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ONWARDS FROM SPENCER

EVOLUTION AND EVOLUTIONISM

BY P. B. MEDAWAR

I HESITATED some little while before accepting Oxford's invitation to deliver this year's Herbert Spencer Lecture. My conscience told me that I could not honorably accept unless I were prepared to steep myself in the work and thought of Spencer himself, an enterprise not to be lightly undertaken. For Spencer was a System Philosopher, one who endeavored – these are Whitehead's words – "to frame a coherent, logical, necessary system of general ideas in terms of which every element of our experience can be interpreted."[1] And his System was set forth in twelve volumes thicker and squarer than Gibbon's, each bound in a cloth which has acquired with age a reptilian color and texture, so putting one in mind of some great extinct monster of philosophic learning.

The prospect did not beckon me on; nor was I cheered up by finding myself the first man ever to have read the two volumes of the *Principles of Biology* acquired by the Royal Society's library more than half-a-century beforehand. But when I began to read I knew that the challenge was not to be resisted. I began to understand why in his lifetime Herbert Spencer's works had sold in tens of thousands. The *Study of Sociology* at 10s. 6d. had sold more than 20,000 copies by 1900, and the cheap edition of his tract on *Education* nearly 50,000 – and these, it should be remembered, lay outside his formal *System of Synthetic Philosophy*. The System comprised the Principles of Sociology, and of Psychology, Biology, and Ethics, the whole knit together by a volume of *First Principles*, "primordial truths" arrived at by deduction from "the elementary datum of consciousness." What a tremendous undertaking! And what a formidable man Spencer was! His energy was apparently equal to any exertion; his thought had a steady pounding forward motion along the lines he had laid down for it in the famous manifesto or prospectus that preceded the first edition of the *First Principles*.[1a]

I think Spencer was the greatest of those who have attempted to found a metaphysical system on naturalistic principles. It is out of date, of course, this style of thought; it is Steam Philosophy; and until a few years ago we should have been tempted to describe it as equally out of date in content. Evidently it is not. Spencer's greatest contribution to philosophy was his Theory of General Evolution, which I shall expound in a moment, and in recent years his ideas have come back to life, or been propped upright again, in the work of men as far apart as Julian Huxley and Father Teilhard de Chardin,[2] to say nothing of the revival of evolutionary sociology and social anthropology. I intend it to be a compliment to both parties when I say that Huxley's thought about evolution is in the same general style as Spencer's. Teilhard, on the contrary, was in no serious sense a

thinker. He had about him that innocence which makes it easy to understand why the forger of the Piltdown skull should have chosen Teilhard to be the discoverer of its canine tooth.[3]

Now what I propose to do is to show that the principle of general evolution is not an important principle, and that abstractions arrived at in the way this one was arrived at have the property of sounding as if they were tremendously "significant" without actually being so. I then turn to a much more important problem arising directly out of Spencer's evolutionism, namely the difficulty he felt obscurely (and others have since felt very clearly) of reconciling a Law of General Evolution with that other great law which pronounces for a general decay of order and a great leveling of energy, and declares that the direction of the flow of natural events is always towards what Willard Gibbs called *mixedupness.* I shall try to identify the various misunderstandings which have led to the belief that living organisms circumvent or actually break this Second Law of Thermodynamics, and shall then argue that the equation of biological order or organization with thermodynamic order, and so in turn with information content and the idea of improbability, is one that cannot be sustained.

To show that I have no grudge against evolution as such, and that I accept the Laws of Thermodynamics in the spirit in which Carlyle's lady correspondent accepted the Universe ("Madam, you'd better!"), I emphasize that I shall say nothing about the principle of General Evolution that I would not be prepared to say about any other attempt to pass off a mere inductive *collage* as a work of philosophic art.

Consider, for example, a great new universal Principle of Complementarity,[4] according to which there is an essential inner similarity in the relationships that hold between antigen and antibody, male and female, electropositive and electronegative, thesis and antithesis, and so on. These pairs have indeed a certain "matching oppositeness" in common, but that is *all* they have in common. The similarity between them is not the taxonomic key to some other deeper affinity, and our recognizing its existence marks the end not the beginning of a train of thought. The several manifestations of complementarity are so completely different in origin, nature, and import that the properties of the one pair teach us nothing at all about the properties of any other. The most we can learn is to be prepared to recognize the relationship if it should turn up in a new and unfamiliar context. The idea of complementarity has, for example, never been far from the thoughts of those who have tried to find out how two chromosomes come to be formed where there was only one before; and for the biologist the quintessential example of complementarity is indeed the relationship between the twin strands of the molecule of deoxyribonucleic acid, DNA.

SPENCER WAS the first great evolutionist, and he gave the word *evolution* its modern connotation in English. His first account of the matter is in "The Development Hypothesis,"[5] a (for Spencer) relaxed and fairly chatty argument that appeared in *The Leader* between 1852 and 1854; that is, seven years before the publication of the *Origin of Species,* and when Spencer himself was in his early thirties. In it Spencer asks why people find it so very difficult to suppose "that by any series of changes a protozoon should ever become a mammal" while an equally wonderful process of evolution, the development of an adult organism from a mere egg, stares them in the face. We can tell from the tone of his article that evolution was already an idea widely discussed by people of philosophic tastes.

As his thought developed Spencer came to think of genetic evolution, evolution in Darwin's sense,

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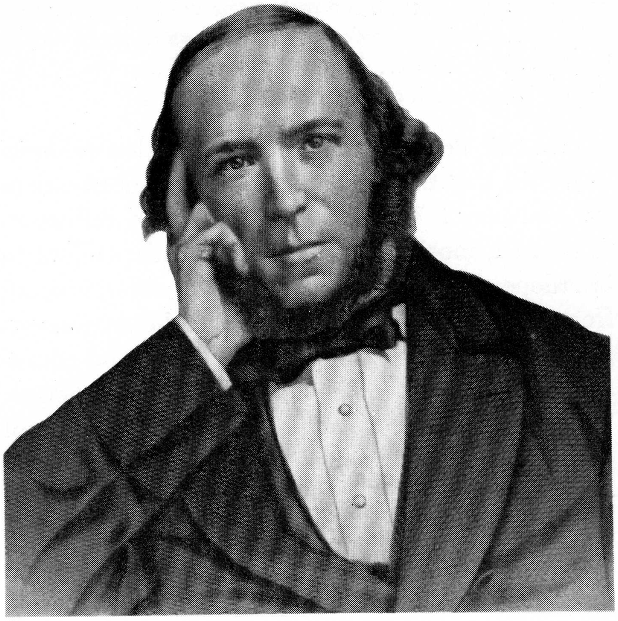
Dr. Peter Brian Medawar is a Visiting Professor of The Rockefeller Institute. While in residence at the Abby in April, Dr. Medawar spoke in Caspary Auditorium on a variety of subjects including genetics, transplantation and immunity, and "Hypothesis and Imagination." Dr. Medawar, who is justly esteemed for his lecturing and writing as well as for his scientific achievements, is a Nobel laureate and Director of the National Institute for Medical Research in London. He exemplifies Buffon's phrase, Le style est l'homme même. *This article appears with the kind permission of the magazine* Encounter *where it was originally published in September 1963. The text ornaments are reproduced from the 1886 edition of Spencer's* The Principles of Biology.

as no more than one manifestation of a far grander and more pervasive process; and out of this conviction his System grew. Today we realize that philosophers devise Systems because it gives them a nice warm comfortable feeling inside; it is something done primarily for their benefit, not for ours. Spencer would not have taken kindly to such an interpretation. Nor did he believe that his concept of evolution grew up empirically. On the contrary: Spencer, like Whitehead after him, the last of the great system philosophers, undertook "the deduction of scientific concepts from the simplest elements of our perceptual knowledge."[6] *First Principles* was an attempt to do just this: to show that the concept of general evolution followed "inevitably" from laws of the indestructibility of matter and of the conservation of energy. Spencer's argument is unimportant and unconvincing, its sole purpose being to justify his expectation of finding evolution at work everywhere. The Universe evolved, and the solar system and earth within it. Animals and plants evolve generation by generation, and within any one generation development is itself an evolution. Society is an organism and society evolves. Moreover, "the law of evolution holds of the inner world as it does of the outer world." Mind evolves; and language and musical expression, the plastic arts and the arts of narrative and dancing, all display one characteristic or another of evolutionary change. Evolution is "a universal process of things." And when we contemplate it as a whole, in its "astronomic, geologic, biologic, psychologic, sociologic, etc.," manifestations,

> we see at once that there are not several kinds of Evolution having certain traits in common, but one Evolution going on everywhere after the same manner.... So understood, Evolution becomes not one in principle only but one in fact.[7]

These larger ideas, I should explain, grew upon Spencer during the latter part of his life. I am quoting from the last edition of *First Principles;* they are not to be found in the first edition of 1862.

What then was this universal law of the transformation of matter and energy? He picked his way towards a definition or description that satisfied him, but even after forty years he was wanting to polish and qualify it still. What he has to say about definition itself, the process of defining, is an example of



HERBERT SPENCER

his splendid good sense and of his powerful, hideous prose — the writing of a man who, lacking and perhaps contemptuous of the stylistic graces, is absolutely determined to be understood:

> A preliminary conception, indefinite but comprehensive, is needful as an introduction to a definite conception. A complex idea is not communicable directly, by giving one after another its component parts in their finished forms; since if no outline pre-exists in the mind of the recipient these component parts will not be rightly combined. Much labour has to be gone through which would have been saved had a general notion, however cloudy, been conveyed before the distinct and detailed delineation was commenced.

The point is commonplace nowadays, but many scientists still persist in the belief that no rational discourse is possible unless one "defines one's terms."

