JANUARY 1970

Engineering and Science

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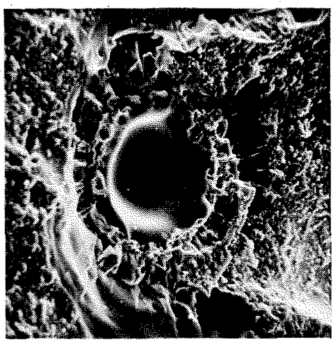
Engineering and Science



In this issue

Moonrocks

The cover shows a microscopic crater (magnified approximately 1,800 times) on a fragment of lunar material collected by Apollo 11 astronauts. Geologist Gerald Wasserburg, who, along with John Devaney and Kenneth Evans of Caltech's Jet Propulsion Laboratory, took the picture, reported to other scientists who have also been analyzing pieces of the moon that these pits were found on all the lunar material he studied. A summary of his findings, and those of two other Caltech principal investigators, Sam Epstein and Leon Silver, is on page 30.

The Limits of Mind

Robert Sinsheimer, chairman of Caltech's division of biology, who presented "The Brain of Pooh" (page 8) during the Caltech Lecture Series last fall, received the 1969 gold medal for virology from the Royal Netherlands Academy of Science and Letters in Amsterdam on December 20. He is also president of the American Biophysical Society for 1970.

Why Study?

Richard Dickerson, professor of physical chemistry, wrote "Why Study Chemistry?" (page 26) as an introduction to a new freshman chemistry textbook, *Chemical Principles,* by Dickerson and H. B. Gray of Caltech and G. P. Haight of the University of Illinois, to be published in April by W. A. Benjamin, Inc. The book—for non-science majors—was written on Martha's Vineyard last summer, using as a point of departure an earlier text by Gray and Haight.

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26 Why Study Chemistry?
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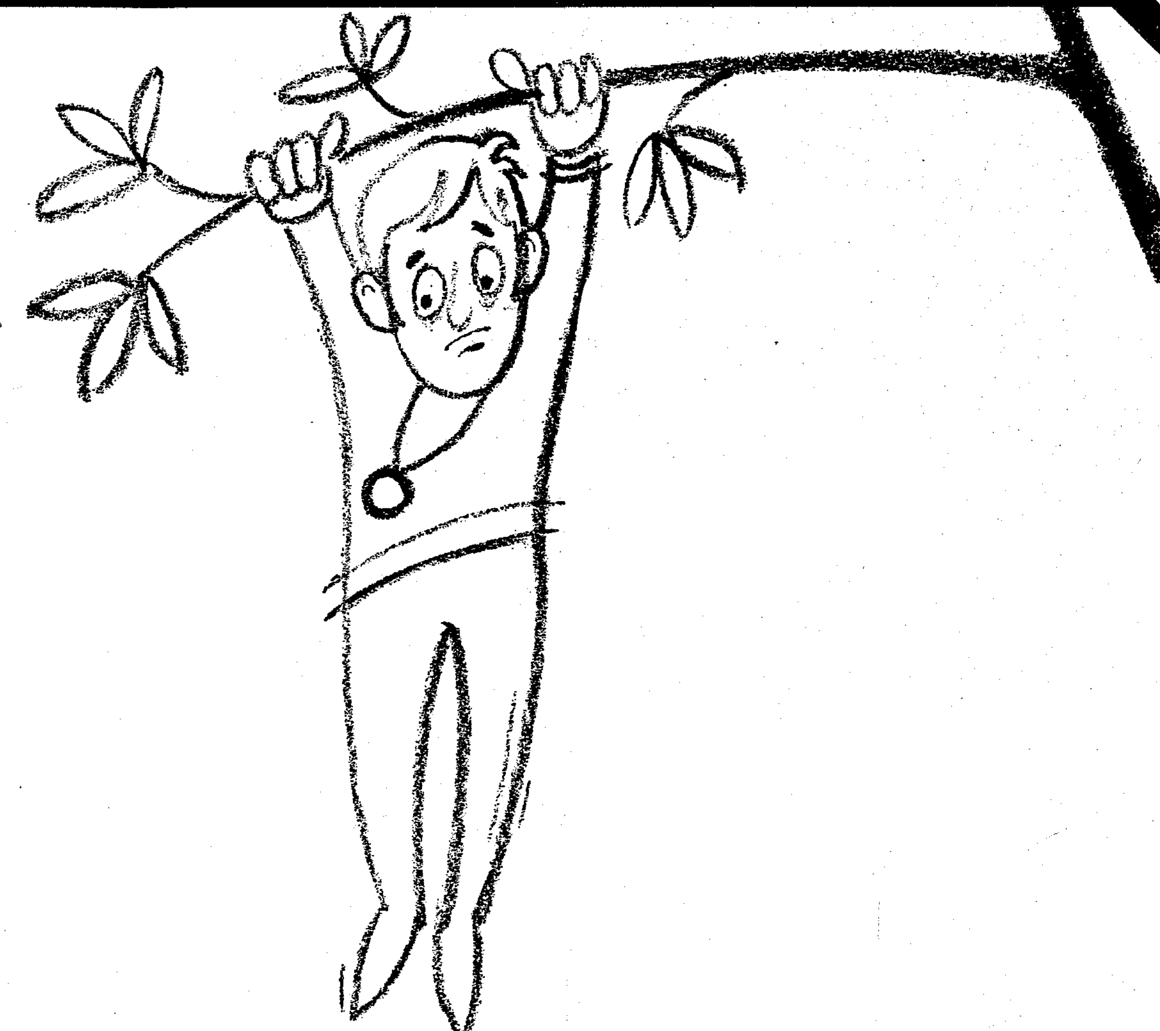

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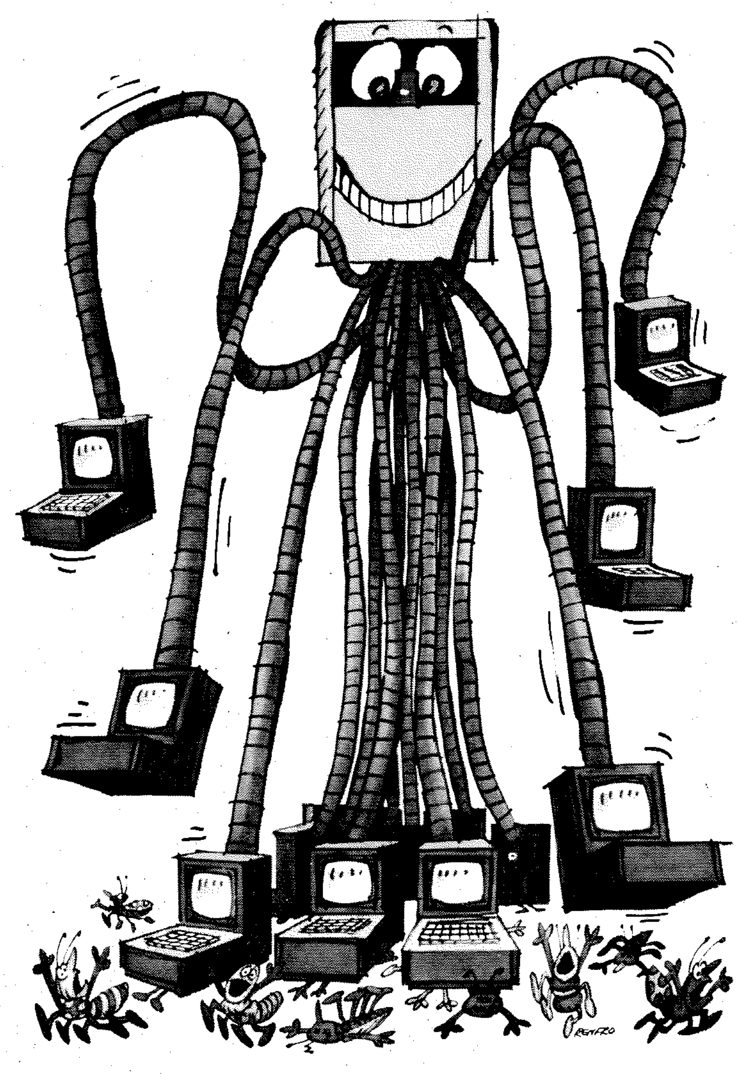

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Engineering and Science

The Brain of Pooh: An Essay on the Limits of Mind

The inviolate principle of causality—that a precisely determined set of conditions will always produce precisely the same effects at a later time—underlies our entire scientific perception of the universe. And yet in the smoothly flowing channels of natural causality there has always been in our conception one seemingly irrational, unordered, swirling eddy—the human mind. Increasingly now we cannot avoid this vortex, nor can we continue to skirt around it, for herein is the ultimate perceiver and herein form the shapes of surmise. And so, as in our dreams where we are surprised by that which we ourselves have conjured, the perceiver must in wonder inquire "How do I perceive?" and the mind ask "What is thought?"

The great discoveries in genetics and our enlarged understanding of the biochemistry of heredity have led to increasing discussion of the possibility of the designed change of human beings—not only of the repair of overt genetic defects but also of the longer range enhancement of the capabilities of man. Naturally, much of this discussion has concerned the improvement of man's finest and most precarious quality, his mind.

To consider this issue in any serious way one must first inquire as to what qualities of mind are considered to be genetic in origin (and are thus susceptible to genetic modification) and to what extent these qualities limit the performance of man—and what might be the consequence of their modification.

In a philosophical sense such an endeavor—man trying to improve his own capacity—is clearly a bootstrap project, an adventure in positive feedback. And yet this is what we have done all the way from the jungle. What we consider now is but an extension, albeit in a new dimension.

What can we honestly say about the mind from our present knowledge? I do believe that such a presentation can be useful in the same sense that the 16th century maps of the world were useful, essentially as a rough chart of what it is we need now set out to learn, bearing in mind that the enterprise may well require as many years as were needed to fill in those ancient maps.

Further, in this *special* case there is special merit in such a projection of knowledge that we may hope to have concerning the human brain and thus concerning its, and our, future potential. For this effort to see how our brain came to be and how it might be advanced can serve to provide us a valuable perspective in which to view our present reality, in which to see more clearly our present limitations and, therein, the origins of some of our most basic dilemmas.

The very opening lines of *Winnie-the-Pooh* provide my theme.

> Here is Edward Bear, coming downstairs now, bump, bump, bump, on the back of his head, behind Christopher Robin. It is, as far as he knows, the only way of coming downstairs, but sometimes he feels that there really is another way, if only he could stop bumping for a moment and think of it.

Now Edward Bear or Winnie-the-Pooh as he was known to his friends was of course a bear of very little brain. But nonetheless I often think that these opening lines constitute a splendid parable to man and his whole scientific enterprise—that we perforce go bump, bump, bump along the paths of scientific discovery when had we but the acumen, the brain power, we could immediately deduce from the known facts the one right and inherently logical solution. This seems particularly true in biology wherein all extant phenomena have for so long been subject to and ordered by the harsh disciplines of natural selection, and wherein the right answer, when we find it, always does seem so inevitably right.

And yet of course we don't have the acumen and we can't immediately deduce the right solution because, like Pooh, our brains too are really very limited compared to the complexity about us and the frequent immediacy of our tasks. And in simple fact what else can we sensibly expect when we are apparently the first creature with any significant capacity for abstract thought? Indeed, even that capacity developed primarily to cope with stronger predators or climatic shifts, not to probe the nature of matter or the molecular basis of heredity or the space-time parameters of the universe.

A physicist friend of mine frequently remarks on how much more difficult it seems to be to teach a 17-year-old a few laws of physics than it is to teach him to drive a car. He is always struck by the fact that he could program a computer to apply these laws of physics with great ease by Robert L. Sinsheimer

"When we've mutated the genes and integrated the neurons and refined the biochemistry, our descendants will come to see us rather as we see Pooh: frail and slow in logic, weak in memory and pale in abstraction, but usually warm-hearted, generally compassionate, and on occasion possessed of innate common sense and uncommon perception."

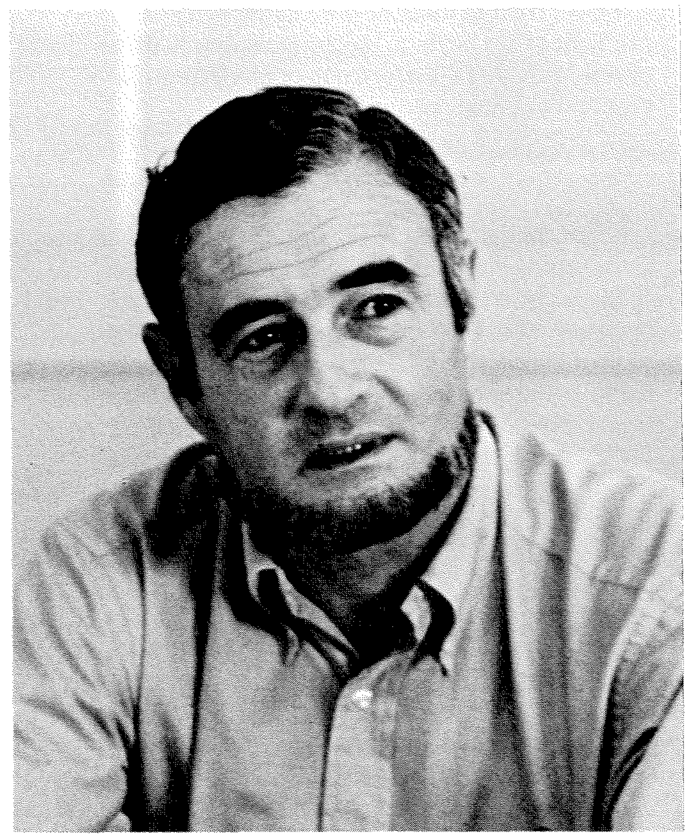
but to program a computer to drive a car in traffic would be an awesome task. It is quite the reverse for the 17-year-old, which is precisely the point. To drive a car, a 17-year-old makes use, with adaptation, of a set of routines long since programmed into the primate brain. To gauge the speed of an approaching car and maneuver accordingly is not that different from the need to gauge the speed of an approaching branch and react accordingly as one swings through the trees. And so on. Whereas to solve a problem in diffraction imposes an intricate and entirely unfamiliar task upon a set of neurons.

I think the computers first made us aware of one of the more evident limitations of the biological brain, its millisecond or longer time scale. Computers flashing from circuit to circuit in microseconds can readily cope with the input and response time of dozens of human brains simultaneously or can perform computations in a brief period of time for which a human brain would need a whole lifetime.

Similarly I believe that we will come to see that our brains are limited in other dimensions as well—in the precision with which we can reconstruct the outside universe, in the nature and resolution of our concepts, in the content of information that may be brought to bear upon one problem at one time, in the intricacy of our thought and logic—and it will be a major contribution of the developing science of psychobiology to comprehend these limitations and to make us aware of them, to the extent that we have the capacity to be aware of them.

For I think it is only logical to suppose that the construction of our brains places very real limitations upon the concepts that we can formulate. Our brain, designed by evolution to cope with certain very real problems in the immediate external world of human scale, simply lacks the conceptual framework with which to encompass totally unfamiliar phenomena and processes. I suspect we may have reached this point in our analysis of the ultimate structure of matter, that in various circumstances we have to conceive of a photon as a wave *or* as a particle because these are the only approximations we can formulate. We, and I mean we in the evolutionary sense, have never encountered and had to cope with a phenomenon with the actual characteristics of a photon.

And likewise with the subnuclear particles. I was intrigued to learn that the latest attempt to formulate a theory of subnuclear particles is a bootstrap or self-consistent field theory, which as I understand it is a bit like saying it is there because it is there and it has to be



Robert L. Sinsheimer

there. To my mind this is in effect a bold attempt to adapt the concepts available to the human mind to an intractable and perhaps unimaginable reality. As Einstein so well said, "The most incomprehensible thing about the universe is that it is comprehensible."

Similar problems of concept may well arise on the vast scale of the universe or, more to the point, in the intricate recesses of the mind. Our problem will be somehow to shape a mirror to the mind such that we can comprehend its reflection.

I have tried to think how we might approach this problem of the limits to thought inherent in the structure of our brain and therefore potentially extensible by genetic modification.

One approach would be comparative or phylogenetic. If we could trace the detailed chemical and structural changes in the central nervous system as evolution has progressed through the vertebrate species, and if we could correlate these changes with the changes in the reactive and conceptual capacities of these species, we would have one basis for future extrapolation.

