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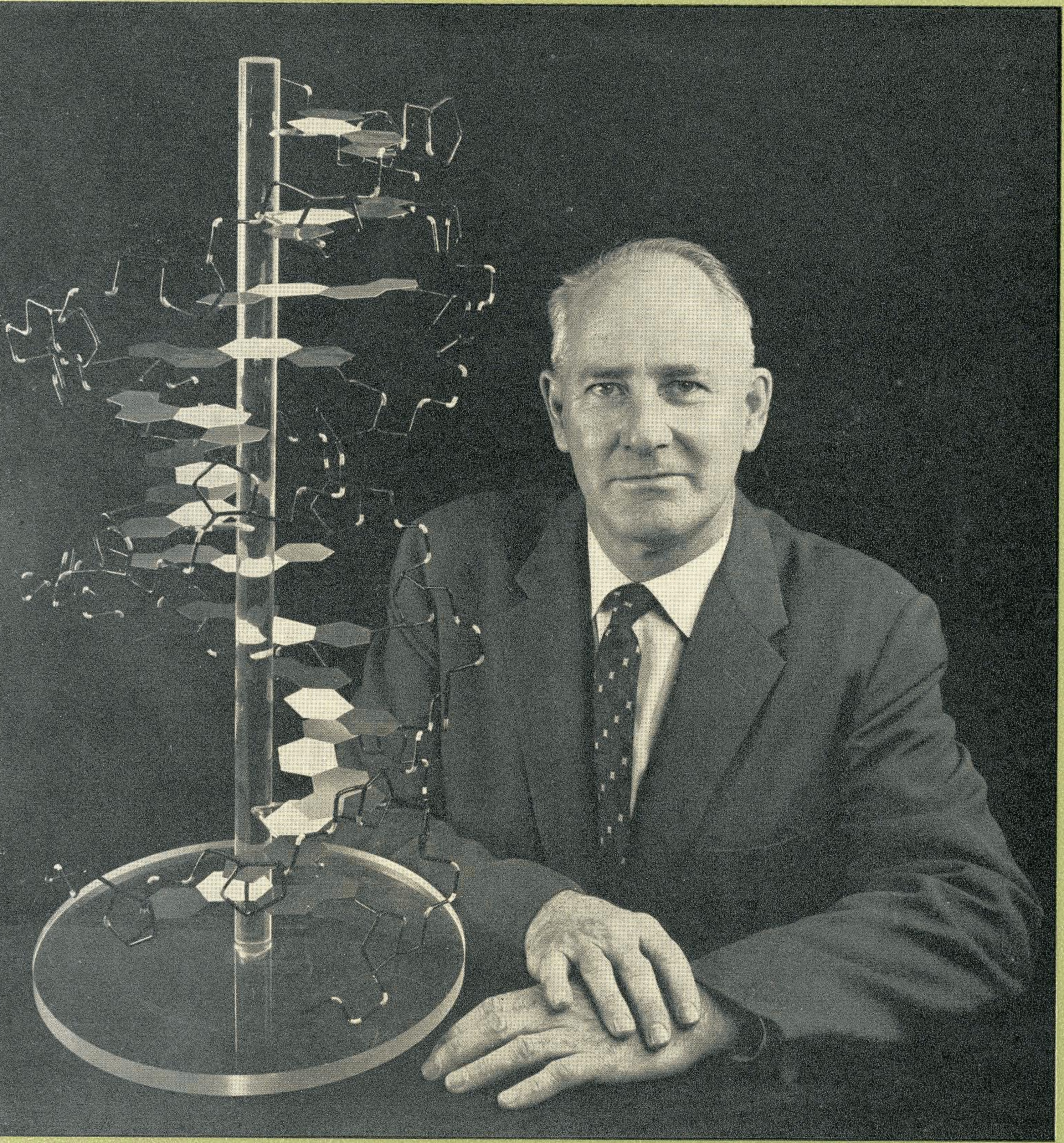
March 1960



Genetics and Modern Biology . . . page 11

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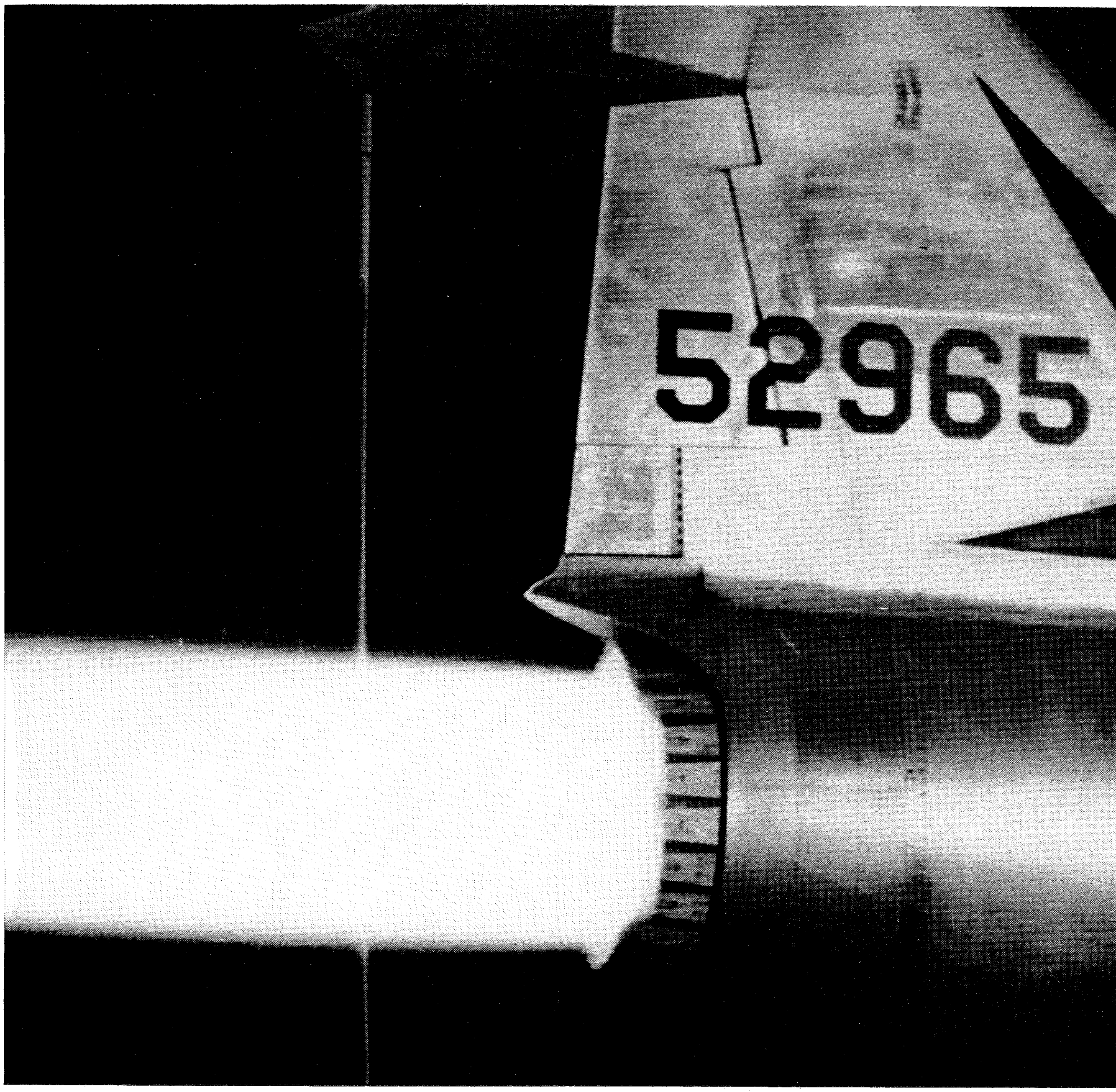
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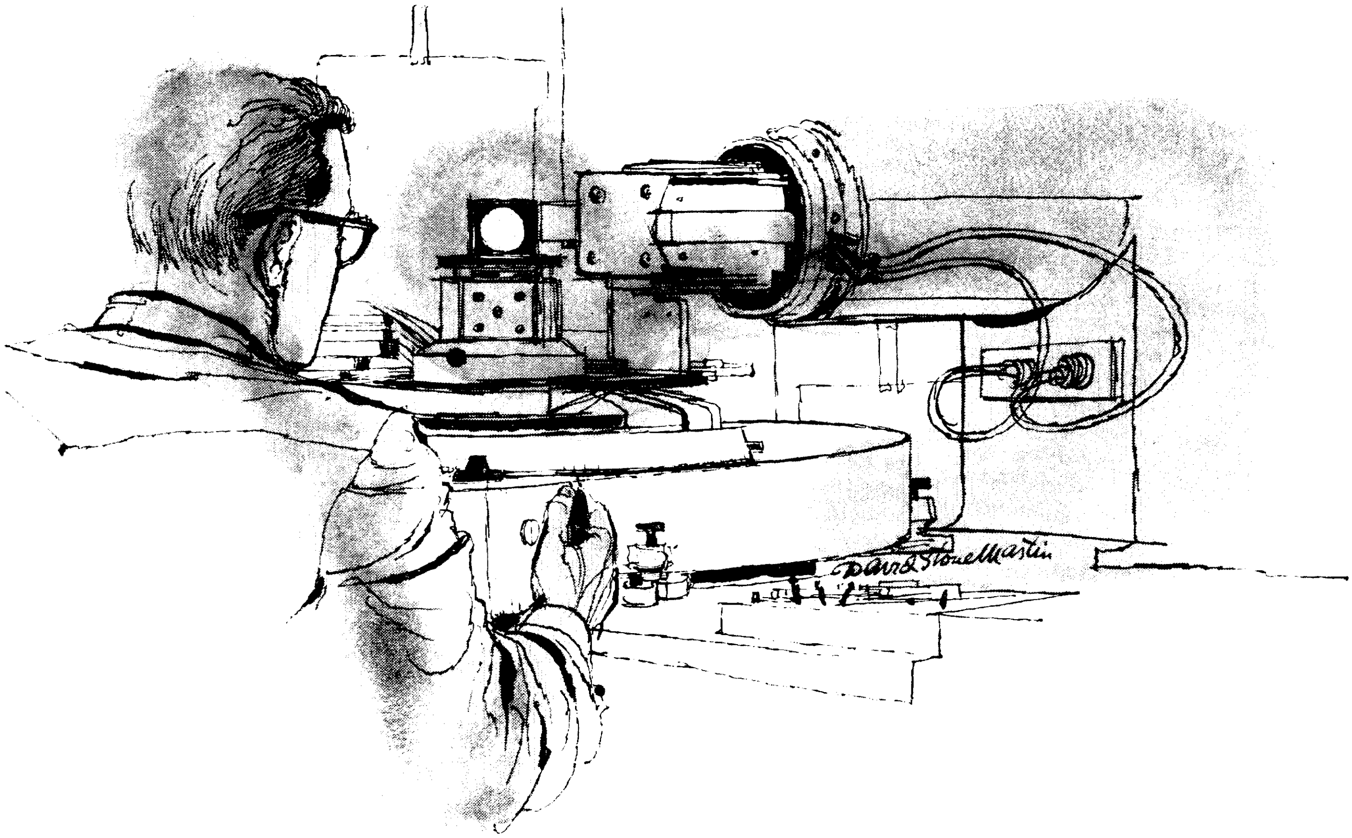

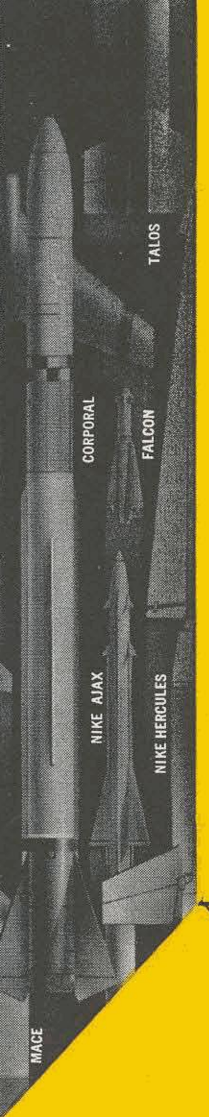

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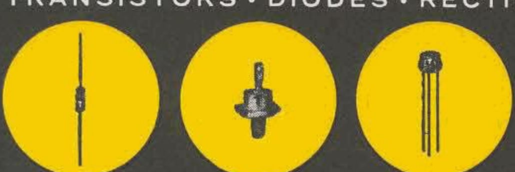

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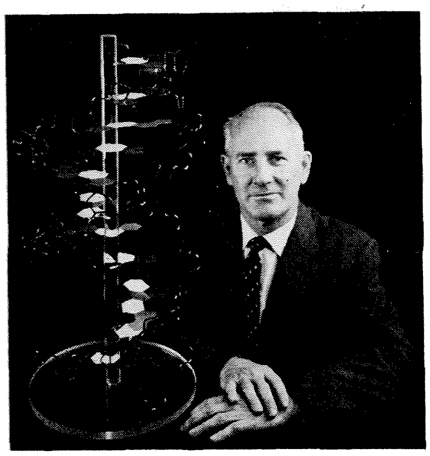

On Our Cover

George W. Beadle, professor of biology, chairman of the division of biology, and acting dean of the faculty at Caltech, holds a model of the chemical structure called DNA – the messenger which transmits hereditary information in all living systems. Dr. Beadle's article on page 11, "The Place of Genetics in Modern Biology," has been adapted from his Arthur Dehon Little Lecture given at MIT last November.

Frederick C. Lindvall,

chairman of the division of civil, electrical and mechanical engineering and aeronautics at Caltech, writes about "The Vanishing Engineer" on page 22. His article has been adapted from a Friday Evening Demonstration Lecture which he gave at Caltech on February 26.

Research in Progress

on page 21 tells the story of an amazing hormone which may eventually be used for the treatment of radiation injuries and anemias. Henry Borsook, professor of biochemistry heads this research now going on in Caltech's biology laboratories.

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Books

A Canticle for Leibowitz

by Walter M. Miller, Jr.

J. P. Lippincott Company . . . $4.95

Reviewed by Harvey Eagleson, professor of English

This novel, I suspect, will not receive the attention that it should, because it will be erroneously classified as "science-fiction" and will therefore be ignored by "serious" critics and readers. It is not science-fiction. On one level it is extrapolated history, but on another it is a symbolical and philosophical novel. *A Canticle for Leibowitz* is one of the most brilliant pieces of imaginative writing this reviewer has ever read.

Four years ago I received, as an advertisement, a copy of the magazine *Fantasy and Science Fiction.* Most of the issue was devoted to the publication of a long story entitled "And the Light is Risen" by Walter M. Miller, Jr. I glanced at the story, having no intention of "wasting my time on it," and was immediately engrossed. That story, much revised, now forms the central section of *A Canticle for Leibowitz.*

The novel, leaping over many centuries in its three parts, centers around the Abbey of the Albertian Order of Saint Leibowitz located vaguely in the New Mexican desert. It begins six centuries after the coming atomic war. What is now the United States is a sparsely inhabited area divided under the jurisdiction of barbaric kings and chieftains and having a cultural level similar to that of Europe in the first centuries after the fall of Rome.

The abbey contains all that is left of the scientific knowledge of our time, saved by a Jewish engineer before he was martyred by the mob during the Simplification, a period after the atomic war when the masses rose and destroyed the intellectuals and all their works as being the cause of man's plight. Now learning once again begins to stir. The novel sweeps on through time until man has again reached a period of technological advance slightly beyond where we now are and again prepares to destroy himself. This narrative is told with such verisimilitude of detail, character, and situation that one feels while reading it that it is indeed not fiction but, as I have said, extrapolated history.

Though this story is the first interest, the second (and by all means the most important) interest is the moral and philosophical aspect of the novel – the presentation of modern man's dilemma. What should his values be? An excerpt from a dialogue between Dom Paulo, the abbot of the monastery, and Thon Taddeo, the scholar whose learning is to inaugurate the new renaissance, suggests in part the theme of the whole.

"'But you promise to begin restoring Man's control over Nature. But who will govern the use of the power to control natural forces? Who will use it? To what end? How will you hold him in check? Such decisions can still be made. But if you and your group don't make them now, others will soon make them for you. Mankind will profit you say. By whose sufferance? The sufferance of a prince who signs his letters X? Or do you really believe that your collegium can stay aloof from his ambitions when he begins to find out that you're valuable to him?'

"'What you really suggest,' said the scholar, 'is that we wait a little while. That we dissolve the collegium, or move it to the desert, and somehow – with no gold and silver of our own – revive an experimental and theoretical science in some slow hard way, and tell nobody. That we save it all up for the day when Man is good and pure and holy and wise.'

"'That is not what I meant . . . .'

"'That is not what you meant to *say*, but it is what your *saying* means. Keep science cloistered, don't try to apply it, don't try to do anything about it until men are holy. Well, it won't work . . . If you try to save wisdom until the world is wise, Father, the world will never have it.'"

This review has only indicated the theme of this brilliant and unusual novel. I urge the reading of it to anyone who wishes a new experience in fiction and at the same time a shock to his "think-cells," which we are all too inclined to use too infrequently.

Project Sherwood—The U. S. Program in Controlled Fusion

by Amasa S. Bishop

Doubleday-Anchor Books . . . $1.25

Reviewed by William A. Fowler, professor of physics

Amasa S. Bishop, BS '43, former Chief of the Controlled Thermonuclear Branch of the Atomic Energy Commission, has written a frank and lucid history of Project Sherwood—the U. S. program in controlled fusion. It is a story of failure. The ups and downs, the hopes and frustrations, the alarums and excursions are all here, and it all makes interesting reading. The book was prepared at the request of the U.S. Atomic Energy Commission's Division of Information Services, so it would not be expected to be a critical appraisal – and indeed it is not.

This reviewer served as a member of the ill-fated Sherwood Steering Committee, the "civilian" members of which resigned in a body over policy disagreements last year. The dim view of our prospects held by the reviewer and his colleagues cannot becloud the devoted and ceaseless labor of those down the line whose story is told by Bishop. After all, the Russians and the British haven't been able to do it either! Why be down-hearted; another 100 million dollars and we may still be able to do it without a good idea! Hope springs eternal; even a good idea may come along!

