenters still resounded through the new structure as we moved in. Three departments of science were organized under separate heads so that at this time the biological sciences received their baptism and became a distinct entity. In this shift Johnson was soon retired with the title of emeritus, and Hill became the titular head of the new department. My foot was placed upon the first rung of a ladder, which was destined to be a long one, since I was appointed as a laboratory assistant to aid Hill in his greatly enlarged program.

The year 1895 was also noteworthy in that it marked a considerable advance in the organization of biological work along marine lines. The

Young Naturalists' Society, aided by a grant from the university, promoted an expedition for the study of the local marine fauna. Stanford University was induced to enter into the program, and Mr. E. C. Starks was appointed to serve as the ichthyologist of the expedition. A camp was established at Rocky Point and a small steamer was employed to facilitate dredging operations. A large amount of material was assembled, which was eventually distributed to specialists for study. The collection of fishes was of especial interest and led to the publication of a paper by Starks in collaboration with Dr. David Starr Jordan entitled, "The Fishes of Puget Sound," in which a number of new species were described, together with much supplementary data. This part of the program aroused my own interests along ichthyological lines, and led eventually to the publication of a paper on the fish fauna of the region.

A similar expedition was conducted in the summer of 1896, when headquarters were established at Mats Mats Bay, a reefy area to the south of Port Townsend.

The summer of 1897 I spent as a member of a group of young scientists taken to Bering Sea by Dr. Jordan to participate in the work of the Fur Seal Commission, at that time engaged in the study of the fur seal herd inhabiting the Pribilof Islands.

In 1899 the well known railroad magnate, E. H. Harriman, with the cooperation of Dr. C. Hart Merriam of the U. S. Biological Survey, organized an expedition to be known as the Harriman Alaska Expedition to explore little known areas of the North Pacific region. This expedition traversed portions of southeastern Alaska and finally penetrated through the Strait to the Bering Sea. This experience made it possible to observe something of the northward extension of the Puget Sound fauna and gain a background for an understanding of the geographic distribution of marine organisms in the Pacific Area.

At the turn of the century, plans for the establishment of a marine laboratory were fermenting. This had been a dominant idea in the mind of Professor Johnson. Some questions arose as to the proper location for the institution, and as a result I was commissioned to examine the available sites and to recommend one of these. The decision was in favor of Friday Harbor in the San Juan Islands, and although this area is relatively difficult of access on account of its insular position, and at a considerable distance from Seattle, no question has ever been raised as to the wisdom of this decision. Beginning in 1904 under the joint auspices of the two biological departments, Dr. T. C. Frye and I undertook the organization of classes in temporary quarters at Friday Harbor, and with the passing years the laboratory expanded in scope and magnitude until it was amalgamated with the Oceanographic Laboratories of the University under the direction of Dr. T. G. Thompson in 1931. The history of this phase of our biological sciences would in itself require as much time as I have at my command today. It has been well set forth in an article published in the *Biologist,* by Lyman Pfifer, who served for a number of years as the local vice-director of the laboratory.

Very early in the development of our biological program some attention was paid to problems arising in connection with the fisheries, and as a result certain courses were initiated for training students in this field. As an outgrowth of this procedure an increasing number of students enrolled for the work, and the time seemed ripe to establish a separate School of Fisheries, which was done in 1919, with John N. Cobb in charge. Relations between the school and the department of zoology have always remained very close.

With the consolidation of the Puget Sound Biological Station with the Oceanographic Laboratories, the program of marine research was greatly amplified. With the sea-going vessel, the *Catalyst,* in commission, the study of marine plankton was greatly accentuated under the direction of Dr. Robert C. Miller, and extensive collections were assembled from a wide area. As a result of this work, several papers have been published and others are in manuscript awaiting publication.

During the first decade of the century, certain difficulties arose in the shellfish branch of the fishing industries, and I was asked to cooperate with the persons engaged in the business in seeking a solution. This led to a relation with the oyster industry and other related lines of activity that has been continued over the intervening years, during which time a great many changes have been brought about in the practice of oyster culture. The introduction of the large Pacific oyster, native to Japan, and the development of an extensive industry yielding many millions of dollars at the present time, called for considerable scientific guidance. Among other problems that presented themselves was that of producing the young oyster in a hatchery under controlled conditions, rather than trusting to the vagaries of the weather, which in three out of four seasons renders the natural production of the species very precarious. Many other problems have arisen from time to time, including the control of native and imported enemies, the danger of pollution from various sources, and the technique of cultivation. The history of this branch of our biological program has never been written, and indeed it might well occupy the entire time at my disposal.

Regarding fresh water biology, only a brief statement can be made.

The main impetus to its development came with the establishment of the College of Fisheries, which called for the training of men in limnological technique. Owing to the immense number of lakes and streams in Washington, this has proved to be a very fertile field of investigation, not only in an economic sense, but also in pure science. Limnological studies have been made of some of our lakes, and a beginning has been made in assembling data regarding our freshwater flora and fauna. We have extended our program into Oregon at times, for we have cooperated with the U. S. Forest Service in working out a report on the plankton of the numerous lakes in the National Forests of Oregon. At the present time Mr. Raymond Coopey is preparing a paper dealing with the limnology of Upper Klamath Lake, based on work done while teaching at Klamath Falls.

In presenting this summary, which deals largely with the development of biological science within the scope of the University of Washington, there is no desire to minimize the progress made by other agencies. The U. S. Bureau of Fisheries, now known as the Fish and Wildlife Service, has been active over the years, particularly in the investigation of practical problems relating to the industries based on aquatic life. From very simple beginnings there have developed in recent years such well organized units as the Montlake Laboratory in Seattle, where a large corps of skilled technicians are employed on the investigation of various phases of the fisheries. The same is true for our State Department of Fisheries and Game, which has fostered many projects involving the aquatic resources of the region. The state shellfish laboratory at Gig Harbor, for instance, has rendered services of the greatest value in the conservation and development of the oyster.

It would be interesting and profitable as well to cross the Canadian border and trace the development of the biological sciences in British Columbia, where many workers have contributed to an understanding of the biological resources of the Province. The leading spirit in this respect, over a long period of years, has been Dr. C. McLean Fraser, of the University of British Columbia. The splendid and well-equipped biological laboratory at Nanaimo has an outstanding record as a center for marine research. Another hour might well be spent in covering this phase of my sphere. Likewise, I have not crossed the border into Oregon, and the history of biology in this state still remains to be written.

In conclusion, it may be said that only the surface has been scratched in preparing a history of the biological sciences on the Pacific Coast. The makers of history rarely write it, and this field awaits the appearance of persons with the leisure available to assemble the information and work it up into a correlated whole.

DR. HANSEN: I am assuming that if there are any questions Dr. Kincaid will be glad to answer them. I want to express my thanks to him for his very interesting, pleasant, and informative talk. We should make more use of our history than we do.

QUESTION: Many of us would like to know the present situation at Friday Harbor.

ANSWER: The station was taken over by the Coast Guard and everything was taken out. Buildings were used by them and bunks were put in. Everything was moved, tagged, and stored, so it is all in fine condition. However, the vessel was sold by the University to the Government, and nothing has been done about reobtaining it, mainly because there was a lot of red tape in getting the station back into the control of the University. Dr. Thompson has been in the army, and has only recently returned. He is at Friday Harbor this week-end overseeing the job of putting everything back into shape. The State is thinking of securing a mine sweeper and rebuilding it for biological purposes, and while I am doubtful about getting anything done this summer, we should be in full swing by 1947.

THE SALMON OF THE UPPER COLUMBIA RIVER AND THE EFFECT OF ENVIRONMENTAL CHANGES ON THE RESOURCES

FREDERIC F. FISH

DR. MACNAB: We started out with a California Current this morning. It then shifted to an Oregon, and later to a Washington current. Now we are going to have more news from the Oregon side, in the person of a newcomer to the state. He has come from across the continent to be with us. He has probably heard too many wisecracks in connection with his name and the salmon industry, so perhaps he has developed a tough epidermis, perhaps scaly. (I am reminded at the moment of a dentist in my home town whose name is DeKay.)

Dr. Fish is a native of New York State. He graduated from Cornell and received his doctor's degree at Johns Hopkins. He has been an aquatic biologist with the United States Bureau of Fisheries and is in charge of the Parasitology Commission. He comes to us in charge of the investigations of the United States Fish and Wildlife Service. He should be taking over some of the work in which Dr. Henry B. Ward was interested in connection with our fishes of Oregon.

I am glad to introduce at this time Dr. Fish.

DR. FISH: In reply, I am eager to bring up the point that I am beginning to get webs between my toes. I was here 10 years ago, and feel there is some hope for me.

The salmon constitute one of the most valuable natural resources of the Pacific Northwest. In common with most natural resources, the salmon are profoundly affected by many of the environmental changes brought about by that which collectively may be called "civilization." When the balanced ecology of the wilderness is upset through the changes wrought by a rapidly expanding civilization, the wild animals find themselves in a losing battle of conflicting interests. In this, the salmon is no exception.

I wish to confine my remarks today to a somewhat unique group of salmon—those that frequent the upper portions of the Columbia River watershed during the fresh-water phases of their life cycle. This group, generally, has been most profoundly affected by the encroachments of civilization. Although salmon are found around the borders of the North Pacific Ocean, from Mexico to China, no runs over this entire area will compare with those to the upper Columbia River. These runs offer the cream of the crop and why this should be so is easily explained.

As most of you know, the adult salmon returns to spawn in the tributary from whence it departed to the ocean as a fingerling fish. Likewise, the adult salmon takes no food after entering fresh water en route to the spawning grounds. The energy required for the spawning migration through fresh water is locked in the body as fat at the time the fish leaves the ocean. The salmon with the longest spawning migration inherently stores the greatest quantity of fat during residence in the sea. The "quality" of a salmon, as the human evaluates this factor, is directly correlated with the quantity of body fat. In short, few salmon travel so far from the ocean on their spawning migrations as do the upper Columbia River fish, hence few are so highly prized by man.

