12-1964

The Rockefeller Institute Review 1964, vol. 2, no. 6

The Rockefeller University

THE ROCKEFELLER INSTITUTE REVIEW

NOVEMBER • DECEMBER 1964

The Rockefeller Institute Review, Nov.-Dec. 1964. The Review is issued bimonthly. This is volume 2 number 6. Published by The Rockefeller Institute, Sixty-sixth Street and York Avenue, New York, N. Y. 10021. Second-class postage paid at New York, New York. The price for a subscription for one year is $3, single copies 50¢, back numbers $1.

THE MENDEL CENTENNIAL

BY THEODOSIUS DOBZHANSKY

Genetics, an important branch of biological science, has grown from the humble peas planted by Mendel in a monastery garden in Czechoslovakia

THE INCEPTION of an important branch of science is seldom traceable to a single work of a single investigator. This is possible with genetics. Genetics takes its rise from the work of Gregor Johann Mendel, the first centenary of which is celebrated this year.

On February 8 and on March 8 of 1865, the Society of Naturalists in the town of Brno (Brünn), Czechoslovakia, heard Mendel describe the results of his experiments on hybridization of varieties of common garden peas. One may well doubt that anybody in the audience, about forty in all, had an inkling of the significance of the work the account of which was presented to them. The estimable Brno naturalists were not alone in this lack of discernment. The importance of Mendel's discovery was not appreciated by the scientific world at large when it was published in the following year, 1866.

Viewed in the perspective of time, Mendel was one of the tragic figures in the history of science. He must have felt that his work was a dismal failure. It was overlooked and ignored. He could hardly have foreseen that it would be rediscovered and appreciated in 1900, 16 years after his death. He published it in an out-of-the-way provincial journal, "Verhandlungen des naturforschenden Vereines in Brünn." This is an only partial explanation of its having been disregarded. Scientific literature was not then the flood it has now become. Copies of the journal were duly sent to some 120 libraries in several countries. Mendel had 40 reprints of his article made for private distribution among biologists who he thought might be interested. Whoever read it paid no attention. Some years ago an eminent German botanist found a reprint of Mendel's paper in the library of his father, who was also a well-known botanist; the pages of the reprint were uncut.

GREGOR JOHANN MENDEL

Another reprint, with an accompanying letter, Mendel sent to the eminent biologist Karl Nägeli. Nägeli was himself making experiments on hybridization of plants, and might have been expected to see the significance of Mendel's findings. His faintly patronizing reply suggested that Mendel's experiments are only a beginning, and that the results obtained with peas ought to be verified using other experimental materials. As such, Nägeli recommended varieties and species of hawkweeds, *Hieracium.* This advice was disastrous. It would be unfair to blame Nägeli for having given it to Mendel; neither Nägeli nor anybody else at that time knew that hawkweeds are plants with a peculiarly aberrant reproductive biology. They are apogamic, and give rise to seeds without a sexual process, without fertilization, by a kind of parthenogenesis. Mendel wanted to cross one variety with another, to obtain hybrids, and to study the progenies of the hybrids. This he had accomplished with peas, and following Nägeli's suggestion he tried to obtain hybrids of hawkweeds. The results seemed to make no sense at all, let alone to confirm his earlier observations and conclusions. In scientific research, as in most human endeavors, sheer luck plays a part. One may surmise that Mendel felt disheartened. He was, to be sure, no stranger to disappointment; only a few years earlier he failed the examination for a high school ("gymnasium") science teacher certification. The supreme irony in this failure was that Mendel, one of the greatest biologists of all time, did most poorly in the part of the examination dealing with biology; the examiner found that Mendel lacked "the necessary clarity of comprehension!"

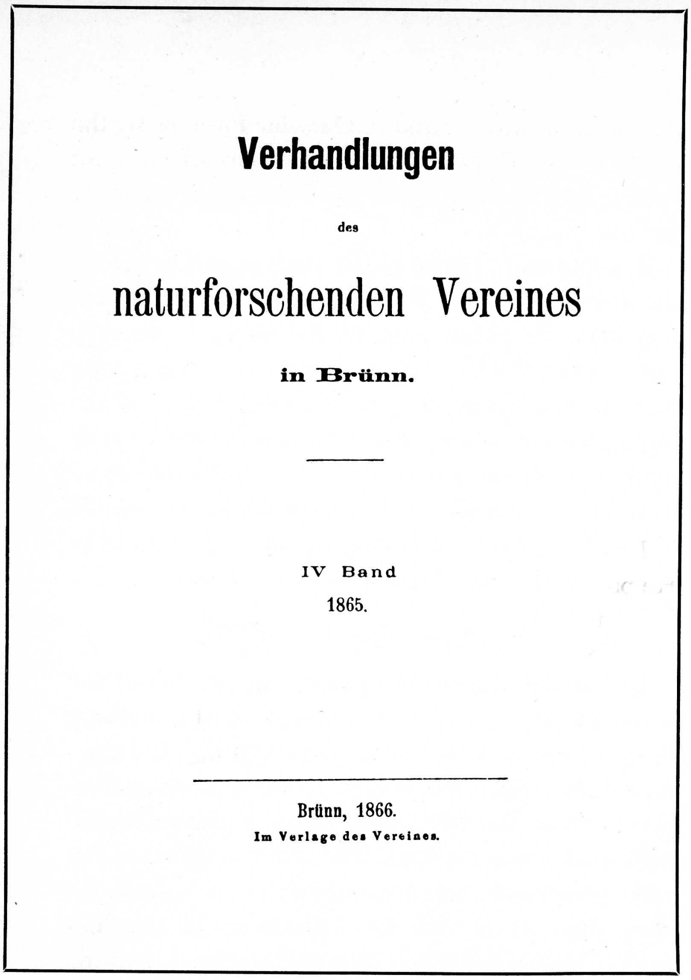
Darwin perhaps alone

It is hard to refrain at this point from an "it might have been" speculation. Biologists of 1865 were evidently less well prepared to understand Mendel's discovery than were biologists of 1900. There was a biologist living in 1865 to whom this statement did not apply however. This biologist was Darwin. Had Darwin chanced to see Mendel's publication, the history of biology may well have been different. Darwin, perhaps alone in his time, might have seen the significance of Mendel's work. Though very different in their backgrounds, they had scientifically much in common. Neither was a professional scientist. Mendel, born in 1822 a son of a Moravian peasant, entered the Augustinian monastery in Brno, and found an opportunity for his intellectual pursuits only behind this monastery's walls. He made his famous experiments in his free time, in the monastery garden. Darwin, a wealthy English country squire, made the study room in his house in Down his laboratory. Darwin's "The Origin of Species" was published in 1859, six and a half years before Mendel's paper, which Darwin never saw.

Breadth vs depth

The problem of heredity was crucial to Darwin. He patiently collected every shred of information on heredity in the biological literature, and he made his own experiments crossing varieties of plants. He came within an ace of obtaining results like Mendel's. Whether or not he would have made an analysis of such results as masterfully as Mendel did is a moot point. The late J. B. S. Haldane argued that Mendel's brilliant conception of "characters" or "factors," which we now call genes, was somehow suggested to him by his familiarity with Thomist philosophy. This is a compliment for Thomist philosophy, but I am not convinced that it is warranted. I see no parallel between the genes and any of St. Thomas Aquinas' ideas known to me. However, Mendel's genius was indeed of a type different from Darwin's. It was in depth rather than in breadth. Mendel was not a generalizer of masses of heterogeneous data, as Darwin so preeminently was. I agree with J. S. Wilkie that "what is impressive in Mendel's papers is not the handling of great masses of varied evidence, but the extent to which he had developed the theoretical consequences of his hypothesis. It is on account of this development that we are so ready to consider Mendel as unquestionably deserving the title of originator."

The problem which Darwin had to face was no less than the nature of heredity and, since evolution obviously involves hereditary changes, the nature of evolution. A belief that was generally accepted before Mendel showed it to be wrong, was that heredity is transmitted through "blood." Such phrases in English and other languages as "half-blood," "noble blood," "blue blood," etc., embody this belief. After the pioneer microscopists late in the seventeenth century discovered the sex cells, eggs and spermatozoa,



Verhandlungen

des

naturforschenden Vereines

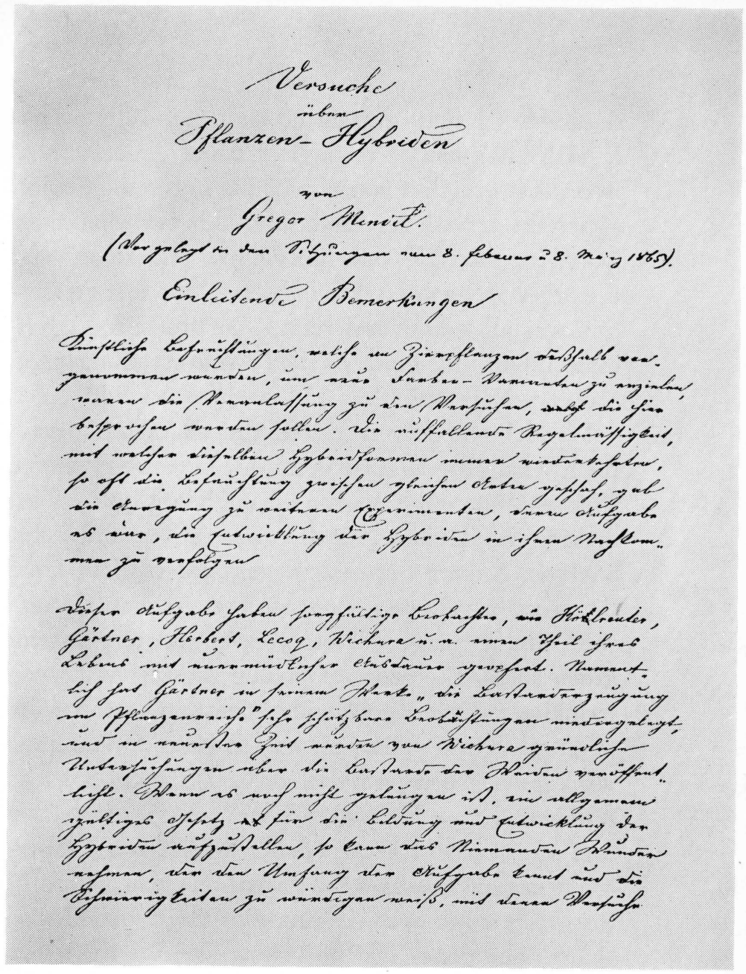
in Brünn.

IV Band

1865.

Brünn, 1866.

Im Verlage des Vereines.



Title page of the journal (LEFT) *in which Mendel first described his experiments on the hybridization of peas. Opening page of the original manuscript* (RIGHT).

it was of course realized that the hereditary "blood" is not the same thing as the red liquid circulating in the heart and blood vessels. The essential part of the "blood theory of heredity" was that the heredity of a child is a blend, a mixture, of the heredities of his parents, and hence of his grandparents and of more remote ancestors.

Darwin accepted the blood theory of heredity for want of a better one, although it created a virtually insuperable difficulty for his own theory of evolution. The difficulty, pointed out to Darwin in 1867 not by a biologist but by an engineer, Fleming Jenkin, was as follows. Suppose that a new variant arises in some population, for example, a light-skinned mutation in a dark, or a dark-skinned in a light population. Could the new variant multiply and eventually replace the original type? It seemed that it could not: because the new variant has to mate with an unchanged individual, its progeny will have its characteristics diluted, and in a few generations these characteristics will disappear as completely as a drop of ink in a sea of water. Darwin struggled in vain to escape from this paradox, unaware of the fact that a paper published by an obscure author in an obscure journal from Brno showed the paradox to be a spurious one.

Mendel's experiments were remarkably simple. He crossed varieties of peas differing in easily visible characteristics; for example, one having yellow seed with one having green seed. The first generation hybrid plants produced yellow seed. The yellow seed color is dominant, the green is recessive; but the ostensible disappearance of the green color in the first generation hybrid plants did not mean that the green heredity was somehow dissolved in, or consumed by, the yellow one. In the second hybrid generation yellow and green seed reappeared. The green

seed characteristic was in no way diluted or weakened by its passage through the first generation of hybrids in which it was not visible in the seed color. When the varieties crossed differed in two characteristics, for example, one had yellow and round and the other green and wrinkled seed — the first generation was all yellow and round, but the second generation had four kinds of seed: yellow round, green round, yellow wrinkled, and green wrinkled.

