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The Rockefeller University Review 1966, vol. 4, no. 1

The Rockefeller University

THE ROCKEFELLER UNIVERSITY REVIEW

JANUARY · FEBRUARY 1966

The Rockefeller University Review, Jan.-Feb., 1966. The Review is issued bimonthly. This is volume 4 number 1. Published by The Rockefeller University, Sixty-sixth Street and York Avenue, New York, N.Y. 10021. Second-class postage paid at New York, New York. The price for a subscription for one year is three dollars, single copies sixty cents.

*Particle physics is devoted to the search for basic laws governing the structure and behavior of matter. Physicists, breaking matter down into ever smaller parts, have had to employ machines of correspondingly increasing energy: at most, some tens of thousands of electron volts for the examination of atomic structure, millions of electron volts for investigating the structure of the atomic nucleus, and finally billions of electron volts for the study of the subnuclear particles. The number of particles discovered at the highest attainable laboratory energies has risen steadily in the last several years, and their abundance and complex behavior have not yet been satisfactorily explained. There is evidence, however, for an underlying order that may ultimately lead to a simple understanding of the fundamental laws of subnuclear structure. These trends were reviewed in a half-hour film, "The Particle Jungle," recently produced for general television viewing by the American Institute of Physics in cooperation with Channel 13/*WNDT*, and shown in Caspary Auditorium last November. The participants included Dr. Pais, together with Maurice Goldhaber of Brookhaven and L. M. Lederman of Columbia. The commentary by Dr. Pais has been adapted from the film transcript for publication here.*

THE PARTICLE JUNGLE

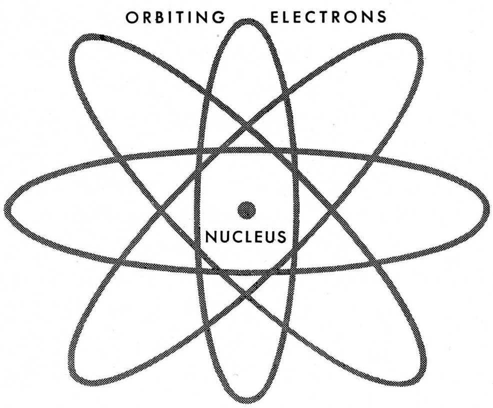
BY A. PAIS

THE PRESENT STATE of particle physics is reminiscent of the situation in chemistry about eighty years ago, at which time there were some ninety elements ordered in the periodic table of atoms by similarities in their properties. There were gaps in the original table which led one to suspect unknown elements, and these, indeed, were found later. In physics we now have some one hundred subnuclear particles, and here also we try to order them in groups of particles with similar properties. For this purpose it has been necessary to invent by trial and error entirely new rules of similarity. If one such rule leads us to suspect unknown particles, and if these are subsequently found, then we say that the rule looks good. And we go on to find even more comprehensive rules.

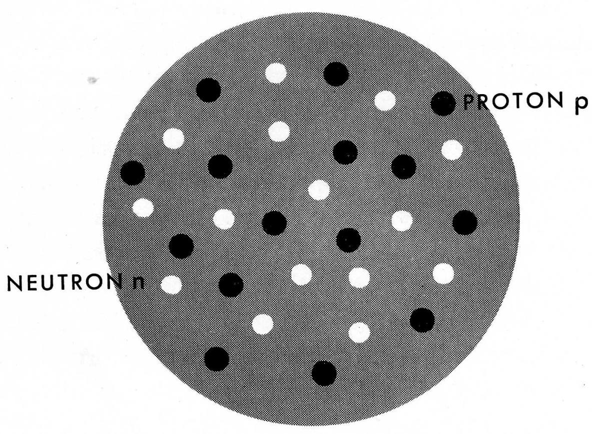
Well, let me go back a little bit and let me talk about the atom. When the periodic table was conceived, atoms were still thought to be something indivisible and about 10^{-8} inches in diameter. Then,

early in this century, beginning with Rutherford and Bohr, man learned to look inside the atom and found it to be a very structured object with the electrons orbiting around the central body, the nucleus. A refined kind of mechanics was needed to understand this structure. This revolutionary new mechanics is the quantum theory.

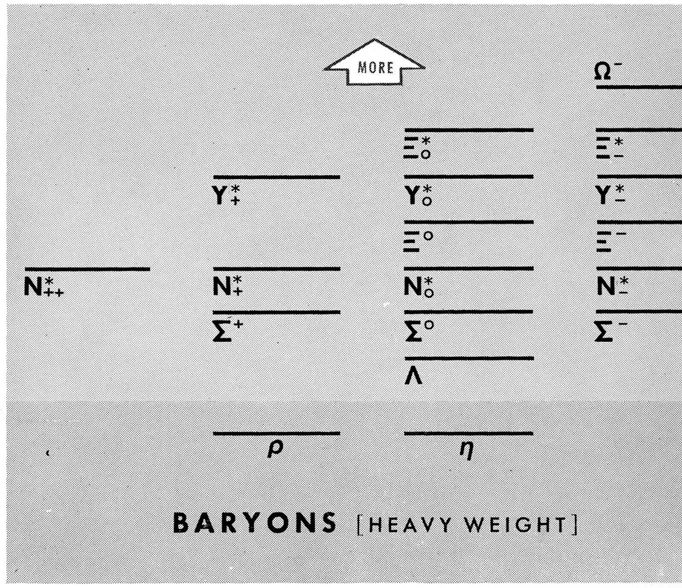
The core of the atom, the nucleus, is a hundred thousand times smaller than the size of the atom.



And at first, little was known about the structure of the nucleus. But man learned to look in even closer, and as early as 1932 it turned out that the nucleus also was quite complex. It consists of two kinds of particles — the proton and the neutron — which collectively are called baryons — meaning in Greek "heavy particles," heavy, that is, compared to the electrons. These two kinds of baryons have about equal mass but a different charge.



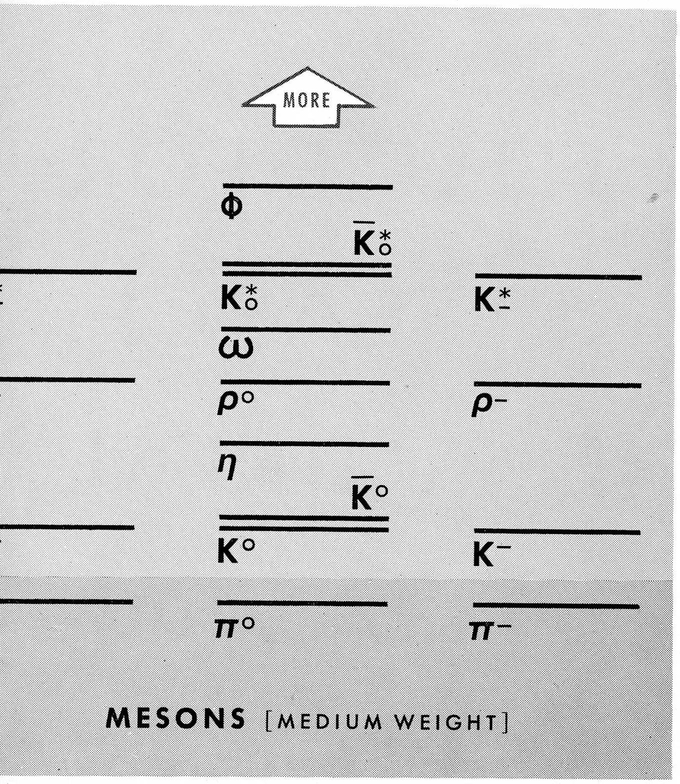
NUCLEUS



And so by the forties we had the idea that maybe matter had been broken down to a few ultimate building blocks, the electron and the two baryons — the proton and the neutron. But then, starting some fifteen years ago, a sequence of discoveries began that had not been dreamt of in anybody's philosophy. We found that there are not just two baryons but a whole family of them — shown here with their code names. These new forms of matter are all quite unstable; they live for only 10^{-10} seconds, or even much less.

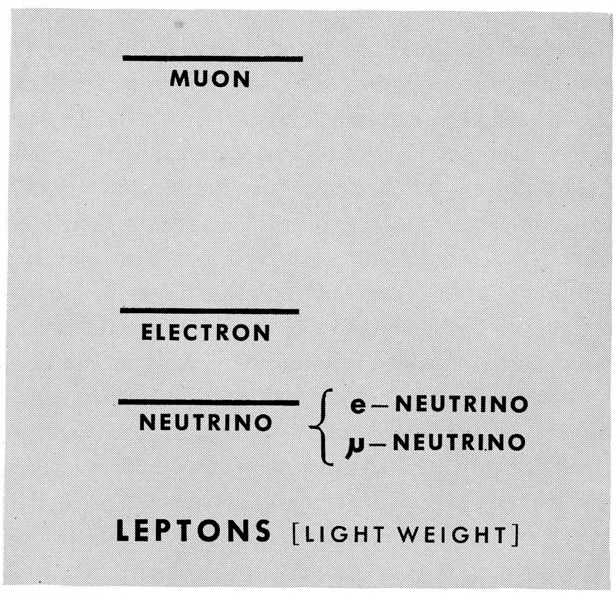
So life was fairly simple before these additional baryons were found. We thought we were on our way to the ultimate in the structure of matter.

How were these baryons found? In a figure of speech, by looking very closely. We look into the atom by making it glow; we excite it by collisions with projectiles and then study the effect of the impact. It is a rule of physics that the smaller the object one wants to look at, the higher the energy of the projectiles must be. To look in detail into the nucleus requires much higher energies than ever before because the nucleus is so much smaller. So physicists have been building machines at higher and higher energies for close examination of the heart of matter. The first new baryons were found with high energy cosmic rays which hit the earth from outer space. In the early fifties the first sufficiently energetic accelerator was available to study these new forms of matter under controlled conditions.



Around 1950 we knew of a second small group of particles — the mesons. We thought there were only three of them in the early fifties. But again, the new accelerators soon showed that there are many kinds of mesons.

Finally, in another very significant development, we discovered that there is in fact a third family, a small one, the so-called leptons or light particles. The two more familiar ones are the electron and the neutrino. In addition there is the muon, and now it turns out that there exist two distinct kinds of neutrinos.



Finding these new forms of matter is exciting. It is also disquieting. Things are not nearly as simple as they seemed in the late 1940's. It is a basic creed of physics, as of other sciences, that Nature's ultimate design is simple. If something does not look simple it usually means that we have not reached the bottom of it. No one can *prove* that Nature must forever be simple, but this drive to simplicity has been an unfailing guide for 300 years of development in physics. We must continue to follow its lead.

So we are led to the belief that behind the complex code of the particles there is a newer, grander design. Just as we could not understand the periodic table until we learned to look inside the atom, so we now believe that we will not understand the particle table until we can look closely inside the particles, inside such extremely small objects as the protons themselves. This exploration is now underway, and the time is near for building still stronger accelerators for an even more penetrating closeup view of matter.