Starting with the basic principles underlying self-sustained, controlled fusion, the book comes very soon to the problem of confinement of the nuclear fuel – deuterium and/or tritium. Magnetic confinement of the hot plasma – ionized but neutral gas – is treated as "the most promising (if not the only) solution" of the problem. The early work on the three major lines of experimental effort is then delineated. Chapters are devoted to the pinch research at Los Alamos, Livermore, and Berkeley; the stellarator research at Princeton; and the magnetic mirror research at Livermore, Los Alamos, Oak Ridge, and

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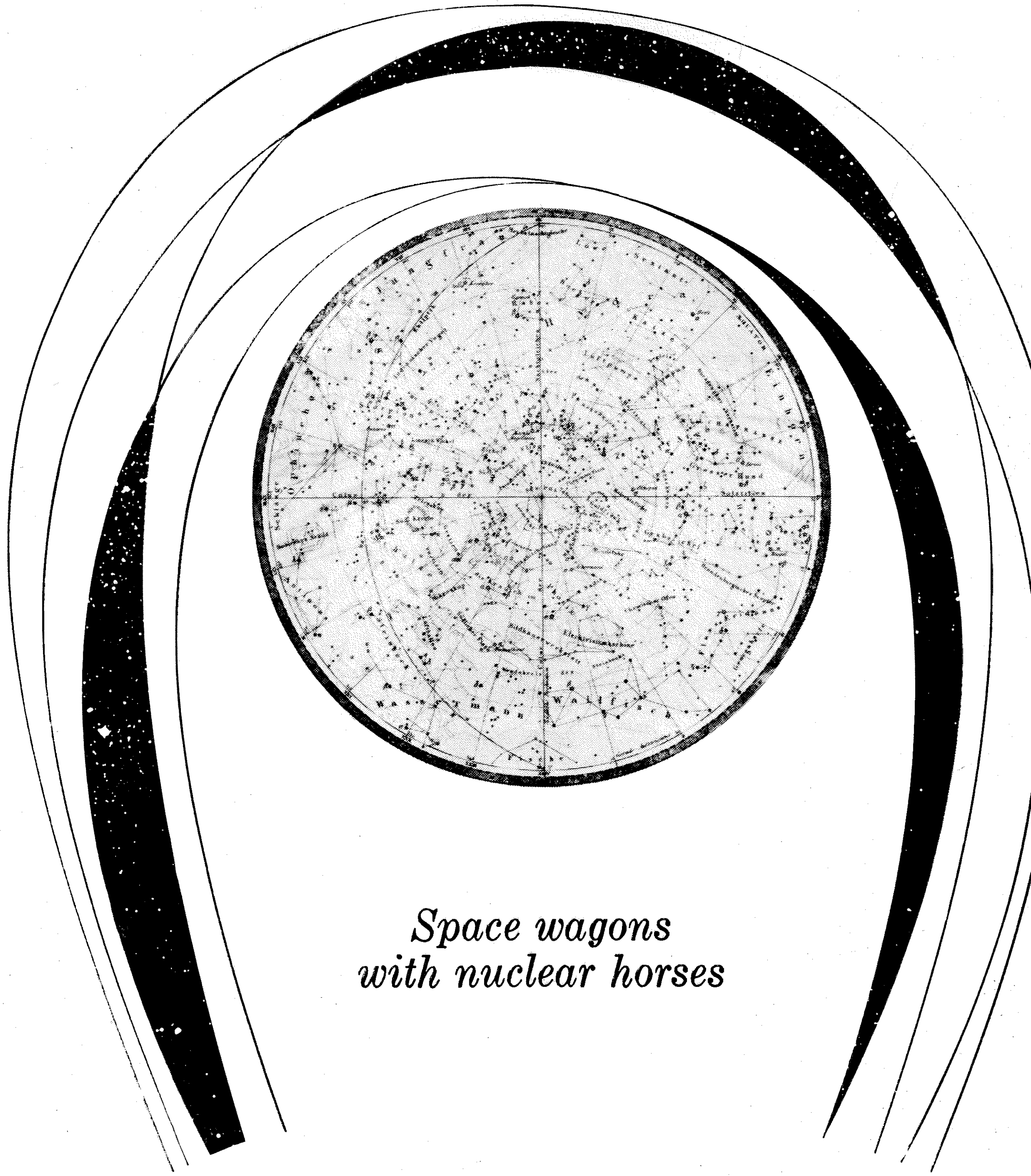

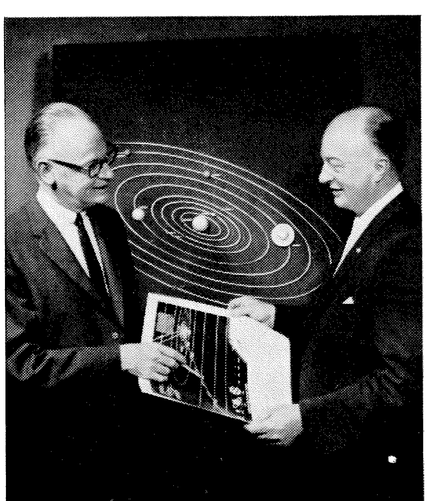

Books . . . *continued*

the Naval Research Laboratory. Then comes the discussion of the gloomy question of stability which in October 1954 brought "the whole of the Sherwood program face to face with a problem which threatened its very existence."

The intermediate chapters are devoted to the major research programs, and others, after stability had raised its ugly head in Nottingham and the men of Sherwood doggedly attacked this most galling nemesis. Early 1955 brought the false hope of "instability neutrons" which were shown by brilliant diagnostic techniques to be of *non*-thermonuclear origin. Thermonuclear neutrons may now be just around the corner, but that corner is far distant from the eventual goal – thermonuclear energy.

In 1956, Oak Ridge started a new approach. A beam of particles, produced in a conventional accelerator at energies already in excess of that needed for thermonuclear reactions, is injected and trapped in a confined region in the hope of igniting the plasma and initiating a self-sustaining thermonuclear reaction. Oak Ridge is still at it.

The final chapters cover the controversial decisions to go to larger geometries in some devices in the hope that bigness would solve some of the problems. The exponentially rising cost and scientific man-hours required for Project Sherwood from 1952 to 1958 are shown forthrightly in a graph in one of these chapters. There is an addendum on "Progress, June 1958 to June 1959," by Arthur E. Ruark, who succeeded Bishop as Chief of the Controlled Thermonuclear Branch, and there are five appendices including a comprehensive glossary of technical terms.

In one sense the judgment that *Project Sherwood* is a tale of failure is perhaps wrong. Plasma physics has become a flourishing branch of science in the quest for easy energy. Perhaps it is best that the book does not play this theme too hard. The message comes through without the need for embellishment. For scientists and laymen, for different reasons, the book is worth reading.

Science Study Series

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Four new titles in the series initiated by the Physical Science Study Committee, set up to revise the teaching and study of high-school physics.

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by I. Bernard Cohen . . . $.95

I. Bernard Cohen, professor of the history of science at Harvard, traces the evolution of modern physics from Aristotle through Copernicus, Galileo, and Kepler to Newton. Dr. Cohen's purpose, as he explains, is not to present a popular history of science, but to "explore one aspect of that great scientific revolution which occurred during the sixteenth and seventeenth centuries, to clarify certain fundamental aspects of the development of modern science."

The Physics of Television

by Donald O. Fink and David M. Lutyens . . . . $.95

The Physics of Television concentrates on the principles of physics that are applied in television, rather than on circuitry – which makes it pretty much of a rarity. Donald Fink is director of research of the Philco Corporation; David Luytens is science editor for Penguin Books.

Waves and the Ear

by Willem A. van Bergeijk, John R. Pierce and Edward E. David, Jr. $.95

This is a brightly written book on the physics of sound and the physiology of the ear – or, to use the book's own subtitle, What We Hear and How. Of the three authors (all of whom work for the Bell Telephone Laboratories), Willem van Bergeijk is a zoologist, Edward David is an acoustics engineer and Caltech Alumnus. John R. Pierce is an electronics engineer.

Crystals and Crystal Growing

by Alan Holden and Phylis Singer $1.45

Crystals and Crystal Growing is not only an introduction to crystallography, but an invitation to scientific experimentation as well. Several chapters of the book are devoted to methods and recipes for growing crystals. Alan Holden is a physical chemist at the Bell Labs; Phylis Singer teaches mathematics and art at the Far Brook School in Short Hills, N.J.

The Place of Genetics in Modern Biology

by George W. Beadle

Twenty-five years ago Professor William Morton Wheeler, a distinguished and admired professor of biology and Dean of the Bussey Institution of Harvard University, wrote a small essay (*Science*, Vol. 57, p. 61, 1923) in which he said, " . . . natural history constitutes the perennial rootstock or stolon of biologic science . . . From time to time the stolon has produced special disciplines which have grown into great flourishing complexes . . . More recently another dear little bud, genetics, has come off, so promising, so self-conscious, but also, so constricted at the base." I am sure Professor Wheeler was convinced that this bud would be abortive.

A few months ago there appeared in *Science* (Vol. 130, p. 959, 1959) a related essay by a distinguished and likewise much admired biologist, Sewall Wright, who had been a graduate student at the Bussey Institution during Wheeler's time. After quoting Wheeler's words, Wright pointed out that, far from aborting, the little bud genetics has flourished mightily and has in many respects replaced natural history in the sense that it has become the rootstock of all biological science, and has bound ". . . the whole field of biology into a unified discipline that may yet rival the physical sciences."

Why such a change in 26 years? For, despite the fact that Wheeler was not above a bit of ragging of his friends and colleagues in genetics, he was basically serious. There has been a great change. We have come to recognize that genetics does in fact deal with the very essence of life. This is why at the present time in biology laboratories there are physical chemists, biophysicists, biochemists, microbiologists, virologists, zoologists, and other varieties of biologists devoting much effort to the study of genetic material.

"The Place of Genetics in Modern Biology" has been adapted from the Arthur Dehon Little Lecture given by Dr. Beadle at the Massachusetts Institute of Technology on November 18, 1959.

I should like to begin a development of the thesis that genetics is the keystone of modern biology by reminding you that every one of us starts development as a tiny sphere of protoplasm, and that somehow in this small sphere there must be contained the specifications, the directions, or the architectural blueprints for making one of us out of that bit of jelly-like material. Of course, the process by which this happens is enormously complex, and we do not yet understand very many of the details. But we do know that a substantial part of these directions is wrapped up in the centrally located nucleus of the cell. These directions are the material heredity that we received from our parents.

In addition to this set of directions in the nucleus, there must be more. There must be cytoplasm, adequate food, suitable temperature and so forth. The environment adds to the information in the original egg. This is particularly impressive in our own species, for in addition to all the other environmental information fed into us during development we are continually bombarded with cultural inheritance — language, art, music, religion, history, science and so on — that in man supplements biological inheritance to a far greater degree than in any other species.

What are the directions in the nucleus and how do they specify that from this minute cell one of us will come? I shall ask five questions about these specifications:

First, how do we get them and how do we transmit them? I shall dispose of this one, though, for it is answered by classical genetics — the Mendelian genetics now found in every elementary textbook of modern biology.

Perhaps you know less about the remaining four questions:

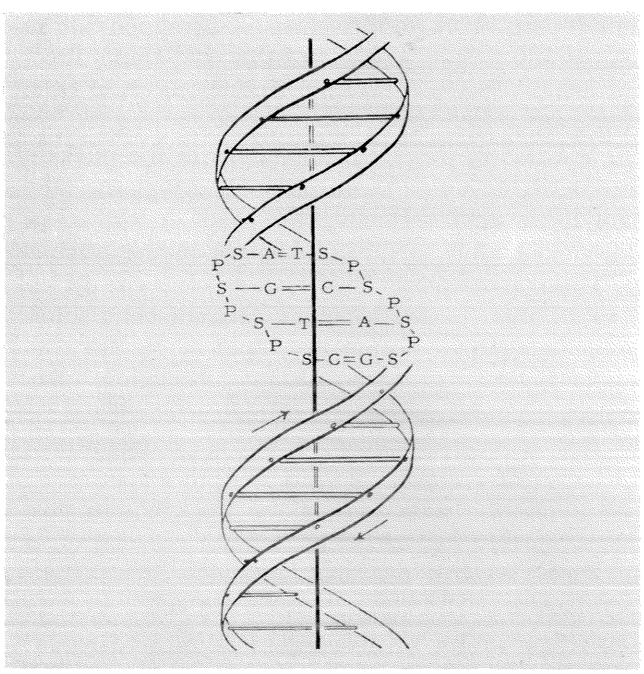
How are the specifications written — that is, what is the language of genetics?

How are the specifications replicated? From the time we start development as a fertilized egg until we transmit them to the next generation, there are perhaps 16 to 25 successive replications of these specifications, depending on whether the carrier is female or male. Each time the material is replicated it doubles, so 20 replications represent more than a million copies. How does replication occur with the precision necessary to avoid intolerable numbers of mistakes?

How are the specifications translated? This is an enormously difficult question and I shall say right now that we know very little about it.

How are specifications modified during the course of evolution? Most of us believe in organic evolution and we want to know how we come to be different from our ancestors? In other words, what is the nature of the mutation process?

A few years ago we would have had a very difficult time answering the four questions that I have just asked. But within the past half dozen years or so, excellent clues have turned up. In 1953 there occurred an important turning point in modern biology. By this time it had become quite clear to a number of biologists that a particular chemical substance called deoxyribonucleic acid (DNA) was important in transmitting hereditary information in bacteria and in viruses. Since the cells of all higher plants and animals contain DNA, it seems probable that it served to carry genetic specification in all living systems.



Diagrammatic representation of the Watson-Crick structure of DNA (redrawn from Watson and Crick, 1953). The parallel spiral ribbons represent the paired polynucleotide chains. Hydrogen bonds are represented by transverse parallel lines. P=phosphate; S=deoxyribose (sugar); A=adenine; T=thymine; C=cytosine; G=guanine. Orientation of nucleotides is indicated by arrows.

I shall attempt to explain how and why this substance is important. DNA has been known for a long time. And it was known that it consisted of long chain-like molecules made of four kinds of units called nucleotides. But it was not known exactly how DNA molecules were internally organized until in 1953 two investigators — James D. Watson, now at Harvard University, and Francis H. C. Crick of Cambridge University — succeeded in formulating a structure that has proved to be substantially correct.

From the information then available from classical chemistry, from x-ray diffraction studies, from analysis of the relative proportions of the four kinds of nucleotides, and through ingenious model building, Watson and Crick proposed the structure illustrated below. This structure was at once exciting to biologists because it suggested such plausible answers to the four questions: How is genetic information written? How is it replicated? How is it translated? And how does it mutate?

The key to the structure of DNA is that its molecules are double in a special way. There are two parallel polynucleotides wound around a common axis and bound together through specific hydrogen bonding.

You can more easily visualize the essential features of DNA if you will imagine a four-unit segment of it pulled out in two dimensions as follows:

A - T - C - G
.. ..
T - A - G - C

in which the four letters represent the four nucleotides and the pairs of dots represent hydrogen bonds. In fact you can very nicely represent such a segment with your two hands. Place your forearms vertically before you and parallel. Fold your thumbs against your palms and place homologous finger tips together as though they were teeth on two combs vertically oriented in a single plane, tooth tip to tooth tip. In this arrangement the two index fingers represent the A:T nucleotide pair and so on.

Imagine many fingers along your forearms — of four kinds, corresponding to the nucleotides A, T, C, and G. The four kinds of fingers or nucleotides can be arranged in any order on one arm but must always have the complementary order on the other; T opposite A, A opposite T, G opposite C, C opposite G. Thus, if one knows the sequence of nucleotides in one chain, the sequence in the other can be determined by the simple rule of complementarity.

This structure suggests that genetic information is contained in the sequence of nucleotides; in other words, DNA is a kind of molecular code written in four symbols. One can think of the code as a sequence of nucleotide pairs or of nucleotides in a single chain, for it is obvious that the double chain and the two single component chains all contain equivalent information. In essence, the two complementary chains are analogous to forms of a single message, one written in conventional Morse code, the other in a complementary code in which each dot is changed to a dash and vice versa.

Let us now ask the question: How much information is packed away in the nucleus of a human egg? It is estimated that there are about five billion nucleotide pairs per single cell. How much information does this correspond to in terms of, say, information spelled out in the English language? Francis Crick has expressed it this way: If you were to make an efficient code for encoding messages in English in the four symbols of DNA, and then started encoding standard sized library volumes in this DNA code, you could get the contents of about 1000 volumes in the DNA of the nucleus of a single fertilized egg cell.

This is another way of saying that it requires the equivalent of about 1000 large volumes of directions in the egg nucleus to specify that a human being like one of us will develop properly from it.

That is supposedly the way the genetic information is carried from generation to generation — in a language we might call D-N-A-ese. Each gene is a segment of DNA of perhaps three or four thousand nucleotides.

Now let us ask about the replication. The double structure of DNA suggested immediately to Watson and Crick how this could happen. If, during cell division, the two chains were to come apart, obviously each could serve as a template for picking up additional units to make new half chains. And this is happening in each of us right now. In many cells nucleotides are continually being made from food components. The replication of DNA according to this scheme is illustrated as follows:

```
                      A - T - C - G  →  A - T - C - G
                                        :   :   :   :
                    ↗                   T - A - G - C
A - T - C - G
:   :   :   :
T - A - G - C                           A - T - C - G
                    ↘                   :   :   :   :
                      T - A - G - C  →  T - A - G - C
```

You can represent the process with your hands. Indicate the double molecule as already directed as paired hands. Take the two hands apart. Imagine free fingers (nucleotides) moving around at random. Each single hand serves to select in proper order the one-fingered units necessary to make a complementary hand. The right hand is a template for making a left hand, and vice versa. So, with a double molecule represented by a pair of hands, two single molecules arise by breakage of hydrogen bonds, with each then directing the synthesis of a new complementary single partner.

This process of replication takes place with every cell division and, as we shall see, with a high degree of precision.

This hypothesis by which two identical bipartite molecules arise from a single such double molecule is very satisfying in its simplicity and elegance. If true, it is presumably the basis of all biological reproduction at a molecular level. Can the hypothesis be tested? The answer is yes. In fact, several kinds of experiments have been made to see if the hypothesis agrees with observed facts.

Testing the hypothesis

In one kind of experiment DNA units are labeled with radioactive phosphorus. Each nucleotide has one phosphorus atom, and a certain number of these atoms can be made radioactive by growing the organism, say a bacterium, in a medium containing radioactive phosphorus for several generations until it becomes equilibrated. Then both chains of its DNA molecules will be labeled. If the bacteria are then allowed to multiply in a medium in which there is no radioactivity, the two chains of each DNA molecule, both labeled, should come apart, each then directing the synthesis of an unlabeled partner. The new double molecules should then be labeled in one chain but not in the other. In the next generation the labeled chain should separate from the non-labeled one. With synthesis of non-labeled partners by these, there should be produced labeled and non-labeled double molecules in equal numbers. The observed results are consistent with this expectation.

Another way of doing essentially the same experiment is to replace the normal nitrogen atoms of DNA with "heavy" nitrogen, the stable isotope N^{15}, instead of the usual N^{14} counterpart. DNA molecules so labeled become heavier but not larger. Hence they are denser. DNA containing only N^{15} can be cleanly separated from that containing N^{14} in an analytical centrifuge cell in which an appropriate density gradient is established. In such experiments it is found that bacteria containing DNA fully labeled with N^{15}, if allowed to multiply once (double in number) in a medium containing only N^{14}, give rise to descendants in which all the DNA molecules are "hybrid," (i.e. "half heavy"), as though one nucleotide chain of the double molecues contained N^{15} and the other N^{14}. This, of course, is what is predicted by the hypothesis. In a subsequent generation, also in N^{14} medium, half the DNA molecules are hybrid and half are fully light as predicted.

While experiments of this kind do not prove that the Watson-Crick hypothesis of DNA replication is correct, they do strongly suggest it. An even more dramatic way of testing the hypothesis is the one used by Professor Arthur Kornberg, now at Stanford University, and his associates. They have devised a test-tube system which contains the four nucleotides A, T, C, and G as triphosphates, a buffer solution, magnesium ions, and a polymerizing enzyme. DNA molecules added to this system appear to be replicated. Is the new DNA like the primer molecules added? One important observation suggests it is. The ratio of A:T nucleotide pairs to C:G pairs of the product is like that of the primer DNA. It is not easy to see how this could be if the primer were not being copied in a precise way. On the other hand, if DNA having known biological activity (as determined by ability to transform the genetic constitution of a bacterium) is used as a primer, both the product and the primer added end up being inactive. Why this is so is not known, but it is strongly suspected that the polymerizing enzyme added contains a small amount of depolymerizing enzyme that breaks up DNA chains and thus destroys activity.

Again, the Kornberg synthesis does not prove that the hypothesis is correct. It is just possible that an unkind nature could have evolved a system that would do just exactly what the hypothesis predicts, but by a different mechanism.

Ribonucleic acid as messenger

How is genetic information translated? These are enormously difficult questions, and we know relatively little in detail about the answers. They involve the whole of development, differentiation, and function. There are working hypotheses – widely used and useful ones – that suggest how some of the steps occur.

We know that in our bodies there are many thousands of kinds of protein molecules – large, long molecules made of amino acids, and very specific in their properties. One, for example, is hemoglobin. It is built of 600 amino acids strung together in a particular way. There are two kinds of chains of amino acids per hemoglobin molecule, each in pairs. Each chain is about 150 amino acids long. And we know that there are segments of DNA – two, we postulate – in our chromosomes that say how to build the two protein subunits.

A widely used working hypothesis assumes that around a double helix of DNA there is wound a helix of another kind of nucleic acid, called ribonucleic acid or RNA. RNA, like DNA, is built in four nucleotides. In this way the DNA code may be translated into a corresponding sequence of RNA. RNA then moves from the nucleus into the cytoplasm. There it is incorporated into microsomes, which are sub-microscopic structures in which protein synthesis occurs. In the microsome, RNA units are believed to serve as templates against which amino acids are lined up in proper sequence. Amino acids, derived from the proteins in our food, are first activated by enzymes and subsequently hooked to small carrier segments of RNA that serve to carry the amino acids to their proper places on the microsomal RNA templates.

Carrier RNA may be thought of as messengers carrying packages and addresses to which they are to be delivered. The messengers carry the amino acid packages along the RNA template until the address matches that on the template. There is a specific RNA messenger for each of the twenty kinds of amino acids. When all component amino acids are correctly ordered, they are linked together to form proteins which then peel off the templates and the process is set to be repeated. For hemoglobin, for example, there are assumed to be two DNA segments, one for each kind of protein chain, and two corresponding RNA templates. This in essence is believed to be the translation process.