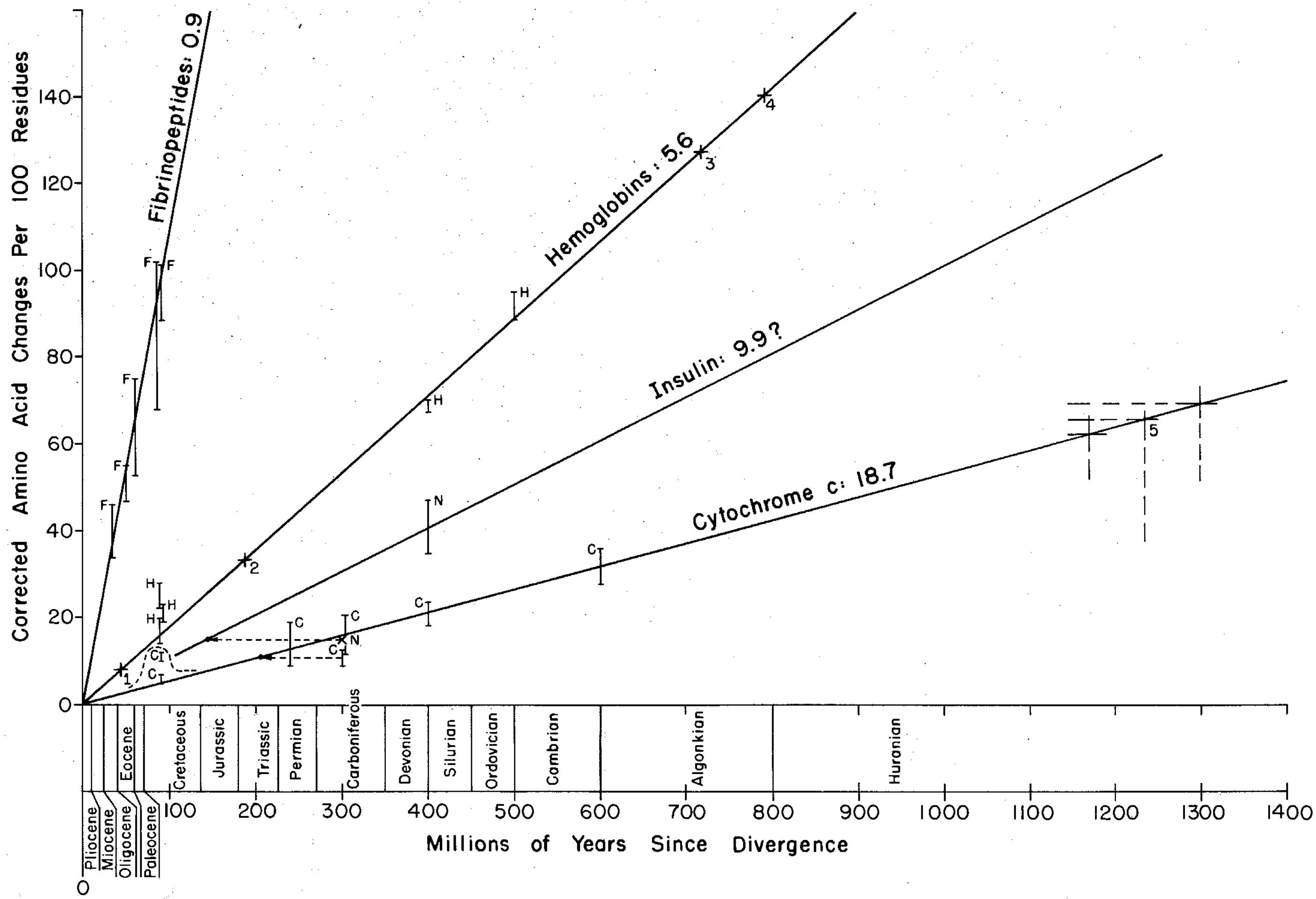
Now the comparative approach to phylogenetic evolution has been somewhat in disfavor in this recent era of biochemical ascendance, and for good reason. The biochemistry of all living creatures is really so similar. Hardly anyone would venture to suggest the differences between man and monkey are a consequence of a novel and major innovation in biochemistry. Indeed the biochemistry of man and a yeast cell are astonishingly similar. It is evident that almost all of the most basic processes of biochemistry must have been elaborated in some very remote time of evolution.

Rather, then, the differences between man and monkey must derive largely from some elaborations of structure, and thereby function on a cellular and multicellular level and primarily in the central nervous system. And these innovations must have arisen through the usual genetic mechanisms. How many genetic changes were there, literally? It's clear they did not require any major addition to the genome. The haploid DNA content of man and monkey is identical within the precision of measurement—a few percent.

Our abilities to compare and homologize or differentiate the DNA's of different species—say, man and monkey—are as yet very crude. The DNA-DNA hybridization experiments of Roy Britten and D. Kohne indicate that, on an average, the DNA sequences of man and monkey are highly homologous. Comparative measurements of the thermal stability of human DNA, chimpanzee DNA, and test-tube hybrids of these DNA's suggest that in the fifteen or so millions of years since these species have diverged there have developed about 1.6 nucleotide changes per 100 nucleotide pairs, or about 5 changes per 300 base pairs—which is equivalent to 100 amino acids of protein sequence. Since, because of redundance, about 20 percent of random nucleotide changes will not result in an amino acid change, we might expect a mean evolutionary distinction between these two species of about 4 amino acids per sequence of 100 in the absence of selective bias.

However, the interpretation of such homologies has since been complicated by the recognition that these experiments as they have been performed to date can only concern or involve certain fractions of the DNA, specifically those fractions that are made up of large families of molecules, or closely related sequences represented literally tens or hundreds of thousands of times in the genome. These represent about 40 percent of primate DNA. Under the conditions of these experiments, sequences represented less often simply never find a partner with which to hybridize in any reasonable time. The existence of these large families of closely related sequences, which may in total comprise some half of the genome, is both a surprise and a conundrum in itself, but in addition it does at present clearly limit the quantitative significance of statements about DNA homology between species, for we can say as yet very little about the possible homology of the less frequent DNA species.

Studies of the available rates of genetic mutation, as evidenced by changes in the amino acid sequences of particular proteins, suggest that the time of divergence of man and present-day monkeys from a presumed common ancestor *has been sufficient* to allow significant changes. The observable changes in amino acid sequence in any special protein are of course strongly biased by possible, and generally unknown, selective pressures that limit permissible change. Thus the alpha hemoglobin in the gorilla differs in only one amino acid from that of man. And that of the chimpanzee is identical to that of man. In an over-all sense, the rate of acceptable mutation in the globins is only about 1 amino acid per 100 residues per 6,000,000 years. For other proteins, such as cytochrome c, the allowable rate proves to be even less: 1 in 21,000,000 years. But a more accurate measure of the *possible* rate of amino acid replacement *may* be obtained from the fibrinopeptides which appear to serve no other function than to be excised from fibrinogen, when it is converted to fibrin in the formation of a blood



The number of changes in amino acids between the same protein from two different species is plotted here against the time in the past at which the two species' ancestors diverged. The unit evolutionary period is the average time required for one difference to show up per 100 residues. Molecules such as cytochrome c, which interact closely with other macromolecules, have longer unit evolutionary periods than such non-specific proteins as the fibrinopeptides.

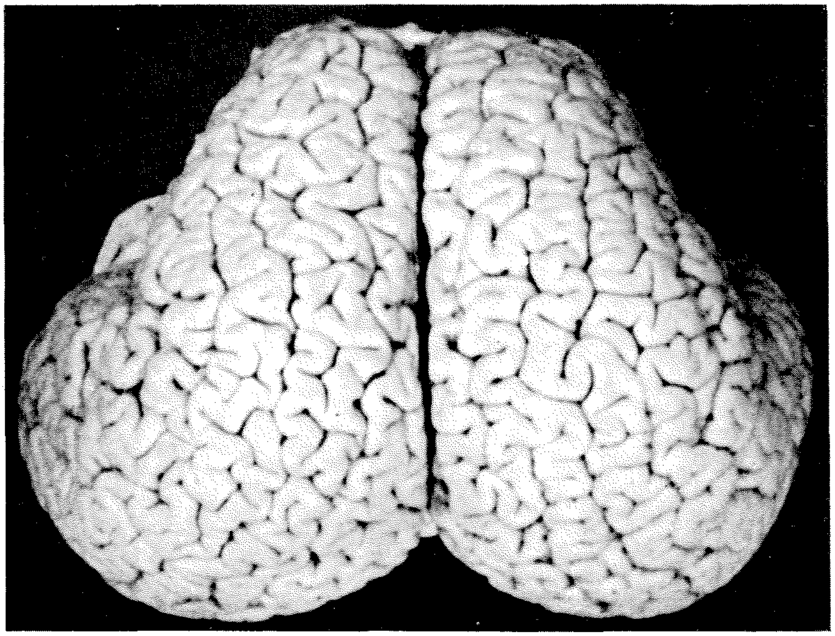
Adapted from R. E. Dickerson and I. Geis, *The Structure and Action of Proteins*, Harper & Row, 1969.

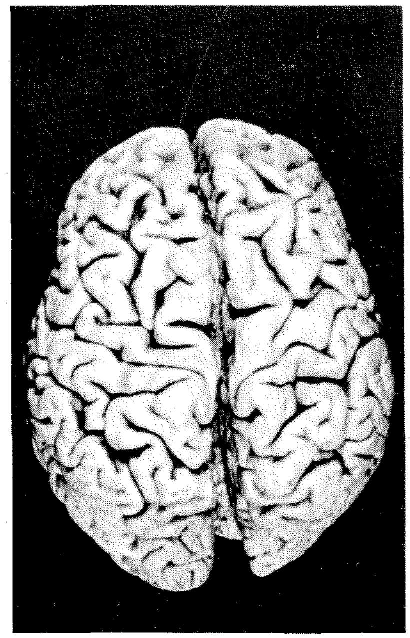
clot, and then to be degraded. In these the apparent rate is 1 amino acid change per 100 residues per 1.2 million years. These numbers are in reasonable agreement with the averaged estimate from nucleotide change—approximately 4 replacements per 100 amino acids per 15,000,000 years.

It is thus possible to suggest that in the last several million years a considerable number of the proteins of man could have undergone mutational changes in one or two amino acids. But a *major* change in a particular protein would be highly unlikely—at least by the mutational processes leading to the changes so far studied.

Now of course the body undoubtedly has mechanisms whereby the consequences of even a single amino acid change in a strategic protein can be greatly amplified. But the conclusion I tend to draw from this admittedly loose argument is that the genetic distinction between a man and a monkey is, in a quantitative sense, not a great one. Hence, there is a greater chance that in time we will

"The genetic distinction between a man and a monkey is, in a quantitative sense, not a great one."





Brain size is a rather crude indicator of brain capacity, and man's (right) is by no means the largest at 1,450 grams. For instance, the brain of the dolphin weighs 1,700 grams, and that of the adult fin whale (left) weighs 6 to 7 kilograms.

be able to define and understand this change and conceivably recapitulate it in the laboratory. In this connection it would certainly be of great value to have phylogenetic comparisons of specific brain proteins as well as of hemoglobin.

In addition to his enhanced capacity for conceptual thought, man exceeds other primates in his enlarged consciousness, his power of speech, and undoubtedly in such underlying functions as memory and capacity for numeration. What changes provide the bases for these qualities?

If we compare the brain of a man and, let us say, that of a rat, we find the rat brain weighs a little over 1/1,000th that of the man: 1.6 grams vs. 1,450 grams. Yet the rat is a rather complex organism. It can learn intricate mazes; it can fight or defend itself; it reproduces; it has, particularly in the wild, quite intricate behavior. After observing a rat for a while, one begins to wonder what the other 99.9 percent of the brain is doing in man. If one compares the volume of the cerebral cortex, the ratio becomes even greater: 5,000 to 1 (500 cubic centimeters to 0.1 cubic centimeter).

Of course size of brain is a rather crude indicator. The brain of a chimpanzee weighs 450 grams, that of a man 1,450 grams. A dog has 80 grams of brain, a rabbit 10. But the brain of man is not all that extraordinarily large. The brain of the dolphin weighs 1,700 grams. It rivals that of man in structural complexity and proportions. What is it doing? The brain of an elephant weighs 5 kilograms, a whale 6 to 7 kilograms.

"One of the most obvious distinctions between man and the lower animals is in the quality and quantity of his consciousness. Man can escape from the here and now; he can compare alternate responses and originate new actions by internal imagery."

If we examine animals at various levels of phylogenetic development, one trend is, clearly, that more and more information is brought into the central nervous system. Thus, in man somewhat over 2,000,000 sensory fibers bring information to the brain, about half through the cranial nerves (optic, auditory, etc.) and half through the spinal cord.

If we compare man with the rat, we find that 12 times as many sensory fibers enter the spinal cord and 10 to 12 times as many fibers carry auditory and visual information. But most of this increase in informational capacity has already developed by the evolution of the primate. The principal difference between the primate and man appears to be in the elaboration of structures for the analysis and integration of the sensory input. If we compare the number of cells in area 17 of the visual cortex in man and in the macaque, or of the areas 17, 18, and 19 of the visual cortex in man and the orangutan, or the number of cells in the auditory cortex in man and the chimpanzee, we find large increments in man over the primates. And, of course, even larger differences are found in the volumes of the frontal cortex, the functions of which are still disturbingly poorly understood. We are only now, in experiments such as those of David Hubel and T. Wiesel, beginning to learn some of the ways in which networks in these areas of the cortex analyze the sensory input in monkeys; we have no information yet as to how these means of handling sensory data may differ between the lower primates and man.

	Sensory Fibers into Spinal Cord	Auditory Fibers	Optic Nerve Fibers
Man	1,000,000	30,000	1,000,000
Macaque	550,000	30,000	1,000,000
Rat	80,000	3,000	80,000

A better indicator of brain capacity is the amount of information brought into the central nervous system. A comparison of man and the rat shows that 12 times as many sensory fibers enter the spinal cord and 10 to 12 times as many fibers carry auditory and visual information.

	Man	**Primate**
Cells, Area 17, Visual Cortex	540,000,000	150,000,000 (Macaque)
Cortical Surface, Area 17	26 cm²	18.7 cm² (Orangutan)
Cortical Surface, Area 18	39 cm²	14.5 cm² (Orangutan)
Cortical Surface, Area 19	39 cm²	14.2 cm² (Orangutan)
Cells, Area 41, Auditory Cortex	100,000,000	10,000,000 (Chimpanzee)

The principal difference between the primate and man appears to be in the elaboration of structures for the analysis and integration of the sensory input. Large increments in man over the primates are shown in this comparison of the number of cells in area 17 of the visual cortex in man and in the macaque, or of the areas 17, 18, and 19 of the visual cortex in man and the orangutan, or of the number of cells in the auditory cortex in man and the chimpanzee.

One of the most obvious distinctions between man and the lower animals is in the quality and quantity of his consciousness. Man can escape from the here and now; he can compare alternate responses and originate new actions by internal imagery. In the nature and origin of consciousness is one of the most profound of mysteries. What determines the modality of consciousness? How do certain stimuli cause pain, others color, others tone or taste? What defines the spectrum of color sensation? Why are there no more colors or no other tones? Clearly there are structural and very likely chemical, and therefore, genetic, bases for these phenomena.

There are individuals, for instance, who are genetically insensitive to pain. In some instances this defect is peripheral. The nerve receptors in the skin which are usually considered to be the sensors of pain are lacking. In others the sensory cells and sensory fibers, at least as far as can be seen, appear to be intact, and the defect may be central—an indifference to pain. An interesting point is that these people, lacking a sensory modality, do not appear to know what pain is. It is absent from their consciousness, which thus seems, in part at least, discrete. It is of interest that such people often can distinguish temperature quite normally but there is no pain associated with hot or cold. This condition is most often disastrous to the individual. It is also of great interest that in two cases siblings from first-cousin marriages have shown this trait, suggesting that it may be a consequence of a fairly simple genetic alteration.

Now I personally rather doubt that we have the conceptual capacity to really comprehend the origin of consciousness; but I do expect that we will learn that consciousness of various modalities may be associated with circuits of the brain connected in diverse ways, possibly with diverse chemical transmitters and effecters, all programmed genetically, and that by modifying these programs we may indeed in a true sense expand consciousness into unknown sensations and into undreamt intensities. If this sounds absurd, consider that many

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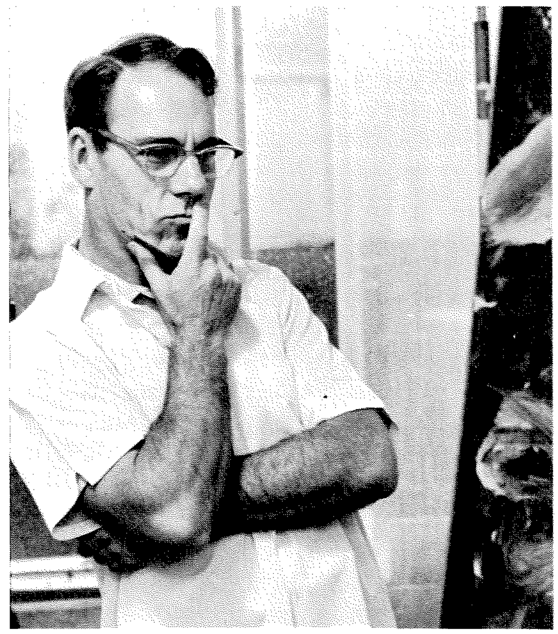
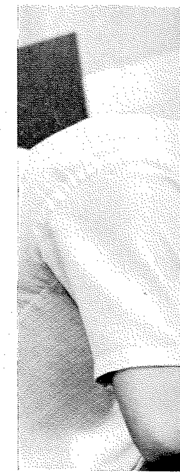
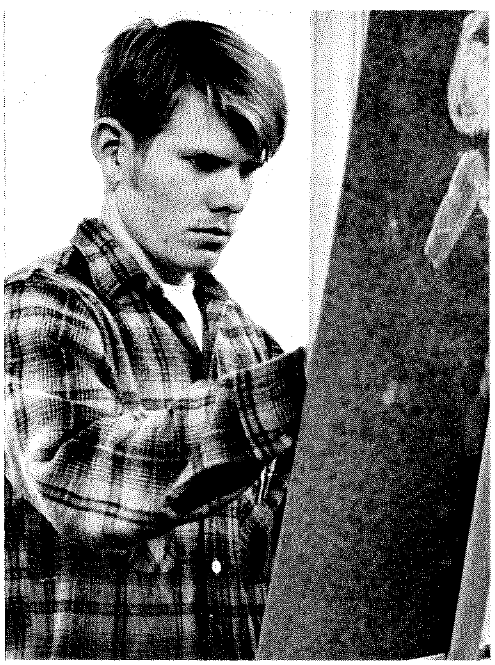
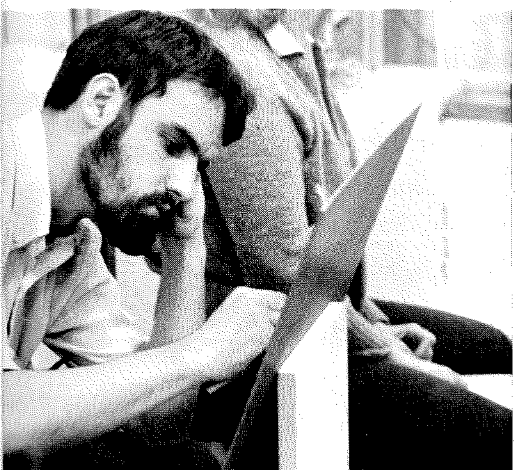