What do we hope to find this way? Perhaps there will be further additions to the particle table. But that is not the essence of the search. We are traveling inward because we want to find the new laws of nature that rule this subnuclear world. These new laws should comprehend and refine the now familiar ones. They should explain the rules of similarity or symmetry which I mentioned at the beginning. We also seek for more unity. A hundred years ago we learned that two kinds of forces — electric and magnetic forces — are really one and the same thing. We now seek likewise for a unification of different subnuclear forces, a unified idea that may show these forces to emerge from one much more comprehensive principle. We want to know if there are more ultimate forms of matter, never yet seen.

And so we have been traveling from molecular physics to atomic physics to nuclear physics to the present frontier of particle physics in order to answer the age-old question: what is the stuff that matter is made of? We have made good progress in the last fifteen years. But there is still very much to learn.

INSTITUTE FOR RESEARCH IN ANIMAL BEHAVIOR

AN AUSPICIOUS COLLABORATION

THE BIOLOGICAL BASIS of behavior — why men and animals behave as they do — will be intensively investigated through a unique program of cooperation between the New York Zoological Society and The Rockefeller University. After a year of discussion and planning, President Bronk and Fairfield Osborn, President of the Zoological Society, announced on December 10, 1965 the establishment of an Institute for Research in Animal Behavior which brings into active partnership two institutions with great potential for mutual reinforcement in a symbiotic approach to some of the most significant questions that face biologists. This institute will be a group of scientists holding joint or separate appointments on the faculty or staff of the University or the Zoological Society who cooperate in research and teaching in the field of animal behavior. The Institute will seek to make more effective use of the resources of both institutions rather than set up any sort of separate corporate structure. This collaborative enterprise will make available to the faculty and students of the University living material and research opportunities

not available to any other university, and at the same time enhance the scientific utilization of the Zoological Society's collections of living animals by facilitating their contribution to behavioral research.

Most of the exciting new developments in biology during the past twenty years have involved more and more sharply focused analysis of cells and their molecular components. But no matter how perfectly they function internally, billions of cells fail to make up a living animal unless organized into an appropriate biological pattern. This kind of appropriateness involves properties of whole animals not readily predictable from analyses of such components as mitochondria or enzymes. Physiologists and developmental biologists are also deeply concerned of course with the "sociology" of cells and organs, but beyond their customary level of analysis lies a whole spectrum of truly biological problems involving the uses made by animals of the complex machinery at their disposal. It is at this level that a new biological discipline is taking shape. Some of its roots lie in comparative psychology, sometimes it is called "ethology," but it is more often known simply as the study of animal behavior. Regardless of semantics, the basic goal of this kind of biological investigation is to understand why, out of all the actions an animal is capable of carrying out, it usually does in fact select certain characteristic patterns of behavior.

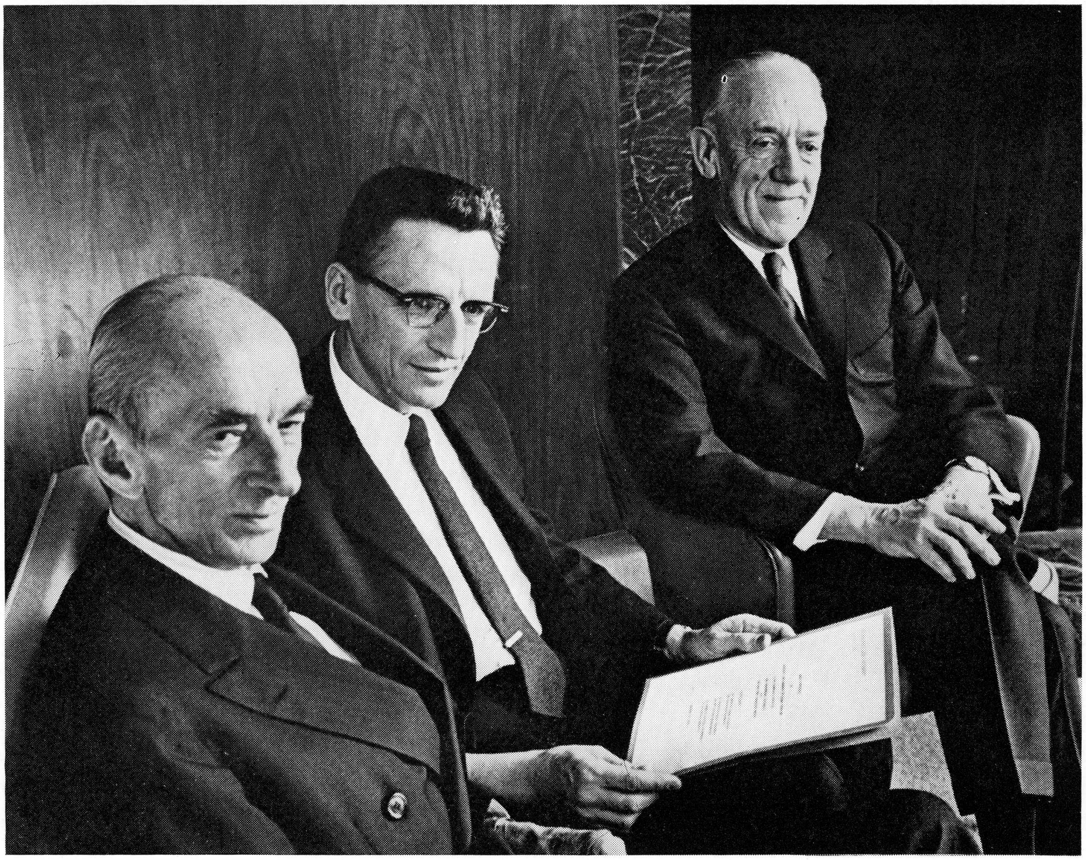
The optimal investigation of animal behavior requires appropriate institutional ecology which differs in some respects from the combinations of human talents and physical facilities assembled in conventional universities. A first prerequisite is an abundant, diversified pool of healthy, normally behaving animals for study. Another requirement is close contact with the whole cluster of resources essential for modern research in experimental biology—including biochemistry, neurophysiology, electronics—plus extensive library resources. Equally essential are two intangible ingredients: a flourishing intellectual climate conducive to creative investigation and scholarship, and the indispensable insights of zoologists who know the animals they study.

These considerations have led to a recognition by the Trustees of the two collaborating institutions that the basic purposes of the Institute for Research in Animal Behavior are "first, to combine the relevant resources, both physical and scientific, of the New York Zoological Society and Rockefeller University to carry out cooperative investigations of the behavior of living organisms, the influence of environment on behavior, and the relevance of animal to human behavior; second, to enhance the effective use of the New York Zoological Society's large and diversified collections of living animals, both terrestrial and aquatic, in scientific research into their normal patterns of behavior and the influence of environmental conditions on behavior; third, to provide opportunities for the faculty and students of The Rockefeller University to study animals in varied environments, including their natural habitats and approximations thereto; and fourth, to strengthen the combined staffs by joint appointments to the faculty of The Rockefeller University and the staff of the New York Zoological Society."

Joint Appointments

The joint appointments include Professor Donald R. Griffin, who is the Director of the new Institute and is already at Rockefeller (July-August 1965 *Review,* pages 1 and 11); together with Professor Peter Marler, Assistant Professors Fernando Nottebohm, Richard Penney, and Roger Payne, who will arrive this summer (see "New Appointments," page 21).

At Rockefeller University where experimental biology has flourished over the same period of time that the Zoological Society has been in existence, the Institute for Research in Animal Behavior is related to the overall development of research and teaching in the behavioral sciences under the general cognizance of Dr. Carl Pfaffmann, recently appointed Vice President of the University. In addition to his administrative concerns Dr. Pfaffmann is also pursuing his own investigations into physiological psychology of the chemical senses with particular reference to the behavioral patterns motivated by taste and olfactory stimuli in animals and men. Another senior appointment in psychology is that of Professor Neal



Presidents Osborn (left and Bronk (right) with Professor Griffin at a press conference for the new Institute for Research in Animal Behavior

The creation of this new Institute means more, we may hope, than the launching of but one more effort to analyze animal behavior as such. The horizons it intends to explore are less limited than those that may be viewed within a laboratory and, in turn, more specific than those within the boundless expanses of nature. The goals of understanding the Institute seeks to reach concern the behavior of all living organisms, whether animal or human. It recognizes the many similarities between both, inherited and melded through countless past ages.

The arrangement by which The Rockefeller University, with its great reservoir of scientific talent, will work in partnership with our Zoological Society justifies the hope that our combined efforts will yield rich results through gaining greater knowledge of the motivations and actions of all living organisms, and thus add to the betterment of human life.

FAIRFIELD OSBORN, *President*
New York Zoological Society

Man's enduring curiosity about the behavior of animals is reason enough for the creation of this Institute. But it has an especial and urgent significance too in these times when science and technology enable man to change and profoundly reshape the surface of the planet on which we live with other creatures. As we thus alter the physical and social forces to which all living beings are subject, we affect the processes of life and the patterns of behavior. From the study of how animals behave in their natural environment and how changes in the environment affect their behavior, we may gain precious clues to the determinants of our own behavior. And then perhaps man will use more wisely his vast new powers to plan the modification of his surroundings and the forces of nature that control him.

When I first discussed this cooperative undertaking with Professor Dubos, his perceptive vision moved him hopefully to say: "I have no doubt that we shall soon witness a new revolution in biological thought and a reorientation of biological research if we can provide an intellectual home and research facilities for the study of the response of the living organism to its total environment."

DETLEV W. BRONK, *President*
The Rockefeller University

E. Miller (see page 21), who will continue his studies on the mechanisms of learning and motivation and on the behavioral effects of direct brain stimulation in freely moving animals. New laboratories in Theobald Smith Hall and East Laboratory (still under construction) are either already in use or allocated for research in physiological and experimental psychology, behavioral biology, neurophysiology, and related fields.

These new appointments and facilities will assure a significant extension of the University's graduate teaching and research into the behavioral sciences. As biological investigators come to grips with the problems of behavior during the next several years, they may confidently be expected to rely upon discoveries of biochemists, neurophysiologists, and endocrinologists just as molecular biologists have based their work on previous progress in the physical sciences. The graduate students of The Rockefeller University form an ideal company of future investigators from which leaders in this important field of biology are likely to arise. Thus the laboratories of The Rockefeller University, and their many distinguished occupants, provide an ideal base from which investigators can explore the unknown and difficult territory of behavioral phenomena.

But a secure base does not suffice to assure creative exploration. There must also be a potentially fruitful wilderness accessible for conquest. Experimental investigation requires abundant and representative samples of the phenomena under scrutiny. It was because marine organisms provide invaluable research material for many areas of experimental biology that the Marine Biological Laboratory at Woods Hole, and many similar institutions elsewhere, were established to bring together the appropriate scientists, living material, and environment for creative research. The optimal study of animal behavior requires innovations comparable to Agassiz's first marine laboratory on Penikese Island in Buzzards Bay in 1873.