What are these salmon of which I am speaking—and how large are the runs? We now have an excellent source of data to answer these questions in the fish counts maintained at Bonneville Dam. Every fish ascending the fish ladders at Bonneville is identified as to species and a continuing record of the numbers maintained.

Bonneville Dam intercepts all fish runs to the upper Columbia tributaries. In case you are not familiar with the fish ladders at Bonneville, let us take a quick look at their general nature and location. Bonneville Dam is, in effect, two dams. One, constituting a power house section, extends from the Oregon shore to Bradford Island; the other, a spillway section, connects Bradford Island with the Washington shore. A collecting race, essentially a large flume, was built across the face of the power house. The fish enter the collecting race by a one-foot jump into any one of the 38 entrances uniformly spaced across the 600-foot length of the power house. The collecting race leads to a conventional gravity type of fish ladder consisting of a series of pools 40 feet wide, 16 feet long, and 6 feet deep, placed one foot above the other, thus leading the fish over the 65-foot maximum climb from the tailwater to the forebay by one-foot steps. Two similar fish ladders discharge at either end of the 1,200-foot spillway section. The water flowing down the fish ladders, and the auxiliary water entering at various levels, utilize approximately 8,000 cubic feet per second to attract the migrating fish to the ladder entrances and to provide a deep, easy, and safe channel for their climb over the dam. About half-way up each ladder, the fish must pass through a one-foot counting gate where they are identified by trained personnel.

Now, to describe the salmon that pass over Bonneville Dam: about April first of each year a run of chinook salmon appears. Known as "spring chinooks" on the Columbia, they are the long-running fish which formerly migrated to the very headwaters with the spring run-off. The spring chinook arrives in the vicinity of its spawning grounds during midsummer and rests in deep pools awaiting the spawning urge that will develop during August and early September. In common with all Pacific salmon, the parent fish invariably die soon after spawning is completed. The spring chinook of the Columbia average between 15 and 20 pounds in weight and spawn at 4, 5, or 6 years of age, the 5-year fish being the dominant spawning age-class so far as is known. These spring chinooks of the upper Columbia, together with their cousins of the Cowlitz and Willamette rivers, constitute the best that salmon flesh has to offer.

Shortly after the spring chinook run subsides in mid-June, a second group of chinook salmon, known as the "summer" chinook, appears at Bonneville Dam. These are large fish, averaging between 25 and 30 pounds in weight with occasional individuals weighing up to 75 pounds. Offsetting their slightly lower fat content, in comparison with the spring chinook, is their greater size. The summer chinook probably never were as numerous as the spring chinook, certainly they are not at the present time. Little is known of the spawning habitat of the summer chinook; presumably they frequent the main stem and the larger tributaries of the upper Columbia area. The summer chinook spawns during late August and September at 3, 4, 5, and occasionally 6 or 7 years of age. The spring and the summer chinook combined comprise the chinook runs of the upper Columbia River.

About the third week in July, the first of the dominant salmon run at Bonneville appears, overlapping the dwindling numbers of the summer chinooks. These fish are known as the fall chinook. Compared with the summer chinook, the fall chinook passing Bonneville is but slightly smaller in size and of a somewhat lower, albeit still a very desirable, quality. The fall chinook spawns during September and early October at 2, 3, 4, or 5 years of age, the 4-year fish comprising the dominant spawning age-class. The spawning grounds of many of the fall chinook migrating above Bonneville are not known, but all evidence indicates that few migrate above the confluence of the Snake River. So much for the Columbia River chinook runs.

During mid-June, another representative of the upper Columbia salmon runs appears at Bonneville—the blueback. The Columbia River blueback is the same species as the Puget Sound sockeye and the Alaskan red salmon, the latter name being quite familiar to the average housewife. The Columbia River blueback, however, has developed a much longer spawning migration than its cousins of Alaska and the Puget Sound country, hence it is of a definitely higher quality. The original spawning grounds of the Columbia River blueback were located above the lakes of the upper basin—principally the Redfish and Payette Lakes of Idaho, Wallowa Lake in eastern Oregon, and Okanogan and Wenatchee Lake of central Washington. The blueback differs from all other species of salmon in that it invariably selects a stream tributary to a lake as its natural spawning habitat. In short, no lakes, no bluebacks; hence this fish is no longer found in the now inaccessible Payette and Wallowa drainages. The Columbia River blueback is a small fish, ranging in weight between 2 and 6 pounds and spawning at 3, 4, or 5 years of age.

The third, and last, run to the upper Columbia appears at Bonneville concurrently with the fall chinook. This fish, the silver salmon or "medium-red," ranges geographically from northern California to Alaska, and gastronomically is far superior to the silver salmon of the lower Columbia and the coastal streams. The silver salmon spawns at 3 years of age and is a fair-sized fish, averaging about 8 pounds in weight. Once the dominant run of the Upper Columbia, scarcely a remnant of the formerly abundant runs now remains.

Two other species of salmon, namely the chum salmon and the pink salmon, seldom range up the Columbia River as far as Bonneville Dam. The sixth species of Pacific salmon, the Japanese salmon, is not found in the eastern Pacific.

Having been introduced to the salmon of the upper Columbia, you may be interested in knowing what is happening to them, and why. We have no source of quantitative data prior to the completion of Bonneville Dam in 1938. Some indication of the earlier abundance of the chinook salmon may be gleaned from records of the commercial pack. Starting with an initial catch of 272,000 pounds in 1866 when the first salmon cannery was operated on the Columbia, the chinook fishery developed rapidly and by 1885 reached the peak yield of 42,000,000 pounds. After the high point was passed, the annual harvest of chinook salmon from the Columbia River declined and finally stabilized in the neighborhood of 25,000,000 pounds until shortly after the close of World War I. Since that time, the chinook pack has slowly but steadily declined. Actually, the decline has been more pronounced than these data indicate, for a shift in the emphasis of the fishery has taken place. In the early days, scant attention was paid to the less desirable fall chinook and virtually all fishing effort was directed toward the spring and summer chinook. During the past two decades, the fishing effort has completely reversed itself for now many fishermen do not bother to wet their nets until the more abundant fall chinook runs appear. The fall run, once virtually untapped, now carries the brunt of the Columbia River commercial fishery.

Since Bonneville Dam was completed in 1938, we have a sensitive index of the fish runs past that point. Insofar as eight scattered points will determine a trend, it appears quite certain that all of the upper Columbia salmon runs are losing ground.

The rate of decline varies markedly with the various runs. It is interesting to speculate as to why the upper Columbia runs should be declining rapidly whereas the fall chinook passing Bonneville appear to be holding their number fairly well.

One immediately thinks of overfishing as the probable cause. There is little doubt that overexploitation of the fishery resources is, and has been, a very important factor contributing to the decline. As Craig has pointed out, however, the annual Indian catch of Columbia River salmon in the days of Lewis and Clark must have been in the neighboorhood of 18,000,000 pounds—essentially the same poundage as the Indian and the white man are catching today. The question arises, why did the resource stand up under the aboriginal exploitation whereas it is declining rapidly under essentially the same degree of exploitation today?

The migration habits of the various runs of salmon offer a clue to the answer. The fall chinook spawns in the lower reaches of the river, possibly in the main stem itself, and its progeny depart for the ocean with the freshets of the following spring. The spring chinook spawns in the upper tributaries and, like the fall chinook, most of its progeny also go to the sea with the high water of the following spring. Neither the fall chinook nor the spring chinook is losing ground as rapidly as are the blueback and the silver. The blueback and the silver possess the common characteristic of spawning in the upper river (as does the spring chinook); but, unlike both the spring and the fall chinook, their progeny elect to remain one year in fresh water. It would appear, therefore, that the salmon runs exhibiting the most rapid rate of decline at Bonneville are those that spawn in the upper river and particularly those in which the young fish remain in fresh water for a year. In other words, one could reasonably suspect that some environmental factor has changed during comparatively recent years and that the effect of this factor is more pronounced on those fish remaining in contact with it for a longer period. Actually, we find ample evidence of recent environmental changes in the upper Columbia Basin.

Dams, constructed for hydroelectric power, logging operations, and similar purposes, have been constructed across many of the important migration routes of the upper Columbia salmon. In certain instances, no fish ladders were provided at barrier dams, in other instances the ladders were improperly designed and failed to serve their intended purpose.

The diversion of water required for irrigating vast areas of arid land east of the Cascade Mountains has constituted another extremely important hazard to the salmon. In many instances, virtually the entire flow of important salmon-producing streams has been diverted into irrigation ditches, leaving a "dry stretch" below the point of diversion through which the adult fish cannot pass to reach their spawning grounds in the headwaters. Similarly, enormous numbers of fingerling salmon have been swept into the irrigation ditches to meet a premature death in the fields and orchards. It is only during the past fifteen years that any concerted effort has been made properly to screen the irrigation ditches and thus prevent the unnecessary and high losses of salmon fingerlings.

High storage dams, hydraulic mining and dredging, accelerated soil erosion resulting from deforestation and improper agricultural practices likewise have contributed to the extensive environmental alteration of the upper Columbia Basin. Each of these factors exerts an indirect, but nevertheless adverse, effect on the salmon resources.

The activities of the white man have affected practically every stream that produced salmon in the days of the Indian. Only a very few in the more inaccessible regions have remained unmolested. A study of the accompanying map of the Columbia drainage will yield some concept of where, and to what extent, the interests of the white man have conflicted with those of the salmon. The extensive competition for water and the failure adequately to safeguard the requirements of the salmon offer full explanation why we can no longer withdraw 18,000,000 pounds of salmon annually without further depletion of the resource. By analogy to agriculture, we now have less seed and less acreage to plant; the inevitable consequence is a smaller annual harvest.

