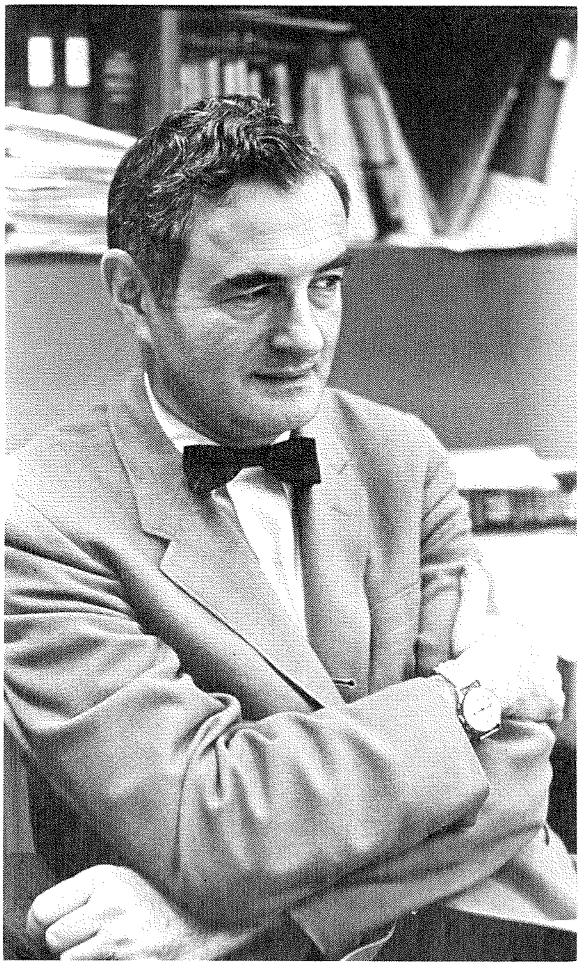


> *"The living organisms of today have had the benefit of two billion years of selective molecular evolution. Soon we shall have that cumulative ingenuity at our fingertips . . . and with it not only the power to alter the natural world, but to alter our very selves."*

Sometimes in the din and gore of a Vietnam, in the fury of a ghetto riot, or even in the drab tension of a traffic snarl, it becomes difficult to remember our larger purposes—our ancient and endless need to understand the deeper sources of these festering trials. And the deepest source, the root cause, lies surely in our own nature, in the nature of man.

That the nature of man has been at once the source of his triumph and the seed of his tragedy has been evident since the Greek philosophers, if not before. In the lines of Alexander Pope:

> Know then thyself, presume not God to scan.
> The proper study of mankind is man.
> Placed on this isthmus of a middle state,
> A being darkly wise and rudely great.

And this is even more true in a world increasingly subject to man's dominion.

There are, of course, many ways to view the nature of man, but with all due respect to the philosophers and the poets, the prophets and the playwrights, I submit that in a scientific and quasi-rational age it is appropriate and indeed valuable to consider man a part of the natural universe—as the latter-day product of two billion years of evolution and as an astonishing evocation of the remarkable potentials inherent in organized matter—yet of one piece with the electrons and the atoms and the molecules, with the waves and the particles that comprise the bulk of the cosmos.

Modern biology is now poised to provide a new and profound approach to the understanding of the nature of man. And with that understanding will come wholly new powers to alter man's very being. If we are to channel these powers to our intent and not to the hapless contrary, then we must soon, in commensurate degree, alter and enlarge our conception of the place of man and his potential.

This year, 1968, is the 100th anniversary of the discovery of nucleic acid by Fritz Miescher. Today we know that Miescher's material—deoxyribonucleic acid, or DNA—is the chemical substance of the gene—the carrier of heredity. The year 1868 was but three years after the then unnoticed publication of Mendel's now famous papers which in one stroke resolved the age-old riddle of inheritance. It was but nine years after the publication of Darwin's *The Origin of Species*, with its revolutionary doctrine of the evolution of living creatures that marked the beginning of the rational attempt to view man as a product of nature.