A large number of proteins serve as enzymes or essential components of enzymes. Enzymes catalyze chemical reactions that would otherwise occur at rates so low that life processes would essentially cease. For each enzyme protein there is supposedly a segment of DNA information in the nucleus – a gene – and corresponding microsomal RNA templates in the cytoplasms of those cells active in synthesis of that particular enzyme protein.

An important question of present day biology is concerned with the nature of the mechanism by which the four-symbol code of DNA is related to the twenty-symbol code of proteins. It is obvious that single symbols of DNA cannot stand for amino acid for there are only four. Likewise, pairs of DNA symbols will not do, for there are only 16 such pairs if the DNA molecule is read in one direction. If one reads in one direction and uses three symbols per amino acid, there are 64 possibilities. However, only 20 of the triplets are useful if successive sets of three are used, for the overlapping sets of three must not encode amino acids or there would be confusion in the translation.

Mutations as a source of evolution

Twenty is the minimum number required to encode all of the amino acids that occur in proteins – that is, if one reads the code in one direction. However, because the two parallel chains in a DNA molecule have opposite polarities as determined by the way the nucleotides are oriented in the two chains, the double DNA molecule is symmetrical and there is therefore no obvious way to know in which direction the information is to be read. Unless there exists some kind of marker, as yet undiscovered, that specifies in which direction to read, the number of three-symbol sets that can be used to encode amino acids unidirectionally is only 10. Four-symbol codes have accordingly been investigated. It turns out that there are 27 such four-symbol "words" that can be used without any of their overlaps making sense when read either forward or backward, and without the four-letter words themselves making sense when read in reverse. This is sufficient, but it is not known if this is indeed the correct coding mechanism.

My fourth question concerns the nature of mutation.

During DNA replication, occasional mistakes are made. Presumably during replication a nucleotide does not pick up a complementary partner as it should, but instead picks up a non-complementary one. It has been postulated that such mistakes result from an improbably tautomeric form in which a hydrogen atom is in an improbable position at the exact moment the nucleotide picks up a partner. A wrong partner is therefore selected. In the next round of replication the "wrong" partner will pick up what is its complementary partner and this will result in substitution of one nucleotide pair for another.

This is somewhat like a typographical error. In typographical errors it is possible to have extra letters, or too few letters; one letter substituted for another, or transposed letters. Presumably, similar kinds of mistakes can be made in genetic information during replication. In fact, there is genetic evidence that these four basic types of mistakes do occasionally occur.

How often do such mistakes occur? Quite infrequently, we believe. From the time one receives a set of directions in the fertilized egg, until one transmits it to the next generation (and remember this is perhaps 17 to 20 successive replications of information, equivalent to about 1000 printed volumes) a mistake is perhaps made about once in a hundred times — that is, a significant and detectable mistake. This is clearly a high order of precision.

What happens to such typographical errors as are made? First of all it is clear that the DNA molecule will replicate just as faithfully whether the information in it makes sense or not. Its replication is a purely mechanical one, it seems. Therefore mistakes in genetic information will be perpetuated.

Accumulated errors

It is obvious that if there were no way of eliminating errors in such a process, such errors would accumulate from generation to generation. Perhaps an analogy will make this clear. If a typist types in a purely mechanical way, never proofreading, never correcting, and types successive copies of the same material always from the most recently typed copy, she will accumulate mistakes at a rate dependent on her accuracy until eventually the sense of the original message will be entirely gone. In the same way, this would have to happen with genetic information if there were no way of taking care of mistakes. With genetic information something does happen that takes care of mistakes. By extending the analogy, perhaps I can make clear what that is:

The typist, typing mechanically, can correct a mistake by a second random typographical error, but obviously the probability of this is extremely low. It is likewise so with genetic information, and it is clear therefore that this is not the principal way in which mistakes are prevented from accumulating. Let us pretend the typist has an inspector standing beside her. When she makes a mistake, he says, "Throw that one away and start over." If in the next try she makes no mistakes, he says, "All right, now you may type another from the one you have just finished." Each time she makes a perfect copy he allows her to go ahead, but each time she makes a mistake, he insists she throw the copy away. That is what happens with genetic information. The inspector is analogous to natural selection. Bad sets of specifications in man are eliminated by natural selection.

A more dramatic term for elimination of unfavorable specifications by natural selection is "genetic death," as used by H. J. Muller. Individuals developed from unfavorable specifications do not reproduce at the normal rate, and ultimately a line so handicapped dies out. To avoid progressive accumulation of mistakes from generation to generation, it is obvious that every error in replication that is unfavorable must be compensated for by the equivalent of a genetic death. That is why geneticists are concerned about factors that increase the mutation rates.

Mutations — favorable and unfavorable

You may quite properly ask, "Are there no favorable mutations?" The answer is yes, there are occasional favorable mutations; they are in fact the basis of organic evolution.

However, because many mutations involve subtle changes that may be favorable under special circumstances of environment or overall genetic constitution it is not easy to estimate the proportion of favorable to unfavorable mutations. Theoretical considerations and a certain amount of experimental evidence agree in indicating that the great majority are unfavorable. Organisms are, in general, already so highly selected for success in their normal environments that the chance of further improvement by random mutation must be very small.

Perhaps an analogy with a fine watch will dramatize the point. Assume the watch is very slightly out of adjustment. A random change brought about, say, by dropping it, could conceivably improve the adjustment. Clearly, however, the chance of making it run less well, or not at all, is enormously greater. Now let us extend our typing analogy. Assume our inspector exercises judgment. When the typist makes an error that improves the original message, he passes it. Thus, improved messages will replace their ancestral forms and the improvement will be cumulative. Something like this happens with living systems. Specifications improved by occasional favorable mutations are preferentially reproduced and thus tend to replace their ancestral forms. This is natural selection.

In recent years many factors have been found to increase the frequency of mutations. High energy radiation that penetrates to the cell is mutagenic in proportion to its amount. A number of chemical agents are likewise mutagenic. It is now possible, for example, to alter nucleotides in known chemical ways that will produce mutations. Oxidation of amino groups of nucleotides with nitrous acid is one way. It is encouraging that biochemists and geneticists who study the mechanisms involved are beginning to be able successfully to predict the types of mutations that are most likely to be produced by specific chemical agents. It is not, however, possible to do this specifically for certain genes only.

The sources of living systems

Let us now turn to the general question of evolution. What do mutations have to do with the processes by which it occurs? It is especially appropriate at this time to discuss this aspect of my subject, for, as you know, this is the hundredth anniversary of the publication of Darwin's *The Origin of Species.*

Organic evolution is interesting and important in many respects. For one thing, it is not logically possible to accept only a small amount of it, for one cannot imagine a living system that could not have evolved from a very slightly simpler system. Starting with man, for example, and working backward toward simpler systems one sees no obvious stopping place. Our ancestors were presumably a bit simpler than we. Early in man's evolution there were primitive men. And before primitive man there were prehuman ancestral forms capable of evolving into true man.

This is true however one defines man. And so one can go backward in the evolutionary process to simpler and simpler forms until finally one begins to think of systems like present-day viruses, the simplest of which consists of little more than nucleic acid cores (DNA or RNA) and protein coats.

One can easily imagine that, before systems of this type, there were smaller and smaller system of nucleic acid and protein capable of replication and of mutation which in turn had ancestors consisting of only nucleic acid. We know that nucleic acids can be built up from nucleotides and these from simpler precursors. In a recent lecture, Melvin Calvin, professor of chemistry at the University of California, talked about the origin of some nucleotide precursors, and presented evidence suggesting that some such compounds, or their relatives, are found in certain meteorites. It is assumed that these were formed by natural chemical reactions that went on and are still going on outside living systems. Presumably through such reactions, precursors of nucleotides were formed. Professor Calvin also mentioned the evidence that amino acids are made from such simple inorganic molecules as methane, ammonia, hydrogen, and water under conditions assumed to have obtained on primitive earth.

It is, I believe, justifiable to make the generalization that anything an organic chemist can synthesize can be made without him. All he does is increase the probability that given reactions will "go." So it is quite reasonable to assume that, given sufficient time and proper conditions, nucleotides, amino acids, proteins, and nucleic acids will arise by reactions that, though less probable, are as inevitable as those by which the organic chemist fulfills his predictions. So why not self-duplicating virus-like systems capable of further evolution?

I should point out that nucleic acid protected with a protein coat has an enormous selective advantage, for it is much more resistant to destruction than is "raw" nucleic acid. Viruses can be stored for years as inert chemicals without losing the capacity to reproduce when placed in a proper environment. Of course, present-day viruses demand living host cells for multiplication, but presumably the first primitive life forms inhabited environments replete with spontaneously formed building blocks from which they could build replicas.

Before molecules like methane, hydrogen, water, and ammonia, there were even simpler molecules. Before that there were elements, all of which nuclear physicists and astrophysicists believe have evolved and are now evolving from simple hydrogen. That is why I say if you believe in evolution at all there is no logical stopping place short of hydrogen. At that stage I'm afraid logic, too, runs out.

The story can, of course, be repeated in reverse. When the conditions become right, hydrogen *must* give rise to other elements. Hydrogen fuses to form helium, helium nuclei combine to give beryllium-8, beryllium-8 captures helium nuclei to form carbon, and carbon is converted to oxygen by a similar process. In this and other known ways all the elements are formed. As one goes up the scale the number of possibilities rapidly increases. As elements begin to interact to give inorganic molecules, the number of possibilities rapidly becomes greater. I do not know how many inorganic molecules are possible, but I do know there must be a very large number.

The number of possibilities increases

With organic molecules the number becomes truly enormous, particularly with large molecules like proteins and nucleic acids. For example, there are something like 4 raised to the 10,000th power number of ways that a modest-sized DNA molecule can be made. There appears to be no stage at which there is a true qualitative change in the nature of evolution. The number of possibilities goes up gradually, the complexity goes up gradually, and there appears to be no point at which the next stage cannot be reached by simple mutation.

Let us suppose that we have a small piece of DNA protected by a protein coat and capable of replication in the presence of the proper building blocks and a suitable environment. During replication, the system will occasionally make mistakes. It is a mutable system. Given sufficient time, there will eventually occur a combination of mutations of such a nature that the protein coat will become enzymatically active and capable of catalyzing the formation of a nucleotide or amino acid from a slightly simpler precursor. If this particular building block happens to be limiting in replication, the mutant type will obviously have a selective advantage. It can replicate in the absence of an essential building block by making it from a simpler precursor. If two such units with protein coats, having different catalytic functions, combine to form a two-unit system, they will be able to make two building blocks from simpler compounds, and will be able to survive under conditions in which their ancestral forms would fail.

In the same way, it is not too difficult to imagine systems arising with successively three, four, five, and more units, with every additional unit serving a catalytic function. With each additional unit the total system would become one step less dependent on spontaneously preformed precursors. With perhaps ten thousand such units the system might be able to build all its necessary parts from inorganic materials as we know present-day green plants do.

Reaching the stage of man

How many units to reach the stage of man? Perhaps 100,000 units carrying out 100,000 functions are necessary. However many it is, we know they carry the specifications for the development of a complex nervous system, by which we supplement blind biological inheritance with cultural inheritance. We reason, we communicate, we accumulate knowledge, and we transmit it to future generations. No other species we know of does this to anything like the same degree. We have even learned about organic evolution and are on the verge of learning how to start the process.

I pointed out that in the Kornberg system, with the four nucleotides present, nothing happens unless a primer is added. That is not entirely true. After a delay of some three or four hours something does happen even without a primer. What happens is that a DNA molecule is spontaneously formed. It differs from all naturally occurring DNA in that it contains only two of the four nucleotides.

Now, if this two-unit co-polymer is used as a primer in a new system, it immediately initiates the synthesis of co-polymers like itself. In other words, it starts replicating. Remember it arose spontaneously. If you believe in mutation, and you must if you accept scientific evidence, you must believe that if you start with a two-unit co-polymer and let it undergo successive replications, there will eventually occur a mutation with which a pair of nucleotides will be replaced by the pair originally excluded in the process. This conceivably could have been the origin of the four-unit DNA of all higher organisms.

Knowing what we now know about living systems – how they replicate and how they mutate – we are beginning to know how to control their evolutionary futures. To a considerable extent we now do that with the plants we cultivate and the animals we domesticate. This is, in fact, a standard application of genetics today. We could even go further, for there is no reason why we cannot in the same way direct our own evolutionary futures. I wish to emphasize, however, that whether we *should* do this and *how*, are not questions science alone can answer. They are for society as a whole to think about. Scientists can say what is possible, and perhaps something about what the consequences might be, but they are not justified in going further except as responsible members of society.

Some of you will, I am sure, rebel against the kind of evolution I've been talking about. You will not like to believe that it all happened "by chance." I wish to repeat that in one sense it is not chance. As I have said, the mutations by which we believe organic evolution to have occurred are no more "chance" reactions than those that occur in the organic chemist's test tube. He puts certain reactants in with the knowledge that a desired reaction will go on. From the beginning of the universe this has been true.

In the early stages of organic evolution, the probabilities were presumably very small in terms of time intervals we are accustomed to think about. But, for the time then available, they were almost certainly not small. Quite the contrary; the probability of evolving some living system was almost surely high. That evolution would go in a particular direction is a very different matter. Thus the *a priori* probability of evolving man must have been extremely small – for there were an almost infinite number of other possibilities. Even the probability of an organism evolving with a nervous system like ours, was, I think, extremely small because of the enormous numbers of alternatives. I am therefore not at all hopeful that we will ever establish communication with living beings on other planets, even though there may well be many such on many planets. But I do not say we should not try – just in case I am wrong!

Scientists and materialists

Some of you will no doubt be bothered by such a "materialistic" concept of evolution. Ninety years ago in Edinburgh, Thomas Henry Huxley faced this question of materialism in his famous lecture on the physical basis of life. What Huxley said can be said today with equal appropriateness.

He said in effect that just because science must by its very nature use the terminology of materialism, scientists need not necessarily be materialists. A priest wears material clothes, eats material food, and takes his text from a material book. This does not make him a materialist. And so it need not with a scientist.

To illustrate, the concept I have attempted to present of the origin of life and of subsequent evolution has nothing to do in principle with the problem of ultimate creation. We have only shifted the problem from the creation of man, as man, to the creation of a universe of hydrogen capable of evolving into man. We have not changed the problem in any fundamental way. And we are no closer to – or further from – solving it than we ever were.

Caltech's Glee Club at the closing ceremonies of the 1960 Winter Olympic Games at Squaw Valley.

The Month at Caltech

Glee Club at the Olympics

Caltech's 52-man Glee Club, which seems to be making a career of collecting honors, collected one of the biggest of all last month when it was invited to provide the music for the colorful closing ceremonies of the 1960 Olympic Games at Squaw Valley on February 28. The program, complete with the release of thousands of colored balloons, a five-gun salute (one for each continent), and the firing of hundreds of parachutes carrying the Olympic banner and competitors' banners, was broadcast over television. Accompanied by the U. S. Marine Corps Band, the Glee Club sang "Ode Triumphant" and "No Man Is An Island." On the night before the closing ceremonies, the club presented a special program for visiting athletes and spectators.

Under the direction of Olaf Frodsham, the Glee Club has become a major extra-curricular activity at Caltech. In great demand throughout the Pacific

Southwest, the club will give some 15 concerts during the Easter vacation this month, in a tour of cities between Los Angeles and San Francicco.

New graduate house

Caltech received a gift of $500,000 for the construction of a residence house for graduate students from Mr. and Mrs. W. M. Keck, Jr., and the William M. Keck, Jr. Foundation this month. The three-story, 53-room house is one of four being built by the Institute to provide more housing for graduate students. It will be located on the east side of Holliston Avenue, north of San Pasqual Street, as one of a four-house L-shaped grouping. The new $1,500,000 graduate center will provide living and social facilities for about 175 unmarried students.

The Keck graduate house will have a central lobby and lounge opening onto a patio. A second-floor kitchen will be available for foreign students who are restricted to diets of their native countries. The house will also be equipped with washers, dryers and ironing boards. Thirteen pairs of the 53 single rooms may be converted into suites which can serve as living quarters for couples who attend scientific meetings at the Institute in the summer or on holidays.

Construction of the new graduate house will start in September and will be completed by the start of the 1961 fall term.

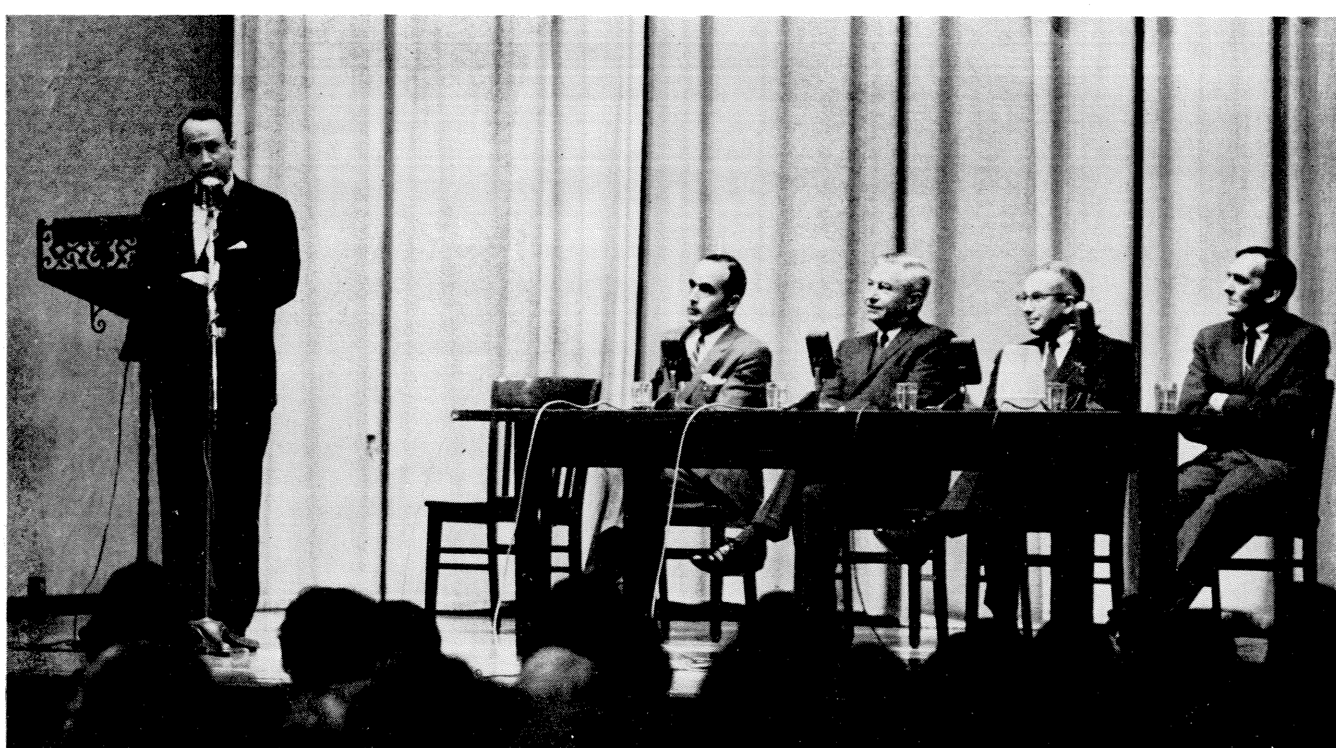
The Immense Design

Caltech presents an hour-long color television show on March 26 on NBC-Channel 4 at 9:30 p.m. The program, called "The Immense Design," is part of the NBC series "World Wide '60," and will be shown nationwide. "The Immense Design" will tell the story of creation from early mythological concepts to present-day findings, and features William Fowler, professor of physics; Jesse Greenstein, professor of astrophysics; Allan Sandage, assistant astronomer at the Mount Wilson and Palomar Observatories; and Fred Hoyle, visiting professor of astronomy from the University of Cambridge (where he is Plumian Professor of Astronomy and Experimental Philosophy), who flew from England to appear on the program.

Norman Cousins

Norman Cousins, editor of the *Saturday Review,* was on the campus from March 2-4 as the first visitor in this year's Leaders of America program, sponsored by the Caltech YMCA.