So much for the past—now what of the future? If the status quo could be maintained indefinitely in the Columbia Basin, the future of the salmon would appear quite bright in spite of the rather dismal record of the past. We now know enough about effectively managing the salmon resources to correct many mistakes of the past. It is very reasonable to assume that we could arrest the downward trend and stabilize the annual yield perhaps in the approximate magnitude of the early 1920's. There appears little point in dwelling on what might be done, however, for it is certain that the status quo of the Columbia Basin will not be maintained.

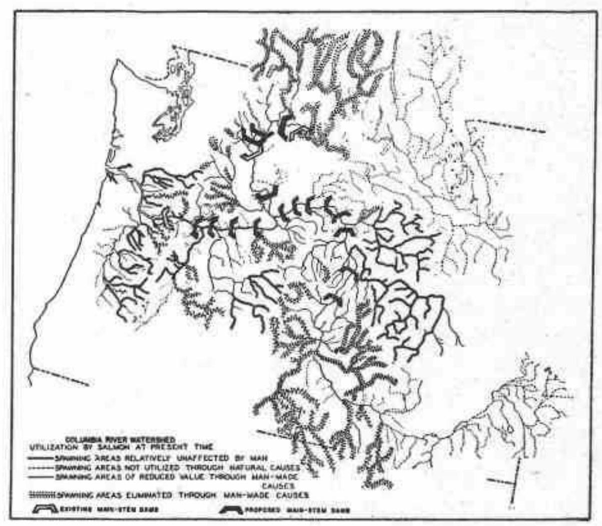
Perhaps the most profound development of many that would affect the future of the Columbia River salmon lies in the proposed series of main-stem dams. Plans are in process for a series of eight or nine new dams across the Columbia between Bonneville and Grand Coulee. In addition, a series of four to six dams is proposed across the Snake below the confluence of the Salmon River, the most important undeveloped tributary now remaining in the entire Columbia Basin. These dams, each to be approximately twice the height of Bonneville, would be located as shown on the accompanying map. Whether or not the salmon runs of the upper Columbia can be maintained in the face of this unprecedented development is a question that no one can answer at this time.

To date, salmon and "civilization" have proved quite incompatible, a result due in large part to the environmental changes that I have attempted to sketch very briefly. We have accumulated considerable knowledge concerning the requirements of the salmon during recent years. Whether we have accumulated sufficient to adapt the encroachments of civilization to the needs of the salmon, particularly the tremendous development that can be anticipated within the very near future, can be revealed only with the passing of time.

DR. MACNAB: Have any questions arisen?

QUESTION: How successful was diversion of the salmon from above Grand Coulee to the Columbia in the summer time?

ANSWER: Quantitatively it was very poor. Qualitatively it was very beneficial. You may know the decision was made not to take adult fish over the Grand Coulee dam. You can always depend on the adult salmon returning to his spawning stream, but it was hoped that the progeny would return to their particular streams rather than to ancestral breeding grounds. In that respect the experiment has been successful. In 1943 or 1944, after five years of transplanting adult fish, during which time virtually one entire cycle had been completed, we felt that if it was ever going to work, it should then. Rubber tires were hard to get and gasoline harder, so we turned the fish loose and let them go where they would. Only two fish appeared at Grand Coulee dam that summer, both of which were very large chinooks and could have come past the site of Grand Coulee dam. So far as relocating the runs is concerned, I think the experiment has been successful. However, adult fish are very difficult to handle, and we took some tremendous losses in our attempts to haul them. It may be generations before we ever recover this loss.



Question: Do these runs establish themselves in the tributaries?

Answer: I think they will. Actually your question is a little closer to Mr. Suomela's field, who was in charge of field operations.

Question: I have a question about the land-locked red salmon which are found in the Upper Columbia Lakes. Do they ever go to the ocean?

Answer: Every year about April we get a definite migration of land-locked forms from above the Grand Coulee, apparently toward the ocean, The question is, does the resident population ever contribute to the sea run resources? What happens to those who are headed toward the ocean? There is some evidence that they do contribute each year.

Question: Have you ever tagged any of these?

Answer: They have been tagged, but results have been confused. We can't attach metal tags to them very successfully. The usual method is to amputate the fins.

Question: How do the fish negotiate the dams on their way down?

Answer: This is a hard question to answer. Apparently at Bonneville the passage through the wheels does not cause quite so much trouble as does the release of pressure below the surface of the water. Of course, I think it is quite true in certain small, high-speed installations that they are actually chopped up, but this is not the case at Bonneville Dam.

Question: Can you give an explanation of the apparent worthlessness of some west side Willamette streams as spawning grounds, according to your map?

Answer: Of these streams, there are a few that both Silver and Chinook use. Why they do not go into Mary's River and other rivers, no one knows.

BIOLOGICAL RESEARCH CONNECTED WITH THE FISHERIES OF OREGON

ARNIE J. SUOMELA

DR. MACNAB: Mr. Suomela grew up in the state to the north with the fish of the Northwest. He has had graduate work at the University of Washington, and at George Washington University in the east. He has been warden of the United States Bureau of Fisheries in Alaska, and he is here as Master Fish Warden of the Oregon State Fish Commission. He has worked with transplanting and restocking salmon in some of the lower tributaries along the Grand Coulee dam.

MR. SUOMELA: Dr. Fish painted a dark picture of the conditions of the fisheries, and I shall make the picture a little bleaker.

To the average citizen and even to a significant portion of the fishermen, the fisheries resources of the rivers and ocean are inexhaustible. It is inconceivable to many people that the amount of fish life of any species inhabiting wide expanses of water can be affected directly or indirectly by man. The fallacy of the hypothesis of an unlimited supply of any and all of our fisheries has been too well established during the past few years. The practices of destroying and misusing, not only the fisheries themselves but the specialized environment necessary for the perpetuation and maintenance of the resources, have led to the rapid diminution and depletion of many of our most valuable species and the possible commercial and recreational extinction of certain of the species most widely sought.

The fisheries industry of the State of Oregon, from its modest beginning near the middle of the past century, has grown into one of the most important basic industries of the state, yielding over 60,000,000 pounds of fish annually.

The commercial fisheries of the State of Oregon may be classified by their environment into three main groups: the anadromous fish, including salmon, shad, river smelt and sturgeon; the ocean fishes including the tuna, pilchard, bottom fishes, sharks; and the shellfish, crabs, clams, and oysters.

The environments of at least a portion of the life history of these three groups are not similar, and changes in the ecological conditions brought about by man, either by direct exploitation of the resource or by changes in the environment, have affected the various habitats and stocks of fish in different ways. Those fisheries on inland waters and close to the shores have been exploited first and their environment has been affected the most. Those fisheries on offshore waters have only recently been heavily exploited and the environment has been changed little, if any.

The commercial salmon industry of Oregon, the state's most important commercial fisheries resource, has produced, until the past few years, over 20,000,000 pounds of all species of salmon annually. These anadromous fish, which hatch in fresh water, migrate to sea when only a few inches long and return to their parent stream after one to four years in the ocean. These fish are dependent on our rivers, streams, and lakes for their very existence.

Evidence is now accumulated to show that the salmon resources of our states are declining. At first glance one might be inclined to point an accusing finger at the salmon industry and place the entire blame on its shoulders for profiteering and overfishing the stocks to a point of depletion. But before we can attribute the cause directly to overfishing, it is proper that we examine some of the other factors which might be contributing to the decline of our salmon populations.

Salmon, in order to spawn and reproduce successfully, must be able to proceed with a minimum of effort to clean, gravelly areas high in the upper reaches of our rivers, and to areas free from pollution and silt where in cool riffles the eggs are laid. These hatch in 45 to 90 days into young salmon, which are ready in a few months to migrate back downstream and out into the ocean. Many natural hazards have always been present to lower the rate of survival; disease, predatory animals and birds, unfavorable climatological conditions which decreased the success of spawning, have all played a part in holding natural production of any given stream to a balanced ratio. Many aspects of civilization have hampered the normal migrations of both the upstream migration of the adult and the downstream migration of the young. These, together with the increased demand by the fisheries, have upset the natural balance, resulting in the decline of the populations of Pacific salmon.

There are many factors influencing the survival rate of the adult and young of the various species of salmon. Let us examine the man-made obstacles and barriers which exist on our rivers and streams and which appear incompatible with the maintenance of our salmon resources. Logging, with its elimination of the cover of the water sheds, the erection of impassable barriers, log jams which prevent both upstream and downstream migration, have all taken a large toll on the available and suitable spawning areas. When the forest covers are taken from the banks of rivers and streams two things occur; first, the summer temperature of that watershed increases and the flow of the stream is materially affected; and second, so-called flash floods occur which scour out the gravel bars and erode the banks of the stream, sometimes leaving a heavy coating of silt over the riffles and gravel, smothering and killing the developing eggs and young. Splash dams used to transport logs by water out of the mountains are by their very nature extremely destructive to the salmon runs. In most instances, when splash dams have been used, entire salmon runs have been eliminated. Miles of potential spawning areas are made unavailable to spawning fishes by these barriers.

Pollution, both industrial and sewage, is making many of our rivers impassable to salmon. Some industrial pollutants, especially waste from certain pulp mills, may be very toxic to both adult and young salmon. Studies are now under way to determine the effects and amounts of these dangerous pollutants to our salmon resources. Flax plants and berry and fruit canneries dump offal into our rivers which reduces the available oxygen supply to a point where it is insufficient to meet the minimum needs of our anadromous fishes.

