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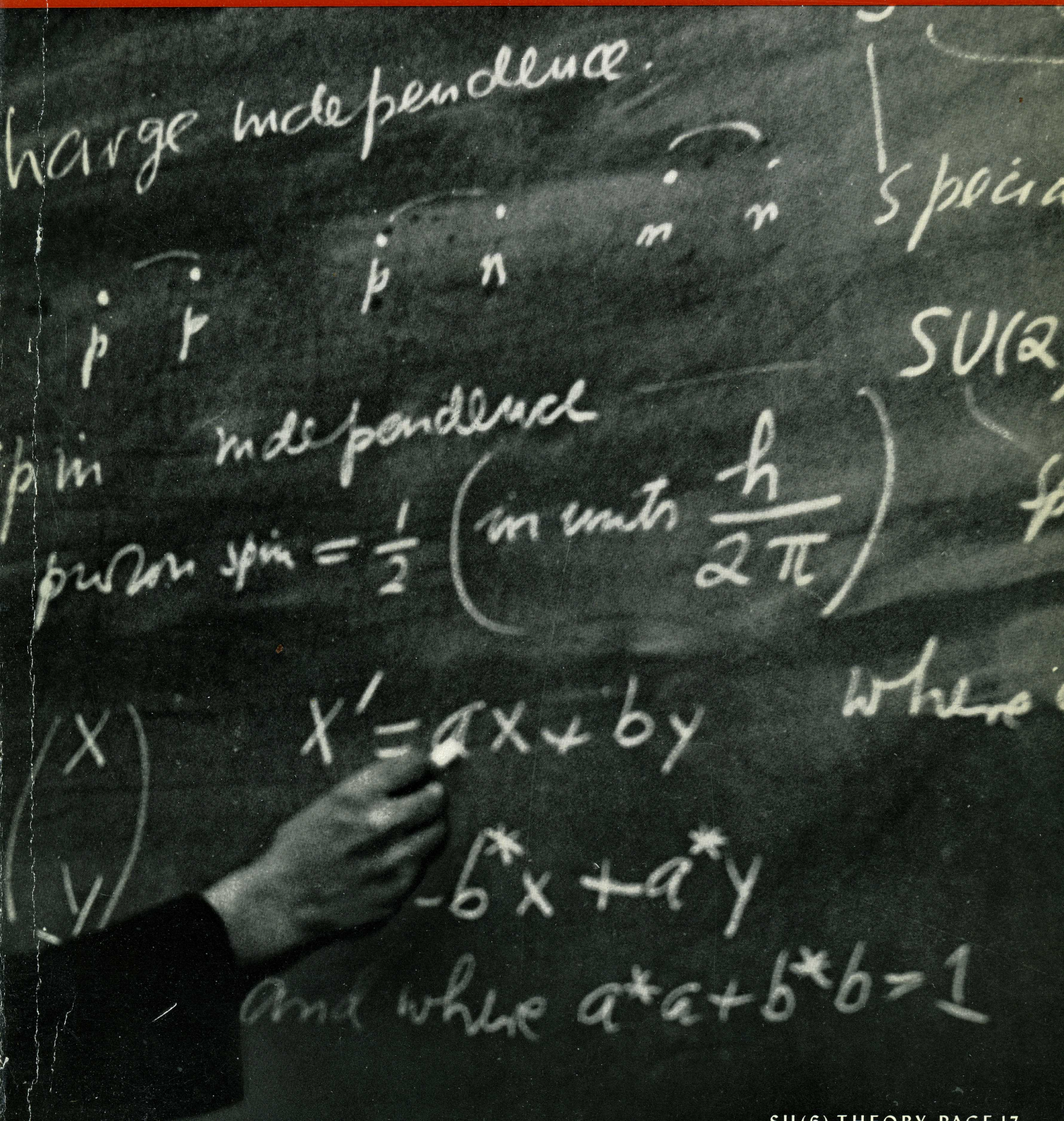

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BOTH THE SAYING AND THE THINKING

BY THE HONORABLE CHARLES E. WYZANSKI, JR.

ELLERY SEDGWICK spoke of his profession as "A Happy Profession"; and his successor has illustrated to you why. Fortunately, Mr. Weeks, Mr. Sedgwick, and myself, all belonged to what Mr. Sedgwick called "the best club in America"—The Harvard Board of Overseers. And thus, from time to time in Mr. Sedgwick's life, I occasionally saw him, and know something of the extraordinary qualities, both professional and lay, which he brought to the *Atlantic*. He increased the circulation of the *Atlantic* from 13,500 to 135,000. But the magnitude of his accomplishment certainly was not to be measured quantitatively. Mr. Weeks has spoken of the role that Mr. Sedgwick played in connection with certain types of controversial issues. It was in the *Atlantic Monthly* that a courageous editor allowed Felix Frankfurter to write about Sacco and Vanzetti. The *Atlantic Monthly* may not have been Ellery Sedgwick's pulpit. He spoke of himself as not having a speaking part, but being in the wings, free to hiss or applaud, or, I suppose, make grunts which were illustrated for us just a moment ago by Mr. Weeks.

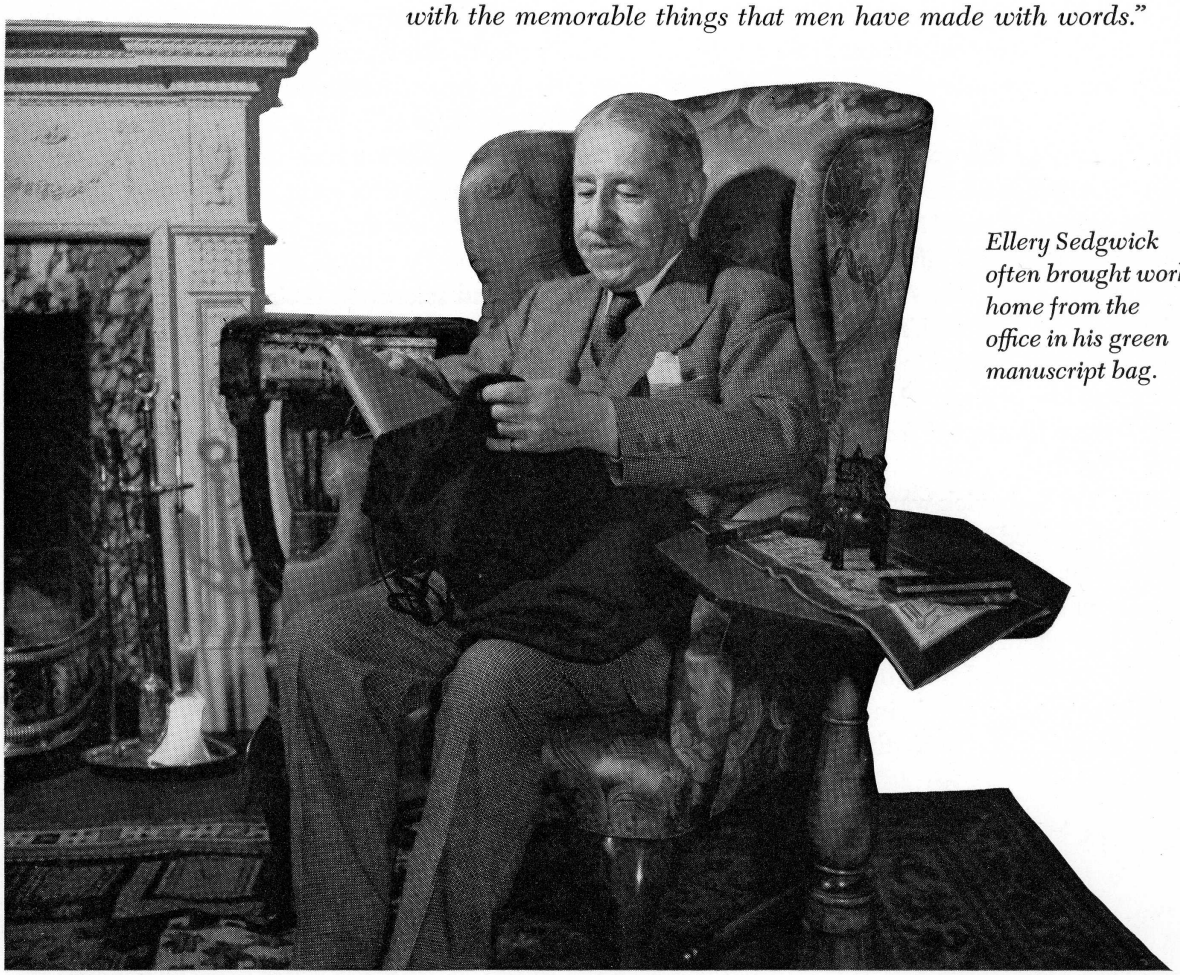
Early in life Mr. Sedgwick was a teacher of Virgil at Groton. And, indeed, was he not all his life like Virgil with Dante, someone leading others to their greatest performance? I rather hope that Mr. Sedgwick would have alertly detected where I got my title, "Both the Saying and the Thinking." He, I suspect, would have spotted it as being part of the sixth fragment of Parmenides. "Both the saying and the thinking are one thing." Mr. Sedgwick would have known that I did not intend to embrace all of Parmenides' doctrine, including his faith that by reason alone, without regard to the senses, one could find the whole of truth. I merely wanted to say that, so far as I am concerned in the great debate, I am on the side of those who believe in The One and not in The Many. Mr. Sedgwick might have warned me that I would have done better if I had taken my title from Sir Isaiah Berlin and said I want to be classified as a Hedgehog and not as a Fox. I am quite sure that Mr. Sedgwick would have looked with sympathy upon that classification because a hedgehog is at least a cousin of the patron saint of the Porcellian Club.