Mr. Cousins is the author of *In God We Trust, The Good Inheritance,* and *Modern Man is Obsclete.* He was the first man to discuss foreign policy before the Praesidium of the Soviet Union, and has lectured before the Soviet Writers' Union and the Academy of Social Science. He is honorary presi-



Norman Cousins, visiting Caltech on the YMCA Leaders of America Program, launches a panel discussion on disarmament. Members of the panel include David Elliott, associate professor of history; President L. A. DuBridge; Robert F. Bacher, physics division chairman; and Matthew L. Sands, professor of physics.

Barbara Ward (Lady Jackson), on campus to deliver the 1960 Haynes Foundation Lectures, is interviewed by student reporters.

dent of the United World Federalists, which is a national organization working for world peace through world government, and is co-chairman of the National Committee for a Sane Nuclear Policy.

Barbara Ward

Barbara Ward (Lady Jackson), British economist, visited the Caltech campus from February 15-23 as the 1960 Haynes Foundation Lecturer. Her series of four lectures was based on the main topic, "India and the Revolution of Economic Growth."

Lady Jackson is assistant editor of Britain's *The Economist* and has written several books – *The West at Bay, Policy for the West, Faith and Freedom,* and *Interplay of East and West.*

Lady Jackson was educated in England, France, and Germany, and received an honors degree in philosophy, politics, and economics from Oxford University in 1935. She makes her home in Ghana, where her husband, Commander Sir Robert Jackson, is chairman of the Development Commission. Lady Jackson is on a four-year Carnegie Fellowship on economic assistance.

Virus Research

An American Cancer Society grant of $100,000 has been given to Caltech's biology laboratories for research on how a virus – the smallest known unit of life – changes a normal living cell into a cancer cell. The research is headed by Renato Dulbecco, professor of biology, whose techniques of isolating and identifying viruses have made important contributions to medical research. These same methods were used in the development of the Salk vaccine.

The work, which will be carried on over a period of five years, could lead to important information about the basic cause of cancer. Working with Dr. Dulbecco will be Howard Temin, a graduate student; Dr. Lionel V. Crawford, a biologist; and Drs. Guiseppe Attardi and Roger Weil, both physicians.

Cooperative Wind Tunnel

The Southern California Cooperative Wind Tunnel may cease operations this June, due to a lack of demand for model testing. Caltech has operated the non-profit facility for five aircraft companies (Convair, Douglas, Lockheed, McDonnell and North American) since 1944. The tunnel was originally used for the study of military and commercial aircraft.

In 1954 an extensive modification was undertaken to adapt the tunnel to supersonic jet planes. Two specially built 20,000-horsepower motors were installed, which, at full capacity, were capable of using about half the electrical energy used in Pasadena. Although there is a slight possibility that operation will be continued beyond June on some other basis and on a greatly reduced scale, it is probable that the facility will be abandoned and scrapped.

CWT has been operated under the directorship of Clark B. Millikan, also director of Caltech's Guggenheim Aeronautical Laboratory; and Fred H. Felberg has been serving as associate director.

Alfred C. Ingersoll

Alfred C. Ingersoll, associate professor of civil engineering at Caltech, left the Institute last month to become dean of the School of Engineering at the University of Southern California. Dr. Ingersoll joined the Caltech staff in 1950, after receiving his MS and PhD at the University of Wisconsin. In the past few years, Dr. Ingersoll has also served as a specialist with the International Cooperation Administration.

A Stimulant for Red Cell Formation

Caltech biologists work on a substance which may eventually be useful in treating radiation injuries and anemias.

Caltech biologists are working on the isolation of a substance called erythropoietin, which stimulates the bone marrow to produce more red blood cells. This substance, a protein, may eventually be useful in treating certain anemias and radiation injuries. Samples of erythropoietin, obtained from the blood of anemic rabbits, have been sent to laboratories in various parts of the nation and Europe, where further research on the isolation and purification of the protein will be made.

Henry Borsook, professor of biochemistry at Caltech, is credited with being the first to learn how to prepare erythropoietin so that it could be injected into other animals. The injection causes a marked increase in red cell production in normal as well as in starving or anemic animals. Red blood cells transport oxygen from the lungs to body tissue and carry away carbon dioxide wastes. Anemia and radiation injuries reduce the red blood count necessary for health.

Erythropoietin has not yet been used on humans. Though all existing forms of purification have been tried, the substance has not been refined enough to try it on people. For another thing, it is not known whether there would be harmful immunological side effects. And finally, there is the problem of a supply source. The only practical way in sight at present to obtain the large amounts required for clinical use would be as a by-product, perhaps from large slaughter-house animals. No assay method has, as yet, been reliable or sensitive enough to detect erythropoietin in normal, healthy, large animals, If biologists could be sure that there is a detectable amount in unconcentrated normal blood, then it would be practical to extract and concentrate the substance from such blood.

Caltech scientists point out that perhaps the difficulty of finding evidence of the protein in the blood or urine of healthy humans and animals may mean that it is an emergency product synthesized only when the body needs more oxygen than it is getting – as in the case of anemias or sudden changes to high altitude. In a research done by Joseph Scaro at the Institute of Altitude Biology at San Salvador de Jujuy, erythropoietin was detected for several days in the urine of Argentine soldiers after they had been taken from sea level to 15,000 feet altitude in the Andes Mountains. However, most scientists believe that it does exist in healthy bodies, but in such minute quantities that its detection by present methods is uncertain.

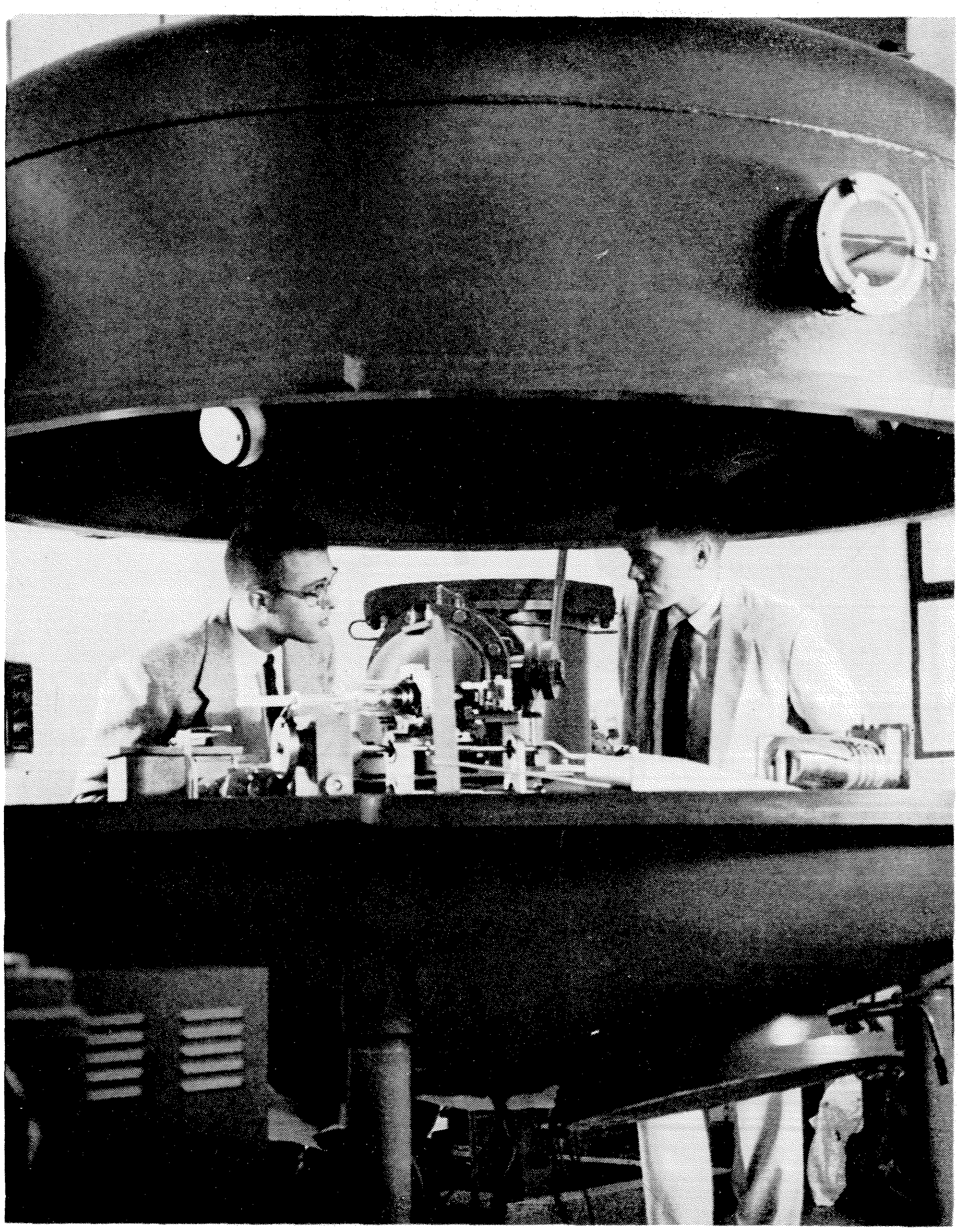
Erythropoietin works by persuading embryonic blood cells in the bone marrow to become red blood cells faster. Subcutaneous injections of it cause an observable increase in the reddening of the bone marrow, where blood cells are born.

Erythropoietin is easy to keep; dehydrated material remains active for several months or longer at room temperature and it will remain active in frozen plasma for over a year.

If erythropoietin can be purified sufficiently, the indications are that it can be used on humans. For instance, it is known that the protein from humans works on rats, mice and monkeys; and that material from dogs works on rats; and rabbit erythropoietin works on rats, mice and monkeys. For some strange reason, the only case where the substance from other animals doesn't work is in guinea pigs.

Although the present research is a large step toward a practical use of this precious substance, many questions remain to be answered. Caltech biologists will try to discover how to isolate the protein in a more pure form; how to detect small quantities of it to find out if there is more than one type; and to study its physiology.

Working with Dr. Borsook on the project are Drs. Geoffrey L. Keighley, senior research fellow in biology; Peter Lowy, research fellow in biology; and George Hodgson, MD, visiting National Academy of Sciences research fellow from the University of Chile in Santiago. The project is wholly supported by the American Cancer Society.



"We need public understanding of the role of the engineer and the place of the engineering function as a part of the technological process."

by
Frederick C. Lindvall

The Vanishing Engineer

The engineer, although he has been with us as a useful and productive member of society for 2,000 years, now suddenly seems to be vanishing from current popular literature.

In the Pasadena *Star-News* of February 24, 1960, a story begins: "Pasadena's foremost space scientist told a Washington committee . . ." After identifying the scientist as Dr. William H. Pickering, director of Caltech's Jet Propulsion Laboratory, the story quotes him as saying that the new NASA space program "represents bold and imaginative thinking based on solid engineering analysis." Dr. Pickering, for over 20 years a member of the electrical engineering faculty at Caltech, can and does identify that which is clearly engineering in the program. This example is typical of the loose public identification of technical developments as science. Indeed, so broadly have the terms "science" and "scientists" been applied to current developments that even the public relations staffs of some of our major engineering firms speak glowingly of the latest hot developments of the "scientists" in their laboratories.

Dr. James Killian, about a year ago, stated in a talk he gave in Detroit: "We need to bring more clearly into focus the image of the engineer in the minds of our citizens. Despite all the efforts of our engineering societies and councils, this image is not sharp nor accurate. For example, the lack of any clear distinction between the scientist and engineer has been manifest in all the recent public discussions of our national strength in science and technology. Some of the great engineering accomplishments of our time have come to be loosely tagged, in the public mind, under the generic title of science. This confusion is not in the interest either of science or engineering, and the scientists are as unhappy about the confusion as the engineers. I do not advocate any less emphasis on science and its importance. I do urge a comparable emphasis on the role and importance of the engineer."

Let me also summarize the statement of another engineering college administrator, who expressed a general reaction: He feels strongly that one of the serious problems in getting qualified young people to go into engineering schools is the great stress today on science — "with the almost total omission of painting the role of the engineer in society for the general public. The development of nuclear power, the development of the atomic submarine, the development of satellites are always spoken of as scientific achievements, when, of course, they are major engineering feats." Over the long run, if we are to "draw into engineering education those students who are eminently fitted and who can make major contributions, we have a major educational job to do. This requires a well-conceived and well-executed continuing plan of painting an accurate picture of what the engineer does and the kind of liberal training for a modern technological society which our very best engineering schools provide."

In this last statement lies the serious aspect of the problem of the vanishing engineer. If failure to receive due credit for engineering achievements were the sole reason for concern, this could be put in the "don't-give-it-a-second-thought department." But there is a very real effect of this emphasis on science which reflects itself in the college enrollment in engineering and science.

Shrinkage in engineering interest

At Caltech, where we have a fixed number of students (180) enrolled in the freshman class, the student choice of engineering and of science shows very dramatically the growth in science interest and a rapid shrinkage in engineering interest. In fact, a projection of the engineering enrollment figures leads quickly to the impression of the vanishing undergraduate engineer.

Our freshman class is not segregated as to option. This selection occurs at the end of the freshman year. So let us take a look at the percentage of the sophomore class electing engineering for the past few years. In 1953 and 1954 approximately one-half of the sophomore class chose engineering options. In 1955 the figure was 35%, in 1956 it was 38%, in 1957 it was 27%, and in 1958 it was 21%. At the same time, of course, because of the fixed enrollment, the percentages for science choice have gone up, to maintain a constant total of 100%.

Further examination of the student choices shows some interesting facts. Caltech's freshman class is selected from a much larger number of applicants, usually ranging from 1,200 to 1,500. On the application blank, each student states a career choice which, however, is not a factor in his admission. In 1953, 55% of all of the applicants declared for engineering as a career choice. This percentage held about constant until 1957, which marked a steady decline until, of the 1959 applicants, only 41% declared for engineering.

Engineering choices

This is really a much smaller decline than the actual engineering choices made by those students who were admitted to the Institute. The engineering interest shown by all of the applicants has fallen off a little faster than the national average, but not markedly so. For example, in 1957, engineering freshmen constituted 17.8% of all male freshmen in the nation. In 1958 the figure was 15% and in 1959 it was 13.6%. While freshmen college enrollment of all colleges has been going up, engineering enrollment has been going down in terms of absolute numbers and, of course, in terms of percentage.

Enrollment in other engineering undergraduate classes has also declined, but the full effect of the present shrinkage will not be felt in terms of graduating seniors until 1962 and 1963. At this time the number of engineering graduates per year will be substantially below the figures for 1959 and 1960. During this same period the USSR expects to nearly double the 1958-59 graduation rate of engineers. By all of the estimates made by the Engineering Manpower Commission, the future demand for engineers will increase, while at the same time the rate at which engineering graduates will be entering into the profession will be shrinking. This is a serious professional gap.

If engineering enrollment is dropping because of current glamor attached to the word "science"— is this bad? Can't the science graduates do engineering work? The answer is, of course, that some scientists can do engineering work if they have the interest and motivation for it. And what about the total numbers of scientists as compared with engineers, and the current interests of students who are studying science?

At a number of schools where engineering enrollment has been dropping and science enrollment has been increasing, most of the increase in science has been in physics and mathematics. But even if there are substantial increases in numbers of graduates in science, the contribution to the needs of technology will not be sufficient.

It is interesting to look at some overall figures. We have in the United States, at the present time, approximately 200,000 scientists; about 1/2 are chemists, 1/4 are biologists, 1/8 are in the earth sciences, 1/10 are physicists, and about 1/30 are mathematicians. (These and subsequent figures are from National Science Foundation sources.) Of these 200,000 scientists, approximately 45% or nearly one-half are in educational institutions. In the country we have approximately 600,000 engineers. This figure includes those who are graduated from engineering curricula or who practice engineering in the sense in which I have been using it; it does not include large numbers of people who have adopted the name "Engineer"--as, for example, the Brotherhood of Locomotive Engineers.

Educational background

It is interesting to make a comparison of the educational background of scientists and engineers. Consider the chemists, who represent about one-half of the total scientists. For 5%, formal education stopped before the Bachelor's degree; for 54%, formal education stopped at the Bachelor's degree; 17% earned the Master's degree; and 24% earned the Doctorate. Of the 20,000 physicists, 3% have no degree, 25% have the Bachelor's only, 27% the Master's only, and 45% have the Doctorate degree.

Among the 600,000 engineers, 27% had four years of high school or less, 17% had some college, 40% had four years of college, 14% had five years of college or more. Of this total number of 600,000 engineers, about 12,000, or only 2%, are in academic institutions. Hence, nearly all of the country's engineers are in industry or other professional practice; while, among the much smaller number of scientists, only about one-half are involved in direct contributions to technology. In this context, engineers outnumber scientists about 5 to 1, and outnumber physicists in industry about 50 to 1. So when we read of a new satellite as a great achievement of science, it is reasonable to suppose that a few engineers had something to do with it. Physicists can be useful but there aren't enough of them!

In the broad scope of science and technology which ranges from research through development, test, evaluation, production engineering, manufacturing, application, and marketing, on to ultimate use, some aspect of the engineering function may appear with greater or less emphasis. The role of the scientist working in science is normally in the research area where new discoveries are made, new physical principles identified and generalized, theories evolved, and new physical facts established. When a scientist works beyond this area, toward application or end use, he is not doing science in the normally accepted sense; he is performing functions better described as engineering or applied science. The engineer, in turn, frequently needs basic data or information which does not exist, and works in the laboratory to add to knowledge in precisely the way a scientist would. So it is not what he is called but what he does that is really the distinguishing feature.

And now let's get down to the difficult job of indicating what engineers do. I made some remarks at a symposium at Marquette University last spring entitled "On the Nature of the Engineer." Some of these thoughts may be helpful in this context.

The engineer is known by his works and his objectives. Long before the word "engineer" came into the language, certain men designed and built the structures of the ancient world, the palaces, the temples, fortifications, roads, and bridges. Fertile but arid lands were transformed by the miracle of irrigation into gardens for produce and for pleasure. Cities were made possible by water supplies brought from great distances in primitive aqueducts, and were made livable by development of systems of waste disposal. The early engineer exploited water transport through canals, locks, and stream improvement, and sought to control floods.

Gradually the ingenuity of man devised machines to replace human labor. The early engineer found new materials and new ways of improving old materials. His objective was to adapt nature to the needs and wants of mankind. But as he devised new schemes and new machines, he was also asking the question, "Why?" He was curious and sought to understand the workings of nature not solely for projection to new applications, but as new knowledge itself.

The beginnings of science

In his efforts to understand, we recognize the beginnings of science. Indeed, many of these early investigators whom we now call "scientists" were first of all pragmatic, practical fellows with specific objectives no different from those of engineers. And experimental science, beginning as early as the thirteenth century and flowering in the seventeenth, adopted empirical experimental methods then used by engineers and artisans. Engineering helped to stimulate the rise of modern science in the seventeenth century, and was in turn changed in character by the birth of applied science in the nineteenth.

Now mid-twentieth-century technology is again working at the frontiers of knowledge. Engineers and scientists jointly are seeking new information and as a team are developing new applications. A new engineering development or new instrumentation brings to light unexpected facts which extend our knowledge in corroboration of existing history, or force re-examination of popular hypotheses.

As Francis Bello aptly stated in *Fortune* ("The 1960's: A Forecast of the Technology," January 1959): "The point where technology leaves off and science begins – the distinction between applied and basic research – has become increasingly fuzzy. In the 60's it will become fuzzier yet, for the great research tools that will dominate physical science in the years ahead will be engineering marvels first and research tools second."

The teamwork is so close that a clear identification of the engineering and science functions is difficult, if indeed such identification is significant. Similarly, the nature of the engineer becomes less clear in our most advanced technological developments. He is not the boots-and-breeches engineer of hoary tradition; neither is he the white-coated scientist of Madison Avenue fiction. Is he, in fact, becoming an applied scientist, or does he have distinctive attributes as an engineer? The answer has more than casual significance for engineering as a profession, and profound implications for engineering education.

Education for the age of science

Several years ago the President's Science Advisory Board created a panel to consider problems in science and engineering education. This panel prepared a paper ("Education for the Age of Science") which attempted to define problem areas and propose some recommendations. The scientist, as defined in this paper, is one who seeks to extend the boundaries of knowledge in his chosen field. The engineer has the task of combining the knowledge of science with his knowledge and awareness of the needs and limitations of human beings and of a human society to develop and create new "things" for human use. These things may vary from a tiny transistor to a huge dam, from a hearing aid to a super-highway, an automobile, an airplane, or a space vehicle. While the scientists have uncovered the basic knowledge, it is the engineers who have created the tangible tools, materials, and products that have revolutionized our daily lives, our community living, and our national defense.