Enterprising explorations are traditional in the New York Zoological Society's studies of animals in their natural environments and in the very closest approximations to nature that ingenuity can devise. For more than fifty years the Society has sponsored pioneers in the study of animal behavior, and many of its operations have opened up entire new areas of investigation previously considered as wholly visionary. Beginning in 1899 and continuing until his death in 1962 William Beebe led expeditions to places as far apart as the Galapagos and the Himalayas, established several successive tropical field stations, and descended into the ocean to record depths during the 1930's in his famous bathysphere. The basic objective of all these expeditions, and of the Society's Department of Tropical Research which he directed, was to understand how animals actually live and behave under natural conditions. This tradition of adventuresome research extended from the social behavior of birds in tropical rain forests to the luminescence of deep-sea fish. Within the past few years the Society has sponsored Margaret Altmann's observations of the social behavior of moose in Wyoming, George Schaller's investigations of gorillas in Africa, and Carleton Ray's studies of acoustic communication and diving behavior of Ross and Weddell seals under the Antarctic ice shelf.

Park and Aquarium

The Zoological Society will also provide the new research institute with an invaluable background of practical know-how in the care and maintenance of animals. This reservoir of experience is based not only on the reptiles, birds, and animals at the Bronx Zoological Park, but also the fresh and salt water fishes and marine mammals at the New York Aquarium, which is just expanding its research program through the construction of the Osborn Laboratories of Marine Sciences. The Society is remodeling a building at the Bronx Park which will provide about 3000 square feet of working space that is well adapted by construction and location for experiments with living animals other than the conventional laboratory animals that can be properly cared for on the University's midtown campus. In this behavior laboratory close to the Bronx Zoo, and in the ample outdoor space surrounding it, animals can be reared and maintained with the close collaboration of the experienced curators and keepers. These men have unique abilities for creating conditions where hundreds of species of mammals, birds, and reptiles not merely survive in good health but exhibit courtship and breeding behavior. This building is the former Farm-in-the-Zoo, which was constructed of solid masonry by the Works Progress Administration

during the late 1930's. The behavioral research area while close enough to the Zoo to permit collaborative work by the curatorial and animal caretaking staff, including the animal hospital, will ordinarily not be open to the public, because controlled behavioral experiments and public exhibition cannot be successfully combined.

The Institute for Research in Animal Behavior will also include from the very start a vigorous program in animal behavior already under way at the New York Zoological Society's William Beebe Tropical Research Station in Trinidad, *page 10.* Courtship, communication, mimicry, orientation, and color vision are all being studied experimentally under optimal, natural conditions by Miss Jocelyn Crane and by visiting scientists from several universities in the United States and elsewhere. Miss Crane's research has elucidated many patterns of animal behavior that are largely hereditary and little affected by learning, such as the signaling system by which male fiddler crabs wave their enlarged and specialized claws to threaten rivals or attract mates. These displays are ritualized in characteristic ways that vary with the evolutionary relationships between the many kinds of fiddler crabs throughout tropical areas.

The Beebe Station is located in forested hills of Trinidad in the midst of an abundant fauna of neotropical birds, bats, reptiles, amphibians, insects, spiders, and many other animals. The Station includes several small buildings with comfortable living quarters, simple laboratories, and air conditioned rooms where electronic and optical equipment can be protected from the insidious deterioration so characteristic of the very tropical climate necessary for the rich fauna. There are numerous cages of several sizes, some wholly out of doors, and others with roofs to protect them from the rain (and falling mahogany nuts) but otherwise accessible to the full flavor of the tropical environment. Immediately adjacent to this natural environment and fauna, modern analytical facilities such as storage oscilloscopes or instrumentation tape recorders, are used for physiological experiments when these are needed for the well-rounded investigation of animal behavior. No attempt is made to duplicate work better done in ordinary laboratories, but many problems of behavior are being solved by the interplay at close range of behavioral and neurophysiological techniques.

For example, Miss Crane had worked out several years ago the essential role of colors in the social behavior of butterflies of the genus *Heliconius,* in particular the genetically programed recognition of the species-specific color patterns that release courtship behavior and mating, *page 10.* More recently Dr. Stewart Swihart from Lehigh University and the State College at Fredonia, New York has investigated the neurophysiology of color vision in these butterflies. While action potentials from the compound eyes themselves do not differ appreciably in any of the species he has studied, Dr. Swihart's electrodes have recorded electrical responses from certain parts of the minute brains of these butterflies which appear to be selectively responsive to the same wavelengths of light that release courtship behavior most effectively. He is thus progressing towards a physiological identification of the neural mechanism that controls a species-specific courtship reaction to colors. Not only does his work require an abundant supply of healthy butterflies capable of normal courtship behavior, it received its initial impetus from and is continually strengthened by the closely relevant behavioral studies under way at the Beebe Station. Comparable opportunities await future investigators of many other groups of animals that display characteristic behavior patterns amenable to behavioral and physiological analysis.

Noctilio leporinus

Professor Griffin has carried out many of his recent experiments with the natural sonar systems of bats at the Beebe Station. When his book *Listening in the Dark* was published in 1958 one of the unsolved problems of echolocation behavior was the ability of certain tropical bats to catch small fish by reaching down just below the water surface with specialized hind claws that form miniature gaffs. It was not known whether these bats could project their ultrasonic signals through the water surface and hear echoes from submerged fish. The best known fish-catching bat, the bulldog bat *Noctilio leporinus,* is available in Trinidad. Using facilities of the Beebe Station, Dr. Griffin and Roderick Suthers of Harvard and Indiana Universities showed that while these bats failed to detect wholly submerged fish except by random dragging, they could locate extremely

tiny objects at the water surface and even discriminate details of surface topography by echo, *page 10*. For instance, blinded bulldog bats consistently located a wire 0.2 millimeters in diameter protruding 5 millimeters above the water, after being trained that this tiny wire marked the location of a barely submerged piece of fish that was otherwise undetectable. In further experiments bats went on to learn that a single 1.3 millimeter wire marked the location of a submerged morsel of fish, but that a closely spaced pair of 0.9 millimeter wires yielded nothing. This discrimination by echo is especially significant because the echoes from the single and double wire differ only slightly. Under natural conditions fish and insects create millimeter sized irregularities at the water surface which these bats distinguished in the dark from inedible floating debris such as leaves, twigs, or bubbles. Human blindness would surely be far less of an affliction if comparable acuity of echolocation could be transposed from the commonplace behavior of bats to a practicable procedure for the use of blind men.

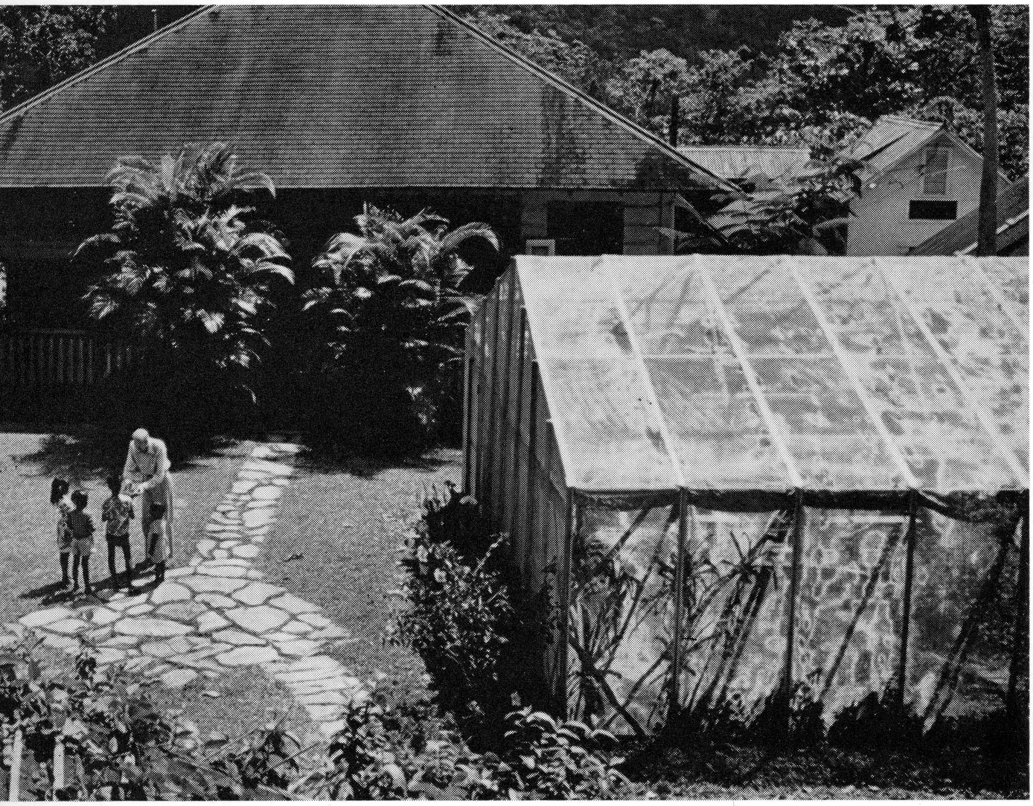
While the ultrasonic sounds bats use for echolocation are absorbed in the air too rapidly to be effective beyond a few tens of meters, some bats migrate for hundreds of miles every spring and fall, and homing experiments have demonstrated returns of marked bats released as much as 250 miles from home. Although highly adapted for short range orientation by echolocation, bats must have other means of finding their way over long distances. Dr. Griffin and Rockefeller graduate student Timothy C. Williams are studying long range orientation of bats by means of homing experiments based at the Beebe Station in Trinidad. The abundant Trinidad bat fauna includes a large (80 gram) species, the spear-nosed bat *Phyllostomus hastatus,* that homes much more faithfully than the bats studied previously in temperate latitudes. Its size permits many procedures which would be out of the question with the 5-to-15 gram bats available in the eastern United States. Under favorable conditions half or more of these spear-nosed bats return home from twenty miles within a few hours. Experiments with blindfolded bats, and control animals fitted with goggles of the same size and weight, have shown that vision is essential for rapid homing from 15 to 20 miles. To learn more about this poorly understood type of orientation behavior, eight gram radio transmitters are now being prepared by the Rockefeller University Electronics Laboratory, and pilot experiments have already demonstrated that "radio tagged" bats find their way home and can be located from distances of a mile or more. This concurrent circuit development on Manhattan Island and field zoology in the tropical rain forest, are typical of the diversified enterprises that must often cooperate in order to solve fundamental problems of animal behavior.

Bird Song

Peter Marler, who will become a professor in The Rockefeller University on July 1, and like Dr. Griffin a member of the Institute for Research in Animal Behavior, is deeply concerned with the experimental analysis of communication behavior in animals. He will continue to investigate the relative importance of learned and genetically determined elements in the social signals used by a variety of animals, but will emphasize bird songs as a favorable case for detailed analysis. Unlike Arthropods where learning has only a minor role, a bird's singing at maturity may be strongly influenced by the sounds heard during its youth. In continuing his previous work on bird song, Dr. Marler will have laboratory facilities at The Rockefeller University, and also adequate space for rearing and studying birds at the behavior laboratory and adjacent outdoor working space at the Zoological Park. The birds in the Bronx Zoo lay hundreds of eggs each year, many of which are hatched either by the parents or in incubators. Dr. Marler can thus isolate numerous species under controlled conditions before their first peep, and raise them in experimentally devised environments with any desired companionship or isolation from the songs of their own or other species. Spectrographic analysis of the songs of different species and hybrids between closely related species with distinct songs, along with the influence of individual experience, will also help determine the genetics of song pattern. Since the curators and animal keepers are experts in the breeding and care of so many species of birds, there will be no need to recapitulate the whole history of zoo keeping.