In the outcome, Spencer's definition, as it is to be found in the final revise of *First Principles,* ran thus:

> Evolution is an integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation.

At once he goes on to say, and we love him for it:

> NOTE. — Only at the last moment, when this sheet is

ready for press and all the rest of the volume is standing in type . . . have I perceived that the above formula should be slightly modified . . . by introduction of the word "relatively" before each of its antithetical clauses.

What his Principle of General Evolution amounts to is this: that the direction of the flow of events in the Universe is from simple to complex, diffuse to integrated, incoherent to coherent, independent to interdependent, undifferentiated to differentiated; from homogeneous and uniform to heterogeneous and multiform; and from an abundance and confusion of motion to a regimentation and loss of motion. These are mostly Spencer's own words. He does not speak of a passage from randomness to orderliness, or from more probable to less probable configurations of matter; but if these antitheses had been put to him, I feel sure he would have accepted them as fair descriptions of the trend or tendency of evolution.

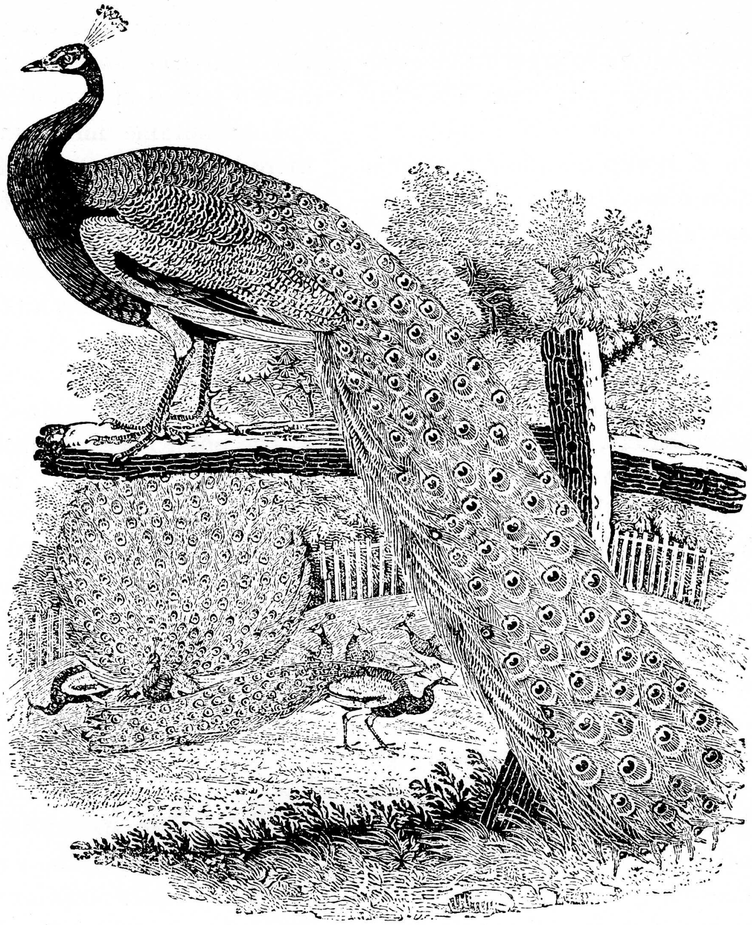
LET US NOW study the principle of general evolution in its biological contexts to see if it actually works. When used without further qualification, the word "evolution" is generally taken to mean evolution in the genetic or Darwinian sense. Provided we confine ourselves to comparisons between grown-up organisms, evolution of this sort answers to Spencer's definition pretty well: there is indeed a passage from simple to complex and towards a differentiation and mutual dependence of parts. But Spencer's formulation fails altogether to define the very real sense in which a frog's egg (or a very young frog) is more highly evolved than, say, a grown-up earthworm. Indeed, Spencer's conception of development (which I shall deal with in a moment) entitles us to suppose that embryos are *less* highly evolved than the adult forms of their own ancestors. This difficulty disappears if we take the view that evolution in the genetic sense is an evolution *of* developments — or, more exactly, of the genetic instructions that constitute the program of development. The genetic instructions that govern the development of a frog are much more complicated than those that govern the development of an earthworm, and for that reason a frog's egg may be considered a more highly evolved object than an earthworm of any age.

But this leads to a paradox. Development itself is the golden example of an evolutionary process as Spencer conceived it to be. His thoughts constantly recurred to the evolution of tree from seed and of infant from 'germinal vesicle' (that is, egg). Unfortunately, development cannot be described as an evolution in the one essential sense in which genetic evolution can be so described. I have just said that we can get round the difficulty of being obliged to think an embryonic frog less highly evolved than an adult earthworm by thinking of an evolution of earthworm-making instructions into instructions for making frogs. Development is the carrying out of these instructions; it is a film that sticks faithfully to the book — an evolution, then, only in the sense of a translation, spelling out or "mapping" of one kind of complexity into another kind of complexity. The adult is "implicit" in the egg in the sense that one day it will be possible, after determining certain parameters, to read off the constitutional properties of the adult animal from a detailed knowledge of the chemical structure of the egg it arose from. Genetical evolution is entirely different, however, for there is no useful sense in which the structure of a mammal is implicit in the structure of a protozoon.

I cannot make up my mind whether Spencer grasped this point or not. As early as 1852, in *The Development Hypothesis,* he wrote:

> The infant is so complex in structure that a cyclopedia is needed to describe its constituent parts. The germinal vesicle is so simple that it may be defined in a line.

Forty-five years of reflection must have confirmed him in this opinion, for the same sentences occur word for word in the first volume of the revised edition of *The Principles of Biology.* Yet in that same volume, grappling with the problem of how a peacock's tail comes to acquire its elaborate pattern, he made a rudimentary attempt to estimate what would now be called the amount of "information" that must be present in a peafowl's egg to specify the pattern of one feather of the adult's tail. By erroneous reasoning[8] he came to the conclusion that 480,000 Weismannian "determinants" would be required to specify the pattern of one feather alone. No wonder he declared that the "organizing process transcends conception. It is not enough to say we cannot know it; we must say that we cannot even conceive it." (To



"... how a peacock's tail comes to acquire its elaborate pattern"

describe as "inconceivable" what he himself could not conceive was one of Spencer's little weaknesses.) However that may be, I think it must be clear that in describing both development and phylogenetic transformation as processes of "evolution" we may be making a useful statement about one or about the other; but not, I fear, about both. They are altogether different phenomena.

Biologists who use English as a scientific language *never* use the word "evolution" to describe the processes of growth and development. (In France the usage is different.) They refrain because to do so would be confusing and misleading.

No such scruples weigh, alas, with biologists who speak about "social evolution" or "psychosocial evolution." So far as I can make out from the writings of its various advocates, this superorganic evolution, as Spencer called it, has many manifestations, of which I shall mention only three, and discuss only the third. They are: 1) the Spencerian evolution of social organization and of social institutions like governments, joint stock companies, banks, and so on (this was what Spencer himself was mainly concerned with). 2) What A. J. Lotka[9] called the "exosomatic" (as opposed to ordinary or "endosomatic") evolution of new sensory organs like spectacles, ear-trumpets, and ultraviolet spectrophotometers, or new motor organs like cutlery and guns. Spencer had some pointed and sensible remarks to make about evolution of this kind in his *Principles of Psychology*. These first two kinds of superorganic evolution are, of course, the consequences of a third. 3) Cultural or psychosocial evolution, the secular accumulation of fact and fancy, knowledge and know-how, rules and rites, that is mediated through tradition.

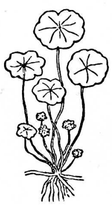
By "tradition" I mean "the transfer of information through nongenetic channels from one generation to the next."[10] I discussed psychosocial evolution at

some length in the last of my Reith Lectures,[11] and tried to explain in just what sense psychosocial evolution represents a fundamentally new biological stratagem. But although psychosocial evolution is immensely important, it is also immensely obvious. Spencer did not ration himself austerely where explanations and examples were called for, but of the changes caused by the prodigious secular growth of the arts and sciences he says only "the proposition is familiar and admitted by all. It is enough simply to point to this great phenomenon as one of the many forms of evolution we are tracing out."[12] He spent much more time, unfortunately, in trying to demonstrate that the exercise of the mind had a direct hereditary effect on the capabilities of the brain in later generations. Perhaps this is why he believed in the inevitability of progress; for if his interpretation were true, social evolution would be cumulative and virtually irreversible. *We* know better: that we are all born into the Old Stone Age and in principle could stay there.

Psychosocial evolution differs from ordinary genetic evolution in three important ways: it is not mediated through genetic agencies; it is reversible, in the sense that what it has gained can in principle be wholly lost, and in one generation; and it is an evolution in the Lamarckian style, in the sense that a father's particular knowledge and skills and understanding can indeed be transmitted to his son, though not (as Spencer supposed) through genetic pathways. Common sense suggests that differences of this magnitude should be acknowledged by a distinction of terminology. The use of the word "evolution" for psychosocial change is not a natural usage, but an artificial usage adopted by theorists with an ax to grind. If by any chance it *had* been a natural usage, people like myself on occasions like this would have said over and over again how wrongheaded it was, and how wise we should be to abandon it.

All who think about psychosocial "evolution" agree that its inception marks a second great epoch of biological history. But I wonder: is it a second, or is it perhaps a third? The first must surely have been an evolution at the chemical or molecular level of integration — a process of which we can have no direct knowledge, for in a certain important sense all chemical evolution in living organisms stopped millions of years before even our faintest and most distant records of life began. So far as I know, no new *kind* of chemical compound has come into being over a period of evolution that began long before animals became differentiated from plants. Nor has there been any increase of chemical complexity; no chemically definable substance in any higher organism, for example, is more complex than a bacterial endotoxin. I have no views on the process of evolution that brought new kinds of chemical compounds into existence, but I should not be surprised to find them very different from the forms of evolution that have been in progress since.