The scientist and the engineer form the team that paces today's technology. In science lie the foundations upon which the engineer builds toward a goal of the utility, comfort, and advancement of man. He is concerned with machines, the environment in which they operate, and with the men who work with them and effect their control. He is further distinguished from his colleagues in science in his constant concern to achieve an optimum design to meet the many and frequently conflicting criteria of performance, reliability, efficiency, cost, and productibility. The associated synthesis, analysis and design of an element or a system are unique characteristics of engineering.

The profession of engineering has thus become one of the most important in modern society. Our civilization would deteriorate, would become too weak to survive in modern world competition without the work of the hundreds of thousands of trained men (and the too-few women) who keep the wheels of industry turning, who create new and useful products, who envisage, design, and build great factories, intricate communication, power and transportation systems, and vast irrigation, navigation, and flood-control projects. The scientist and engineer have created for the first time in history a society potentially free from want – one more concerned, in fact, with surplus than with scarcity of many material products, as well as a society in which freedom from back-breaking toil has been largely achieved. Finally, in today's great international competition, America's ability or inability to help others in their engineering progress may be crucial.

In this definition of the engineer I stress the design function, the creative effort, and the objective weighing of alternatives which mark the good engineer and always have. Some 60 years ago A. M. Wellington, an engineer, wrote a book in which he discussed the problems of railway location. To paraphrase Wellington, no matter how forbidding a region, nor how many feasible routes there may be, one route exists which will be superior to all others in overall long-range cost, and it is the essence of good engineering to find that optimum solution. This statement could easily apply to present-day engineering systems, but the details are much more complex and cover a wider range of the physical sciences.

A lively motivation

The engineer has the lively motivation of finding the best solution to a problem, and as time goes on he has at his disposal new tools which allow him to analyze larger problems with more assurance. Analog and digital computers are rapidly becoming important design tools, and it is possible to make synthetic solutions to problems and discover the effects of varying any of the parameters which can affect the end result.

Civil engineering structures, for example, lend themselves well to computer techniques and give the engineer an opportunity to run quickly through several alternative designs to give the one which most nearly meets all of his design objectives. For example, an analysis of a concrete arch dam has recently been made electronically, and the engineers had the satisfaction of varying several important boundary conditions and constraints – a change in any one of which would have required several days more of desk-type calculation.

Computers, of course, are no substitute for the creative effort required in engineering synthesis and design. The engineer must first create a system or a device which he expects to be a reasonable solution to his problem. The engineer can then proceed to analyze this proposed solution for its feasibility and possible performance. Depending upon circumstances, this analysis may be simple or complex. It may be that the analysis can be done through the medium of a mathematical model and can be handled on a modern computer. But this basic design calls for creative effort of a high order. Then, as the analysis proceeds, modifications develop and a final configuration emerges. It may become apparent that essential information is lacking. Basic science has failed to give necessary information in ranges of temperature or stress or corrosive conditions which are inherent factors in the new design. Then the engineer must undertake to develop this new information for himself. He will then be working as a scientist and his work may be indistinguishable from that of the scientist as to technique or information sought. But he has a definite engineering objective. He knows why he needs the information, where he is going, and when he is expected to arrive with the finished design.

The engineer has always had to work without complete knowledge of his materials. One of our commonest materials, mild steel, has some peculiar properties which other steels and non-ferrous materials do not have. Among other properties, mild steel has the annoying one of fracturing in a brittle manner at moderately low temperatures. The temperature at which the nature of failure changes from plastic to brittle is called the "transition temperature," which describes but does not explain the effect. Certain recent work promises to yield an explanation, but in the meantime hundreds of annoying brittle failures have occurred because we do not know how to eliminate the transition or how to push the transition temperature far below normal environmental temperatures.

Engineer and medical practitioner

In some ways the engineer functions in the service of mankind the way the medical practitioner does. The recent development of polio vaccine is a good example. Basic research on the nature and behavior of the polio virus has been underway for some time, but, rather than wait until everything is known about the polio virus, Dr. Salk undertook the development of the vaccine which has had such dramatic and effective results in removing most of the curse of polio.

But engineering of today is clearly in a state of transition. New developments in science which have claimed the attention of scientists have left the engineer with large areas of what are called classical physics and chemistry which he must explore for himself if he wishes to develop the new knowledge he needs for application. Much of physics has become the domain of the engineer – including the physical properties of materials at extended temperature, solid state physics, electricity and magnetism, physical electronics, theoretical mechanics, thermodynamics, spectroscopy, and thermodynamic properties.

The engineer has also become increasingly concerned with problems of chemistry, particularly reaction kinetics and combustion processes. And the engineer today is perhaps the most important contributor to applied mathematics and to computer logic and design.

We can look ahead and see many problem areas which will require engineering solutions. For example, energy conversion is assuming greater and greater importance. Considering electrical power systems alone, we have in the United States a total generating capacity of nearly one kilowatt per person – and this is a point on a curve which has shown a doubling approximately every ten years. But, in addition to conventional energy conversion, ideas are beginning to emerge which are based on nuclear reaction (fission now and fusion a little later), on fuel cells which make direct chemical conversion, with energy release not limited by thermodynamic temperature considerations, and on solar or other radiation. Fuel cells of efficiency comparable to that of a modern thermoelectric station could change radically the complexion of our public utility systems in terms of generation and distribution. It is not fanciful to think of automobiles powered by fuel cells and electric motors. Indeed, one of the automotive research laboratories has mentioned this dream car.

Materials are both a handicap and a challenge for the engineer. "If," as one writer maintains, "any one factor were to be singled out as holding back progress in atomic power and other advanced technologies, it would be lack of suitable engineering materials – particularly metals and alloys. The materials situation is regarded as so serious that a number of worried scientists are urging that the government establish a major new research institute wholly devoted to the problem . . . The problem in metallurgy is easy to state: There has as yet been no major breakthrough in metals comparable to the transistor in electronics, nylon in high polymers, or nuclear fission in energy creation."

The engineer of the future

Clearly, the engineer of the future has opportunities and responsibilities beyond those which we know today. His capabilities in science, in analysis, and in design call for continuing professional development. Furthermore, the sophistication of the components and the complexity of the systems with which the engineer must work will call for educational effort which goes beyond the present, if he is to function as a truly professional man.

Then, in addition to the greater understanding of modern science, and the synthesis of knowledge into engineering systems, a third function of the engineer is growing in importance. This is his management and technical leadership function. His education must include substantial work in the humanities and the social sciences, in addition to facility in communicating his ideas and understanding those of others.

The repeated plea from industry that engineers

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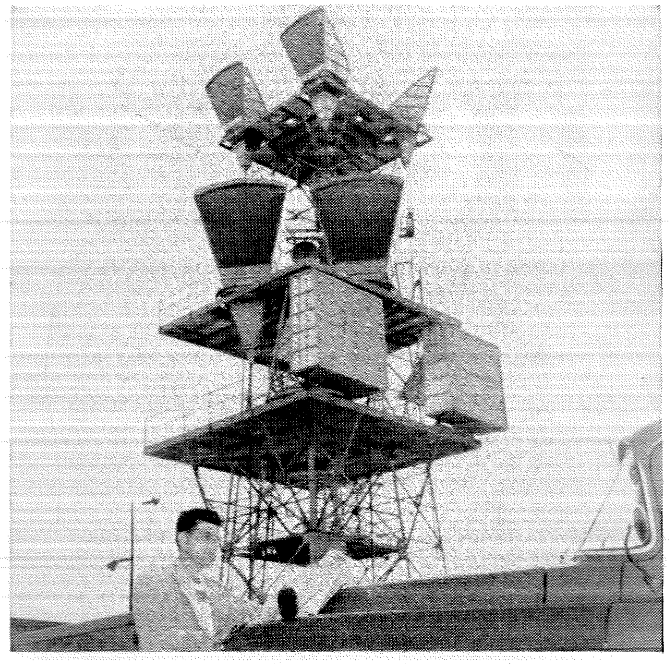
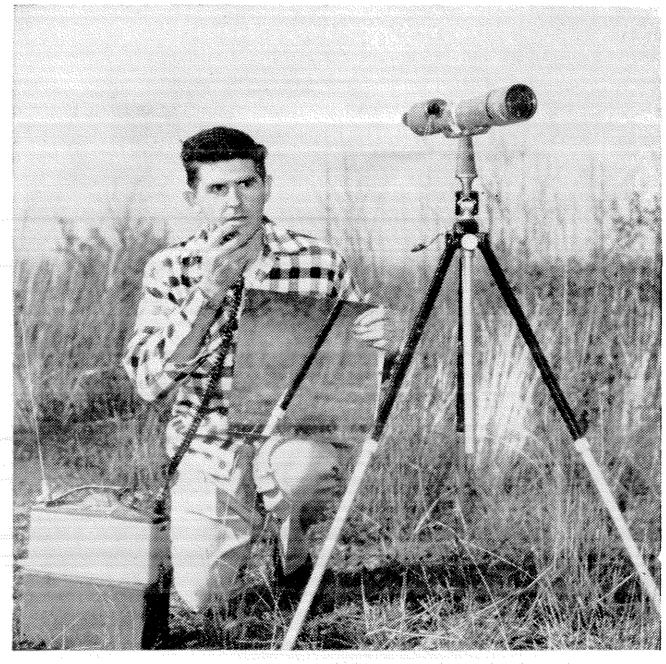


Dick Ernsdorff studies a microwave site-layout chart atop a mountain near Orting, in western Washington state. On assignments like this, he often carries $25,000 worth of equipment with him.



Here, Dick checks line-of-sight with a distant repeater station by mirror-flashing and confirms reception by portable radio. Using this technique, reflections of the sun's rays can be seen as far as 50 miles.

He wears two kinds of work togs

For engineer Richard A. Ernsdorff, the "uniform of the day" changes frequently. A Monday might find him in a checkered wool shirt on a Washington or Idaho mountain top. Wednesday could be a collar-and-tie day.

Dick is a transmission engineer with the Pacific Telephone and Telegraph Company in Seattle, Washington. He joined the company in June, 1956, after getting his B.S.E.E. degree from Washington State University. "I wanted to work in Washington," he says, "with an established, growing company where I could find a variety of engineering opportunities and could use some imagination in my work."

Dick spent 2½ years in rotational, on-the-job training, doing power and equipment engineering and "learning the business." Since April, 1959, he has worked with microwave radio relay systems in the Washington-Idaho area.

When Dick breaks out his checkered shirt, he's headed for the mountains. He makes field studies involving microwave systems and SAGE radars and trouble-shoots any problem that arises. He also engineers "radar remoting" facilities which provide a vital communications link between radar sites and Air Force Operations.

A current assignment is a new 11,000 mc radio route from central Washington into Canada, utilizing reflectors on mountains and repeaters (amplifiers) in valleys. It's a million-dollar-plus project.

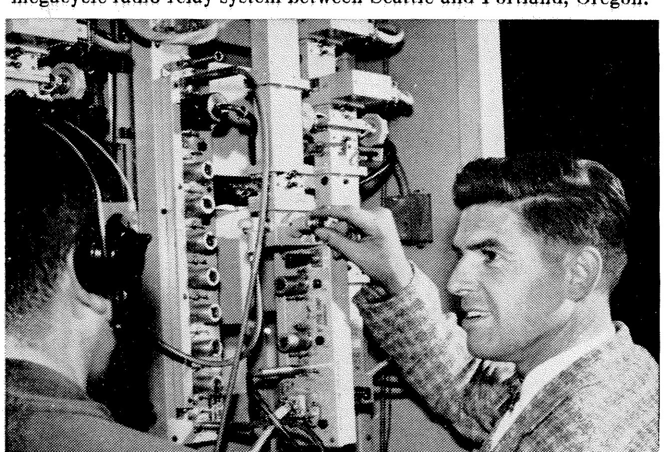
"I don't know where an engineer could find more interesting work," says Dick.

* * *

You might also find an interesting, rewarding career with the Bell Telephone Companies. See the Bell interviewer when he visits your campus.

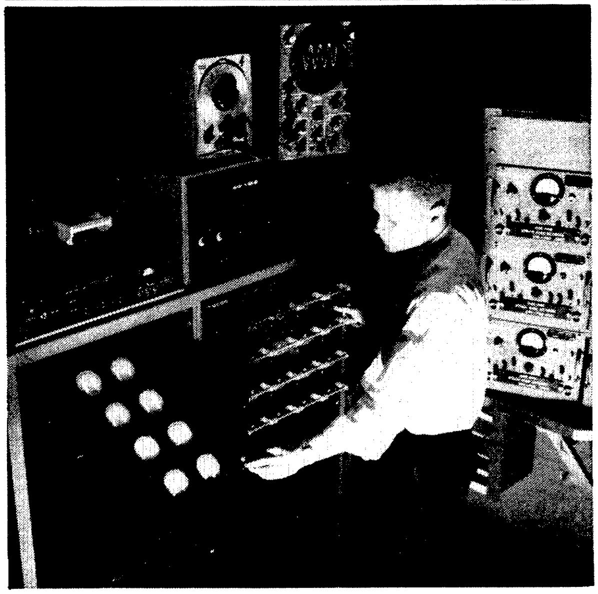
BELL TELEPHONE COMPANIES

Dick stops by the East Central Office building in Seattle to look at some microwave terminating equipment. It's involved in a 4000 megacycle radio relay system between Seattle and Portland, Oregon.

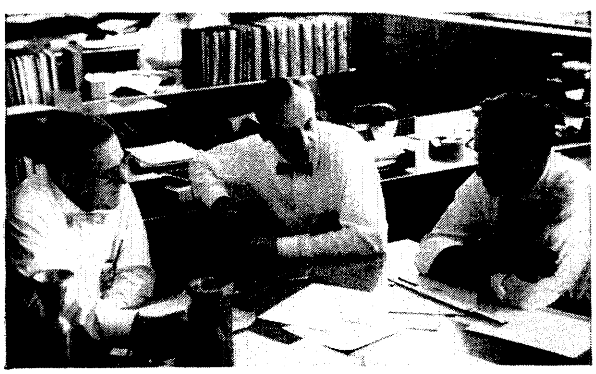


In the Engineering Lab in downtown Seattle, Dick calibrates and aligns transmitting and receiving equipment prior to making a path-loss test of microwave circuits between Orting and Seattle.

engineers



Automatic systems developed by instrumentation engineers allow rapid simultaneous recording of data from many information points.



Frequent informal discussions among analytical engineers assure continuous exchange of ideas on related research projects.

Under the close supervision of an engineer, final adjustments are made on a rig for testing an advanced liquid metal system.

and what they d

The field has never been broader
The challenge has never been greater

Engineers at Pratt & Whitney Aircraft today are concerned with the development of all forms of flight propulsion systems—air breathing, rocket, nuclear and other advanced types for propulsion in space. Many of these systems are so entirely new in concept that their design and development, and allied research programs, require technical personnel not previously associated with the development of aircraft engines. Where the company was once primarily interested in graduates with degrees in mechanical and aeronautical engineering, it now also requires men with degrees in electrical, chemical, and nuclear engineering, and in physics, chemistry, and metallurgy.

Included in a wide range of engineering activities open to technically trained graduates at all levels are these four basic fields:

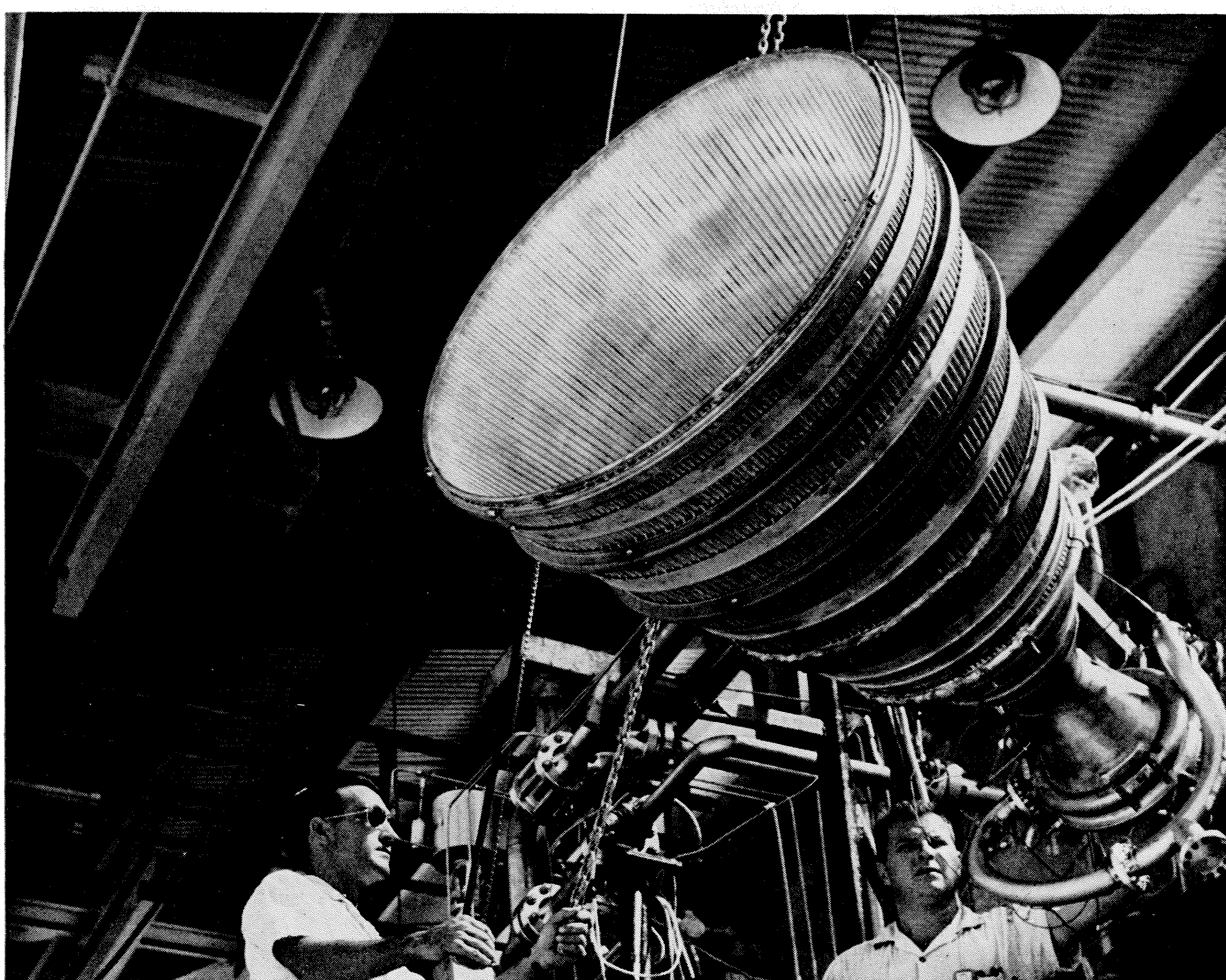
ANALYTICAL ENGINEERING Men engaged in this activity are concerned with fundamental investigations in the fields of science or engineering related to the conception of new products. They carry out detailed analyses of advanced flight and space systems and interpret results in terms of practical design applications. They provide basic information which is essential in determining the types of systems that have development potential.

DESIGN ENGINEERING The prime requisite here is an active interest in the application of aerodynamics, thermodynamics, stress analysis, and principles of machine design to the creation of new flight propulsion systems. Men engaged in this activity at P&WA establish the specific performance and structural requirements of the new product and design it as a complete working mechanism.

EXPERIMENTAL ENGINEERING Here men supervise and coordinate fabrication, assembly and laboratory testing of experimental apparatus, system components, and development engines. They devise test rigs and laboratory setups, specify instrumentation and direct execution of the actual test programs. Responsibility in this phase of the development program also includes analysis of test data, reporting of results and recommendations for future effort.

MATERIALS ENGINEERING Men active in this field at P&WA investigate metals, alloys and other materials under various environmental conditions to determine their usefulness as applied to advanced flight propulsion systems. They devise material testing methods and design special test equipment. They are also responsible for the determination of new fabrication techniques and causes of failures or manufacturing difficulties.

it Pratt & Whitney Aircraft...