Dr. Marler and his associates plan to investigate the neurophysiology of sound production and song recognition in birds, studying the developmental

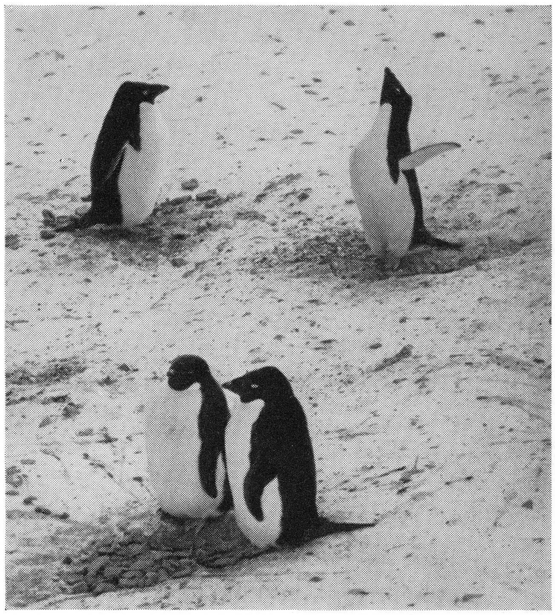
Bats show remarkable ability to fish by echolocation. Discrimination tests were carried out in total darkness.

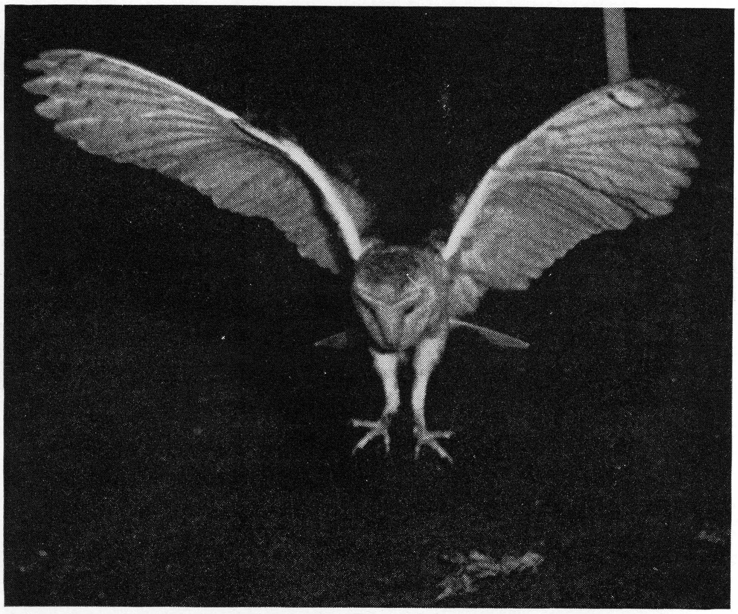


LEFT: *Trinidad field station of the Zoological Society, 1957. View of laboratory, insectary (in right foreground) and living quarters. Dr. Beebe is accepting a gift of insects.* ABOVE: *Jocelyn Crane paints surfaces of butterfly wings to test color responses.*

A rare Antarctic Ross seal.

Penguin at upper right is in ecstatic display.





Barn owl, photographed in the dark by infrared-sensitive film, about to pounce. BELOW: *pattern made by claws of striking owl maximizes its chances for fastening at least one talon into a mouse.*

stages through which the brain passes as the bird attains increasing auditory capability. Especially important in these studies is an experimental control of the degree to which the developing bird can hear its own vocalizations. Dr. Nottebohm and Professor Marler have been analyzing the role of auditory and proprioceptive feedback in the sound production in birds. This type of work will doubtless result in fruitful new directions of inquiry when carried out in the collaborative proximity of physiological psychologists, neurophysiologists, and neuroanatomists.

Dr. Penney has studied the celestial navigation of Adelie penguins in the Antarctic, and he will continue these investigations on captive penguins at the behavior laboratory in the Bronx Park. When these penguins are transported away from their nesting colonies and released in flat, featureless terrain, they start walking in the direction which would take them to the sea if they were in their home longitude, *page 11*. This orientation occurs only when the sun is visible. Although this initial heading may not be towards home, if the penguins have been displaced to distant parts of the Antarctic continent, many of them eventually make their way home by swimming hundreds of miles along the coast. Penguins are highly specialized birds which are persistent and, of course, unable to fly—qualities which make them promising experimental animals. Dr. Penney plans to construct in the Bronx Park a dome-shaped sun simulator, 75 feet in diameter, in which he will study the behavioral and physiological bases of sun orientation.

Sun Orientation

Honeybees and certain other animals that display sun compass orientation are able, in appropriate experiments where they cannot see the sun, to extrapolate its apparent movement in an arc across the sky. In such experiments the animal's directional choices with respect to a real or simulated sun are tested after it has not seen the sun for several hours. The direction of this extrapolated movement seems to be learned, at least in honeybees. Of course the apparent direction of sun movement is opposite in the Northern and Southern Hemispheres, and one of the experiments on Dr. Penney's agenda will be to determine how penguins transported from the Antarctic without any view of the sun will react to the Northern Hemisphere sun movement. This will be of especial interest because, unlike bees, the Antarctic penguins as a group have been confined to high southern latitudes for millions of years. It would be significant if so specific a behavioral character as the direction in which the sun is "expected" to move across the sky should prove to be genetically fixed in penguins as a result of their evolutionary history. Once the new facilities and research programs are well established, solid facts should begin to replace speculations.

Owls and Moths

Dr. Payne is concerned with the mechanisms of localizing sound sources in two very different animals which are alike in that both fly and both depend heavily upon auditory localization in their normal lives. Owls can fly twenty feet or more in total darkness and impale a mouse with their talons, guided only by the rustling sounds it makes moving among dry leaves. They can also strike loudspeakers broadcasting recorded mouse rustlings in total darkness, *page 11*. The soft feathers of an owl's face conceal effective sound-collecting "horns" formed from stiff feathers around each ear. Unlike mammals, owls have assymetrical external ears, which may well be involved in producing the assymetrical patterns of directional sensitivity which Dr. Payne has measured in his owls. He also plans to extend his previous experiments by considering whether an owl can determine the distance as well as the direction to its prey in vertical as well as horizontal planes. And he will continue his functional comparison of owls' directional hearing with the rather different auditory systems of noctuid moths which can hear the sonar signals of approaching bats and start evasive flight maneuvers that sometimes enable them to escape the bat's acoustically guided pursuit. Building on the previous work of Roeder and Treat, Dr. Payne has shown that despite its simplicity in having only two auditory neurons from each ear, the moth's auditory system can nevertheless achieve directional discriminations. This is probably accomplished through differences in directional sensitivity patterns as the moth's wings move up and down, casting a fluctuating acoustic shadow over the ears themselves. These experiments will be significantly related to Dr. Griffin's continuing studies of the discriminative abilities

of echolocating bats, and there will thus be adequate representation of both the predators and the prey involved in this competitive evolution of offensive and defensive tactics over millions of years.

Because so many fascinating behavior patterns are exhibited by various flying animals — birds, bats, and flying insects are expected to receive considerable attention in the near future, but many other kinds of animal behavior will doubtless be investigated with equal enthusiasm as research interests expand in various significant directions. One further type of research with flying animals has been initiated, however, and this is uniquely suited to the combination of facilities available at The Rockefeller University and the New York Zoological Society. Dr. Griffin is preparing to study the flight behavior of birds and bats in an especially developed wind tunnel. The basic idea is simply to elicit normal flight in a moving air stream where the flying animal maintains itself in approximately the same position and is thus available for closer observation, photography, and experiment than is feasible with an experimental animal moving rapidly in three dimensions. Preliminary tests are under way on the sixth floor of Theobald Smith Hall, employing the blower from a Navy wind tunnel loaned by the Engineering laboratories of Columbia University. This is intended only for preliminary tests to learn what general sort of wind tunnel will be best adapted to the behavioral reactions of birds or bats. The varied collections of living birds at the Bronx Zoo will be drawn upon, cautiously, in an attempt to find species adaptable to this unusual type of flight. It may prove helpful, or even essential, to provide visual simulation of a moving ground below the bird. Variations in flight speed will almost certainly make problems. Initially a divergent air stream with a velocity that varies along the direction of flow will be tried, rather than attempting to regulate the air flow rapidly enough to compensate for variations in air speed of a small bird. In such a flow with varying velocity the bird or bat should be able, within limits, to find air moving at its preferred air speed, moving forward if it gains speed, or drifting back if it slows down slightly.

Once normal flight behavior has been elicited in a wind tunnel, many new sorts of experiments will become feasible. The directional pattern of the emitted orientation sounds of bats have never been measured in any satisfactory fashion, but this will become much simpler if the bat flies and emits its sonar signals from a fixed position around which multiple microphones can be set up, rather than hoping the bat will cooperate by flying through just the right point, heading in the precisely desired direction, and emitting a typical orientation sound at just the critical moment when it is equidistant from three or more microphones. How do the insect-catching maneuvers of insectivorous birds, which are presumably visually controlled, compare with the intricate pursuit maneuvers of bats that are guided by echoes from the insect prey? A more ambitious and uncertain objective in developing the wind tunnel for bats and birds is the hope that eventually celestial navigation or other factors that direct migratory and homing flights over long distances can be studied during actual flight. Previous work by Gustav Kramer, Franz Sauer and others with orientation cages has been confined to birds fluttering in small circular cages that allow no appreciable forward motion (July-August 1965 *Review*, pages 1-3). Ideally a bird exhibiting migration restlessness should be able to fly for long periods as it would in nature. Can the still embryonic wind tunnel be adapted in time to allow would-be migrants not only to fly for some hours, much as dogs willingly exercise on a treadmill, but also to allow the birds to choose their direction of flight?

Promising Prospects

As in the case of Dr. Penney's penguins when they are first faced with the Northern Hemisphere sun, the actual results cannot be predicted with any confidence. If the outcome were predictable, research would thereby cease to be research. Investigations of animal behavior require detailed planning to be effective, but the plans must always be subject to instant, and often drastic, modifications on the basis of current findings and new ideas.

The Institute for Research in Animal Behavior is designed to bring together inquiring zoologists, a smorgasbord of healthy animals capable of normal behavior, and all necessary facilities and stimulating colleagues to encourage original discoveries. The ingredients are unrivaled, the blend is a new and promising one, and the prospects appear uniquely auspicious.