The point I wish to make is that evolution since those primordial days has been an evolution of structure at a higher level of integration than the chemical (using the word "chemical" in the way it is used by chemists). It was these thoughts that led me to the discussion that now follows on the relationship between biological and thermodynamic order.



THE SIXTEENTH CHAPTER — in effect the last — of the first edition of *First Principles* contains an argument on the phenomenon of equilibration from which Spencer ultimately drew

> a warrant for the belief, that Evolution can end only in the establishment of the greatest perfection and the most complete happiness.

This sentence cannot be found in the latest version of *First Principles.* Its place is taken by some somber and, I must also say, rather confused reflections upon the ultimate state of the Universe: for Spencer now enlarges and develops an argument of which, in the first edition, we see only the embryonic rudiments — an argument tending to the conclusion that unless something unforeseen and unforeseeable turns up, all things must "beyond doubt" tend towards a universal quiescence, an "omnipresent death." What can have been responsible for the much greater weight he gave in his later thought to the phenomena of dissipation and dissolution?

The theory of General Evolution was first hinted at in Spencer's *Development Hypothesis* of 1852. One year before, in the *Transactions* of the Royal

Society of Edinburgh,[13] Lord Kelvin (then Professor William Thomson) called attention to and elaborated upon some "remarkable conclusions" arrived at by Clausius and Rankine after studying the properties of "thermodynamic engines," engines that translate heat into mechanical work. The First Law of Thermodynamics (though not then so described) had already brought the reassuring news that heat, as a form of energy, could not be lost, for the total quantity of energy in the universe remained constant, no matter what its transformations. But though not lost to the universe, it now became certain that heat was "irrevocably lost to man, and therefore 'wasted,' though not *annihilated*" in thermodynamic transactions; for (Thomson went on to say) "it is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects." The conversion of heat into mechanical work depends on inequalities of temperature within the system, and these inequalities are progressively done away with in a great and universal process of leveling up.

Like the principle of General Evolution, this Second Law of Thermodynamics was in due course taken out of its native environment, here the pithead and the railway workshop, and generalized. And just as Spencer had tried to abstract the essentials from every concrete manifestation of evolution, so also, in all natural transformations, has it been possible to discern the working of that fundamental principle of which the Second Law of Thermodynamics is the most familiar concrete instance.

With the growth of the science of statistical mechanics, it became possible to translate the Second Law into a statement about the history of a system of particles whose behavior was known in the aggregate only, not individually. This historical statement declares that, in an isolated system, the pattern of the distribution of the elements within it passes from order towards randomness, from separatedness to mixedupness, from less probable towards more probable configurations. Our sense of the fitness of things tells us that something is being lost in the process — orderliness, perhaps, or availability of energy or thermodynamic competence — but the historical origins of the concept still persuade us to speak of a gain of something, of *entropy*, a quantity which, in its native context, is a simple ratio expressing the degree to which thermal energy is no longer available for the execution of mechanical work. "*Die Entropie strebt einem Maximum zu*" was Clausius' own formulation of the Second Law.

The most recent context for the general law of the decay of order and increase of entropy is in the theory of communication. A message encoded in symbols (for example, a Morse signal) owes its specificity, its property of being *this* message and not that message, to the particular configuration of the symbols, and a random or disorderly configuration of symbols does not make sense. The information capacity of a system of communication obviously depends on the range of different configurations of symbols at the command of the transmitting agent. In a sense, therefore, information capacity is a measure of order or, by a natural extension of the idea, of improbability; information capacity is thus analogous to negative entropy, and may be measured in formally similar terms. This formal similarity has led some people to declare that information *is* negative entropy, but the usage strikes me as perverse. There is much the same formal similarity between the equations for the diffusion of heat and for the diffusion of solutes, but (as I think Hogben somewhere remarked) we nevertheless resist the temptation to refer to heat as a caloric fluid. "Information," said Professor Norbert Wiener, in a passage more than usually full of negative entropy, "is information, not matter or energy." Elsewhere he points out that the concepts of information and of *pattern* are not coextensive: information is a concept normally (if not necessarily) applied to patterns which are spread out or must be read out in a series, in practice a time series.[14] Such is the case with the information in a gramophone or tape record and also, so it now appears, in a chromosome. The order matters.

By the end of the nineteenth century the philosopher could choose between alternative doctrines of world transformation, the one apparently contradicting the other. The principle of General Evolution spoke of a secular increase of order, coherence, regularity, improbability, etc., and Spencer's own derivation

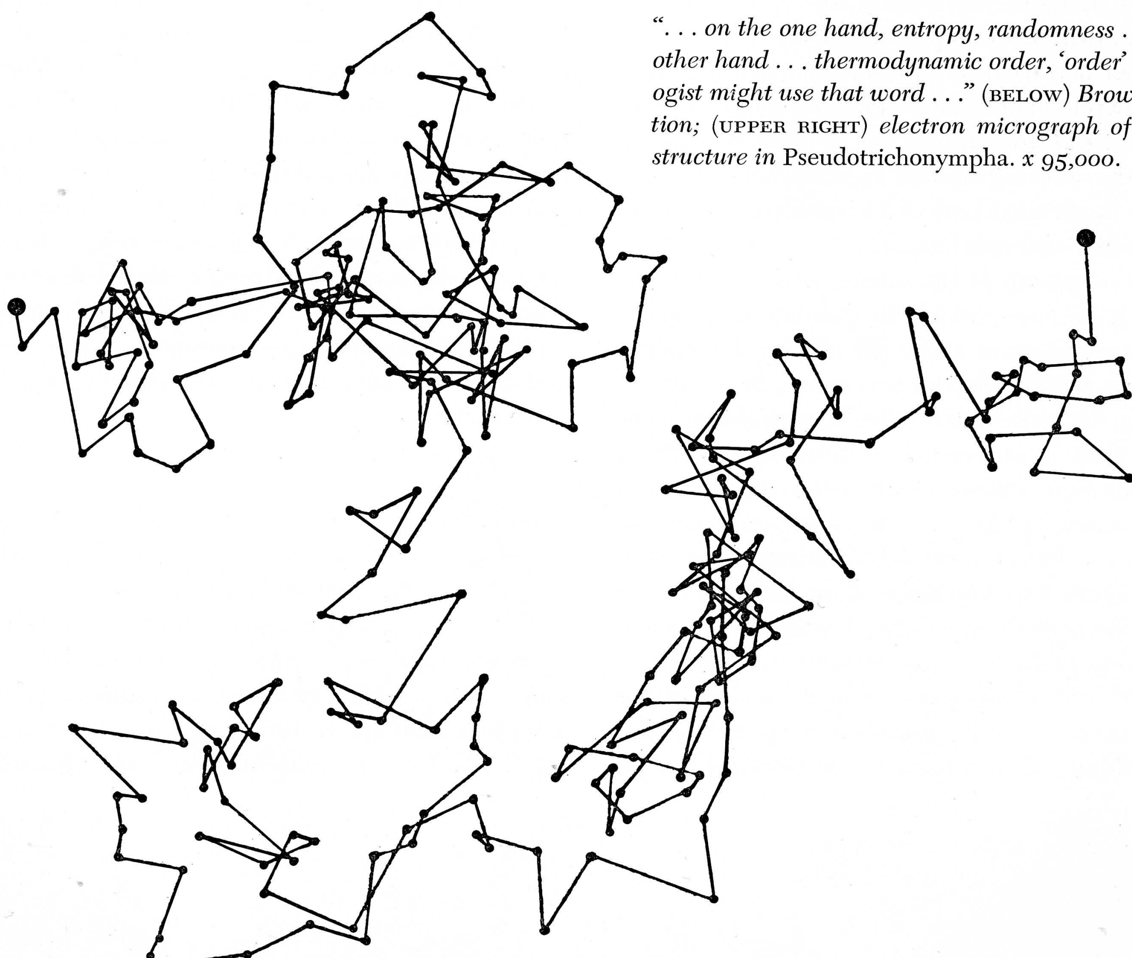
made it appear to follow logically from physical first principles; while the Second Law of Thermodynamics, suitably generalized, spoke of a secular decay of order and dissipation of energy.