Mendel not only recorded the characteristics in his hybrid progenies of peas, but he counted them. This was not merely for the sake of being meticulous; making the data quantitative was indispensable for analysis. Among the second generation seeds from the cross of yellow with green seeded plants, there were about three-quarters yellow and one-quarter green seed. The cross of yellow round with green wrinkled gave in the second generation a proportion of 9 : 3 : 3 : 1 of yellow round : green round : yellow wrinkled : green wrinkled seed. These proportions follow if the sex cells, ovules and pollen, carry "factors" or "genes," the presence of which in the developing organism causes the formation of the yellow or the green color, or of the round or the wrinkled seed shape. The genes for the yellow and for the green color segregate. One-half of the sex cells carry the yellow and the other half the green gene. The genes for the round and the wrinkled seed shape also undergo segregation. The important fact is that the segregation of the color genes and the shape genes is independent. Equal numbers of sex cells are formed with yellow-round, green-round, yellow-wrinkled, and green-wrinkled gene combinations. At fertilization the sex cells unite regardless of which genes they carry. The chances of a pollen with the green gene to fertilize an ovule with either the yellow or the green gene is simply proportional to the numbers of the ovules available.

Jenkin paradox resolved

The Jenkin paradox, which was insoluble to Darwin, now vanishes; a changed gene will not disappear by blending with unchanged ones, even if these latter are a majority. Whether Mendel himself realized his scientific kinship with Darwin may never be known. The library of the Brno monastery had copies of some of Darwin's books with marginal notes in Mendel's handwriting. Why did Mendel fail to send a copy of his publication to Darwin? Perhaps by the time he read Darwin he had given up all hopes of having his own work understood and appreciated by anybody.

It is impossible in an article such as this to review the developments of Mendel's work during the century since its publication, or the 65 years since its rediscovery. Such a review would amount to a summary of the whole of genetics. Only a few of the highlights can be mentioned. Although studied originally in peas, the inheritance in most diverse organisms has eventually been analyzed in Mendelian terms. The genes are among the most general components of the machinery of life.

A few highlights

To Mendel, and to the pioneer geneticists of the current century, a gene was a symbol of something the presence of which in the sex cells had to be assumed, to explain the results of observations and experiments on the inheritance of traits in man, in animals, and in plant species. The symbolic genes of the early geneticists soon acquired a material abode. In 1903, three years after the rediscovery of Mendel's work, T. Boveri and W. S. Sutton independently pointed out that the genes must be borne in the chromosomes. An interesting detail — Boveri was then a famous professor in Germany, Sutton a graduate student at Columbia University in New York. It was, however, T. H. Morgan and his collaborators and students who starting in 1910, unraveled the gene-chromosome story. They were helped by the choice of a favorable new material, the vinegar fly *Drosophila* (often misnamed the fruit fly), now familiar to college, and even high school, biology students. It was shown that the genes are arranged in a chromosome in a single linear file, "like beads on a string," to use a now outmoded simile. Maps were prepared, indicating the relative positions, and even the relative distances, of the genes in the chromosomes. In 1927, H. J. Muller announced that genes and chromosomes are changed in the offspring of flies treated with X rays and other short-wave radiations, more frequently than without such treatments.

Utilization of bacteria, viruses, and other microorganisms as experimental materials has in recent years brought most significant developments in the study of the genes. Although these developments

Mendel's garden in the Augustinian monastery at Brno

may seem infinitely remote from the simple experiments which Mendel was contriving with his pea plants in the Brno monastery a century ago, an unbroken intellectual continuity can be discerned in genetics from Mendel and Darwin to our day.

Any complex organism has many kinds, thousands or tens of thousands, of different genes (the exact number is not known for any particular species). What makes these genes different from each other? And how do human genes differ from those of, say, a Drosophila fly? The hypothesis put forward by J. D. Watson and F. H. C. Crick can best be envisaged by means of an analogy. The twenty-six letters of the English alphabet are sufficient to write any number of words and messages; in fact, everything can be written with the aid of the three "letters" of the Morse telegraphic code: dot, dash, and gap. A word or a phrase is represented by a certain sequence of letters. It appears that there are four "letters" in the genetic "alphabet": the four kinds of nucleotides which are arranged in different sequences in the chain-like molecules of DNA in the different genes. Evolution can be described as a sequence of changes in the Mendelian genes. The genes normally perpetuate themselves with remarkable accuracy; only rarely does the copying go awry, and the new, mutant, gene differs from the old in one or more "letters." High-energy radiations and some chemical treatments increase the frequencies of these inaccuracies in the gene copying, and hence act as mutation-inducers. The process of mutation does not, however, constitute evolution, it only supplies the raw materials from which evolutionary changes may be compounded. It is here that the process of natural selection, envisaged by Darwin, comes into play.

Every person unique

The biological meaning of sexual reproduction is another problem which Mendel's discovery helps to elucidate. A corollary of sex is the process of meiosis; meiosis normally leads to Mendelian recombination of genes, and thus to the emergence of countless new

genetic endowments, genotypes. In sexually reproducing organisms, including man, every individual (except identical twins) has a gene constellation of its own, which never existed in the past and has a negligible chance to reappear in the future. This is significant in at least two ways. First, genetics upholds the affirmation of the uniqueness of every human person. It gives the lie to the allegation that science can deal only with what repeats itself, and is irrelevant to the understanding of the individual and the unique. On the contrary, genetics shows why every human being is indeed an individual, and not merely a pale reflection or a distorted image of some archetype of man. The human nature is different in every human. It should be stressed in this connection that we inherit from our parents some of their genes but not their genotypes, and pass to our children some of our genes but not our genotypes. The genes work in the development of the body not as isolated but as interacting units, not as solo players but as members of a symphony orchestra.

Sex and natural selection

A second but no less important consequence of the Mendelian gene recombination in sexual reproduction, is continuous proliferation of innumerable ever-new genotypes, which are exposed to testing by natural selection. The outcome is a trial-and-error process of vast proportions. Evolution must have been going on before the appearance of sex; sex was, however, the greatest evolutionary "invention," which made the subsequent evolutionary "inventions" possible. It has made natural selection a mechanism to achieve what would otherwise be in the highest degree improbable. George Wald said that "living organisms are the greatly magnified expressions of the molecules that compose them." This is true, but it is only a part of the story. The Cartesian, reductionist, explanation needs a Darwinian, or as George Simpson calls it "compositionist," counterpart. Organisms do not arise by accidental conflux of molecules. The creatures that are alive today are the products of unbroken sequences of patternings of molecular components, and these sequences extend back to the origin of life more than two billion years.

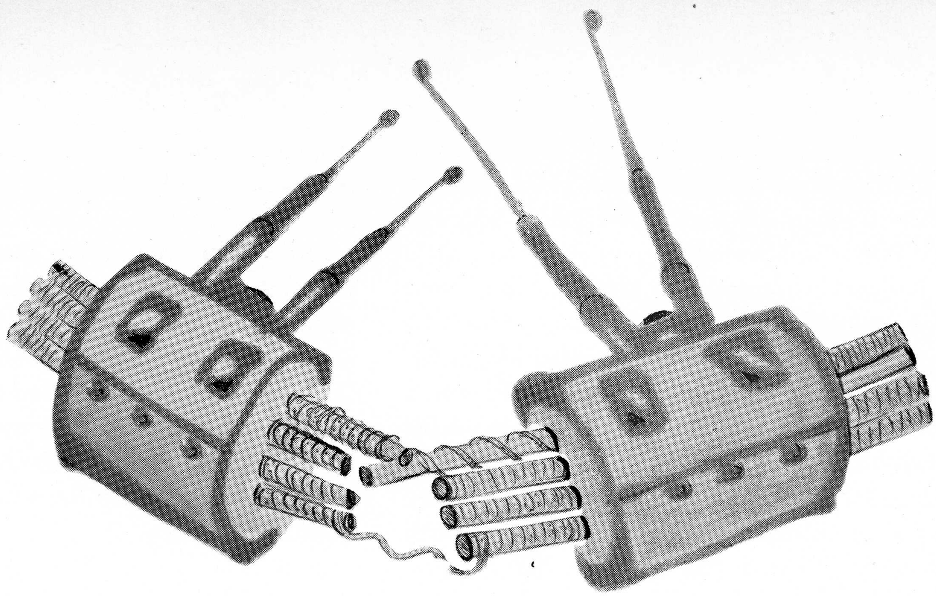
A few years ago, one of the outstanding living mathematicians sent me a long private letter, in which he argued that a combination of many gene mutations adding up to a viable body is so absurdly improbable, that we have to suppose that the process is guided by a spirit or a deity. I cannot gainsay his mathematics, but would like to controvert the biological assumption he has tacitly made. The genes that compose a human genotype did not arise and all come together in one place at the same time. Mendelian recombination and natural selection were working in a long succession of generations; they were not "aiming" to build the body we observe now in a state of relative perfection; they were making minor modifications in a succession of ancestral bodies, in response to the challenges of the ancestral environments.*

A parable

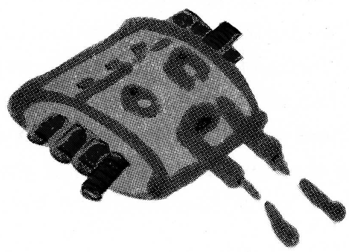
The development of an individual, ontogeny, also seems to be planned by some foresight, as if attracted by its end rather than impelled by its beginning. This leads E. W. Sinnott to contend that the development is governed by a "psyche," a new name for the old vital force. However, ontogeny is understandable only as a product of phylogeny, not the other way around. Organs in a developing individual are formed for future uses, because in evolution they were formed for contemporaneous utility. Individual development ends in death; its biological meaning is that it continues in the progeny. And this may be taken as a parable. An individual scientist accumulates knowledge and hopefully wisdom, only to wither and disappear. The accumulation may continue in his intellectual progeny. Mendel probably despaired having any intellectual successors at all, and yet he set in motion a scientific enterprise which a century later comes to occupy an increasingly important place in the intellectual advancement of mankind.

*I am not at liberty to name my mathematical correspondent. The negative part of his argument, without the benefit of mathematical reasoning, has been stated by Jacques Barzun, among others. It is unbelievable to Barzun "...that pure chance could combine atoms and cells into forms that fulfill a profusion of complex and varied purposes. The words 'natural selection,' 'adaptive value,' 'variation,' 'environment,' 'struggle for life,' and 'survival,' now seem question-begging formulas that do not mask or answer the grave difficulties which from the start made Darwinism unsatisfactory."

THEODOSIUS DOBZHANSKY *is a Professor in The Rockefeller Institute and one of the world's authorities on genetics.*



LIFE ON EARTH



BY PAUL A. WEISS

THE YEAR IS 2064. Interspace Airways conducts monthly round-trip flights to Mars. Terrestrial Fulbright scholars in cryptography and comparative linguistics have VIP priorities. They have come to outrank the physical scientists of the hardware variety and the biological scientists of the garden variety, who only had confirmed that, after all, mass is mass, and energy is energy, and those telescope-discovered green patches up there are just ordinary grass. And so most research on Mars has been entrusted to the "Neo-Socio-Humanities," whose scientific status symbols are electronic scanners, counters, computers, and probability calculus. They have been asked to check some vague reports about weird, elusive objects on Mars, said to roll around with a metallic noise, behaving much like living creatures – perhaps the Martian version of man. On orders of The World Security Board, teams of investigators went up to look, and here are the results:

There are indeed lots of bodies tumbling around up there, shaped like drums with sturdy rods protruding from both sides. Hard to the touch, they clang and clatter harshly whenever two of them collide, as they quite often do. They definitely are some sort of animate hardware, or rather metallic organism. An artist's rendering of those curious structures appears above. They all carry tapelike wrappings around the rods and, most amazingly, when two such bodies meet, some of the wrappings unwind partly from each of the bearers and coil around the other's rods.

What is supposed to be the meaning of all this? It did not take long for our investigators to find out. By sheer good luck, they came upon some dumping grounds littered with scraps of Martian tape to which they helped themselves in quantity. Back on earth, acting on a hunch, they ran these fragments through the transcriber of a magnetic tape recorder. Miraculously, out came long sequences of squeaky sounds, not unlike Morse code. Computer people and cryptographers got busy and in short order managed to decode the Martian language.

This then was the way in which Martians communicate. The rods are evidently magnetic recorders, committing language symbols to metallic tape, to be read off from there by the receiving rods of the ac-

costed partner. (The baby in the picture, as you note, is still short on taped information.) How sobering for man to contemplate that once again nature has scooped his proud technology.

As more and more of these taped records were collected, collated, and connected, they yielded an amazingly coherent chronicle of Martian life, civilization, and history. Its publication on earth was a bombshell. Indeed, for a while, it shook man's faith in his own security. For the Martian story revealed with unassailable certainty that more than a century earlier a Martian expedition had visited the Earth without being detected. Just how they had escaped detection, despite the radar screens around the globe, is still a mystery.

At any rate, the excitement eventually died down and people turned their attention to the substance of the Martians' story of their expedition. This brought the next wave of astonishment. The Martians' report asserted that they had discovered beyond the shadow of a doubt that there was *life* on earth; more lowly than their own, but true life all the same.