BY BRUCE R. VOELLER

CROZIER UNCOILING OF FERNS

One of the earliest promises of spring is the sight of clusters of fiddleheads raising their coiled tops above ground. Although once far more popular than now, the young leaves of a number of ferns are still collected during the early spring months, cooked like asparagus, and eaten. In fact, one species is still commercially available from a cannery in the province of New Brunswick. Years ago the young coiled leaves were served as a delicacy at the best hotels in New England and New York but have now disappeared from menus. Interestingly, even the name "fiddlehead" seems to be disappearing. Although used by the Scottish naturalist James Hardy in 1881, the name is unknown to most botanists in Britain today.

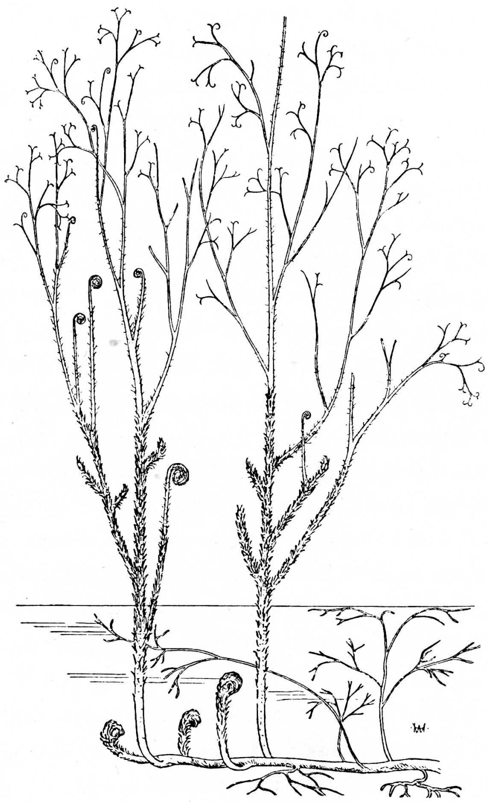
Nearly all of the 10,000 known species of ferns have their young leaves coiled into fiddleheads, or *croziers,* as they are called by botanists. This trait of coiled leaves seems to be very old, in an evolutionary sense, as evidenced by its presence in many fossils. Indeed, some of the earliest vascular land plants, such as the ancient relatives of the ferns, *Asteroxylon elberfeldense, Psilophyton princeps,* and *Protopteridium,* had crozier-like structures. A few scattered exceptions, such as the familiar bracken fern, the staghorn fern, and various species of *Pteris* and *Hemionitis,* do not have true fiddleheads.

A small number of flowering plants *do* have young coiled leaves. Some of these flowering plants are in the insectivorous group. Also, the young floral stalks of plants such as heliotrope, forget-me-not, and *Phacelia* are coiled. The scientific name of the forget-me-not, *Myosotis scorpioides* L., given by Linnaeus, alludes to the scorpioid, or coiled, appearance of the inflorescence. As older buds along the outer cycle of such an inflorescence begin to bloom and develop fruits, the coil starts to unwind and becomes a more or less straight stalk, as illustrated on page 16.

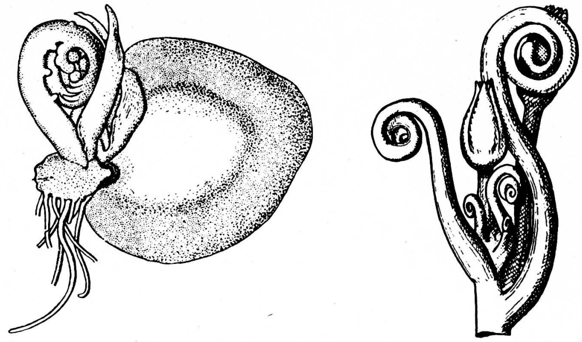
The young leaves of many of the ferns growing in our American forests develop underground for as long as three or four years. Then in the final season the leaves burgeon rapidly, push aboveground, and in a few weeks of growth and uncoiling are transformed into mature fern fronds. Taylor Steeves, Ian Sussex, and James Caponetti have shown that young embryonic fern leaf primordia may be surgically removed from the shoot and grown sterilely in tissue culture. Even in sterile-culture flasks, tiny, immature, isolated leaves grow and uncoil in a manner quite similar to that of intact leaves. So it appears that at a very early stage the embryonic leaf possesses the necessary developmental information to complete its morphogenesis. Indeed, Steeves and

his colleagues have succeeded in growing tissue-cultured fronds all the way from tiny primordia to fronds bearing their reproductive organs, sporangia.

Despite the centuries-old familiarity of the sight of fiddleheads, the developmental physiology of their formation and of their uncoiling and expansion until the last few years has been almost unexplored. Recently, Winslow Briggs and Taylor Steeves of Harvard University, and the present author working independently at Rockefeller, determined some of the physiological and cellular events which underlie the uncoiling of croziers. The Harvard group conducted experiments with the cinnamon fern, *Osmunda cinnamomea* L., common throughout the woods of eastern United States and Canada. My own studies were mainly of the giant tropical tree ferns *Cibotium* and *Alsophila.* In each of our studies, work began by examining the over-all development of the growing frond and then the underlying physiology of the uncoiling.



Crozier-like structure of the fossil plant Asteroxylon elberfeldense, *350,000,000-year-old relative of the ferns.*



Tightly coiled leaves of insectivorous plants: a sundew, Drosera pygmaea, *left, and* Byblis linfolia, *right.*

In order to obtain an idea of the rates of growth and uncoiling of the young fern fronds, a simple and familiar technique was used. Just before the young croziers were about to begin rapid growth, the dry hairs and scales which cover the croziers were carefully removed. Zones of the abaxial, or back, side of the rachis, shown on page 18, were marked with India ink. By careful work it was possible to mark zones almost all the way to the tip of the crozier — the tip which would eventually be the end of the frond. Approximately every other day, each zone along the rachis was measured with a flexible tape measure and the relative positions of the zone within the crozier were noted. Representative results are shown on page 17.

For example, curve 12 is parallel to curve 11 until the twenty-fifth day, indicating that no growth took place in zone 12 on the abaxial side of the rachis. On the twenty-fifth day, curve 12 diverges upward from curve 11, showing that the zone began to grow in length. The curves continue to separate until the twenty-ninth day. Thereafter, curve 12 is once again parallel to curve 11, growth having ceased. In summary, these variations reflect the fact that zone 12 was quiescent until the twenty-fifth day. At that time the zone underwent a rapid burst of elongation for 4 days and finally ceased extending.

We see from this study several interesting facts regarding crozier growth. For more than a week, following the onset of growth, little or no uncoiling of the crozier occurred. During this period the crozier increased considerably in height, however, through elongation of the straight region of the rachis supporting the crozier. After an initial elevation phase,

Some flowering plants have fiddleheads, which uncoil as the buds open and the fruits develop: Heliotropium índicum *L., left, and* Phacelia leucophylla, *Torr., right.*

the height of the crozier increased both through further elongation of that part of the rachis and through uncoiling of the crozier itself. Little elongation took place within the inner parts of the coil, as indicated by the fact that the curves representing these zones remain nearly parallel and at uniform distance from each other. Comparison of the regions of divergence of the curves, with the diagrams below the graph, shows that at all developmental stages the only zone of elongation or growth was the outer 180-270° of the crozier and the straight area of the rachis immediately below the crozier. Note, for example, that between the eighteenth and the twenty-first days, zones 4, 5, 7, and 8 were lengthening but all other zones were quiescent. Between the twenty-first and twenty-third days, zone 4 ceased elongating and zones 9 and 10, as they moved into the outer 180-270° of the crozier, began to grow. The narrow region of elongation proceeded up the rachis until the frond attained full, mature size. During the course of this rapid growth the rachis of the frond increased severalfold in length.

These observations have been confirmed by the use of time-lapse films, which show particularly clearly the *crozier elevation phase* and the progressive shift of the *zone of rapid elongation* that moves up the leaf axis until the crozier has completely uncoiled and expanded.

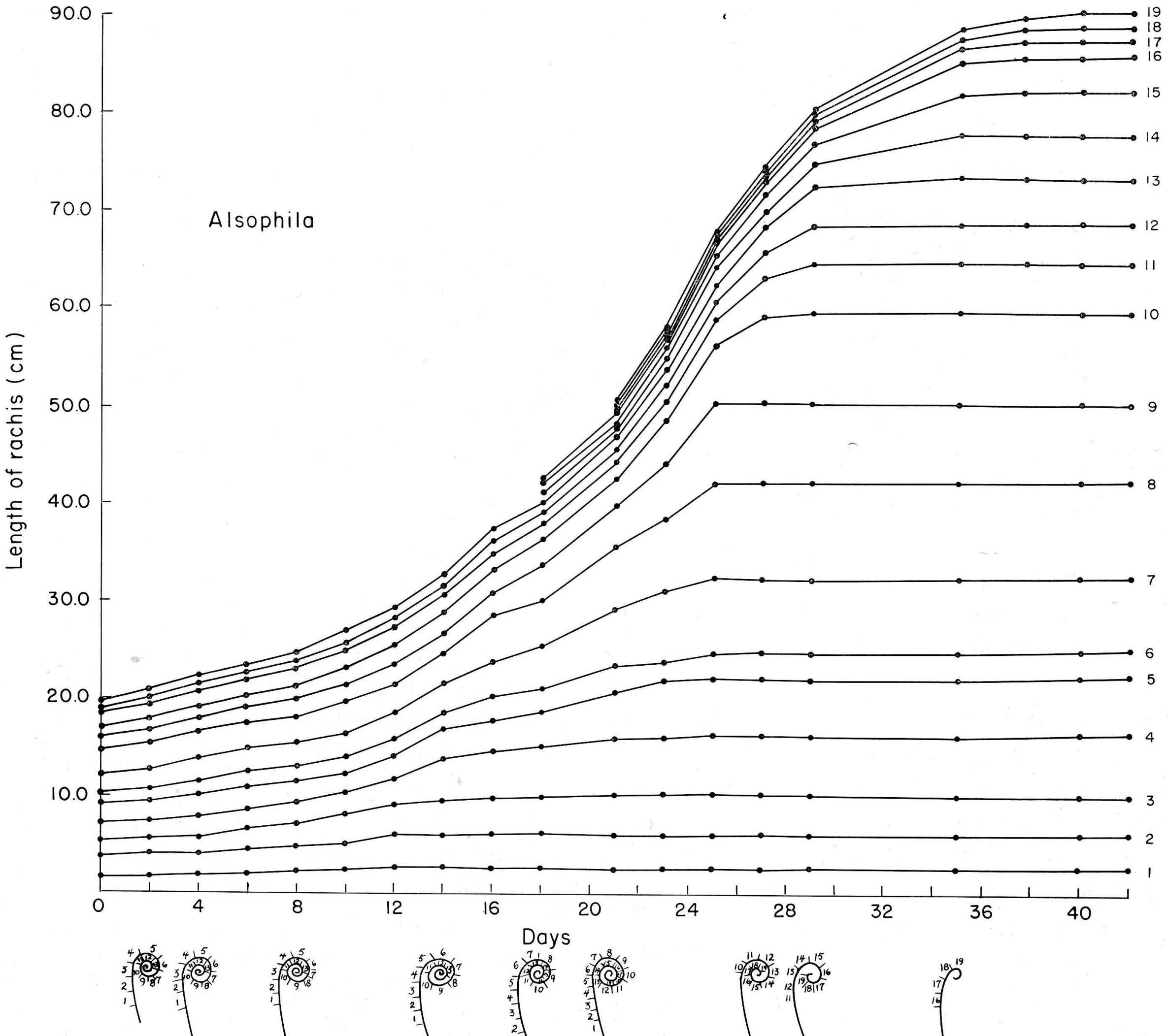
Microscopical studies of crozier tissues show that very great cellular elongation occurs in the young fronds. Much of this increase in length takes place in the zone of elongation defined in the growth studies on marked fronds. In *Alsophila* the length of parenchymatous cells in the tissue of croziers just beginning to uncoil was found to increase from about 35-40 μ, near the beginning of the zone, to about 120 μ just below the zone of rapid elongation. Thus, cells elongated to about three times their initial length while in the zone. This cellular elongation is reflected in the growth curve for the *Alsophila:* on the fourteenth day, zone 8 began elongation which was completed by the twenty-fifth day. It can be seen from the distances between curves that during the period of elongation this zone increased about threefold in length. In *Osmunda,* Briggs and Steeves found that zones increase from five to seven times in length, and that cell length increased in similar proportion. It is clear then that the increase in the length of the rachis during the rapid phase of uncoiling is due almost entirely to *cell elongation* rather than increase in the *number of cells* through mitosis. This view is confirmed by the nearly complete absence of mitotic figures or other evidence of recent divisions in the zone.