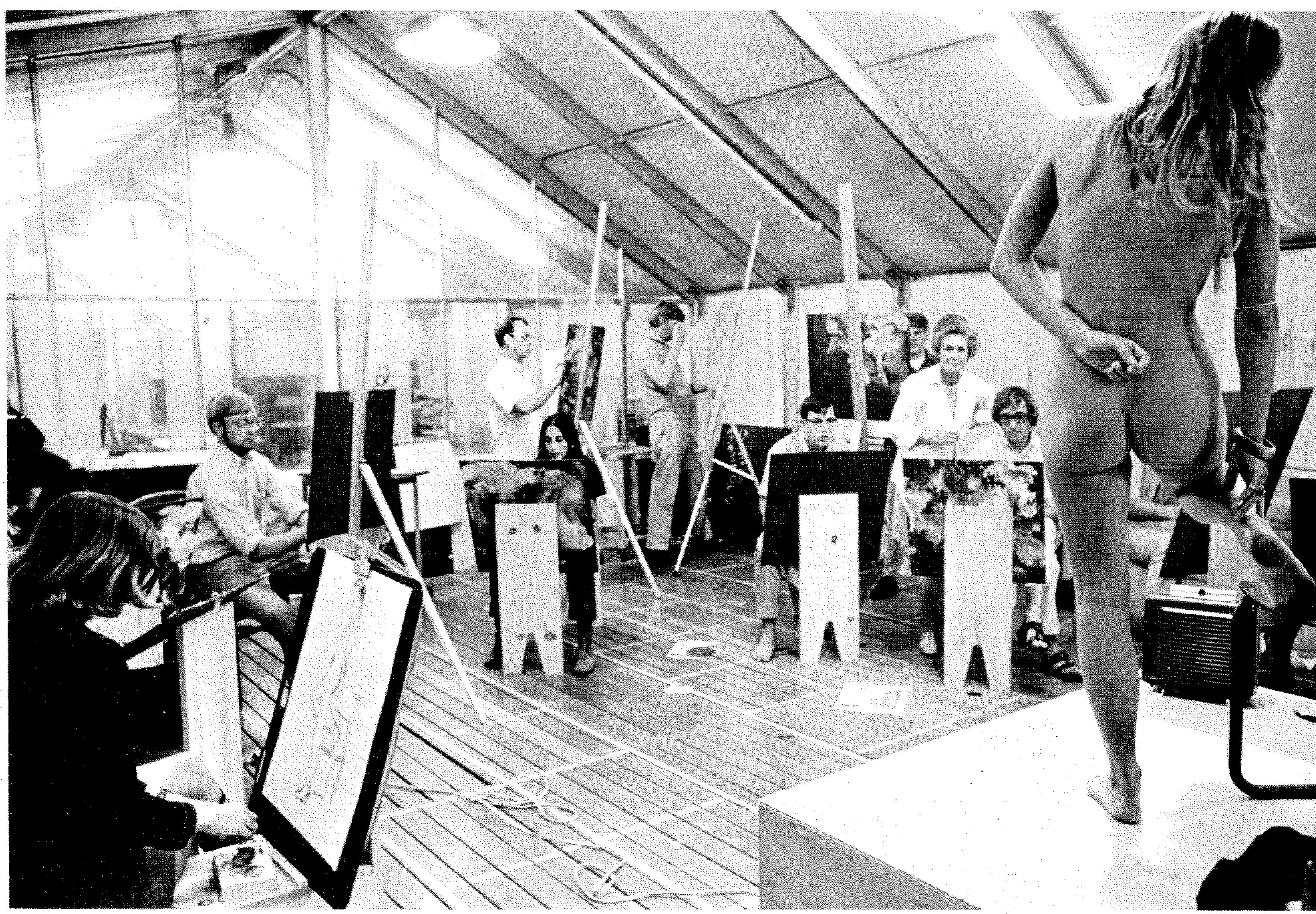




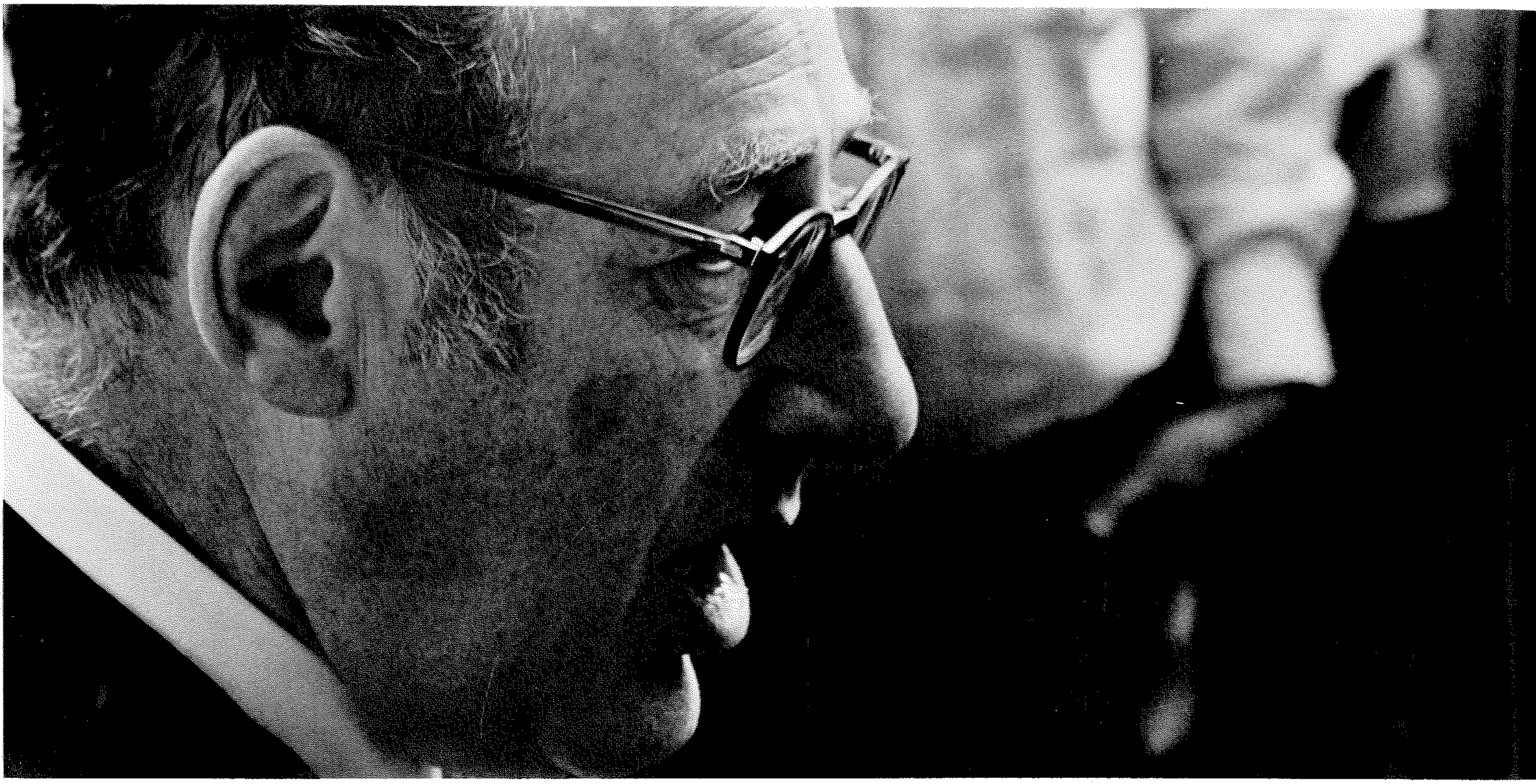
Back to the Drawing Board



Caltech launched an ambitious art program last fall by converting the old Earhart Plant Laboratory greenhouses into art studios and offering classes in painting, sculpture, printmaking, life drawing, and the use of technological devices such as computers or lasers in art. Because there was some doubt as to how many students would sign up, the classes were opened to faculty, staff, and friends of Caltech as well. To everyone's delight, the greatest support for the program has come from the undergraduates—and anyone who thinks the students don't take their art seriously is directed to these pictures of a recent life class in session.



"Mr. Agnew and I share the view that television journalism leaves something to be desired. We are apparently in profound disagreement on our crying need for more, not less, interpretive reporting."



Fred Friendly

When Spiro Agnew launched his surprise attack on the television networks in a Des Moines speech on November 13, he recalled how "Several years ago Fred Friendly, one of the pioneers of network news, wrote that its missing ingredients were conviction, controversy, and point of view." Now, Agnew said sharply, "the networks have compensated with a vengeance."

Friendly disagreed—publicly—in a talk sponsored by the YMCA at Caltech on November 21. Friendly served as president of CBS News from 1964 to 1966. (He resigned after the network insisted on showing a fifth-run "I Love Lucy" episode instead of a Senate Vietnam hearing.) A partner of Edward R. Murrow's for 12 years, Friendly is now the Edward R. Murrow Professor of Broadcast Journalism at Columbia University. He is also television consultant to the Ford Foundation. His talk on "Some Second Sober Thoughts on Vice President Agnew" was given while he was on the Caltech campus as a member of the Institute's new visiting committee for humanities and social sciences. It stands as one of the most reasonable, and reasoned, of the many responses to the Agnew statement.

SOME SECOND SOBER THOUGHTS ON VICE PRESIDENT AGNEW

by Fred Friendly

In defending Vice President Agnew, one of the most fair-minded men in the United States Senate said, "It is the pig that is caught under the fence that squeals." The analogy may be partly accurate, but the question is who is stuck under the fence—the broadcast journalist or the Administration. Long ago, when broadcasting was fighting for its right to be responsible, Edward R. Murrow (then under attack) spoke words which might be paraphrased today: When the record is finally written, it will answer the question, who helped the American people better understand the dilemma of Vietnam—the Administration or the American journalist? History will, of course, decide that question. But I would suspect that in the recent struggle between the news media and the last two Administrations, the record has been with the journalists.

The American people are worried about Vietnam, race, and youth—the three crucial stories of our time. What the Vice President of the United States is attempting to do is create doubts in the minds of the American public about the motivation and background of those charged with the responsibility of trying to understand and explain these complicated and sensitive controversies.

When Mr. Agnew asks, "Are we demanding enough of our television news presentations?" he is certainly asking a question that others, including many inside the profession, have asked for a generation. For some the Vice President's questions seem to be about raised eyebrows, caustic remarks, and too much news analysis. For me it was really a speech about too little analysis. In fact, the Vice President may have provided a most valuable service in his Des Moines speech. He sharpened an issue that has been diffuse for too long, inviting us all to consider once again the state of broadcast journalism.

Mr. Agnew and I share the view that television journalism leaves something to be desired. We both fear the concentration of great power in a few individuals in the broadcasting industry. But we are apparently in profound disagreement not only on the nature of the networks' coverage of the President's Vietnam address but, even more importantly, on our crying need for more, not less, interpretive reporting. We require bolder, not blander, illumination of the issues which divide men of reason.

Where Mr. Agnew went astray, in my view, was in his suggestion that the media ought somehow to be a conduit for the views of the government, or merely a reflector of public opinion. He was not the first, nor the last, high official to equate fairness and the possession of great power with the obligation of conformity.

The Vice President forgot history when he criticized ABC's journalistic enterprise in arranging for Ambassador Harriman to participate in the broadcast that followed Mr. Nixon's speech of November 3. I don't think President Kennedy rejoiced in having Senator Homer Capehart (R-Ind.) critique his Berlin crisis speech of 1961, or having Ladd Plumley, president of the National Chamber of Commerce, pursue him after his controversial 1962 speech on the state of the economy. How many times after a major address did President Johnson have to listen to the cutting remarks of Minority Leaders Dirksen and Ford? It was all part of the democratic process. After all, President Nixon had had prime time on all three networks, and a small measure of counterfire from the loyal opposition was hardly stacking the deck. Perhaps ABC should not be faulted for inviting Ambassador Harriman, an experienced negotiator with the Hanoi government, but rather for not asking him enough hard questions.

The Vice President doubts that President Kennedy, during the Cuban missile crisis of 1962, had his words "chewed over by a roundtable of critics" immediately following his address to the nation. Would the Vice President believe Sander Vanocur, Ray Scherer, Frank McGee, David Schoenbrun, Roger Mudd, George Herman, Richard C. Hottelet, and Douglas Edwards? The date on that is October 22, 1962. The Vice President did not mention the Bay of Pigs, but certainly he must remember the news analysis and the GOP counterbriefings that followed. President Kennedy, who earlier had called upon broadcasters for self-censorship of the story in the national interest, later told the managing editors of *The New York Times* that revelation of the Bay of Pigs plan might have saved the nation "a colossal mistake."

A generation ago the most savage denouncements

"It took broadcasting several years during the McCarthy period to learn that merely holding up a mirror could be deceptive."

ainst news analysis involved Senator Joseph McCarthy. In an inflammatory speech in Wheeling, West Virginia, in 1950 he declared there were 205 Communists in the State Department. Good news analysis, in fact good reporting, would have required that the journalist not just hold his mirror up to that startling event but that he report that the Senator had not one scrap of evidence to substantiate so extravagant a claim. It took broadcasting several years during the McCarthy period to learn that merely holding up a mirror could be deceptive, as in fact holding up a mirror to a riot or peace march today can be deceptive. It took the shame of the McCarthy period and the courage of an Ed Murrow to elevate broadcast journalism to a point where it could give responsible insights to issues such as those raised by the junior senator from Wisconsin.

For generations editors and students of journalism have tried to define news analysis and interpretive reporting. The late Ed Klauber, one of the architects of broadcast news standards, provided the most durable description. I have always kept it in my wallet, and I provide copies to all my students at the Columbia Graduate School of Journalism:

> What news analysts are entitled to do and should do is to elucidate and illuminate the news out of common knowledge, or special knowledge possessed by them or made available to them by this organization through its sources. They should point out the facts on both sides, show contradictions with the known record, and so on. They should bear in mind that in a democracy it is important that people not only should know but should understand, and it is the analyst's function to help the listener to understand, to weigh, and to judge, but not to do the judging for him.

If the Vice President would test the brief analyses of November 3 against Mr. Klauber's criteria, I think he might agree that the correspondents did not cross the line in any attempt to make up the viewer's mind on a course of action. Mr. Agnew felt that the response to the President on November 3 was instant analysis. But it seems fair to remind the Vice President that the Administration had provided correspondents with advance copies of the speech for study earlier that evening, and there had been a persuasive White House briefing on the content. While the comments of the correspondents were clearly appropriate, my own personal opinion is that only those of Sevareid and Marvin Kalb were probing and thoughtful. Kalb conceivably erred in not quoting pertinent paragraphs from the Ho Chi Minh letter which he believed were subject to different interpretation from that of the President.

Part of our Vietnam dilemma is that during the fateful August of 1964, when the Tonkin Gulf Resolution escalated the war, there was little senatorial debate worthy of the name, and there was a dramatic shortage of news analysis. If I am inclined to give the networks an A for effort and a B for performance the night of November 3, 1969, let me tell you that I give CBS News and myself a D for effort and performance on the night of August 4, 1964, when President Johnson, in his Tonkin Gulf speech, asked for a blank check on Vietnam.

In spite of the pleas of our Washington bureau, I made the decision to leave the air two minutes after the President concluded his remarks. I shall always believe that if journalism had done its job properly that night and in the days following, America might have been spared some of the agony that followed the Tonkin Gulf Resolution. I am not saying that we should have, in any way, opposed the President's recommendations. But, to quote Klauber's doctrine of news analysis, if we had "out of common knowledge or special knowledge . . . pointed out the facts on both sides, shown contradictions with the known record . . . ," we might have explained that after bombers would come bases; and after bases, troops to protect those bases; and after that, hundreds of thousands of more troops. Perhaps it is part of the record

"Here we are in 1969, with one leg on the moon and the other on earth, knee-deep in garbage. That's going to require some news analysis."

to note that Ed Murrow, who understood the value of interpretive journalism from his years as a practitioner and from his experience as director of the U.S. Information Agency, called minutes after the Johnson speech to castigate me and CBS for not providing essential analysis of the meaning of the event.

One key aspect of the Vice President's speech did strike me as relating to the public interest as distinguished from the Administration's political interest. This was his concern over the geographic and corporate concentration of power in broadcasting. Here he had the right target but a misdirected aim. His criticism of broadcasters for centralization and conformity better describes the commercial system and its single-minded interest in maximum ratings and profits.

To some extent, it may be true that geography—and working out of New York and Washington—affects the views of Dan Rather of Wharton, Texas; Howard K. Smith of Ferriday, Louisiana; Chet Huntley of Cardwell, Montana; David Brinkley of Wilmington, North Carolina; Bill Lawrence of Lincoln, Nebraska; and Eric Sevareid of Velva, North Dakota. But I, for one, simply do not buy the Vice President's view that these responsible decision-makers in news broadcasting and the professionals who work with them are single-minded in their views or unchecked in their performance. There is an independent, sometimes awkward, complex of network executives, station managers, producers, and reporters whose joint production is the news we see. These represent a geographic, ethnic, and political profile nearly as far ranging as American society itself, with the tragic exception of blacks. The heads of the three major network news bureaus find their constituencies and their critics among the station managers they serve, the correspondents they employ, sponsors they lose, and in the wider public they please and occasionally disappoint. The news program emerges from a complicated system of argument, conflict, and compromise.

Beyond that, the record suggests that the best professionals recognize and acknowledge their limitations. Walter Cronkite was the first to admit that he erred in some of his reporting at the 1968 Democratic Convention. It was David Brinkley, admitting that no reporter could always be objective but only strive for fairness, who gave the Vice President a high-visibility target. In his commentary on November 3 Mr. Sevareid clearly noted that his views were "only the horseback opinion of one man, and I could be wrong."

Yet, if the Vice President's aim was wild, his target of concentrated power is valid and endures. The "truth" of commercial broadcasting is that it maximizes audiences by maximizing profits. This system minimizes the presentation of hard news and analysis, leading the broadcast journalists into occasional oversimplification in the interest of time and overdramatization in the interest of impact.

If such distorting tendencies do exist, and I believe they sometimes do, the proper measure is not to subject the performance of professional journalists to governmental direction or to majority approval. Rather, the task for government is to apply its leadership and authority to expand and diversify the broadcasting system and environment in which professional journalists work.

