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On Our Cover

John A. Petruska, senior research fellow in biology, and Alan J. Hodge, professor of biology, members of a team of Caltech researchers engaged in work on one of the body's most important proteins, collagen. Their success in unravelling the structural design of a collagen molecule is described in the article on page 18. The research provides new insight into how the molecules are assembled to form the strong collagen fibers in the connective tissue of the body.

The New Mathematics

Add now, to all his other miscellaneous distinctions, the fact that Richard P. Feynman has read 500 lbs. of elementary-grade arithmetic books — enough to fill 18 feet of shelf space. He did this last year, as a member of the California State Curriculum Commission, in order to select textbooks for use in the new, modified arithmetic course for California's elementary schools. As a result of this unenviable experience, Dr. Feynman, who is Richard Chace Tolman Professor of Theoretical Physics at Caltech, has some firm convictions about the teaching of the "new" mathematics in grade school — as he explains in his article on page 9 of this issue.

Books

Combustion Theory

By Forman A. Williams, PhD '58

Addison-Wesley $15.00

Intended for advanced graduate students and people in the combustion field, this book was prepared while Williams was assistant professor at Harvard on a National Science Foundation grant for fundamental studies of sprays. He is now associate professor in the department of aerospace engineering at the University of California, San Diego.

Principles of Dynamics

by Donald T. Greenwood '44, MS '48, PhD '51

Prentice-Hall, Inc. $14.00

A text designed for graduate students or senior undergraduates. The author is now a professor in the department of aeronautical and astronautical engineering at the University of Michigan. The book is part of a series on dynamics edited by Y. C. Fung, professor of aeronautics at Caltech.

The Eightfold Way

By M. Gell-Mann and Y. Ne"eman

W. A. Benjamin, Inc. $3.95

A review of all work done on the eightfold way since 1961, including reprints of the most important professional articles on the subject. The authors – Murray Gell-Mann, professor of theoretical physics at Caltech; and Yuval Ne'eman, visiting professor of theoretical physics – proposed the eightfold-way theory independently, and simultaneously, in 1961.

Listen to Leaders in Science

Edited by Albert Love and James Saxon Childers

David McKay Company, Inc. $5.50

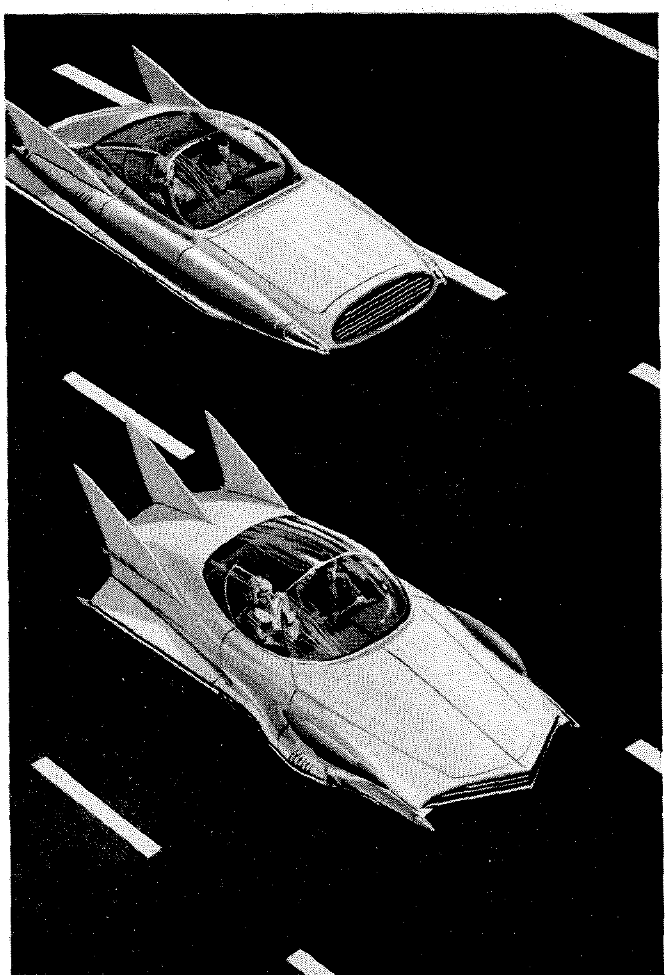
Of the 18 scientists who describe their fields in this book, six are (or were) Caltech men. James Bonner, professor of biology, writes on botany; Frank Press, professor of geophysics and director of the Seismological Laboratory, covers geophysics. Caltech's President Lee A. DuBridge contributes "Preparation for a Lifetime in Science," and George Beadle, now president of the University of Chicago, writes "An Introduction to Science." Robert Oppenheimer, now director of the Institute for Advanced Study, covers physics; Warren Weaver, now vice president of the Alfred P. Sloan Foundation, describes "Careers in Science."

Listen to Leaders in Engineering

Edited by Albert Love and James Saxon Childers

David McKay Company, Inc. $5.95

Engineering leaders in this popular-level collection include Simon Ramo, PhD '36, president of The Bunker-Ramo Corporation, who writes on "The Design of the Whole – Systems Engineering;" Bernard M. Oliver, MS '36, PhD '40, vice president of the Hewlett-Packard Company, who covers electronics; John R. Pierce '33, MS '34, PhD '36, director of communications research at the Bell Telephone Laboratories, who writes on communications; and Newman A. Hall, PhD '38, executive director of the Commission on Engineering Education, who discusses "The Profession of Engineering."



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Dale Anderson
B.A., Wittenberg University

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ENGINEERING
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March 1965, Vol. XXVIII, No. 6

NEW TEXTBOOKS FOR THE "NEW" MATHEMATICS

by Richard P. Feynman

As a member of the California State Curriculum Commission last year, I spent considerable time on the selection of mathematical textbooks for use in a modified arithmetic course for Grades 1 to 8 in California's elementary schools.

I have carefully read all of the books submitted by their publishers for possible adoption in California (18 feet of shelf space, 500 pounds of books!). Here I should like to describe and criticize these books in a general way, particularly with regard to the mathematical content – what it is we are trying to teach. I shall omit important matters, such as whether the books are written so that it is easy for the teacher to teach well from them, or the student to read them. Many of the books finally selected by the State for adoption do still contain some of the faults described below. This is because one could only select from what was submitted by the publishers, and few really good books were submitted. Also, budget limitations prevented adoption of most of the supplementary books that the Commission recommended in order to try to compensate for the faults of those basic books that were selected.