In any event, my theme in general, to which I am going to come by very slow stages, is the unity of literature and science in their most fundamental aspect. I realize that the topic assigned me does not seem entirely to permit of that possibility, for I was asked to speak on literature as a medium of interpretation of the role of science in our culture. But I hope to be, in general, faithful to the outline of the topic, though not to fulfill in every detail its command.

Literature and Science

Of course, in speaking of science, I assume that the man who formulated the topic must have thought of science in the grand manner, as an end in itself, as an exciting aesthetic experience, as a field of rigorous

"BOTH THE SAYING AND THE THINKING"
the second Ellery Sedgwick Memorial Lecture on Science and Literature, was given in Caspary Auditorium on 26 May 1964. Judge Wyzanski was presented by Edward Weeks, present Editor of the Atlantic Monthly, *who described with humor his own affectionate recollections of his distinguished predecessor, Ellery Sedgwick, in whose memory this series of lectures is named: "I welcome this opportunity to tell you why I think it is important that those of us who love English, good books, and the unfettered competition of ideas, should cherish the memory of Ellery Sedgwick. He had such an insatiable zest for life. He would respond to new people as to new ideas, as if an electric current had suddenly been plugged in. His eyes would light up, his whole being would radiate the delight in the intercourse...."*
The Honorable Charles E. Wyzanski, Jr., is District Judge of the United States Court in Boston, Trustee of the Ford Foundation, Fellow of the American Academy of Arts and Sciences, Member of the International Labor Organization, and Honorary Senior Fellow of the Society of Fellows of Harvard University. In his warm tribute to Judge Wyzanski, President Bronk concluded with the words of the English essayist, F. L. Lucas of Cambridge: "Like a gigantic snowball, larger and larger, faster and faster, science hurtles with us all into the unknown.... But whatever the future, no part of our traditional inheritance from the past seems less likely to be superseded than human speech—together with the memorable things that men have made with words."



Ellery Sedgwick often brought work home from the office in his green manuscript bag.

method and as a constant invitation to exercise with discretion the search for great adventure. But I am not unmindful that to the average person – of whom I suppose there are relatively few in this audience – science bears the burden of its child, scientific technology. And for many people the notion of science is primarily that of practical dominion: power over things, the capacity effectively to organize, and the ability to exploit resources natural and human.

It would be quite impossible to talk today about science without knowing that for many people I must address myself in part to that close relative of science, scientific technology. But I hope you will bear in mind that though I am making this necessary concession, and doing it promptly at the outset, I intend to return later to talk of science in its more essential, primary, and noble aspect.

For all of us, the scientific technology of today is a familiar phenomenon. After all, communication, transportation, and every other aspect of our physical lives are quite different from those of a preceding generation.

Rate of Change

Perhaps one might truly say that of the effects of scientific technology, the first and most obvious is the rate of change which it has imposed upon us. Needless to say, every generation on this planet has seen a change from earlier times, but the rate has accelerated immeasurably in the lifetime of persons sitting in this room. To some of you the Inaugural Lecture given ten years ago by C. S. Lewis, when he became at Cambridge University the first professor of Mediaeval and Renaissance literature, will be familiar. His lecture, "De Descriptione Temporum," was addressed to the problem of the rate of change. He said there were those who had criticized him for being willing to take a professorship which united Mediaeval and Renaissance learning. But he said: Was the union in that single professorship as strange as the union in his own experience of the outlook of his father, his son, and himself? For, surely, the change between his father and his son was greater than the change between the outlook of the Mediaeval man and the Renaissance man. Whether in literature or in art, whether in science or technology, whether in social or religious life, the change was so spectacular that it far outreached the change of hundreds of years in past eras.

We have lived in a time in which the rate of change has occurred not only in outward matters but in affairs of the mind. Is there any learned man fifty years of age who does not know that in his specialty, that which he learned as a university student is for the most part obsolete? In his own experience he has found it necessary to go to school a second time in middle life, or, rather, continuously to go to school throughout his middle years.

Moreover, we have lived in a time in which this rate of change has presented us with the most serious problems of social and political control. I need hardly refer to the 6th of August 1945 when a cloud shaped like a man's hand seemed to threaten us with a second Noah's Flood, but this one of fire. We have lived in an era in which we have seen the greatest changes, not merely in Asia, in Africa, in Latin America, in the Caribbean, but within our own land. For empires have dissolved not only on the wide-scale map, but within our own land. Those who dislike what goes on may choose to echo Rathenau's statement that we are faced with the vertical invasion of the Barbarians. But whether one likes it or not, the unsettling force of technology in connection with all kinds of social and political arrangements is one of the dominant characteristics of our time. It is not only labor and the Negro that illustrate this. Consider our children and ask yourselves whether the car and the contraceptive have not entirely altered the patterns of control which were traditional.

Throughout all realms there has been a shaking of the older values. We are aware that as far back as 1857 when, as it were, Darwin and Wallace nailed on the door of the Linnaean Society their theses, they started to open that portal through which a new era of mankind was sure to enter. For some, the time when that door swung open was the time when God walked out.

Shaking of Values

Even those for whom so serious a consequence was not the result, agree that entirely new premises had to be sought and that a complete restudy of the values which were to guide mankind had become appropriate. Now faced with this awful problem – and

awesome problem – there are those who hope that somehow we shall enter upon a new Axial Period, to use the phrase which, borrowing from Von Strauss in the middle of the nineteenth century, Jaspers and Schrödinger have chosen to denominate that period centering on the fifth century B.C., but beginning as early as the eighth century B.C. and concluding somewhere around the second century – the period during which Isaiah and the Prophets wrote; the Ionian philosophers did their work; and, as far east as China, Buddha and Confucius flourished.

The Grand Style

While an Axial Period would surely be welcome, what reason have we to suppose that there is in the wings at the moment someone ready to assume this mantle of prophecy? Had we not better content ourselves at least for the present with trying to analyze more deeply the science, the literature, the art, and the humanities as we know them? And is it not appropriate again to return to the title and to see what the relation is between science and literature? I am sure that neither the man who chose the topic nor you would expect me to be so trivial as to talk about the kind of relation between literature and science involved in a popularization of science, even by so competent a hand as that of H. G. Wells in fiction and in nonfiction, nor of Rudyard Kipling, particularly in the second phase of his short-story writing when he dealt in fictional and in poetic form with the second Industrial Revolution. Nor do I suppose that you or the author of the subject tonight expected me to address myself to the degree to which literature has been a precursor and harbinger of science, whether in theory, as in Democritus and Lucretius, with respect to the atom, or in practical terms, as in the case of Jules Verne with the submarine and the rockets to the moon.

I rather expect that you and he want me to address myself to what I call the grand style of science, and its relation to our way of looking at things. No doubt, Mr. Sedgwick would want me again to bear in mind Alfred North Whitehead, a friend of his and a friend of mine, and a man about whom Mr. Sedgwick and I talked the last time that I saw Mr. Sedgwick in his home – which he quite proudly knew to be the house in which his family had lived for seven generations, and which was built by an early ancestor who had been the Speaker of the House of Representatives in the time of George Washington. Mr. Sedgwick, I think, would have wanted me, as I hope you want me, to consider science in its long-range view – not just seven generations, but all the way back. As a classicist, would he not ask me to remember that there was a day – to be sure before Aristotle and Plato – when science was not separate from philosophy but was then acknowledged – as only, it seems to me, Santayana among contemporary philosophers has acknowledged it – as being a part of a general Life of Reason, part of one of the Realms of Being, merely an aspect of the total thought of man.

At any rate, not only in classical times but even as late as mediaeval times, science was not sharply divided from the humanities. The trivium and the quadrivium originated, we are told, by Philo and perfected by Alcuin, do not draw their lines on the basis that science is in one area and the humanities are in another area. It is merely a seventeenth-century and later notion that science is a different department of learning from that of the humanities. But that segregation is a mere matter of academic convenience and should never blind us to the fact that in universities, and in intellectual life generally, truth in the form of organized knowledge is a seamless web.