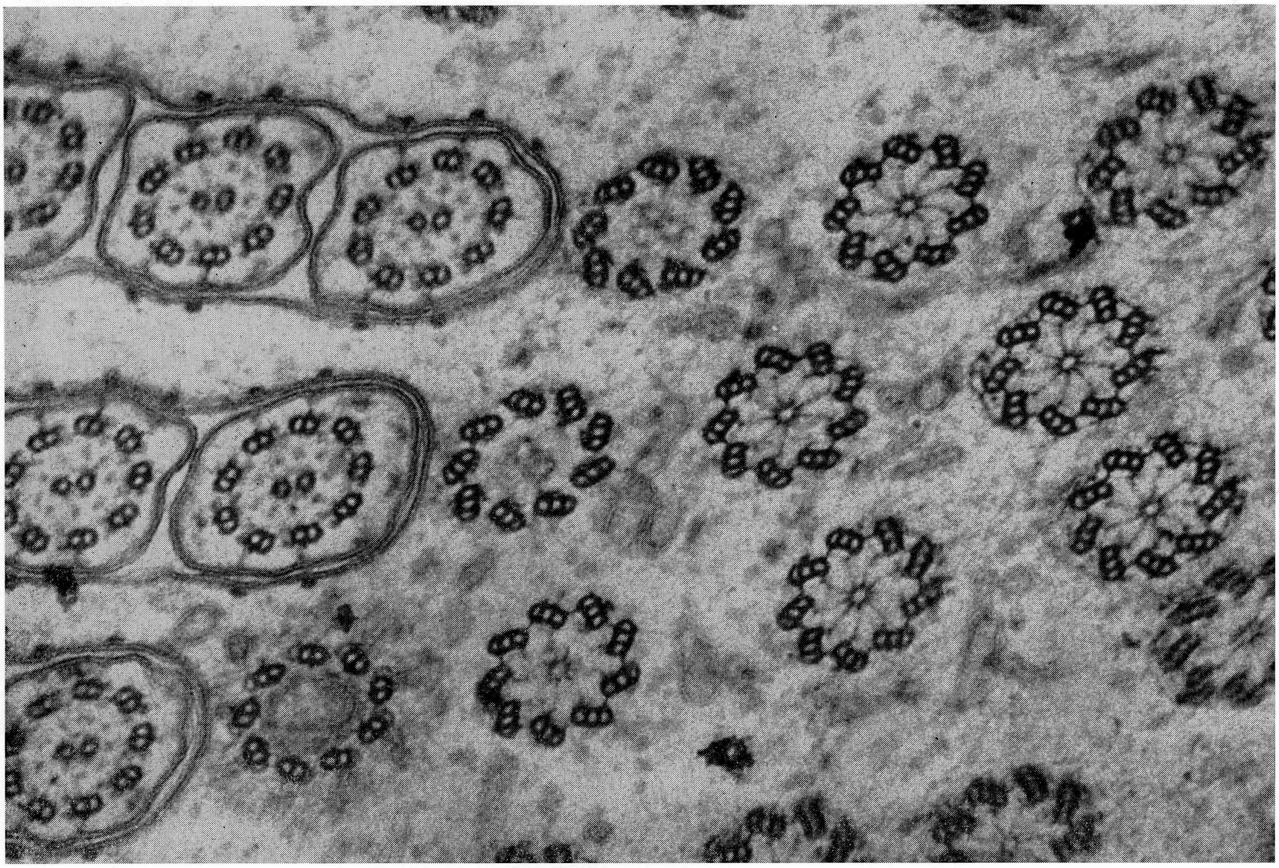
There can be no doubt that Spencer's thought took on a darker complexion in later years for what were surely thermodynamic reasons; but such was the prestige of evolution theory that the Second Law of Thermodynamics was over and over again described as a Law of Evolution, sometimes as *the* law of evolution. A. J. Lotka, the greatest of modern demographers, upheld this interpretation and applied it to biological evolution,[15] but to most people biological evolution and increase of entropy seem mutually contradictory ideas. "Evolution," says Julian Huxley,[16] who can be spokesman for all who have thought likewise, "is an anti-entropic process, running counter to the Second Law of Thermodynamics with its degradation of energy and its tendency to uniformity." François Meyer[17] speaks of a principle of Anti-chance at work among living things.

In fact the two concepts are not antithetical. That they are popularly supposed to contradict each other is due in part to a fairly obvious misunderstanding about the physical situations in which the two generalizations hold good and make sense, and in part to a more subtle and correspondingly less obvious confusion of language.

Spencer himself, not unexpectedly, was unable to work the problem out; for this reason the final, revised edition of *First Principles* is much less satisfactory than the first, in which his thoughts were still untroubled by the ideas of universal mixing-up and running-down that grew out of the work of Boltzmann and Willard Gibbs. Spencer at all times believed that evolution had a natural limit, and came to an end when a certain state of equilibrium was reached, as he believed it always must be—for "all terrestrial changes are incidents in the course of cosmic equilibration." His arguments are not very clear because the equilibrium he refers to seems sometimes to mean a state of quiescence and rest, and at other times a steady state in which evolution and its exact opposite, Dissolution, just cancel each other out. But Dissolution eventually supervenes and the universe ends in a ruin of order. Evolution may start up again locally, and perhaps evolution and dissolution may alternate, but the matter must be left open since it is

". . . on the one hand, entropy, randomness . . . on the other hand . . . thermodynamic order, 'order' as a biologist might use that word . . ." (BELOW) *Brownian motion;* (UPPER RIGHT) *electron micrograph of flagellar structure in* Pseudotrichonympha. *x 95,000.*

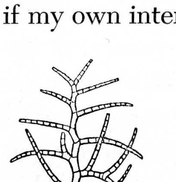




"beyond the reach of human intelligence." Spencer's answer seems to have reconciled the laws of evolution and of thermodynamics by supposing them to mark not incompatible but successive episodes in a history of world order. But this will clearly not do, and we must seek other more convincing interpretations.

If we confine ourselves merely to considerations of energetics, there is no problem; or at least, there is no confusion. The Second Law of Thermodynamics applies to isolated systems, systems in which there is no external trade in matter or energy; the law in no wise excludes the existence of sub-domains in which entropy may be decreasing,[18] though necessarily at the cost of a disproportionate increase of entropy elsewhere. The answer that has satisfied most physicists is that living organisms, thermodynamically *open systems*, are just such domains. They have been described as "privileged domains," and this sounds well; though the corollary, that the rest of the system is underprivileged, sounds rather silly. But if we contemplate the over-all transformations of matter and energy within the biological system as a whole, as Lotka did, then of course nothing happens to contravene the Second Law.

A biologist might still protest that, while living organisms obey the letter of the Second Law of Thermodynamics, they fail to observe it in the spirit. I should now therefore like to make a very hasty and perhaps superficial attempt to clarify some of the real confusions of thought and language that underlie the entire argument. The confusions are genuine, even if my own interpretations turn out to be inexact.



I SPOKE A moment ago about the possibility of a grand abstract equivalence between, on the one hand, entropy, randomness, probability, and nonsense; and on the other hand between thermodynamic order, "order" as a biologist might use that word, improbability,

and information content. Each of these concepts or pairs of antitheses has been applied, sometimes critically, more often recklessly, to the description of living organisms. Let us therefore consider the sense, if any 1) of regarding biological order as a form of thermodynamic order; 2) of describing organisms in evolution or in everyday life as seats or centers of improbability or Anti-chance; and 3) of using the concepts and terminology of information theory to describe biological organization. If these correspondences or equivalences should be found faulty then the antithesis between evolution and entropy, using both words in their widest senses, will disappear; for it will turn out that they refer to different properties pertaining to different physical situations.

1. First, then, thermodynamic order and biological order or structural organization. So far as I can make out, all physicists who have considered the matter virtually equate the two, though Eddington[19] had some misgivings. Erwin Schrödinger, in his remarkable little book *What Is Life?* (1944), says that living organisms maintain and add to their state of order by, in effect, feeding on negative entropy; by "drinking orderliness from the environment"— or, to put it more temperately, by breaking down molecules coming from outside the system to pay the thermodynamic bill for synthesizing molecules within the system. Schrödinger explicitly defines "order" in the language of energetics, equating it to what was later to be called information capacity.

There must surely be a misunderstanding here.[20] Order or organization as the biologist understands it means complex regularity, with the extra connotation of stability. By "regularity" I do not mean symmetry or periodicity; I mean rather "tidiness" or regimentation in the sense that each element of the system has its proper place. Order of this kind is by no means confined to the living world: it is the orderliness of a crystal, of a molecule, or in general of the solid state. An increase of complex regularity may accompany a *decline* of free energy; for example, in the combination between gaseous hydrogen and oxygen to form molecules of water, which are more highly "organized" in the biological meaning of the word than the parent molecules; or, again, in the phenomena of polymerization and crystallization. In all such cases an increase in the degree of "organization" accompanies an *increase* of entropy — the opposite of what we should expect if biological and thermodynamic order were essentially the same. Willard Gibbs said entropy was "mixedupness"; biological order is not, or not merely, unmixedupness.[20]

2. Probability. Biologists in certain moods are apt to say that organisms are madly improbable objects or that evolution is a device for generating high degrees of improbability; I have already referred to M. Meyer's views on the workings of a principle of anti-chance. This is entirely in keeping with the idea that evolution generates negative entropy, because the Second Law of Thermodynamics can be taken to declare that the spontaneous motion of all natural events is from less probable to more probable states.

I am uneasy about this entire train of thought for the following reason. Everyone will concede that in the game of whist or bridge any one particular hand is just as unlikely to turn up as any other. If I pick up and inspect a particular hand and then declare myself utterly amazed that such a hand should have been dealt to me, considering the fantastic odds against it, I shall be told by those who have steeped themselves in mathematical reasoning that its improbability cannot be measured retrospectively, but only against a prior expectation. Name a hand before the deal, I shall be told, and then everyone will be suitably taken aback if it turns up.

For much the same reason it seems profitless to me to speak of natural selection's "generating improbability." When we speak, as Spencer was the first to do, of the Survival of the Fittest, we are being wise after the event: what is fit or not fit is so described on the basis of a retrospective judgment. It is silly to profess to be thunderstruck by the evolution of organism *A* if we should have been just as thunderstruck by a turn of events that had led to the evolution of *B* or *C* instead. The hollowness of the pretense that biologists should spend their time marveling at the improbability of evolutionary change is shown up by artificial selection, a sieving process in which we ourselves determine the properties of the sieve. The sieve will retain some elements and exclude others, for such is the nature of sieves; the outcome of sieving is therefore a highly probable one, if not certain. If I expose a culture of staphylococci to a certain concentration of penicillin, I *expect* (that is,

I attach a high probability to) the evolution of a strain resistant to penicillin. Any other outcome would be improbable and would require a special explanation.