Why do we wish to modify the teaching of mathematics in the schools? It is only if we see this clearly that we can judge whether or not the new books satisfy the need. Most people – grocery clerks, for example – use a great deal of simple arithmetic in their daily life. In addition, there are those who use mathematics of a higher form – engineers and scientists, statisticians, all types of economists, and business organizations with complex inventory systems and tax problems. Then there are those who go directly into applied mathematics. And finally there are the relatively few pure mathematicians.

When we plan for early training, then, we must pay attention not only to the everyday needs of almost everyone, but also to this large and rapidly expanding class of users of more advanced mathematics. It must be the kind of training that encourages the type of thinking that such people will later find most useful.

Many of the books go into considerable detail on subjects that are only of interest to pure mathematicians. Furthermore, the attitude toward many subjects is that of a pure mathematician. But we must not plan only to prepare pure mathematicians. In the first place, there are very few pure mathematicians and, in the second place, pure mathematicians have a point of view about the subject which is quite different from that of the users of mathematics. A pure mathematician is very impractical; he is not interested – in fact, he is purposely *disinterested* – in the meaning of the mathematical symbols and letters and ideas; he is only interested in logical interconnection of the axioms, while the user of mathematics has to understand the connection of mathematics to the real world. Therefore we must pay more attention to the connection between mathematics and the things to which they apply than a pure mathematician would be likely to do.

I hear a term called "new mathematics" used a great deal in connection with this program. That it's a new program of mathematics books is, of course, true, but whether it is wise to use "new," in the sense of very modern, mathematics is questionable. Mathematics which is used in engineering and science — in the design, for example, of radar antenna systems, in determining the position and orbits of the satellites, in inventory control, in the design of electrical machinery, in chemical research, and in the most esoteric forms of theoretical physics — is all really old mathematics, developed to a large extent before 1920.

A good deal of the mathematics which is used in the most advanced work of theoretical physics, for example, was not developed by mathematicians alone, but to a large extent by theoretical physicists themselves. Likewise, other people who use mathematics develop new ways to use it, and new forms of it. The pure mathematicians have in recent years (say, after 1920) turned to a large extent away from such applications and are instead deeply concerned with the basic definitions of number and line, and the interconnection of one branch of mathematics and another in a logical fashion. Great advances in this field have been made since 1920, but have had relatively little effect on applied, or useful, mathematics.

What we're after

I would consider our efforts to find new books and modify the teaching of arithmetic as an attempt to try to make it more interesting and easier for students to learn those attitudes of mind and that spirit of analysis which is required for efficient understanding and use of mathematics in engineering, science, and other fields.

The main change that is required is to remove the rigidity of thought found in the older arithmetic books. We must leave freedom for the mind to wander about in trying to solve problems. It is of no real advantage to introduce new subjects to be taught in the old way. To use mathematics successfully one must have a certain attitude of mind — to know that there are many ways to look at any problem and at any subject.

You need an answer for a certain problem: the question is how to get it. The successful user of mathematics is practically an inventor of new ways of obtaining answers in given situations. Even if the ways are well known, it is usually much easier for him to invent his own way — a new way or an old way — than it is to try to find an answer by looking it up. The question he asks himself is not, "What is the right way to do this problem?" It is only necessary that he get the right answer.

This is much like a detective guessing and fitting his answer to the clues of a crime. In terms of the clues, he takes a guess as to the culprit and then sees whether that individual would be likely to fit with the crime. When he has finally suggested the right culprit, he sees that everything fits with his suggestion.

Any way that works

What is the best method to obtain the solution to a problem? The answer is, any way that works. So, what we want in arithmetic textbooks is not to teach a particular way of doing every problem but, rather, to teach what the original problem is, and to leave a much greater freedom in obtaining the answer — but, of course, no freedom as to what the right answer should be. That is to say, there may be several ways of adding 17 and 15 (or, rather, of obtaining the solution to the sum of 17 and 15) but there is only one correct answer.

What we have been doing in the past is teaching just one fixed way to do arithmetic problems, instead of teaching flexibility of mind — the various possible ways of writing down a problem, the possible ways of thinking about it, and the possible ways of getting at the problem.

This attitude of mind of a user of mathematics is, it turns out, also really the attitude of mind of a truly creative pure mathematician. It does not appear in his final proofs, which are simply demonstrations or complete logical arguments which prove that a certain conclusion is correct. These are the things that he publishes, but they in no way reflect the way that he works in order to obtain a guess as to what it is he is going to prove before he proves it. To do this he requires the same type of flexible mind that a user of mathematics needs.

In order to find an example of this, since I am not a pure mathematician, I reached up on the shelf and pulled down a book written by a pure mathematician. It happened to be *The Real Number System in An Algebraic Setting* by J. B. Roberts, and right away I found a quotation I could use:

"The scheme in mathematical thinking is to divine and demonstrate. There are no set patterns of procedure. We try this and that. We guess. We try to generalize the result in order to make the proof easier. We try special cases to see if any insight can be gained in this way. Finally — who knows how? — a proof is obtained."

So you see that mathematical thinking, both in

Richard P. Feynman, Richard Chace Tolman Professor of Theoretical Physics at Caltech

pure mathematics and in applied mathematics, is a free, intuitive business, and we wish to maintain that spirit in the introduction of children to arithmetic from the very earliest time. It is believed that this will not only better train the people who are going to use mathematics, but it may make the subject more interesting for other people and make it easier for them to learn.

In order to take this discussion of the character of mathematics away from the abstract, and to give a definite illustration, I'll choose material from the first and second years of school as an example; simply the problem of adding.

We suppose first that children can learn to count and that after a while they are very adept at counting. And now we wish to teach them addition. May we remark immediately that a child who can count well, say to 50 or 100, can immediately solve a problem such as $17 + 15 = 32$. For example, if there are 17 boys in the class and 15 girls, how many children are there in the class? The problem doesn't have to be given in the form of an abstract addition; it is simply a matter of counting the boys, counting the girls, and counting the class. We have, as a summary of the result: 17 boys plus 15 girls equals 32 children.

This method could be used to add any pair of whole numbers but, of course, it's a rather slow and cumbersome method for large numbers, or if a very large number of problems come up. Similar methods exist, such as having a set of counters or fingers and counting the things off with them. Another way is to count the numbers in the head. For example, after a while it is possible for a child to be able to add 3 to 6 by thinking to himself, 7, 8, 9. A more practical method is to learn by rote some of the simpler combinations, such as $3 + 6$, so that if they come up often it is not necessary to do the counting.