But no one could have foreseen that these seemingly disparate discoveries made within a short period of years would, 90 years later, flow together into a great synthesis that gives us the deepest insight into the molecular strategy of life and a coarse sense at least of the craft of evolution as the architect of biology. This synthesis has conceptually bridged the long-mysterious gulf between the world of the living and the non-living and thus permitted an easy acceptance of the continuity between the inanimate and the animate matter, based upon a calm understanding of the potential for life inherent in molecular organization. Today we understand the self-renewing structural order and molecular flux intrinsic to a living cell. This synthesis had, of necessity, to await a prior maturation of physics and chemistry—the sciences of matter. With their maturity, in the early part of this century, with the insight they provided into the nature of atoms and molecules, and with the techniques and instruments that could be devised with this knowledge—with the radioisotopes, the ultracentrifuge, the x-ray camera, and the electron microscope—modern biology could truly begin.

And it is because modern biology has sought understanding at the molecular level where it could rely upon the sure footing of physics and chemistry that we have made the dramatic, self-confident progress of the past two decades.

This synthesis had also to await the slow, growing realization that living systems are in fact, if gently and widely dissected, surprisingly dissociable. A priori, this was not self-evident. A living cell could have been such an intricately integrated device that the isolated individual parts would be largely inert and functionless. But it is not so. With increasing skill and knowledge, we can perform more and more functions of the cell with purified components reassembled in a test tube.

It is probable that this dissociability is in fact a necessary consequence of an evolutionary mode that has proceeded by independent, unitary steps. If the biochemical networks be-

DARKLY WISE AND RUDELY GREAT

by Robert L. Sinsheimer

"Walter, explain DNA just once more and I promise I won't ask you again."

Drawing by Alan Dunn; © 1968 The New Yorker Magazine, Inc.

came too tightly interwoven, even if more efficient, they would soon have come to an evolutionary dead end, incapable of unitary change. There is in this perhaps a moral to be observed in our modern social structures.

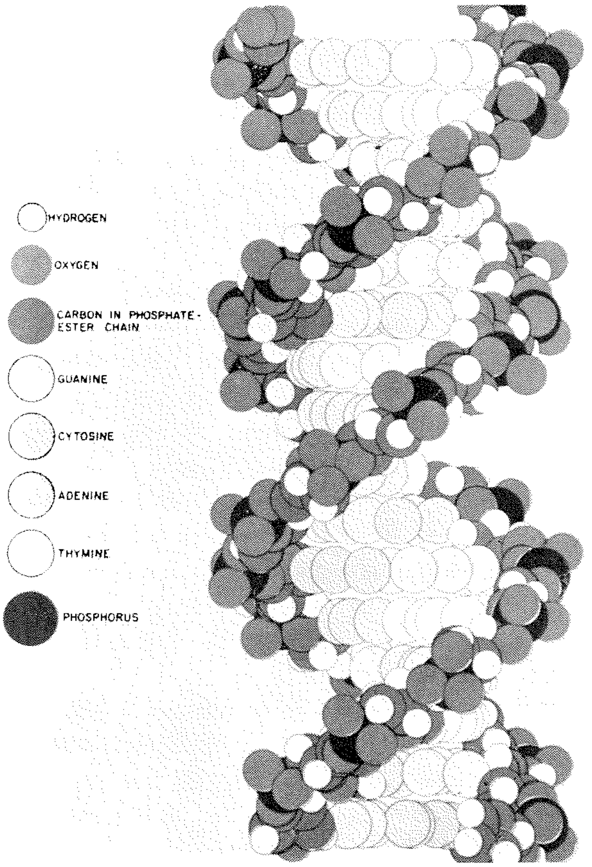
One relevant example of the dissociability of cellular function is the recent synthesis in a test tube of an intact, infective DNA molecule. One can only wonder if Miescher, fishing his nucleic acid out of an unknown soup of compounds with the crude chemistry of his day, could have foreseen the time when this nucleic acid would be combined with other functional cellular components, each carefully identified and isolated and purified, to bring about thereby, at will, a true molecular replication—the synthesis of new DNA molecules as exact copies of the old.

Now we all know what DNA is. Russell Baker, in his last list of New Year's resolutions, has as number seven: "Find out what the DNA molecule is." Of course, this came between number six: "Learn to speak Italian," and number eight: "Get an introduction to Sophia Loren." So there is some uncertainty as to what use he planned to make of this knowledge.

DNA is most often found as the now famous double helix. Each strand of the two-ply helix is composed of linked subunits, of which there are principally four kinds. And the two strands bear a defined relationship such that, if the sequence of units in one strand is specified, the sequence in the other is determined. The hereditary information is conveyed in a special code in the ordered sequence of subunits, which the cell, in effect, is able to read. Each gene, each unit of heredity, comprises a tract along this chain—a tract which may be several hundreds of subunits in length. Each cell must also, of course, be able to replicate these molecules to make an exact copy of each, so as to pass on the inherited information to each daughter cell.