Conventional Account

Science is, nonetheless, something which we can deal with as being a sister in a family of related forms of knowledge. And it does have its special characteristics as well as its general family character. There is no doubt that science deals, primarily, not with facts, but with observations of facts. And science is an attempt to organize those observations upon the assumption that the observations are not random and the result of arbitrary disconnected events but reflect in some way a system of order. Science assumes that the observer may either be left out of the equation entirely or, what is probably the case more frequently, be recognized as being in the equation, but, once recognized, can be discounted and the equation can be examined as though there were no observer. Science goes on the theory that quantitative judg-

ments have a value, and that qualitative judgments are nonscientific and are more apt to reflect mere prejudice or tradition than anything inherent in the observed events themselves. Thus science deals allegedly objectively and with a positivist basis. Supposedly science uses mathematics primarily as a tool for exposing what is in the observed facts. It is a mere method of explication, adding nothing to what is observed. And thus, if we are to believe the account given by the scientists, science leaves unanswered problems – ultimate problems of cause and effect, ultimate problems of free will, ultimate problems of qualitative value.

But do we really get from this conventional account of science what does indeed take place? Is it true that scientists are as positivist as they depict themselves? Do they not at least go so far as Justice Holmes in admitting that they are in the belly of *a* universe – not only *inside* a universe, but inside *one* universe, not many universes? Do they not thus admit the unity within which we dwell? Is there not

> . . . a spirit that impels
> All thinking things, all objects of all thought,
> And rolls through all things.

But the scientists may say: "No concession by us is made that there is one designer – there may be many universes." We do not know beyond this world. And even in this universe wherein we dwell, there is much that makes us wonder if there is only one designer. For how can we explain the evil and the accidental? In the terms of Sir Charles Sherrington (adapting Tennyson), do we not find that Nature is "red in tooth and claw"? Is there any altruism? Many of you will recall his famous example of the worms who enter the snails, who are in turn devoured by the sheep, who get sheep-rot and who die; and Sir Charles Sherrington's question as to how it is that what appears to us to be the higher life is sacrificed for the lower life.

It seems to me that scientists do concede that we are in *a* universe with order, and that they do not in reality pay much attention to the possibility of conflict among the masters that run this order.

Moreover, is it really true that science depends merely upon observation and the explication of what is evident in observation, when rigorous tools, mathematical or otherwise, are put to testing what is implicit in the observation? Is that what the great geniuses of science tell us? Some of you will have noticed a recent book about Alfred Wallace, to whom I have already referred. You will know of a letter which he wrote, describing how he came upon the theory of evolution. And the description which he gives, which he says parallels the experience of Darwin, is to me an entirely indistinguishable experience from poetic fury. It is an imaginative experience from without – where, I say not; but not as a result merely of an unfolding of experience in the way that mathematics is alleged to unfold observation.

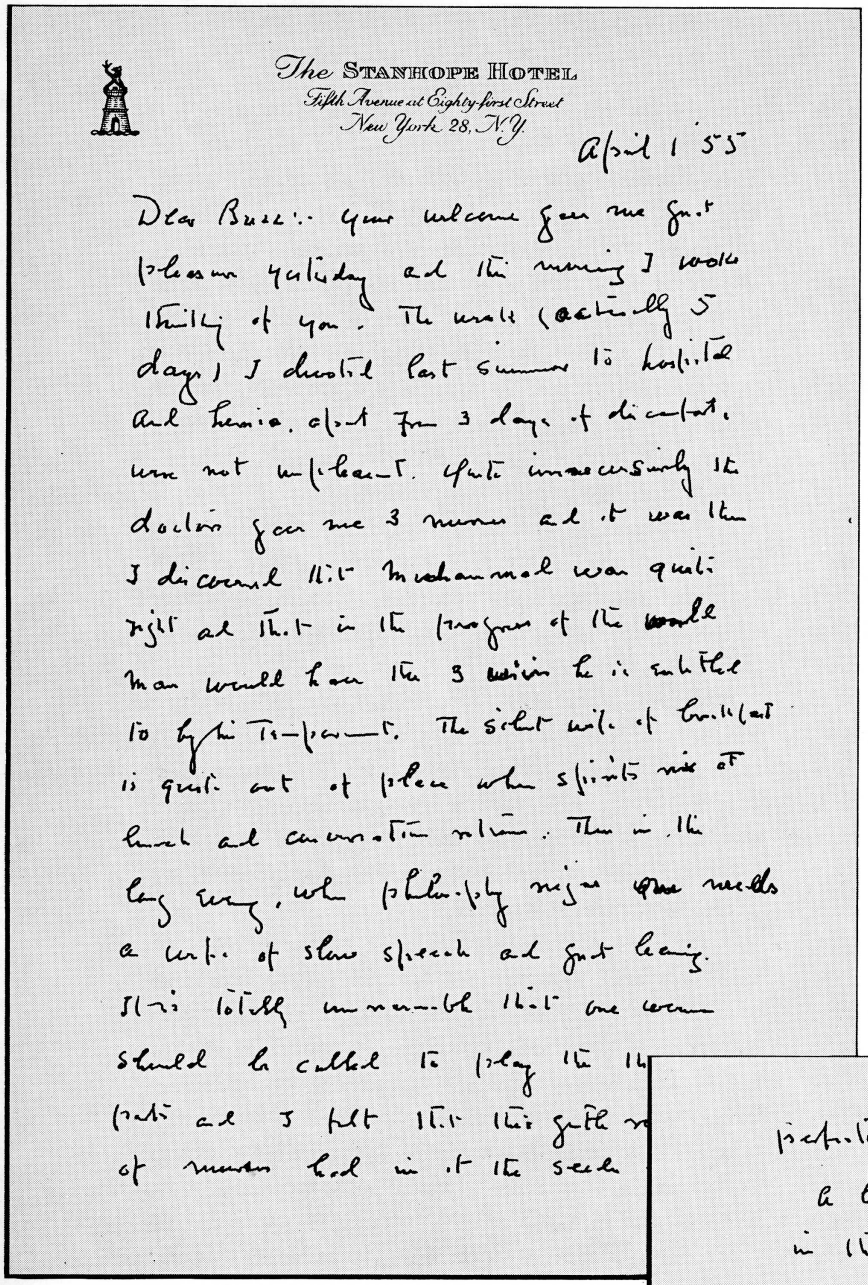
At any rate, what I have tried to say about science up to now is that although it has characteristics which make it a distinguished younger sister in the family of the Muses, it is nonetheless basically like the other sisters.

And now let me turn to literature, and by literature I mean not only the writing of prose and verse. I mean, as I hope the man who set the topic meant, the humanities in their widest reach, including art and music and philosophy and all those disciplines which fall within the general area of arts and sciences other than the natural sciences.

Now I am not unaware that there are persons of scientific bent who suggest that literature is a kind of opiate – a fairy tale for the amusement and entertainment of the tired populace, a method by which we are led more easily to accept those social controls which are inevitable in an organized society, a way of making it possible for a man to face with courage and stability that which he cannot conquer. If this were all the humanities did, we ought not to regret it. To have "Negative Capability" is, as Keats told us, a great accomplishment. If we can "envisage circumstance all calm, it is the top of sovereignty." And literature which performs that function is not to be regretted.

Nor need we feel badly if literature did little more than stimulate the sense of reverence and tradition. Man cannot live merely on the basis of that knowledge which is immediately useful. He needs the structure of a social order for communication, for confidence; and literature insofar as it stimulates his sense of reverence, has performed a most important social task.

But the scientist errs if he thinks that literature


The Stanhope Hotel
Fifth Avenue at Eighty-first Street
New York 28, N.Y.

April 1 '55

Dear Buzz:- Your welcome gave me great pleasure yesterday and this morning I woke thinking of you. The week (actually 5 days) I devoted last summer to hospital and hernia, apart from 3 days of discomfort, was not unpleasant. Quite unnecessarily the doctors gave me 3 nurses and it was then I discovered that Mohammed was quite right and that in the progress of the world man would have the 3 wives he is entitled to by his temperament. The silent wife of breakfast is quite out of place when spirits rise at lunch and conversation returns. Then in the long evening, when philosophy reigns one needs a wife of slow speech and quiet learning. It is totally incredible that one woman should be called to play the three parts and I felt that this gentle round of nurses had in it the seeds of perfection. So enjoy it while you may.

A lovely morning with our friend Rorimer in the Museum marveling at the new treasures which being still unpublished are hidden in the bowels of the cellar.

Good luck and show the doctor you are as good a man as he is.

Affectionately
(Signed) Ellery Sedgwick

TEXT:

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Ellery Sedgwick wrote this letter to Barklie McKee Henry at The New York Hospital the day before Mr. Sedgwick became gravely ill and entered the Hospital of The Rockefeller Institute. Both men recovered to enjoy many more pleasant associations: Mr. Sedgwick continuing his editorial interests and Mr. Henry as a Trustee of The Rockefeller Institute.

is merely a palliative and a device for keeping men within the chains of a society. Literature is responsive to science. A former President of Harvard University, James Bryant Conant, suggested – and Dr. Bronk reminds me that E. H. Carr, the British historian, agrees with Mr. Conant's view – that there is a distinction between science and the humanities on the ground that science is a progressive discipline with cumulative knowledge, whereas the humanities, and literature in particular, are noncumulative; that the insights, according to Mr. Conant, of the ancients in literature are equal to the moderns, whereas what has been learned by scientists over the period of thousands of years has made modern scientists the beneficiaries of accumulated knowledge. Is Mr. Conant right? Is Mr. Carr right?