Counting large numbers – of pennies, for example – can be simplified by counting in groups instead of counting all the pennies. You can make little piles of five and count the piles of five; or better, you can make the piles of five into ten and then count the piles of ten first, and the number left over. Adding numbers could then be done more easily by adding the groups and the leftovers together.

Other ways of getting at addition facts (or doing additions, I should say) is to have a line on which the numbers are marked, or a thing like a calendar on which a whole series of numbers are written, one after the other. Then, if you want to add 3 to 19, you start at 19 and count off three more spots along the line and come to 22. Incidentally, if these numbers are written as dots equally spaced along a line – called the number line – this becomes very useful later for an understanding of fractions and also of measurements; for inch-rulers and other things like thermometers are nothing but a number line written along the edge of the ruler. Therefore, putting the numbers on a line is useful, not only for learning addition in the first place, but also for understanding other types of numbers.

(Another special trick to remember, at a very elementary level, is that it is possible to determine which is the greater of two numbers without actually counting the numbers. If we have two rather large groups of things, it is easy to find out which group is larger by matching the things in pairs and seeing which group has objects left over. This is the way the number of molecules in different gases was first compared, by the way.)

Addition – the old way

In older books, addition is handled in a very definite way, without any variety of tricks or techniques. First we learn the simpler sums by drawing pictures of ducks – 5 ducks and 3 ducks, swimming, makes 8 ducks, and so forth – which is a perfectly satisfactory method. Then these numbers are memorized, which is again satisfactory. Finally, if the numbers are bigger than 10, a completely different technique is used. It is first explained how to write the numbers that are larger than 10 and then rules are given for the addition of two-column numbers, without carrying at first. It is not until the third grade that carrying can be done for the first time.

The dissatisfaction with the old text is not that any of the methods used to teach addition are unsatisfactory; they are all good. The trouble is, there are so few methods allowed that only a rigid and formal knowledge of arithmetic can result.

For example, a problem such as $29 + 3$ is not a legitimate problem for two years, for it is not given in the first and second grades, and the child is presumably unable to do that problem because, of course, for it you must carry. On the other hand, if you really understood what addition was, you could obtain the result of $29 + 3$ not very long after you have learned to count. Very early – in other words, in the first grade – you could do it by simply thinking 30, 31, 32.

It is true that this method is slow, but if no other method is available, then this is the method which ought to be used. It should be permitted to be used. It should be one of the possible things that a child might do when he has to add by hook or by crook in a difficult problem. As he gets older he may increase his efficiency at doing the problems by using other methods, but it should be possible at the very earliest age to do addition problems with any reasonable numbers. There is really nothing different about adding 3 to 6 and adding 3 to 29; it is just that the technical, and generally more efficient, way we finally use when we get older is somewhat different.

A limited approach

In understanding the meaning of addition of two numbers – the meaning of sum, and how to get at it – there is no difference in the two problems. So the objection to the standard text is that only one method is given for making additions – namely, when the numbers are small, memorize them; when the numbers are larger, formally add them in a vertical column, two numbers together, and not carrying until after the second year. This is entirely too limiting for two years of study. If a child will not learn, or is unable to learn the formal rules, it should still be possible for him to obtain the result of some simple problem by counting or making a number line or by other technical methods.

In order to develop the kind of mental attitude which is required later, we should also try to give as wide a mathematical experience as possible. The sum should not appear always in the same form. There is no reason why every sum should be written 17 with a 15 underneath and a line drawn to obtain 32. A problem such as $17 + \quad = 32$, to fill in the blank, is a somewhat different variety but exactly the same type of question with numbers. So let the first-grade child cook up a way to obtain the answer to this problem. This is exactly the type of problem he will have to solve later if he becomes an engineer. I don't mean he will have to learn how to subtract. What I mean is that he has to deal with a new form of an old type of situation. The problem is to fill in a blank by any method whatsoever. However, when the blank is finally filled in, it must be correct.

We would not usually be interested, in engineering or in physics, in how a man obtained the result that 15 will go into the blank as long as he finally shows that 15 does work by simply adding the 15 and 17 and seeing if it comes out to 32.

(The only time we would be interested to know how he obtained the 15 is if this is the first time that such a problem has ever been done, and no one has ever known a way to do it previously – or if it seems likely that this type of problem will appear again and again in the future because of a new technical development, and that we would like to have a more efficient method. Then it would be worth while to discuss the methods of obtaining the 15.)

So this problem, $17 +$ a blank $= 32$ is an analogue of the general problem of applied mathematics, to find a way to fill in a blank number by any method whatsoever. It is a problem that could be given very early in the first year, leaving a freedom for the children to try to obtain the solution by any method they want, but of course not permitting wrong answers. The thing has to be checked out at the end.

Developing freedom

Here is another example of developing freedom, of a somewhat more complex form. Two times an unknown number $+ 3$ is 9. What is the unknown number? This is, of course, algebra, and there are very definite rules for solving such a problem – subtracting 3 from both sides and dividing by 2. But the number of algebraic equations that can be solved by definite rules is very small.

Another way is to try various numbers for the blank until one is found which fits. This way should be available to children at a very early age. In other words, problems should be put in many different forms. Children should be allowed to guess and to get at the answers in any way that they wish, in terms of those particular facts which they happen to memorize. Of course, it is necessary as time goes on for them to memorize the ordinary addition facts, the ordinary methods of making additions, multiplications, divisions, and so on, in addition to being allowed a freedom about the solution and the form of the various problems that are given to them.

Later, in more advanced work in engineering, when we have more complex algebraic equations, the only available method is, in fact, to try numbers. This is fundamentally a method that is of great power and will only have to be learned later by the student, or the engineer. The old teaching, that for every problem there is a definite fixed method, is only true for the simplest problems. For the more complex problems which actually arise there is *no* definite method, and one of the best ways to solve complex algebraic equations is by trial and error.

Another exercise which involves a greater degree of freedom is guessing a rule. This type of problem appears in more complex forms later, but a simple example, and a typical engineering or scientific problem, is the following: In a series of numbers 1, 4, 7, 10, 13, what is the pattern of rule by which they are being generated? The answer could be given in several ways. One is by adding 3 each time. Another is that the nth number is $3 \times n + 1$.

The key, then, is to give a wide variety of mathematical experience and not to have everything in a limited and stringent fixed form. This is not an argument about teaching methods. The point is not that it will then be easier to teach the regular arithmetic (although, for all I know, that may be so). The point is, it will be teaching a new subject in a sense – an attitude of mind toward numbers and toward mathematical questions which is precisely that attitude of mind which is so successful later in technical applications of mathematics.