I do not see these public actions as inconsistent with or disruptive of the protections of the First Amendment. When Congress passed the Communications Act enabling the FCC to restrict a limited number of frequencies and channels to a limited number of license holders, everyone's freedom was slightly qualified because everyone cannot simultaneously broadcast over the same television channel. The Communications Act insisted that license holders operate their franchise "in the public interest, convenience, and necessity." By every definition I have ever heard, that includes responsible news coverage. Selling cancer-giving cigarettes and not providing enough news and public affairs programming is certainly ample reason for reconsidering a station's license, and doing so has nothing to do with the First Amendment. The FCC would be fulfilling long-standing national policy by demanding more, not less, public service broadcasting from the commercial systems, as well as by accelerating development of a publicly supported noncommercial alternative.

The Vice President quotes Walter Lippmann to make a case that the networks have hidden behind the First Amendment. He does not add that Mr. Lippman's point was that this demonstrated the necessity for just such a competitive, alternate system, which most commercial broadcasters today support. Mr. Lippmann has also said that "the theory of a free press is that the truth will emerge from free reporting and free discussion, not that it will be presented perfectly and instantly in any one account." Public television, with national interconnection due in part to a new ruling by the FCC, now has a chance to make that free reporting and free discussion 25 percent more widespread and more effective.

In the days since the Vice President's speech, I have been jarred by the strange coalition of Americans who find an assortment of reasons for identifying with parts of the Vice President's remarks. The mobilizers for peace don't like the way the peace march was covered or, as they put it, left uncovered. My Democratic friends point to the Humphrey defeat which they say happened at the hands of the television cameras in Chicago. My journalism students at Columbia feel that time after time the broadcasters of my generation misjudge the youth movement and the black movement. In the end I have had to plead for the students to believe in the integrity of a Cronkite, a Smith, a Brinkley, and in the professionalism of their producers—men like Les Midgley of CBS, Av Westin of ABC, and Wally Westfeldt of NBC. My defense was only partly successful, and this was an audience generally quite hostile to the main thrust of the Agnew attack. With sadness, I have painfully learned that the reservoir of goodwill that broadcast journalists could once rely on in time of crisis has now been partially dissipated.

Perhaps if the public knew that the broadcast newsman was fighting for longer news programs, fewer commercials, more investigative reporting, there might be a broader sense of identity.

The broadcast journalist knows how little news analysis appears on the air. Five or eight minutes after a major Presidential address is not interpretive journalism as much as it is time to be filled to the nearest half-hour or to the nearest commercial. He also knows that a half-hour minus six commercials is just not enough air time to present and analyze the news properly. Perhaps the broadcast newsman of today can no longer afford the luxury of abdicating his role in a decision-making process that now so clearly affects his profession and his standards. He is a far better newsman than the public ever sees, and he has far more power to change the system than he and the public imagine.

For a long time the broadcasting companies have relied on the prestige of their news organizations to enhance their own corporate prestige, in fact, their very survival. The reputation of these newsmen is now at stake. They need to do their best, not their worst. They need to be seen at their most courageous, not to slip into timidity. This is not a time for public relations experts, although there will be a frantic search for a corporate line which will once again be asked to salvage the good name of broadcasting.

Television's battles will not be fought or won on the polemics of corporate handouts, First Amendment platitudes, or full-page ads. They will be won by what is on the air, and they will be lost by what is *not* on the air. It is later than we think, and we all have Mr. Agnew to thank for reminding us of that.

Here we stand, with the image orthicon tube, the wired city, and the satellite—the greatest tools of communication that civilization has ever known—while the second highest officeholder in the land implies that we should use them less. Here we are in 1969, Mr. Vice President, with one leg on the moon and the other on earth, knee-deep in garbage. That's going to require some news analysis.

What the Vice President says is that he wants editorials (which network news divisions don't use) labeled for what they are. Certainly it is general custom to label news analysis and comment when it is taking place, and omission of that even under the pressure of time is a mistake. But Mr. Agnew ought to label his speech for what it was. Did he want to encourage responsible journalism, or did he wish to silence it?

Perhaps the journalist and the party in power are always destined to be on the outs. President Eisenhower was pretty sore with television news until he left office, when he became a big fan. President Kennedy was reading and watching more and enjoying it less. President Johnson watched three sets and knew how to talk back to three talking heads at once, and the Nixon Administration has let us know where it stands and what kind of climate it wants to create. It is my theory that when the message from Des Moines or the White House itself is always a valentine or a garland of flowers, television and radio will have failed their purpose.

RE-EXPLORING THE COLORADO

A group of geologists match footprints with the men who made the first trip down the river a century ago.

In Utah's Desolation Canyon, Eugene Shoemaker, chairman of Caltech's division of geological sciences, uses topographic maps to match a camera site with that used by photographers on the Powell expedition of 1871. In all, about 150 of the original sites were rephotographed in 1968.

In 1869 the canyons of the Green and Colorado Rivers were the last major sections of the United States still untraveled and unknown. In many places the raging water flowed between canyon walls as high as a mile on each side, and it was questionable whether anyone could safely travel the length of the rivers. But in that year geologist John Wesley Powell did just that, and revealed this magnificent canyon country to the world. The record of the 1869 expedition and another in 1871 and 1872 includes his remarkable journals (*Exploration of the Colorado River of the West and its Tributaries*) and several hundred photographs.

What changes have those powerful rivers made along their banks in 100 years? To find out, Eugene Shoemaker, chairman of Caltech's division of geological sciences and long-time student of the canyon country, took three months in the summer of 1968 to retrace Powell's 900-mile route. The purposes of Powell's expeditions were to map and photograph. Shoemaker's objectives were to identify the landscape in the Powell pictures, to locate the sites where Powell's photographers took their pictures, and to determine how, and how fast, the canyons have eroded.

The exploring, mapping, and photographing of the Green and Colorado were done by Powell and his group in two trips. They traveled in wooden boats with enclosed compartments designed to withstand the buffeting of rocks in the many rapids. The boats were lowered into the river by ropes from the Union Pacific railroad bridge at Green River Station, Wyoming.

The first expedition took three months, down the Green to its confluence with the Colorado, and from there on down the Colorado through Cataract Canyon, through the canyons of what is now 165-mile-long Lake Powell, and into the Grand Canyon. On the 1871 expedition the canyons were mapped and photographed, and their geology studied over a period of a year and a half.

Early in July Shoemaker set out with geologist-photographer Hal Stephens in neoprene rubber boats from

"August 15 [near Sockdologer Rapid]—
It rains! Rapidly little rills are formed above, and these soon grow into brooks, and the brooks grow into creeks, and tumble over the walls in innumerable cascades, adding their wild music to the roar of the river. When the rain ceases, the rills, brooks, and creeks run dry. The waters that fall, during a rain, on these steep rocks, are gathered at once into the river; they could scarcely be poured in more suddenly, if some vast spout ran from the clouds to the stream itself."
—J. W. Powell, 1869

Powell's starting point—Green River, Wyoming. As they moved downstream Shoemaker located the camera sites using the Powell photographs as guides. In his pictures photographer Stephens of the U.S. Geological Survey framed the same topographical features that had appeared in the early pictures.

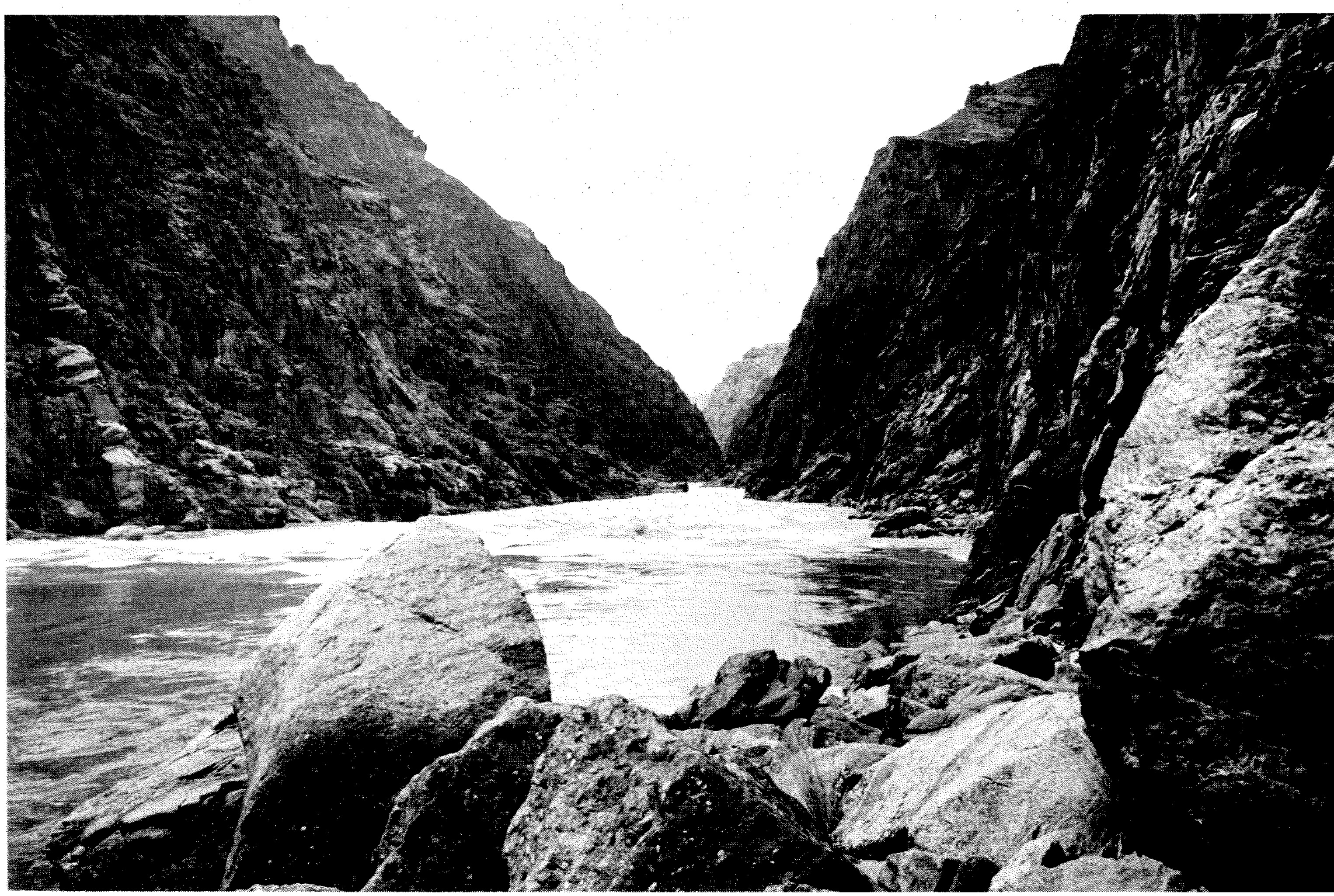
After comparing the old photographs with those taken by Stephens, Shoemaker concludes that the canyons were carved largely by catastrophes such as cloudbursts and floods rather than by the gradual erosion of rain and river. In most places there is no apparent change in topography. Often, even sandbars along the river banks are unchanged from a century ago. Where topographical changes have occurred, however, they are dramatic.

Sections of cliff have collapsed or sometimes sections of the riverbank have been washed away or replaced with new deposits of boulders.

Locating the exact camera sites of Powell's photographers was challenging, because the photographs were identified only with general captions, some of which were wrong—placing the sites hundreds of miles off or even on the wrong river. (The captions were written more than 25 years after the photographs were taken.)

Shoemaker is now preparing an extensively annotated album of the Powell Expedition photographs to be published as a Professional Paper of the U.S. Geological Survey. Shoemaker's trip was supported by the Geological Survey, which had Powell as its second director.

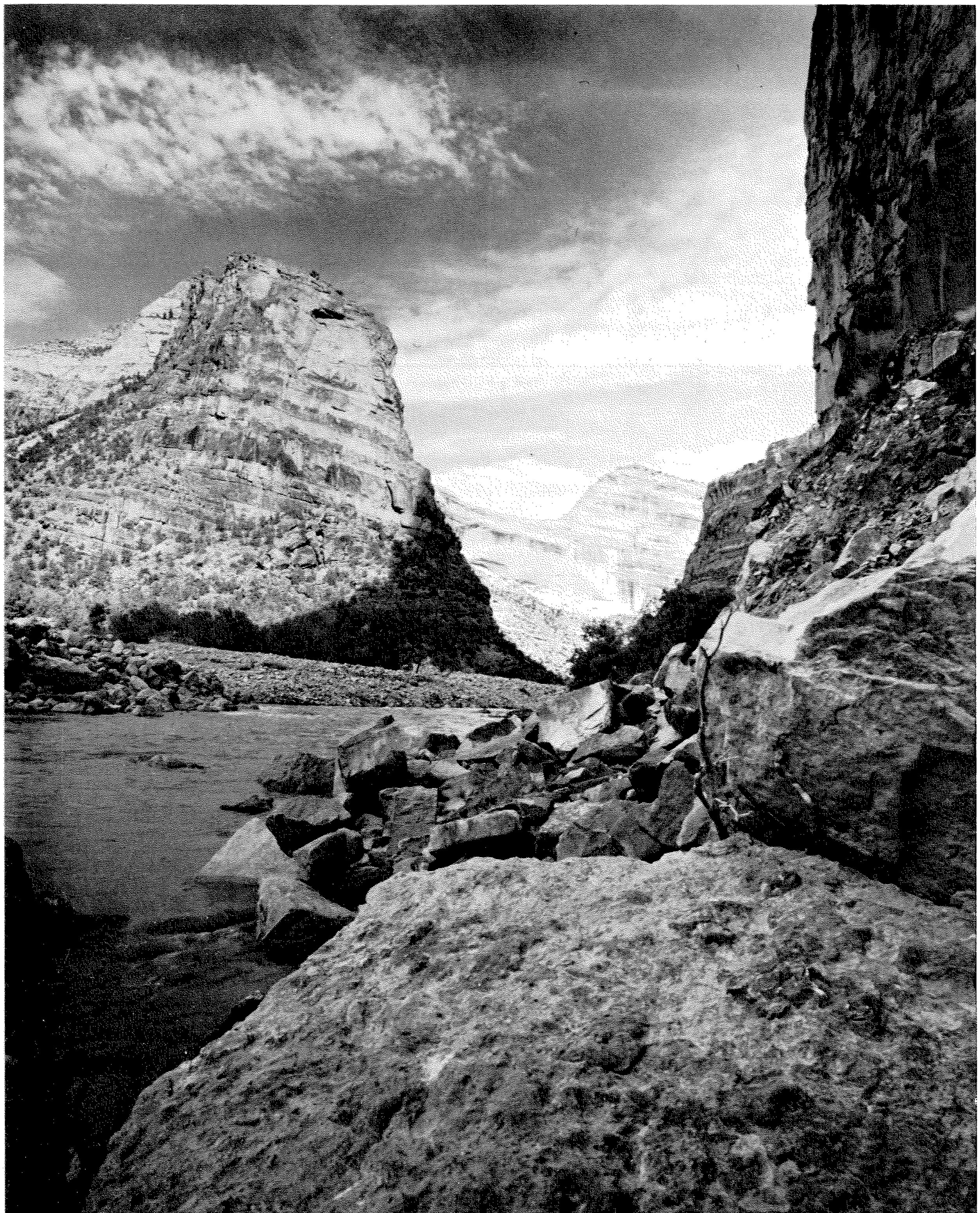
The striking similarity of these two identically framed photographs (old one on the left) in the Grand Canyon at the head of Sockdologer Rapid shows how little change the river has wrought in many locations. Powell's photographers spent at least an hour taking a photograph. For each one they had to coat a glass plate with emulsion, then develop it right after making the exposure. Six pictures a day were considered very productive.



The topography here on the Yampa River in Colorado's Canyon of Ladore was dramatically changed by a flash flood in 1965 (which happened to be witnessed by Caltech graduate student Bruce Julian, who was camped there). As a result, all the foreground rocks shown in the old photograph (left) are gone, including the huge one behind Powell's chair. The two photographs are not framed identically because the original camera site is now about 10 feet out in the river.

"June 17.—We run down to the mouth of Yampa River. This has been a chapter of disasters and toils, notwithstanding which the canon of Ladore was not devoid of scenic interest, even beyond the power of pen to tell. The roar of its waters was heard unceasingly from the hour we entered it until we landed here. No quiet in all that time. But its walls and cliffs, its peaks and crags, its amphitheaters and alcoves, tell a story of beauty and grandeur that I hear yet—and shall hear."

—J. W. Powell, 1869



WHY STUDY CHEMISTRY?

by Richard E. Dickerson

For one thing, there are blunders of the past to correct. For another—we might even find out what life is, where it came from, and how it operates.

Why study chemistry? What does a chemist do that inspires you to be one or prompts you to learn something about the field even if you do not plan to pursue it as a career? In the past, the answer has often been given in terms of the many important products that have come from the laboratory: dyes, petrochemicals, plastics, fertilizers, drugs, synthetic fibers. Older texts are filled with photographs of blast furnaces and rayon spinning mills, and eulogies to the Haber process for ammonia and the Solvay process.

A shift in values has come about in the present generation. Material comfort and a colored plastic telephone do not seem as centrally important as they once did. Synthetic rubber now hardly seems like one of the higher manifestations of the human spirit. Indeed, many of our once-heralded achievements have backfired on us. We can travel from one place to another rapidly at the cost of polluting the air and filling it with noise. We can manufacture cheap paper to support widespread literacy at the cost of killing off the water life downstream. Our hopes for abundant nuclear power are clouded by the problems of thermal pollution. We keep the wheels of transportation turning, but blacken our coastlines with escaping oil to do so. We eradicate insects to aid our crops and then find that we have also killed the robins and contaminated the salmon in Lake Michigan. The genie of chemistry seems to be a malevolent spirit who accompanies each gift with a trap that leaves us with a new problem for every one we solve.