And thus it has been, with gradual modifications, since the very beginning of life. For the code and the translation is the same in all life on earth.

In the dim world between the living and the non-living lurk the viruses. For these, too, the genetic substance is nucleic acid, sometimes in



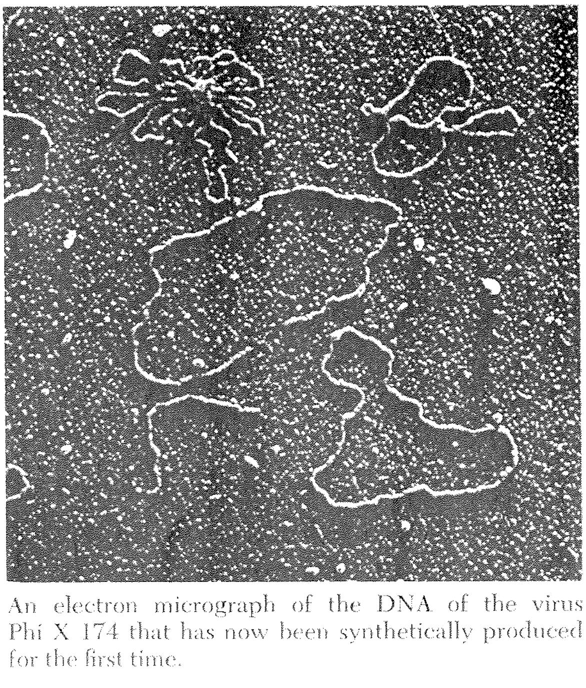
DNA is most often found as a double helix—each strand being composed of linked subunits of principally four kinds. Hereditary information is conveyed in a special code in the ordered sequence of subunits.

curious and unusual forms. The simplest viruses consist of nothing more than nucleic acid and a protective coat. Upon invasion of the cell the coat is shed, and the viral nucleic acid—this foreign piece of genetic material—is seen as the true infective agent. It is possible under special laboratory conditions to dispense entirely with the coat and to accomplish penetration of the cell and infection with the free, viral, nucleic acid molecules alone.

The recent test-tube synthesis of DNA is an illustration of the capability of modern biochemistry to reproduce vital functions. The actual steps are few and not complex. The background knowledge behind these steps is considerable. The work, which was a collaborative enterprise between our Caltech laboratory and that of Arthur Kornberg at Stanford, started with a viral nucleic acid, a DNA.

For the sake of simplicity, we started with a small and unusually simple type composed of only one strand in the form of a ring. The actual DNA ring has some 5,000 subunits comprising about eight genes, and the circumference of the ring is approximately two microns, a micron being roughly one ten-thousandth of an inch. To these DNA molecules were added subunits—a small initiator molecule composed of a few appropriately linked subunits and two highly purified normal cellular components—two catalysts, enzymes normally concerned in the cell with the function of DNA synthesis, named, respectively, polymerase and ligase. The subunits of the original DNA and the free subunits always pair up in a particular complementary way. That they pair up in this way is determined intrinsically by their atomic geometry—by their electronic and molecular structures. The polymerase then progressively links the subunits of the newly forming chain as it grows around the old chain. However, the polymerase is unable to close such a chain; and thus the second catalyst, the ligase, is necessary to perform the final step.

In this way we can make a new ring—the same size as the original, but obviously not the same. Instead, the one we have made is the *complement* of the original ring. But now, in the laboratory, these two rings can be separated—the original from the complement. And after we isolate the complementary ring, we can start the process all over again using it as the template. Clearly, then, in the second



An electron micrograph of the DNA of the virus Phi X 174 that has now been synthetically produced for the first time.

round we will make *its* complement, which is now an exact copy of the original. The process is quite analogous to a negative and positive in photography.

It was just this synthetic copy of the original DNA that was obtained, and when this copy was tested, it was shown to be biologically active; that is, it was fully infective. It gave rise in the infected cell to normal progeny virus particles. The copied DNA looked just like the original. We had made, then, in a test-tube, a DNA which could serve as the progenitor of an indefinitely long chain of progeny virus from this day on throughout time.

The significance of this successful experiment is not simply that we have synthesized a viral nucleic acid, or that, having done so, we could now set out deliberately to introduce specific changes into our copy and to observe the subsequent effect on the nature of the virus—that is, to create modified forms at will. The significance is that the infectivity of the copy proves the accuracy of the whole process and proves that this process is open-ended. In principle it can be applied to any DNA, from a virus or a bacteria, from an amoeba or a mouse or a man.