It will not do simply to teach new subjects in the old way. For example, it has been recommended that numbers written in a different base than 10 be discussed in the early grades. This could serve to illustrate the freedom in mathematics to generalize, and help toward a deeper understanding of the reason behind the carrying rules in arithmetical operations. For this, a mention and an explanation with a few examples might delight some students. But if the matter is not understood by some of the slower members of the class, it is senseless to drill it in with interminable exercises, changing from one base to another. For such students, for whom a short exposure doesn't "take," more practice in the usual rules of base-10 computation is surely more sensible than *drilling* to perfection, calculation in base 5 and 12.

Words and definitions

When we come to consider the words and definitions which children ought to learn, we should be careful not to teach "just" words. It is possible to give an illusion of knowledge by teaching the technical words which someone uses in a field (which sound unusual to ordinary ears) without at the same time teaching any ideas or facts using these words. Many of the math books that are suggested now are full of such nonsense – of carefully and precisely defined special words that are used by pure mathematicians in their most subtle and difficult analyses, and are used by nobody else.

Secondly, the words which are used should be as close as possible to those in our everyday language; or, as a minimum requirement, they should be the very same words used, *at least*, by the users of mathematics in the sciences, and in engineering.

Consider the subject of geometry. It is necessary in geometry to learn many new words related to the mathematics. For example, one must learn what a triangle is, a square, a circle, a straight line, an angle, and a curved line. But one should not be satisfied solely to learn the words. At least somewhere, one should learn *facts* about the objects to which the words refer, such as the area of the various figures; the relations of one figure to another; how to measure angles; possibly the fact that the sum of the angles of a triangle is 180°; possibly the theorem of Pythagoras; or maybe some of the rules that make triangles congruent; or other geometrical facts. *Which* facts may be decided by those having more experience with curriculum, for I am not intending here to make any specific suggestions of what should be included and what not. I only mean to say that the subject of geometry, if it is taught at all, should include a reasonable knowledge of the geometrical figures over and above what the conventional names are.

Some of the books go a long way with the definition of a closed curve, open curve, closed regions, and open regions, and so on — and yet they teach no more geometry than the fact that a straight line drawn in a plane divides the plane into two pieces. At the end of some of these geometry books, look over to find, at the end of a long discourse, or a long effort at learning, just what knowledge of geometry has been acquired. I think that often the total number of facts that are learned is very small, while the total number of new words is very great. This is unsatisfactory. Furthermore, there is a tendency in some of the books to use most peculiar words — the words that are used in the most technical jargon of the pure mathematician. I see no reason for this.

It will be very easy for students to learn the new words when, and if, they become pure mathematicians and discourse with other mathematicians on the fundamentals of geometry. It is very easy indeed to learn how to use such words in a new way when one is older. A great deal of the objection that parents have to the so-called new mathematics may well be merely that it sounds rather silly to them when they hear their child trying to explain to them that a straight line is a "curve." Such arguments in the home are absolutely unnecessary.

Precise language

In regard to this question of words, there is also in the new mathematics books a great deal of talk about the value of precise language — such things as that one must be very careful to distinguish a number from a numeral and, in general, a symbol from the object that it represents. The real problem in speech is not *precise* language. The problem is *clear* language. The desire is to have the idea clearly communicated to the other person. It is only necessary to be precise when there is some doubt as to the meaning of a phrase, and then the precision should be put in the place where the doubt exists. It is really quite impossible to say anything with absolute precision, unless that thing is so abstracted from the real world as to not represent any real thing.

Pure mathematics is just such an abstraction from the real world, and pure mathematics does have a special precise language for dealing with its own special and technical subjects. But this precise language is not precise in any sense if you deal with the real objects of the world, and it is overly pedantic and quite confusing to use it unless there are some special subtleties which have to be carefully distinguished.

A fine distinction

For example, one of the books pedantically insists on pointing out that a picture of a ball and a ball are not the same thing. I doubt that any child would make an error in this particular direction. It is therefore unnecessary to be precise in the language and to say in each case, "Color the picture of the ball red," whereas the ordinary book would say, "Color the ball red."

As a matter of fact, it is impossible to be precise; the increase in precision to "color the picture of the ball" begins to produce doubts, whereas, before that, there was no difficulty. The picture of a ball includes a circle and includes a background. Should we color the entire square area in which the ball image appears or just the part inside the circle of the ball? Coloring the ball red is clear. Coloring the picture of the ball red has become somewhat more confused.

Although this sounds like a trivial example, this disease of increased precision rises in many of the textbooks to such a pitch that there are almost incomprehensibly complex sentences to say the very simplest thing. In a first-grade book (a *primer*, in fact) I find a sentence of the type: "Find out if the set of the lollypops is equal in number to the set of girls" — whereas what is meant is: "Find out if there are just enough lollypops for the girls."

The parent will be frightened by this language. It says no more, and it says what it says in no more precise fashion than does the question: "Find out if there are just enough lollypops for the girls" — a perfectly understandable phrase to every child and every parent. There is no need for this nonsense of extra-special language, simply because that type of language is used by pure mathematicians. One does not learn a subject by using the words that people who know the subject use in discussing it. One must learn how to handle the ideas and then, when the subtleties arise which require special language, that special language can be used and developed easily. In the meantime, clarity is the desire.

I believe that all of the exercises in all of the books, from the first to the eighth year, ought to be understandable to any ordinary adult — that is, the question of what one is trying to find out should be clear to every person. It may be that every adult is not able to *solve* all of the problems; perhaps they have forgotten their arithmetic, and they cannot readily obtain 2/3 of 1/4 of 1-1/3, but they at least should understand that that product is what one is trying to obtain.

By putting the special language into the books, one appears to be learning a different subject and the parent (including highly trained engineers) is unable to help the child or to understand what the thing is all about. Yet such a lack of understanding is completely unnecessary and *no gain whatsoever* can be claimed for using unusual words when usual words are available, generally understood, and equally clear (usually, in fact, far clearer).

New definitions — and no facts

I believe that every subject which is presented in the textbook should be presented in such a way that the purpose of the presentation is made evident. The reason why the subject is there should be clear; the utility of the subject and its relevance to the world must be made clear to the pupil.