Unscreened power and irrigation diversions and canals trap and exterminate many thousands of young salmon migrating back down to the ocean. Multipurpose dams, several hundred feet high, are being built and contemplated on almost every major river in Oregon. These large dams form the most serious menace to the salmon. The problems of getting all the fish over the dams into the water above and of trapping and by-passing the young downstream provide problems which to this date have not been successfully solved.

Artificial propagation, which has accomplished wonders in restocking streams low in adult population, has not yet provided evidence of being far enough advanced in method to carry the task of completely maintaining, or in many cases increasing, the total runs of salmon in the streams below these proposed high dams.

The advisability of constructing high impassable barriers for further utilization of our river waters without careful and advised consideration of the salmon is a problem which should be wisely studied. Monetary values alone are insufficient and incomplete in assessing the value of a fisheries resource. We have a natural resource in our salmon, which was provided for and belongs to all of the citizens of this state for all time. If any group of us is so unwise as to destroy this resource, which is capable of perpetually producing, with a minimum of care, millions of pounds of fish and fisheries products annually, then we are guilty of gross neglect and selfishness which may seriously affect the welfare of the future generations of our citizens.

In the case of salmon it is obvious that we must study methods of circumventing the inroads on this resource. First, we must minimize the logging damage by prohibiting or limiting the type and use of splash dams, and transfer runs from a watershed barren of trees and subject to excessive temperature and flash floods to streams upon which the second growth has begun to grow and where environmental conditions are within the tolerance limits of salmon. We should encourage selective logging, where the cover will never be completely stripped from the hill. We must find methods and devices for preventing the young from being swept down canals and other diversions of the rivers where they are completely lost. More efficient fishways must be provided to pass fish around and over natural and artificial barriers. Careful consideration should be given before additional barriers are erected across the natural migratory paths of our salmon. High dams across the main tributaries of our rivers may have the effect of destroying all of the salmon inhabiting the upper reaches of these watersheds.

Artificial propagation must be studied and improved and scientific methods must be applied to hatchery management practice which will provide the basis for the eventual increase in efficiency of hatcheries so as to insure a greater return of adult fish, and decrease the cost of producing fish to a practical economic level. Finally, we must study the habits and migration of the various stocks of salmon so thoroughly that the catch of the commercial and sports fish can be regulated to allow an adequate escapement of the salmon to their spawning grounds. The escapement of adults must be large enough to provide a progeny run of the same abundance if the fishery is to be stabilized at its optimum level, and larger numbers must be allowed to escape if a greater increase in population is necessary. Sewage disposal plants in cities and towns must be provided in order that organic matter requiring a high b.o.d. will not be released directly into the stream. Industrial disposal methods which do not involve the dumping of waste materials into the waters must be discovered. Only then can we be sure that the anadromous fish runs of our state will continue to produce millions of pounds of valuable meat protein annually.

There are several other commercially important anadromous fishes in Oregon waters. The shad, a herring-like fish introduced from the Atlantic coast in 1871, became a very important food fish on the Pacific Coast. These fish migrate into the lower areas of most of our coastal rivers to spawn. The shad was not sought after for food to any great extent during the early years of the fishery. Only the roe or eggs were utilized at that time and these were canned. During years of economic depression, fishing effort to the capture of shad was reduced, and even in normal times shad has not been intensively sought for by fishermen. During the past few years, the acceptance of shad by the market on this coast has been widespread. As a result of the previously limited and economically controlled fishery, the abundance of shad has remained at a relatively high level.

This species should be studied and a management program instituted which will provide for a sustained yield. Signs of increasing fishery effort during the past few years indicate that this is needed soon.

The sturgeon fishery of Oregon was once second only to the salmon in economic value. Of the two species of sturgeon, the white has always been in greater demand. In the early years of the salmon fishery the value of the sturgeon as a food fish was not realized, and as they were a nuisance to the salmon fishermen they were destroyed by the thousands. In 1889 a commercial fishery for this species began on the Columbia River. As early as 1900 a serious decline in yield and abundance was noted. The peak of production of sturgeon on the Columbia River occurred in 1892 when 5,500,000 pounds were landed. Fish up to 1,000 pounds were not rare; now the landings fluctuate between 100,000 and 200,000 pounds per year. Very few sturgeon are taken in the coastal rivers of Oregon.

Only a fraction of the runs of sturgeon remain in the Columbia. The fishery at the present time is not separate and distinct, and for the most part the fish are taken only incidentally to salmon fishing.

Very little is known of the life history of the sturgeon. All the available scientific work has been done in Russia on similar species. Without specific biological knowledge of our species, proper regulations will be difficult. It seems certain that both the commercial and sports fishery are exploiting the fish before they are mature; that is, the smaller sturgeon, 2 and 3 feet in length and under, have not spawned.

The Columbia River smelt, *Thaleichthys pacificus,* has provided the basis for an important fishery on the Columbia River since about 1895. The production of smelt has fluctuated widely, around an annual yield of 500,000 pounds during the past few years. The greatest catch in the history of the fishery was recorded in 1945 when over 1,500,000 pounds were landed by the commercial fishery alone in Oregon. There is also a very intensive sports fishery on the species. Although little biological data are available on the stocks in our rivers, there is no evidence that the intensive fisheries have caused the violent fluctuations in abundance.

A program of research designed to study the life history and to discover the factors influencing the fluctuations in abundance is indicated for this species.

The striped bass, *Roccus lineatus,* is rapidly becoming of considerable commercial importance in Oregon. This species, introduced from the Atlantic to the Pacific Coast in the vicinity of San Francisco Bay, has slowly distributed itself along the coast of California and Oregon, and is now found in considerable abundance in the waters at and near many of our coastal streams.

Probably the first commercial fishing for striped bass occurred in Coos Bay in 1931 when about 18,000 pounds were landed. A few were landed at the mouth of the Umpqua River as early as 1934, but no greater quantities were caught until 1941. The catch is now significantly larger; over 250,000 pounds were landed from Oregon waters in 1945. These fish spawn in the lower tributaries and estuaries of the rivers. They are also excellent sports fish. An intensive sports fishery is developing in the southern Oregon Coastal areas.

The effect of this carnivorous and predatory fish on the downstream salmon migrants is as yet unknown. It is not found in the estuaries the year around; from preliminary observations it appears to enter the bays in Oregon around May and feeds upon smaller fishes in the bays at that time and throughout a portion of the summer.

Of the ocean fisheries, the otter trawl fishery, which lands many types of flounders and rock fishes, together with ling cod, black cod, and dogfish sharks, has been the most important. While not new, it has expanded within the past ten years into one of the most important fisheries of the state. The otter trawl fishery landed over 31 millions of pounds of fish in 1943 and 26 millions in 1945. This is in contrast to less than 50,000 pounds landed in 1933.

For a time the increase in production of bottom fish was the direct result of an accumulation of unfished stocks, but now, although very little direct evidence has been obtained, there are some statistical data available to indicate that certain species are being overfished and are declining in abundance. Until recently most of the trawling took place off the coast inside the 60-fathom mark, thereby offering protection to that portion of the population in the deeper waters and in turn provided a reserve of spawning stock. However, as the numbers of bottom fish began to decline the demand increased, and as larger, better equipped boats entered the fishery, fishing began in deeper waters until now, with the use of fathometers, it reaches to the very edge of the continental shelf. The relatively shallow strip off our coast is narrow compared with the shelf on the Atlantic Coast, and it seems likely that the population densities of bottom fishes have reached the maximum limit of their productivity. Probably the high level of yield of the otter trawl fishery is being maintained at the expense of the spawning stocks; this will in a few years deplete the stocks and lower the commercial yield.

The problem of the proper biological management of this fishery is extremely complex. With so many species involved, it appears difficult to apply directly our now known methods of decreasing the fishing effort on any particular group or species. It is possible that indirect methods of regulation on the size of the mesh or some similar action allowing a greater proportion of small fish to escape will have a beneficial effect on the stocks and species of fish.

The tuna fishery in Oregon is relatively new. The first catch of these fish in northern waters, which amounted to 40,000 pounds of albacore, was landed in Oregon in the fall of 1936. In 1944 approximately 23 million pounds of tuna were landed in Oregon ports. Because of the nature and habits of this species, it is not possible to state whether the Oregon fishery will support a permanent industry. Although some data are available to indicate extensive movements of this fish, the life history and complete migration paths are not thoroughly understood. There is reason to believe that this pelagic fish migrates throughout the tropical and temperate waters of the Pacific, appearing off our Oregon Coast in July, August, September, and part of October before disappearing completely for another year. An extensive albacore fishery existed off the southern coast of California about 30 years ago. The abundance of albacore in California was suddenly reduced and for many years few were caught by the California tuna fishery. The sudden appearance off the northern coast, coupled with the sudden disappearance of the California albacore years ago, leads to the belief that the albacore fishery in Oregon may not be permanently established and the northern occurence of this fish is due to some unknown conditions subject to change at any time.

A research program is contemplated by all three Pacific Coast states which will encompass all phases of this problem. Through this program we will endeavor to determine the life history and habits of the albacore in order to determine the stability of the present northern fishery. A beginning already has been made, and we hope that it may be carried out in full cooperation with other fisheries agencies along the coast.

The crab fishery of Oregon has produced over 4,000,000 pounds of crabs annually during the past few years. The exploitation of the stocks of crabs has been so heavy during the past ten years that there is grave danger of depletion. The fishery operates out of several ports on the Oregon coast, using traps of various types to capture the crabs. It locates in bays, just inside the open ocean, and outside off the coast to a distance of several miles. For the most part the traps are placed in waters of from ten to thirty fathoms in depth.