The complexity, of course, becomes progressively greater. Six hundred thousand different DNAs would be needed to match the DNA content of man.

This is only a specific and a personal example of the power of our growing understanding of the world of life and of our growing competence to direct its processes to our ends. The living organisms of today have had the benefit of two billion years of selective molecular evolution. Soon we shall have that cumulative ingenuity at our fingertips as well as *in* our fingertips, and with it not only the power to alter the natural world but also the power to alter our very selves.

For we have learned not only to copy a virus, but we have learned to understand—at least in bold outline—the functional machinery of the living cell—the unit of life.

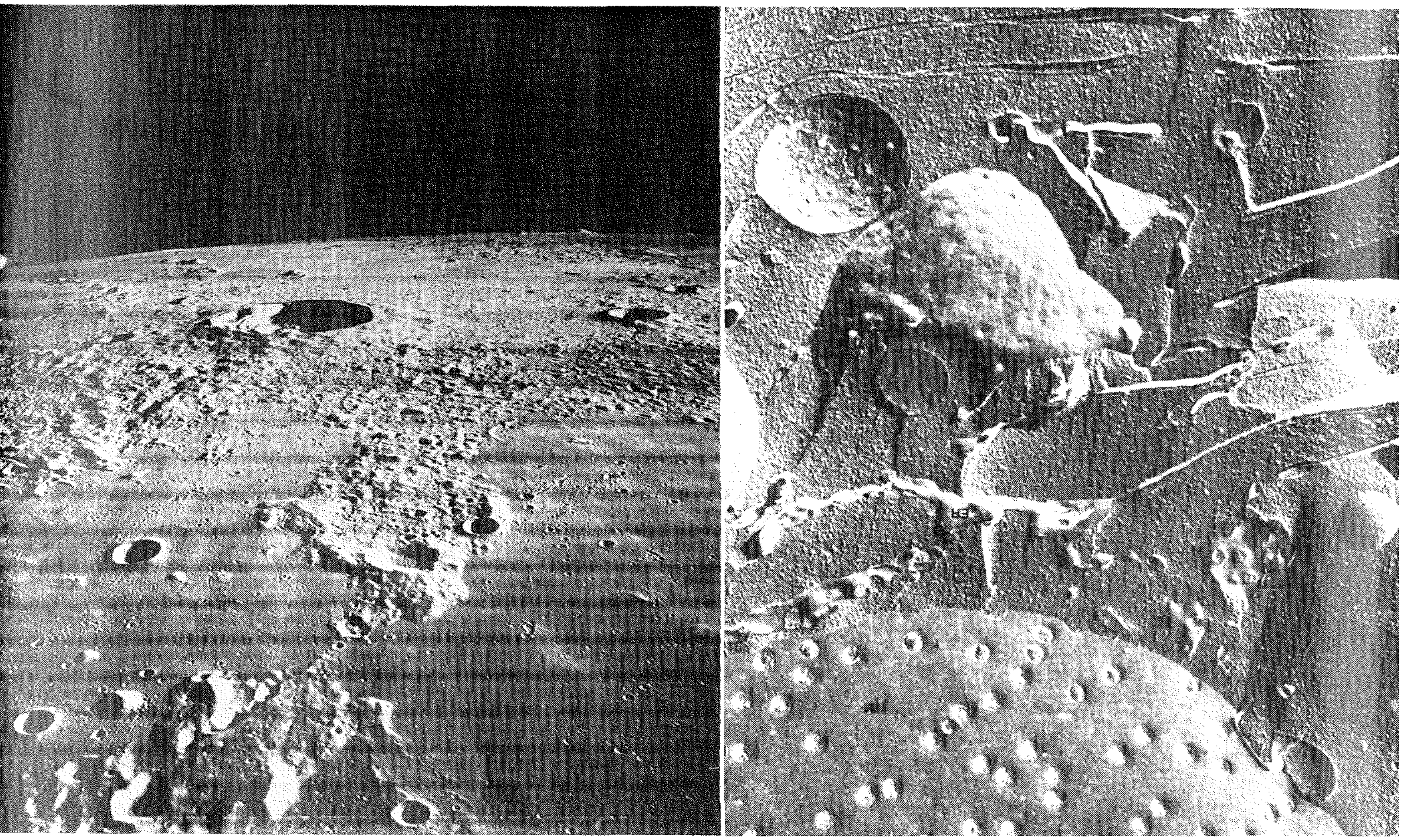
In a manner similar to our comprehension of nucleic acid replication, we now comprehend the principles of macromolecular architecture and the basic tactics of molecular recognition and of self-assembling systems. We understand the means of molecular information storage and expression, and the adroit use of a common energy currency. We appreciate the vital role of the processes of molecular repair and the pervasive importance of the phased, interacting cybernetic systems of molecular control that preserve balance and proportion. All of these together form the material basis of life.