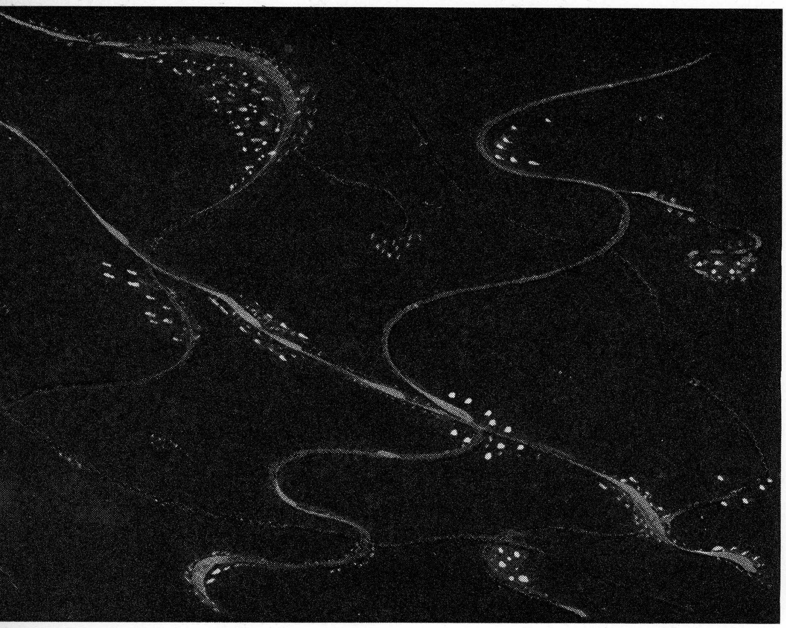
Thanks to the efficiency of the terrestrial decoding and interpreting machines, the Martians' account of their epochal discovery could be fully reconstructed. It speaks highly for Martian literacy that the description is so articulate, lucid, and pictorial that it was easy for a terrestrial artist to compose a pictorial record of the whole story. That story is not only exciting, it is also a superb model of cogent logic — the equal of the peak achievements of inductive reasoning by man. And here it is — the Martians' story of "Life on Earth" — transcribed to a first-person rendition for effectiveness. The accompanying pictures, though apocryphal, are certainly no less authentic than those gracing the illustrated editions of Homer's *Iliad* and *Odyssey*.

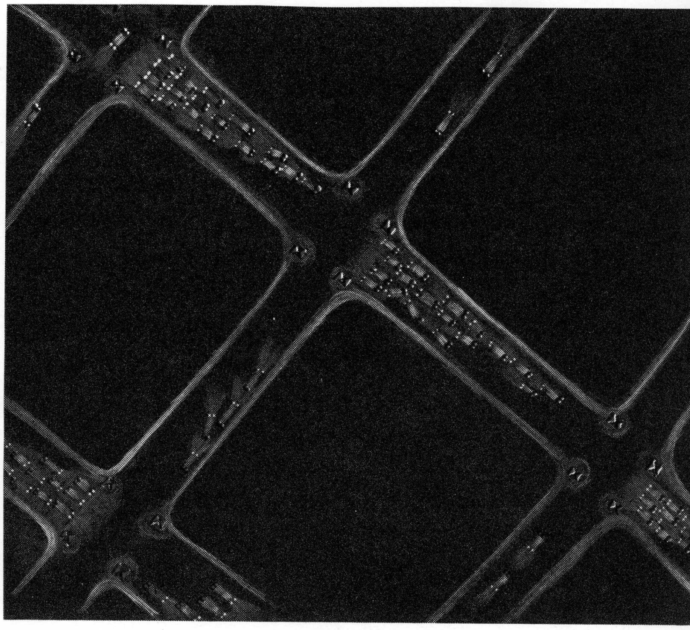
LIFE ON EARTH

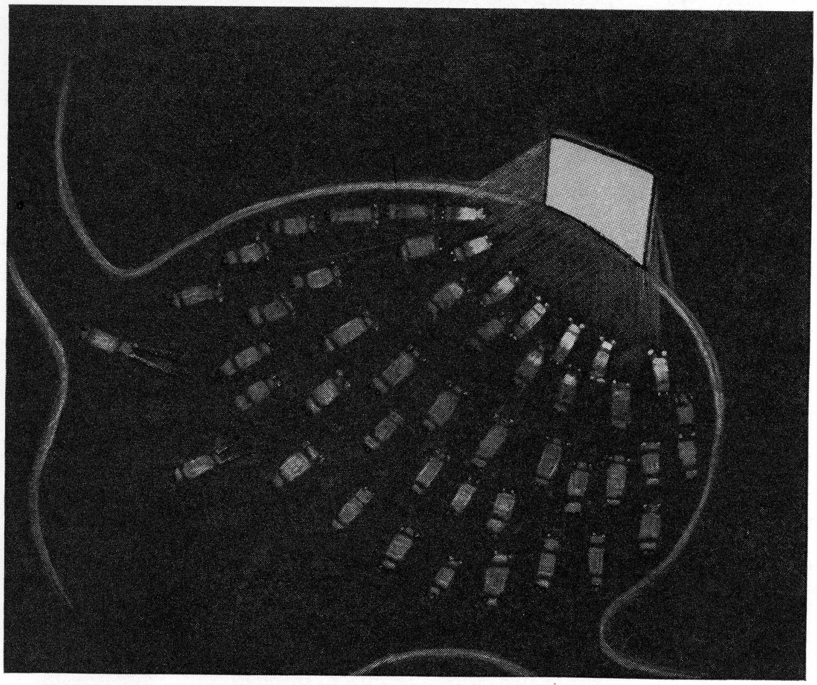
BY A MARTIAN

"WE HAD TIMED our approach to earth to fall into the dark phase of the diurnal cycle. Yet, as we came nearer, we noticed that not all was darkness. There were streaks of light like knotted ribbons. They seemed to move in waves, mostly in one direction. From a still closer view, the knots proved to be separate bodies; they moved indeed, in spasms of alternating spurts and stalls. If life is motion, here was life. Each luminous knot was obviously an individual organism. Each had the polarized appearance of

"If life is motion, here was life, attracted by a flickering light source"

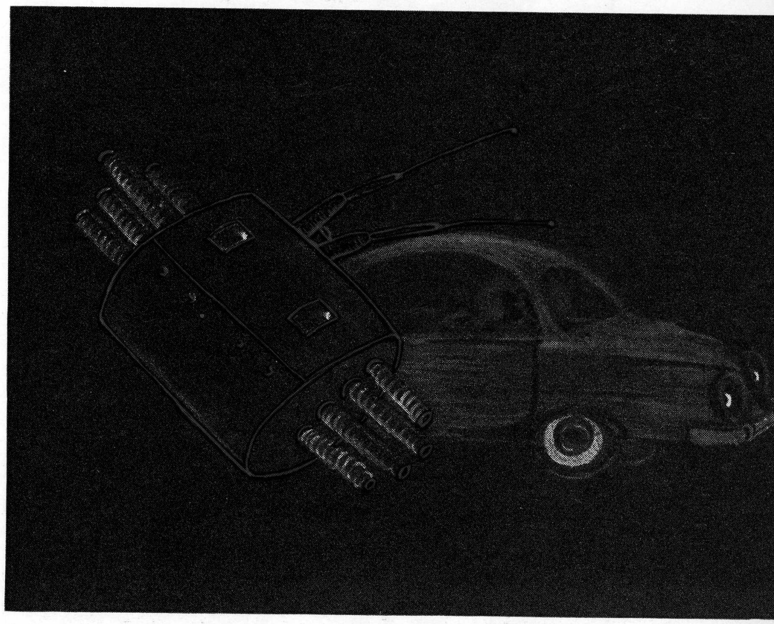






"the true elemental carriers of life on earth formed a handsome sort of crystalline array"

"inside each unit we perceived a pair of structures squirming"



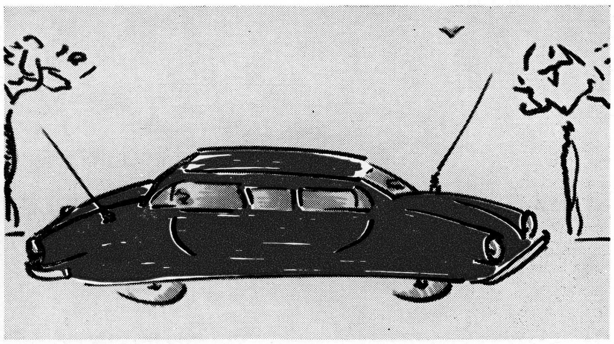
a wedge and seemed in finer resolution to consist of smaller subunits; something like cells. Why they should move in file and unison did not become clear to us until we came in still closer and saw the cause: they all were positively phototactic, attracted by a flickering light source, toward which we likewise now steered our course. Hovering over it, we recognized our first mistake: the knots, which from a distance had looked to us like single individuals, had dissociated into the putative "subunits." These latter thus revealed themselves, by their separate existence and independent motility, as the true elemental carriers of life on earth.

So we kept watching them. Rather than rush right on into the attractive light source, they stopped just short of it and formed a handsome sort of crystalline array. For some time after, they remained immobile and soundless. The only sounds we heard came from that light trap. We thought they slept. So, we took courage to land and inspect them. That was when we noticed that motion had stopped only superficially. For inside each unit we perceived a pair of structures that kept on squirming. Whether these were peristaltic internal organs or some sort of wriggly endoparasites, we had to leave unresolved, for our inspection was cut short abruptly when suddenly the light went out and the various creatures resumed locomotion, all in the reverse direction, though not all at once.

In order to study life on earth in more detail, we decided to wait for daylight, fully prepared to be discovered. Unaccountably, this never happened.

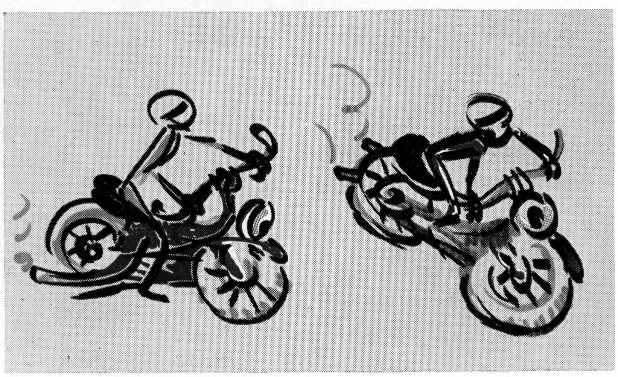
We therefore were able to go about our explorations undisturbed and at great leisure. And what we learned was truly unexpected, almost incredible. To sum it up: Life on earth has so many features in common with our own that we must concede the possibility that Martians and "Earthians," as we shall call them, might be akin. Unpalatable though this deduction may be to the glorious leaders of our superior Martian people, in our conscience as scientists we cannot evade it, provided we can document its premise. And document it we can. For we can prove that Earthians metabolize, eat, drink, and groom; generate heat and light and sound; proliferate and die; and they, like us, vary in size and mood; in short, have individualities.

In structure, they are, like us, of symmetrical build and slightly polarized, although one cannot always



"of symmetrical build and slightly polarized"

tell the two ends easily apart, a feature perhaps correlated with their ability to move in opposite directions. Just how they move at all, we are unable to explain. What confounded us was that while most of them make contact with the ground at four points,



"most of them contact with the ground at four points, others use only two"

others use only two; should the latter, more unstable, perhaps be rated as degenerative forms?

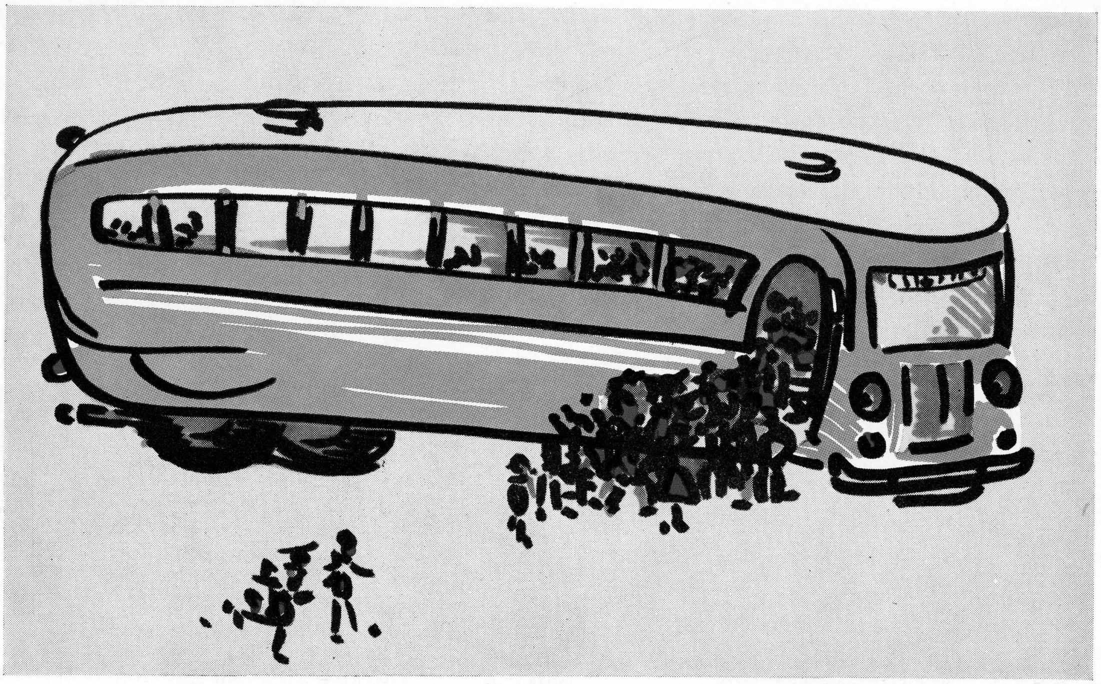
In volume, the majority fall roughly into three size classes. These evidently represent three different age groups, mass increasing with age, though

"three size classes represent three different age groups"

not continuously, but rather in metamorphic steps. Moreover, our measurements of locomotor speeds revealed a striking inverse relation between velocity and size, which would bear out the familiar rule that vigor and speed decline with age.