There are two species of clams of commercial importance dug in Oregon, the razor and the soft shelled variety. The razor clam, which in former years supported a large fishery in this state, has been badly overfished and now operates only on a small part-time basis. Until proper and uniform regulations are imposed upon the razor clam resources, there is little chance of increasing the annual yield. With proper management and regulations, the annual yield of razor clams in Oregon might be increased from ten to twenty times its present average yield of about 100,000 pounds.

The eastern soft-shelled clam, *Mya arenaria,* was first introduced into California waters and later into more northern waters of the Pacific Coast with shipments of eastern oysters. This clam thrived in its new habitat and for many years has been the basis for a fishery in California. It has been exploited intermittently in Oregon and Washington, but commercial utilization has not been extensive. It is likely that this species could support a more intensive fishery in Oregon. A survey of the bays along the coast should reveal whether there now exist any of these clams which are not being utilized.

Oysters from Oregon once constituted an important export product. Improper utilization and methods of culture have reduced the yield of native oysters to a fraction of their former yield. In recent years Professor R. E. Dimick of Oregon State College has carried on researches on the native oysters, and the information which he has gathered will undoubtedly contribute to the rehabilitation of the native oyster industry.

In recent years the Japanese or Pacific oyster has been introduced into several bays along the coast of Oregon. This industry is dependent upon outside sources for young oysters or "seed" to replenish those harvested.

The Japanese oyster requires water temperatures of at least 18° C. before extensive spawning occurs. As the eggs and larvae develop freely in the water, these relatively warm temperatures must prevail for from three to four weeks for the successful "setting" of the young oysters. Because of the proximity of relatively small bays to the ocean, and the interchange of the colder ocean waters with those of the bays, it is unlikely that large scale successful reproduction of Japanese oysters will occur regularly in Oregon waters. The industry will probably be dependent upon Japan for seed as was the case before the war. Even with this handicap there are many reasons to believe that the Japanese oyster industry of Oregon can be expanded far beyond its present limits.

Several other smaller fisheries in Oregon contribute to the magnitude of the fisheries resources of this state. Soupfin sharks are fished extensively off the coast, the fish being tangled and gilled in large-meshed gill nets. The fishery, which expanded rapidly during the war, has declined alarmingly in the past two years. Studies should be made to determine the cause of this sudden diminution of catch. There is a definite possibility, based on observations all along the Pacific Coast, that this lowered catch indicates a state of depletion. The low rate of reproduction coupled with a slow rate of growth may have been unable to keep pace with the intensive exploitation by the fishery.

Some halibut are taken off the Oregon coast, but the coast is near the southern limits of the range of this species. The stocks are not extensive, and very little expansion can be foreseen in spite of the excellent management program of the International Fisheries Commission.

Although at the present time the outlook for many of the fisheries of Oregon is not particularly favorable, there is every reason to believe that, by a vigorous and active program of research, practical fisheries management programs may be evolved for each fishery which will rehabilitate and conserve the fisheries resources.

The potential economic development which may be derived from the fisheries resources of Oregon is very great. The present investments of this basic industry, together with the investments of those men who harvest the crops, amount to many millions of dollars. The fisheries resource furnishes a livelihood directly to thousands of people, and indirectly to as many more. Activities of shipyards, machine shops, linen and cotton mills, and other industries, for a good part, are based upon the requirements of the fishing industry. Rarely is an industry so inseparably bound to other industries and with the economic welfare of the state and nation. Its perpetuation and preservation are of paramount importance. On sound conservation depends its future. Wise planning will greatly aid in truly conserving our fisheries resource. True conservation entails the wise utilization of the resource, exploiting no phase to the detriment of any other. It is our objective to protect and manage the fisheries resources of this state in order that the maximum benefits may be derived for the people of Oregon.

QUESTION: I should like to ask a question about sturgeon. Did they not spawn up the Snake River at one time?

ANSWER: Yes. There are still large numbers of sturgeon in the upper Columbia and Snake rivers.

QUESTION: Do they go over fish ladders?

ANSWER: Very few have been counted at Bonneville. Very few sturgeon can ascend the gravity ladder. Apparently they stock the fish in the upper rivers. I do not know whether they migrate to the ocean; that is something we will have to find out.

DR. MACNAB: I was hoping that you would say something about the dogfish shark. It seems to me they are smaller than they used to be.

MR. SUOMELA: Mr. McKernan, our chief biologist, came to the meeting today. He probably could answer something about the dogfish shark.

MR. MCKERNAN: I will do my best. In all likelihood, the average size of the dogfish shark is decreasing and it may be caused by over-fishing. It is not well understood. We do know that the abundance of dogfish sharks off the coast is diminishing and the fishermen are having a more difficult job of finding sufficient stocks of these fishes. The dogfish shark grows very slowly, and reproduces only once every two years.

DR. CHELDELIN: Mr. Chairman, I think there is some indication that, perhaps unhappily, the shortage of the sharks may be transitory. Their demand was occasioned by the great need for high-vitamin oils (A and D), during the war years when Norwegian cod liver oils were unavailable. The latter oils are more desirable to the trade, and when they can again be bought in prewar quantities the dogfish will be needed more for classes in anatomy than for the vitamins which they contain. An even more serious competitor is synthetic vitamin A, which has recently been produced in Dr. Milas' laboratory at M. I. T. This material may likely appear upon the market in 1947.

PUBLIC HEALTH PROBLEMS RELATED TO AQUATIC BIOLOGY

IVAN PRATT

DR. MONK: I hold in my hand a little cartoon. It is a picture of two hippos in the water. One of them is washing himself with soap. The other one says, "Hey, no soap; this is drinking water."

Our speaker is Dr. Pratt, assistant professor at Oregon State College. He received his Ph.D. at the University of Wisconsin, and taught at the University of Idaho before the war. During the war he was a Lieutenant (j.g.) in the Health Service and was connected with the headquarters of the Tennessee Valley Authority. He came to Oregon State College last December. This afternoon he will speak to us on certain problems of public health aspects of aquatic biology.

DR. PRATT: Public health problems related to aquatic biology are numerous, but I shall restrict my discussion to two of these: first, certain promising advances in malarial mosquito control, and second, the biological aspects of filariasis and its control.

Malaria is a mosquito borne disease. By virtue of that single fact, the mosquito becomes the most important aquatic insect in the world. To effect adequate mosquito control is to wipe out malaria. Efforts to do so have been exerted for many years, but with only local and limited success. Because only certain species of anopheline mosquitoes transmit the disease, the work has been limited to studying the ecology and biology of a few forms. The malaria-bearing anophelines live during their aquatic stages among the weeds growing in the margins of clean and fairly large bodies of water, although not in currents. These animals are not found breeding in rain pools and artificial containers.

The major problem has been to eliminate or make unsuitable their aquatic habitat. Methods include draining swamps, ditching certain low areas, introducing top feeding minnows that prey upon the larvae, spraying with oil, and dusting with Paris green.

In view of the plans to impound the waters of the Willamette drainage, I want particularly to discuss the water level management plan as developed by Hess and Kiker (1944) for the reservoirs of the Tennessee Valley Authority. This plan combines malaria control, wildlife conservation measures, flood control, power development, and navigation facilities in a workable fashion.

Before the reservoir is allowed to fill for the first time, the area to be inundated is freed of stumps and lesser vegetation. Drainage is provided for pools that will be above water line during any part of the year, but submerged during the high water period. This prevents trapping of fish and other aquatic animals.

During the winter and early spring the reservoir is allowed to become overfull. This spring surcharge brings the water up around trees and vegetation. The high water accomplishes two functions. First, it controls floods, and it brings debris up into the vegetation area so as to strand it there. However, the high water can remain only as long as the trees remain dormant, so that the trees will not be killed. Also, it must not stay up around vegetation after mosquito breeding starts, for that would provide an excellent habitat for them.

About April first the water is lowered to the upper line of clearing and held there until about May 15. This has been named the constant pool level. During this time plants eventually develop in the shallow water and begin to provide a suitable habitat for mosquito breeding. However, the period of constant pool level is maintained as long as possible to discourage the growth of marginal vegetation, so that the shoreline will be clean when the water is drawn down later. Also, the constant pool decreases the cost of an annual shoreline conditioning program by postponing the beginning of the growing season of willow and other shoreline woody plants that do not start to grow until their buds are exposed to air. Finally, it provides ideal spawning grounds for bass and other centrarchid fishes long enough for their eggs to hatch, and until they can follow the water down. Near the end of the period airplane dusting with Paris green or DDT may be employed to hold back the mosquito breeding.

Between May 15 and July 1 a cyclical fluctuation of the reservoirs is effected. The water is lowered a foot and raised a foot within each successive week to bring the water below the band of marginal vegetation once a week to provide a clean shoreline inimical to mosquito breeding. There are three, perhaps four, effects: (1)

Unfavorable conditions are created for oviposition by mosquitoes. (2) The production of food organisms for the larvae is interrupted. (3) The larvae are brought out into open water where their predators are. (4) Some larvae and eggs may be stranded.

Starting about July first it becomes necessary to combine the fluctuation of water levels with a seasonal recession. The combined schedule keeps the water below the marginal vegetation growth, to combat the increased mosquito breeding. Too, by this time of year it is necessary to draw on the reservoirs for maintenance of power development and to supply water for navigation. The schedule of fluctuation is to draw the water down a foot each week and bring it back 0.9 foot until about the first of October. This latter date marks the end of mosquito breeding. Recession without fluctuation may continue after October first to maintain power and navigation until the winter rains start refilling the reservoirs. Shoreline clearance programs can be carried out with greatest convenience during this low water period.

Shoreline control includes introduction of the water shield (*Brasenia scheberi*) and the squarestem spikerush (*Eleocharis quadrangulata*). These are probably good plants to use in wildlife conservation, and they discourage anopheline mosquito breeding.