Now, there is no doubt that some ancient men, like the authors of the Psalms, the Greek dramatists, Dante, Goethe, all seem greater than any living man. But which living scientist is greater than Faraday? Which living scientist is greater than Newton?

Wider Range

Surely Mr. Conant did not mean that the scientists of today are greater than their predecessors. He meant that they have a wider range, a greater depth, as a result of what their precursors had done. And is this not true of literature? Before the nineteenth century, who is it that wrote about the non-affluent, non-middle class people in our society? Before Dickens and Dostoevsky and James Joyce and Kafka, what did we really know about those who were not kings and queens and people around well-to-do establishments, or sufficiently well-off to have members of their clans in the writing classes? Until the end of the nineteenth century, was there an American novel in which the hero, not some side character, was not white, Protestant, and usually of English stock?

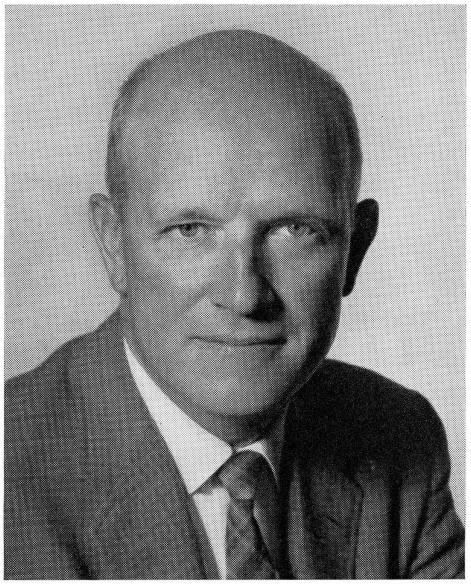
The range of literature is responsive to the culture of a society. The culture of a society is responsive to its technology. Its technology is responsive to the advances in science. Q.E.D. Advances in science promote advances in literature and the preceding progress in science ultimately transmits itself in some strange way into a progressive widening of the boundaries of the humanities.

But there is something more in common between science and the humanities. It is true that each depends to a considerable extent upon the atmosphere of the times, the climate of the society, the friendly collaboration of those in the same or adjacent calling. But each, for its greatest advances, ultimately turns upon the single mind of the man of genius – someone through whom the parts of experience filter so that they seem somehow to have a unity not heretofore perceived, someone who sees in experience that which has been accomplished as well as that which is possible, and gives a new and greater vision.

Were my field science, I am sure I could give appropriate illustration. But mine is the law; and to a man of law I am going to turn not for what he said, but for what he drew to my attention. John Sparrow, formerly a barrister, now the Warden of All Souls', has recently published in collected form his *Independent Essays,* the first of which deals with "Great Poetry" or, as he makes you see, with the great poets. For, as he says, great poetry does not turn upon a single line nor even a short poem or two, but upon a poetic mind, reaching deeply into the manifold forms of experience and drawing from them a new vision of unity. He gives many examples; but I shall in concluding take one that he cites and which I am ashamed to say I did not know until I read it in his essay, although I dare say that to many of you in this room "A Dialogue of Self and Soul" by William Butler Yeats will be familiar territory:

> A living man is blind and drinks his drop.
> What matter if the ditches are impure?
> What matter if I live it all once more?
> Endure that toil of growing up;
> The ignominy of boyhood; the distress
> Of boyhood changing into man;
> The unfinished man and his pain
> Brought face to face with his own clumsiness;
> The finished man among his enemies? . . .
> I am content to follow to its source,
> Every event in action or in thought;
> Measure the lot; forgive myself the lot!
> When such as I cast out remorse
> So great a sweetness flows into the breast
> We must laugh and we must sing,
> We are blest by everything,
> Everything we look upon is blest.

TWO VICE PRESIDENTS APPOINTED



CARL PFAFFMANN

MACLYN MC CARTY

THE APPOINTMENTS of Carl Pfaffmann and Maclyn McCarty as Vice Presidents and Professors of The Rockefeller Institute have been announced by President Detlev W. Bronk. They will both collaborate with the President in the general administration of the Institute. Dr. McCarty will also be especially concerned with the clinical sciences and their extension and with the conduct of the Institute Hospital; Dr. Pfaffmann will foster the development of the behavioral sciences.

Dr. Pfaffmann, who is now Florence Pirce Grant Professor of Psychology at Brown University, was graduated from Brown in 1933; as a Rhodes Scholar he received the degree of B.A. from Oxford in 1937 and the Ph.D. from Cambridge University in 1939 under the direction of Lord Adrian. After a year at the Johnson Foundation of the University of Pennsylvania and four years as a psychologist in the United States Navy from which he retired as a Commander, he returned to Brown University where he has been since that time. He is a member of the National Academy of Sciences and the American Philosophical Society. He has recently completed a two-year term as Chairman of the Division of Behavioral Sciences of the National Research Council. In 1960 he received the Warren Medal of the Society of Experimental Psychologists and in 1963 the Distinguished Science Award of the American Psychological Association.

Dr. Pfaffmann is an international authority on the physiology and psychology of the senses of taste and olfaction and the behavior they control. He is unusually well fitted to relate the many behavioral studies now under way at the Institute and to aid in extending their scope because of his broad competence in the neurophysiological bases of psychology and his familiarity with all aspects of the related behavioral sciences.

Dr. McCarty, who is Professor and Physician in Chief, has been a member of the professional staff of the Institute since 1941, coming first as a Fellow of the National Research Council. He was graduated from Stanford University in 1933 and The Johns Hopkins University in 1937 with the degree of M.D.; at the Hopkins he was successively intern, Assistant Resident, and Assistant in the Department of Pediatrics. He served in the Rockefeller Unit of the United States Navy as a Lieutenant Commander from 1942 to 1946.

Dr. McCarty is a member of a number of profes-

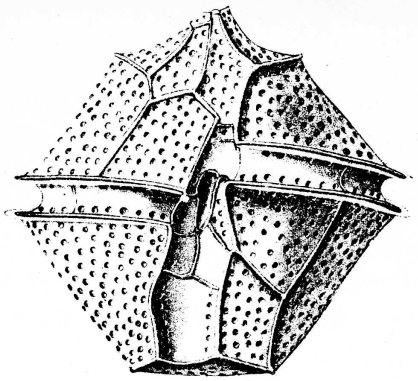
sional societies, including the National Academy of Sciences and the Association of American Physicians. He received the Eli Lilly Award in Bacteriology and Immunology in 1946. In collaboration with Avery and MacLeod, he isolated the substance responsible for transformation of pneumococcal types and identified it as deoxyribonucleic acid. The great importance of this work in demonstrating for the first time the biological activity and genetic significance of DNA is widely recognized. Dr. McCarty assumed his new duties on 1 January and Dr. Pfaffmann will join the faculty and administration on 1 July.

SCIENCE MEDAL TO DR. DOBZHANSKY

PROFESSOR THEODOSIUS DOBZHANSKY was among eleven recipients of the National Medal of Science, awarded on February 8. The Medal, which was first presented in 1962, is given annually to persons who are "deserving of special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, or engineering sciences." Before this year, only six such medals had been awarded.

Dr. Dobzhansky received this high honor for his many contributions in the field of genetics and evolution. The medals were presented personally by President Johnson at the White House. The ceremony was followed by luncheon at the National Academy of Sciences.

Dr. Dobzhansky is replete with honors this season. In the previous week, on the other side of the Atlantic, he received the degree of Doctor Scientiarum Agronomicarum, Honoris Causa, from the University of Louvain.



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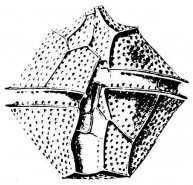


This article is based on the work of Dr. J. Woodland Hastings, Professor of Biochemistry at the University of Illinois. Dr. Hastings is editor of The Journal of General Physiology *published by The Rockefeller Institute Press, and a frequent visitor to the Institute; last spring at a meeting of the Developmental Biology Discussion Group he described some of the studies here reported. Dr. Hastings will be a member of the visiting faculty in residence at the Institute next year.*

MOST INVETERATE ocean travelers and many seaside dwellers as well can recall nights when the sea flashed with light. On such evenings, a touch of an oar or a splash of a pebble sparked an incandescent glow, a wading child traced an enchanted moonpath through the water, while the churning propellers of an ocean liner set the entire sea ablaze.

This "burning of the waters," as the early voyagers called it, has been recorded from all the corners of the world. Columbus saw mysterious lights in the water the night before he landed on San Salvador. Paulus Biononius wrote in 1674 that the water off the coast of Iceland "shineth like Fire bursting out of a Furnace." Johann Reinhold Foster, naturalist for Captain Cook's voyage aboard the *Resolution*, described the sea as "being all over on fire" during a gale off the Cape of Good Hope. Darwin mused on these same lights from the *Beagle* along the South American coast: "As far as the eye reached," he wrote, "the crest of every wave was bright, and the sea above the horizon from the reflected glare of these livid flames, was not so utterly obscure as over the vault of the heavens." As the *Spray* slipped through the Torres Strait into the Arafura Sea, Joshua Slocum saw that "her wake was a path of fire."