As we kept on observing, we could not fail to be struck by one peculiar and constant attribute of Earthians: they had invariably associated with them some rather unimpressive bodies of much smaller size. These we have now definitely identified and classified as obligatory parasites of the Earthians, for the following good reasons:

1. They are lodged, for the most part, in the interior of Earthians.
2. Although at times they are disgorged to the outside, they never stray far off, and soon re-enter their hosts.
3. They are more numerous in larger hosts. Therefore, since host size reflects host age, the accessory bodies obviously multiply inside the hosts as the latter grow.
4. Even when detached from their hosts, the little bodies show only extremely limited capacity for independent active motion. Whatever motility we could observe contrasted drastically with that of Earthians by its sluggishness and, above all, its lack of direction.
5. Lastly, the fact that they make only unstable two-point

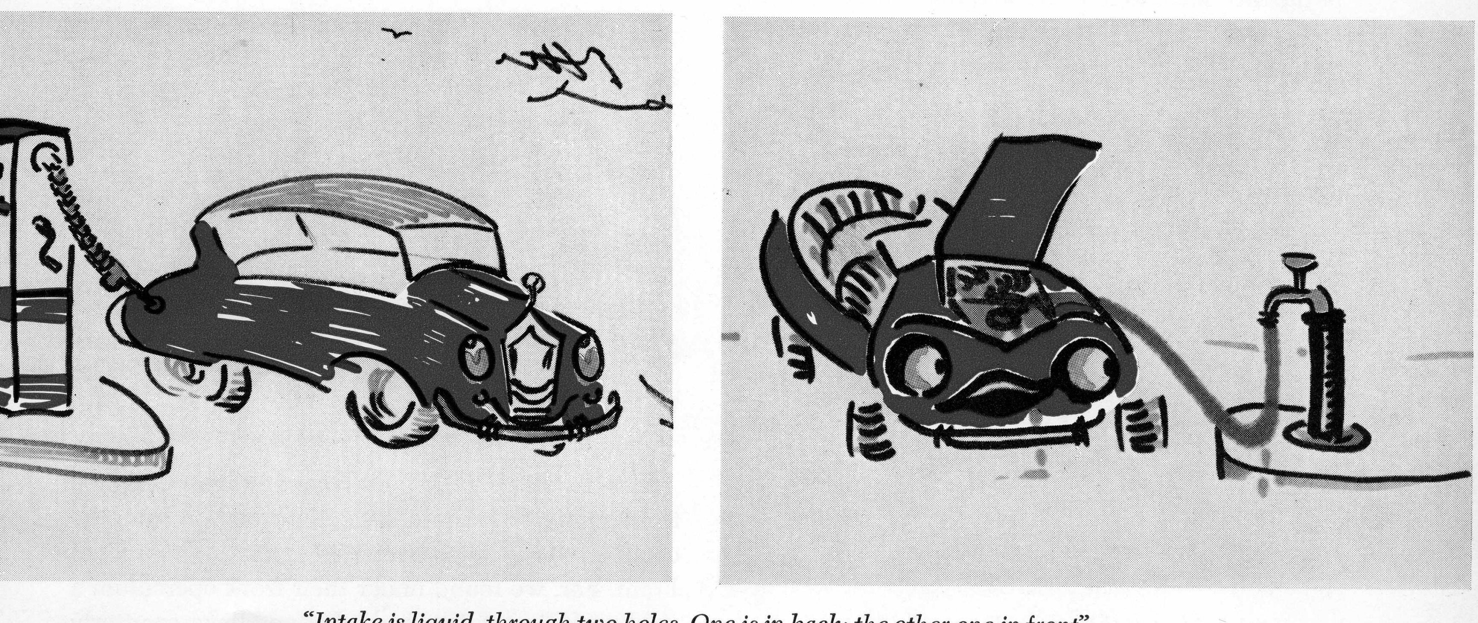


"invariably associated with them some bodies of much smaller size identified as parasites"

contact with the ground likewise puts them into the degenerative class.

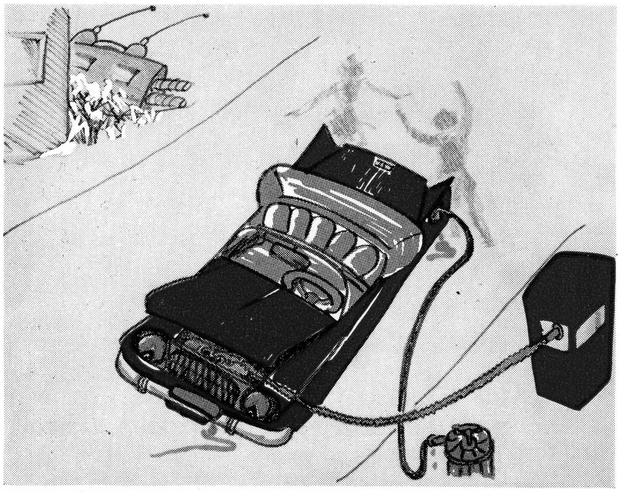
We have given these parasitic bodies the name of "Miruses." Because of their plainly ancillary nature, we shall ignore them in our detailed story, which now returns to our main subject — *The Earthians* themselves. The evidence that these are truly living creatures is overwhelming.

In the first place, they metabolize; that is, they take in substances from the environment, extract energy from them, and give off wastes, mostly as gas and smoke. Intake is mostly liquid, through two



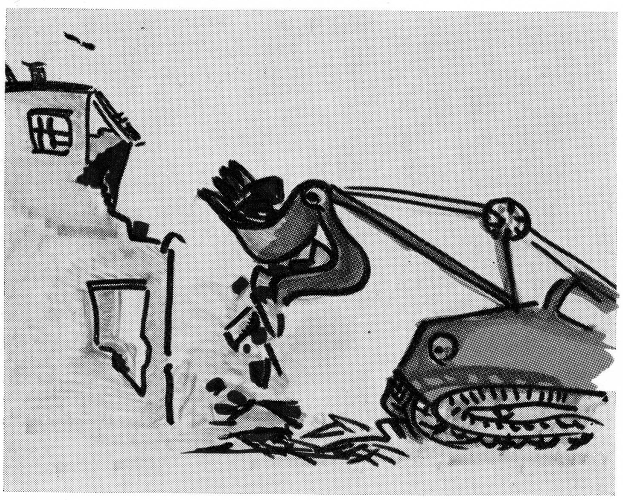
"Intake is liquid, through two holes. One is in back; the other one in front"

holes. One is in back; the other one in front. The front one seems to be much more important because it is quite near the brain, protected by a huge operculum. In fact, the two seem to have totally different functions. We judge this from a test made by a daring member of our party who managed surreptitiously to cross the feeder tubes. The Earthian so treated became completely paralyzed; his parasites, by contrast, showed signs of extreme agitation, the source of which remains unexplained.



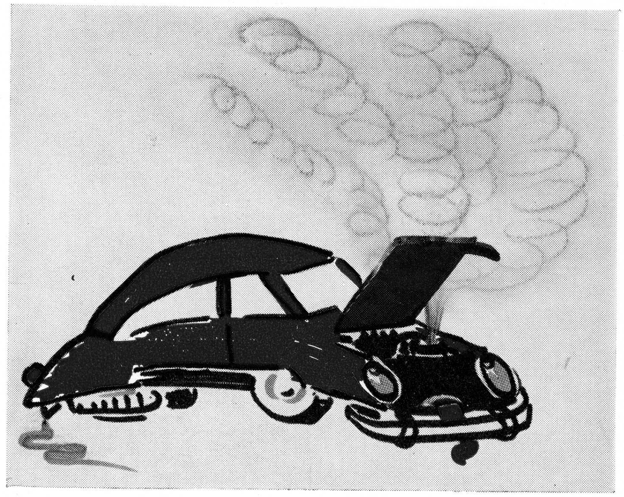
"crossing the feeder tubes, they became paralyzed"

Although most Earthians thus live on liquid food sucked in through tubes, the largest, hence oldest, of the race seem to have formed the habit of gulping solid matter with special organs sprouted for this purpose.



"the oldest of the race gulping solid matter"

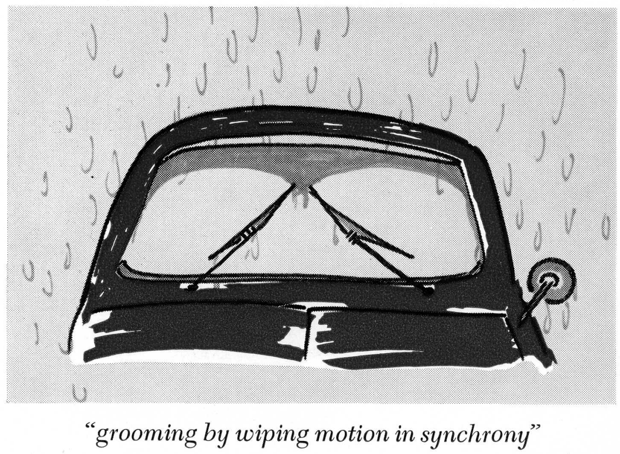
Some of the energy derived from intake goes into heat; and more than once, we saw it explode in spouts of vapors. The functional utility of these geysers is obscure. Some other part of energy, as



"energy from intake goes into heat in spouts of vapors"

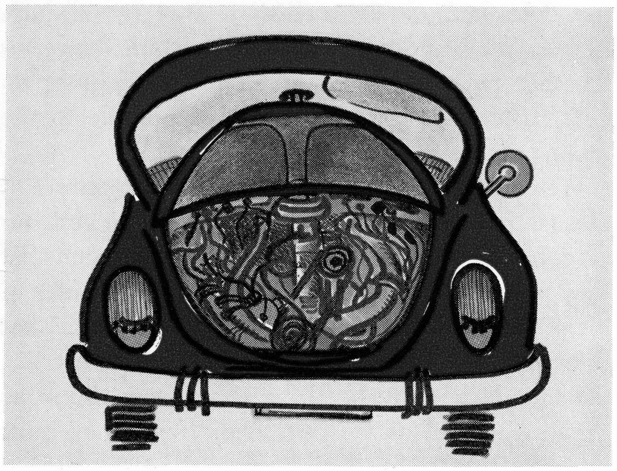
noted earlier, is converted into light, and still another part, into sound. The volume of this sound grows as the square of traffic density.

Off and on, we noted signs of grooming by a wiping motion, but only in front. Astonishingly, this was started and stopped in synchrony by all the members of the population, as if they obeyed some secret commands. Does this imply that they have brains?



"grooming by wiping motion in synchrony"

Unquestionably, they do have an organ designed to integrate and shape data of information from the outside world into concerted actions—a sort of brain. For, we found under their front operculum a wild profusion of lines and tubes and links, so utterly



"an organ to integrate information — a sort of brain"

mixed up and tangled that our "systems analysts" have persuaded us of its basic resemblance to a thinking machine much like our own.