Reservoir managers attempt, on the other hand, to control the plants that are likely to encourage anopheline breeding. These plants are also considered undesirable as water-fowl food plants. This group includes alligator weed (*Achyranthes philoxeroides*), lotus (*Nelumbo lutea*), cattail (*Typha latifolia*), giant cutgrass (*Zizaniopsis miliacea*), water chestnut (*Trapa natans*), and water hyacinth (*Eichornia orrassipes*).

Two good waterfowl food plants, the wild millet (*Echinochloa crus-galli*) and rice cutgrass (*Leersia oryzoides*), thrive particularly well on areas flooded early in the spring and summer, but which are exposed later. The flooding and subsequent exposure on the cleared shoreline is therefore beneficial to the waterfowl and accomplishes a useful conservation effect in addition to mosquito control.

To sum up, the controlled water levels of impounded reservoirs can be so managed as to accomplish an important part of anopheline mosquito control, reduce annual shoreline clearance work, and promote conservation of fish and waterfowl.

The other public health problem that I wish to discuss briefly is filariasis. Before this war, this problem was of interest only to a few parasitologists, but filariasis became one of the first allies of Japan and remains a problem, still, out in the Pacific and in Asia. In addition there are many returned service men in the States who have filariasis or who are apparently over the disease. Recovering from the primary acute stage of the disease, however, and being cured are unfortunately two different things. The infective stage usually comes some months after the symptoms have disappeared.

The life history of the filaria worm, *Wuchereria bancrofti,* is briefly as follows: The adult worms inhabit the lymph nodes of man and the females give forth motile larvae which find their way to the peripheral blood stream. When certain species of mosquitoes ingest the larvae with a blood meal, the microfilariae, as the larvae are called, undergo a development in the thoracic muscles of the mosquito and after about 2 weeks reach the infective stage. These infective larvae may enter the proboscis of the mosquito and reach a new human host when the mosquito takes another blood meal.

There are what appear to be two strains of this species of worm in the world. The difference between the two lies in a physiological variation. The commoner form produces microfilariae which are found in the peripheral blood stream only at night. The usual intermediate host of this form is the southern house mosquito, *Culex quinquefasciatus,* which feeds at night when the human host is asleep. The other strain produces microfilariae which can be found under the skin during the daytime and its usual host is a day-feeding *Aedes.* This strain occurs in the South Pacific from Samoa to Guadalcanal.

When the men in endemic areas contracted the disease, they were sent home promptly. As you probably know, the hospital at Klamath Falls was one of the recuperation centers for filariasis patients. The important question arose as to whether we had native mosquitoes that could transmit the disease. The southern house mosquito is found in the southern part of the United States from California to the Atlantic Ocean. It was not known whether this mosquito could transmit the day-periodic type of filaria, but tests by a group of workers in Asheville, N. C., quickly indicated that it could. It is probable that any mosquito which can transmit one strain can transmit the other one also.

Exhaustive tests of North American mosquitoes have established several points. No important anopheline mosquito in the United States can be a vector of filariasis. None of the North American *Aedes* mosquitoes so far tested are good hosts for the parasite, but many species remain to be tested including all the Pacific Slope ones. Because an *Aedes* does act as the usual vector in the South Pacific Area, there is a possibility that some species of this genus will be found a good host here.

The two species of *Psorophora* mosquitoes of the Southeastern States that most commonly bite man have been shown to be good hosts of the filaria.

All the species of *Culex* that commonly bite man are potential vectors of filariasis. A few of the less common species have not been tested.

We are prepared to track down the vectors of filariasis that might produce an endemic focus and apply control measures at fairly short notice. What the chances are of a focus becoming established remains to be seen—slight I hope. The control measures to be employed are quite different from those employed in malaria control. The mosquitoes that can act as vectors breed in small pools, preferably polluted ones. Local control could be instituted where necessary. Control of the breeding would require that the pools where breeding was taking place be discovered and eliminated or subjected to larvicides.

The patient harboring the filaria worms should be tested regularly for the presence of microfilariae in the blood. If microfilariae are found, the patient should be isolated from mosquitoes by means of screens, by staying indoors at night, and by treatment of the walls with insecticidal paint. Control of this disease requires trained mosquito students first of all.

The foundations of control of the two public health problems I have discussed lie in aquatic biology. Many of the factors in malaria control by water level management were discovered by research work in aquatic ecology that was reasonably "pure" when taken alone. The only efforts to solve the filariasis problem that have given any results so far have been through the application of biological principles based on a knowledge of the life history of the worm and the ecology of the mosquito hosts.

DR. MONK: The chamber is open for discussion. I wonder if there are any questions that you may have?

QUESTION: I should like to add to the discussion of filariasis. Most people are under the delusion that if they have filariasis they will usually contract elephantiasis. Working on a hunch while I was on Saipan with the Health Corps, I experimented on the native population and found that even though they had no outward symptoms of filariasis, they were nevertheless infected with a certain strain of it. Evidently the strain on hand there did not produce any ill effects on the body.

DR. PRATT: About ten per cent of the people think that they will develop elephantiasis usually as a result of repeated attacks of filariasis. Elephantiasis probably will not follow filariasis, but it is difficult to make the patient believe this.

DR. MOTE: I should like to emphasize the need for making a thorough study of the life habits of the mosquito in its control. I do not believe that is fully realized here in the Pacific Northwest. I want to call your attention to another phase of control which you have all heard of—DDT. It occurs in several insecticidal preparations—dust sprays and oil solutions. The Bureau of Entomology and other investigators have carried on a series of investigations in the use of this material in the control of mosquito larvae. I should like to read briefly a report that I have received from the United States Department of Agriculture Bureau of Entomology on the effect of DDT spray on fish and wildlife:

> The Bureau of Entomology and Plant Quarantine, realizing the possible danger that DDT applications over extensive forested areas might have on fish and wildlife, requested the assistance and cooperation of specialists in this field to aid in obtaining facts. In the spring of 1944 a cooperative agreement was entered into with the Illinois Natural History Survey, and late that fall their report indicated high toxicity of DDT to fish when applied at rates of one pound or more per acre.
>
> In the spring of 1945 a cooperative agreement was made with the Fish and Wildlife Service, after which a program of work was arranged for that season by A. L. Nelson, E. W. Surber, and C. H. Hoffmann. Three large areas, many ponds, and three streams were treated during the summer. The principal facts obtained from this study were briefly stated in a press release of the Fish and Wildlife Service dated August 22, 1945, and will be fully reported in a forthcoming publication of the Department of the Interior. In general, fish in ponds and streams can be seriously affected at rates of ¼ to 1 pound of DDT per acre. However, these amounts on certain occasions produced little effect on fish life. Much more information is necessary.
>
> Birds and mammals are affected less than fish, at least directly, by applications of DDT sufficient for the control of forest insects. In the 1,200-acre study area in Pennsylvania several dead and affected birds were found and there was a significant reduction in the number of insectivorous birds left on the sprayed area three days after the application. It was several weeks before it was repopulated. This reduction was due in part to the death of the birds, but the exact proportion attributable to this cause was not determined. Some of the reduction was due to birds leaving the area because of lack

of food. Parts of this area appeared to receive much more than five pounds of DDT per acre because of the drift of the insecticide. There was a heavy population of cankerworms and leaf rollers on oak, and numerous caterpillars on other trees at the time of spraying, and insectivorous birds were freely feeding on them. No effects on birds were reported in the 100- and 300-acre acres in Pennsylvania. It is reasonable to conclude, therefore, that dosages which are quite satisfactory for the control of forest insect pests—i.e., ¼ to 1 pound per acre—will not disturb the bird or mammal populations to any appreciable extent. However, it is not yet fully understood how these birds were affected, and until more is learned about the use of DDT, caution is necessary in applying it on large acreages.

I should like to read another paragraph from this report with regard to aquatic life:

Aquatic life was, in general, much more seriously affected than arboreal or terrestrial forms. One-half pound of DDT per acre can destroy tremendous numbers of aquatic insects, crustaceans, and other forms. This depletion of food for fish might have some effect on the stocking of the streams. One area, through which a stream flowed, was treated at the rate of one pound per acre, but actually only about ¼ of a pound per acre was deposited in the water. The stream was practically depleted of insect life, but relatively little direct harm was done to trout. The fish population was determined by E. W. Surber, and further study in the spring of 1946 should show whether or not starvation resulted from the reduction of food supply. Much more research work is necessary, but present information indicates that as little as ¼ pound of DDT per acre actually going into the streams should be avoided if possible.

DR. MONK: Are there further questions or comments? As chairman of the last session this afternoon, I thank Dr. Pratt for his very interesting presentation of these matters, and I think I may also express the appreciation of all of us to all who have so far spoken to us. I remind you of the dinner at the Benton Hotel at 6:15 this evening when Dr. Miller again will address us.

BIBLIOGRAPHY

Hess, A. D., and C. C. Kiker, *J. Natl. Malaria Soc.* **3,** 181 (1944).

Newton, W. L., W. H. Wright, and I. Pratt, *Am. J. Trop Med.* **25,** 253 (1945).

WATER AS AN INTERNAL ENVIRONMENT

Robert C. Miller

Mrs. Winston: On behalf of Phi Kappa Phi I welcome all of you who are here to attend the Seventh Biology Colloquium at Oregon State College. I extend a welcome particularly to the out-of-town people who come from other campuses and towns to hear our distinguished speakers.

Phi Kappa Phi is an example of democracy in the academic world since it embraces recognition of scholarship in all fields of study, the liberal arts as well as the pure and applied sciences. The chapter is very proud of the opportunity this year to present the Biology Colloquium for the seventh time on the O. S. C. campus. We have been most fortunate indeed to have as the leader Dr. Robert C. Miller, Director of the California Academy of Sciences.