Rapid cell elongation does not of itself, however, account for *uncoiling* of the frond. Uncoiling must result from greater elongation of the adaxial side of the frond than of the abaxial side. Indeed, in *Osmunda,* the abaxial/adaxial cell length ratios may be as high as 1.43:1 in the outer cycle of the crozier, whereas at maturity, cells on the two sides have a length ratio of 1.0. It appears that as cellular elongation extends into the crozier and cell division diminishes, it is the greater elongation of cells on the adaxial side which leads to the actual straightening of the rachis. The shorter cells of the adaxial side grow faster than those on the back side of the frond and finally cease growth when they are as long as those on the back side.

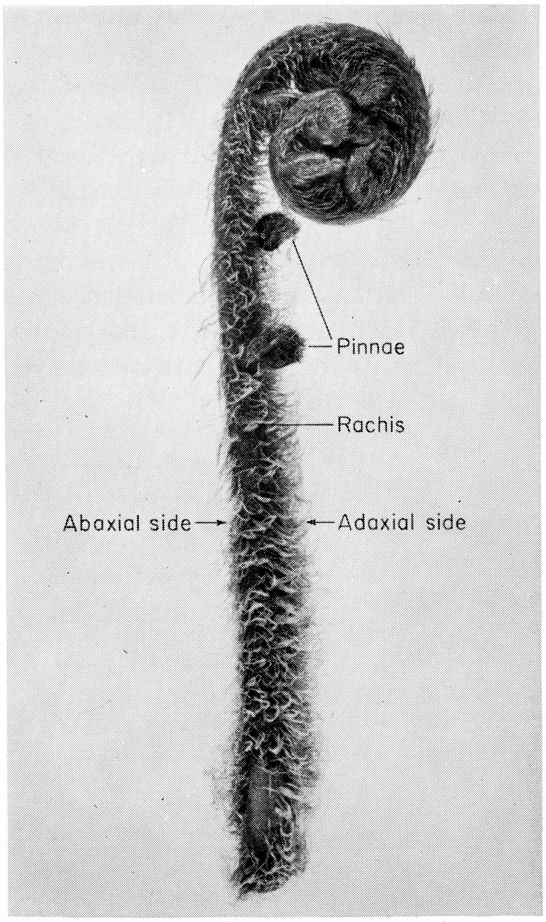
About the same time as the growth measurements were being made, we carried out other experiments which led us to some quite unexpected results. If the pinnae, or leaflets, were carefully excised from the rachis of a fiddlehead which was just beginning to uncoil, growth ended abruptly. Not only did this occur in the fronds of the tree ferns, but in the croziers of seventeen other genera of ferns comprising eight different families. Thus, the cessation of uncoiling in the absence of pinnae seemed to be a general phenomenon in ferns. Inasmuch as the rachis remained green and healthy in appearance, it seemed unlikely that uncoiling had ceased because of exces-

sive injury to the rachis. Moreover, it was possible to remove as many as two-thirds of the pinnae without markedly impairing frond growth. Apparently the presence of at least some pinnae was needed in order for crozier uncoiling and growth to occur. This led us to suggest that one or more growth substances were produced by the pinnae. For convenience, we termed these postulated substances the pinna substance, or uncoiling substance.

After performing additional experiments, we recognized an unusual and important property of this postulated pinna substance. When pinnae were removed from the *outer* coils of the frond — i.e. pinnae that would be at the lower part of the frond at maturity — the crozier uncoiled normally. When pinnae were removed from the *inner* coils of the frond — i.e. pinnae that would be at the tip of the frond at maturity — the crozier stopped uncoiling at the point where the pinnae were removed. We interpreted these results in terms of our pinnae substance model, and concluded that the substance must have the remarkable property of being effective upon the rachis



Growth of a crozier of Alsophila. *The abaxial side of a living crozier was marked with India ink into 19 numbered zones as described on pages 15 and 18. As the frond uncoiled, the length of each zone was measured and plotted. The diagrammatic croziers indicate the position of the zone the day the measurement was made. Divergence of a curve from the one below it indicates growth. Parallel curves indicate no growth.*



Fiddlehead of Alsophila (Cyathea) australis.

only at points *below* the pinna from which it came. In short, the substance was preferentially transported away from the tip of the frond toward the base of the leaf.

The apparent property of one-directional transport at once brought to mind the group of plant hormones known as the auxins. These hormones, in particular indole-3-acetic acid, are of the greatest importance in plant growth and tropisms. Moreover, it is solidly established that little or no auxin is moved upward toward the tip of a leaf or flower. Rather, it is conducted *away from* the tips of plant organs.

With these hormones in mind, Briggs and Steeves conducted experiments which greatly strengthened the idea that the pinna substance is an auxin. They placed the cut surface of the base of small expanding fronds in contact with cubes of agar. After a period of contact with the base of the young frond, the agar block was assayed for auxin in the standard auxin bioassay known as the *Avena* test. They found that copious quantities of auxin were produced by the growing frond. In fact, they were able to measure the auxin produced by the pinna itself, and found that the amount of auxin closely correlated with the rate of growth of the frond. Moreover, fronds from which the pinnae had been removed *did not produce auxin.* Thus, a remarkable parallel existed between the properties of the auxins of the fronds and the properties of the pinna substance. In order reasonably to conclude that the pinna substance and auxin were one and the same, however, at least two additional pieces of information were needed. First, could the pinna substance be isolated and chemically identified as an auxin? Second, could "physiological" quantities of pure synthetic auxins applied to fiddleheads replace the effect of the pinna substance?

In order to answer the first question we attempted to isolate the pinna substance. The pinnae from expanding fiddleheads were frozen with dry ice and quickly ground to a coarse powder. At −10°C the powdered fronds were extracted with methanol. In turn, the methanol extract was applied to paper chromatograms, which were developed in various solvent systems. The chromatograms were then compared with control chromatograms of a great many chemically pure substances, including the auxins indole-3-acetic acid (IAA), indole-3-pyruvic acid, and indole-3-acetonitrile. Some chromatograms of the pinna extract were bioassayed with *Avena* coleoptiles to determine at which regions of the chromatograms biological activity occurred. The *Avena* coleoptile is a particularly sensitive assay object for measuring small amounts of cell elongation hormones, and the fern frond itself could not readily be used as an assay object because the amounts of hormone obtainable from chromatograms were too small. There was no simple way to supply such small amounts of the hormone to the fern frond.

Other chromatograms bearing the pinna substance were sprayed with indole color-test reagents. These test reagents develop characteristic colors when in contact with various indoles. Moreover, the complexes formed show distinctive fluorescent colors under ultraviolet light. We found that the extract of each fern contained material which moved to the

same position on the chromatogram as control spots of IAA, showed similar test reagent reactions and fluorescent properties as IAA, and had a biological activity similar to IAA. For these reasons it seems fair to conclude that young fiddleheads contain the chief plant growth hormone, indole-3-acetic acid. An additional biologically active substance in *Cibotium* has total activity much lower than that attributed to IAA. In other ferns, no growth-promoting substance other than IAA was detected. The principal pinna substance thus appeared to be IAA.

The remaining and critical question was, could IAA be experimentally shown to bring about uncoiling? In order to determine this, fiddleheads were freed of their pinnae, thence of their natural supply of hormone, and a bit of lanolin paste containing IAA was applied to the rachis. By mixing fairly large amounts of IAA with lanolin, a small portion of the IAA slowly diffuses from the lanolin into the plant. Unfortunately, the amount of material required is so great that it was not possible to test the natural substance by this method.

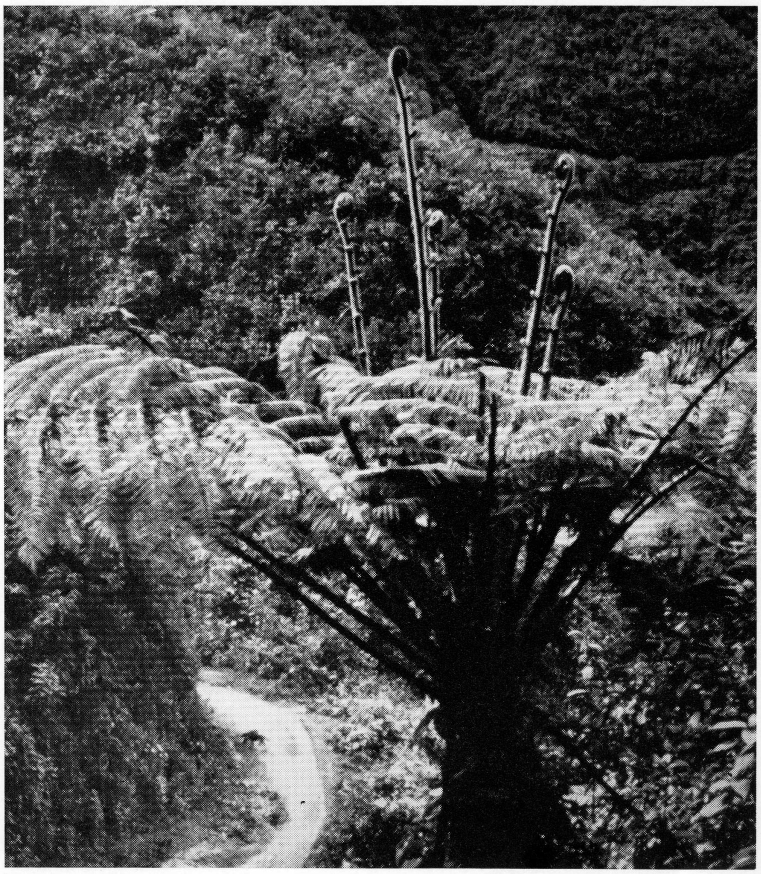
In *Osmunda,* uncoiling was found to proceed up to, but not beyond, the ring of lanolin paste. These results are analogous to those from the study in which pinnae had been removed from only the tip half of the frond but not the lower half. With *Alsophila* and *Cibotium,* IAA-lanolin paste was applied at or near each point where a pinna had been excised. Pinnae were removed from control fronds and lanolin alone was applied.