Life for the Earthian, as it must for all living beings, ends in death. Death either comes slowly, heralded by a phase of disarray, unsightly appearance, and frequent breakdowns, or suddenly in a violent noisy disintegration. As you will see, the fast kind has deep vital significance. Much as in our own world, the corpses are collected in heaps destined,

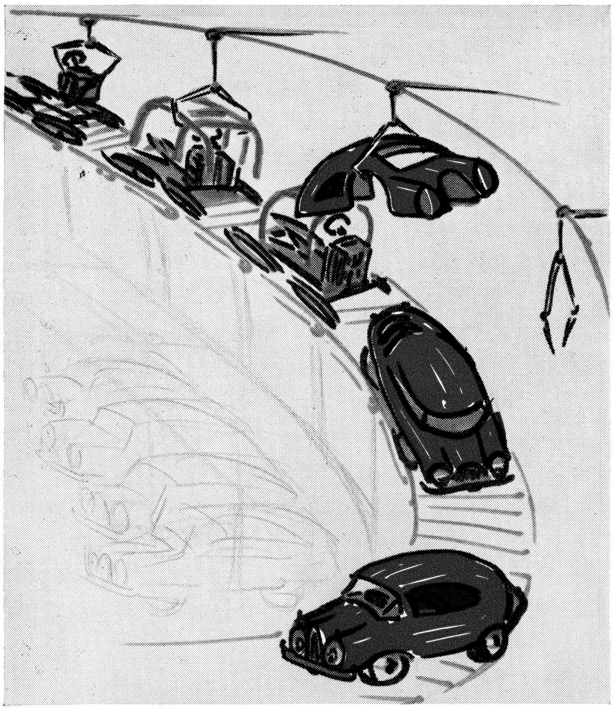
"the corpses are collected in heaps"

at least in part, for some sort of reincarnation. In fact, it was from this source that we could gather clues as to the amazing method by which the Earthians propagate their kind. It took us an inordinate amount of time, effort, and imagination to reconstruct their mode of reproduction. Our conclusions, based partly on observation, partly on deduction, are these. The Earthians definitely do not reproduce by fission or budding. New Earthians are the products of true synthesis from elementary nonliving parts which are assembled stepwise in an orderly nonrandom sequence — a code. Life comes into them only at the end of this process. The elementary constituents themselves are of uncertain origin. However, a series of lucky incidents has made us favor the following theory:

On several occasions we noted two Earthians, fiercely attracted to each other, embrace in a crushing hug, losing their shape, vitality — indeed, identity — in the encounter. They evidently gave up their individual existences for a higher union. We could not help being mystified by this sacrificial act, till

"two Earthians, attracted to each other, embrace"

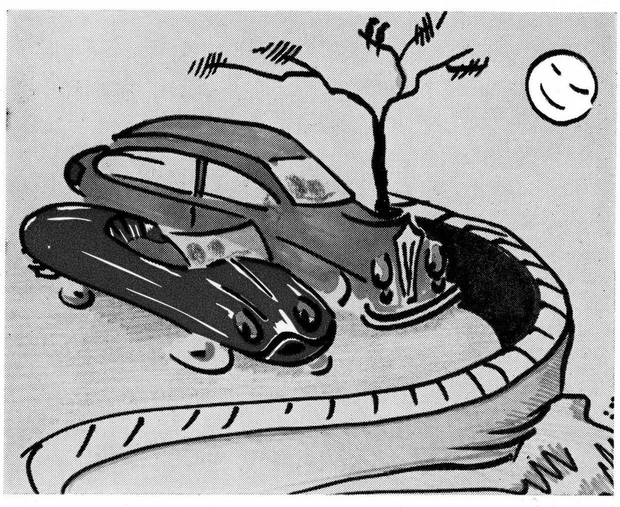
we discovered that it marked not an end, but rather a beginning: a renascence. In following the fate of the devitalized scraps picked up by other Earthians, we saw them vanish in a complex of huge structures which spouted fire and colored smoke and later reemerge as handsomely molded parts, preformed and ready for assembly into new Earthians. From this experience, we are convinced that the observed crash encounters are truly a mating of two individuals, which in loving abandon expunge their lives so that their merged substance may be reincarnated in living offspring. At times, a considerable lag period



"New Earthians are the products of true synthesis from elementary nonliving parts"

separates the act of love and the reprocessing of its products to new life.

A rather curious correlation ought to be mentioned in this context. It was not at all uncommon for us to find pairs or groups of Earthians resting motionless in rather isolated spots. It could not escape us that, in the vicinity of such locations, the incidence of the described mating collisions was significantly higher. We wonder if this is sheer coincidence, or whether perhaps the observed phase of quiet togetherness might not be a sort of prelude to the mating crash.



"Earthians resting motionless in rather isolated spots"

We could go on documenting the living nature of these Earthians still further. However, we rest our case, having proven to everybody's satisfaction that they possess at least three of the basic attributes of life — metabolism, motility, and reproduction. That they are alive cannot be doubted. Being metallic, they might conceivably have come from the same primordial stuff as we ourselves. If so, they must have evolved at a much slower rate to have remained on such a primitive level of behavior as we succeeded in recording. This gives us comfort; for it assures us that they could hardly ever come over to our lands to bother us. Far from disheartening, the discovery of life on earth has, on the contrary, strengthened our faith in our Martian supremacy as the unequaled climax of evolution.

Moreover, by actually witnessing the stepwise assembly of Earthians from nonliving scraps, our expedition has once more confirmed the brilliant deduction of our chemists, reached long ago, that *all* living matter can be synthesized from scratch. Not that we needed confirmation; for have we not *known* that life, wherever in the Universe it may exist, was not created, but has originated?"

The Martians' summary report ends here. No doubt, to us genuine Earthians, it sounds utterly farcical. What an absurd trick their logic and inductive reasoning has played them: those smug, vainglorious, and self-assured creatures imagining they had the key to life, its essence and its origin. We, who know better, glory in our superiority. Would we ever let ourselves be deluded by such glib contentions? Would we, in comparable circumstances, not exercise our native faculty for sober, balanced, critical, restrained, and undogmatic judgment? Would we?

PAUL A. WEISS *delivered this address as the President of the Eleventh International Congress of Cell Biology held in Providence, Rhode Island on September 3rd. Dr. Weiss is Professor Emeritus of The Rockefeller Institute and also Professor and Dean of the Graduate School of Biomedical Sciences of the University of Texas, Houston* (Review, *September-October, 1964, page 19). The illustrations are by Vera Teleki.*

THE USES OF LITERATURE IN AN AGE OF SCIENCE

BY JOSEPH WOOD KRUTCH

First of all I must say that I am intimidated as well as greatly gratified by the honor which has been done me. Though I am not a scientist it has been assumed, first, that some of my writing is respectable as a commentary upon problems which science raises, and, second, that I may be able to say something worth hearing on the subject I have chosen: The Function of Literature in an Age of Science.

I am also very much aware of the fact that Dr. Paul Sears, the first recipient of the honor which has just been bestowed upon me, is a distinguished scientist who writes eloquently and that the director of the Creative Writing Program is an outstanding illustration of the fact that it is possible to be a distinguished scientist and a brilliant man of letters at the same time.

And yet, intimidated though I am, I feel obligated to avoid merely safe platitudes and to risk the attempt to say things which may take me beyond my depth.

But before I attempt anything of the sort I had perhaps best say that I am aware how completely the tables have been turned on those of us whose culture is primarily literary.

There was a time when the question was not whether literature had a function in the Age of Science but whether science could be called part of education or culture in an Age of Literature.

Despite the fact that Francis Bacon was a man of letters who heralded an age of science and despite the fact that many writers hailed Newton without, perhaps, understanding him very well, the fact remains that the "Projector" (as the proponent of applied science was then called) was a figure of farcical fun, as is illustrated by two of the satires on him amusing enough to be still remembered—I mean the chapter in *Gulliver's Travels* devoted to the Island of Laputa where the scientists are engaged upon such projects as the bottling of sunshine extracted from cucumbers and the long passage in Samuel Butler's *Hudibras* which describes the Puritan scholar-scientist who knew more about the moon than he did about the earth and among whose technological triumphs was the invention of a new rat trap:

> He made a *Planetary Gin*,
> Which *Rats* would run their own *Heads* in,
> And come on purpose to be taken,
> Without th' Expence of Cheese or Bacon;

—which obviously prefigures our own electrical and even electronic vermin destroyers.

Nowadays when a man of letters satirizes science and scientists, he does not imply that their projects wouldn't work but rather that they work all too well for his comfort. He calls the scientist, not absurd, but dangerous.

Perhaps, however, I have already spent too much time on the past and I should turn now to my real subject.

You will have noticed that my title refers to the function of literature rather than merely to the function of the writer in an Age of Science. That the writer has such a function is seldom doubted. He can act as a sort of middleman between the scientist and the uninstructed layman. Sometimes he is little more than a ghost writer who on the one hand shares enough of the scientist's knowledge to have some idea of what the scientist is doing and at the same time knows enough of the ignorance and other limitations of the uninstructed layman to know how to tell this layman as much as he will be able to understand.

Such a writer is useful; in fact, he is desperately needed by both the scientist, who must have the financial and political support as well as the confidence of the layman if science is to play its full part in society, and by the layman himself if he is not to regard science as a form of black magic which must remain totally incomprehensible.

This importance of the writer is, as I have just said, great and beyond dispute. But is there such a thing as literature which is not antiscientific on the one hand and not mere popular science on the other; something which concerns itself often with the same subject matter as science but in some different way? And when I say literature, I am thinking not only of fiction and drama and poetry but also, perhaps especially, of expository writing which deals with many of the same facts and themes as pure science but with an approach and emphasis that are different.

Now I am not, I hasten to assure you, about to launch upon a "defense of the humanities" of that familiar sort which consists of vague reference to literature as a graceful ornament and relaxation, as a home of lost causes to which we pay sentimental deference, or as a land of "dreams" to which we retire when reality is too much for us. What I am trying to define for myself is a function, or rather a group of functions, which literature performs when it is neither an escape from scientific truth nor a mere popularization of such truths, but a way of looking at them which is not, and need not be, the scientist's way but which makes it easier for many of us to live comfortably in that world of science which is so different from the world our imagination gave us, in the days when imagination was free to imagine pretty much what it pleased about nature, about human nature, and about a God made in man's own image.

I propose then to take up, one by one, some of those functions of literature in an Age of Science which I am able to define, at least vaguely, and in ways meaningful to me. And I will begin with the simplest and most obvious.

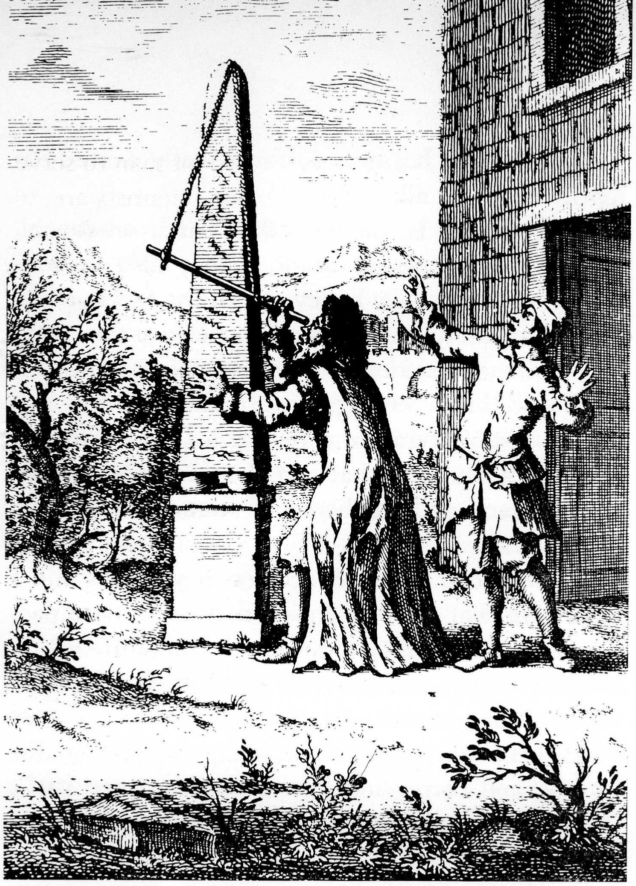
Because literature, unlike science, is as much subjective as it is objective, because it is so distinctly man-centered rather than centered outside man and around some concept of absolute truth to fact, literature constitutes a continuous reminder of something the man of letters believes to be true and believes that the scientist sometimes denies or forgets, namely, that science exists to serve man, not man to serve science. He is not so ready, as many scientists are, to say that we must never ask whether this discovery or that machine is likely to be a blessing or a curse to mankind and that we must be prepared, if necessary, to perish for the Glory of Science, much as Jonathan Edwards said he would be willing to be dammed for the Glory of God.

The inventor of an airplane in Samuel Johnson's romance *Rasselas* refuses to make his invention public because he believes that man should not be able to fly until he has first become virtuous. We are not likely to take, and perhaps should not take, quite that position, but it is a reminder that the power which science so abundantly supplies us with is good only insofar as it is used for good ends; that, if we are not willing to refuse to fly until we have become virtuous, we ought at least to realize that being able to fly will not necessarily and in itself make us either virtuous or happy — which is what the more extreme proponents of technological progress seem to assume.

If mankind really does presently enter upon a scientific and technological utopia, instead of either perishing in a catastrophe or being reduced to slavery by its own machines, it will be because it has remembered what many scientists who have a touch of literature in them and what literature itself have reiterated in many different ways: namely, that unless man sees science as his servant rather than his all-demanding god, he may end by immolating himself on that god's altar as the victims of religious superstition have immolated themselves upon the altars of their own, and not stranger, gods.