It is of the greatest significance that these basic vital patterns of organization are essentially similar in all forms of life—including man. All of life on earth has evolved progressively, though in gradually divergent ways, from a common source. This kinship, this continuum of life, was first demonstrated by Darwin, largely with morphological evidence. But today we can document evolution anew on the most basic level—in the universality of all hereditary codes and in the detailed structure of common proteins.

It is even possible to recognize in our very molecules the traces of our descent from incredibly ancient progenitors, to whom all superficial resemblance was lost ages ago. It is possible to trace through the tens and hundreds of millions of years the progressive molecular changes that have permitted adaptation to more varied circumstance and allowed the evolution of life to a greater scope and freedom.

In the molecules of hemoglobin—the essential oxygen-carrying protein in our red blood cells—there are two large subunits called alpha and beta hemoglobin. The alpha subunit is a folded linear chain composed of a sequence of smaller subunits called amino acids. In nature there are some 20 different kinds of amino acids, and all proteins are composed of these same 20. In any particular protein there is a particular selection of these amino acids arranged in a particular and specific linear order.

It is the number, frequency, and sequence of its amino acids that determines the properties of the protein, whether it is a hemoglobin or an insulin or a cytochrome or a polymerase. In the amino acid sequence of the alpha chain of normal human hemoglobin, there are some 141 amino acids beginning with valine and ending with arginine. Each can be specified by an abbreviation of its name. This is known from modern biochemistry. We can similarly analyze the amino acid sequence of



The mysterious and unfamiliar terrain of the moon (left) and the interior of a simple cell (right), unknown in detail until recently, have now been mapped. Herein, perhaps, lie the keys to the mysteries of the universe and of life.

the alpha chains of the hemoglobins of other animals. When this is done for a related primate, such as the gorilla, one finds that the sequence differs in only one amino acid from that of the human hemoglobin. A glutamic acid has been replaced by an aspartic acid in *one* place. The rest are the same. If the amino acid sequence of the alpha chain of hemoglobin of a chimpanzee is analyzed, we find that it is identical with that of the human.

But not all hemoglobins are similar. As we go further back along the evolutionary course and examine the hemoglobin of species that have been on divergent paths from man for a longer time, we find increasing distinctions.

The evolutionary relationships between various animal species can, in fact, be firmly demonstrated in the molecular relationships of the alpha chains of their hemoglobins. The more closely related the species, the more similar are the hemoglobins; the more distantly related, the more disparate are the hemoglobins. In the alpha chain of the hemoglobin of the horse, there are some 18 differences from that of the human. Horse and human have been on separate evolutionary paths for quite a long time. Conversely, 123 amino acids that are common to the human hemoglobin and the horse hemoglobin must in all probability have been present in the hemoglobin of their common ancestor at some remote time. The alpha chain of the mouse hemoglobin also has some 18 differences from that of man. Interestingly, however, these are not the same 18 as are found in the horse. Indeed if one compares the horse and the mouse hemoglobins, there are 23 differences.

Hemoglobin only appeared in the course of evolution with the rise of vertebrates. Can we find traces of even older evolutionary ties? For this we must turn to an even more vital and ubiquitous protein—to the cytochrome found

Comparisons of the Amino Acid Chains of Cytochrome C from Various Species.