Striking growth occurred in fronds supplied with IAA. There was essentially no growth in controls. Actually, at the most favorable concentration of IAA, 0.1 mg IAA per gram of lanolin, the growth almost equaled that of intact fronds of the same species. Both the rate and the duration of growth were similar. Moreover, the optimal concentration of IAA supplied to the fronds proved to be the same as those which have been shown by other workers to replace the natural supply of auxin in various flowering plants. Concentrations of IAA which were higher or lower than 1.0 mg/gm led to less striking growth, although response was evident.

In a sense, the essentials of Koch's principles thus have been fulfilled. The postulated pinna substance is isolated from fiddleheads and chemically identified. When the pure pinna substance is applied to fiddleheads depleted of their natural supply, growth and uncoiling resume.

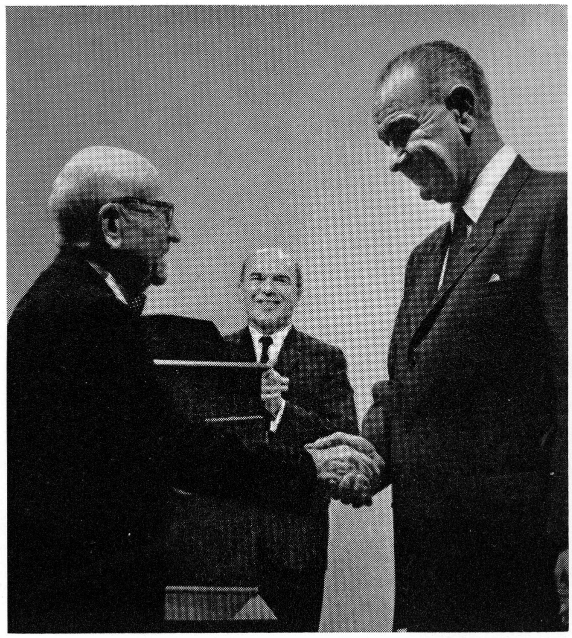
We have explored a little of the chemistry and physiology underlying a familiar biological process. Attention must now be directed toward the manner in which the hormone acts in affecting cell elongation. One promising approach is suggested by the impressive advances being made by zoologists studying the relationship between animal hormones and gene action. Comparable techniques may result in greater understanding of the onset and termination of cell elongation in the crozier uncoiling of ferns and in plant development generally.

Dr. Voeller, now an assistant professor in the University, received the Ph.D. degree from Rockefeller in 1961, and the uncoiling of the crozier was the subject of his doctoral dissertation.



Fiddleheads on a large tree fern of the genus Cyathea, *growing near the remote mountain village of Zacatepec in the State of Oaxaca, Mexico.*

MEDAL TO ROUS AND VAN SLYKE



Dr. Rous (LEFT) *and Dr. Van Slyke* (RIGHT) *receive the National Medal of Science from President Johnson*

PEYTON ROUS and DONALD D. VAN SLYKE, emeritus members of the University, were among the recipients of the National Medal of Science awarded by President Johnson at the White House on February 10. The Medal, which was first presented in 1962, is given in recognition of individual achievement in the physical, biological, mathematical, or engineering sciences. In conferring the Medal upon this year's eleven recipients, President Johnson stated that it is "the highest tribute their government can pay them."

Peyton Rous has been with the Rockefeller for fifty-seven years. Early in his career, in 1911, he reported in the *Journal of Experimental Medicine* that a cell-free filtrate of a fowl sarcoma could produce a tumor when inoculated into another fowl of the same breed. This discovery has lost none of its impact on cancer research over the last fifty-five years; and Dr. Rous, who still can be found in his laboratories in Flexner Hall, has remained an important contributor to the increasing knowledge of the relationships between viruses and cancer. Dr. Rous has also worked rewardingly in additional fields, such as tissue culture. He has received many other honors, including the Walker Prize of the Royal College of Surgeons, the Lasker Award, the Gold Medal from London's Royal Society of Medicine, the United Nations Prize for cancer research, and in 1964 the gold-headed cane of the American Association of Pathobiologists and Bacteriologists.

Donald D. Van Slyke joined the staff of the Rockefeller in the same year as the young Peyton Rous, first working as a biochemist with Phoebus Levene on the structure of nucleic acids and later heading his own group of laboratories in the Hospital. Dr. Van Slyke contributed a long series of fundamental papers on the physical chemistry of the blood, developed the generally adopted Van Slyke Apparatus for exact biochemical measurement of the blood and other body fluids, and also made notable contributions to the knowledge of the natural history of Bright's disease. He is widely credited with having created and pioneered an entire new field of research – that of clinical chemistry – and with having developed the tools, techniques, and rigorous standards of the new discipline. Most of the leaders in the field of clinical chemistry today are either directly or in-

directly students of Dr. Van Slyke. He has received numerous honors here and abroad, including the Order of Jade (China), the John Phillips Memorial Award of the American College of Physicians, the Kober Medal, the Scientific Achievement Award of the American Medical Association, and in 1965 the Elliott Cresson Medal of the Franklin Institute. Since 1948 Dr. Van Slyke has been associated with the Brookhaven National Laboratories, where he is still engaged in active research.

In presenting the awards, President Johnson said, "We are very pleased today to welcome men who have chosen to be on the side of truth, and to pursue truth as a way of life. They honor us by their presence and by their accomplishments. They honor the entire Nation."

THE ROCKEFELLER UNIVERSITY

NEWS

New Appointments

THE APPOINTMENTS of Neal E. Miller and Peter R. Marler as Professors in The Rockefeller University and of Richard L. Penney and Roger S. Payne as Assistant Professors have been announced by President Bronk. These new faculty members, all of whom are engaged in research in the behavioral sciences, will join the staff of the University by July 1, 1966.

Dr. Miller, who is now James Rowland Angell Professor of Psychology at Yale University, is noted for his research on the biological basis of motivation and learning. Dr. Miller was graduated from the University of Washington in 1931 and in 1935 received the Ph.D. from Yale, where he spent most of his early career, working at the Institute of Human Relations. During World War II he was with the Army Air Corps, serving from 1942 to 1946, and became the director of the Psychological Research Project, Flying Training Command. He returned to Yale in 1947, became Professor in 1950, and Angell Professor in 1952.

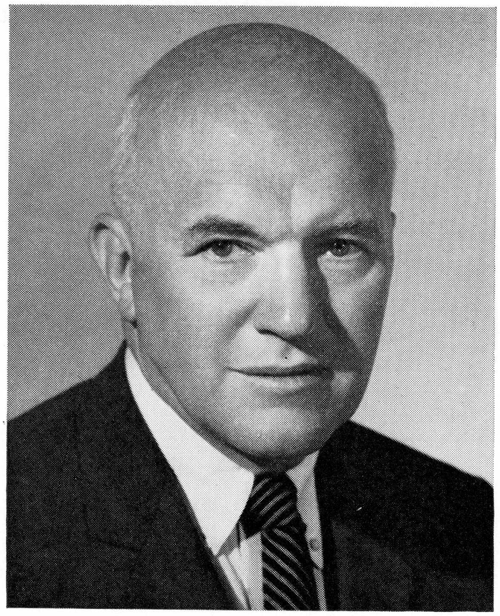
Dr. Miller has been President of the American Psychological Association and Vice President of the American Association for the Advancement of Science; he is a member of the National Academy of Sciences and has received many other honors. He is so far the only psychologist to receive the National Medal of Science (1964), which was awarded in part for "sustained and imaginative research on the basic principles of learning. Through brilliantly conceived and skillfully executed experiments, he and his students have served as a major spearhead in the current breakthrough in the area of motivation and learning."

Dr. Miller has been making weekly visits to Rockefeller during the current semester to conduct a seminar in physiological psychology on the "Biological Basis of Learning," in which some of his own significant experiments on the effects of direct electrical stimulation of the brain are being discussed.

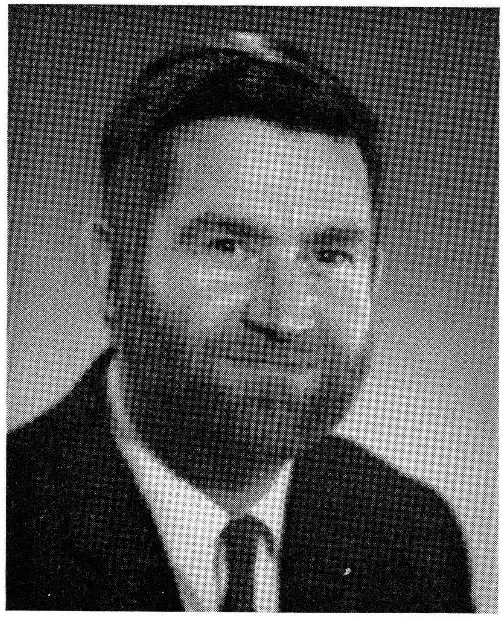
Peter Marler, who will also join the University this summer (see page 9), is at present Professor of Zoology at the University of California, Berkeley. Dr. Marler is a specialist in vertebrate behavior, particularly animal communication systems. He received the B.Sc. in 1948 and a Ph.D. in Botany (Plant Ecology) in 1952 from the University of London. He was granted a second Ph.D. in 1954 from the University of Cambridge, this time in Zoology (Animal Behavior). From 1954 to 1956 he was Research Fellow at Jesus College, Cambridge, and in 1957 he came to the University of California as Assistant Professor of Zoology. He has continued working in the United States, except for the year 1964-65 when he was a Guggenheim Fellow studying vocalizations in forest monkeys in East Africa. In 1965 he was appointed Professor at Berkeley. He became a naturalized citizen of the United States in 1963.

Dr. Marler's research includes descriptive studies of the natural behavior of animals, particularly the function and evolution of animal communication systems. He is interested in the experimental analysis of the role of experiential and genetic factors in the development of animal vocal behavior, especially the ontogenetic basis of bird song.

Like Professor Marler, Doctors Penney and Payne



NEAL E. MILLER



PETER R. MARLER

will be associated with the new Institute for Research in Animal Behavior that is conducted jointly by The Rockefeller University and the New York Zoological Society. Richard L. Penney, who will join Rockefeller May 1 as Assistant Professor, received the B.S. from St. Olaf College, Minnesota, in 1957 and the Ph.D. in 1963 from the University of Wisconsin. He is currently Assistant Professor in the Department of Pathobiology of the School of Hygiene and Public Health at Johns Hopkins. Dr. Penney has been particularly interested in the behavior of Adelie penguins – the topic of his thesis and a number of journal articles.