It is not only in their evolution but in their growth and persistence from day to day that organisms have been said to be wildly improbable phenomena. By this is meant, I suppose, that if all the ingredients of the world or the solar system were to be shaken up in a dice box of divine dimensions, the emergence from it of a configuration like an earthworm would be most improbable. How very true! But in the physical circumstances that actually prevail, the growth and maintenance of an organism is the most probable outcome of the events it is taking part in. When I eat a meal, for example, I expect part of it to turn into more of myself. In particular, I shall expect some of it to turn into the chemical substance characteristic of my own blood group, group B. So very highly probable is it that substance B will be formed that a court of law would discountenance the possibility of my manufacturing a certain amount of blood group substance A — though substances A and B are almost identical physically and chemically.

Similarly, if I spark a mixture of gaseous hydrogen and oxygen, the most probable consequence is the formation of water, though (as I have suggested) water is a more highly "organized" substance, as the biologist uses that word, than the elements out of which it was compounded. What *may* be said, I think, is that the conjunction of circumstances of which the formation of water is the most probable outcome is itself very improbable — I mean, the coming together of gaseous oxygen and hydrogen and the application of a spark to the mixture. The same applies to the conjunction of events of which the formation of More Organism is the most probable outcome: a good deal of the actual business of living consists in bringing about these improbable conjunctions, and organisms pay heavily for it in energy.

3. Finally, "information." The ideas and terminology of information theory would not have caught on as they have done unless they were serving some very useful purpose. It seems to me that they are highly appropriate in their proper context, where we have to do with storing information or sending messages; chromosomes, for example, convey from one generation to the next a message about how development is to proceed. But I feel we have to be on our guard against the train of thought that runs "negative entropy — thermodynamic order — biological organization — information capacity"; on our guard, that is to say, against treating information content as a measure of biological organization. If it were indeed so then, as Waddington has pointed out,[21] we should be obliged to infer that complexity or degree of organization increased very little in biological development. For development, at all events when it occurs in a nearly closed system, is, from the standpoint of information theory, merely a verbose and repetitious spelling out or re-formulation of the information embodied in the chromosomes. This is not a helpful description of development.

In my opinion the audacious attempt to reveal a formal equivalence between the ideas of biological organization and of thermodynamic order, non-randomness, and information must be judged to have failed. While it professes to give a general account of everything that is entailed by the antithesis between order and disorder, it has in fact failed to give any adequate account of order in its most interesting and important form, that which is represented by the complex functional and structural integration of living organisms. One great difficulty, I feel, is that there has been a hopeless attempt to comprehend within one theoretical declaration, a) a theory of order, an entirely abstract idea which can be expounded in a mathematical or logical language making no reference to particular concrete instances; and b) the empirically founded notion that entropy increases or that evolution occurs, and so on.

Should we not rather say that, in biology, the concepts of entropy and thermodynamic order are appropriate when we are dealing with problems of energetics; of information theory when we are studying how messages are sent and acted upon; and of probability where we are dealing with phenomena that have a random element, as in predicting the outcome of breeding experiments? In our moods of abstract theorization we tend to forget how great and how diverse are the functional commitments of bio-

logical macromolecules. They insulate, they fill out; they fetch and carry; they prevent the organism as a whole from falling apart or from dissolving in water; they prop up, they protect; they attack and defend; they store energy and catalyze its transfer; they store information and convey messages, and sometimes they themselves *are* messages. The successful prosecution of all these activities depends upon properties more complex and more particular than can be written down in the language of energetics or information theory.

Where a consortium of brilliant and imaginative theorists has failed, so far, to provide us with the right theoretical equipment for studying biological organization, we need not wonder that Herbert Spencer, working pretty well single-handed, failed too. His System of General Evolution does not really work, we know; the evolution of society and of the solar system are different phenomena, and the one teaches us nothing about the other.

Development, on the one hand, and the secular transformations of species on the other hand, are both evolutionary processes, but in senses so different that to describe one as an "evolution" makes it imperative to find some different word to describe the other.

But for all that I for one can still see his System as a great adventure, and now that I know my way about those thick square volumes I do not feel I am taking leave of them for good.

REFERENCES

[1] A. N. Whitehead, *Process and Reality* (Cambridge, 1929).

[1a] Spencer began his professional life as a railway engineer.

[2] See *The Phenomenon of Man* (London, 1959).

[3] On August 30th, 1913. The whole story is to be found in *The Earliest Englishman* by A. S. Woodward (London, 1948); see also Charles Dawson and A. S. Woodward, *Quart. J. Geol. Soc. London, 70*, pp. 82-99, 1914. See also my critical notice on Teilhard in *Mind* (January, 1961).

[4] Not to be confused with Niels Bohr's.

[5] Reprinted in *Essays: Scientific, Political and Speculative* (London, 1868).

[6] *An Enquiry concerning the Principles of Natural Knowledge* (Cambridge, 1919).

[7] *First Principles* (6th Edition, revised 1900), § 188.

[8] See *The Principles of Biology* (Revised Edition, 1898), pp. 372-373. The computation is not possible even with the evidence now available to us; but if we were to attempt it we should certainly not assume that the individual elements of the pattern behaved as "independent variables."

[9] *Human Biol. 17:* 167 (1945).

[10] *The Uniqueness of the Individual* (London, 1957), p. 141.

[11] *The Future of Man* (London, 1960).

[12] *The Principles of Psychology* (4th Edition, 1899), Vol. 1, § 158.

[13] Vol. 20 (1851), pp. 261-288.

[14] *Cybernetics* (New York, 1948), p. 156, and *The Human Use of Human Beings* (London, 1950), p. 21.

[15] *The Elements of Physical Biology* (Baltimore, 1925). Lotka chose to regard evolution as the change undergone by the *total* system "organisms + environment" conceived as an isolated system (or rather as a closed system with a known input of radiant energy). Conceived thus, the evolving system certainly obeys the second law, and there is much to be said for Lotka's viewpoint. But if we use the word "evolution" to describe this general transformation, we shall have to invent another word to stand for evolution in its more usual biological sense.

[16] In his *Introduction* to Teilhard de Chardin's *Phenomenon of Man.*

[17] *Problématique de l'évolution* (Paris, 1954).

[18] *E.g.*, in a refrigerator, a heat engine in reverse in which heat flows from a colder to a warmer environment to increase the temperature of the latter. Needless to say the flow is far from spontaneous. See A. R. Ubbelohde: *Man and Energy* (Penguin Books, 1963).

[19] *New Pathways in Science* (Cambridge, 1935).

[20] See Dr. Joseph Needham's searching and thoughtful analysis in his essay on "Evolution and Thermodynamics" in *Time the Refreshing River* (London, 1943).

[21] "Architecture and information in cellular differentiation," in *The Cell and the Organism*, eds. J. A. Ramsay and V. B. Wigglesworth (Cambridge, 1961). For discussions of information theory in biology, see *Information Theory in Biology*, ed. H. Quastler (Illinois, 1953); *The Physical Foundation of Biology*, by W. M. Elsasser (New York, 1958).

Henry James and the Mouse BY PEYTON ROUS

In 1911 Henry James visited The Rockefeller Institute. He had become enthusiastic about it and on learning that his own favorite nephew, "Harry," the eldest son of William James, was to be its Business Manager, had written him a deliciously warm-hearted and excited letter about how much he might help in the fight against disease.

I was standing in a room walled to the ceiling with small, wooden cages containing white mice when the Director of the Institute, Simon Flexner, unexpectedly brought two visitors in. One was Oswald Villard, a potent worker for social good; the other was Henry James.

Mr. James was an arresting figure. He had a serious, rather leaden face, made the more so by what were then called "bankers' eyeglasses," having large lenses held together by a black, horizontal bar, with a black ribbon arching from them, past a black waistcoat striped with white, to the lapel of his black, cutaway coat. His "boots" were almost arrogantly British, of a sort never seen today, very thick-soled and turning up toward their rounded toes. But all this I only noted later because Dr. Flexner was introducing me as in charge of cancer research. Forthwith Mr. James clapped a heavy hand on my shoulder and exclaimed in a resounding voice, "How magnificent! To be young and have divine power!"