Hardly less obvious or less often recognized than this, is that thorny question of values. Can science establish them and, if not, are they then necessarily either merely arbitrary or fictitious and unnecessary? To the first question, "Can science establish values?", scientists themselves give an answer which is sometimes a "Yes" and sometimes a "No"; and if the answer is "No," those who give it sometimes answer the second question, "Are values then merely arbitrary or fictitious?" with a "Yes." Yet, if you do answer "Yes," then you fall into the completest possible moral relativism and the monster is as admirable as the saint.

Because this question has been so often discussed, I am not going to discuss it at length but make only two comments. So far as I myself can see, science



"the Puritan scholar-scientist who knew more about the moon than he did about the earth . . ."

as such cannot by its very definition establish values, and I rest my case for this opinion on the very simple statement made some years ago, not by a man of letters but by an official scientist of great repute, namely, Dr. Vannevar Bush, who put it as simply as it can be put. A value, he said, cannot be deduced from a statement of fact. That seems to me to be conclusive: science is concerned only with facts and a statement of fact cannot define a value.

If the methods of science cannot define a value, then it may be asked, "Can anything else do so?" Certainly neither literature nor philosophy has ever done so in any fashion which established values as themselves statements of fact accepted as such with the degree of unanimity with which scientific statements of fact have been accepted—for a time at least.

But though a given science may reach a very high state of development without concerning itself with values, either directly or indirectly, literature might be defined as the attempt to give some account of human life on the assumption that values are of supreme importance.

Though even literature may sometimes raise the question whether or not the universe outside of man actually is morally neutral, I would certainly hesitate to say that either science or extant philosophy has conclusively demonstrated that it is neutral and it seems to me that the question must be asked again and again as searchingly as possible.

And even if you do dismiss such attempts to find a human meaning in the external universe, one fact seems to me to remain. All civilizations have rested upon the explicit or tacit assumptions of some system or hierarchy of values, however arrived at and however different from that accepted in other and perhaps equally successful civilizations. And it is literature in one form or another, literature oral or written, which transmits the civilization's value system however it may have been arrived at.

If science cannot establish a system of values and if civilization can't survive without one, then civilization cannot survive without literature.

In an Age of Science, it is important that this literature should not be antiscientific or ignorant of science. To be either is to make it certain that it will be defeated and discarded much as fundamentalist theology was defeated in the old war between science and religion. But literature can and should have its own way of treating the facts and themes of science.

Let me now try to say something concerning a theme neither so easy to state nor quite so frequently explored as either of the two I have just been touching upon.

It used to be said that science was merely systematized common sense. Such it obviously was in the days of Galileo and such it still was, to a considerable extent at least, well into the nineteenth century. But no one would maintain that it is mere common sense today. Over the portal that marks the entry to modern physics and to that modern biology which is coming more and more to unite with physics and chemistry is written a sort of parody of Dante's *Inferno:* "All common sense abandon, ye who enter here."

If science began in the Renaissance when men began to put more trust in the evidence of their senses than in logical and metaphysical arguments, modern science demands that we reverse the process. In the first place, our senses are of little use because the facts that we are pursuing lead us into the realms of the small, smaller, and smaller where first our unaided eye cannot follow, then where our

optical microscopes cannot wholly penetrate. At best we have only to deduce or infer what we can never expect to see or hear or feel. What is even worse, we are now used to being told that the real but invisible world which we cannot reach with our senses, is also not capable of being reconstructed in our minds; used to being told even that ultimate reality is not only not understood but is quite possibly not understandable. The paradoxes of the metaphysicians, like that involving fate and free will, are no less unsolvable than the paradox of the wave and the corpuscle. Yet it is to such dilemmas that the enterprise of common sense ultimately conducts us.

As far back as the nineteenth century we began to realize that things were not what they seemed; that, for instance, when our five senses told us that the chair we sat on was a solid object, all five of them were lying. By now the world we seem to inhabit is composed of mere fantasies, created by the senses which, one and all, are united in a conspiracy to deceive us.

Yet most of our lives are necessarily lived in the realm of appearance and we act upon the false assumption that it represents reality. Call it Animal Faith if you like, but whatever you call it, our active, our emotional, and a large part of our intellectual life continues and will probably continue to have its being in the world of seeming rather than in the world of scientific facts.

Even if you are inclined to dismiss literature as no more than an account of the universe as it really isn't, such is the universe of appearances which is, in many ways, more real to us than any other. If we did not have Animal Faith, we could not survive and at a minimum literature helps us to retain an Animal Faith by which we can live in our human world.

The last claim I have to make is the most inclusive of all, perhaps indeed includes all the others. It is based upon the simple fact that man is, or at least always has been so far, a creature of emotions as well as of intellect. But pure science has to do with the intellect only. It is concerned exclusively with knowing and through knowing with doing. The phrase "coldly scientific" has become a cliché. And science performs its special function only when it *is* cold in the sense that it refuses to allow its conclusions to be influenced by its emotions. But the man who is nothing but "coldly scientific" (if indeed such a creature has ever so far actually existed) is hardly a man at all.

All literature is, on the other hand, emotional. To a greater or lesser extent, it may also be concerned with what we believe to be the facts of life. But it inevitably involves also (as science does not) an emotional reaction to these actual or supposed facts. And this is very significantly the case with that special sort of literature with which I am concerned this afternoon; with that sort, I mean, which deals with the facts and the themes of science but in some literary way.

You may call it impure science, if you like, and I am aware that some scientists despise it more passionately even than they despise the literature which is admittedly an escape from fact into the realm of fantasy and dreams. To them it seems not only childish but dangerous: something capable of disturbing and corrupting the vision of science itself. But surely it is no threat to that vision so long as it acknowledges what it is and does not pretend to be pure science.

Perhaps I can put the same thing in another way if I say that man needs not only to know but also to wonder and to love and that science, as such, has nothing to do with either wonder or love; while it is those two things that are perhaps the essential concern of the kind of literature I have been trying to defend and as perfect examples of which I might point to recent books by Loren Eiseley.

Now I am aware that certain extremists would reject everything which I have said and would maintain that what I have called the function of literature has turned out to be purely the attempt to preserve certain of the all-too-human weaknesses which true scientists have by now got rid of for themselves and which they believe are destined in time to cease to cripple, as to date they have always crippled, all attempts to create a thoroughly rational and scientific civilization.

A few months ago I came across a very clear statement of this position in an imaginary conversation written by J. Bronowski in which he celebrates the macromolecular biologist as the man who has at last enabled pure science to answer all the needs of the human being. "He is," and I quote, "a man who unravels the secrets of life by using the tools of physics. He shows — we have shown — that the structures of biology become intelligible when we treat

them, not as strings of mysteries, but as strings of molecules. . . . That is the universal unity in which we believe." Bronowski then goes on to compose a scientific poem which is quite as bad as Erasmus Darwin's famous "Botanic Garden" and proclaims that when he regards biology, not as a string of mysteries but as a string of molecules, "An icy sweetness fills my mind."

If this is indeed not only all we know on earth and all we need to know, then I have this evening talked nothing but foolishness. But so far as I am concerned, I still do not see how treating biology as a string of molecules removes all the mystery and wonder and if it did then I would fall back upon the contention that an "icy sweetness" is not enough for me and that I do not believe mankind as a whole would be satisfied with it.

Neither do I see how an understanding of the macromolecular structure of the living cell can throw any light on any question involving either ethics or aesthetics. If such knowledge is indeed all we know on earth and all we need to know then the only conclusion which can be drawn is one which some positivist philosophers have drawn already—namely, that all questions involving ethics or aesthetics are, as they are fond of saying, meaningless questions.

If they are not meaningless but so fraught with meanings and consequences of tremendous import, then we must attend even to those often contradictory hints which literature in various forms has attempted to communicate.

We may *say* that good and evil, like ugliness and beauty, are merely the prejudices of a given society but few people have ever consistently acted upon that assumption and no society which, as a whole, acted upon it could last for long.

Of all scientists the physician is perhaps the one who is most aware of ethical problems and he sometimes says that medicine has an ethic, but I do not see how it can be deduced from the science of medicine itself.

Consider the case of those Nazi physicians who thought it ethical to perform upon human beings experiments which shocked the physicians who adhered to other political (not other scientific) creeds. Their scientific training was the same. They knew the same facts of anatomy, physiology, and pathology. They would have agreed upon the diagnosis and treatment of any suffering patient—assuming that they wanted to relieve him. Whatever made the difference between them was the result of beliefs and attitudes derived ultimately from nonscientific literature.

The ultimate concern of all science is an answer to some question *how* this or that happens or how this or that can be done. The question whether or not something should be done is one to which science as such can give no ultimate answer. Science is concerned with *know how* not with know what or know whether.

Shortly after the end of the Second World War, Robert Oppenheimer entered upon the current discussion of the threat to the human race which the discovery of atomic fission had raised. He concluded by saying that what he most feared was not the physical destruction of mankind, not that the race of human beings would lose its life but that it might (and the phrase is his) "lose its humanity."

Ever since I first read that statement I have wondered just what he meant by it and the only answer

[H]e had been Eight Years upon a Project for extracting Sun-Beams out of Cucumbers, which were to be put into Vials hermetically sealed, and let out to warm the Air in raw inclement Summers."

to that question which I can arrive at is simply this: "Man will have lost his humanity when and if he has become concerned exclusively with questions concerning how, not at all with those questions concerning what and whether."

During the Middle Ages when science was popularly confused with magic, it was assumed that it came from the devil and that those learned in it had lost their souls or, to return to Mr. Oppenheimer's phrase, their humanity. At the very least science was a black art and therefore a very dangerous one.

Today, so it seems to me, the scientist is necessarily exposed to a similar danger. While acting in his professional or specialized capacity he must ask no questions to which there is not, potentially at least, a scientific answer. He must be unemotional, objective, and neutral. He must not instinctively prefer one answer or another, must not allow himself to be swayed by prejudice, not even by prejudice in favor of what, as mere human being he feels to be the good and the beautiful. If he abandons this kind of objectivity he risks perverting his science.

But there is nevertheless in this necessary attitude something which I am tempted to compare to the risk of trafficking with the devil.

It is opposed to certain aspects of human nature, to if you like certain amiable weaknesses of that nature. And he can save his soul only if he leaves complete scientific coldness, objectivity, and neutrality in the laboratory where it belongs and, when he leaves it, resumes interest in what I would call other aspects of truth and other methods of searching for it but which he may, if he likes, call merely human prejudices. And it is of course literature which tries to persuade him to do just this.

May I also put here in parenthesis something which I think not entirely irrelevant: though the scientist is likely to say that nothing is further from the scientific spirit than any sort of orthodoxy, the fact remains that he often deals with unorthodox suggestions with a fury positively theological.

Not long ago I read in a magazine published by one of our most respected scientific institutions a review of a popular book on botany in which the author of the book was fiercely castigated for saying that "some plants like dry soil" and sternly told no plant "likes anything" and that if he would avoid heresy he must say instead "Some plants are adapted to dry soil."

I was tempted (but I did not yield to the temptation) to write a letter to the editor congratulating him and to suggest that he refuse to recognize the botanical genus philodendron and insist upon some new name for those blood cells now called by ridiculously anthropomorphic physiologists Eosinophiles.

This is the end of my parenthesis and I must now conclude with a very brief return to the mainstream.

Time was, as I said at the beginning, when it was science not literature which had to fight for recognition as a part of human culture. To contrast this former attitude with the present one I would like to quote a passage relating to the subject from Dr. Samuel Johnson, who represented an ultraconservative position even for the eighteenth century.

> The truth is that knowledge of external nature and the sciences which that knowledge requires are not the great or the frequent business of the human mind. Whether we provide for action or conversation, whether we wish to be useful or pleasing, the first requisite is the religious and moral knowledge of right and wrong, the next is an acquaintance with the history of mankind, and with those examples which may be said to embody truth, and prove by events the reasonableness of opinions. Prudence and Justice are virtues and excellences of all times and places; we are perpetually moralists but we are geometricians only by chance.

How quaint and how wrong-headed that sounds. When Johnson wrote it he was defending what was already a lost cause. What he called the "knowledge of external nature and the sciences which that knowledge requires" have conferred enormous benefits upon human beings. They have in addition provided subjects of discussion which are pleasing as well as useful. And if technology has exposed us to penalties and dangers most of us are convinced that the price is worth paying.

Nevertheless, certain of the highest prices we have paid, including the threat of losing what Mr. Oppenheimer called "our very humanity" we are paying and may pay because, having ceased to be moralists perpetually and geometricians only by chance, we have tended to become geometricians perpetually and moralists only by chance—if at all.