HUMAN

Gly · asp · val · glu · lys · gly · lys · lys · ilu · phe · ilu · met · lys · cys · ser ·
gln · cys · his · thr · val · glu · lys · gly · gly · lys · his · lys · thr · gly · pro ·
asn · leu · his · gly · leu · phe · gly · arg · lys · thr · gly · gln · ala · pro · gly ·
tyr · ser · tyr · thr · ala · ala · asn · lys · asn · lys · gly · ilu · ilu · trp · gly ·
glu · asp · thr · leu · met · glu · tyr · leu · glu · asn · pro · lys · lys · tyr · ilu ·
pro · gly · thr · lys · met · ilu · phe · val · gly · ilu · lys · lys · lys · glu · glu ·
arg · ala · asp · leu · ilu · ala · tyr · leu · lys · lys · ala · thr · asn · glu ·

TUNA FISH

Gly · asp · val · **ALA** · lys · gly · lys · lys · **THR** · phe · **VAL** · **GLN** · lys · cys · **ALA** ·
gln · cys · his · thr · val · glu · **ASN** · gly · gly · lys · his · lys · **VAL** · gly · pro ·
asn · leu · **TRP** · gly · leu · phe · gly · arg · lys · thr · gly · gln · ala · **GLU** · gly ·
tyr · ser · tyr · thr · **ASP** · ala · asn · lys · **SER** · lys · gly · ilu · **VAL** · trp · **ASN** ·
ASN · asp · thr · leu · met · glu · tyr · leu · glu · asn · pro · lys · lys · tyr · ilu ·
pro · gly · thr · lys · met · ilu · phe · **ALA** · gly · ilu · lys · lys · lys · gly · glu ·
arg · **GLN** · asp · leu · **VAL** · ala · tyr · leu · lys · **SER** · ala · thr · **SER** · . . .

HORSE

Gly · asp · val · glu · lys · gly · lys · lys · ilu · phe · **VAL** · **GLN** · lys · cys · **ALA** ·
gln · cys · his · thr · val · glu · lys · gly · gly · lys · his · lys · thr · gly · pro ·
asn · leu · his · gly · leu · phe · gly · arg · lys · thr · gly · gln · ala · pro · gly ·
PHE · **THR** · tyr · thr · **ASP** · ala · asn · lys · asn · lys · gly · ilu · **THR** · trp · **LYS** ·
glu · **GLU** · thr · leu · met · ilu · phe · ala · gly · ilu · lys · lys · lys · thr · glu ·
pro · gly · thr · lys · met · ilu · phe · **ALA** · gly · ilu · lys · lys · lys · **THR** · glu ·
arg · **GLU** · asp · leu · ilu · ala · tyr · leu · lys · lys · ala · thr · asn · glu ·

MOTH

Gly · val · pro · ala ·
GLY · asn · ala · **GLU** · asn · **GLY** · **LYS** · **LYS** · **ILU** · **PHE** · val · gln · arg · **CYS** · ala ·
GLN · **CYS** · **HIS** · **THR** · **VAL** · **GLU** · ala · **GLY** · **GLY** · **LYS** · **HIS** · **LYS** · val · **GLY** · **PRO** ·
ASN · **LEU** · **HIS** · **GLY** · phe · tyr · **GLY** · **ARG** · **LYS** · **THR** · **GLY** · **GLN** · **ALA** · **PRO** · **GLY** ·
phe · **SER** · **TYR** · ser · asn · **ALA** · **ASN** · **LYS** · ala · **LYS** · **GLY** · **ILU** · thr · **TRP** · **GLY** ·
asp · **ASP** · **THR** · **LEU** · phe · **GLU** · **TYR** · **LEU** · **GLU** · **ASN** · **PRO** · **LYS** · **LYS** · **TYR** · **ILU** ·
PRO · **GLY** · **THR** · **LYS** · **MET** · val · **PHE** · ala · **GLY** · leu · **LYS** · **LYS** · ala · asn · **GLU** ·
ARG · **ALA** · **ASP** · **LEU** · **ILU** · **ALA** · **TYR** · **LEU** · **LYS** · glu · ser · **THR** · lys · . . .

YEAST

Thr · glu · phe · lys · ala ·
GLY · ser · ala · lys · **LYS** · **GLY** · ala · thr · leu · **PHE** · lys · thr · arg · **CYS** · glu ·
leu · **CYS** · **HIS** **THR** · **VAL** · **GLU** · **LYS** · **GLY** · **GLY** · pro · **HIS** · **LYS** · val · **GLY** · **PRO** ·
ASN · **LEU** · **HIS** · **GLY** · ilu · **PHE** · **GLY** · **ARG** · his · ser · **GLY** · **GLN** · **ALA** · gln · **GLY** ·
TYR · **SER** · **TYR** · **THR** · asp · **ALA** · **ASN** · ilu · lys · **LYS** · asn · val · leu · **TRP** · asp ·
GLU · asn · asn · met · ser · **GLU** · **TYR** · **LEU** · thr · **ASN** · **PRO** · **LYS** · **LYS** · **TYR** · **ILU** ·
PRO · **GLY** · **THR** · **LYS** · **MET** · ala · **PHE** · gly · **GLY** · leu · **LYS** · **LYS** · glu · lys · asp ·
ARG · asn · **ASP** · **LEU** · **ILU** · thr · **TYR** · **LEU** · **LYS** · **LYS** · **ALA** · cys · glu · . . .