Phi Kappa Phi has been assisted by other groups on the campus, Phi Sigma, biology honorary, Omicron Nu, home economics honorary, and Sigma Xi. Without their help we could not possibly have achieved the things that have been done today.

I do think that there was never a time when we who are not scientists were looking to the scientists to solve so many problems for us as today. We are looking with almost bated breath for them to bring forth these truths.

There are a number of ways in which we are reminded of the importance of the field of Biology, a study of the life history of plants and animals. Many of us think of the study of man as the major field, but of course that is only one phase. It seems to be true, however, that *any* study of life in even its most primitive form can teach us some things about man. The importance of the biological sciences as they relate to man has been expressed in Alexis Carrel in his book *Man the Unknown,* wherein he says:

> Many of the questions put to themselves by those who study human beings remain without answer. Immense regions of our inner world are still unknown. It is quite evident that the accomplishments of all the sciences having man as an object remain insufficient and that our knowledge of ourselves is still most rudimentary. Man should be the measure of all; on the contrary he is a stranger in the world that he has created. He has been incapable of organizing this world for himself, because he did not possess a practical knowledge of his own nature. There, the enormous advance gained by the sciences of inanimate matter over those of living things is one of the greatest catastrophes ever suffered by humanity. The environment born of our intelligence and our inventions is adjusted neither for our stature nor our shape. Since *natural* conditions of existence have been destroyed by modern civilization, the science of man has become the most necessary of all sciences.

The importance of the animate over the inanimate problems in the biological aspects of marine-borne problems has been pointed out by Dr. Kofoid and Dr. Miller in one of their joint papers in these words, "The physical obstacles which loomed large in the early history of marine transportation—the dangers of storm and shipwreck, delays due to adverse winds and currents, and the hazards of navigating uncharted seas—have been more nearly eliminated. The biological problems involved, however, have not been so successfully coped with."

I have been intrigued with the many phases of biological science that have become sufficiently important children to be named in the unabridged Webster's dictionary. I counted one list of 27 different sciences with the prefix "Bio." Some of them are very stimulating to the imagination of the layman: "bio-mathematics," "biometry," "biodynamics," "biochemistry," "biogeography," "biolinguistics," "biostratigraphy," "biogeochemistry" to mention a few; and I particularly like what seem to be the implications of the adjective "biologicohumanistic." It would seem that Phi Kappa Phi could continue to hold biology colloquia almost indefinitely without repeating any one theme.

Dr. Edmund W. Sinnott, writing for the *Yale Quarterly Review,* suggests in his theme the "Biological Basis of Democracy" that we may well add to the list "biopolitical science." His theme is a very compelling one, comparing the individual in society with the primitive forms of living substance. Dr. Sinnott says, "Persons are of greater worth than any systems which they may compose; we may be assured and comforted by the great fact that protoplasm comes not at wholesale but in individual packages . . . the infinite variety of man is not expressed in populations but in personalities and the roots of personality lie deep in that mysterious, fecund, integrative stuff which is the common basis of the life we share with even the humblest creatures." He further points out that liberty, progress, and individualism are common characteristics of a salutary environment for both the primitive living substance and the human individual. I detect some correlation in this same area, if I can interpret it correctly, in the study Dr. Moore made wherein he was able to reveal the ability of earthworms and salamanders to make some associations in the nervous systems that we can call learning, learning being usually thought of as an attribute of the higher forms of animal life only, and particularly of man. This seems to give us hope; if an earthworm and a salamander can be taught perhaps there is still hope for man.

Today we have been hearing outstanding scholars in that division of biological science which deals with forms of life in a water environment. The committee in charge has organized what seems to me to be a very complete, finished product in this seventh Colloquium. I thank them sincerely on behalf of Phi Kappa Phi.

It now gives me great pleasure to reintroduce to you the main speaker of today's program, Dr. Miller, who will extend and summarize today's activities for us.

DR. MILLER: Among the researches preceding my appearance on this program has been an investigation of the merits of "colloquium" versus "symposium" as the proper designation for a gathering of this character. While there are, as will speedily become apparent to any ingenious mind, certain possible experimental approaches to the problem, I limited myself to consulting the literature—to be specific, the Century Dictionary:

> SYMPOSIUM (Gr., a drinking party, drinking after a dinner). The symposium usually followed a dinner. . . .

So far so good. What could be more fitting than a symposium on the physical and chemical properties and biological uses of water. One could even pass around samples, to alleviate the desiccation of the after dinner speech. But I read further:

> Its enjoyment was heightened by intellectual *or* agreeable conversation (italics mine), by the introduction of music and dancers, and by other amusements.

In the absence of music and dancers, I assume that my contribution to the program of the evening would fall into the category of "other amusements." I think your committee was well advised to abandon the word "symposium."

But when I turned to the word "colloquium" I was hardly reassured:

> COLLOQUIUM (L., a conversation). 1. In law, that part of the complaint or declaration in an action for defamation which shows that the words complained of were spoken concerning the plaintiff.—2. A colloquoy; a meeting for discussion.

I earnestly hope it was the second meaning your committee had in mind, and not the first.

While on the subject of etymology, I had best make some defense of the title of these remarks, as well as that of my remarks this morning. Environment is defined in the dictionary as the sum total of conditions surrounding an organism. In speaking of an external environment I am accordingly open to the accusation of tautology, and in referring to an internal environment I may likewise be criticized for placing in juxtaposition two antithetical terms. In feeble self-defense I can only offer the statement that I considered all other possible titles without finding any that expressed even as well as these the line of thought I have wished to develop.

The discussions of today have been partly biological, partly physicochemical, and partly historical. Professor Kincaid gave us a very interesting account of some biological events between 1894 and the present. To complete the picture, I wish to cover the period between 1894 and the beginning of Archaean time—roughly a span of two thousand million years. Unhappily I shall not be able, like Professor Kincaid, to illuminate my story with personal recollections.

This morning we discussed the properties of water which make it particularly available as an environment for living organisms. We mentioned its fluidity, specific gravity, specific heat, and solvent action as significant properties in this respect, and in conclusion pointed out that the particular salts dissolved in sea water, together with the properties of the water itself, render that substance a practically ideal biological medium. This evening I wish to discuss some of the particular ways in which organisms have made use of this medium.

The lower invertebrates—and lower plants as well—have their cells and tissues in direct contact with the fluid environment. Unicellular forms have the protoplast separated from the water only by the cell membrane or by such cuticular structures as they may develop for added stability and protection. Even at this primitive level, mechanisms are found for the handling of water, whether by vacuoles or merely by altering the permeability of the cell membrane. It would be hard to estimate the number of wrinkles in the brows of physiologists that have been made by finding osmosis through a cell wall proceeding in the wrong direction.

Some years ago Tashiro, in a little book entitled *A Chemical Sign of Life,* maintained that respiration is the clue to the diagnosis of living protoplasm. What we might term "a physical sign of life" is the ability to regulate water content. The regulatory mechanism may sometimes be impaired without complete disaster; but when an organism finally loses control of the ingress or egress of water, all else is lost.

Sponges, which are hardly more than colonies of cells, are nevertheless organized around channels through which the life-giving water is actively circulated. Coelenterates, with a distinctively higher type of organization, have their combined digestive tract and body cavity open to the sea.

In Platyhelminthes we find a greater tendency to personal privacy, with a digestive tract more specifically limited to that purpose, and with water (lymph) enclosed within the body wall and irrigating the loosely organized mesenchyme. Here also we first find a definitely organized excretory system. The regulation of water proceeds apace with increasing complexity of organization.

In annelids we first find a well-developed circulatory system and, significantly enough, this is the first group (if we may except soil Protozoa and a few flatworms) in which we find any important tendency to adopt a terrestrial life.

Earthworms, however, with all their admirable traits, are still subject to desiccation, and are restricted accordingly to a limited—one might even say a dull—environment. It is first in the insects, with their chitinous exoskeleton which simultaneously gives protection and support and resists desiccation, that we find a group of organisms equipped for terrestrial life. While many, as I remarked this morning, still undergo their larval stages in the water, at least the adults have a new freedom. They may dance for a day like the May-fly, be industrious like the ant, or cheerfully disreputable like the grasshopper, or like the moth burn both ends at the candle. They get around.

The only other great terrestrial group is the vertebrates, who have met the problem in a different way. With an endoskeleton for support, such protective surfaces as skin, scales, feathers, or hair, a four-chambered heart, arteries, veins, capillaries, lymph vessels, several miles of renal tubules, and a semblance of a brain, the higher vertebrates challenge the insects in a struggle for the domination of the world. By a curious train of circumstances, if a few atomic bombs, for which they are in no degree responsible, go off at the right time and place, the insects win.

But to get back to the subject of water. The point of all this is that water is indispensable to life. The lower organisms are surrounded by the fluid necessary to their existence; the higher organisms have the vital fluid inside. Flagellates, sponges, coelenterates, are bound to the aquatic environment; reptiles, birds, and mammals carry their sea water with them.

It is probably not too much to say that the greatest single step in evolution was this enclosing of the vital fluid within the body, and of regulating its composition. It meant emancipation from the disasters formerly attendant on fluctuations of the aquatic environment. The organism with a closed circulatory system was able to provide its own internal environment, to regulate the concentration of salts and other substances in that environment, and in the higher vertebrates to regulate even its temperature.

I should be pleased to claim this masterpiece of deduction as a product of my own cerebration. It was, however, proposed by a German named Bunge in 1889 and by a Frenchman named Quinton in 1897, both of whom pointed out the similarity in the salts of sea water and those of the blood of higher organisms and offered in explanation the hypothesis I have just suggested.

The idea was developed in considerable detail by Macallum in 1926, who in fact went a great deal farther than the present speaker is willing to follow.