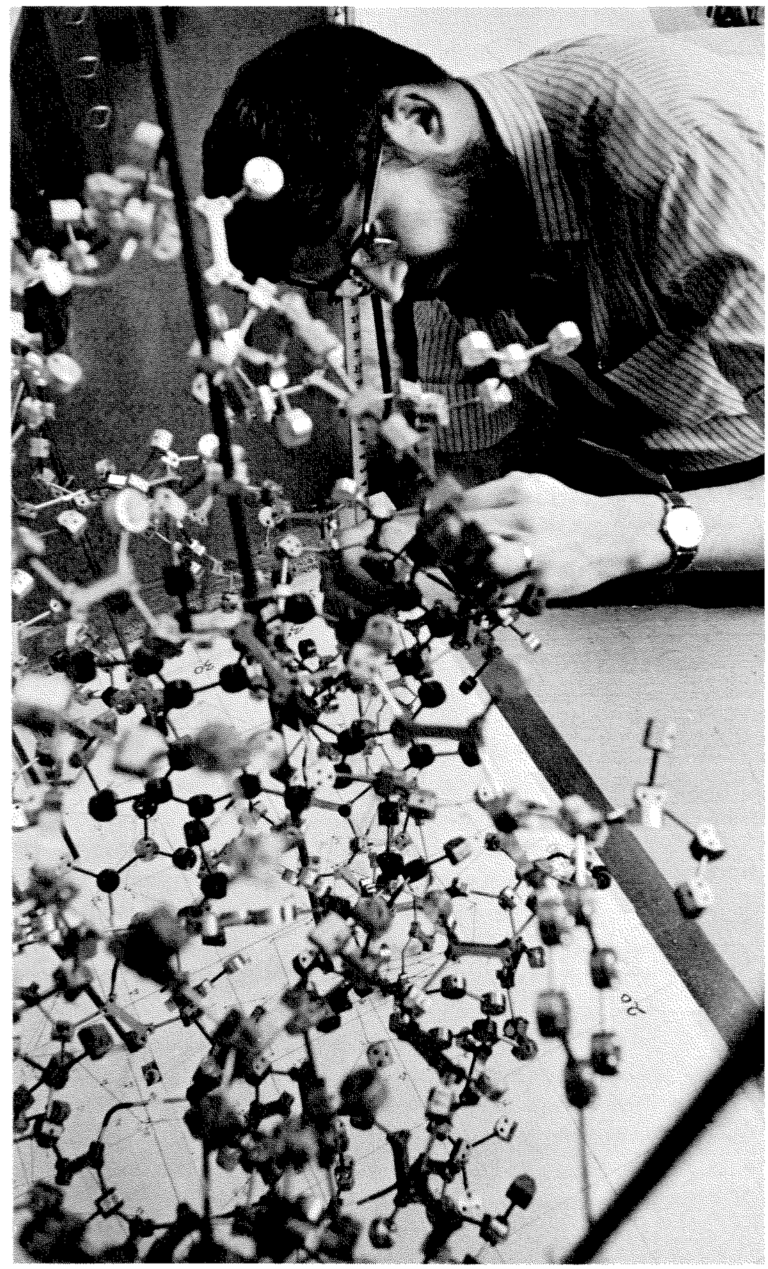
Most of these traps have evolved because we looked at each technical advance in isolation and paid too little attention to the ultimate effects of each new development. The enthusiasm of past generations for the "wonders of chemistry" was sincere but naive. The proper response is not to turn away from science, but to use it more intelligently. We desperately need a generation of scientists who are committed to the wise use of their discoveries. Moreover, we need a generation of nonscientists who know enough about chemistry and physics to anticipate the outcome of technical decisions and to compute long-range costs and benefits as well as short-term gains. There has never been a time when it was more important for the nonscientist to understand chemistry and physics, for there has never been a time when political and economic judgments were as likely to get us into scientific trouble. Perhaps in another generation the proper entry into government and politics should not be a degree in law but in general science.

A child never worries about where his home came from or who will provide his food and clothing. These things are just there, in the natural order of life. If the child leaves his room in a mess, somehow it will all be put right. We have all been living in a very small room, the planet earth. Like children, we have accepted its gifts as inexhaustible and free. We have littered our room with garbage—solid, liquid, and gaseous—and trusted that it will all disappear somewhere. Yet we are entering a troubled intellectual adolescence, in which we are realizing that these assumptions are not true. If the planet is to remain livable, someone must keep it so. There are no such things as either endless resources or infinite capacity for waste disposal. One man's garbage inevitably becomes someone else's raw materials. One of the tasks of the chemist in the coming years is to create workable plans by which we can live together on this planet, and the job of the scientifically literate citizen is to make it possible for such plans to be put into action. The Greeks were ingenious in imagining torments for their fallen heroes, but even they did not imagine Prometheus finally drowning in garbage.

So far we have been talking about what we should do with chemistry. But what can chemistry do? Just as we are beginning to look at life on this planet as a whole, so we are beginning to look at the chemistry of an entire living organism. Chemists at last are beginning to have something concrete to say about that most intricate of chemical systems, a living creature. Francis Crick, who together with James Watson discovered the molecular structure of the hereditary material of life, DNA, was a physical chemist. The deciphering of the nucleic acid code, or the system by which the information for building a living organism is stored in DNA, was a triumph of biochemists. When Arthur Kornberg and his colleagues succeeded in copying the complete DNA of a virus and in demonstrating that this synthetic genetic material would build a new virus as well as natural DNA would, they did so with the intimate cooperation of enzyme chemists and molecular biologists. Organic and biochemists are now able to synthesize vitamins, hormones, and enzymes in a way that would have seemed incredible ten years ago. Penicillin, insulin, and even the enzyme ribonuclease have been made synthetically, and the tour de force of vitamin B_{12} synthesis is on the way. Physical chemists and biochemists can solve the three-dimensional structures of enzymes and can construct atomic models of them. With these models as a starting point, enzyme chemists can make more progress than ever before in understanding how the catalytic action takes place.

The implicit purpose of knowledge in chemistry, as in any other area, is control. If we know how hormones act, perhaps we can control their action. If we understand enzymatic catalysis, perhaps we can correct metabolic failures such as phenylketonuria, in which the inability to metabolize one key substance can lead to feeblemindedness in an infant. If we learn enough about the chemistry of DNA and genetic information transmission, perhaps we can detect and cure mongoloidism, which is produced by an extra chromosome early in the life of the embryo. Even more dramatic hereditary engineering has been proposed, but we need to distinguish between the verbs "can" and "should." As R. S. Morison has said, "In a short time we will be able to design the genetic structure of a good man. There is some uncertainty about the date, but no doubt that it will come before we have defined what a good man is." ["Science and Social Attitudes," *Science*, **165**, 150, (1969)]

New examples of chemical influences—both natural and artificial—on behavior are continually coming to light. Two rare chemicals in the bloodstream have a suggestive but unproven connection with schizophrenia. Large doses of the common lactic acid can produce anxiety neuroses



Richard E. Dickerson, professor of physical chemistry.

"One of the advantages of alcohol over LSD is that the euphoria induced by alcohol is so clearly second-rate and temporary."

in humans, and the behavior-changing effects of mescaline and LSD are a matter of concern. Before LSD became a cult, it was a research tool in the study of artificial schizophrenia.

Rats are most like humans in their clannishness and their reaction to overcrowding. Their sense of community identity and their enmity to strangers is strong (one is tempted to add "and human"). Experimenters have actually brought about a reduction in the rat population of a city block area by introducing new rats. The reason, interestingly enough, is chemical. The presence of new and alien rats on the territory of an existing group leads to fighting, stress, and anxiety. But it is not the fighting that lowers the numbers of rats. When a rat is made neurotic by conflict and overcrowding, its body secretes a hormone that reduces sexual aggressiveness in males and interferes with pregnancy in females. The birth rate therefore falls, and the pressures that led to the anxiety are thereby eased. Such chemical control of behavior clearly is adaptive and advantageous, at least for wild populations of rats. Is part of our behavior similarly subject to chemical control? The answer is certainly yes. What we do about it is a tougher question. Giving everyone tranquilizers is no answer to the problem; they do not even permanently relieve the symptoms. In a sense things are more difficult when there are quick chemical responses to psychological and social problems, for they can weaken the pressures to find solutions to the real ills. One of the advantages of alcohol over LSD is that the euphoria induced by alcohol is so clearly second-rate and temporary.

In the past our control of our environment has been as haphazard and uncertain as our control of the chemistry of our bodies. The very permanence of the products of chemical technology has brought trouble. So long as we built with materials that were collected rather than synthesized, our debris stood a good chance of blending back into the environment without leaving permanent scars. Wood and cloth will rot, organic matter will be eaten by microorganisms, iron will rust, and glass will shatter and mix with the natural silicates that make up the soil. But aluminum remains intact long after iron has disappeared. Polyethylene and most other plastics will neither break up nor be eaten by microorganisms. Synthetic detergents have created foaming rivers downstream from sewage disposal plants because they cannot be degraded by bacteria in the way that soaps can. It is possible to make biodegradable detergents, but they are more expensive. At what point do we decide that the expense of these biodegradable compounds is less than the damage to the environment in terms of fish killed and streams polluted? And who pays the cost? Do we similarly regulate the use and discarding of inert materials such as aluminum and polyethylene, or do we find microorganisms to eat plastic? (This is a tough assignment. What would polyethylene-eating microorganisms have done in the millions of years before Lavoisier?)

Insecticides such as DDT have proven embarrassingly effective. Their resistance to chemical breakdown is an advantage to the farmer who wants one spraying to last a long time, but a disadvantage to the higher organisms in which the DDT concentration builds up with time to near-lethal or lethal doses. In one marsh on the Long Island shore, where spraying with DDT for mosquito control has been carried out for 20 years, the plankton have accumulated 0.04 parts per million (ppm) of DDT by wet weight. But the clams which eat the plankton have 0.42 ppm of DDT, the minnows have 1.0 ppm, and the sea gulls that eat both clams and minnows have as much as 75.0 ppm of DDT. Another tenfold increase in this concentration of insecticide in the food chain would lead to death, as it has done for smaller birds in some parts of the midwest. The hopes of Great Lakes fishermen that the introduction of Coho salmon from the Pacific Northwest would bring on a renaissance in sport fishing in the area were dimmed when the flesh of one fish was found to have a high DDT concentration because of drainoff from agricultural land around the lakes. No one intended for the sea gulls on Long Island or the Coho salmon in Lake Michigan to accumulate DDT, but the unintended happened. Ironically enough, many pests tend to flourish under such circumstances because they are lower down the food chain and have a shorter lifetime; hence, they do not necessarily accumulate so much insecticide. The higher animals that formerly kept them in check meanwhile die off.

What do we do about DDT? How can we balance the increase in insect-free crop production and the decrease in insect-borne diseases like malaria against the contamination and death of higher animals that keep other pests in check? If we decide to forbid a course of action that offers immediate financial return to a farmer because the ultimate damage to society is greater, do we owe him compensation for our action? If so, who pays? Or do we convince him that no compensation is called for because he had no right to pollute the environment to his own gain in the first place? Such questions are not going to be solved by a panel of scientists, no matter how well informed. But neither can they be solved well by government policymakers, congressmen, or corporation advisory boards whose members are not literate in the field of chemistry. In the past, ignorance, if not bliss, was at least moderately harmless. Now, it can be disastrous. If the choice had to be made for the next generation between teaching chemists chemistry or teaching nonchemists chemistry, we could almost say that the latter course of action would be preferable.

From the preceding statements, chemistry may seem like only a scientific way of managing the planet. But man does not live by carbon dioxide-foamed wheat starch product alone. There is also the satisfaction of knowing what we are, and where we are, and where we came from. How did life evolve from nonliving chemical matter on this planet? How did this chemical matter itself arise? We cannot turn back the clock and watch the process, but we can set up what we believe to be primitive earth conditions and study the reactions that are likely to have taken place. We can see how the raw materials of living systems could have arisen naturally, and why more complex chemical assemblages would have been stable and long-lived. We can understand, in principle, how assemblages so complex that they must be called "living" would have developed. To a limited extent we can check our experimental paleochemistry with the evidence of mineral deposits laid down at various stages of the history of the earth. The apparently inhospitable conditions for life on the moon and possibly on Mars and Venus are disappointing, but they do not eliminate the fundamental question: "Given the proper conditions, is the evolution of life natural and virtually inevitable, or is its appearance on Earth a fortuitous accident?" We can design and carry out experiments which help to answer this question even if only one planet in our solar system were to prove to have the proper conditions.

Even if the moon does not reveal much about life, the chemistry of its rocks will allow us to reconstruct the history of the solar system. The first reports on lunar rock samples show a far higher concentration of high-melting-point metals than in any terrestrial ores. Does this mean that the moon solidified at high temperatures, at which much of the lighter material boiled away and was lost? Does the contrast between earth and moon mean that the moon was a wanderer captured by the earth rather than a daughter formed as the earth was? The answers to such queries will come, in part, from detailed chemical comparisons of the materials of earth and moon. Such efforts will not keep Lake Michigan from being polluted or make it possible for Earth to feed 10,000,000 more people, but they will provide a stretching of the human spirit that our species sorely needs.

Knowing where we came from and how we developed has an effect on how we think about ourselves. The revolution in thought that is sometimes symbolized by Copernicus and Galileo, which removed man from the center of the universe to one of several planets on a rather obscure star, shaped the patterns of thought of the citizens of Europe for generations. Man lives by ideas more than his pragmatist representatives in mid-twentieth century America like to admit. We are now slowly piecing together a new picture of man and his universe that is based on what we are learning in cosmology, astronomy, physics, geochemistry, molecular biochemistry, and behaviorial biology. This new picture of man will be as influential to future generations as the Renaissance picture of man was in its time. Chemistry has much to contribute to this picture of the nature of man and of his origins.

To the question "Why study chemistry?" there is a practical answer and an intangible answer. The practical answer is not the same as that of a generation ago; in part, today's answer is a need to make up for the blunders of the past. But just because the problem is more complicated, it is more interesting. We can begin to see wholes rather than parts, and the organization of a whole is almost always more interesting than the collection of parts. The intangible answer arises from the things that we can know from chemistry that we had no hope of knowing a generation ago: what life is, where it came from, how it operates, what our solar system is like, and how it arose. A man can be overwhelmed by a surfeit of knowledge, but understanding can be a source of strength. For the first time, in chemistry, we are on the verge of understanding.

Ernest Rutherford, in one of his less charitable moments, remarked that there are two kinds of science: physics and stamp collecting. Lavoisier and Dalton's atomic theory brought chemistry one step above stamp collecting. The quantum revolution of the 1920's and 30's set chemistry on the road to becoming a science, and the current studies of the chemistry of life promise to bring the field to the level where Rutherford's partisan figure of speech will have to be revised. Chemistry in the next generation will be fascinating and absorbing both as a participatory and a spectator sport.

Research Notes

The Moon Revealed—I

The moon, says Gerald Wasserburg, professor of geology and geophysics, is 4.6 billion years old, and the lava that flowed out on the surface of the Sea of Tranquillity is one billion years younger. Wasserburg, one of three Caltech principal investigators for Apollo 11 lunar samples, told NASA's first Science Conference on Lunar Materials that if the lava was caused by the bombardment of great meteorites (instead of internal melting and volcanoes), then the earth's surface, too, must have been heavily bombarded by them. This could account for the absence on the earth of a geologic record prior to 3.6 billion years. Wasserburg also told the meeting of Apollo investigators that:

At least the outer 62 miles of the moon have been molten. If the moon originally was a part of the earth and then separated from it, this must have happened in the first 300 million years in the history of the solar system.

Tektites cannot come from the moon.

There are single, individual rocks on the moon's surface that are 4.4 billion years old, which is still 200 million years younger than the age of the moon. These rocks may possibly come from the lunar highlands.

The apparent lunar age (4.6 billion years), said Wasserburg, was determined from analysis of lunar soil, which is the result of mixing of different rocks and of melting. Some of the melting was caused by meteorites, and iron meteorites and glass containing little balls of iron meteorites were found on the lunar surface.

The group's samples included a variety of rocks covering 700 million years of time. A complicated geologic evolution in the formation of different rock bodies must have taken place in the first billion years of the moon's history.

The surface of all rocks and grains of soil are covered with pits as small as 10 microns in diameter, the centers of which are glass surrounded by radial fracture zones caused by bombardment of the lunar surface with tiny, high-velocity dust particles. Wasserburg also said that the solar wind's gasses have peculiar isotopic composition and must be related in some important way to the atmosphere of the earth.

The research was done by a Caltech group (which calls its laboratory the Lunatic Asylum) composed of scientists from the United States, Greece, Spain, Switzerland, Germany, Egypt, and China. Associated with Wasserburg in the work were co-investigators Arden Albee, professor of geology, and Donald Burnett, associate professor of nuclear geochemistry.

The Moon Revealed—II

A second principal investigator—Samuel Epstein, professor of geochemistry—reported that studies of the isotope ratios of oxygen, silicon, hydrogen, and carbon showed that the rocks formed at temperatures (1,150 to 1,340 degrees Centigrade) a little higher than the temperatures at which earth rocks formed.

The bulk of the oxygen and silicon isotope ratios of lunar basalts are identical with terrestrial basalts, but lunar glass, breccia (hardened aggregate of surface debris), and dust are slightly enriched in the heavier isotopes. This suggests either that sublimation-evaporation took place at some high temperature or that there is a source of material enriched in the heavier isotopes of oxygen and silicon elsewhere on the moon.

Epstein and his co-investigator, Hugh Taylor Jr., professor of geology, also found that the lunar dust and breccia contain hydrogen from the solar wind, and this hydrogen is very low in deuterium content (less than one-tenth of terrestrial abundance).

The carbon in the dust and breccia is considerably enriched in carbon-13 and is unlike any reduced natural carbon found on earth or in meteorites. This enriched carbon may come in part from the solar wind or may have resulted from the process involved in formation of the lunar material. Epstein and Taylor say it is unlikely that terrestrial contaminants, such as grease or rocket fuel, were a factor since that source of carbon is low in carbon-13.

The Moon Revealed—III

A third investigator for Apollo 11, Leon T. Silver, professor of geology, told the conference about his studies of the abundances of lead, uranium, and thorium isotopes in the lunar samples. He found that the lunar dust contained radiogenic isotopes Pb-206 and Pb-207 in a ratio which suggested an apparent age of 4.63 billion years—as old as anything measured so far in the solar system. A piece of lunar breccia showed an apparent age of 4.60 billion years. Silver cautioned the conference, however, that these ages may be more apparent than real because the dust and breccias are complex mixtures of rocks, minerals, and glasses of uncertain origin, and the isotopes observed are peculiar composites which cannot be uniquely interpreted at this time.