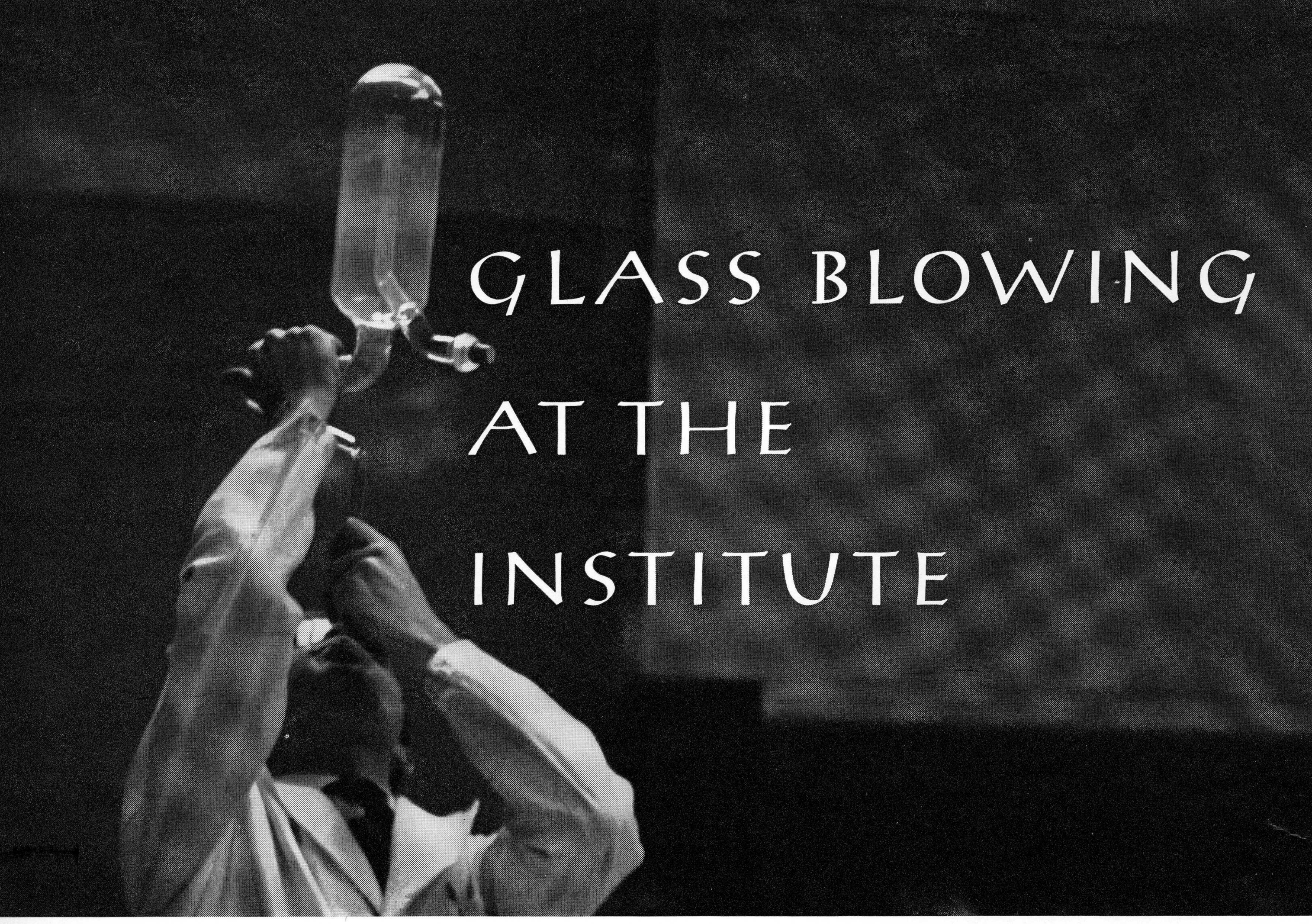
What should one say! So flustered was I as tacitly to acknowledge the power, answering only that I was not as young as I looked, and going on to show some mice with breast tumors and describe experiments with them. After this Dr. Flexner and Mr. Villard left; but Mr. James lingered, standing in thought before the mouse cages. Then, looking at me almost furtively, he said — and no word has been added or forgotten — "May I ask, has the individuality, I might say the personality, of these little creatures impressed itself upon you?"

Now as a matter of fact it had. In those days conduct was conduct, with no intrusive, hormonal mitigations; and this was what had happened, as I told it to Mr. James:

A breast cancer had appeared on a female mouse and grown to such size while she was nursing her young as to be needed for experiment. To save her sucklings when she was killed, I gave them to another mother mouse, removing her own litter which happened to be big enough for weaning. She accepted the new ones as if they were her own and duly reared them. Immediately, with the callousness of interested youth, I supplied her with a second litter. Them she raised too. Now for a third! She nursed these until they were somewhat more than an inch long and had reached that entrancing stage of young mouse life when — judging from how they look and behave, bright-eyed and joyously frisking about — their world of wooden walls and shavings must seem to them utterly good. Then during a single night she killed them all. It was an act of self-preservation; the urge to live had overcome maternal feeling — though why she should have eaten parts of some of them was another matter.

I made no such comment to Mr. James, but told him only the facts. To these he listened intently and remained silently standing in front of the cages and pondering. He pondered for what seemed a very long time while I, eager, waited. Then at last, turning toward me, he was about to speak, when Dr. Flexner put his head in the door saying, "Mr. James, will you please come!" And with a quick bow, but no word, Mr. James came.

Dr. Rous is an emeritus member of the faculty of The Rockefeller Institute, who is still actively associated with it. This article is reprinted with his kind permission and through the courtesy of the publisher, from Perspectives in Biology, *Summer 1964.*



GLASS BLOWING AT THE INSTITUTE

Science and the ancient skill of glass blowing have been linked together through the centuries. Today at the Institute, as a reminder of both the oldness and the newness of the art, a young man, in a bright modern room, using tools and techniques, some of which have been unchanged for centuries, fashions and repairs much of the elaborate and special glass equipment needed by the various laboratories.

The Institute itself has made many contributions to the use of glass in scientific research, perhaps the most important of which was the development in the mid-thirties of a glass of suitable composition for use in the construction of the now well-known glass electrode. This glass, which was of an unusual softness, was developed by Dr. D. A. MacInnes in collaboration with a younger colleague, Dr. Malcolm Dole. The glass "electrode" is really a membrane, and the electrical potential across this membrane depends primarily on the pH of the two solutions bathing it.

At that time the glass blower at the Institute was Mr. Otto Hopf, a man of extraordinary genius and an almost legendary character. Mr. Hopf came from the Black Forest where his forefathers had been glass blowers for generations. His grandfather was allegedly the first to make glass eyes on order, with the synthetic orb an artful match for its natural mate. Mr. Hopf himself, before coming to this country, was a glass blower for Professor Walther Gerlach's laboratory of physics.

Among the special apparatus developed at the Institute with the aid of Mr. Hopf's suggestions and great skill, were the Carrel and the Rivers culture flasks, the Carrel-Lindbergh perfusion pump, the Shedlovsky electrolytic conductivity cells, and the MacInnes-Belcher glass electrodes, some of which are still functioning satisfactorily after more than a quarter of a century.

When Otto Hopf resigned in the 1930's to set up his own establishment, he left behind him Otto Post, who had learned considerable of the trade from him

and did extensive repair work on specialized laboratory glassware throughout the Institute. Mr. Post, who worked with Dr. Walter A. Jacobs, soon set up his own shop devoted almost exclusively to making parts for the countercurrent distributor developed by Dr. Lyman Craig.

Thereafter the Institute had no glass blower on its staff for a number of years, and so was forced to depend upon outside services. A few years ago, however, Dr. Lyman Craig, who is well known as an extraordinary consumer of glassware, initiated a move to reopen the Institute glass-blowing shop. Through his efforts, he was able to arrange for the employment of a talented young native of Bonn, Wolfgang Papperitz, who had just completed his three-year apprenticeship.

Traditionally glass blowers are proud not only of their skills, but also of the venerable history of glass. Obsidian, the natural glass formed by the heat of volcanoes, was used for tools as far back as the Stone Age, and was employed thereafter for centuries for knife blades, spearheads, and mirrors.

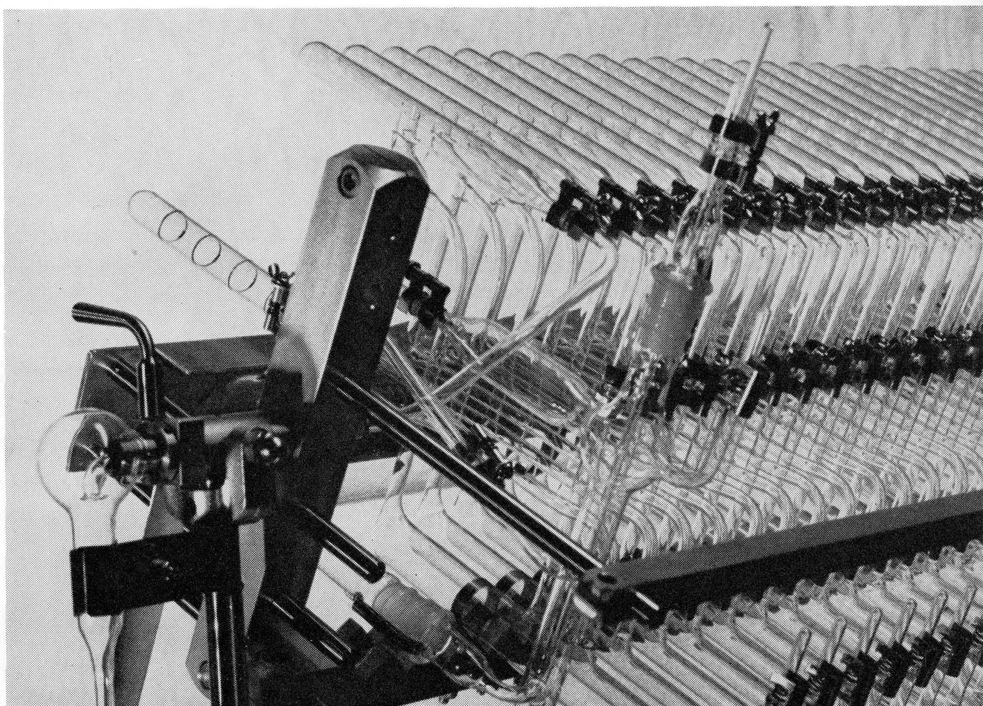
The exact origin of man-made glass is still obscure. Yet a logical explanation can be found in the relationship between glass and faïence, a ceramic-like material, which was used by the Egyptians as early as the third millennium B.C. Both are made with the same materials and it may well be that the production of faïence eventually led to the development of glass. The Egyptians often used glass as a substitute for semiprecious stones, as for example in the funerary mask of Tutankhamen.