Exhaustive testing of full-scale rocket engine thrust chambers is carried on at the Florida Research and Development Center.

For further information regarding an engineering career at Pratt & Whitney Aircraft, consult your college placement officer or write to Mr. R. P. Azinger, Engineering Department, Pratt & Whitney Aircraft, East Hartford 8, Connecticut.

PRATT & WHITNEY AIRCRAFT

Division of United Aircraft Corporation

CONNECTICUT OPERATIONS — East Hartford

FLORIDA RESEARCH AND DEVELOPMENT CENTER — Palm Beach County, Florida should have such breadth leaves no doubt concerning the importance of the humanities. Furthermore, we are urged as educators to omit practical training such as labor relations, personnel management, and similar things which have little meaning for the young graduate, and which industry can supply more effectively later on. In short, industry believes it can do a better job than colleges can in giving supervisory or management training, but that the colleges can function better in their traditional role of education in the broad social-humanistic areas. Also, in the broader sense, engineers have come to value the humanities as fundamental to understanding man in his social environment. The engineer thus recognizes his growing professional responsibility.

Now comes the important question: Can the necessary basic science, the engineering sciences, synthesis and design, and the humanities be fitted into a four-year program? In a superficial way, yes – but not with the level of comprehension needed for tomorrow's work. Everything points to the necessity for more extensive education than is possible in a four-year BS program. More graduate work will be essential for the engineering leaders of the future; and the pressure for it is evident now. The objective must be an education which will have the breadth to permit broad-scale systems thinking, and at the same time have sufficient depth to permit the necessary specialization.

Who designs the hardware?

Mr. Luke Noggle of the Westinghouse Company has written: "This science education is fine, but who is going to design the hardware? There is emerging a new type of educational institution which expects to train personnel to handle this type of work. These schools are engineering-oriented technical institutes and feature a two-year terminal program. Such programs comprise specialized courses which prepare the student for a particular technology. Since these programs are for only two years' duration, naturally much of the instruction is directed toward a particular field such as industrial control, electronics, power and radio engineering.

"The student's preparation is up-to-date in these technologies and the course content in the applied sciences approaches an equivalent of a BE degree earned ten to fifteen years ago. It is possible to find some of these schools teaching the application of differential equations in circuit analysis, the use of vector analysis in field theory and the use of LaPlace Transformations in transients. These are exceptions, but most of the accredited technical institutes offer course work using the applications of differential and integral calculus. The graduates from these schools could easily, with practical training and experience, be placed in many positions which are normally reserved for the college graduates in engineering."

Our colleagues in science have never regarded the Bachelor's degree as anything but a good start. Real professional education comes in graduate work. Engineering is rapidly approaching this state. It is also clear that engineering art and practice does not belong in college instruction, but is knowledge which industry should expect to provide. The college responsibility, in turn, should be for more intensive education, extending beyond our conventional four years, including greater emphasis on creative design and the synthesis of more comprehensive systems.

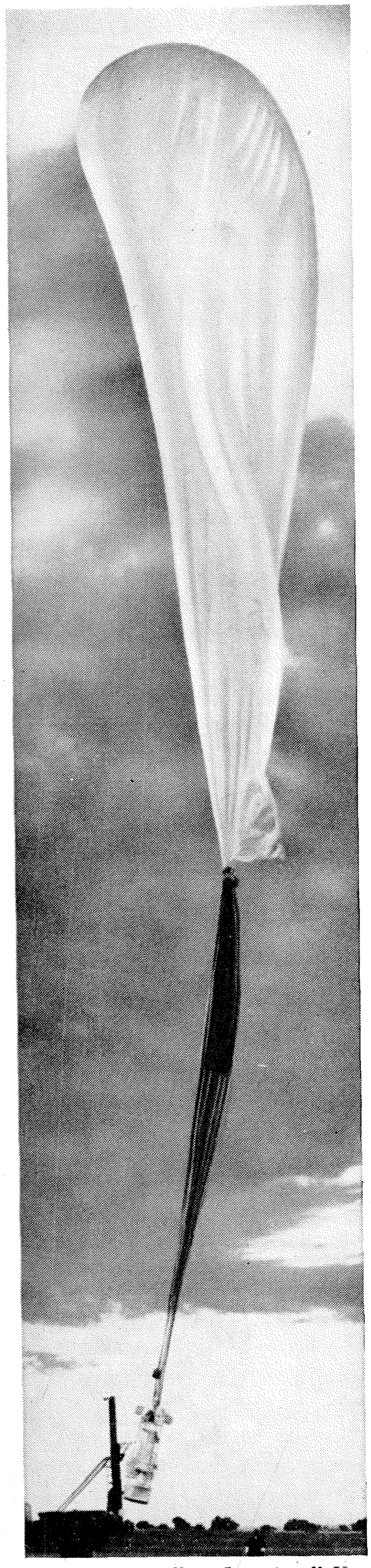
New areas, new problems

Going back to total engineering figures (600,000), we must conclude that not all of these engineers are capable of modern technological advances. A relatively small number have the education and background to apply modern science to the new needs and wants of mankind. What is needed is more engineers who have the basic education and the flexibility to move into new areas, attack new problems, conceive new applications. In other words, we need engineers who can work with scientists, but who are motivated toward new applications and new uses of scientific information, who can see the device or system to meet a need and who can, if necessary, work *as* scientists to develop new knowledge and new information to supply basic ideas, principles, and facts which may not now exist.

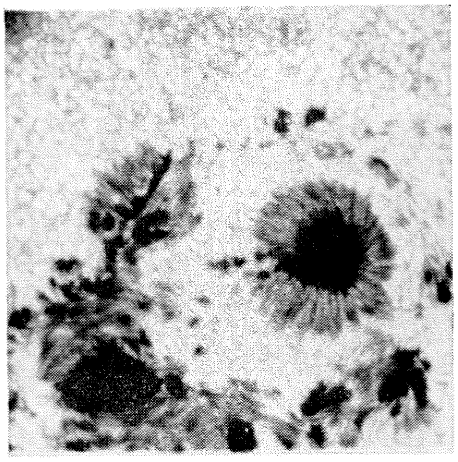
This kind of engineer does not rely solely on the "state of the art," nor on handbook information. He is a pioneer in advanced technology, as his colleague in science is a worker on the frontiers of knowledge. This engineer needs the same type of basic education and research experience as the scientist does if their partnership is to be effective.

It follows, then, that the engineer shall have an education similar to that of the scientist in fundamentals, methods, and extent – but distinct and different in objective and motivation.

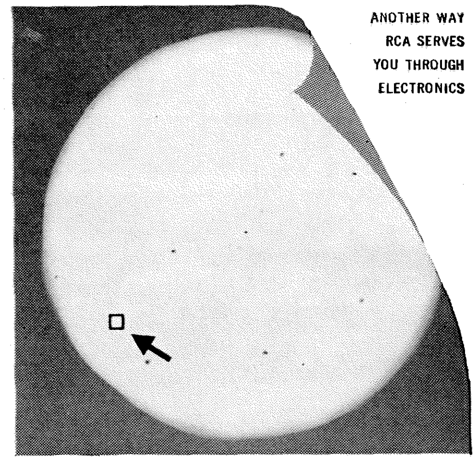
All of this points to more and better education for engineers; to higher professional standards for engineering practice; to better support for engineers in the less exciting details of their work. We need public understanding of the role of the engineer and the place of the engineering function as a part of the technological process. Science provides support but not end objectives. The engineer must be recognized as a man of action with a high order of versatility in application of new knowledge to practical problems. He is a new kind of engineer. He is not vanishing; he is changing.



Going up for "good seeing." Unmanned balloon-observatory starts its ascent to take sunspot photos. "Project Stratoscope" is a continuing program of the Office of Naval Research and the National Science Foundation.



One of the sharpest photos ever taken of sun's surface. It, and hundreds of others taken by stratoscope, may answer mystery of violent magnetic disturbances on earth.



Exact position of photograph in relation to the total sun surface is shown here. Plotting and photography of precise areas was made possible by airborne RCA television.

RCA REPORTS TO THE NATION:

REMARKABLE NEW PHOTOS UNLOCK MYSTERIES OF SUN'S SURFACE

Special RCA Television, operating from stratosphere, helps get sharpest photos of sun's surface ever taken

Scientists recently took the first, sharp, searching look into the center of our solar system. It was achieved not by a missile, but by a balloon posted in quiet reaches of the stratosphere.

The idea was conceived by astronomers at the Princeton University Observatory. They decided that a floating observatory—equipped with a telescope-camera—would offer a stable "work platform" from which sunspots could be photographed free of the distortion caused by the earth's atmosphere.

But "Project Stratoscope" encountered an unforeseen and major obstacle on its initial flight. A foolproof method was needed for aiming and focusing the telescope of the unmanned observatory. Princeton asked RCA to help.

A special RCA television system was devised which enabled observers on the ground to view exactly what the telescope was seeing aloft. This accomplished, it was a simple matter to achieve precise photography—directed from the ground by means of a separate RCA radio control system.

The resulting pictures reveal sunspot activities in unprecedented detail. They provide the world with important information regarding the magnetic disturbances which affect navigation and long-range communications.

The success of "Project Stratoscope" is another example of RCA leadership in advanced electronics. This leadership, achieved through quality and dependability in performance, has already made RCA Victor the most trusted name in television. Today, RCA Victor television sets are in far more homes than any other make.

RADIO CORPORATION OF AMERICA

THE MOST TRUSTED NAME IN ELECTRONICS

BRING ON THE GIRLS!

Few tears should be shed over the lot of the Caltech undergraduate – large scholarships, hearty fellows, superb faculty, and a pleasant climate more than compensate for the rigors of the scientific life. Yet, as jealous members of less fortunate communities are quick to point out, there is a worm in the Caltech apple. Namely, there are no girl scientists to lighten and brighten the Techman's daily toil. Caltech has been, is, and will remain 100 percent male.

If our undergraduates were as dedicated to Science ("twitchy") as these same critics often contend, the absence of women would pose no problem. Alas, this is not the case. Comes the Vernal Equinox and even a physicist will drop his book to the Athenaeum lawn, sniff the musky air, and think to himself, "Hmmmmm, I could do with a date this term."

Where to search for the missing female? This question has more or less confounded forty years of Techmen. A partial answer, based on the cumulative experience of one generation's students, is given in the ensuing catalogue. Of course, it has been practical to list only the *main* sources of local pulchritude. This in no way detracts from those hardy pioneers whose ingenuity and perseverance uncovered many a minor windfall where none was thought to exist.

Occidental College

"Nine out of ten girls are beautiful, and the tenth one goes to Oxy." So runs the old folk myth, and so it may seem to the hapless freshman, beginning his Tech social career with a blind date from our nearest neighboring college.

Like most myths, this one has little basis in fact. Not all ugly girls go to Oxy; only those with the more vicious personality traits are allowed to matriculate. On the other hand, not all Oxy girls are ugly. A small minority are beautiful of soul and body, and a small minority of these will even date Techmen.

Occidental College prides itself on its high academic standards, and one might suspect that the brainy Oxy girl would be a perfect match for the

continued on page 36

...THE EXPLORATION OF SPACE

Since its inception nearly 23 years ago, the Jet Propulsion Laboratory has given the free world its first tactical guided missile system, its first earth satellite, and its first lunar probe.

In the future, under the direction of the National Aeronautics and Space Administration, pioneering on the space frontier will advance at an accelerated rate.

The preliminary instrument explorations that have already been made only seem to define how much there is yet to be learned. During the next few years, payloads will become larger, trajectories will become more precise, and distances covered will become greater. Inspections will be made of the moon and the planets and of the vast distances of interplanetary space; hard and soft landings will be made in preparation for the time when man at last sets foot on new worlds.

In this program, the task of JPL is to gather new information for a better understanding of the World and Universe.

"We do these things because of the unquenchable curiosity of Man. The scientist is continually asking himself questions and then setting out to find the answers. In the course of getting these answers, he has provided practical benefits to man that have sometimes surprised even the scientist.

"Who can tell what we will find when we get to the planets? Who, at this present time, can predict what potential benefits to man exist in this enterprise? No one can say with any accuracy what we will find as we fly farther away from the earth, first with instruments, then with man. It seems to me that we are obligated to do these things, as human beings."

DR. W. H. PICKERING, *Director, JPL*

jpl

CALIFORNIA INSTITUTE OF TECHNOLOGY

JET PROPULSION LABORATORY

A Research Facility operated for the National Aeronautics and Space Administration

PASADENA, CALIFORNIA

Employment opportunities for Engineers and Scientists interested in basic and applied research in these fields:

INFRA-RED • OPTICS • MICROWAVE • SERVOMECHANISMS • COMPUTERS • LIQUID AND SOLID PROPULSION • ENGINEERING MECHANICS STRUCTURES • CHEMISTRY • INSTRUMENTATION • MATHEMATICS AND SOLID STATE PHYSICS

Send professional resumé for our immediate consideration. Interviews may be arranged on Campus or at the Laboratory.

cerebral Caltech lad. Unfortunately, this is not usually the case.

In the first place, Occidental seems to attract a majority of "over-achievers" rather than true psuedo-intellectuals.

Secondly, Oxy girls are shot through with "Oxy spirit," a particularly saccharine form of college rah-rah, repellent to the really-care Techman.

Finally, and most divisive, is the religious chasm separating the two schools. Occidental is a "Christian College," and a majority of Oxy girls tend to run with the Billy Graham crowd. Combine this with "Pagan Tech," and you have all the ingredients of a Holy War.

Advice concerning Oxy:

Before date – read the Good Book
During date – forget sick jokes
After date – forget date

Scripps College

Physically three times further from Caltech than her Oxy counterpart, the average Scripps girl is spiritually much closer to the Tech ideal: lazy, slovenly, lacking in moral fibre and the Protestant Ethic, she scorns the accumulation of mere facts, depending instead on flashingly incorrect insight.

Having presented her good side, fairness forces me to reveal the Scrippsie's two main drawbacks:

I – She often falls in love with residents of nearby Claremont's Men's College, southern California's wealthiest penal colony.

II – She lives in Claremont, centrally located between San Bernardino and Azusa. Once there, there's nothing to do; once gone, it's too far to come back.

What about looks? The following jingle may prove a useful mnemonic guide to the various dorms:

Dorsey's child is fair of face,
Browning's child takes second place,
Toll's child is mediocre,
Grace Scripps' child is three-fourths ogre.

Pasadena City College

One must remember that PCC is primarily a device for the extension of adolescence. Hence, on the great "stuff" scale, (married stuff, young stuff, expensive stuff) most PCC girls rate as stupid stuff.

Neverthless, aside from the notable convenience, there is substantial prestige associated with dating at our Hill Street neighbor. One need not search far for the answer: PCC is the home of the Rose Queen and the Rose Princesses. What greater thrill than to write the folks back in Minnesota that *you*, country hick a mere two years ago, now are lavishing your scholarship money on a member of the fabled Rose Court? Even if you can't reach these royal heights (and you probably can't), there's always the "final twenty-five" to choose from. Empirical evidence suggests that each year at least 800 girls make the final twenty-five.

Miscellaneous advice: Being vaguely aware of Caltech, the PCC girl's first question is likely to be, "What's your IQ?" The proper answer is "192." This will be instantly believed, and is high enough to make you worthwhile dating (once!) just to tell the kids back at the soda bar.

It is not difficult to amuse your PCC date. Left to her own devices, she and her crowd are slavish ruiners of good places. In San Francisco she'll visit the Top of the Mark, in Hollywood it's the Unicorn or Grauman's Chinese. Give her a ride up Angel's Flight or take in an experimental movie. She'll treasure you always as her Count of Monte Cristo.

L. A. County Hospital Nurses School

Tired of prima donnas? Sick of intellectual pretension? Disgusted with mealy-mouthed idealism? Date a Nurse!

Nurses do filthy work ten hours a day – they're *grateful* to go out! Nurses see life as it really is! They like what they see! Nurses are clever, flattering, unneurotic, enjoyable, good for the mind and the body. Oh, yes, they're almost all very ugly.

One word concerning nurses: They have heard *all* the bedpan jokes; it will not raise your stock to tell them again. Relax, enjoy yourself. There's no date like a nurse date. Just one and you'll be able to take out girls again.

Miscellaneous Sources

PASADENA PLAYHOUSE: Home of the how-now-brown-cow set. Unless you enjoy discussing theatre to the exclusion of all other earthly subjects, forget about P.P. There's a fascinating story behind every Playhouse girl. Let me tell it to you sometime.

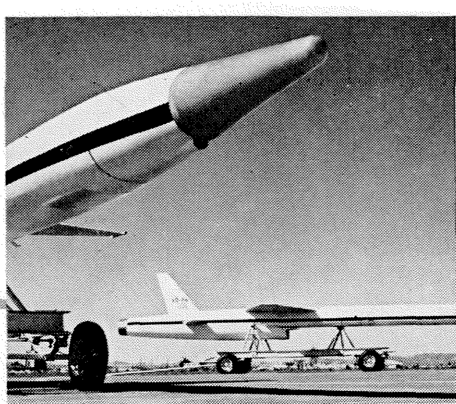
BULLOCK'S DEPARTMENT STORE: This is a dependable source only during the pre-Christmas rush season, when a large amount of feminine labor is employed to help bait the public. A good ploy is the "millionaire's eccentric young son" pose. Prerequisites are two-days' beard, Tech-quality clothes, and a shuffly walk. Reject all suggested items as too inexpensive.

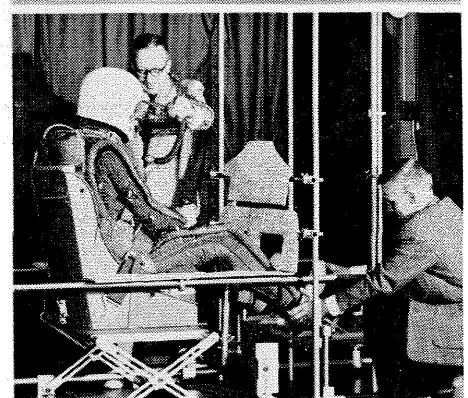
LOCAL HIGH SCHOOLS: Most notable of these is Westridge, training ground for tomorrow's entrenched wealth. Freud is king in this neck of the woods, so come armed with libido and id. Not a place for those above preying on other's neuroses.

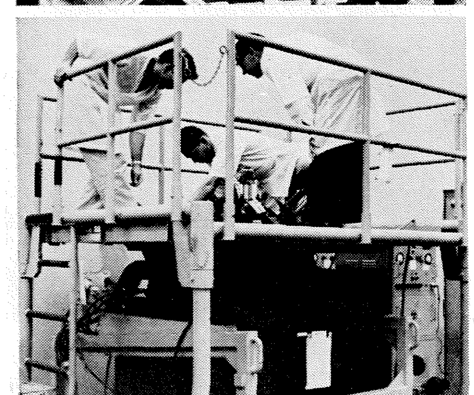
– Brad Efron '60

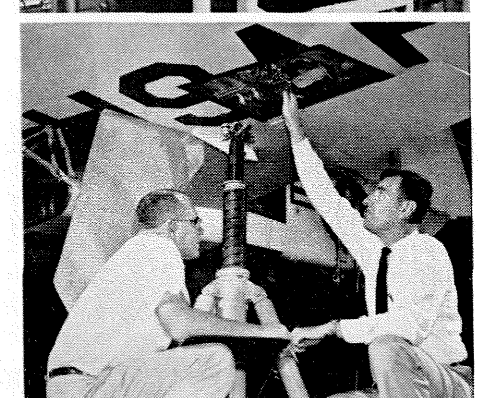
...NEWS IS HAPPENING AT NORTHROP

Take this 3-Minute Quiz to help you determine your future









1. *What part of the country has the best future for your type of work?*
2. *What part of the country offers an outstanding opportunity to enjoy your leisure?*
3. *Where can you work and still earn advanced degrees?*
4. *How important to you is the challenge of opportunity — and salary that matches your achievements?*
5. *Where can you work with outstanding men in your field?*

FIVE IMPORTANT QUESTIONS... NOW CONSIDER THESE ANSWERS:

1. If your interests are in the fields of electronics or the aircraft/missile industry, you will want to join the outstanding scientists and engineers in the space age center of the world – Southern California.

2. If you work at Northrop you will live in Southern California – famous for its year-round vacation climate. Here you're close to the beaches, mountains and desert where you can enjoy an active life in the sunshine.