I would take, as an example, the subject of sets. In almost all of the textbooks which discuss sets, the material about sets is never used — nor is any explanation given as to why the concept is of any particular interest or utility. The only thing that is said is that "the concept of sets is very familiar." This is, in fact, true. The idea of sets is so familiar that I do not understand the need for the patient discussion of the subject over and over by several of the textbooks if they have no use for the sets at the end at all.

It is an example of the use of words, new definitions of new words, but in this particular case a most extreme example, because *no facts whatever* are given at the end in almost all of the books. A zoo-keeper, instructing his assistant to take the sick lizards out of the cage, could say, "Take that set of animals which is the intersection of the set of lizards with the set of sick animals out of the cage." This language is correct, precise, set theoretical language, but it says no more than, "Take the sick lizards out of the cage." The concept of things which have common properties by being a member of two groups (such as the Chinese Communists, or of a larger number of groups such as East German refugee children) does involve intersections of sets, but

"You see, Daddy, this set equals all the dollars you earned; your expenses are a sub-set within it. A sub-set of that is your deductions."

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

one does not use that language. No lack of precision results from this. And, besides, people who *use* mathematics in science, engineering, and so on, never use the long sentences of our imaginary zoo-keeper.

If we would like to, we can and *do* say, "The answer is a whole number less than 9 and bigger than 6," but we do not have to say, "The answer is a member of the set which is the intersection of the set of those numbers which is larger than 6 and the set of numbers which are smaller than 9."

It will perhaps surprise most people who have studied these textbooks to discover that the symbol U or ∩ representing union and intersection of sets and the special use of the brackets { } and so forth, all the elaborate notation for sets that is given in these books, almost never appear in any writings in theoretical physics, in engineering, in business arithmetic, computer design, or other places where mathematics is being used. I see no need or reason for this all to be explained or to be taught in school. It is not a useful way to express one's self. It is not a cogent and simple way. It is claimed to be precise, but precise for what purpose?

Making the "new" mathematics worth while

In the "new" mathematics, then, first *there must be freedom of thought;* second, *we do not want to teach just words;* and third, *subjects should not be introduced without explaining the purpose or reason,* or without giving any way in which the material could be really used to discover something interesting. I don't think it is worth while teaching such material.

Astronomers find new evidence that stars of all types and sizes will wind up as the faint, hot, stellar clinkers called

WHITE DWARFS

by Graham Berry

An eight-year study of the faint, hot, stellar clinkers called white dwarfs indicates how stars of many types, ages, and sizes — including our sun — will shrivel into white dwarfs in their old age.

The study of white dwarfs by Jesse L. Greenstein, professor of astrophysics at Caltech, and a staff member of the Mt. Wilson and Palomar Observatories; and Olin Eggen, formerly of the observatories and now at the Royal Greenwich Observatory in England, contains new information about the brightness, temperatures, sizes and surface conditions of nearly 200 of these important little stars. The study also supports the widely accepted theory of how stars evolve.

White dwarfs are significant because they are the dying stars. They are white hot, even though their nuclear fires are extinguished, and they are small — about the diameter of the earth. However, they weigh 200,000 times more than the earth. The matter of which they are made — a peculiar form of degenerate gas, enormously condensed, has a density of 1,000 tons per cubic inch at the center of the star.

All the white dwarfs in the survey are comparatively near because they are too faint to be seen far away. The farthest is about 200 light years distant. The brightest known are intrinsically 100 times fainter than the sun, while the faintest one is 30,000 times dimmer. None is visible without a telescope. They were studied through the 200-inch telescope at Palomar.

Spectroscopic analysis of the light of some of the white dwarfs shows that their gaseous surfaces are composed largely of helium, while others are composed mainly of carbon. Ordinary stars are made largely of hydrogen, and most white dwarfs still have hydrogen at their surface.

Finding helium and carbon dwarfs is evidence confirming the theory of stellar evolution and the concept that different kinds of stars wind up as white dwarfs. These two special kinds of dwarfs represent the end products of two different types of massive parent stars. The larger, according to theory, evolves a further step in burning fuel than does the smaller one, before becoming a white dwarf. In all of them, hydrogen fuel must be completely exhausted except at the surface.

The theoretical picture of stellar evolution is that in stars of moderate size, like the sun, the nuclear fire goes out after the hydrogen "fuel" has been converted into helium "ashes." The more massive the star, the hotter the nuclear fire, the quicker it consumes its fuel, and the shorter its life. In an evolutionary stage where massive stars swell up to 100 times the sun's diameter, the central cores reach temperatures of 200,000,000 degrees Fahrenheit and convert helium into carbon.

After the nuclear fire is extinguished, a star must somehow lose a great deal of material, leaving only its core of "ashes" — helium, carbon, or even heavier elements. These eventually contract under gravity to become stabilized as a white dwarf. Although they have no nuclear fires, they continue to shine for billions of years as they cool off.

The new observational data provide several direct confirmations of what happened inside the original stars. For example, the average white dwarf weighs less than the sun, while the parent stars weighed at least twice as much.

The two astronomers found about an equal number of helium and carbon-rich dwarfs among the smaller and more massive specimens, suggesting that carbon production is quite common. The composition of a few of the most massive white dwarfs is still a mystery. They show no spectral "fingerprints," no atomic lines or molecular bands to disclose their chemical composition. These stars probably have made even heavier elements, and have very high pressures, even in their outermost atmospheres.

Additional evidence supports the theory that white dwarfs evolve from stars of many sizes and ages. Some white dwarfs were formed only a few

Jesse L. Greenstein, professor of astrophysics at Caltech; staff member, Mt. Wilson and Palomar Observatories

million years ago, while others must be nearly 10 billion years of age.

One white dwarf was found to exist in the Pleiades Cluster of stars. All the stars in that cluster are believed to have formed at the same time, only a few million years ago. The one white dwarf among them, according to Dr. Greenstein, "must be the remnant of a very large star that burned its evolutionary candles brightly at both ends."

However, in the Hyades Cluster, whose stars are some 200 million years old, no fewer than 14 white dwarfs were studied.

White dwarfs are found by two main methods. Because they are nearby, their motion through space is detectable as a movement across the sky. When observers of such star movements note a bluish object, they suspect it to be a white dwarf. Drs. Eggen and Greenstein definitely confirmed many of these by colors and spectra.