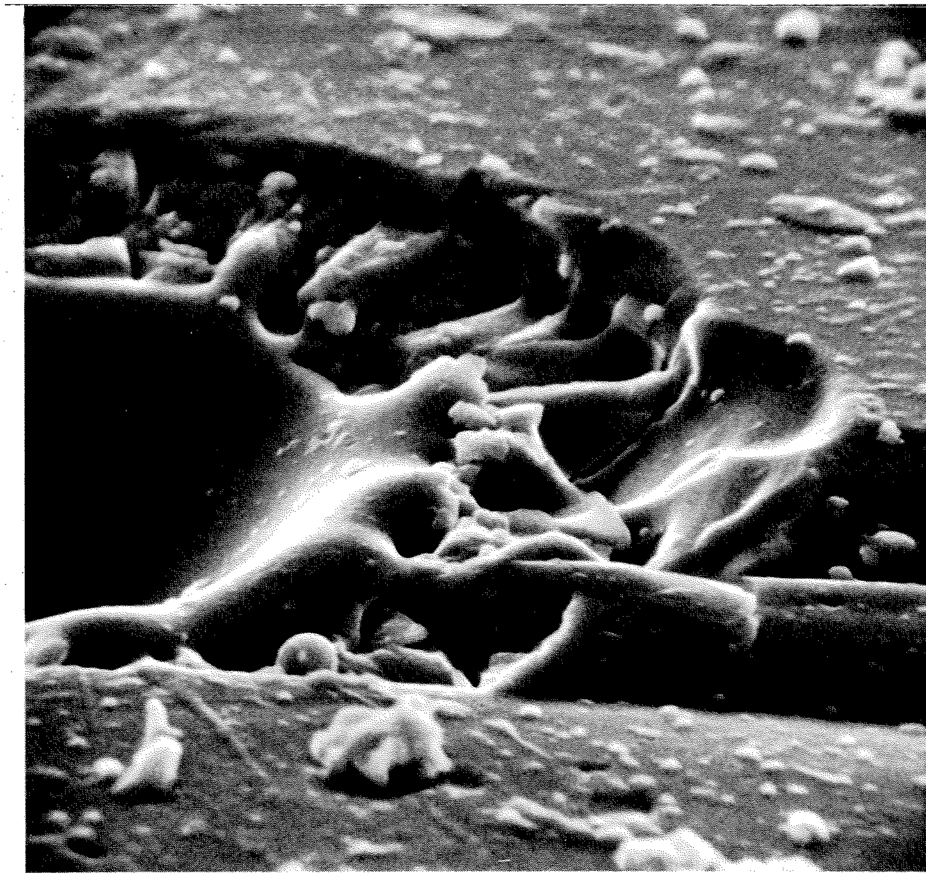
Four fragments of rocks, all from the same site, showed apparent ages between 4.1 and 4.2 billion years. Another investigator, using the same "geologic clock" on a fragment off the same rock as one of Silver's fragments, got almost identical results, but Silver points out that other age-dating techniques give different apparent ages on similar samples, and he doesn't know how to reconcile the discrepancies.

If the four rocks represent sources that have contributed to the dust also, and many data suggest this, then it may be inferred that the dust contains some materials with greater ages than that measured from the dust sample. This would imply an even greater age than 4.63 billion years for some part of the lunar surface.

But Silver, questioning a generally held belief that the moon is 4.5 or 4.6 billion years old, is not convinced that anyone yet knows its exact age. He agrees the moon is ancient—at least 4.2 billion years old—but suspects that all the rocks so far examined came from the same source—just as almost any rocks around Pasadena came, at one time or another, from the disintegrating San Gabriel mountains. The dust, however, shows variations in isotopic ratios that imply a mixed source. Silver wants to see analyses of samples from many other sites, with some independent tests for historical sequence, before he will have confidence in a definitive age of the moon.

The most striking thing he found, and something he thinks is of more interest than the precise age of the samples, is that lead has been separated or fractionated from uranium to a degree never observed in rocks on the earth. This indicates that the lunar processes being studied are very different from modern terrestrial processes, although they may not be so different from processes that occurred early in the evolution of the earth. Studying lunar rocks, says Silver, may be the only way of getting at an understanding of the processes that took place early on the earth.

The mass spectrometer used in Silver's work (called Dulcinea, after Don Quixote's dream girl) was specially built for the moon samples. Ages were determined by measuring the ratios of radioactive materials to their decay products. The "geologic clocks" used were uranium 238 decaying to lead 206, uranium 235 to lead 207, and thorium 232 to lead 208. Assisting Silver in the work were Geraldine Baenteli and Maria Pearson.



Tiny, high-velocity dust particles hitting the moon created pits like this one (magnified about 5,000 times) in the surfaces of lunar materials. The center of the pit is glass.

Place in the Sun

Unlike stellar astronomers, who must search the world for dark, clear skies to peer through, solar astronomers look for bright sunshine and still air. Smoggy Pasadena happens to be a good observing site because the temperature inversion layer that traps smog also results in a relatively non-turbulent atmosphere.

Now astronomers at the Hale Observatories have found an even better location—6,758 feet high in the middle of Big Bear Lake in southern California's San Bernardino Mountains. A new observatory opened there in October, and solar astronomers are already making excellent detailed observations of the sun's structure. Warm air rising from the ground ordinarily causes disturbances in the atmosphere, but at Big Bear the nearly constant daytime temperature of the water surrounding the site makes the air turbulence minimal.

Much of the observing is done with time-lapse movie cameras—invaluable in studying the "metabolism" of the sun as reflected in sunspots, flares, prominences, and shock waves. Exposures are made every five to ten seconds. The telescope barrel actually contains four observing instruments—two for cinematography in different wavelengths; one for a spectrograph to analyze the sun's chemical composition and temperatures; and one for a coronagraph to study the hot region above the sun's surface.

The observatory is 800 feet from shore and includes four acres of land on the lakefront, a three-bedroom dormitory for visiting observers, and a laboratory.

Harold Zirin, Observatories' staff member and Caltech professor of astrophysics, is in charge of research being done at Big Bear. Two observers, an electronics technician, and a machinist work at the site permanently. The equipment was financed by NASA, and the buildings were funded by NSF and the Max C. Fleischmann Foundation of Nevada.

Leukemia and DNA

Although the problems of cancer—its causes and cures—appear to be awaiting advances in the molecular biology of normal cells, the abnormalities of cells are giving researchers new insight into certain types of leukemia. Research by Caltech graduate student David A. Clayton and Jerome Vinograd, professor of chemistry and biology, has disclosed what appears to be a significant link between granulocytic leukemia in humans and an abnormality in the DNA of white blood cells.

The anomaly was found not in the DNA of the nuclei of the white blood cells (where most of the genetic material of the cell is located), but in the mitochondria. These are microscopic structures in the main body (cytoplasm) of the cell that supply the energy for the cell's metabolism.

Normally the mitochondrial DNA is in the form of a small ring five microns in circumference. But Vinograd and Clayton found in the leukemia patients a large percentage of abnormal DNA rings that were of double size (called dimers). The mitochondrial DNA from 14 leukemia patients was studied, and in all instances the double-size DNA rings were found. Significantly, treatment of patients with anti-leukemic drugs substantially lowered the frequency of the circular dimers.

Vinograd and Clayton cannot be sure whether the DNA abnormality is a symptom or a cause of the leukemia. The present state of knowledge about normal cells is not adequate to make possible an immediate understanding of the significance of their finding.

The Month at Caltech

Coed Progress Report

Since Caltech announced that it will admit women undergraduates, the response from young women who want to enroll as freshmen has exceeded all expectations. According to Peter Miller, director of admissions, applications are arriving at the rate of one a day. He expects to have 100 applications by the February 1 deadline. From those the admissions committee hopes to select 20 to 25 fully qualified first-year students. Additional women may be admitted as sophomore and junior transfer students; they have until April 1 to apply.

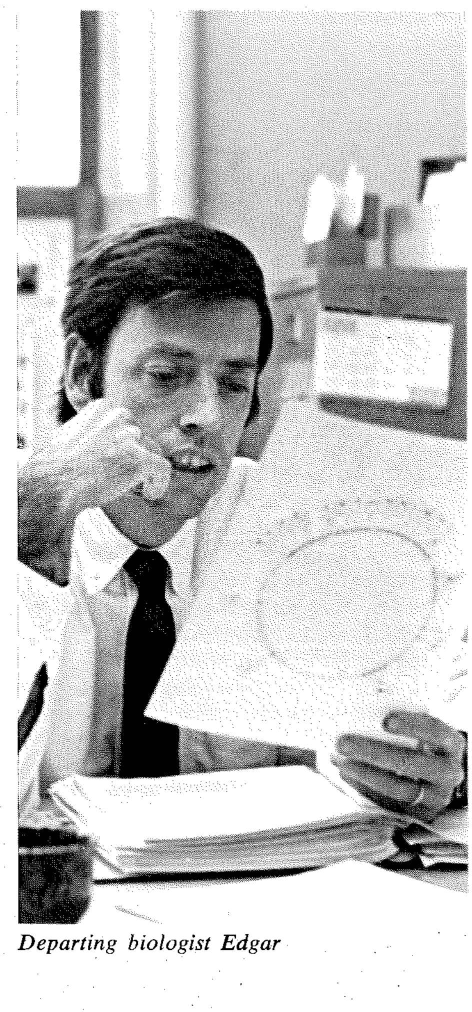
Change of Name

The Mount Wilson and Palomar Observatories are now the Hale Observatories, according to a new plan of joint operation for the Carnegie Institution of Washington and Caltech. The change of name honors George Ellery Hale, founder of both observatories and one of the founders of Caltech, who did more than any other scientist of his day to awaken interest in and find support for science.

Observatories director Horace Babcock also announced the appointment of J. B. Oke, staff member and Caltech professor of astronomy, as associate director of the Observatories. Oke is known for his work on the structure and composition of the universe and for his development of electronic instrumentation.

Observatories associate director Oke

Mathematics executive officer Luxemburg



Departing biologist Edgar

Awards and Appointments

WILHELMUS A. J. LUXEMBURG, professor of mathematics, is the new executive officer for mathematics. Luxemburg, who has been on the Caltech faculty for 11 years, succeeds Marshall Hall Jr. who, after four years as executive officer, wants to devote more time to research in algebra and combinatorial problems concerning arrangements.

A native of the Netherlands, Luxemburg received his undergraduate education at the University of Leiden and his PhD at the Delft Institute of Technology. His main field of mathematics is functional analysis. During the last six years, however, he has spent a great deal of his time developing methods for applying certain techniques of model theory to conventional mathematics, thereby resolving certain paradoxes of the infinitesimal calculus that go back to the discovery of the calculus.

ROBERT EDGAR, professor of biology, left Pasadena on January 1 to become provost of College No. 6 of the University of California at Santa Cruz. A member of the Caltech faculty since 1957, Edgar has made important contributions to understanding the molecular basis of heredity. In 1965 he received the United States Steel Foundation Award in Molecular Biology, given by the National Academy of Sciences, in recognition of this work.

At Santa Cruz, College No. 6 is still unbuilt, unfunded, and unnamed; however, its new provost hopes it can start operations soon, even if classes have to be held in a dormitory.

The University of California at Santa Cruz is organized as a cluster of self-contained colleges, each with all the regular academic departments and, theoretically at least, each with a special orientation. College No. 6 will have a science "flavor"—to be implemented, Edgar hopes, by focusing on some area of general interest that will promote interdisciplinary activities and consequent interaction among all the faculty. One possibility he is currently considering is that of environmental studies.

Because he is interested in upgrading both the teaching and the learning process, Edgar also hopes that the faculty and student body of College No. 6 will be willing to experiment with applying behavioral science techniques to teaching and to their relationships with each other. He believes that much of the current student dissatisfaction stems from an academic atmosphere devoid of both feeling and action. "We faculty project a pretty unsatisfactory set of values," he says. "I'm looking for a program that will excite the faculty to teach what they want to teach rather than what they think students ought to learn. Maybe in the process we can validate authenticity in both scholarship and relationships."

WILLIAM H. CORCORAN, vice president for institute relations and professor of chemical engineering at Caltech, has won the $500 Western Electric Fund Award of the American Society for Engineering Education for excellence in the instruction of engineering students.

At Caltech, Corcoran has developed one course based on the design of artificial kidneys, and another that includes the social and economic aspects of chemical engineering. His two books are widely used in chemical engineering, and he has developed laboratory techniques that are useful in teaching the subject.

WHEELER J. NORTH, professor of environmental health engineering, was appointed in December by Governor Reagan to the State of California's Advisory Commission on Marine and Coastal Resources. An authority on marine biology and the author of several books on that subject, he serves as a consultant to the city of San Francisco and to the National Science Foundation.

Trustee No. 43

Benjamin F. Biaggini, president, chief executive officer, and director of the Southern Pacific Company, has been elected to Caltech's board of trustees. He becomes the 43rd member.

Biaggini has been associated with the Southern Pacific railroad for more than 33 years, starting as a surveyor's assistant at Ennis, Texas. He spent several years in engineering work before he was made vice president for Southern Pacific Lines in Texas and Louisiana in 1955. He became vice president of the company, with headquarters in San Francisco, in 1956; executive vice president in 1963; president in 1964; and also chief executive officer in 1968. Biaggini was born in New Orleans and was graduated magna cum laude from St. Mary's University of Texas in 1936.

Leader of America

The Caltech YMCA's Leaders of America program has been reactivated after several years in hibernation. The first visitor this year was California Assembly Minority Leader Jess Unruh on November 25 and 26.

The Leaders program was begun in 1955 with money provided in the estate of Robert Millikan. It brings important and stimulating people to campus for two or three days of mostly informal discussion with students and faculty. But in recent years the nation's increasingly affluent students have booked speakers in such numbers that the demand has far outstripped the supply—in spite of the hundreds of people now on the academic lecture circuit. The honorarium the YMCA used to provide for three days is now the going rate for a 45-minute lecture and sherry session afterwards.

Politicians, however, don't expect to be paid to talk. And although they don't usually spend much time at any one speaking engagement, Unruh stayed on campus for two days. While he did give two public addresses, he spent the greater part of his time just listening to Caltech faculty talking about the kinds of problems they thought a politician should know about.

The topics discussed centered on priorities in science and how to provide support for the future, on problems of environmental degradation and how they might be approached technologically, and on progress and predictions for relief of poverty.

When Unruh announced shortly after his Caltech stay that he would run for governor of California in 1970, at least 16 Caltech faculty members had the unusual satisfaction of knowing that a major candidate was aware of their opinions on subjects of deep concern to them. It is, after all, a rare occasion when a politician comes to the campus seeking guidance. Even so, the YMCA invited two other likely candidates for governor of California—Governor Ronald Reagan and San Francisco Mayor Joseph Alioto—to participate in similar programs. Reagan has said he would like to and will do so if he can work it into his schedule; Alioto has since decided not to run.

Letters

EDITOR:

This is a very subjective analysis of an extraordinary event in which I recently participated. My feeling is that an insider's view will interest my fellow alumni.

I decided to become a marshal for the November 15 March on Washington because of my belief that widespread violence during the activities would completely discredit the peace movement in this country. Wanting the United States to leave Vietnam promptly, I hold that continual, peaceful protest will hasten a withdrawal.

On the eve of the parade, I walked to the White House to see the March Against Death, the 40-hour procession of 40,000 people carrying the names of war dead from Arlington National Cemetery to the Capitol. In sharp contrast to this civilian demonstration were the army convoys that patrolled the streets near the President's residence.

The 200 marshals who had volunteered for the "front wedge" met at 8 a.m. on Saturday, just southeast of the Capitol. (Only six-footers were asked to join this group; I cheated by one quarter inch.) The chief marshal of the parade gave us our instructions—to protect the dignitaries and keep the procession moving.

Midmorning found thousands of people already gathered at the parade staging area on the Mall. March leaders distributed huge placards, enabling members of various interest groups to walk together. Banners reading "Trade Unionists," "Nationality Groups," and "New York City" suggested that the organizers had yielded to great American political traditions. Senator Eugene McCarthy (Minn.) then spoke to the throng, and the paraders began moving toward Pennsylvania Avenue. The front wedge led the way.

We eventually reached the grounds of the Washington Monument, where food, drink, and toilets were available. The marshals formed a locked-arm wall three people deep around the stage area as the site filled with thousands of people. Those who brought food and those who bought food shared it; I remember taking a bite from three different sandwiches and an apple, and taking one swig from a gallon of California wine. Several people bought entire cartons of apples from the concessionaires and proceeded to throw the apples into the crowd. In this wonderful spirit of community the rally began.

Reverend William Sloan Coffin, Dr. Benjamin Spock, Senators Charles Goodell (N.Y.) and George McGovern (S.D.), and Mrs. Coretta King spoke to the multitude, but the feelings of the day swelled forth with the singing of Arlo Guthrie and Pete Seeger. The message to the President was in Seeger's refrain:

All we are saying is,
Give peace a chance.

There were angry people at the Mall too. About 1,000 ralliers were militant, and many of them bore North Vietnamese or Vietcong flags and wore crash helmets and gas masks. They shouted at the speakers, were respectful of nobody, and threatened to penetrate the lines of marshals. (They could not though because the crowd was too dense.) What they did achieve was photographic exposure. This thousand in the multitude looked ludicrous in battle dress, and we know that they spoiled an otherwise peaceful day by their confrontation with the police at the Justice Department after the rally was officially over. The police, to be sure, were superb.

One person in the throng was angrier than any of the more obvious militants. He carried a sign which read: "Hitler Too Had A Silent Majority."

Minutes were hours to the marshals who had been outside since early morning and on their feet most of that time (as the police had been). The speeches seemed interminable. As sunset approached, however, four members of the Cleveland Orchestra played a Beethoven string quartet, and finally the cast of the play *Hair* led the crowd in 15 minutes of dancing in place to the joyous strains of "Let the Sun Shine."

The emotions of the day did not subside quickly, but fatigue overwhelmed them. My lasting hope is that the depth of feeling expressed by so many will hasten the end of United States military participation in Vietnam.

Today I received a letter from the fellow Caltech graduate with whom I shared a room during our first week in Pasadena six years ago. A week ago he killed at least three people on trails in Vietnam. He closed his letter not with the usual "Peace," but with "Peace, how hollow it rings after today."