3. Northrop encourages you to work for advanced degrees and to keep current with the latest developments in your chosen field. With Northrop's program, you will continue to learn while you earn with no-cost and low-cost education at leading Southern California institutions.

4. At Northrop you will work with the newest, most-advanced research and test equipment. And with over 30 operational fields from which to choose you can apply your talents to the work you enjoy–in the fields best suited to your inclinations.

At Northrop you will earn what you are worth. With this growing company you receive increases as often as you earn them. And these increases in salary are based on your own individual achievements.

Northrop's vacation and fringe benefits are extra liberal.

5. Men you work with at Northrop are acknowledged leaders in their fields. They are selected because they have the skill to guide younger men. These are men who know how to delegate authority, encourage your progress, and assure you of your fair share of credit for engineering achievements.

IT'S NOT TOO EARLY TO PLAN YOUR FUTURE. WHICH OF THESE 3 DIVISIONS OF NORTHROP ARE BEST FITTED TO YOUR TALENTS?

NORAIR DIVISION is the creator of the USAF Snark SM-62 missile now operational with SAC. Norair is currently active in programs of space research, flight-testing the USAF-Northrop T-38 Talon trainer and Northrop's N-156F Freedom Fighter.

RADIOPLANE DIVISION, creator of the world's first family of drones, produces and delivers pilotless aircraft for all the U. S. Armed Forces to train men, evaluate weapon systems, and fly surveillance missions. Today Radioplane is readying the recovery system for Project Mercury.

NORTRONICS DIVISION is a leader in inertial and astronertial guidance systems. Nortronics explores infrared applications, airborne digital computers, and interplanetary navigation. Other current programs include ground support, optical and electro-mechanical equipment, and the most advanced data-processing devices.

Write today for complete information about your future at Northrop.

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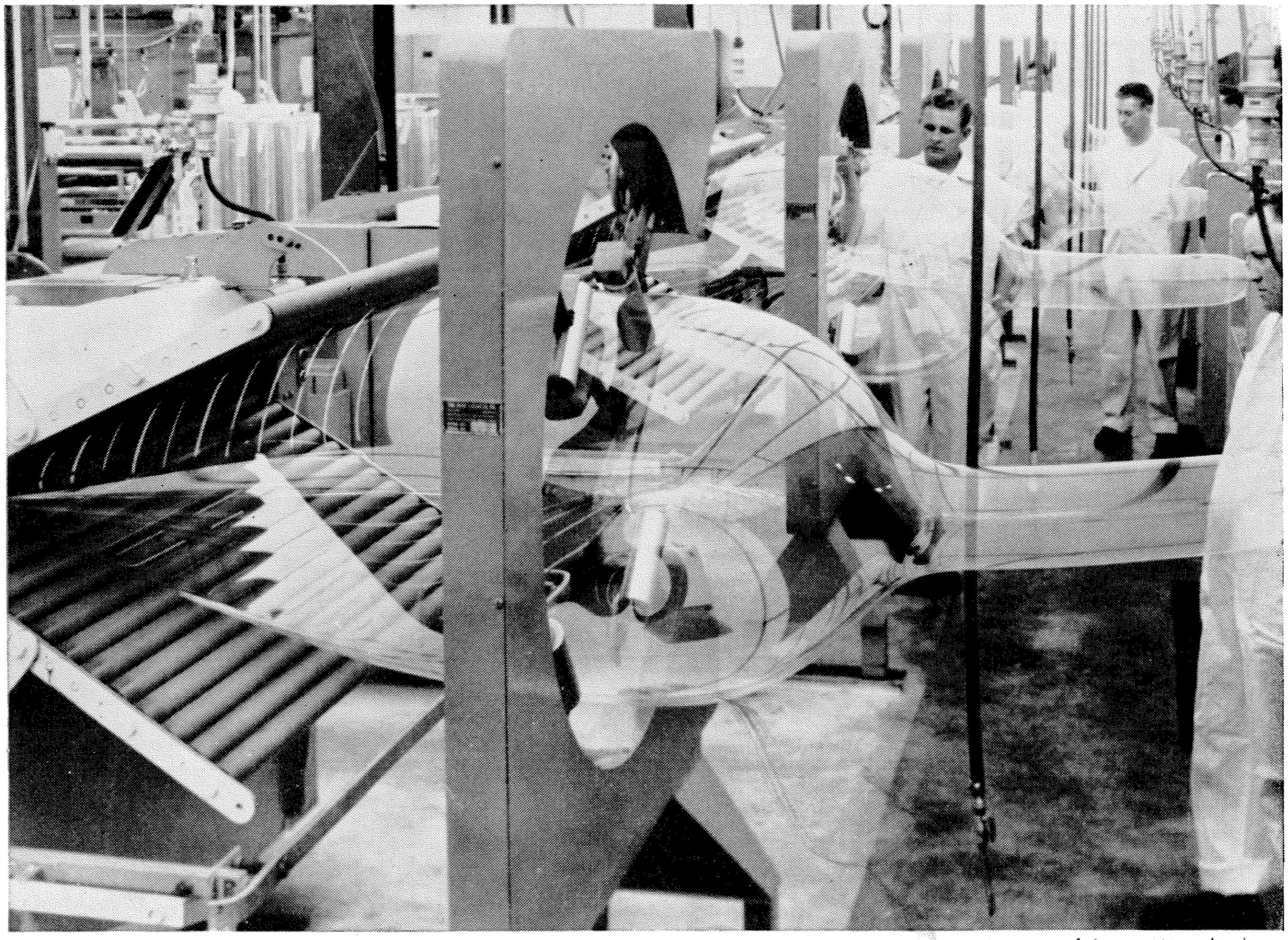


Interior of Saran Wrap* plant.

DOW is tomorrow-minded

product

Publishing a *complete* list of Dow products—all 700 odd of them—is an elusive project. By the time such a list was off the press, new names would have to be added to bring the list up to date. The reason: development of new products is the order of the day at Dow, every day of the working year.

These new products are developed to meet the needs of the many industries Dow serves. *Today's* problems in manufacturing and processing must be solved, and, as these industries advance, new chemicals and materials will be needed to implement tomorrow's technology. At Dow, research and development aim at anticipating these future needs . . . thus a "tomorrow-minded" attitude toward products is always evident.

The product group of Dow Agricultural Chemicals, for example, has expanded manyfold in recent years through a vigorous research and developmental program. In the early '50's it consisted of two or three products. Today it includes many varieties of weed killers, fertilizers, fumigants, insecticides, feed additives and animal health aids. A new crab grass killer has recently made its debut, first in a series of new "ag chem" products slated for the homeowner market.

Dow's work in automotive chemistry is typical of the "tomorrow-minded" attitude. Dow currently supplies a number of chemicals and plastics materials to auto makers—latex-based metal primers, antifreeze, upholstery materials and brake fluids, to name a few. But a quick tour through Dow's two Automotive Chemicals Laboratories would reveal that Dow will be ready with the right chemicals and plastics for the job, no matter which way future automotive design goes! One under development, for example, is a chemical that cools the engine by continuous boiling.

One of the most outstanding success stories at Dow is that of Separan®, a product developed to fit into industry's future. This chemical is a flocculant, or "settler" of solids in solution. Perhaps "super flocculant" would be a better description because Separan takes minutes to do jobs that formerly took days. Introduced in 1955, it has gained widespread recognition in mining, pulp and paper and other industries.

In such a climate of creativity and tomorrow-mindedness, new opportunities at Dow are constantly opening up for people who have their eyes—and their thoughts—on the future. If you'd like to know more about the Dow opportunity, please write: Director of College Relations, Department 2426FW, THE DOW CHEMICAL COMPANY, Midland, Michigan.

*TRADEMARK

THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

Alumni News

Board Nominations

The Board of Directors of the Alumni Association met as a Nominating Committee on February 23, 1960, in accordance with Section 5.01 of the By-Laws. Five vacancies will occur on the Board at the end of the fiscal year (June 1960)—one vacancy to be filled from the present Board, and four members to be elected by the Association. The present members of the Board and their retirement years are:

Frank E. Alderman '30	1960	Holley B. Dickinson '36	1961
Robert J. Barry '38	1961	Frederick Drury, Jr. '50	1961
Frank C. Bumb '51	1960	Wm. W. Haefliger '50	1960
Franklin G. Crawford '30	1961	Ralph W. Jones '38	1960
Francis E. Odell '44	1960		

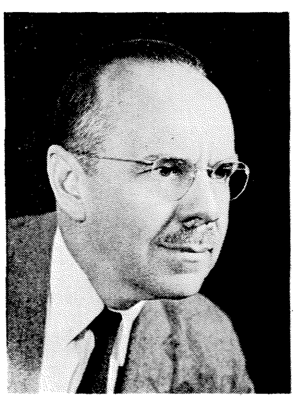
The following nominations have been made:

President – Ralph W. Jones '38	(1 year)
Vice-President – Holley B. Dickinson '36	(1 year)
Secretary – Donald S. Clark '29	(1 year)
Treasurer – George B. Holmes '38	(1 year)
Director – John D. Gee '53	(2 years)
Director – Howard B. Lewis, Jr. '48	(2 years)
Director – William L. Holladay '24	(2 years)
Director – Claude B. Nolte '37	(2 years)

Section 5.01 of the By-Laws provides that the membership may make additional nominations for the four (4) Directors by petition signed by at least twenty-five (25) members in good standing, provided the petition is received by the Secretary not later than April 15. In accordance with Section 5.02 of the By-Laws, if further nominations are not received by April 15, the Secretary casts a unanimous ballot for the members nominated by the Board. Otherwise a letter ballot is required.

Statements about the nominees are presented below.

—*Donald S. Clark, Secretary*



WILLIAM L. HOLLADAY received his BS in electrical engineering in 1942 and went to work for General Electric in Schenectady. He was sales engineer in the Dallas office for two years, then was transferred back to California, where he spent the next 14 years as product manager with GE's appliance distributor. In 1947 he joined the V. P. Engineering company, manufacturers of environmental test equipment. Since 1952 he has been vice president of Holladay & Westcott, consulting engineers, in Los Angeles.

JOHN D. GEE received his BS in 1953 and, in the same year, went to work for the Bethlehem Steel Company in Pennsylvania. He spent two years in the U.S. Army as an instructor in the Corps of Engineers School at Fort Belvoir, Va. In 1955 he returned to Bethlehem Steel for Loop Course Training. Since early in 1956 he has been a salesman working on specialty construction products, special fasteners and forgings in the Los Angeles office of Bethlehem Steel. He served as chairman of the Oxy Game Homecoming in 1958 and is chairman of the Alumni Social Program for 1959-60.

CLAUDE B. NOLTE received his BS in geology in 1937, and then worked progressively for Chanslor Canfield Midway Oil Company, and North American Oil Consolidated in Taft, as a geologist and petroleum engineer. In 1942 he joined the engineering staff of the Fluor Corporation, Ltd., advancing to head of the instrument and hydraulics department. In 1946 he joined the Barton Instrument Corporation and became successively sales manager, manufacturing manager, and engineering manager. He is now vice president in charge of advance product planning and research. He is serving as the general chairman of the Caltech Seminar Day Committee.

HOWARD B. LEWIS, JR., received his BS in mechanical engineering from Caltech in 1948, and then spent two years as engineer and sales engineer at the Smoot-Holman Company in Inglewood. He came back to Caltech to get his BS in electrical engineering in 1951. Then he went to work at the Bill Jack Scientific Instrument Company for a year. In July 1952 he joined the Consolidated Electrodynamics Corporation as a development engineer and, in 1959, became chief engineer. In this position he directs development activities in the Transducer Division in Monrovia.

RALPH W. JONES, who has been nominated as president of the Alumni Association, received his BS in mechanical engineering in 1938, and then worked for the Byron J. Jackson Company in Los Angeles for two years as a design engineer. In 1940 he joined the St. Paul (Minnesota) Engineering and Manufacturing Company as chief engineer, becoming works manager in 1943. Early in 1945 he returned to Caltech to work on wartime projects, then served briefly with the Manhattan District Engineers in the Army, and worked for a year at the Naval Ordnance Test Station. Since 1947 he has been with the national management consulting firm of Booz, Allen & Hamilton in Los Angeles and was elected to a partnership in 1952. He served on the Alumni Seminar Program Committee in 1956-57, and was general chairman of the committee in 1957-58.

HOLLEY B. DICKINSON, who has been nominated as vice president of the Alumni Association, received his BS in aeronautics in 1936 and his MS in mechanical engineering in 1937, then went to work for the Lockheed Aircraft Corporation from 1937 to 1948. He joined the Telecomputing Corporation in North Hollywood as an engineer in 1948 and eventually became vice president, treasurer, and director. In 1956 he joined the Consolidated Electrodynamics Corporation in Pasadena as assistant to the president, and later became director of their Datalab division. In January 1960 he left Consolidated to become vice president of American Systems, Inc., in Inglewood. He is permanent class secretary for the Class of 1936 and also served as a team captain for the Alumni Committee on the Caltech Development Program.

Save the Date!

ANNUAL ALUMNI SEMINAR

SATURDAY, MAY 7, 1960

Dinner Program

It is our extreme good fortune to have President Lee A. DuBridge as featured dinner speaker at the Huntington Hotel. Subject to be announced.

Morning and Afternoon Lectures

Kent Clark:	*Adventures in Madness*
William Fowler:	*Nuclear Furnaces in the Sky*
Horace Gilbert:	*Explosive Africa*
Mitchell Glickstein:	*Experiments on Brain Functions*
Trevor Hatherton:	*South Pole Deep Freeze*
Albert Hibbs:	*A New Look at the Moon*
Donald Hudson:	*Hunting Big Earthquakes in India*
Jack McKee:	*Desalting Sea Water*
Matthew Meselson:	*DNA—a Carrier of Heredity*
Robert Oliver:	*Our Changing Cities*
John Richards:	*Nature's Moldy Factory*
Anthonie Van Harreveld:	*How Our Nerves Work*
Charles Wilts:	*Ferromagnetic Thin Films*

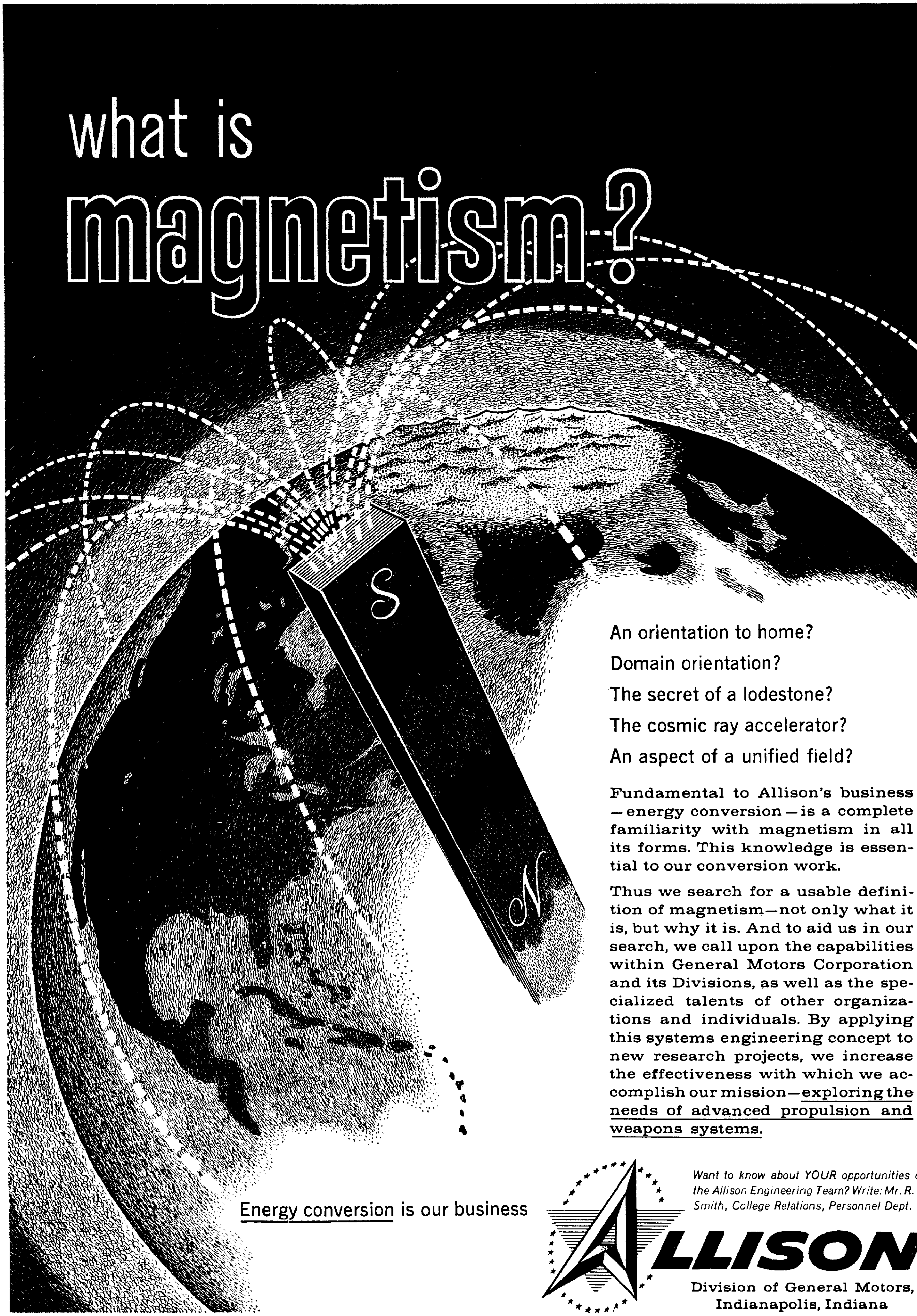
Exhibits, Tours and Films

Unconducted and informal tours of the Synchrotron and of the Computer Lab.

Informal exhibit on the subject of Hemoglobin by Richard Jones.

Continuous showing of selected documentary films

Don't Miss It!



An orientation to home?
Domain orientation?
The secret of a lodestone?
The cosmic ray accelerator?
An aspect of a unified field?

Fundamental to Allison's business — energy conversion — is a complete familiarity with magnetism in all its forms. This knowledge is essential to our conversion work.

Thus we search for a usable definition of magnetism — not only what it is, but why it is. And to aid us in our search, we call upon the capabilities within General Motors Corporation and its Divisions, as well as the specialized talents of other organizations and individuals. By applying this systems engineering concept to new research projects, we increase the effectiveness with which we accomplish our mission — exploring the needs of advanced propulsion and weapons systems.

Want to know about YOUR opportunities on the Allison Engineering Team? Write: Mr. R. C. Smith, College Relations, Personnel Dept.

ALLISON

Division of General Motors,
Indianapolis, Indiana

Personals

1926

C. Hawley Cartwright, PhD '30, writes from Indianapolis that, since the first of the year, he has been taking on jobs as a consulting physicist, and that his first job is a six-month-long project.

1930

Edward E. Kinney, MS, says he's "just living the life of Riley, having retired from Michigan State University after 38 years service. My wife and I just returned to our winter home in Florida after a nine-day cruise through the West Indies."

James H. MacDonald, owner-president of Magparts in Azusa, writes that the company has moved into its own building. They've been making magnesium castings for ten years now and are currently running parts for the old Corporal missile. Jim reports that he has five and a half grandchildren—5 of them boys.

1932

James C. Mouzon, PhD, is now associate dean of the college of engineering at the University of Michigan, where he has been a professor of electrical engineering since 1957. Jim has two married daughters and two grandsons.

Jack M. Roehm, MS, has been made vice president for research and development of the Kawneer Company in Niles, Michigan. He joined the company in 1953.

Charles M. Blair, PhD, is now a director of the Mercantile Bank and Trust Company in St. Louis, Mo.

1935

Alan Beerbower, MS '36, has been appointed a research associate by the Esso Research and Engineering Company in Linden, New Jersey. The position of associate is awarded to scientists with outstanding technical ability. Alan has been with Esso since 1936, and his current research is on aviation oils.

1937

John R. Austen has been appointed assistant general manager in charge of the compressor division of the Ingersoll-Rand Corporation plant in Phillipsburg, Pa. He was formerly assistant to the general manager. He will now be responsible for engineering, manufacturing and customer service activities for all of the division's products.

Foster C. Bennett, MS, is president of the midwestern section of the American Die Casting Institute in Midland, Mich., and is also on the Institute's national board of directors. He holds down the chairmanship of the Die Casting and Permanent Mold Division of the American Foundrymen's Society too. Next May he will be a delegate to the International Die Casting Congress at Stresa, Italy.