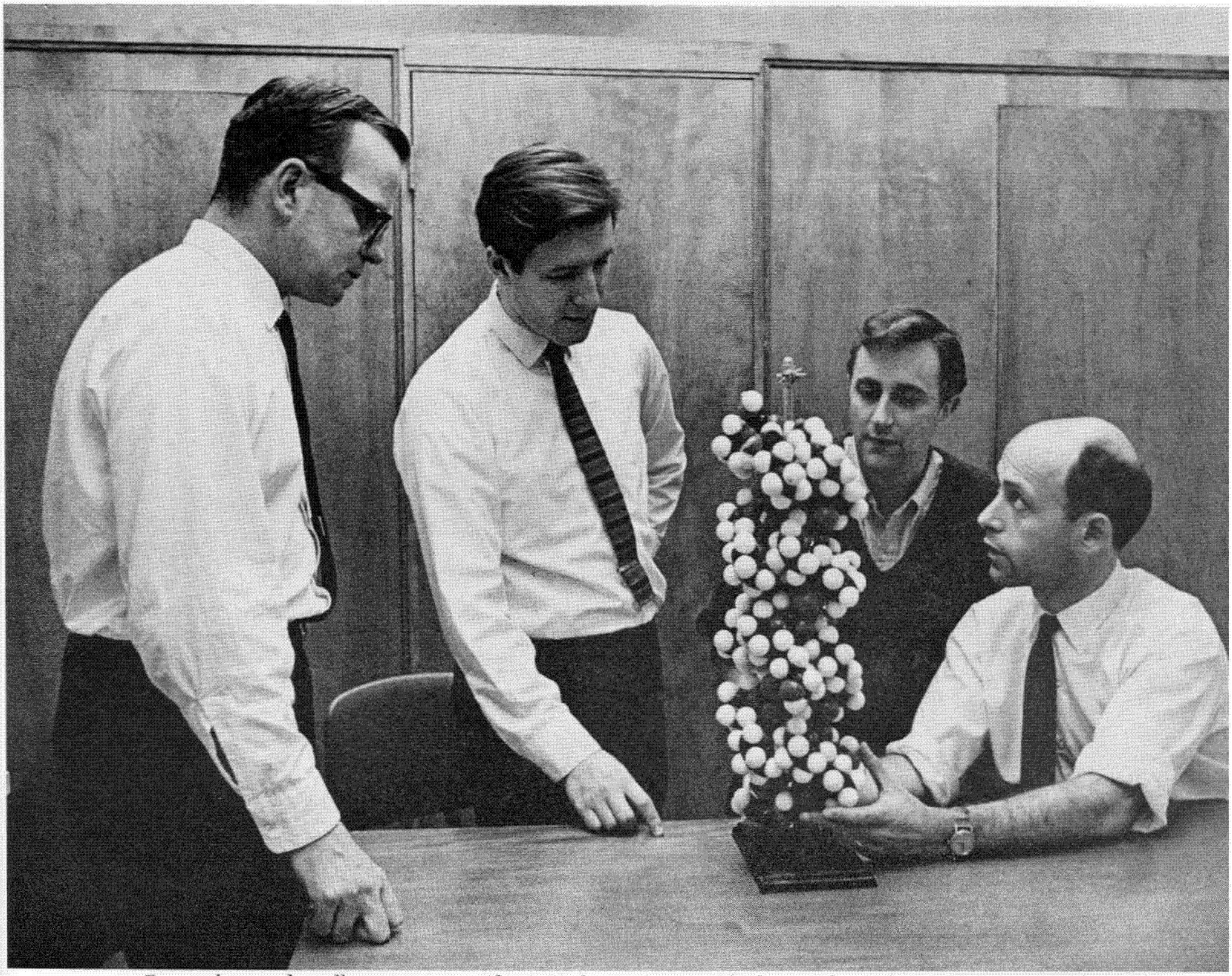
Still another method of finding them is to make surveys among faint stars for those that look blue. The majority of faint stars usually are red normal dwarfs. Many of these faint blue stars were found to be slow-moving white dwarfs.

An important result of the Eggen-Greenstein survey is proof that white dwarfs occur among all kinds of star populations. Slow-moving stars belong to the young population found in the spiral arms of our Milky Way Galaxy. Very fast-moving objects, speeding by the sun at up to 200 miles a second, come from the remote areas of the galaxy, or even from near its center. These white dwarfs are among the oldest stars, formed soon after the galaxy was born.

The astronomers discovered a second major kind of white dwarf which is twice as large, and probably weighs half as much, as ordinary white dwarfs. These brighter ones appear to be younger stars, perhaps still in the process of evolving, or still losing matter.

One of the unsolved mysteries of the dying stars is how a large star loses enough material to become a white dwarf. One theory is that a massive star suffers some kind of a violent explosion. But the existence of large numbers of white dwarf descendants of massive stars suggests a less catastrophic process. Armin J. Deutsch, staff member of the Mt. Wilson and Palomar Observatories, has suggested that red giant stars expell a large fraction of their mass.

Although white dwarfs are considered the dying stars of the universe, Drs. Greenstein and Eggen believe that none of them has actually expired. The universe is not old enough for any to have faded into invisibility. Even the faintest known of them are still going strong, still white-hot, with surface temperatures of 6,000 degrees.