LES FISHBONE '68
College Park, Maryland
November 17, 1969

This letter, received by Hallett Smith, chairman of the division of humanities and social sciences, is a rare enough communication that E&S is printing it for other readers as well—with the permission of the writer (whose name we have withheld).

DEAR DR. SMITH:

You probably don't remember me, but I met you a couple of times while taking some humanities courses leading to my BSEE degree of 1963. And because you were head of the humanities department while I was attending Caltech, this letter is being written to you.

I will start off by saying that this letter is very difficult for me to write because it concerns my behavior at Caltech, of which I am not at all proud. During my time at the school I didn't write many of the papers assigned to me for humanities classes. At that time I made the age-old mistake of rationalizing that this wrong was right because I had to complete a goal—my degree in engineering. I won't say who did my "ghost" writing, but just that it wasn't a fellow student or anyone connected with Caltech. It was a person who saw that I was undergoing a great deal of emotional stress and probably knew that I wouldn't last without some help.

I'm sure that you have encountered more students than you like to remember who have thought the humanities a waste of time in a science-oriented institution. During my time at Caltech I felt the same too. However, these few years since graduation have taught me that an all-science-oriented education is totally lopsided and can only result in an individual insensitive to human responses and interrelationships. A scientist or engineer is not truly complete without this awareness.

What I am saying is that the humanities deserved just as much devotion to study as my science courses did. Just telling myself that even though I did all the tests in the sciences and humanities honestly (except maybe taking a little longer on some tests than allowed) doesn't justify in my mind that I wasn't guilty of breaking the honor system.

Many reasons could be given, I guess, to say that I had just cause to bend the rules a little for a necessary end. But the end doesn't justify the means, for if I believed otherwise I wouldn't be writing this letter.

A personal evaluation might be that the entering of Caltech and the temporary modification of my beliefs and ethics was a manifestation of Peter's Principle —namely, rising to the level of my incompetency. I entered Caltech from a junior college (where I was doing very well) and in due course became almost emotionally "poleaxed" from the extreme work load and separation from home. In time this "percussive sublimation" seemed to erode away my feelings of personal achievement and identification brought in from the other school. But I'm sure my story is not unique, particularly in view of the statistic that one out of four fail or drop out before reaching the end of the fourth year.

This letter is not written with the hint to ease the Caltech workload, but to keep it tough. My personality problems at that time are no reason that the school curriculum should be changed. Either you survive or you don't. I look back and see that the experience made me mature very fast, but not without the aforementioned growing pains.

You may think that this letter is very strange to send after so many years out of school. Possibly so, but it means a great deal to me, for if I didn't believe that the previous mentioned change in my beliefs and ethics was temporary I couldn't write this letter. The fact that I have written it tells me that I still can admit an error in judgment and behavior.

My basic reason for writing is to admit a past wrong against the Caltech honor system. Furthermore, I want to reaffirm the Caltech policy of heavy humanities. For I can look back at my time at Caltech and see that those courses have done much to shape my thinking. I wish that I had taken the humanities more seriously then instead of viewing them as a "necessary evil."

I will finish by saying that if you have ever asked the question, "Am I getting through to those science-oriented students?," take it from me that you did get to this one.

NAME WITHHELD

Books

ALFRED NOBEL,
THE LONELIEST MILLIONAIRE

By Michael Evlanoff and Marjorie Fluor
The Ward Ritchie Press........$10.00

Reviewed by Dr. Judith Goodstein, Institute Archivist.

This book about Alfred Nobel and prizes that bear his name adds little to our fund of understanding about science or its impact on society. Authors Evlanoff and Fluor explore briefly Nobel's career as an inventor of explosives, including dynamite and blasting gelatin; there are also chapters dealing with Nobel's family-tree; thumbnail sketches of several prize winners; and Evlanoff's reminiscences of life in the Caucasus, working for Alfred Nobel's nephew, Emmanuel. Scant attention is paid to the development of his scientific thinking, his changing ideas about peace movements and disarmament conferences, or how he came to the idea of setting up annual awards to honor those making the "greatest services to mankind" in the fields of physics, chemistry, physiology and medicine, literature, and the cause of peace.

DISCOVERY, INVENTION, RESEARCH
THROUGH THE MORPHOLOGICAL APPROACH

By Fritz Zwicky
The Macmillan Company $6.95

Solutions to our scientific, technical, and social problems can be found in the study of the structural interrelationships that exist among all ideas, objects, concepts, and phenomena, according to this book on the advantages of morphological research and planning. The problems of designing a telescope, an automobile, a power plant, and a possible model of the universe, are among the suggested instances in which integrated engineering, collaboration between the sciences and the humanities, and an evaluation of available human resources might yield the most objective and efficient methods of problem-solving. Zwicky, professor of astrophysics emeritus at Caltech, hopes, in time, to subject all types of problems to such analyses "in order to find the most reliable ways to successfully plan and construct a unified and organically sound world."

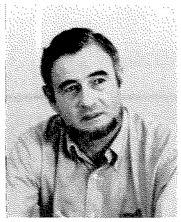
A HISTORY OF EAST AND CENTRAL AFRICA
TO THE LATE NINETEENTH CENTURY

By Basil Davidson
Anchor Books.................$1.95

Beginning with the early African Stone Age this history follows the growth and expansion of the indigenous East and Central African civilizations through periods of migration, settlement, European colonization, and the final emergence at the close of the last century of some modern nation-states. Basing his writing on the most recent archaeological findings and an extensive background knowledge, the author presents a fresh approach to understanding the current political, economic, and cultural circumstances of the central and eastern regions through a cohesive and penetrating examination of the African past.

Basil Davidson, visiting lecturer in African studies at Caltech, gave the November 24 Beckman Lecture, "The African Heritage of the American Black Man." Among his other books on related subjects are: *The African Genius: An Introduction to African Cultural History,* and *A History of West Africa.*

The Brain of Pooh



Continued from page 13

vertebrates have no color vision at all. By changing their genetic program an entire new sense has been added. We might be able to build chemical switches into various sectors of consciousness so that pain specifically could be turned off for surgery or a widened sense of taste or color turned on for enjoyment.

Conceivably new receptors—for electric fields or radio waves, for ionizing radiation or what have you—could be developed to go with new modalities of consciousness.

Whatever may be the basis of conscious thought, it is clear that much of the operation of the brain cannot be brought to consciousness; it is, somehow, inaccessible or screened. There is very likely much merit in the automation of many activities. Yet, as we know, conflicts and distortions on the subconscious level can produce grave disturbances of the psyche and are most difficult to detect and analyze. If more of the unconscious could be made at least selectively accessible, it could be a very considerable boon.

Of course one of the major distinctions of man is his ability to communicate, particularly through speech. Remarkable as this capacity is, it must be recognized that it is a limited device.

There are very real limitations of language and communication. Can we truly express everything we experience or conceive in speech? There are problems of precision, of connotation, and of association. We frequently have to coin new words for new concepts, and still it is difficult to convey their meanings to others, The expression of feelings and emotions is particularly difficult and seems to interweave several dimensions of emotionality. One can sum up a whole complex of emotions by an analogy (such as an Oedipus complex or a messianic complex) which is extremely hard to decompose analytically in words.

The average person is said to know some 20,000 to 60,000 basic words (dependent somewhat upon the definition of "know") and perhaps 100,000 derivatives of these. In ordinary speech he uses 2 to 3,000 basic words; in ordinary writing, maybe 10,000. (This difference between stored information and effective information is curious. It is of interest that there is a similar difference between the over-all sensory input—2 to 3,000,000 fibers—and the over-all motor output—about 350,000 fibers in man.)

The rate of direct communication is typically about 150 words per minute. These it may be estimated contain at most 2,000 bits of information. Of course that depends a little upon the speaker.

Speech is probably genetically one of the newest of nature's inventions and obviously one of major importance for the development of inter-individual communication, the consequent development both of group behavior and properties, and the transmission of knowledge and culture from one generation to the next. Yet there is no reason to believe this relatively recent innovation is perfected. Indeed, as we have indicated, there is good reason to believe speech is a very imperfect device for communication.

If we could manage a significant improvement in the potential precision and speed of our vocal communication, this could be of major consequence. We could, for instance, use many more of the potential phonemes and thereby markedly increase the potential information density.

I think it is interesting that our friend Pooh, although of little brain, used language with considerable precision and economy—as in the time he was hanging onto a balloon suspended in the air and, wanting down, he asked Christopher to shoot the balloon. So Christopher aimed very carefully and fired.

> *"Ow!"* said Pooh.
> "Did I miss?" Christopher asked.
> "You didn't exactly *miss,*" said Pooh, "but you missed the *balloon.*"

One well-known indicator of the limitations of our capacity for speech is our frequent inability to bring to mind the right word for an object or a person or a concept. Pooh also suffered from this all-too-human failing—as when Christopher says:

> "What do you like doing best in the world, Pooh?"
> "Well," said Pooh, "what I like best—" and then he had to stop and think. Because although Eating Honey *was* a very good thing to do, there was a moment just before you began to eat it which was better than when you were, but he didn't know what it was called.

I am of course assuming here that our command of language and indeed the structure of language, whatever language it is, are at least in large part a consequence of genetically determined neuronal structure. I think this is very reasonable. And along these lines I would like to return to the concept I developed earlier—that we can learn to do certain things rather easily because, in effect, approximate programs for these operations are built in.

Could we not extend this? Could we not build in through the proper circuitry certain packets of knowledge so that every generation need not learn these anew, such as a language, or a periodic table, the Krebs cycle, etc. Migratory birds evidently have genetic programs that enable them to recognize stellar constellations. Other birds innately recognize rather complex songs. It does not seem inconceivable.

This is only an extension, although certainly in another dimension, of the wise ideal so well expressed by Whitehead, who wrote: "It is a profoundly erroneous truism—that we should cultivate the habit of thinking what we are doing. The precise opposite is the case. Civilization advances by extending the number of important operations which we can perform without thinking about them."

Statistically at least it is clear that there are changes in the human brain with aging. There are times of optimum ease of learning such matters as language or mathematics. There are optimum periods for creative work, and these seem to differ in the different sciences. In early childhood there are critical periods for mastering certain skills, and if these are past, the effect may well be nearly irreversible. Also we know there are at various times in life irreversible hormonal influences on parts of the brain. We know the number of cells in the brain does not increase after six months or a year of age and, indeed, decreases after 30 to 40 years of age.

If we understood these matters, we could perhaps control these factors. We might keep open and extend critical

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periods of learning. We might learn to reverse untoward hormonal effects or even to increase the number of brain cells and thus permit continued increase of information and counteract senility.

Matters of learning clearly involve the intake of information and the storage of memory. We do not understand these matters well. Numerous studies of varied design indicate that the rate at which we can abstract information from our sensory presentation—visual, for example—is highly limited by a narrow channel capacity. Various studies have been made and, despite some variation of interpretation, there seems to be a general agreement that while some 40 to 50 bits of information may be taken in visually in a flash and held for somewhat less than a second, at the most 10 bits of information per second can be abstracted from a presentation and used to control an output or relayed to a memory bank.

This channel capacity is certainly a major parameter in the determination of the speed and quality of the working of the brain.

The limited capacity of the brain to abstract information from a visual display underlies the McLuhan fallacy and explains why people still read books. Could this rate of information-handling be markedly increased? If so, we could enter the McLuhan era.

Further, it seems likely that the limitation upon the bits of information we can process at one time is related to a deeper question. How many data can we hold in our mind at one time, how many can we bring to bear upon a particular conceptual problem? Surely this is limited, and this in turn restricts our ability to cope with problems of great complexity except by over-abstraction and over-simplification. Conceivably we might be able to increase this quantity.

Now, of course, it is easy to list various qualities and suggest independently improving this or that one. But properly one needs to consider and needs to be able to consider the effect of changing any one facet of intellectual performance upon an individual's whole personality. Personality is like a network with more-or-less-balanced tensions and strains; modification anywhere can affect the whole. Consider what one might first think to be a purely mechanical element such as memory. Upon reflection, memory is easily seen to be a central element in the whole cerebral process. With a little reflection I think it becomes obvious that the quality of memory, its extent, its rapidity, its precision and acuity must influence the whole life pattern through our perception of and response to any situation.

We know all too little about memory. It has become known that there is a short-term memory for the relatively brief storage (on the order of seconds) of information, and a longer term, more enduring memory, of a qualitatively different nature. I suspect that we do not yet begin fully to grasp the significance and function of these distinct memories. As we learn more about the roles of these separate memory systems, we may find that the existence of erasable short-term memory provides an essential gap that permits a distinction between our internal and external worlds. It provides a transient recording that permits us to respond to the immediate yet not to be constantly overwhelmed by the immediate, so we may select from it the important and the general. Without such a buffer we could not plan, we could not withdraw sufficiently from immediate reality.

It is even possible that our sense of time and of time passing is related to the rate of decay of our short-term memory. In our subconscious and in our internal world there is little sense of time. A past event can seem as real as the present. Drugs which affect our sense of time may do so through their effects upon these processes.

If these speculations have any validity, then the ability to alter physiologically or genetically the rates and extent of these processes of memory could have profound effects upon our perception of the world.

I might insert at this point that to a biochemist one of the major impediments to research upon many of these questions is the existence of the so-called blood-brain barrier. This is a poorly understood physiological mechanism that stringently restricts the transport of foreign substances into the central nervous system. Presumably this was designed to provide a specific neuronal environment and to protect the brain against physiological vicissitudes and not just to frustrate biochemists. But certainly one major contribution that genetics could

> "The limited capacity of the brain to abstract information from a visual display underlies the McLuhan fallacy and explains why people still read books."

make would be to alter this barrier—optimally, perhaps, by incorporation of some biochemical switch whereby it could be opened or closed so as to permit biochemical investigation.

Another and different approach to the potentials inherent in further development of the brain is by a consideration of the attributes of individuals with special gifts of one character or another. It is clear that, presumably by genetic circumstance, individuals arise with marked asymmetries of talents. It is also clear that in accord with the concept of interdependence of various cerebral functions the hypertrophy of one talent is often accompanied by major, even disastrous, consequences to others, although we are at present unable to trace the causal connections.

The so-called idiot savants who have a general mental age of two or three years but can, with great rapidity, perform extraordinary numerical feats are an extreme example. One of these, given the series 2, 4, 16, immediately continued to square each successive number into the billions. Similarly, given the numbers 9-3, 16-4, he proceeded to do square roots of numbers into 3 and 4 digits.

Another class of feeble-minded individuals is known with extraordinary talents of mimicry.

Of a less drastic and more desirable nature are the special talents we associate with musical genius, such as a Mozart who composed significant works at the age of four, or artistic genius, or literary genius, or extraordinary skill at chess. There are individuals who are extraordinarily articulate; there are others with extraordinary ability in three-dimensional visualization and spatial orientation far beyond the corresponding talents of normal people.

The capacities of these individuals indicate levels of achievement that could become commonplace, beside which we may feel like Pooh who was somewhat weak in this matter of spatial orientation and symmetry.

"I *think* it's more to the right," said Piglet nervously. "What do *you* think, Pooh?"

Pooh looked at his two paws. He knew that one of them was the right, and knew that when you had decided which one of them was the right, then the other one was the left, but he could never remember how to begin.

"Well," he said slowly—

A particular case of an extraordinary development of the faculty of memory has recently been described in considerable detail by A. R. Luria in the book *The Mind of a Mnemonist.* This analysis is of particular interest because Luria is especially concerned not only with this unusual mnemonic talent but with its consequence for the whole personality of the man who had it.

This man's memory in truth could not be saturated and was apparently imperishable. He could quickly, in two or three minutes, learn a table of 50 numbers or a list of 70 words which he could then repeat or just as easily present in reverse order, or, if given an intermediate word, go forward or back from this. He memorized a nonsensical formula

$$N \cdot \sqrt{d^2 \times \frac{85}{vx}} \cdot \sqrt[3]{\frac{276^2 \cdot 86x}{n^2v \cdot \pi 264}}\; n^2b = sv\, \frac{1624}{32^2} \cdot r^2s$$

in a few minutes, and when asked 15 years later, without warning and with no intervening exposure, he was able to reproduce the earlier test situation and the formula without error. He literally never forgot or lost anything once committed to memory.

Indeed this was a problem for him as a professional mnemonist. He would give several performances in an evening, quickly memorizing, for example, tables of numbers that persons from the audience would write on a blackboard. But since it was the same blackboard in each performance, he could see in his memory all the earlier tables as well as the present one he was supposed to reproduce and would become confused. He claimed that at one time he tried writing things down he did *not* want to remember. He thought that if he wrote them down he would know he did not have to fix it in his memory, but this did not work. Ultimately he claimed he developed an ability willfully not to remember.

As Jerome Bruner suggests in his foreword to this book, it is as though the metabolism responsible for short-term memory was defective in this man and everything experienced was transferred into the long-term memory.

This man's world was one of intense visual imagery. He was never able to develop and grasp or project ideas and generalities. He was, in effect, overwhelmed by an endlessly increasing store of perceptions.

As another corollary, the man had significant difficulty in distinguishing between the internal and the external world. He had great difficulty in planning. He could not withdraw enough from the immediate reality. Furthermore, his sense of time was often faulty. For this man the past was as real as the present. He had no childhood amnesia and seemingly could remember impressions to very early childhood.

This man was also remarkable in another way. He had a strong synesthesia. As I have pointed out, to most of us our senses are quite distinct. Sight, sound, taste, smell, touch, pain are all uniquely stimulated, except when under the influence of certain drugs which appear to facilitate sensory interaction. In this man almost all the senses seemed fused. Every sound also had an image in color, often a taste and a touch and a smell as well. (It is conceivable that this effect is also related to a short-term memory defect. The persistence of a sensory input may permit it to spread and involve other perceptual centers.) He said, "I recognize a word not only by the images it evokes but by a complex of feelings the image arouses. It is not a matter of vision or hearing but some over-all sense I get. Usually I experience a word's taste and weight, and I don't have to make an effort to remember it. But it is difficult to describe. What I sense is something oily slipping through my hand. Or I am aware of a slight tickling in my left hand caused by a mass of tiny lightweight points. When that happens I simply remember without having to make the attempt." "Even when I listen to works of music I feel the taste of them on my tongue. If I can't, I don't understand the music. This means I have to experience not only abstract ideas but even music through a physical sense of taste."