"I have seven children," he writes. "The oldest won a five-year cooperative scholarship at Cincinnati this year and the second boy will be in college before long. I don't run into people from Caltech in my business—guess they are all in electronics!"

Daniel G. Schuman is now controller of the Bausch & Lomb Optical Company in Rochester, N.Y. He was formerly vice president and controller of the Stromberg-Carlson Division of the General Dynamics Corporation.

Le Van Griffis, MS '38, PhD '41, is now dean of engineering at Rice Institute in Houston, Texas. He was formerly at the Borg-Warner Corporation's research center in Chicago.

1938

Frank B. Jewett is now president of the Vitro Corporation of America. He joined Vitro in 1956 after eight years with General Mills, Inc., where he directed engineering, research and development.

David K. Beavon is now assistant superintendent of Texaco's Lockport, Ill., refinery. He was formerly in the process and production division in the New York office. Dave has been with Texaco since 1938.

1939

Stephen C. Clark, test officer at L.A. State College, has taken a leave of absence to serve as research associate with the State Research Department of the California Teachers Association. He is serving under *Garford G. Gordon,* '34, assistant director of research. Steve has also been working part-time in the applied mathematics section at Electro-Data, programming statistical applications. He writes that *Munson Dowd,* '38, engineer with the Metropolitan Water District, lives just down the block from him in Altadena.

James E. Stones, formerly geophysics supervisor at the Superior Oil Company in Los Angeles, is now with the production and exploration department of the Monsanto Chemical Company's Lion Oil Company Division at Midland, Texas.

Willard M. Snyder, airplane pilot with the Bureau of Reclamation in Billings, Montana, writes that "the life, fishing, hunting and square dancing are great in Montana; we like it here."

A. *Martin Eichelberger,* MS, has re-

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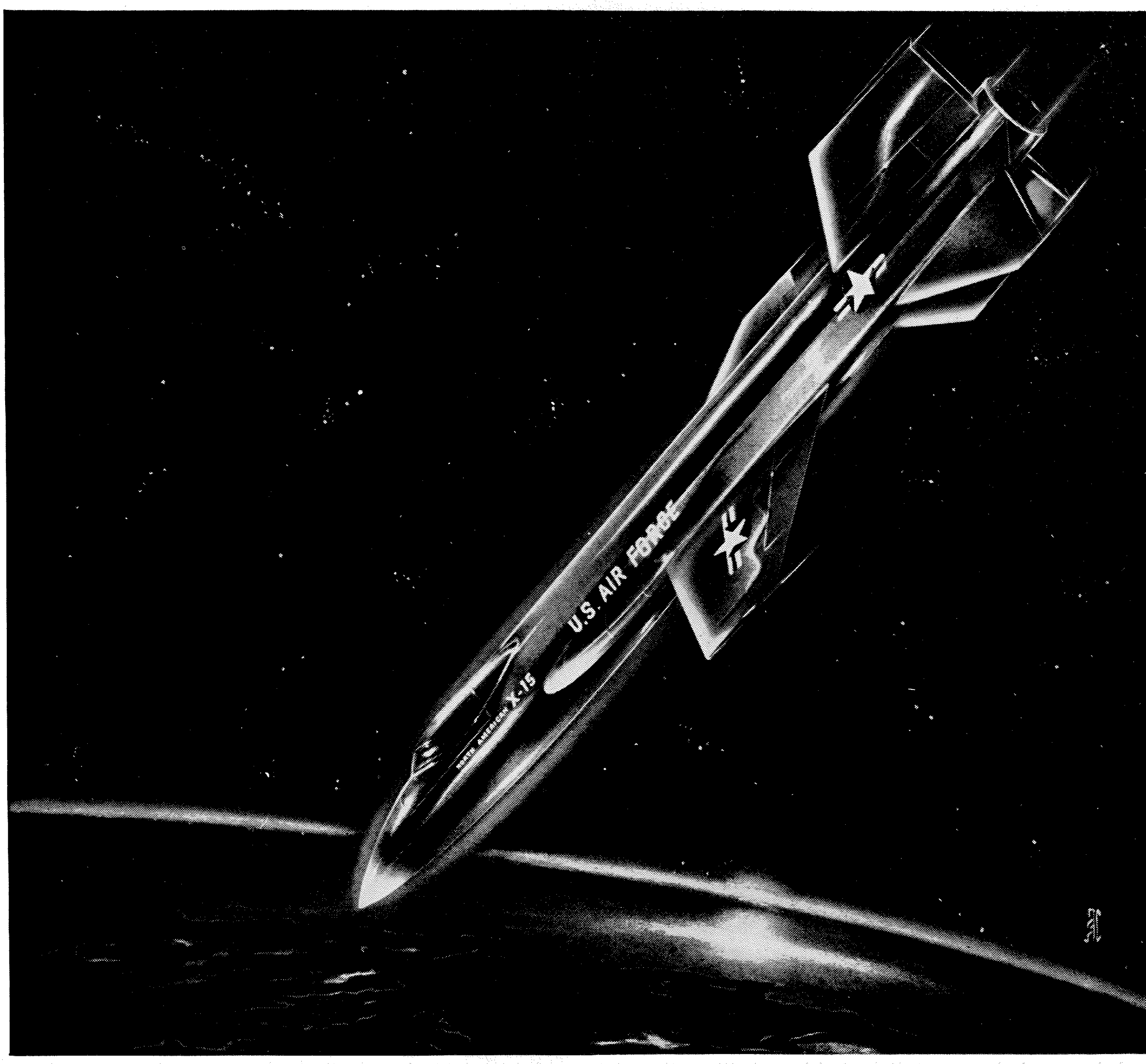

Nosing its way down to earth, X-15's skin of a high-Nickel-containing alloy will glow with the dull cherry red of a tossed rivet.

Inco-developed alloy to help X-15 carry first man into space

Alloy perfected by Inco's continuing research program will help new rocket plane withstand destructive heats

When the first manned rocket plane streaks in from space, temperatures may build up to as high as twelve hundred degrees.

The ship's nose and leading edges heat to a dull glowing red in seconds. At this destructive temperature, X-15's metal skin could weaken, could peel off.

Aircraft research personnel found the answer to this high-temperature problem in one of a family of heat-treatable nickel-chromium alloys developed by Inco Research. It withstands even higher temperatures than 1200°F!

Remember this dramatic example if you're faced with a metal problem in the future. It may have to do with product design, or the way you make it. In any event, there's a good chance Inco Research may help you solve it with a Nickel-containing alloy.

Over the years, Inco Research has successfully solved a good many metal problems, and has compiled a wealth of information to help you. You may be designing a machine that requires a metal that resists corrosion, or wear, or high temperatures. Or one that meets some destructive combination of conditions. Inco Research can help supply the answer. Help supply the right metal, or the right technical data from its files.

When you are in business, Inco Nickel and Inco Research will be at your service.

The International Nickel Company, Inc., New York 5, N. Y.

Inco Nickel *makes metals perform better longer*

signed from the Aero Service Corporation in Philadelphia and has joined the management consulting firm of Dibrell and Company, Inc., in the same city, as a participating partner and executive vice president for market development.

1940

William C. House has been made director of systems management at the Aerojet-General Corporation in Azusa, to coordinate the work of the company's separate systems and space technology divisions. Bill, who has been with Aerojet since 1949, recently returned from a year's leave of absence with the Advanced Research Projects Agency in Washington, D.C., where he was assistant chief of the space technology branch for advanced programs.

Richard W. Powell, MS '47, is now manager of Aerojet-General's Avionics Division in Azusa. He has been with Aerojet since 1950.

1941

Alfred Schaff, Jr., has been appointed executive vice president and general manager of the Allegany Instrument Company in Cumberland, Md. He had been working for Aerojet in Sacramento, in technical and management positions —including test and technical services on important rocket and missile programs.

1942

Robert J. Clark, MS '43, writes from Geneva, Switzerland: "I'm still director of European operations for North American Aviation, Inc. We've been here three years now and enjoy our town and the country. During the winter we manage to spend a fair amount of time skiing at Gstaad, three hours from here.

"I've been elected president of the American Men's Club of Geneva for 1960. We have about 400 members, of whom about 1/3 are non-American. Although this is not a bargain paradise and we pay Swiss taxes of several varieties, there are still about 280 American businessmen in Geneva—and we're still growing.

"*Fred Felberg*, '42, MS '45, and his wife were over last year and we had a get-together after the wind tunnel conference was over."

1943

Edward P. Fleischer, formerly assistant to the president of the electro mechanical instrument division of Consolidated Electrodynamics Corporation in Pasadena, has been appointed assistant director of the division. In the newly created post, he will be responsible for manufacturing operations. Ed has been with the company since 1951.

Redgnald D. Bushell, MS, is now assistant manager of the eastern region of the sales department of the Ethyl Corporation. He has been with the company since 1938, and his most recent assignment was as manager of the New York district of the sales department.

1944

Donald T. Greenwood, MS '48, PhD '51, is associate professor at the University of Michigan in Ann Arbor and is teaching in the graduate instrumentation engineering program. He's been there since 1956. The Greenwoods have two children – Anne, 5, and Brian, 3.

Comdr. Bradley Ballard, Jr., BS, MS, is engineer in charge of seats and underbodies at the Fisher Body Division of the General Motors Corporation in Birmingham, Mich. The Ballards have three children—Diana, 1; Pam, 9; and Jimmy, 7.

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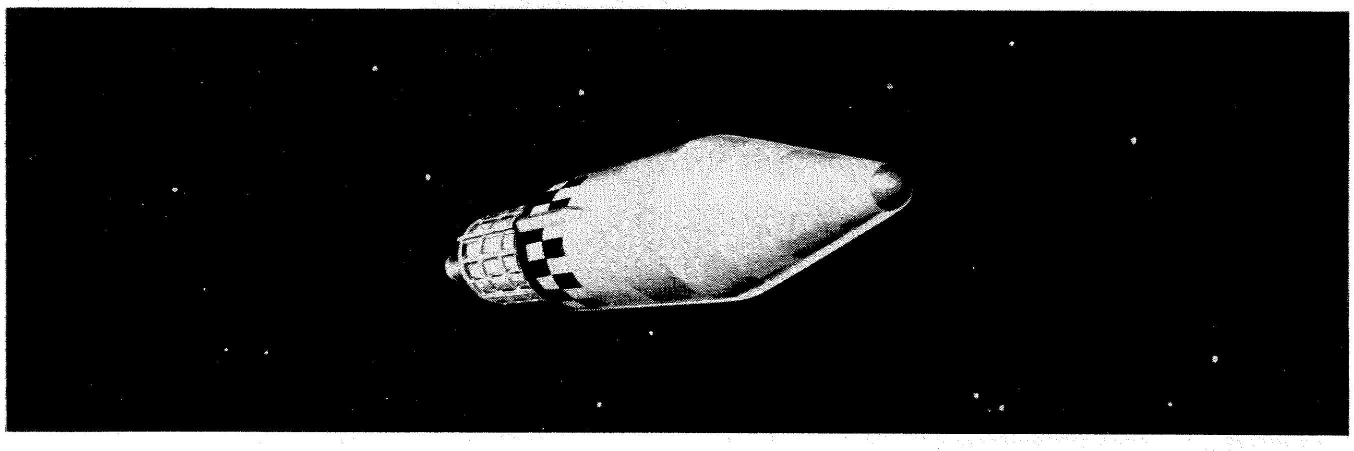

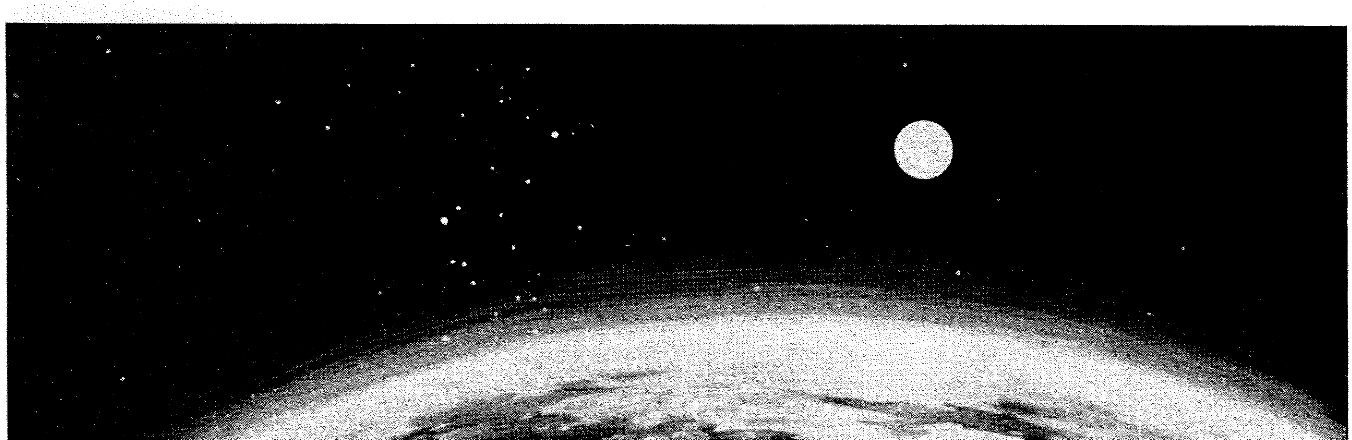

IT'S LITERALLY ALL AROUND YOU!

The word *space* commonly represents the outer, airless regions of the universe. But there is quite another kind of "space" close at hand, a kind that will always challenge the genius of man.

This space can easily be measured. It is the space-dimension of cities and the distance between them . . . the kind of space found between mainland and offshore oil rig, between a tiny, otherwise inaccessible clearing and its supply base, between the site of a mountain crash and a waiting ambulance—above all, Sikorsky is concerned with the precious "spaceway" that currently exists between all earthbound places.

Our engineering efforts are directed toward a variety of VTOL and STOL aircraft configurations. Among earlier Sikorsky designs are some of the most versatile airborne vehicles now in existence; on our boards today are the vehicles that can prove to be tomorrow's most versatile means of transportation.

Here, then, is a space age challenge to be met with the finest and most practical engineering talent. Here, perhaps, is the kind of challenge *you* can meet.

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For information about careers with us, please address Mr. Richard L. Auten, Personnel Department.

Personals . . . *continued*

1945

Ralph S. White is now general manager of the Electronic Systems Development Corporation in Ventura, a subsidiary of Solar Aircraft. Before joining the company, he was assistant to the division manager of Beckman Instruments' Spinco Division, in Palo Alto.

Col. Lawrence Ely, MS, special assistant to the Deputy Commander for Military Space Systems at the AF Ballistic Missile Division in Inglewood, is technical advisor for the "Men into Space" TV program on CBS. His job is to check everything from space suits and missile instrumentation to uniform insignia and military haircuts.

1945

William S. Tatlock died of multiple sclerosis on January 14 in Delaware City, Del. He was 44. He had been employed by the DuPont Company since 1950 and his main interests were in the organosilicons and silica. He had several US patents to his credit. Bill served in the US Navy from 1943 to 1946 and received his PhD in chemistry in 1951 from Harvard University. He is survived by his wife, Carol.

1947

Robert Ilfeld, MS, has been president of the Quick Industries in Jackson, Michigan, for the past five years. The company's plastics division (extrusions) will build a new plant this spring, for use by early summer. Bob founded the plastics business in 1956 and it has grown tremendously in the past 18 months. The Ilfelds have four children—Ricky, 13, (born in Pasadena, while Bob was at Caltech); Kathy, 10; Martha, 7; and Ellen, 4. Bob was recently elected to the local school board and is serving his fifth year on the Community Chest Board.

1948

James C. Elms is now vice president and general manager of defense operations in the Crosley Division of the AVCO Corporation. He was formerly vice president of ground electronics and communications. Before joining Crosley almost a year ago, Jim was manager of the avionics department of the Martin Company in Denver. The Elms' and their four children live in Cincinnati.

1951

Rex Ragon is now working as a seismologist at the Precision Exploration Company in Houston, Texas.

Robert E. Cobb writes that he's "still working as a staff geologist with Mobil Exploration Mediterranean in Ankara. Our second girl, Vivian Nell, was born on November 13 and will be exhibited to her grandparents this summer when we take our long vacation."

1954

Roland Miller and his wife announced the arrival of a son, David Lawrence, on January 26. Roland is a project engineer with William D. Coffey Associates, Inc., in Los Angeles.

Howard L. Croswhite is now senior engineer at the Ford Motor Company in Detroit, where he has worked since he graduated from Caltech. He has a daughter, Linda, 4, and a son, Steve, 1.

William A. Nevill, PhD, has been promoted to associate professor of chemistry at Grinnell College in Iowa.

Henry Gershowitz, writes that he has been appointed serological consultant to the blood bank of the University of Michigan Hospital and that he and his wife have a new daughter—their third child.

1955

Donald R. Petersen, PhD, writes that he's working in the chemical physics research lab of the Dow Chemical Company in Midland, Mich., on the applications of digital computers to chemical process control. The Petersens have two children – Karen, 5, and Eric, 2.

Roger De Wiest, MS, writes that he got his PhD in civil engineering in 1959 at Stanford and is now assistant professor of geological engineering at Princeton.

1956

John M. Manville, graduate student in astrogeophysics at the University of Colorado, recently announced his engagement to Nancy Koontz, a research assistant at Harvard Medical School. The wedding will take place in Los Alamos on March 26th.

1957

Alan Farley writes that "I passed the doctoral preliminary exams last fall and am looking around for a thesis topic in topology. Also, I am now awaiting the galley proofs from Dover of my translation of Alexandroff's *Einfochste Grundbegriffe der Topologie* which is soon to be published. I originally did the translation for L 35 at Caltech."

1958

David J. Wilson, PhD, instructor in chemistry at the University of Rochester in N.Y., has received a grant of $10,000 from the Research Corporation for exploratory research in any field of chemistry he chooses. Last August, Dave was named director of a basic research project entitled "proton magnetic resonance study of molecular processes" under a $10,500 grant from the National Science Foundation.

CALTECH CALENDAR

ALUMNI EVENTS

May 7	Annual Seminar
June 8	Annual Meeting
June 25	Annual Picnic

ATHLETIC SCHEDULE

Golf

March 28
Cal Poly (Pomona) at Cal Poly

April 1
Pomona at Caltech

April 4
Occidental at Occidental

April 8
Cal Poly (Pomona) at Caltech

Tennis

March 31
Pasadena College at Caltech

April 2
UC Riverside at Riverside

April 5
Cal Western at Caltech

April 9
Redlands at Caltech

Baseball

March 29
Claremont-Harvey Mudd at Caltech

April 2
Redlands at Redlands

April 6
Whittier at Caltech

April 9
La Verne at La Verne

Swimming

April 1
Claremont-Harvey Mudd at Caltech

April 2
Long Beach State at Long Beach

Track

April 2
Claremont-Mudd & Pomona at Claremont

April 9
Whittier at Caltech

FRIDAY EVENING DEMONSTRATION LECTURES

Lecture Hall
201 Bridge, 7:30 p.m.

March 18
Chemical Engineering
—Neal Richter

April 1
Metals—Pace Setter of Progress
—Donald S. Clark

April 8
Molecular Diseases
—Linus Pauling

April 15
Rocks Under the Microscope
—Arden L. Albee

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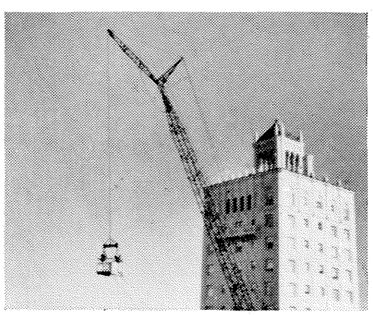
Though the building is not yet built, this is a view from one of the apartments.

How to look out a window before the building is up



With 180 "view" apartments to sell, the developers of The Comstock turned to photography to get a jump on sales

A feature of The Comstock, San Francisco's new co-operative apartments on top of Nob Hill, will be the spectacular panoramic views of the Bay area from their picture windows.

How could these views be spread before prospective buyers—before the building was up? The developers, Albert-Lovett Co., found the answer in photography. From a gondola suspended from a crane, color photos were made from the positions of the future apartments. Now, the sales representative not only points out the location of a possible apartment on a scale model, but shows you the view from your window as well.

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