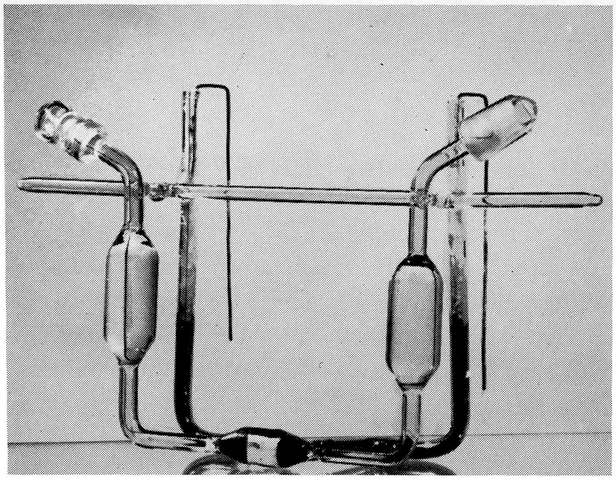
Most authorities feel that blown glass owes its origin and development to craftsmen working in the Eastern Mediterranean along the Syrian and Palestine coast, who probably discovered the art toward the middle of the first century B.C. The blowpipe they used was apparently similar in size and shape to the ones used now — a hollow iron tube about four to five feet long with a mouthpiece at one end. When the other end is dipped dexterously into a pool of molten glass, a mass will adhere to it that can then be blown into a hollow bulb.

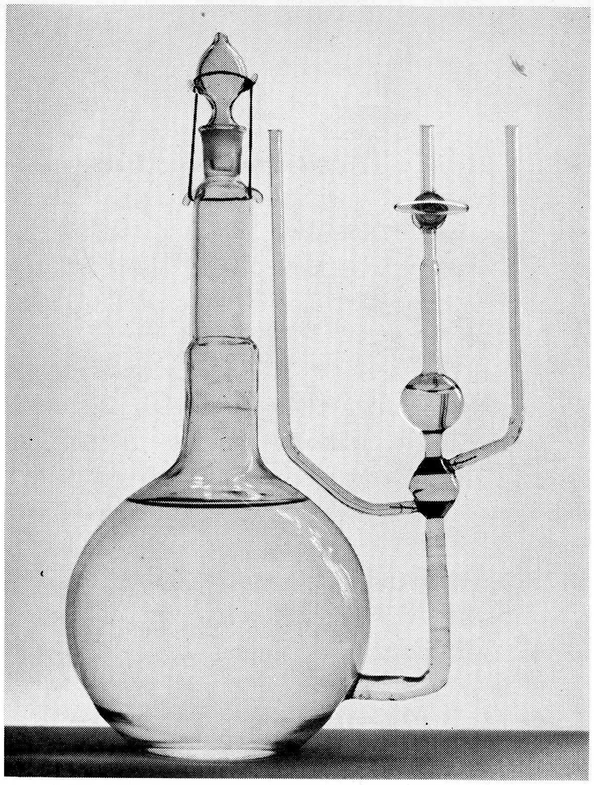
By the eleventh century, glassmaking had been established in Venice. In the fifteenth and sixteenth and early seventeenth centuries, Venetian glass had attained international fame, and in elegance and complexity had few rivals. The scientific pre-eminence to which Italy rose in the sixteenth century is directly related to the ascendancy of Venetian glass manufacture. The thermometer, for example, was invented during this period (by the amazing Galileo), as was the barometer. On a less respectable level, alchemists were among the chief customers for glass. As alchemy gave way to modern chemistry, glass became increasingly important for scientific purposes.

From Italy the art of glassmaking spread throughout Europe, with new centers or "schools" develop-

Annealing a lyophilization trap, the glass-blowing shop (LEFT). *Countercurrent distributor developed by Dr. Craig and fabricated by Otto Post* (RIGHT).







Two electrolytic conductance cells built in the middle thirties by Otto Hopf for Professor Theodore Shedlovsky. The flask (RIGHT) *is of quartz, the electrodes of platinum sealed into soft glass. A graded seal is used consisting of fourteen successive rings of glass with thermal expansion properties ranging from that of quartz to platinum.*

ing, particularly in England and Germany. The secrets of the trade were jealously guarded and often handed down from father to son, and it was not until the twentieth century that machine-made glassware came into being.

Today most laboratory glass is made of pyrex introduced by the Corning Glass Works half a century ago. The advantage of pyrex over soft glass is its lower coefficient of expansion and greater mechanical strength which make it relatively resistant to both thermal and mechanical shock. At present, much laboratory glassware is made by machine—the most commonly used items, such as beakers, test tubes, flasks, and tubing—but the many specially shaped items still must be made to order and blown by hand. Hence the importance to the Institute of the glass shop.

A layman visiting the glass shop might be surprised to notice that Mr. Papperitz does not work with the blowpipe in the fashioning of glass for the laboratories, but rather starts with glass tubing. Using his left hand, he turns the piece of tubing over the flame, at the same time with the aid of his other hand bending the softened tubing into the desired shape or angle. This is apparently one of the many reasons that glass working is so difficult to master: it is necessary to perform an extremely precise, machine-like motion with the left hand while carrying out very delicate and intricate maneuvers with the right. In order to produce a bulb or bulge, he blows directly into the end of the glass tube, producing a concavity of the exact desired size and shape just where he wants it. The art is extraordinarily precise: Mr. Papperitz, for example, is not dismayed by a request for vessels of close dimensions for volumetric purposes or for a series of fifty identical receptacles, even though he may make these measurements largely by eye.

Although not so obvious to the uninformed observer, the skill of the modern glass blower includes, in addition to the traditional skills of the craft, a knowledge of the different properties of the various glasses and the temperatures produced by different types of flames. In addition he must know how to seal glass to other materials including metals.

One of the greatest admirers of the skill of the glass blower is George DeMartino, who has been working as an apprentice in the glass shop for the past two months. "When *he* does it," Mr. DeMartino says, "it looks so simple. But when *I* try it, the glass does just what it wants to do." It may perhaps be some consolation to Mr. DeMartino that these words were first uttered—probably in Phoenician—some two thousand years ago.

This article was written by Helena Curtis. The Corning Glass Library generously checked the historical data.

NEWS

National Academy of Sciences

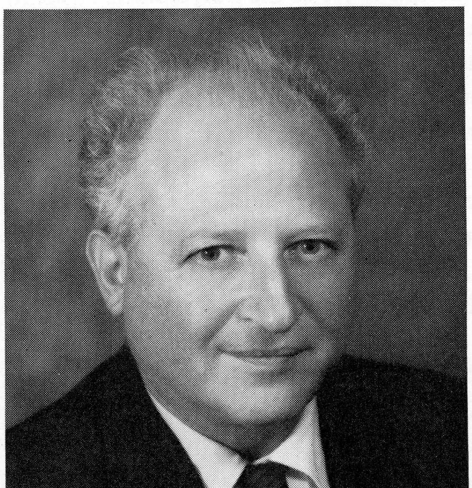
MEMBERS OF the faculty of the Institute figured prominently in the news emanating from the 102nd Annual Meeting of the National Academy of Sciences in April. Professors Sam Granick and Mark Kac were among the newly elected Members of the Academy chosen in recognition of their distinguished and continuing achievements in original research. Election to the Academy is considered one of the highest honors an American scientist can achieve: the American members number only 700, with a maximum of 35 elected annually. Dr. Peter Brian Medawar, Visiting Professor of the Institute, became a Foreign Research Associate of the Academy—an especially high honor since there are only 74 foreign members, with 4 elected each year. Dr. Edward J. McShane, Professor of Mathematics at the University of Virginia and also a Visiting Professor at the Rockefeller, was elected a Councilor for a three-year term. On April 26, the first day of the meeting, Professor Maclyn McCarty chaired a symposium on "Antibody Structure and Formation."

Law and Science

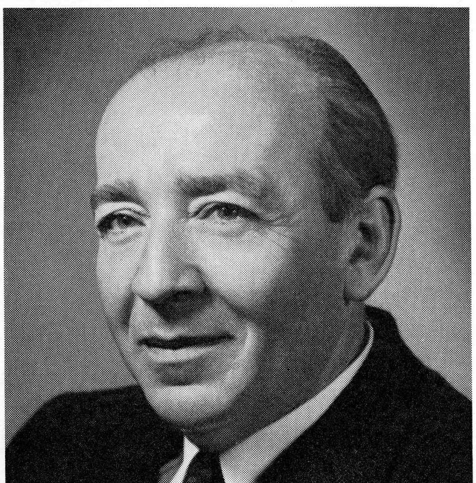
A CONFERENCE on "Law and the Social Role of Science" was held April 8 and 9 under the auspices of The Rockefeller Institute and the Walter E. Meyer Research Institute of Law. During these two days a group limited to about thirty lawyers and a like number of prominent scientists gathered in the Caspary Auditorium for five sessions at which papers were given on such diverse subjects as "Confidentiality and Research," "Restrictions on the Use of Drugs," "Animals and Persons in Research," and "Legal Inquiry and the Methods of Science." Three members of the Institute's governing corporation chaired three of the sessions: John E. Lockwood, Secretary and Counsel, Barklie McKee Henry, and E. Whitney Debevoise. In the final session President Bronk delivered an address on "Science and the Law in a Changing Society," and Professor Jones of the Columbia University Law School summarized the conference with his address on "Legal Inquiry and the Methods of Science."

The conference was organized by Dr. Donald R. Young, the distinguished sociologist and former President of the Social Research Council and of the Russell Sage Foundation, who is now Visiting Professor at the Institute. The Proceedings will be published in book form by The Rockefeller Institute Press.

This conference was the first of a series which will



SAM GRANICK



MARK KAC

be held at the Institute, on the social role of science in relation to other fields of scholarly endeavor that have a primary concern for man.

Student Forum

THE STUDENT FORUM was founded three years ago by a group of graduate students who sought to bring lecturers to the Institute in "nonscientific" fields such as art, history, literature, and politics. The speakers for March and April, for example, were Dr. Morse Peckham of the University of Pennsylvania, who spoke on "Poetry: Order and Disorder," basing his theme on the first ten lines of "Paradise Lost"; and Dr. Lewis Mumford, who addressed the group on April 13 on "The City as a Biological Problem," expanding on some of the topics raised in his excellent films. Other recent speakers include Dr. Kenneth Clarke, a professor of psychology at City College and a director of Haryou; Dr. Hannah Arendt; and Dr. Robert Farris Thompson of Yale University, who lectured on "An African Aesthetic."