For some observers, the sea lights had a special, ominous meaning. The Romans, always on the watch for portents, recorded phosphorescence of the sea. Along our own northern Pacific coast, the Indians patrolled the shores in the spring looking for the sea glow; to them its appearance meant that the coastal mussels, a staple of their winter diet, had become poisonous. From then until fall, when the flashing warnings ceased, the Indians generously posted sentinels to warn off unwary seaside foragers.

Benjamin Franklin speculated briefly on the nature of the flickering lights. At first he believed them to be electrical in origin, but his closer examination of the phenomenon — carried out by shaking seawater in a bottle — led him to the conclusion, quite correct, that it might be caused by an "extremely small animalcule," an opinion soon confirmed by the microscopists. Although a number of marine creatures are luminous, the "burning of the sea" is caused chiefly by members of a group of "small animalcules" known as the dinoflagellates. Protozoologists and algologists alike lay claim to the dinoflagellates because, while they possess the animal-like attribute of motion and, sometimes, the ability to ingest particles of food, they are also capable of photosynthesis. These organisms, which make up a large proportion of the ocean's plankton, contain chromatophores, pigment-containing bodies, that give them a reddish or red-brown color; colonies of dinoflagellates cause the peculiar red tides off our own coasts and have given the Red Sea its name. The first discovered of the phosphores-

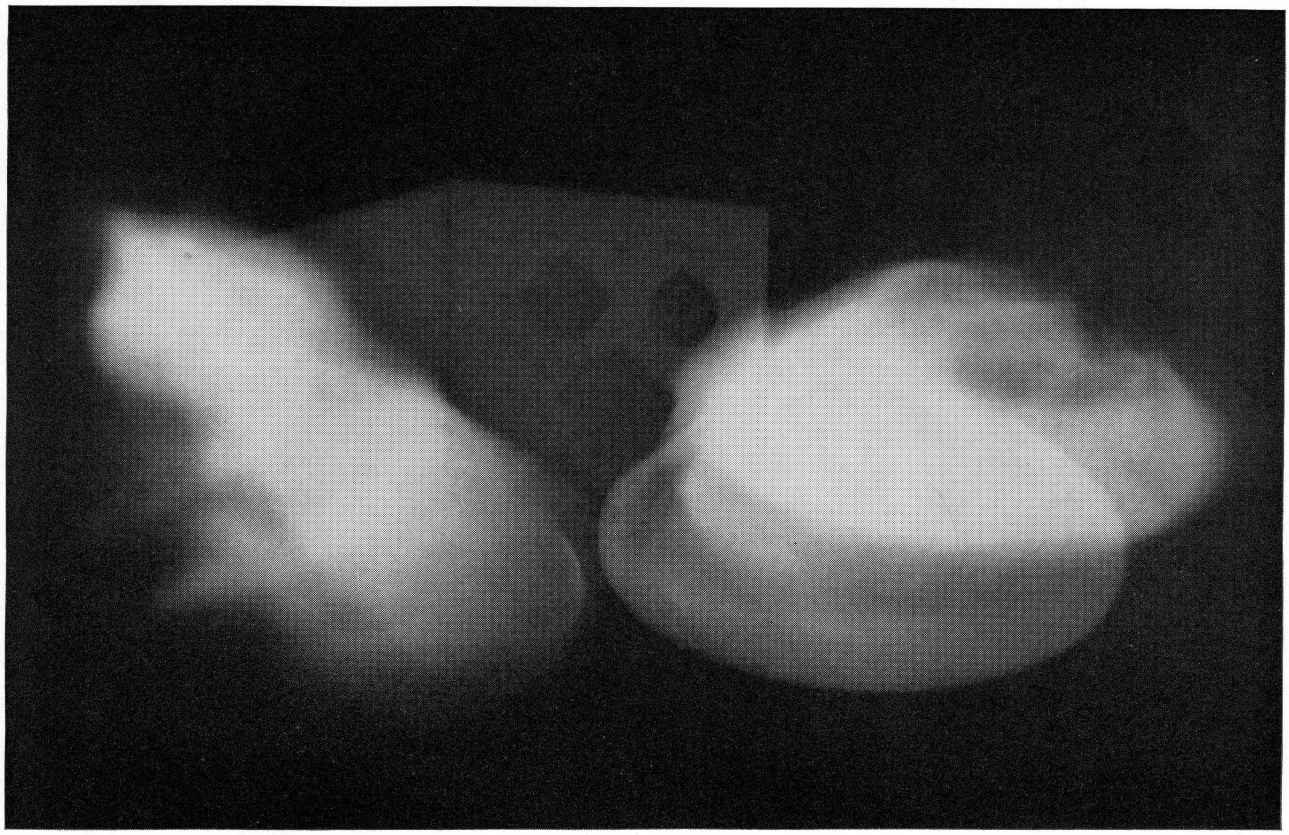
cent dinoflagellates was a relatively large organism, *Noctiluca miliaris*. Almost a millimeter in diameter and thus on the edge of being visible to the unaided eye, *Noctiluca* was accurately described and drawn by observers more than one hundred years ago. Other luminescent dinoflagellates are considerably smaller; it is one of these smaller ones, *Gonyaulax polyedra,* that has commanded the special interest and attention of Dr. J. W. Hastings.

To the microscopist, *Gonyaulax polyedra* possesses a highly ordered and characteristic appearance. Only about 50 micra in diameter, it is armored with cellulose plates and girdled by a sulcus or deep groove in which one of its two flagellae beats transversely. The other beats simultaneously in a shorter, posterior groove. It is this beating of the two flagellae at virtual right angles to one another that gives the dinoflagellates their characteristic spinning motion as they move through the water, a motion, incidentally, that students of hydrodynamics have found to be extraordinarily efficient. Indeed, *Gonyaulax polyedra* may be considered to be a highly efficient organism in all respects, at least by the stringent test of evolutionary survival; microscopic fossils indicate that it has persisted virtually unchanged at least since the Jurassic epoch, some 170 million years ago.

Actually, although *Gonyaulax polyedra* is one of the organisms responsible for the northern Pacific lights, regarded by the Indians as warnings, it is not the source of the poison. This is the special property of a closely related species, *Gonyaulax catenella,* which appears in abundance during the same season. *Gonyaulax catenella* contains an extraordinarily powerful toxin – currently under study by the chemical warfare division of the Army – that mussels concentrate in their liver and which, though not poisonous to them, is very dangerous to higher organisms.

Dr. Hastings first became interested in *Gonyaulax*

The light given off by Gonyaulax is bright enough to read by. In this photograph two agitated flasks of Gonyaulax illuminate the book pages in the background. These cultures are being used at the Institute in experiments conducted by Graduate Fellows Lewis Kleinsmith and Fred Russell Kramer.



polyedra when he observed its phosphorescence or bioluminescence as it is more accurately called, while visiting in La Jolla, California, during the summer of 1955 and learned how little was known of the phenomenon. Actually, bioluminescence is a property of many living things besides the dinoflagellates: bacteria, fungi, sponges, marine worms, jelly fish, crustaceans, clams, snails, squid, centipedes, millipedes, fish, and of course, the familiar firefly. Many of the phyla possess members capable of glowing. Curiously, however, this ability is limited almost entirely to marine life; only a few terrestrial forms and almost no fresh-water organisms have this property, even ones that are closely related to salt-water forms that luminesce. It has been known for some years that the phenomenon does not result from or depend upon the prior absorption of light, as was once believed, but is, rather, a mechanism by which chemical energy is transformed into light energy. As long ago as 1887, the French physiologist Raphael Dubois extracted two substances from the luminous boring clam, *Pholas dactylus,* one of which he termed luciferin (after Lucifer, the bearer of light) and the other luciferase or, simply, the enzyme that acts upon luciferin. By combining the two, Dubois was able to produce the characteristic glow in his laboratory.

Scintillons

Since that time, a number of other bioluminescent organisms, although by no means all, have been shown to owe their luminosity to this combination of luciferin and luciferase. Recently Dr. William D. McElroy and coworkers of The Johns Hopkins isolated luciferin from the firefly, established its chemical structure, and even synthesized it. They have also obtained the enzyme in pure form and demonstrated that the reactions also require oxygen and ATP. Luciferin and luciferase have also been isolated from *Gonyaulax polyedra* in experiments carried out by Dr. Hastings and his group.

In 1963, however, in a discovery that engendered a great deal of interest and excitement, Dr. Richard DeSa, Dr. Hastings, and Dr. A. E. Vatter succeeded in isolating some unusual inclusions from *Gonyaulax polyedra* to which they gave the apt name of "scintillons." Bodies had previously been observed in bioluminescent organisms (some investigators had believed them to be symbiotic luminescing bacteria) but this was the first time they had been extracted in an active form. The isolated particles emit a bright flash when the pH is lowered rapidly from 7.5 to about 5.7. This flash of light which reaches its maximum in less than 40 milliseconds appears to be identical to that seen in the intact cells (page 14).