Roger S. Payne, who on July 1 will also become Assistant Professor in the University, is at present Assistant Professor of Biology at Tufts. He received the A.B. from Harvard in 1957, where he did undergraduate work with Professor Donald Griffin on the echolocation of bats, and the Ph.D. from Cornell University in 1962. Dr. Payne's recent work has been on the acoustic location of prey by owls and the directional sensitivity of the ears of noctuid moths.

Music

Referring to the literature of medieval and renaissance music, Noah Greenberg once said, "We have just barely skimmed the surface . . . there are vast continents of music that have yet to be discovered, understood, and performed." Mr. Greenberg's activities as musical discoverer, conductor, and composer have led to a great deal of the initial exploration of early music and to its increased availability for an appreciative modern audience.

Mr. Greenberg founded the New York Pro Musica in 1952 and was its leader and conductor until his death early in January. The Pro Musica concerts have been warmly received at Rockefeller for the past three years, and the skill, freshness, and vitality with which the music is performed are a tribute to Mr. Greenberg, as well as to the artists and composers. Tempo, dynamics, and instrumentation must be determined primarily by the conductor's own good taste and knowledge – the notes may be written down, but the composer very rarely indicated who was to sing or play them.

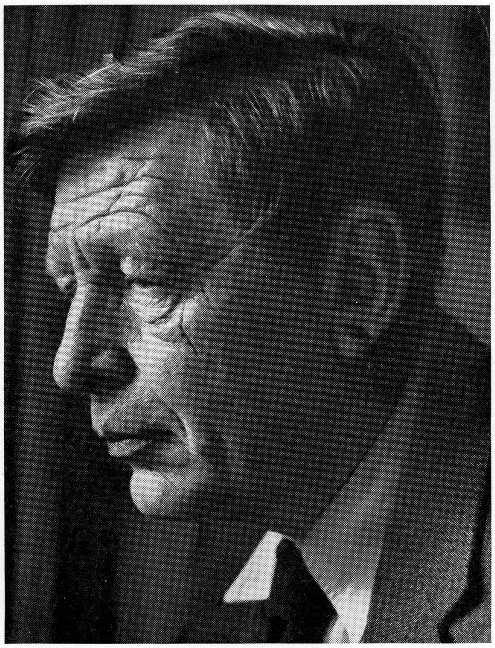
One of the most exciting ventures undertaken by Mr. Greenberg and the Pro Musica was the reconstruction of two twelfth-century musical dramas, the *Play of Daniel* and the *Play of Herod.* Through the beautiful music and pageantry of these plays, Mr. Greenberg and his performers re-created the atmosphere of another age, revealing medieval man's mystic religious feelings and restoring for modern man a sense of the simplicity with which the deepest human emotions can be expressed.

Poetry

"EVERYONE should have two languages," said the poet. "His own, and mathematics." The poet was W. H. Auden and the occasion the year's first Student Forum, on January 11. Participating were sixty graduate students, faculty members, and friends of the University, some of whom had heard Mr. Auden read from his works and discuss the art of writing on an evening in January 1962 when he made his initial appearances as guest speaker at Rockefeller.

Here was a poet who studied biology under Julian Huxley at Oxford, a writer who has equated the contemporary scientist with the classical hero as the only man in modern society embarking on true adventures, the Auden who — in "The Dyer's Hand" — said, "When I find myself in the company of scientists, I feel like a shabby curate who has strayed by mistake into a drawing room full of dukes," and the gamesman who — again, in "The Dyer's Hand" — drew a straight line from Iago to practical joker to scientist.

Mr. Auden did not present a speech to his audience but parried, with wit and urbanity, questions on topics ranging from Tolkien's three-volume epic, *The Lord of the Rings,* to the ineffectiveness of the writer in the social order. He also read selections from his works. One poem, from his recently published book *About the House,* concluded with a lovely elegy to Louis MacNeice, and was set on the outskirts of Vienna where Auden now has a farm and spends part of the year.



W. H. AUDEN

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Many physicists have amused themselves by versifying and parodying well known literary works. As Professor Goudsmit points out, Kurd Lasswitz, the mathematical physicist, has written delightfully in German. Best known is his parody of *Faust* commissioned by the Breslau Mathematical Society in 1882. There is also the famous Copenhagen *Faust* performed at the Institute for Theoretical Physics in 1932, and not long ago the *New Yorker* published an amusing poem about anti-matter by the Berkeley physicist, Harold P. Furth.

The great Scottish physicist, James Clerk Maxwell, was especially prolific. Admirers of Tennyson will recognize in the iambic tetrameters of Maxwell's opening verse to "Lectures to Women on Physical Science," allusions to Tennyson's "The Princess":

The lamp-light falls on blackened walls,
    And streams through narrow perforations,
The long beam trails o'er pasteboard scales,
    With slow-decaying oscillations.
Flow, current, flow, set the quick light-spot flying,
Flow current, answer light-spot, flashing, quivering, dying.

Less familiar will be the reference to William Thomson's mirror galvanometer of the day, often used as a telegraph signalling device. Many more verse travesties came from Maxwell's pen, including this timely example, "Valentine by a Telegraph Clerk to a Telegraph Clerk" — one of Dr. Goudsmit's favorites:

The tendrils of my soul are twined
    With thine, though many a mile apart,
And thine in close-coiled circuits wind
    Around the needle of my heart.

Constant as Daniell, strong as Grove,
    Ebullient through its depths like Smee,
My heart pours forth its tide of love,
    And all its circuits close in thee.

O tell me, when along the line
    From my full heart the message flows,
What currents are induced in thine?
    One click from thee will end my woes.

Through many an Ohm the Weber flew,
And clicked this answer back to me,—
"I am thy Farad, staunch and true,
Charged to a Volt with love for thee."

John Frederic Daniell, William Robert Grove, and Alfred Smee were inventors of electric cells and contemporaries of the author.

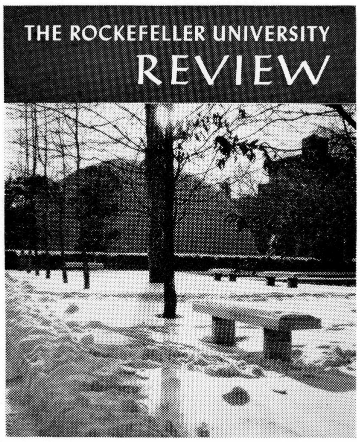
¶ Professor Edward L. Tatum was one of four Nobel laureates who appeared before a special Senate subcommittee to urge that the government take an active role in curbing population expansion. Dr. Tatum said that the recent progress achieved in understanding the molecular basis of heredity offered new potentials for the intellectual and physical development of man. These potentials cannot be realized, he warned, unless the world population can be kept in step with natural resources and with education and opportunity for intellectual development. The alternative might be a new "Dark Age" in which intellectual, scientific, and social progress would come to a halt. The other three Nobel laureates speaking at the Washington hearings were Dickinson W. Richards, Jr., of the Columbia University Medical School, Dr. Albert Szent-Györgyi of the Marine Biological Laboratory at Woods Hole, Mass., and Dr. Polykarp Kusch of Columbia University.

¶ Thomas S. Kuhn, Professor of the History of Science at Princeton University, spoke at Rockefeller University February 1 on "Science as Conceptual Revolution." Dr. Kuhn's thesis, illustrated by events in the development of understanding of the nature of electricity, is that scientific progress is not a steady accretion of knowledge, but rather is marked by sudden shifts — revolutions — in scientific thought. These abrupt transitions are metaphorically comparable, as Dr. Kuhn explained, to the sudden shifts in vision experienced by the observer of a Gestalt diagram, in which the same details may be seen as composing, alternatively but not simultaneously, two completely dissimilar pictures. This same thesis is the subject of Dr. Kuhn's recent and highly acclaimed book, *The Structure of Scientific Revolutions,* on which his lecture at the University was based.

¶ Professor Lyman C. Craig received the $1000 Fisher Award in Analytical Chemistry at the winter meeting of the American Chemical Society on January 17 in Phoenix. The next day Professor Craig presented his Award Address, "The Use of Membrane Diffusion as an Analytical Tool," before a symposium held in his honor in which two other members of the Rockefeller faculty participated. William H. Konigsberg, an affiliate of the University, spoke on "The Development of Peptide Separation Methods for Amino Acid Sequence Determinations," and Professor Edward H. Ahrens, Jr., on "Isolation, Quantification, and Identification of Neutral and Acidic Steroids in Biologic Mixtures."

¶ John J. Cebra, who received the Ph.D. from Rockefeller in 1960, has been appointed Associate Professor of Biology in The Johns Hopkins University. He has this year received the P. R. Edwards Award by the Southeastern Branch of the American Society for Microbiology. The Award is given in recognition of outstanding work in microbiology and is named for ASM past president Philip R. Edwards, an authority on enteric bacteria. Dr. Cebra's work has been concerned with active sites on antigens, antibody structure and chemistry, fluorescent protein tracing, and the activities of lymphoid tissues. Dr. Cebra, who was Associate Professor in the University of Florida Medical School, is at present at the Wright-Fleming Institute of St. Mary's Hospital, London, on an NIH Career Development Award.

¶ John Maddox, former editor of the *Review,* has been appointed editor of the British journal *Nature,* considered in professional circles as one of the most influential of the scientific magazines. Mr. Maddox, Welsh-born, was graduated in 1947 from Christ Church College, Oxford. After teaching theoretical physics for six years at the University of Manchester, he joined the *Manchester Guardian.* In 1963, he came to Rockefeller where he was the first editor of the *Review,* which made its initial appearance in February 1963, succeeding *The Rockefeller Institute Quarterly.*



THE LATE afternoon sun casts long shadows across the gardens north of Caspary Auditorium after a snowfall in January. Photographed by Joseph Barnell.

ACKNOWLEDGMENTS: Pages 2 and 3 illustrations adapted from *Particle Jungle* film through the courtesy of the American Institute of Physics. Page 6 photograph courtesy of *The New York Times.* Page 10 photographs *top* courtesy of Donald R. Griffin, *center and bottom* by M. Woodbridge Williams courtesy National Geographic Magazine © National Geographic Society. Page 11 photographs *top* courtesy of Carleton Ray, *bottom left* courtesy of Roger Payne, *bottom right* courtesy of Richard Penney. Pages 14 and 18 photographs by The Rockefeller University Illustration Service. Page 15 illustrations: col. 1 from R. Kräusel, 1930, "Die Flora des deutschen Unterdevons," *Abh. Preuss. Geol. Landesanst.* n.f. 131: 1-92; col. 2 *left,* from K. Goebel, 1932, *Organographie der Pflanzen,* 3. Aufl., Dritter Teil, Erste Halfte, Jena, G. Fischer; col. 2 *right,* from Francis E. Lloyd, 1942, *The Carnivorous Plants,* Chronica Botanica Company, Waltham, Mass. Page 16 illustration from Nathaniel Lord Britton and Addison Brown, 1913, *An Illustrated Flora of the Northern United States, Canada, and the British Possessions,* Charles Scribner's Sons, New York. Pages 17 and 19 illustrations by the author. Page 23 photograph by George Cserna.