Responsible for this year's varied program are Graduate Fellows Glenn L. Paulson, Lewis Kleinsmith, Kenneth Nadler, Richard Nagin, and Daniel Rifkin, who operate with the help of a faculty committee. The lectures are open to all students and members of the faculty and are held in the Graduate Students Residence Hall on the second Tuesday of every month.

NOTES

¶ April 15 was the official publication date of *A History of The Rockefeller Institute* by Dr. George W. Corner. "The fifty years encompassed by this History was a period of extraordinary scientific progress in the United States. The Rockefeller Institute played a unique and important role in that dramatic development," comments President Bronk in the foreword to the work, and he concludes, "George Corner has the ability and the will to write with clarity and grace." The volume was published by The Rockefeller Institute Press, and was written by Dr. Corner while in residence for five years as Historian of the Institute.

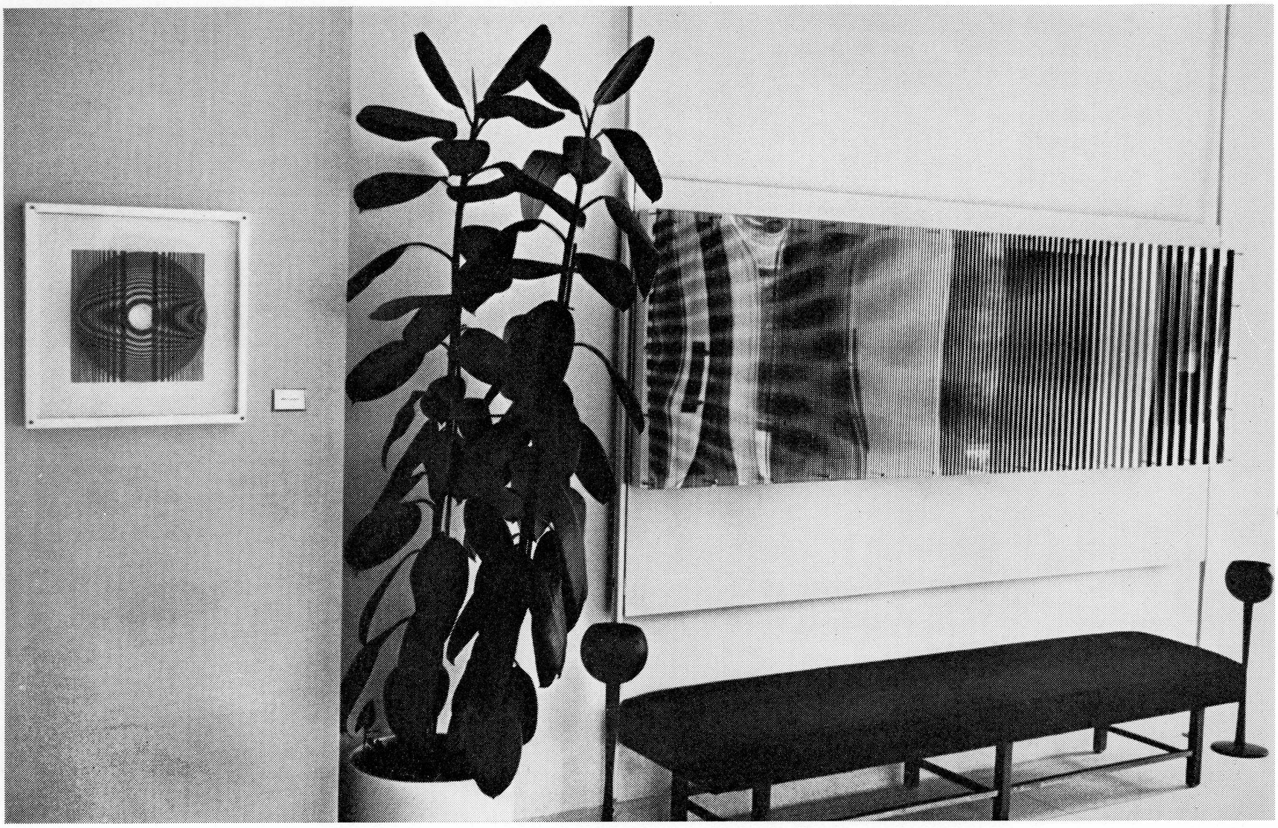
¶ Dr. Theodosius Dobzhansky, on April 8, was elected Foreign Member of The Royal Society of London. This brings to four the number of Rockefeller faculty who are Foreign Members of the oldest academy of science: Rous, Bronk, Lipmann, and Dobzhansky. No other university in the world has so many.

¶ President Bronk gave the annual Alpha Omega Alpha Society lecture at the University of Pennsylvania in early March. Noting the challenge to physicians that they enable man to live more as well as longer, Dr. Bronk took the theme, "The Humane Values of Physicians in our Technological Society." A few weeks later at a Duke University Symposium in honor of Paul Gross, distinguished chemist and educator, Dr. Bronk delivered an address on the "Leadership of Educational Institutions in Scientific Developments."

¶ Dr. Jules Hirsch and his group now occupy new quarters on the second and third floor of the Hospital which will afford greatly increased facilities for Dr. Hirsch's studies of behavioral and metabolic aspects of obesity. The new facilities provide for biochemical analyses of metabolism in fatty tissues, for psychological testing and interviewing of the patients, and for inpatient care of three volunteers. On March 17 Dr. Hirsch presented some of the findings and the problems in his studies of human obesity and, in particular, the psychological difficulties faced by the grossly obese patient who has undergone a large weight loss.

¶ Professor Gerald Oster of the Polytechnic Institute of Brooklyn gave four lectures during March and April on the timely subject of moiré optics. Dr. Oster's discussions included a description of the mathematical principles involved in moiré patterns, their use in making exceedingly fine measurements and in analyzing wave forms, and the psychological effects produced by the patterns in terms of movement, color, and contrast. Through the courtesy of the Howard Wise Gallery, eight examples of moiré patterns by Dr. Oster were on exhibit in the lobby of the South Laboratory while, concurrently, other works by him were being displayed in the op art show at the Museum of Modern Art, "The Responsive Eye."

¶ Professor Mark Kac became Chairman of the Division of Mathematics of the National Research Council on February 25. Dr. Kac had been named Chair-



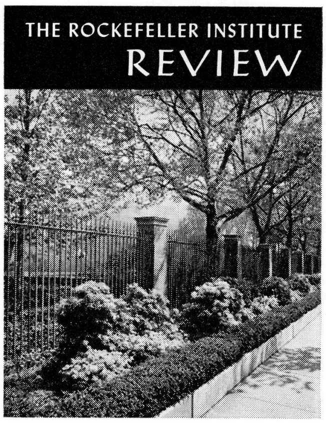
Moiré patterns by Gerald Oster: (LEFT) Sphere on Cylinder Projection, (RIGHT) Triple Log Major.

man-designate of the Division last year for the term starting July 1, 1966, but assumed office earlier upon the resignation of the present Chairman, Dr. Gustave A. Hedlund.

¶ In April, two of the Institute faculty presided at sessions of the Spring Meeting of The American Physical Society in Washington: Professor A. Pais at the session on "Symmetries of Strong Interactions," and Associate Professor Nicola N. Khuri at the session on "Scattering Theory." An invited paper on "SU_6 and Related Symmetries" was presented later in the meeting by Assistant Professor M. A. B. Bég.

¶ On March 18, the Institute was once again host to the Sloan-Rockefeller Advanced Science Writing Fellows of the Graduate School of Journalism, Columbia University. For the benefit of the Fellows, a daylong seminar was held on "Variable Gene Activity." Professor Alfred E. Mirsky introduced the subject and laid the historical setting, then Professor Igor Tamm spoke on gene activity in relation to virus infection. Dr. Eric H. Davidson discussed growth and development, and finally Dr. Sam Granick presented his recent work on protoporphyrin.

¶ A collection of original American prints on loan to the Institute from International Business Machines was shown in the Caspary Auditorium Gallery from March 8 to April 7. A variety of techniques was represented — relief, intaglio, planography, and stencil — and an even wider variety of styles and moods, with prints dating from the early nineteenth century to the present. An original block cut by Dr. Alexander Anderson, the most prolific and famous early American wood engraver, was included; also, a masterpiece by James A. McNeill Whistler, *Black Lion Wharf,* with a note in the catalog that the artist was dropped from West Point for deficiency in science. The exhibit was opened officially with a lively description of "How Prints are Made," by A. Hyatt Mayor, Curator of Prints at the Metropolitan Museum of Art.



The view south along the York Avenue mall is a colorful prospect in early May. Beyond the walkway edged with close-knit ilex, our cover photograph shows purple and pink azaleas and japonicas with their small, bell-shaped, white flowers. The dome of Caspary auditorium is in the background, shaded by overhanging sycamores.

ILLUSTRATIONS: COVER photograph by Joseph Barnell. PAGE 3 from a steel engraving by George E. Perrine, *The Eclectic Magazine of Foreign Literature, Science and Art,* Vol. XV, New York, 1872. Bettmann Archive, Inc., New York. PAGE 5, Bettmann Archive, Inc. PAGE 8, classic example of Brownian movement, taken from *Les Atomes,* Jean Baptiste Perrin, first edition, 1913. PAGE 9, electron micrograph courtesy of Dr. Ian R. Gibbons, Harvard University. PAGES 14-17, 19, The Rockefeller Institute Illustration Service.