A Biological Clock

Even more interesting, perhaps, from the biological point of view, are the rhythmic cycles that characterize the luminescence of *Gonyaulax.*

Many biological processes in both animals and plants, as is well known, are timed with respect to the daily tidal, monthly, and annual cycles of the environment. Leaves bud in the spring, flowers unfold in the morning sun, and mice and other night creatures stir after dark. Less familiar, however, is the concept that many of these cycles, particularly the diurnal ones, are endogenous. In other words, even if removed from the daily stimulus of light and dark, many plants will continue to move their leaves and petals in a 24-hour cycle, and many animals, the cockroach, for instance, or the bat, will show alternating cycles of restlessness and quiet. Such internal timing devices have come to be known as biological clocks. *Gonyaulax polyedra,* Dr. Hastings has found, is the possessor of no less than three such timepieces.

In his investigations of the biological rhythms of luminescence, a culture of the tiny dinoflagellates is stimulated by bubbling air through it and the subsequent light emission is measured by a photometer. (One of the great advantages of bioluminescence from the biochemist's point of view, Dr. Hastings reports, is that it can be measured very simply and accurately.)

Using such methods, Dr. Hastings and his colleagues were able to establish, first, that light emission by the organism is 60 to 100 times greater at night than during the daylight; in an artificial laboratory day of twelve hours of dark and twelve hours of light, peak emission occurs just about in the middle of the dark period. If, on the other hand, the cultures are kept in continuous darkness, the same rhythm persists but the total amount of light emitted steadily decreases as the colony grows progressively weaker from lack of energy. (Unlike *Noctiluca* and some other dinoflagellates, *Gonyaulax* lives by photosynthesis alone.) Continuous bright light completely

inhibits the rhythmicity. Dr. Hastings and a collaborator, Dr. Beatrice Sweeney, have been able to show by isolating single cells, that the loss of rhythm is not merely a matter of the colony of cells getting out of synchronization with each other but that rhythm is lost by each cell singly.

In continuous dim light (120 foot-candles), however, both the rhythm and the amplitude of luminescence remain almost the same as during the alternating light-dark cycles. However, in continuous dim light the period tends to deviate somewhat from exactly 24 hours, ranging anywhere from 23 to 27. This tendency to adopt a rhythm which approximates but is not exactly 24 hours in length has been seen in other organisms whose metabolic functions are controlled by biological clocks and the word *circadian* has been coined to cover these approximate diurnal cycles. The circadian rhythm is considered of great theoretical importance since its existence indicates that the clock is actually endogenous rather than dependent on some unidentified environmental factors which would be more likely to have periods of exactly 24 hours.

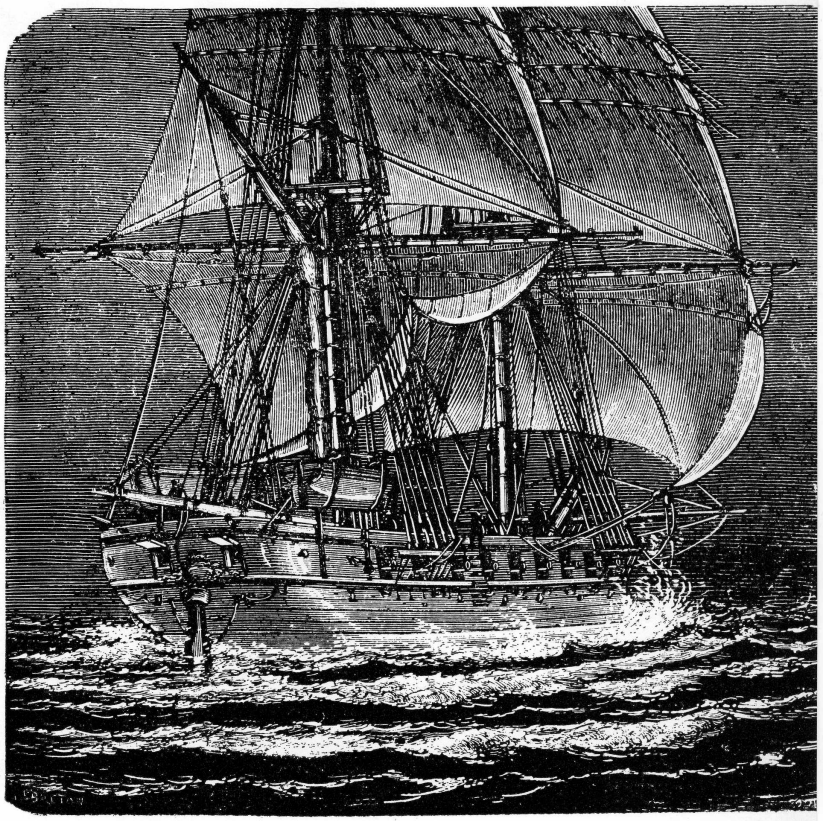
Another important feature of biological clocks — and one that intrigues Dr. Hastings and other biological clock watchers — is how the mechanism, since it is obviously a biochemical one, can remain independent of temperature, a property which is obviously of great importance for the metabolic stability and therefore survival of the clock-directed organism. One must assume the existence of some sort of feedback system. In *Gonyaulax,* the regulating device is comparatively inaccurate. At 16°C, the circadian period is 22.8 hours, while at 26°C it is 26.5 hours. The fact that the clock runs faster instead of slower at lower temperatures strengthens the hypothesis of feedback since it suggests a slight overcompensation in the operation of the mechanism. Dr. Sweeney is considering the possibility of sending a culture of *Gonyaulax polyedra* up in a satellite next year to study possible effects on its biological rhythms.

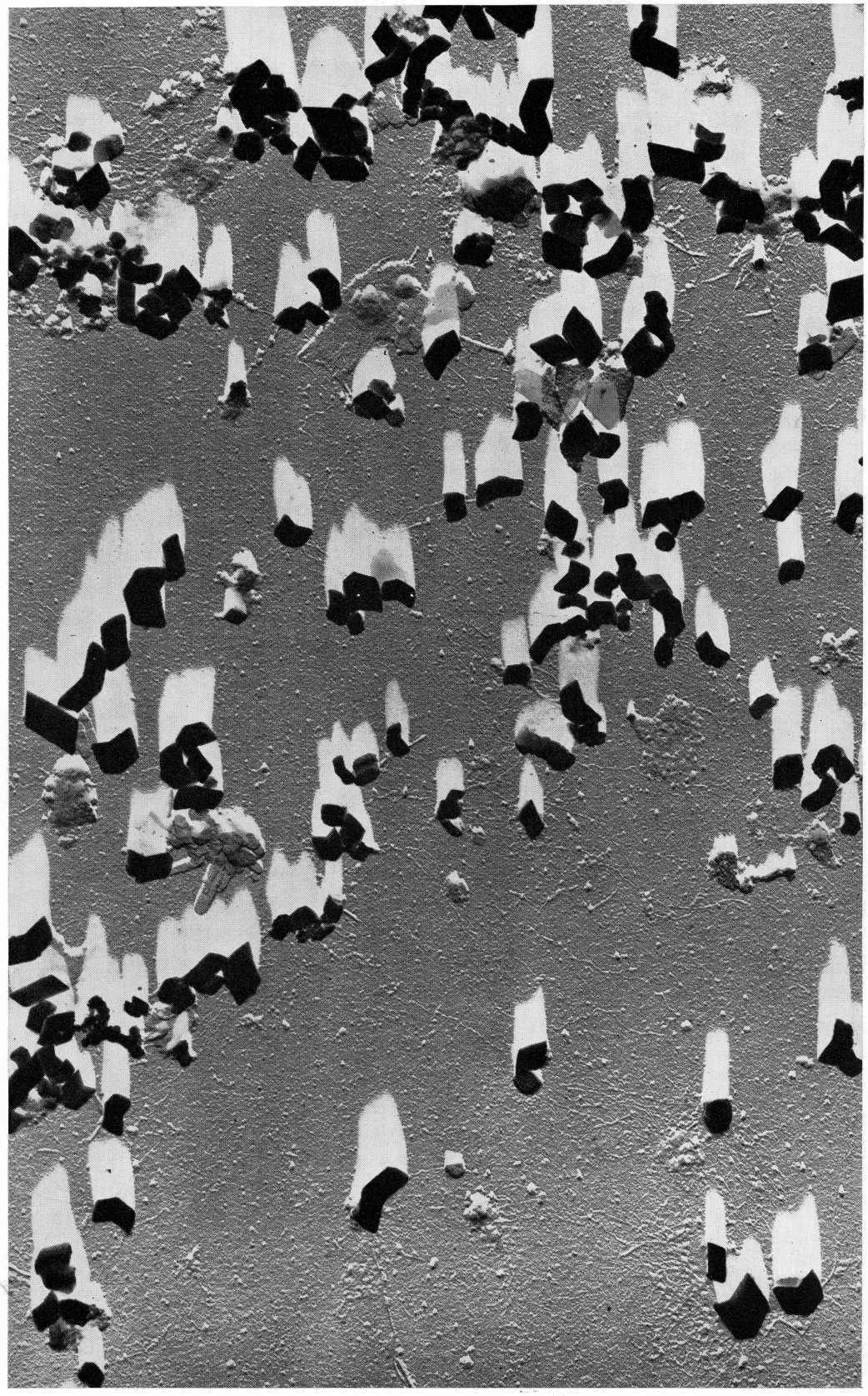
Circadian Rhythms

In addition to luminescence, both photosynthesis and cell division in *Gonyaulax polyedra* also follow endogenously determined diurnal cycles. Moreover, these have maxima which occur at different times of day. In cultures grown in alternating light and dark periods of 12 hours each, the maximum rate of photosynthesis tends to occur in the middle of the "day." Although they occur at exactly opposite points in the cycle, photosynthesis and bioluminescence do not seem to be linked. It is possible by the use of drugs to inhibit the rhythm of the former without affecting that of the latter. Similarly, cell division in *Gonyaulax,* which tends to occur just before either the real or artificial dawn, will also follow a rhythmic pattern in constant dim light. These three rhythms are independent of one another. Either the organism possesses three different systems for measuring time, or one master clock that times each of the processes separately.