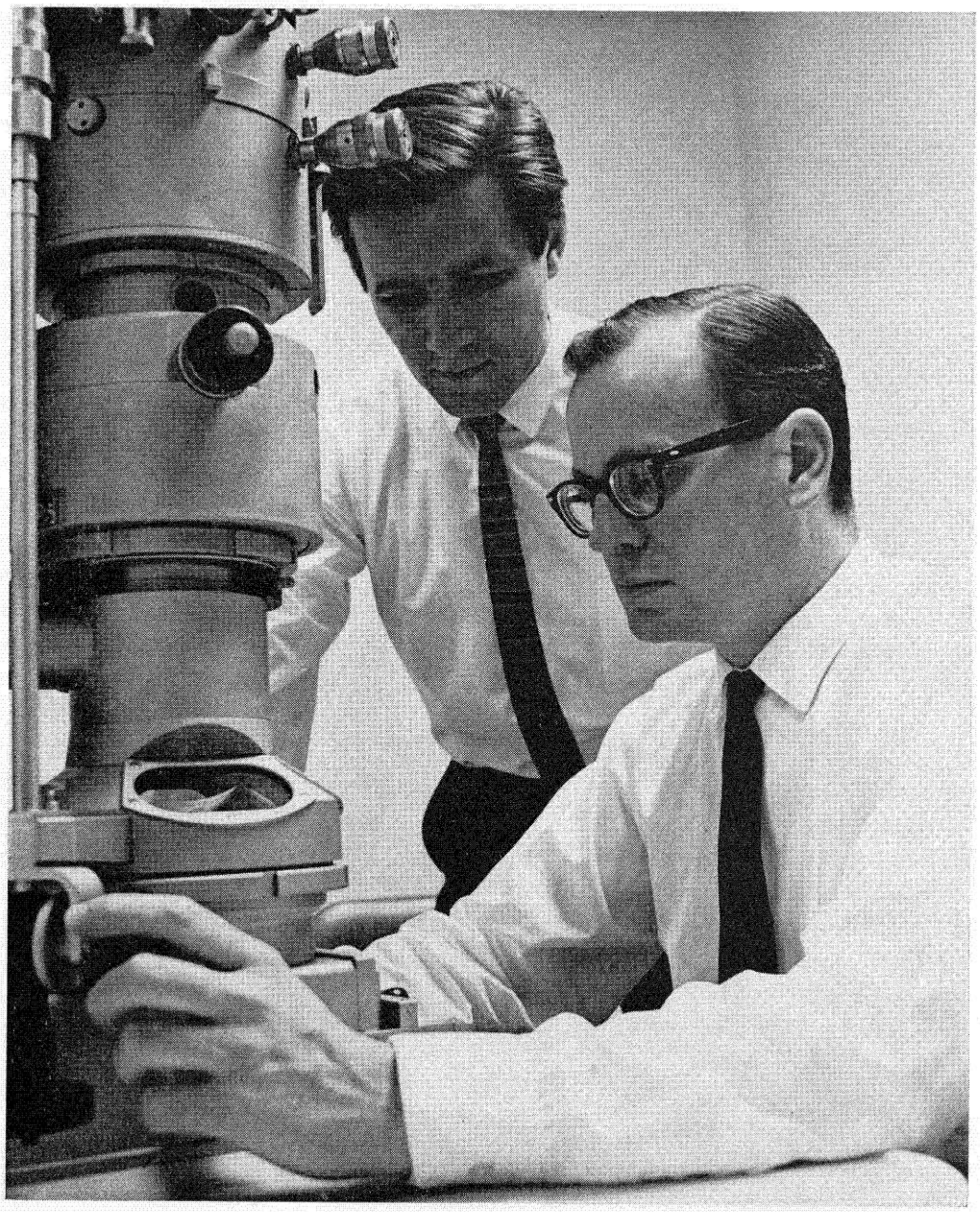
Researchers in the collagen project — Alan J. Hodge professor of biology; John A. Petruska, senior research fellow; Allen J. Bailey, research fellow; and John H. Fessler, senior research fellow — study a model of a small part of a collagen molecule, representing about 1/100th of the full molecule.

Collagen – A Masterpiece of Engineering Design

Caltech biologists work out the detailed subunit structure of the collagen molecule

Collagen is the most abundant protein in the body; it makes up about 30 percent of the protein in a human adult. It is the main constituent of connective and skeletal tissue. In bone it is like steel rods in reinforced concrete, in skin like pliable steel mesh, and in tendon like a steel cable.

Researchers in the laboratory of Alan J. Hodge, *The electron microscope makes it possible to study molecular details in crystallites of collagen magnified more than 100,000 times.*



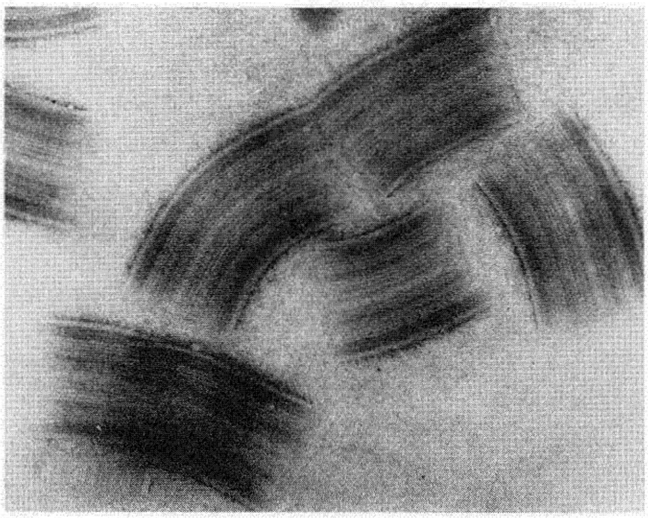
professor of biology at Caltech, have now worked out the detailed subunit structure, or architecture, of the collagen molecule. This is the first fibrous protein molecule to be so mapped. The research is supported by the National Institutes of Health, which is interested in the prevention and treatment of arthritis and other so-called "collagen diseases." Such basic structural research as this is an essential adjunct to medical studies and also may lead to a more fundamental understanding of the aging process in general.

The collagen molecule proves to be a masterpiece of engineering design. The strength of the collagen fiber results from both the design of the individual molecule and the overall pattern in which the molecules are linked together into a unified structure. The pattern appears to be the same in all animals.

Collagen is composed of protein threads, or polypeptide chains, each about 1/85,000th of an inch long. These are twisted, overlapped, and bonded together in such a manner as to take the greatest possible strains.

The Caltech model of the collagen molecule emerged after extensive mathematical analyses of data obtained with the electron microscope, x-ray crystallography, and biochemical techniques. John A. Petruska, senior research fellow in biology, collaborated with Dr. Hodge in the mathematical phases of the work, while Allen J. Bailey, Commonwealth Fund fellow, has been primarily responsible for the chemical investigations. John H. Fessler, senior research fellow, has been doing research designed to detect the subunits of collagen in early stages of biosynthesis. The Caltech model rests on many major contributions from laboratories at other institutions, also.

The collagen modecule consists of three chains



Electronmicrograph of a particular crystalline form of collagen in which the molecules lie side by side with no longitudinal displacement. The band pattern in each of the crystallites shown is a map or "fingerprint" of the molecular details. Magnification is 90,000 diameters.

of amino acids, which are the building blocks of proteins. Each chain is fashioned into a left-handed helix, or spiral. The three chains are wrapped together, right-handedly, to form a super helix of 35 turns about 1/85,000th of an inch long.

In addition to being wrapped around each other, the chains are linked together by hydrogen bonds whose attachments are sideways instead of end to end. Nature uses similar hydrogen bonding to produce tough fibers of silk.

Not only is the individual molecule designed for tensile strength; so also is the arrangement of the molecules in a fiber. The fiber has neighboring molecules systematically displaced to form a pattern like a wall of offset brick or stone, with a small space between each brick or stone on the horizontal plane. Each space is some one and a half millionths of an inch long, or about one-seventh the length of the three-stranded molecules (as shown in the diagram below). In bone, these spaces are filled with calcium phosphate, which provides rigidity and is the equivalent of cement in reinforced concrete.