The evolutionary relationships between various species can be documented in the universality of the detailed structure of their common proteins. When the chain of 104 amino acids making up the cytochrome C of the human is compared to that of the tuna fish, 19 differences are seen (indicated here in bold face). In the horse there are 12 differences. When we compare *similarities* of the amino acid chains, yeast is found to have 64 in common with the human, and the moth has 77 in common with man.

in every cell, where it plays an essential role in the metabolism of nutrients to provide energy. The cytochrome of the human is a chain of 104 amino acids. That of the Rhesus monkey is identical with the human. The cytochrome of the horse has 12 differences from that of the human. Going farther back in time, the tuna fish cytochrome has 19 differences from that of the human cytochrome and actually one less amino acid at the far end of the chain.

But since cytochrome is common to all cells, we can go farther back. If we examine the cytochrome of a still more remote species—an invertebrate, the moth—we find 26 differences from that of the human. In addition, four amino acids have been added at the near end and one deleted at the far end of the chain. But if we emphasize the *similarities*, we see how closely related the cytochromes of the human being and the moth are, even though the evolutionary paths relating to these two species must have diverged in a very remote time.

But we can go still farther back. In what far-distant era did the lines that led to yeast cells and man diverge? In the cytochrome of yeast we find there are five more amino acids at the near end of the chain and one removed at the far end. Of the remaining amino acids, 64 are identical to those in the human cytochrome. It is most reasonable to suppose that these same amino acids were present in the same position in the cytochrome of that unremembered common ancestor. Thus we bear, in every cell, the indelible imprint of a long-vanished, incredibly ancient past—our past.

When the historians of a hopefully more humane future look back at this, the 20th century, one may wonder what they will consider worthy of note. Our recurrent wars? Our ideological and racial fanaticism? Hardly likely! More likely they will recall that this was the century in which man first left earth or the century in which man first kindled nuclear fire. And they will surely recall that this was the century in which man first understood his inheritance and evolution, first saw clearly how he came to be. For the first time in all time, a living creature understood its origin.

No doubt I am biased, but of these I believe the last will seem the most extraordinary. The unimagined becomes reality. We are the heirs of Icarus; we have become the latter-day Prometheus. But even in the ancient myths men were men and the gods were gods, and man could not rise above his nature to chart his destiny. Now we can begin to confront that chance and choice; soon we shall have the power consciously to alter our inheritance, our very nature. Not even the Greeks had a word for DNA.

But there is more to come. Whereas biology had to await the maturity of physics and chemistry, so we now believe that psychology, the science of the mind, has had to await the maturity of biology. We now comprehend life as a manifestation of inherent properties of organized matter, and we have a belief that we will learn how to see mind as a further consequence of the inherent properties of organized matter—as a property of living cells highly specialized and intricately organized.

If we consider the brain as the seat of the mind, we now understand much of its basic physics and chemistry. We know of what it is made. We know the basic structure and properties of its unit cells. We do not yet know its superstructure. We do not yet know the connections and functional interactions, the complex integrations and cybernetics. But we do know increasingly well the substructure, its properties and its potentials—and this is an essential base and springboard for the future.

In recent research it has become increasingly clear from studies of vision and optical illusions and the processing of visual information in the brain, from the studies of color and of predictable color illusions, from studies of motivation, of imprinting and ethology that very much of our being is built into the brain from the beginning, in terms of preformed circuits and prescribed chemical transmitters and receptors. It is clear that so much is genetic, and thus it is reproducible; it can be studied and analyzed just as we have learned to analyze other genetic phenomena.

A short scientific film made in the laboratory of James Olds at the University of Michigan shows a rat learning his way about in a maze—a not entirely unfamiliar situation. At first he is not very skilled; he makes all kinds of mistakes and doesn't know where he is supposed to go. He goes up blind alleys, but eventually he gets to his goal. Then he wants to get back to the other end, but he doesn't know the way. However, he does increasingly well. With experience and motivation to get to each goal, he learns very quickly and remembers well. What was the motivation of this rat? What was his reward for which he performed so capably? The reward was nothing more than a small electric current sent into a microelectrode implanted into what is called a reward center in his brain. When the rat pressed the lever at each end of the maze, he received a pulse of current for three presses. After three presses, he had to return to the other end for more. He liked it; indeed, he liked it very much.