These normal circadian rhythms may be variously "entrained" by altering the cycles of illumination in the laboratory. For example, by exposing cultures

"Le navire, en sillonnant les ondes, semble s'avancer au milieu de flammes rouges et bleues... La phosphorescence de la mer est due à la présence d'une multitude d'animalcules." La Terre et les Mers, *Louis Figuier, 1864*





Scintillons, flashing biologically active particles isolated from Gonyaulax polyedra (x 24,000)

to alternating light-dark periods of six, or seven, or eight hours each, it is possible to coax the organism to "follow" a day of 12 hours or 14 hours or 16 hours, with the maxima of the various functions occurring at the appropriate corresponding times. If, however, the entraining frequency differs too widely from the natural frequency, the coupling breaks down and the organism reverts to its innate cycle. Furthermore, when cultures that have been subjected to unusual cycles are returned to constant dim light, they revert immediately to the natural period. In one experiment, cells entrained for seven months to a sixteen-hour day promptly fell into a circadian rhythm when put back in constant conditions of dim light.

Resetting the Clock

The biological clock, though persistent, can be "reset." Organisms that have lost their rhythm by being grown in bright light will regain it after one exposure to a light signal and then will keep it indefinitely in constant light. Moreover, the timing of organisms that have been grown in constant light can be changed by a relatively brief (two and a half hours) exposure to bright light. Depending on when in the cycle the exposure to light occurs, the clock may be advanced or retarded; in Dr. Hastings' words, it is rather like holding back a pendulum for a moment or, alternately, giving it a little push. Lewis Kleinsmith and Fred Kramer, Graduate Fellows at the Institute, have been using *Gonyaulax* in classical conditioning experiments attempting to "teach" them, so far unsuccessfully, to emit light in response to stimuli to which they ordinarily do not respond.

One clue to the nature of biological clocks, recently uncovered by Dr. M. W. Karakashian, in Dr. Hastings' laboratory, is that light emission rhythms can be inhibited by the addition of Actinomycin D to the culture. Actinomycin D has been shown by a number of investigators (chief among whom is Dr. Edward Reich of The Rockefeller Institute) to block the formation of messenger RNA, the molecules that transmit the instructions from the chromosomal DNA for cytoplasmic translation into enzymes and other proteins. Doctors Hastings and Karakashian have been able to show that the actinomycin-sensitive stage in *Gonyaulax* occurs 6 to 12 hours before the expression of the rhythm, suggesting that the clock-related RNA synthesis occurs only intermittently.

In other biochemical studies, Doctor Hastings has shown that both luciferin and luciferase are present in greater amounts in extracts taken from cultures during the dark phase of the cycle than in those taken during the "day." This difference, however, is only about fourfold and so does not begin to account for the magnitude of the day-night differences in light emission.

A fundamental question which arises in studies of the versatile *Gonyaulax polyedra* is why it glows at all. Some bioluminescence is clearly functional. Certain fish, for example, possess luminescent spots on their heads that resemble and appear to function as headlights. The larvae of fungus gnats dangle a long luminescent thread to trap small phototropic insects. Fireflies use their lights as precisely timed mating signals, and female fireworms swarm in the evening waters after the full of the moon to lure the males by their pooled luminous glow.

Usefulness Uncertain

In the case of other bioluminescent organisms, however, including the bacteria and fungi and probably the dinoflagellates, no apparent function can be found for the light emission. Dr. Hastings believes that luminescence may have arisen in these cases as an adaptively useful biochemical mechanism valuable not because of light emission but because of high energy biochemical intermediates formed in the reaction. Such intermediates may have important roles in the biochemical economy of the organism ranging from energy regulation and control to the carrying out of metabolic functions requiring unusually large energy packets. This general problem remains an area of active interest and investigation and no final conclusions are possible at the present time. If, however, this theory is right, according to Dr. Hastings, the light itself in the luminous dinoflagellates can be said to have no "usefulness," serving only to excite the wonder and admiration of mariners, of Dr. Hastings, and of other natural philosophers.

This article was prepared by Helena Curtis, editorial consultant for the Review. *Many of the early observations on the "phosphorescence of the sea" are borrowed from* A History of Luminescence *by E. Newton Harvey, published by the American Philosophical Society. Dr. Hastings worked under Harvey at Princeton University as a graduate fellow.*

DR. MIRSKY IS APPOINTED LIBRARIAN

Dr. Mirsky stands in front of the portrait of Antoine Laurent Lavoisier and Madame Lavoisier in the Institute Library. Dr. Mirsky is holding a first edition of Lavoisier's Traité Élémentaire de Chimie *from the library collection. The painting, by Jacques Louis David, is the gift of John D. Rockefeller, Jr.*

IN JANUARY Professor Alfred E. Mirsky assumed new responsibilities as Librarian of The Rockefeller Institute. In making the announcement, President Bronk stated, "The appointment of this distinguished scholar accents the central importance of the Library and will ensure its wise development during the coming period of great expansion which is contemplated." Dr. Mirsky will continue his previous activities in research and teaching.

In his own characteristically modest summation, Dr. Mirsky says that his special qualifications for the post are simply that he "likes books and likes to use them." Actually, Dr. Mirsky's "liking of books" has kept him in close touch with the library and its problems for almost a decade. His official connection began a number of years ago when he chanced to remark to Dr. Bronk, shortly after the latter's arrival at the Institute, that he felt the library should have more books of a nonscientific nature; he instantly found himself appointed head of a library committee whose function was the selection of such volumes.

In addition to expansion of the library along essentially traditional lines, there will be a future development of quite a different nature, for it is now clear that libraries will be vastly enriched by the use of computer systems for information retrieval. This would undoubtedly be a cooperative program with one or two computers serving libraries all over the country. These machines could store elaborate combinations of references and cross-references in their vast "memories," and provide, within an instant, a list of publications on specific subjects.

In addition to Miss Sonia Wohl, who will continue as Associate Librarian, Dr. Mirsky will be assisted in his new responsibilities by Miss Daphne Morse, Mrs. Zdenka Munzer, Miss Margery McDonald, Mrs. Mary Alice Sell, and Miss Beverly Gilliam, Assistant Librarians.

THE ROCKEFELLER INSTITUTE

NEWS

Dr. Pais Presents SU(6) Theory

A NEW THEORY unifying the known families of nuclear particles was presented in January at the annual meeting of the American Physical Society by the Institute's Professor Abraham Pais. The theory is named SU(6). The so-called "eight-fold way" proposed by Dr. Murray Gell-Mann last year was also known as SU(3) and so the current theory proposed by Dr. Pais and his colleagues may be considered a further step in the direction of ordering information about high-energy particle behavior.

Preliminary work on SU(6) was done last summer at Brookhaven National Laboratory by Dr. Pais, Dr. Feza Guersey of the Middle East Technical University in Ankara, and Dr. Luigi Radicati of the Scuola Normale Superiore in Pisa. Other contributors included Dr. M. A. Baqui Bég of The Rockefeller Institute, Dr. Virenda Singh of the Tata Institute in Bombay, and Dr. Bunji Sakita of the University of Wisconsin.