JOSEPH WOOD KRUTCH *critic, naturalist, author, and for many years Brander Matthews Professor of Literature at Columbia University, delivered this address in The Rockefeller Institute on November 12 when he received The Richard Prentice Ettinger Award and Medal for creative writing.*

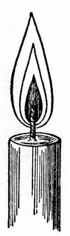
"TO A JUVENILE AUDITORY"

FOLLOWING A TRADITION still young at the Institute but now venerable in the annals of science, Professor James G. Hirsch this holiday season addressed an eager and knowing audience of secondary school students in the sixth annual series of Christmas lectures at the Institute. During the week between Christmas and New Year's, some 500 boys and girls from the New York area, mostly high school juniors and seniors, climbed the frosty hill to Caspary Auditorium for four successive mornings to hear Dr. Hirsch's lucid, straightforward account of his own particular field of work, "The White Cell." Despite competition from other vacation delights, the auditorium was practically as full on the last day as on the first – a tribute both to Dr. Hirsch and to the youngsters themselves. From the second lecture on, earnest teen-agers were overheard at the door each morning trying to wheedle tickets for less fortunate colleagues who had heard "how great it was."

In four one-hour lectures, Dr. Hirsch introduced the white cell historically, discussed the common features of the various types, and went on to describe in some detail what is known and not known about the functions of each. One of the "greatest" features of the series, according to all observers, was the imaginative and skillful interweaving of visual material ranging from daguerreotypes of Metchnikoff and Ehrlich through animated drawings, to the most sophisticated of electron micrographs. Most exciting of all, in the consensus of the students, were the technically superb film strips of white cells in action; the series began with a phagocyte as big as the screen, engulfing a bacterium, and the students literally held their breath until the contest was over.

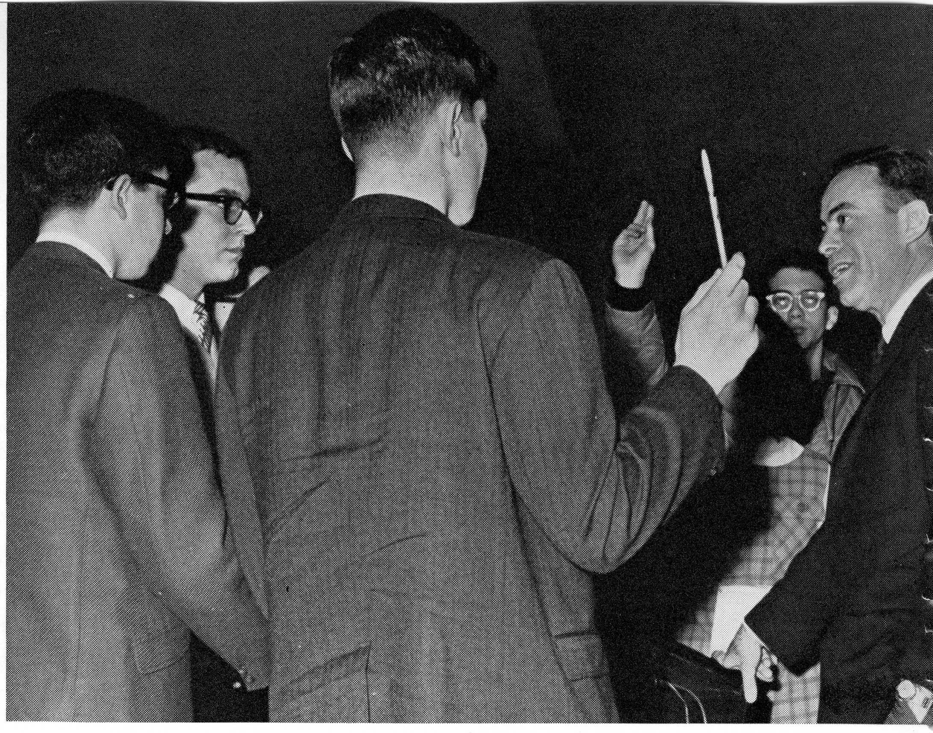
Most rewarding from Dr. Hirsch's point of view was the intelligence and receptivity of the young people, whom he congratulated collectively as the best audience he ever had. After setting the stage and defining terms on the first two days, Dr. Hirsch spoke to them thereafter "exactly on the same level as lecturers to professional colleagues." Adult observers could not fail to be impressed by the calm assurance with which phrases like "polymorphonuclear leukocyte" and "reticuloendothelial system" were exchanged across the podium. "One lecture," Dr. Hirsch reported, "was essentially the same as that given at a Federation Symposium last year."

As is part of the tradition, a half hour at the close



When Faraday was a young boy, the prospect of his ever achieving stature as a scientist seemed dim, indeed. His parents were very poor and his formal education consisted solely of the rudiments of reading and writing. When he was fourteen, he was apprenticed to a bookbinder and bookseller in London. For seven years he performed his duties, learning the art of bookbinding and, incidentally, training his hands to use tools with precision and dexterity. These skills were to serve him well, for his manipulative ability often permitted him to discover effects which had escaped his clumsier colleagues. The young Michael had a keen mind and an insatiable curiosity. He read avidly and indiscriminately until one day, purely by accident, he discovered an article on electricity in a volume of the Encyclopaedia Britannica brought in to be rebound. He threw himself whole-heartedly into this new-found subject, constructing his apparatus out of old bottles and anything else he could find. With direction now given to his reading, he began to pursue science with a passion.

As Faraday's love for science grew, he cast about desperately for some way to escape from trade and gain entry to the world of science. One day a customer in the shop offered him tickets to a series of lectures given by Sir Humphry Davy. Faraday went, took careful notes, copied them out in a clear hand, bound them, and sent them to Davy with a request for employment. Davy was flattered but could do little to help. A few weeks later, Davy was injured by an explosion in the laboratory and was unable to read or write. He sent for the young man with the clear handwriting who had been desirous of entering the temple of science. Although this was but a temporary job, Davy was evidently satisfied with Faraday's work for when a position of laboratory assistant became vacant in the spring of 1813, he offered it to Faraday who eagerly accepted. —An attentive juvenile listener at a lecture became an immortal scientist.



James Hirsch counting white cells, Christmas lecture motion picture, and (RIGHT) *discussion afterward.*

of each lecture was set aside for questions from the audience and the caliber of these was perhaps the most accurate index of the interest and awareness of these sixteen- and seventeen-year-olds. Some questions concerned techniques, reflecting clearly first-hand experience in a laboratory. Others were of a more theoretical nature — the clonal selection versus the instructive theory of antibody formation, for instance. One question was based on an article on lymphocytes in an issue of *Science* that had appeared the very day of the lecture — an issue which, fortunately, Dr. Hirsch had had a moment to look at!

One of the aspects of Dr. Hirsch's presentation that impressed the students the most, according to their own accounts, was his emphasis on what was not known and what remained for them, the students, or others like them, to find out. It was clear that most members of the audience had read and studied and thought a great deal about science, but it seems probable that this was their first exposure to the way in which a scientist himself looks at a particular field of investigation and approaches its problems.

One of the reasons why Dr. Hirsch was able to convey this impression so sharply was that he chose to discuss a limited topic in great depth rather than considering a broad branch of science in a necessarily superficial manner. In closing Dr. Hirsch told the boys and girls — who were obviously most impressed — that those who had listened and understood know more than most physicians and biologists do about the white cell. They were left at the close of the series poised right on the forefront of knowledge in this field of scientific study.

Planting a final seed at the close of the fourth lecture, Dr. Hirsch explained that the subject of the white cell had been chosen deliberately in this day when most emphasis was on molecular biology, to remind at least this particular group that there was much that still could not be explained simply by research on DNA and RNA. Many phenomena must be studied in terms of the organized operations of whole cells and living organisms.

Dr. Hirsch's presentation was the sixth in the series inaugurated in 1959 through the efforts of President Detlev W. Bronk and Professor Alfred E. Mirsky. The Institute lectures were inspired, of course, by those originally given at the Royal Institution in London — a "Christmas Course of Lectures Adapted to a Juvenile Auditory," which were begun in 1826 by Michael Faraday and have been given almost every year since that time. Faraday himself gave the series on nineteen occasions, including perhaps the most famous of his lectures to any audience, "The Chemical History of a Candle." This year's lecturer at the Royal Institution was the Curator of Mammals at the Zoological Society of London, who spoke on "Animal Behaviour" in the one hundred and thirty-fifth presentation "adapted to a juvenile auditory."

SCIENTISTS AND THE PUBLIC

ALMOST EVERY Wednesday at The Rockefeller Institute a small group composed largely of faculty members meets for lunch to discuss the program and the affairs of the Scientists' Institute for Public Information. The conversation at these familiar gatherings ranges from philosophical discussions of the social responsibility of scientists, through practical matters concerned with arrangements for symposia and workshops in various parts of the United States right down to the basic and unavoidable review of financial resources. A young organization, two years old this February, SIPI, as it is inevitably known, is still growing, changing, and experimenting—and because of the nature of its problems probably always will.

Though the range of its activities and the scope of its ideas are broad, the motive of SIPI is simple and well-defined. It was created out of a concern for the public's need to know and understand scientific issues which concern public policy. In its own words, it "represents a unique and pioneer effort to solve a social problem created by the accelerating advance of science." To this end, it is developing a nationwide program to accumulate information on special aspects of this problem—environmental conservation, for instance—and to encourage dissemination of this information to citizens who will then be able to take intelligent social and political action.

SIPI has no formal affiliation with The Rockefeller Institute but many close ties. Dr. Edward L. Tatum is its Chairman; Dr. Jules Hirsch, Vice-Chairman; and Curtis A. Williams, Jr. is Secretary.

Doctors Theodosius Dobzhansky, René Dubos, and Ludwig Edelstein are members of SIPI's Board. Others among the twenty-three Board members familiar to The Rockefeller Institute include Barry Commoner of Washington University, Margaret Mead of the American Museum of Natural History, Russell H. Morgan of The Johns Hopkins Hospital, and Warren Weaver of the Alfred P. Sloan Foundation. Associate Director is Robert E. Light whose headquarters is SIPI's office at 30 East 68th Street.

SIPI was founded in 1963 as a national coordinating body for some twenty local groups then in existence. These groups varied greatly in the details of their organizational structure. They shared a common resolve, however, that scientists have the responsibility to inform people in order that they may make up their own minds about issues which confront the public, but which have a large technological or scientific component. In short, as SIPI states in its *Credo,*

> Scientists, as custodians of the technical information, have an obligation to bring such information to their fellow citizens in understandable terms, with due regard for scientific objectivity. With respect to the resultant value judgments, scientists have no greater or lesser competence than other informed citizens and ought not to arrogate such decisions to themselves.

Workshops and symposiums

SIPI itself does not communicate directly with the public but rather serves the various local groups for which it was created: inspiring new activities, implementing the formation of new groups, and collecting and distributing pertinent information. In May 1964, for example, the U. S. Public Health Service in cooperation with SIPI held a two-day workshop on air pollution. Each of the local groups was invited to send at least one representative to the meeting which was held at The Rockefeller Institute. In December a similar workshop on the use of insecticides was held in Chicago under SIPI sponsorship at which representatives of the Department of Agriculture, U. S. Public Health Service, and Department of the Interior, despite an unexpected blizzard, addressed representatives from the local groups. In December, at the annual meeting of the AAAS in Montreal, Doctors René Dubos and Jules Hirsch were among those participating in a symposium on "The Scientist's Responsibility Toward an Informed Public," also sponsored by SIPI. Over ninety scientists signed cards expressing a desire to join a local information committee.

The participation of so many of the faculty in the operations of the Scientist's Institute is no coincidence; SIPI can trace its origins almost directly back to the same dining room in Welch Hall where many of its affairs are now decided. In 1958, controversy

was raging concerning the biologic effects of the testing of the nuclear weapons. Precise scientific data on the subject were meager and a bewildered public was being exhorted by its politicians and, simultaneously, presented with widely divergent viewpoints by scientists qualifying as experts in this field. Among those concerned with this state of affairs were Doctors Jules Hirsch, Halsted R. Holman, and Malcom L. Peterson, who were all at the Institute and frequent luncheon companions. (Dr. Holman is now at Stanford University Medical School and Dr. Peterson at Washington University in St. Louis.) Dr. Holman inaugurated the informal activity when he volunteered to speak on the subject at a meeting of the Physicians' Forum. He was greatly impressed at the eagerness of this and other groups for information on the subject and described his experience to his luncheon companions. The National Academy of Sciences, of which Dr. Bronk was the President, had just published its report on the biological effects of radiation, making available a body of authoritative information with which to work. Doctors Hirsch, Holman, and Peterson let it be known that they were available for speaking engagements to any group that might assemble anywhere in the metropolitan area. They soon found that they had far more requests than they could possibly handle and, as a result, the group began slowly and informally to expand. Doctors Philip Siekevitz, Tom Stonier, and Curtis Williams, Jr. were among the early recruits. By 1959 the group took upon itself the title of the Scientists' Committee for Radiation Information (SCRI). That same year it received a grant from the Alfred P. Sloan Foundation and opened a small office with space made available by the New York Academy of Sciences. The office served chiefly as a clearing house for requests for information and for speakers.