Such a current is one of the most powerful rewards known, and by coupling a task to this reward the rat is quickly motivated to learn a wide variety of procedures. These centers which bring about such strong positive reinforcing behavior are genetically built into the rat's brain in various well-defined regions. Similar centers are known in monkeys. The biochemical and physiological bases of the action of these centers are not known at present, nor has their psychological significance to the function of the animal as yet been defined. But there is certainly a strong suggestion that here is a direct clue to the origin of behavior.

I do not wish to imply that human behavior may be so simply engendered. But evolution is most often conservative—an add-on process. And as there are motivation centers in other primates, it is not a far inference to suggest that similar processes have some part to play among the causes and courses of human action. Other investigations are beginning to probe into the way in which the brain acts to analyze visual and other sensory input data, or into the stages and events in the deposition of memory traces. It becomes increasingly clear that there are built-in, inherited pathways for these processes, immensely complex but reproducible and subject to analysis.

In the past decade, man has learned how he came to be. In the future he will seek to understand understanding—to know how he comes to know. I believe that here, not in mescaline, lie the true doors to perception. Here, not in ancient scrolls, lies the path to the understanding of man. And here, not in carnage and strife, lies the greater promise for the future of man.

The great discoveries in genetics and the great discoveries yet to come open a new dimension of human potential, a new route for the improvement of man. There are surely the gravest of risks ahead in our use of this potential. The Cassandras of our time see this very well, sometimes with gray or black humor, sometimes with lament for a simpler age, sometimes in an essayist's alarm. Archibald MacLeish has written, in an essay entitled *When We Are Gods:*

> There is in truth a terror in the world, and the arts have heard it as they always do. It is the sound of apprehension. We do not trust our time because it is we who have made the time—and we do not trust ourselves as gods. We know what we are.

In part, I disagree. There is no terror in the known. The fear is that we do not know what we are. We fear the unknown within. We are, for better or worse, the one creature with reason. It is the mark of man, and we are committed to its path—committed to the unending use of reason to free us from the external tyrannies of nature and the internal constraints of our inheritance. If there is a hidden, fatal flaw, if behind reason there is the abyss, then it is our destiny and we can do no better. But it seems to me that all of knowledge speaks otherwise.

"The proper study of mankind is man," Pope wrote, seeing with a clear vision. But he was ahead of his time, for it is only now that the analytic study of man can properly begin. Some will be distressed by this view of man, and I would not presume that it is complete or final. It is part of our folly when we claim the one eternal truth of man. Nevertheless, I believe that this truth is a valid one for our time. It is our answer to the ancient exhortation at the entrance to the temple at Delphi, "Know thyself."

I also conceive that some such orientation of thought will be essential from this time on as a frame of reference if we are to use in a wise and wholesome, rational and constructive manner the potential implicit in the great discoveries of modern biology. We, mankind, are to have the opportunity to design the future of life, to apply intelligence to evolution. What an astounding chance and infinite challenge.

On yet another plane it seems to me that one underlying cause for the malaise of man for many millennia has been his seeming divorce from the rest of nature and the physical universe. Man has seemed a creature apart, a lonely alien "placed on this isthmus of a middle state."

This problem has been met in various ways over the centuries by various conceptions and theologies which have served to provide a rationale for man on which to base his existence. And thus these have provided, over moderate areas of the earth, that reasonably common set of aims and goals that is necessary for any coherent society.

But today, in an age of science molded implacably by the triumphs of rational thought—if not always rationally applied—the older rationales come to seem unsuited, and to many, unacceptable. Many need a newer charter for man.

Perhaps we can provide a new anchor for man in a lucid understanding of our roots in nature—in the clear demonstration that man in his complex and often erratic behavior is, in fact, the logical outcome of his evolutionary origins; in the conception that we are in and of nature, an extraordinary product of unfulfilled and perhaps undreamed potential. But we are not alien.

And, as "darkly wise and rudely great" we climb, arduously, out of ignorance, out of the shadowed depths, to look back from time to time may help us to understand where we are. And to see how far we have come can help us to sense how very far we may yet advance.

In the words written in an old church, "You are a child of the universe, no less than the trees and the stars. You have a right to be here."