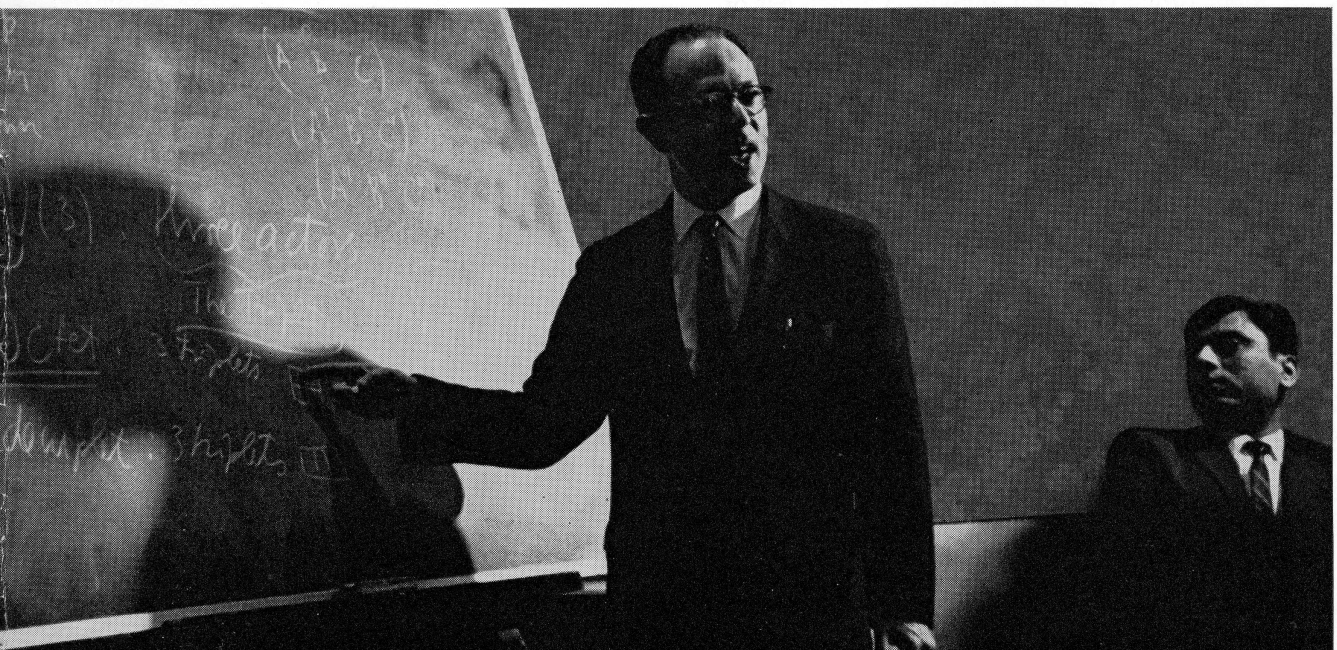
Among the experimental triumphs of the theory, according to Dr. Pais, is a successful prediction of the ratio of magnetic moments between the proton and the neutron. SU(6) theory predicts that the ratio of magnetic moments between the two particles should be 0.667 – the experimental value is .68. (This result was obtained by Doctors Pais and Bég in collaboration with Dr. Benjamin W. Lee of the Institute for Advanced Study.) The more recent work in this field concerns the problem of harmonizing the properties of the SU(6) theory with those of the relativity theory.

Dr. Tatum Speaks at Symposium

PROFESSOR EDWARD L. TATUM was among the speakers at the first of a series of Nobel Symposia which will be held annually to consider the ways science affects man. In his address, which was entitled "The Possibility of Manipulating Genetic Change," Professor Tatum stated we can "fairly confidently predict that to the extent to which we learn to manipulate genetic change in microorganisms, we should in time be able to do so with higher, multicellular organisms." He concluded by saying "It behooves us then, as we are doing in this Symposium . . . to devote some time and deliberate thought to the even more difficult question of how this knowledge is to be used wisely for the welfare of all mankind."

The Symposium, "Genetics and the Future of Man," was held on February 8 and 9 at St. Peter, Minnesota. The Gustavus Adolphus Series has been approved by the Swedish Nobel Foundation, and four of the eight speakers, including Dr. Tatum, were Nobel prize winners.

Professor Abraham Pais explaining SU(6) theory at American Physical Society meeting. Assistant Professor M. A. Bég (RIGHT).



Concert Series

On March 24, members of The Rockefeller Institute staff and their guests will be able to attend one of the first concerts of the Guarneri String Quartet. Following their debut on February 28, the playing of this newly organized quartet received high critical acclaim in the press. Michael Tree (viola) and David Soyer (cello) have played here a number of times previously as members of other groups. The program will include works by Mozart, Berg, and Dvorak.

On April 7, the French pianist, Evelyne Crochet, will perform works by Bach, Schönberg, Mozart, and Schubert. Miss Crochet has appeared as soloist with the Boston Symphony Orchestra and until recently was a member of the music faculty of Brandeis University. Performers in May will include the outstanding concert tenor, Charles Bressler, ably assisted by the pianist David Garvey. The concert series will end on May 19 with the performance by the well-known New York Chamber Soloists, who have chosen works by Boismortier, Haydn, Couperin, Kodály, Mozart, and Aitken.

On April 4, there will be a special afternoon concert given by the Kohon String Quartet, and of particular interest to the Institute. Their performance will open with a composition by Reba Paeff Mirsky, dedicated to the memory of the late Dr. Winthrop J. V. Osterhout, Member Emeritus of the Institute, who died last spring in his ninety-third year.

NOTES

¶ President Bronk has been appointed a member of the National Advisory Environmental Health Committee of the Department of Health, Education and Welfare, a trustee of the New York State Science and Technology Foundation, and a trustee of the New York City Hall of Science.

¶ Professor Rebecca C. Lancefield gave the major address at the 112th Meeting of the Society of Microbiologists, held in New York City on February 11. Dr. Lancefield spoke on "Current Knowledge of Serological Groups of Streptococci."

¶ In January Dr. Ervand G. Kogbetliantz was unanimously elected a Fellow Member of the World Academy of Art and Science. Dr. Kogbetliantz is an Affiliate of the Institute in the field of mathematics and he has been a member of the faculty of the Institute since 1957.

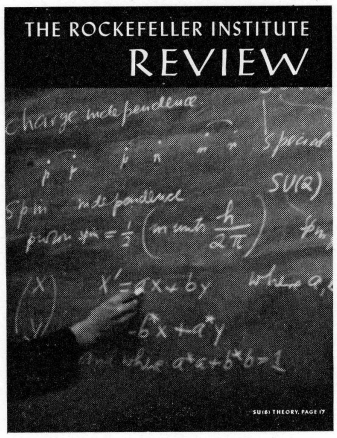
¶ Mayor Robert F. Wagner of New York City announced the appointment of Dr. Vincent P. Dole on February 4, to direct an experimental program at Manhattan General Hospital for the testing of methadone, a heroin-substitute, in the treatment of narcotics addicts. In Dr. Dole's pilot studies on the drug, carried out with six patients at the Institute Hospital, he found that addicts maintained on methadone do not exhibit withdrawal symptoms nor do they experience the euphoria associated with heroin use. Even when kept on high doses for long periods of time, they appear to have a normal capacity for work and study. An additional twenty-five patients will be studied at Manhattan General.

¶ Dr. William J. Robbins, Trustee of the Institute, and Professor Armin C. Braun were among the four speakers at the opening of the Laboratory of Plant Morphogenesis of Manhattan College. The opening ceremonies were held on February 6.

¶ On January 7, Professor Richard E. Shope received the Medal of the New York Academy of Medicine "in recognition of many contributions to our knowledge in the field of virology and epidemiology." The Medal, which is awarded annually, was presented to Dr. Shope by his long-time friend and colleague, Dr. Peyton Rous.

¶ Dr. Gerald M. Edelman has been named an Associate of the Neuroscience Research Program. This Program was organized in 1962 by a group of eminent scientists both here and abroad to foster research and disseminate information on the physiological and biochemical processes underlying behavior. The group meets regularly at the American Academy of Arts and Sciences under the sponsorship of the Massachusetts Institute of Technology.

¶ Dr. Dan H. Moore paid a visit to Calcutta in February, to attend the Second Regional Conference on Electron Microscopy in the Far East. The Conference was held at the Saha Institute of Nuclear Physics from February 2 to 6 under the auspices of the International Federation of Societies for Electron Microscopy. Dr. Moore is the official representative to the Federation from the United States.



THE COVER PHOTOGRAPH shows some of the mathematical representations for the properties of elementary particles, written on a blackboard by Professor Abraham Pais as he explained the SU(6) theory at the annual meeting of the American Physical Society on 27 January (story on PAGE 17) photograph by Mitchell Valentine.

ILLUSTRATIONS: PAGE 2 courtesy of Mr. and Mrs. John E. Lockwood. Fay Foto Service, Boston. PAGE 6 letter courtesy of Mr. Barklie McKee Henry and Mr. Ellery Sedgwick, Jr. PAGE 8 Dr. Pfaffmann courtesy of Brown University, the Secretary of the University; Dr. McCarty, The Rockefeller Institute Illustration Service. PAGE 9 courtesy of Abbie Rowe, The White House. PAGE 10 ventral view of theca of *Gonyaulax polyedra,* University of California Publications in Zoology, Volume 8, Number 4, 1911, plate 17, courtesy of the University of California Press, Berkeley. PAGE 11 The Rockefeller Institute Illustration Service. PAGE 13 courtesy of the Burndy Library, Norwalk, Connecticut. PAGE 14 courtesy of *Science,* Volume 141, cover, 27 September 1963, and Richard De Sa, J. W. Hastings, and A. E. Vatter. PAGE 16 photograph by Heka. PAGE 17 photograph by Mitchell Valentine.