I think it is obvious that for such a person the world would be a very different place than it is for us.

His strongest reaction was imagery. He lived very much in a world of images. Obviously this could create very serious problems. For some words, for example, the images the sound of a word created would fit its meaning, but for others there would be a conflict and confusion. Many words we know have multiple meanings (fast, for example). This

"We are the victims of a variety of emotional anachronisms, of internal drives no doubt essential to our survival in a primitive past, but quite unnecessary and undesirable in a civilized state."

created great difficulty for him. He could not comprehend metaphors at all.

"Take the word nothing. I read it and thought it must be very profound. I thought it would be best to call nothing something. I *see* this nothing and it is something. If I am to understand any meaning that is fairly deep I have to get an image of it right away. So I turned to my wife and asked her what nothing meant. But it was so clear to her that she simply said nothing means there is nothing. I understand it differently. I saw this nothing and thought she must be wrong. If nothing can appear to a person then it means it is something. That's where the trouble comes in."

It's interesting that Pooh had the same difficulty with abstractions—as when Christopher says:

> ". . . what I like *doing* best is Nothing."
>
> "How do you do Nothing?" asked Pooh, after he had wondered for a long time.
>
> "Well, it's when people call out at you just as you're going off to do it, What are you going to do, Christopher Robin, and you say, Oh, nothing, and then you go and do it."
>
> "Oh, I see," said Pooh.
>
> "This is a nothing sort of thing that we're doing now."
>
> "Oh, I see," said Pooh again.

There is one other aspect of this man's unusual mental and psychical structure that should be mentioned. His poor distinction between external and internal reality was perhaps reinforced by an extraordinary control over his autonomic functions. He could increase his pulse rate from 70 to 100 by imagining he was running and then reduce it to 64 by imagining he was lying quietly in bed. He could raise the temperature of his right hand by two degrees and then later lower that of his left hand by one degree. How did he do this? He said, "There is nothing to be amazed at. I saw myself put my right hand on a stove. Oh, it was so hot. So naturally the temperature of my hand increased. But I was holding a piece of ice in my left hand. I could see it there and began to squeeze it and of course my hand got colder."

He claimed also to be able to alter his sensitivity to pain at will. "Let's say I'm going to the dentist. You know how pleasant it is to sit there and let him drill your teeth. I used to be afraid to go but now it's all so simple. I sit there and when the pain starts I feel it. It's a tiny orange-red thread. I'm upset because I know that if this keeps up the thread will widen until it turns into a dense mass. So I cut the thread, make it smaller and smaller until it's just a tiny point and the pain disappears." It was demonstrated that he could vary his eye adaptation by imagining himself to be in rooms of varying levels of illumination.

His strange memory and his synesthetic experience created in this man a critical difficulty in distinguishing between the world of his imagination and the external world. Lacking a clear distinction, such as we know is observed in certain drug states, his fantasies could be as real or more real to him than the external world. "This was a habit I had for quite some time. Perhaps even now I still do it. I look at a clock and for a long while continue to see the hands fixed just as they were and not realize time had passed. That's why I'm often late."

All of which may bear importantly on the major question of how we make this critical distinction between internal and external.

I have gone into detail because this individual provides such a powerful illustration of the interlocking and interdependent character of our various mental and psychological attributes, and thus of the extensive consequences of what are undoubtedly a few strategically placed genetic alterations. Conceivably, they might amount to little more than an altered metabolism leading to the localized endogenous synthesis of an unusual substance with certain LSD-like properties.

I have thus far been principally concerned with the more cerebral and operational aspects of central nervous system function. Another most important field for genetic intervention is our motivational and emotional states.

It seems all too clear to me that we are the victims of a variety of emotional anachronisms, of internal drives no doubt essential to our survival in a primitive past, but quite unnecessary and undesirable in a civilized state.

We have surely more than we need in aggression. Could we not lower aggressiveness, bearing in mind that we must be on guard for possible corollary consequences?

Pessimism and depression are perhaps necessary in a world that merits suspicion, but their exaggeration has little merit. This is illustrated splendidly in the Pooh stories, where Eeyore, the donkey, one of Pooh's friends, is the embodiment of depression. One day

"So much of what we see is in truth what we conceive."

Drawing by W. Steig; © 1968 The *New Yorker Magazine*, Inc.

The Brain Of Pooh . . . *continued*

Eeyore finds his tail is missing.

"You must have left it somewhere," said Winnie-the-Pooh.
"Somebody must have taken it," said Eeyore. "How Like Them," he added.

But in a hopefully more humane world such qualities might be of little use.

We will undoubedly continue to have need of compassion. There is in the Pooh stories another episode in which after a period of intense rain and general flooding of the premises Edward Bear and Christopher Robin are impelled to rescue their close friend Piglet, who is stranded on a tree branch not much above the rising water. But how to accomplish this? After both are stumped for some time, Pooh has an idea which certainly far exceeds his normal cortical limitations. He suggests that they invert Christopher Robin's umbrella and use it as a boat. Christopher is so awed by this unexpectedly brilliant and, I might add, successful invention that he later names this worthy craft *The Brain of Pooh.*

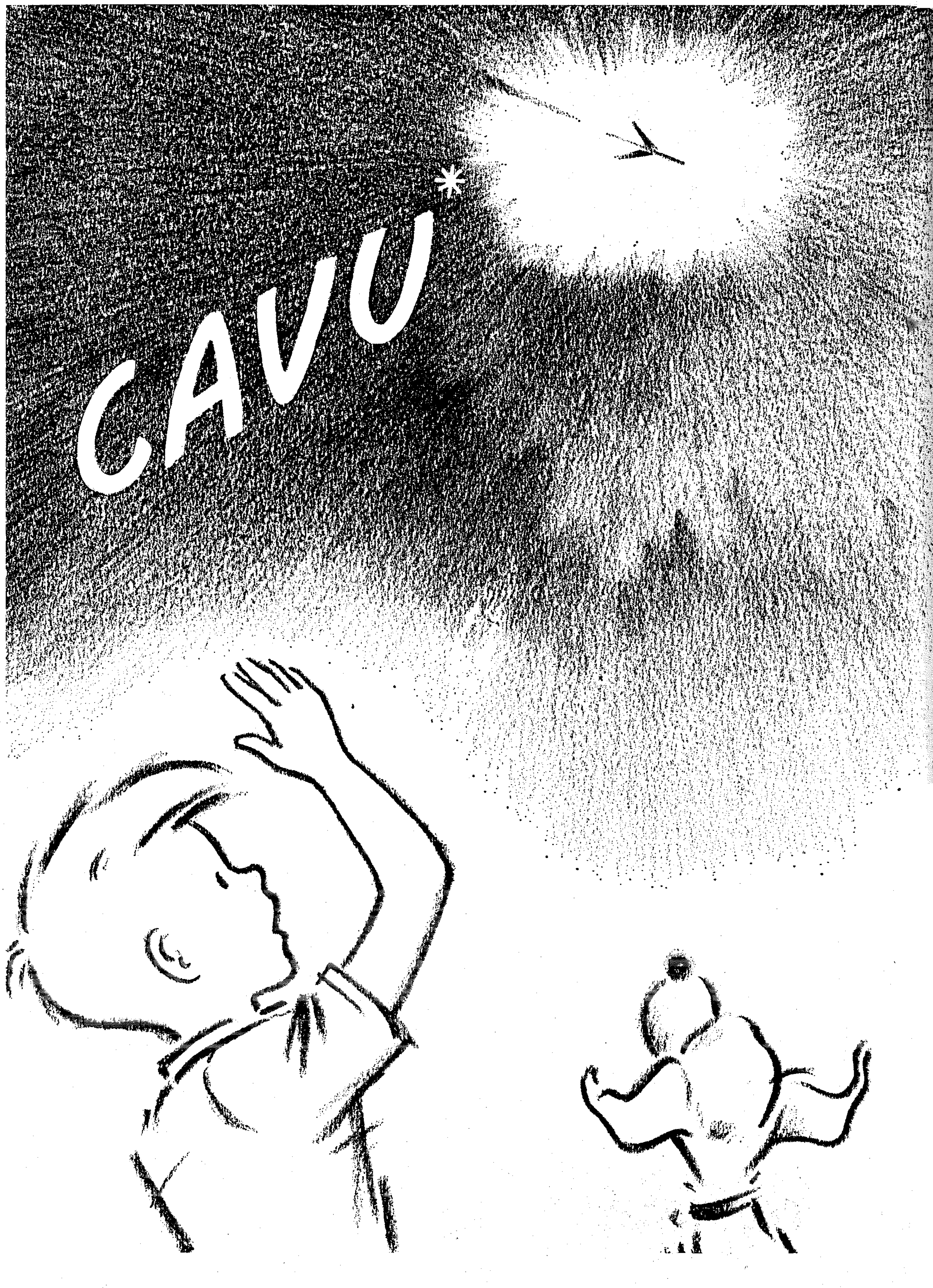
I like to think that driven by necessity or even better by compassion we too will learn to exceed our normal cortical limitations and we too may tap talents yet unseen.

So much of what we see, so much of what we perceive, so much of what we experience is in truth what we conceive. It is contributed by the mind of the beholder and thus must depend in detail upon the innate structures and functions of the mind, upon its accumulated experiences, upon its physiological state, and even in a regenerative manner upon how the mind conceives of itself. And our view of the mind, even the very concept that we may at some future time be able to augment and improve our capacities, may react upon our behavior long before we achieve these visions.

For a number of the most strategic and salient structural elements of the mind there is already evidence of significant genetic determination. These genetic factors, and they may not be so many in number, define our intellectual and conceptual limits. I propose that through phylogenetic studies and through studies of the rare human genetic variants we can learn much concerning their basic cerebral components, in preparation for the day when we wish to begin to move back their limits.

And so perhaps, when we've mutated the genes and integrated the neurons and refined the biochemistry, our descendants will come to see us rather as we see Pooh: frail and slow in logic, weak in memory and pale in abstraction, but usually warm-hearted, generally compassionate, and on occasion possessed of innate common sense and uncommon perception—as when Pooh and Piglet walked home thoughtfully together in the golden evening, and for a long time they were silent.

"When you wake in the morning, Pooh," said Piglet at last, "what's the first thing you say to yourself?"
"What's for breakfast?" said Pooh. "What do *you* say, Piglet?"
"I say, I wonder what's going to happen exciting *today*?" said Piglet.
Pooh nodded thoughtfully.
"It's the same thing," he said.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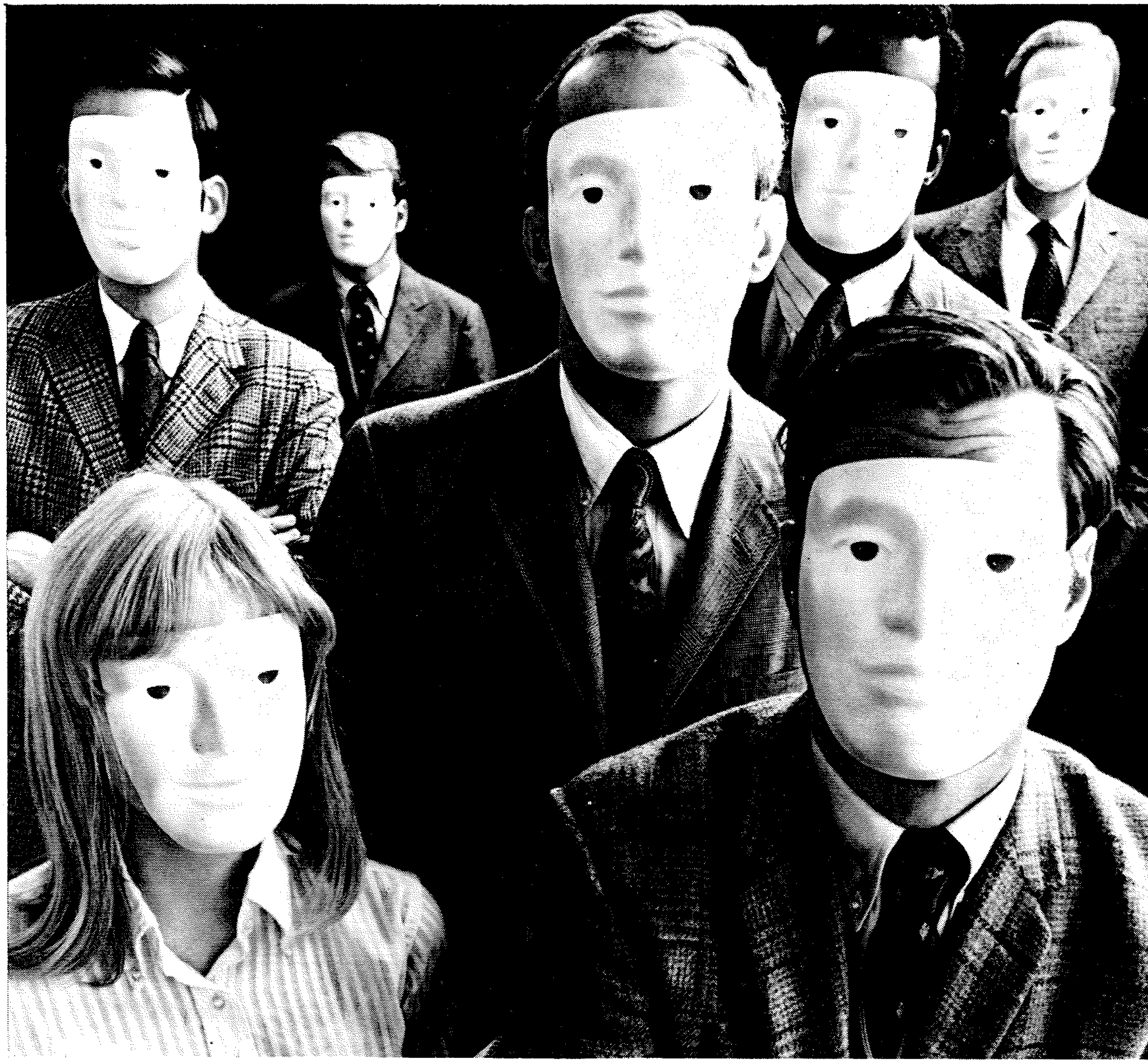

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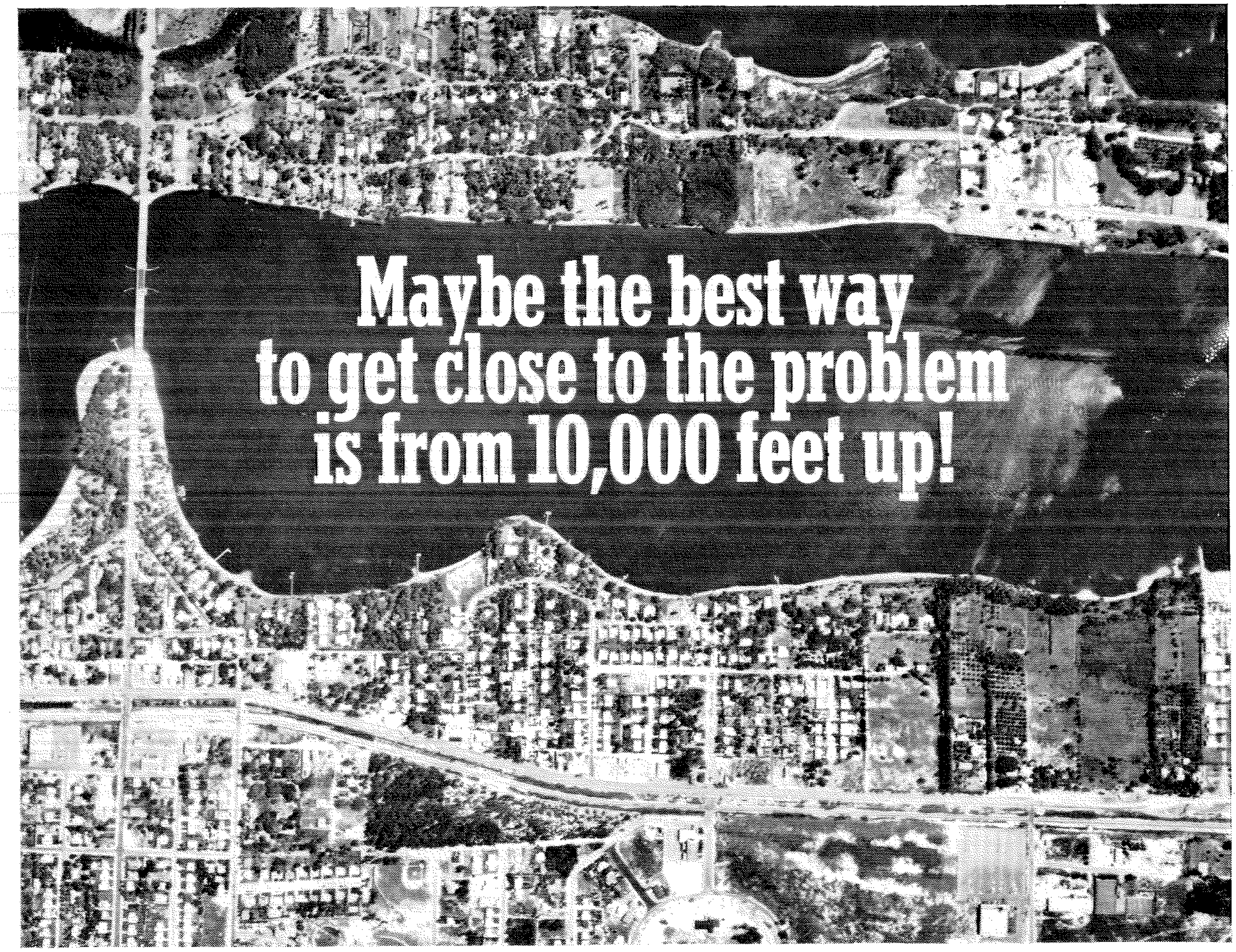

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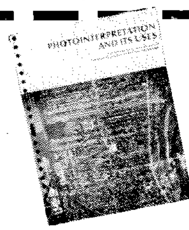

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