SCRI's principles of operation were simple. Information was gathered carefully, fully documented, and presented objectively. In areas where there was scientific disagreement, reasons for the disagreement were explained. Speakers could present their own opinions provided they were clearly identified as such. Any group was addressed, regardless of its purpose or political complexion. Typically—and many members felt, ideally—a SCRI speaker would appear on the same platform with two others, usually one favoring the shelter program and another criticizing it, both using SCRI's basic information as the platform for their own judgments.

Dr. Dubos addresses two-day SIPI *workshop* (LEFT); *a point is discussed afterward by Doctors Edelstein and Tatum* (RIGHT).

In practice, the operation was even more simple. When a request came for a speaker, a volunteer would set forth, often to Long Island, Philadelphia, or New Jersey. It was not unusual for a speaker to travel several hours, at his own expense, to address a dozen people, although large audiences would often assemble also. SCRI members have now given some 2200 lectures before PTA's, fraternal and political groups and religious and civic organizations and high school and college students. They have also conducted two series of twelve lectures each at the Academy of Medicine, designed as an adult education course on ionizing radiation and its biological effects. In April 1964, under a grant from Resources for the Future, SCRI undertook the preparation of a study on the problems of the use and the location of nuclear reactors. A few months ago, SCRI changed its name to the Scientists' Committee for Public Information (SCPI) as an indication of the broadening of its interests and responsibilities, but the program is continuing on the same basis and with undiminished vigor.

Nuclear information

During its early years, SCRI kept in touch, informally, with the Committee for Nuclear Information in St. Louis. This group, which differed organizationally from SCRI in that it had a large and active body of laymen associated with it, had commanded a great deal of public attention because of its baby tooth survey and its publication of the outspoken Nuclear Information Bulletin. In April 1960, SCRI, the St. Louis group, and the AAAS sponsored a two-day conference at the New York Academy of Sciences. Scientists from twenty-one cities in the United States and Canada participated in the conferences. Many of them reported a lively demand in their own areas for information on fall-out, strontium 90, nuclear waste disposal and the effects of radiation. SCRI volunteered to serve as a clearing house to assist scientists interested in participating in programs similar to their own and CNI agreed to supply them with the Nuclear Bulletin.

By the beginning of 1963, some 21 separate groups were in existence throughout the country, and on February 16th of that year more than one hundred scientists and physicians representing these groups met at The Rockefeller Institute and on the following day at the New York Academy of Sciences. Present at that time were not only the initial nucleus of young scientists from The Rockefeller Institute but also Doctors Dobzhansky, Dubos, Tatum, and Edelstein who had been drawn into it by the enthusiasm of their junior colleagues as well as by their concern for the problems being discussed. A chief result of that meeting was the formation of the Scientists' Institute for Public Information. The following April, Dr. Tatum was elected Chairman of its Board.

In the immediate future SIPI plans to focus attention primarily on problems of environmental conservation, "a matter of urgent attention for the scientist and the public," as all would agree. The New York Scientists' Committee, or SCPI, is concerned with this matter, particularly with air pollution, but it is continuing to enlarge its scope and its members are now presenting lectures throughout the New York area on automation and population control. Other local groups will similarly mold their own programs in keeping with the needs of their communities and the special interests and abilities of their members.

One of the members of such a local group once remarked that even if each volunteer were to talk to twenty people every single evening, it would take eons to reach everybody in the United States alone. This is true, of course, yet it now seems clear that along with the objective scientific data that are being so conscientiously distributed, SIPI is also communicating a concept: the tenacious notion of increased responsibility on the part of scientists and citizens alike. Ideas often begin to develop lives of their own and there are indications — such as the increasing interest in these activities evinced at the recent meetings of the AAAS — that the idea is beginning to spread. This might be the most valuable of all the products of the luncheon gatherings in Welch Hall.

"In sum, we conclude that the scientific community should, on its own initiative, assume an obligation to call to public attention those issues of public policy which relate to science, and to provide for the general public the facts and estimates of the effects of alternative policies which the citizen must have if he is to participate intelligently in the solution of these problems. A citizenry thus informed is, we believe, the chief assurance that science will be devoted to the promotion of human welfare."

The AAAS Committee on Science in the Promotion of Human Welfare

AAAS

THE MEETINGS of the American Association for the Advancement of Science, held this year in Montreal, attracted many members of the Institute's faculty, a number of whom contributed to the proceedings.

On December 29, Professor René Dubos delivered the Joint Annual Address of the Society of the Sigma Xi and the United Chapters of Phi Beta Kappa. In his talk "Humanistic Biology," widely acknowledged to be one of the highlights of the AAAS meetings, Professor Dubos described a biology which would form a complementary aspect to the humanities. "In the very process of responding to environmental stimuli," Dr. Dubos stated, "each individual human being creates his physical and mental personality from the biological attributes which are shared by all men. Human societies and cultures emerged from the progressive integration of these responses.... By neglecting the study of a large variety of man's responses, biology is betraying one of the responsibilities of science—namely the development of objective methods for describing all aspects of reality."

On Sunday, December 27, on the second day of the sessions, President Bronk presided over a symposium on "Science and International Relations." The following day he was one of six speakers on "The Research Environment." At this latter symposium, Dr. Bronk discussed the role of the federal government, foundations, and university administration in the determination of the environment of research within universities, pointing out that the interaction of these agencies has greatly increased the channels of communication but at the risk of losing the kind of isolation that used to make pure research so desirable to the brilliant mind.

Professor Sam Granick arranged and presided over a day-long symposium on "Cytoplasmic Units of Inheritance," also held on December 27. At this meeting, evidence was presented for the presence of DNA and for its coding activity in cytoplasmic organelles, including plastids, mitochondria, centrosomes, and kinetosomes. Among the speakers were Doctors Aharon Gibor, David Luck, William Trager, and A. Cecil Taylor, all of the Institute.

On December 28, Dr. Curtis A. Williams, representing the Scientists' Institute for Public Information, spoke at an interdisciplinary symposium on "Science and the Public Mind," at which he discussed "A Scientist's Role in Scientific Literacy." On the evening of December 29, following Dr. Dubos' formal address, Doctors René Dubos and Jules Hirsch were participants in an open discussion on "The Scientist's Responsibility Toward an Informed Public." Some of the background of these activities of Doctors Williams, Dubos, and Hirsch can be found in the article "Scientists and the Public" in this issue of the *Review*.

The Christmas Festivities

THE HOLIDAYS were celebrated at the Institute by a variety of gala occasions, each with its special flavor and appeal. Most exuberant was the Children's Christmas Party held on December 16 at which some three hundred children of the Institute staff were entertained by such celebrities as Bozo the Clown and Princess Ticklefeather (unexpectedly assisted by Doctors Herbert Jaffe and Abraham Pais). Santa burst in from an outside terrace, and stockings and ice cream and colored balloons were distributed to all. On December 18, at the invitation of President and Mrs. Bronk, members of the Institute staff gathered for a traditional Carol Singing at which tea and punch were served.

The high point of the holiday season was the elegant Christmas ball given by the graduate students for the faculty and Trustees. The Students Residence was decorated with six resplendent Christmas trees, pine boughs, and giant snowflakes bathed in starlight. Four hundred and fifty hosts and guests danced past 2:00 a.m.

On January 3, the Institute's celebrations were informally brought to a close by a gracious eggnog party given by President and Mrs. Bronk at their home to welcome in the New Year.

Rasmussen to Pennsylvania

HOWARD RASMUSSEN (Ph.D. 1959) has been appointed Benjamin Rush Professor of Biochemistry and Chairman of the Department of Biochemistry in the University of Pennsylvania. Following his graduation from the Institute, Dr. Rasmussen was Assistant Professor at the Rockefeller for two years and then Associate Professor of Biochemistry in the University of Wisconsin from 1961 to 1964.

The chair that will be held by Dr. Rasmussen is named for the first Professor of Chemistry in the first medical school in the United States. Benjamin Rush, a signer of the Declaration of Independence, was Professor from the time the University of Pennsylvania Medical School was founded in 1765 until his death in 1813.

News and Notes

PROFESSOR STANFORD MOORE was awarded the degree of Docteur *honoris causa* by the University of Paris on November 15.

The same day here in New York, Professor Fritz Lipmann was awarded the honorary degree of Doctor of Humane Letters at the Albert Einstein College of Medicine. The degree was conferred by Dr. Samuel Belkin, President of Yeshiva University, at the Academic Convocation of the College.

President Detlev W. Bronk presented the Convocation Discourse at the 175th Fall Convocation of Georgetown University on October 29; the subject of his address was "The Sanctity of the Individual." At the Georgetown ceremonies, he was awarded the degree of Doctor of Laws, *honoris causa,* "as an eminent physiologist and biophysicist whose skills in the art of administration bridge creatively the exigencies of science, government, and the transmission of learning." The following month, on November 18, Dr. Bronk was presented with a citation from the Council of Higher Educational Institutions in New York City on the occasion of his retirement as President of the Council. Dr. Bronk had held this position for two years, serving, in the words of the citation, "with energy, devotion, perspicacity, and kindly wit."

In December, Dr. Hans J. Eggers left the Institute to return to his native Germany where he will join the Max Planck Institute for Virus Research in Tübingen. Dr. Eggers came to work in the laboratories of Dr. Igor Tamm as a research associate five years ago and has collaborated with Dr. Tamm on a variety of studies of virus synthesis and its inhibition.

After a long search, the library is now in possession of an early edition of Georges Cuvier's *Recherches sur les ossements fossiles....* Cuvier, the French naturalist, wielded great authority and determined the general direction of biological, and especially of zoological activity in the first half of the nineteenth century. *Recherches* . . . , first published in 1812, is generally considered a classic since it is in effect a synthesis of many of Cuvier's ideas on the classifications of living things. The edition of 1821-24 acquired by the library is profusely illustrated.

A small working conference on the mouse mammary tumor virus was organized by Dr. Dan H. Moore and held at Inverness, California, on October 28 through October 30. The purpose of the conference, which was made possible by a grant to The Rockefeller Institute by the Lillia Babbit Hyde Foundation, was to discuss in an intimate and informal fashion the present state of research on the nature and functions of this virus. The meeting was assembled by invitation and attendance was limited to some twenty investigators who are working actively in this field.

The annual Arts and Crafts Show was held this year in a new and handsomely designed setting of special panels erected for the purpose in the Faculty and Students Club room. Among the featured exhibits were photographs, oils and water colors; embroidery; stained glass; and pencil drawings. An objet d'art commanding much attention was an ingeniously designed automatic push-button bar created by Eduardo J. Principe of the Machine Shop.

During November and December, the Institute was honored by the presence of a number of distinguished guest lecturers. These included Dr. Robert Oppenheimer who, on the second anniversary of the death of Niels Bohr, spoke most movingly to a packed auditorium of Bohr's vision for world unity and cooperation; Sir John Eccles of the Australian National Laboratory who presented two stimulating seminars on neurophysiology; and Joseph Wood Krutch, winner of the Richard Prentice Ettinger Award and Medal, the text of whose address is presented in this issue of the *Review.*

Miss Esther Judkins retired as Librarian at the end of December after 39 years at the Institute. In commenting on her retirement, President Bronk said: "Our regret for your departure is coupled with deep gratitude for your loyal service to the Institute and for your significant achievements. We are grateful for your gracious response to the challenge of great change and rapid expansion as the Institute's faculty widened the scope of their activities during the last ten years."

THE COVER PHOTOGRAPH: the Club Room of Abby Aldrich Rockefeller Hall looks out upon the snow-covered dome of Caspary Auditorium on a wintry December day. The arch at left spans the drive extending from the parking pavilion to the Sixty-sixth Street drive; photograph by Don C. Young. Illustrations PAGES 1-6 courtesy of the Burndy Library, Norwalk, Connecticut. PAGES 7-14 drawings by Vera Teleki. PAGE 17 William Hogarth. PAGE 19 wood engraving by Fritz Eichenberg, reproduced with the permission of The George Macy Companies, Inc. PAGE 22 *left* courtesy of Prism Productions, Inc., *right* The Rockefeller Institute Illustration Service. PAGE 24 photographs by Bernard Cole.

THE QUOTATIONS on PAGES 15-20 are from: Samuel Butler, *Hudibras,* London, J. Bettenham, 1744, part 2, canto 3, lines 277-280; Samuel Johnson, *The History of Rasselas, Prince of Abissinia,* Oxford, Clarendon Press, 1927, p. 32; Vannevar Bush, "Scientific Motivation," *Proceedings of the American Philosophical Society,* vol. 98, 1954, p. 231; J. Bronowski, "The Abacus and the Rose; a Dialogue After Galileo," *The Nation,* vol. 198, no. 1, 1964, p. 17; Samuel Johnson, "Life of Milton," *The Works of Samuel Johnson in Nine Volumes,* Oxford, 1825, vol. vii, p. 76. The quotation on PAGE 21 is reprinted by permission of The Macmillan Company from *The Chemical History of a Candle,* Michael Faraday, Collier Books, New York, 1962.