Now, although the same ions occur in sea water and in vertebrate blood, the proportions are somewhat different. The cations listed in order of their abundance in sea water are sodium, magnesium, calcium, and potassium. In vertebrate blood the order is sodium, potassium, calcium, and magnesium. Macallum explained this by the theory that the Archaean ocean contained more potassium and less magnesium than the ocean today.

The concentration of salts in the blood—and hence its osmotic pressure—are about one third that of sea water. This, Macallum reasons, represents the concentration of sea water at the time the higher vertebrates moved out of it—or at least the time when the ancestors of higher vertebrates developed closed circulatory systems.

The bloods of modern invertebrates are much closer to sea water than the blood of vertebrates. This Macallum interprets as evidence that their circulatory systems have become closed in more recent geologic time. Postulating a continuous increase in the saltness of the sea since Archaean time, he deduces that the salt content of the blood of any organism will indicate the period at which the circulatory system in its ancestors became closed off.

Macallum also investigated the salt content of protoplasm, taking herring eggs as a convenient source. He found the concentration of salts in herring eggs to be 0.5905 per cent compared with sea water at 3.5 per cent. He further remarks:

> As the sodium in the ova amounts to 0.08179 per cent, and that in the ocean is 1.0 per cent, it may then be inferred that one-twelfth of all geological time had intervened between the beginning of oceanic history and the fixation of the inorganic concentration and ratios in the cytoplasm. Further, as the amount of sodium in the blood plasma of the higher Vertebrates ranges around 0.3 per cent, it may be estimated that inorganic concentrations in the cytoplasm of undifferentiated animal cells became fixed after about one-fourth of the time passed which intervened between the formation of the oceans and the appearance of Eovertebrates.

Macullum's views have been criticized by Pantin, Dakin, and others, and they do seem a trifle over-theoretical. But another physiologist has gone even farther. C. G. Rogers in speaking of the development of thermoregulatory mechanisms in higher vertebrates says (Textbook of Comp. Physiol., McGraw-Hill, 1927):

> It may be assumed that in the development of these mechanisms an attempt has been made to maintain in the animal bodies about that temperature to which the ancestral forms had become accustomed, or which they had found most advantageous in their original marine environment. It appears possible that there is in the body temperature of birds and mammals an indication of the temperature of the sea at the time when the ancestral forms left the sea.

All we can say of this is that, if man's ancestors were swimming about in water of a temperature of 98.6° F. or thereabouts, it was high time they moved out and took up life on land.

Rogers says further:

> Another fact of peculiar interest is the diurnal change of temperature in warm blooded animals and in the sea. The body of the warm blooded animal reaches its highest temperature normally between 2 and 6 p.m., and then slowly cools, reaching its minimum between 2 and 6 a.m. The difference is not great, being about 1° C. A similar daily variation is known to occur in the sea.

Unfortunately for this interesting comparison, owls have their highest temperature at night. As Adam Sedgwick emphasized a long time ago, it is unnecessary to urge an evolutionary explanation of a phenomenon if a functional one will suffice.

Before leaving this subject I should like to make two further observations by way of a critique of Macallum's conclusions.

1. The assumption that the concentration of salt in protoplasm represents the salt concentration of the ocean in Archeozoic or early Proterozoic time seems to me physiologically unsound. I see no reason to postulate a primitive organic system in precise osmotic balance with the surrounding medium. This does not accord with life as we know it, and is, indeed, just the situation in which we should expect nothing to happen—a kind of Proterozoic Nirvana. Protoplasm, if I may so speak, is essentially lazy. What the organism needs if it is to do anything is not an isotonic medium, but a medium of *different* osmotic pressure, so that it has to get to work.

2. The assumption of a progressive increase in the salt content of the ocean, at a determinable and steady rate, appears definitely doubtful, notwithstanding that most of us have been taught this theory somewhere along the line. Many years ago Joly, after repeated calculations based on this assumption, arrived at a figure of 97,600,000 years for the age of the ocean, an age so far short of probability as immediately to cast doubt on the validity of the premises. Moreover the salt content of igneous rocks is negligible, and the only considerable amounts of salt in the world today, outside of the ocean itself, are relict deposits of ancient seas.

Charles H. White has lately (Amer. Jour. Sci. 240:714. 1942.) advanced the interesting and plausible hypothesis that in the cooling of the earth, the silicates, which have a higher melting point than the chlorides, would solidify first, leaving the salt to accumulate as a surface layer to be taken into solution as further cooling permitted condensation of water. On this assumption, the primeval ocean would have had a salt concentration hardly different from the ocean today, an hypothesis which merits serious consideration and a possible revaluation of some long established concepts.

Biologists in general, I think, will accept the thesis that the circulatory systems of higher animals represent an enclosure within the body of the organism of the medium in which it was originally bathed. The correspondence of the salts in the blood to the salts in sea water, together with the similarity in hydrogen-ion concentration and buffer effect as related to the carbonate-bicarbonate equilibrium, while not perfect in detail, is nevertheless too impressive to be dismissed as mere coincidence. Yet we have the problem of accounting for the difference in concentration. Most vertebrates (with the exception of elasmobranchs in which the osmotic pressure of the blood is raised by a large urea content) have blood with an osmotic pressure about one-third that of sea water. If we abandon the concept of an ocean that has grown progressively more saline through geologic time, how shall we account for this discrepancy?

It has been customary for biologists to think of the early course of evolution as having taken place in the sea, and of the major phyletic groups as having had their origin in that environment. In 1900 T. C. Chamberlin advanced the hypothesis that the early vertebrates had their origin in continental fresh waters, and in that medium had undergone their evolution in Silurian and Devonian time. This stirred up considerable controversy, and there is a large literature on the subject.

We are not compelled, however, to choose between the salt- and fresh-water hypotheses. There is another alternative to which, curiously enough, only a small amount of attention has been given. I refer to a complex of conditions which the aquatic biologist finds in many respects more interesting than any other: the brackish water environment.

If we can think back to the earliest period at which land and sea were segregated, wherever rain ran off the land to join the ocean there existed an intermediate zone of brackish water. The extent of this environment would vary with climate and physiography, as it does today—ranging, let us say, from conditions at the mouth of the nearly dry Salinas River to conditions at the mouth of the Amazon. In an epoch of wide shallow seas and heavy rainfall the brackish water environment must have been vast indeed. Schuchert has stated: "Since the close of the Proterozoic, North America, and especially the United States, has been widely flooded by warm and shallow marine waters at least twelve times, and probably not less than seventeen times."

We have to consider the possibility that these seas were at some times concentrated through evaporation, as well as being at other times diluted by rainfall. But still they measure up to at least one primary specification for the cradle of evolution. They fluctuated. They subjected the organism to stress.

I have already expressed the opinion that protoplasm is essentially lazy. Organisms like to loaf. If we had a theme song for the animal kingdom it would probably be the Negro spiritual, "When I Get to Heaven, I'se Gwine to Sit Down." There is no deeper instinct—and this may have political implications—there is no deeper instinct than the desire for comfort and the status quo. Reformers have two strikes on them at the start, because nobody likes change. I realize I may be challenged on this, but I am willing to adduce evidence that mammals, birds, and even fish prefer the familiar to the new.

This does not at all mean that I consider the status quo desirable. No one has demonstrated that what the organism wants is what it needs. That is only a fiction of progressive education. As I see it, the basis of evolution is the constant struggle of the organism to maintain a degree of comfort in an environment that is continually prodding it and pushing it around. Evolution, like revolution, occurs only when organisms are uncomfortable.

Physiologists have a word for the effort of the organism to maintain the status quo. They call it "homeostasis," the constant state. Without being too specific as to detail, I can conceive of the residents of some ancient estuary, buffeted by the continual interchange of fresh and salt water brought about by fluctuating rainfall and the ebb and flow of the tide, meeting the problem by enclosing a portion of the fluid environment within themselves, where they could keep it under control. Indeed I can think of no reason for the development of a closed circulatory system except the need of maintaining a constant state amid troublesome surroundings.

In reflective moments I have sometimes pressed this line of thought further, and considered the idea that philosophy and theology might be regarded as the efforts of one organism, *Homo sapiens*—the thinking man, the worrying man—to achieve a homeostasis of the mind. But this is getting away from the subject of water, to which in closing I wish to return.

No one has yet discovered the fountain of youth; but we are well advised to speak of it as a fountain. Sixty-five per cent of the human body consists of water. There is increasing evidence that old age is literally a matter of drying up. The four major causes of death, statistics show, are heart disease, cancer, intracranial lesions of vascular origin, and nephritis. Three of these at least have to do with the mechanism for handling water. We survive only as long as we can successfully maintain a satisfactory internal aquatic environment.

Man has been given various definitions, flattering or unflattering, from "thinker" to "featherless biped." From my remarks this evening you are probably regarding him at this moment as an animated waterspout—a comparison that I fear is all too apt, because a waterspout involves a great deal of wind.

SELECTED REFERENCES

Chamberlin, T. C., 1900. On the habitat of the early Vertebrates. *Jour. Geol.*, 8:400-412.

Dakin, W. J., 1935. The aquatic animal and its environment. *Proc. Linn. Soc. New South Wales,* 50:vii-xxxii.

Macullum, A. B., 1926. The paleochemistry of the body fluids and tissues. *Physiol. Rev.,* 6:316-357.

Pantin, C. F., 1931. The origin of the composition of the body fluids in animals. *Biol. Rev.,* 6:459-482.

Rogers, C. G., 1927. *Textbook of comparative physiology.* (New York, McGraw-Hill), 635 pp.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming, 1942. *The oceans.* (New York, Prentice-Hall), 1087 pp.

White, C. H., 1942. Why the sea is salt. *Amer. Jour. Sci.,* 240:714-724.