Dr. Hodge began his investigation of collagen eight years ago at the Massachusetts Institute of Technology with Dr. F. O. Schmitt, professor of biology there. Because the molecule is too small to observe directly in the desired detail, the problem was attacked indirectly.

The biologists grew crystallites of the molecule in which all the molecules were aligned side by side instead of being offset like bricks. In these crystallites the like molecular features were in register and could be seen as bands in the electron microscope, as shown above. Staining with heavy metal ions served to further intensify these bands. Up to 90 bands could be resolved for certain types of staining.

Detailed analysis disclosed that the band pattern could be explained in terms of a subunit model like that shown below. Two of the molecule's three polypeptide chains consist of five identical subunits joined end to end, while the third chain consists of seven subunits. All three chains are the same length. Detailed computer refinement of the pattern by Dr. Petruska lends strong support to this concept.

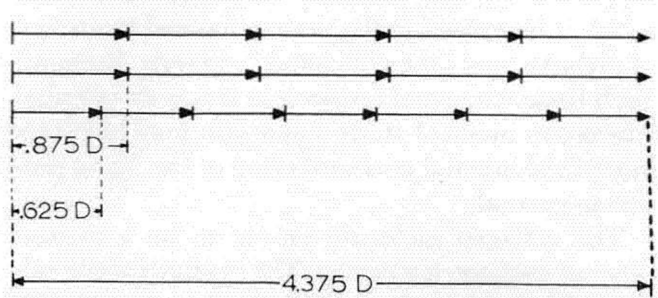
Although the sequence of the amino acid building blocks has not yet been worked out in detail, it is known that two of the chains are chemically very similar, or identical, while the third is distinctly different. In each chain, glycine, the smallest of the 20 amino acids used in building proteins, comprises 33 percent of the amino acid units. The presence of the small glycine units in every third position enables the three fibers to fit snugly together and to be maximally hydrogen-bonded.

The new model of the collagen molecule has these advantages, according to Dr. Hodge:

Relatively little genetic information is required for assembling it — only that needed to form the two types of polypeptides, the shorter one and the longer one.

The unequal lengths of these subunits suggest mechanisms of growth assuring the assembly of very large molecules which are homogeneous with respect to length, thus insuring their capacity to form highly ordered structures.

The next step is to map the sequence in which the amino acids are strung together in the two subunits. This will further increase the understanding of the important molecule. Preliminary work indicates that the same kind of unequal subunit structure may explain the lengths and properties of other important large molecules, such as myosin, which is the major protein component of muscle.



Schematic representation of the subunit model of the collagen molecule. Two of the three chains contain five subunits each, while the third contains seven. The molecular length is 4.375D (where D is the systematic displacement of the neighboring molecules in the native fiber). It is because this length is not integral in respect to D that "holes" occur in the fiber.

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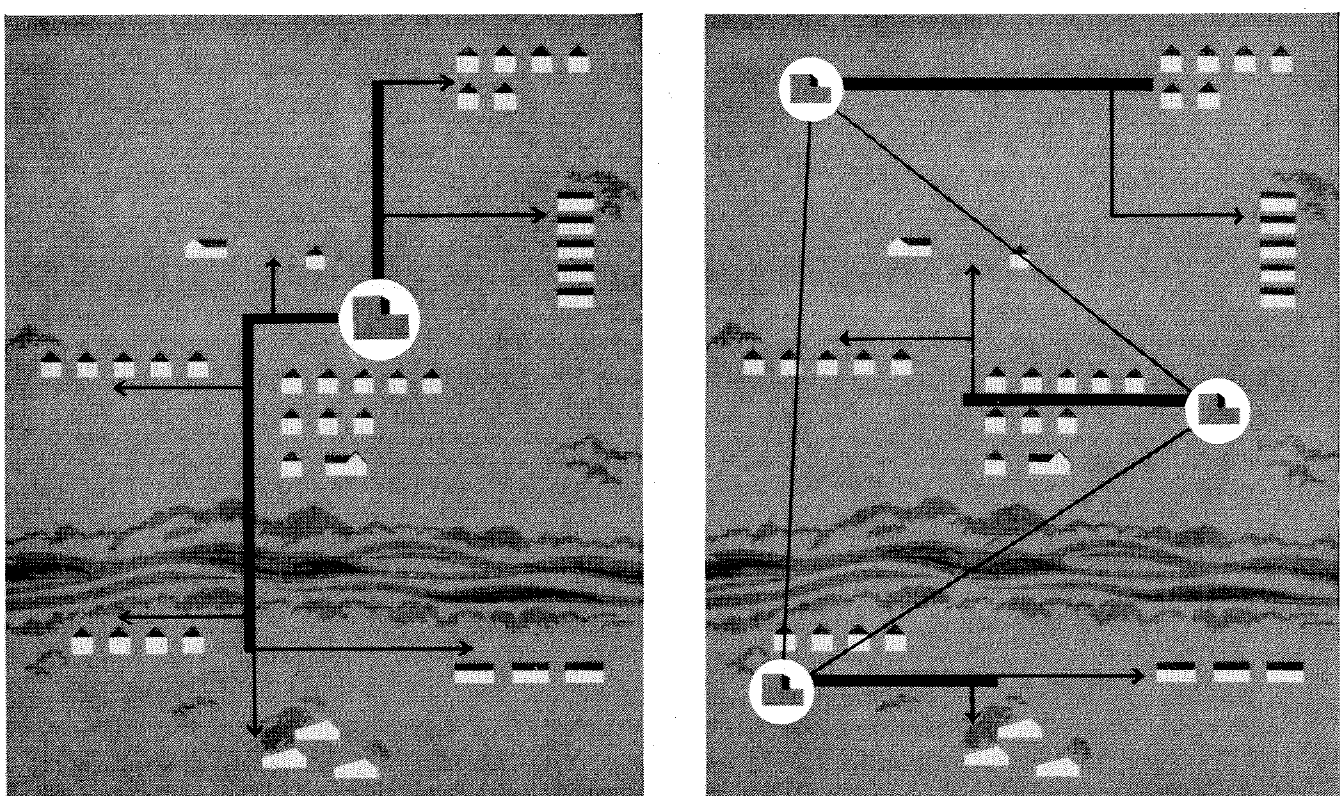
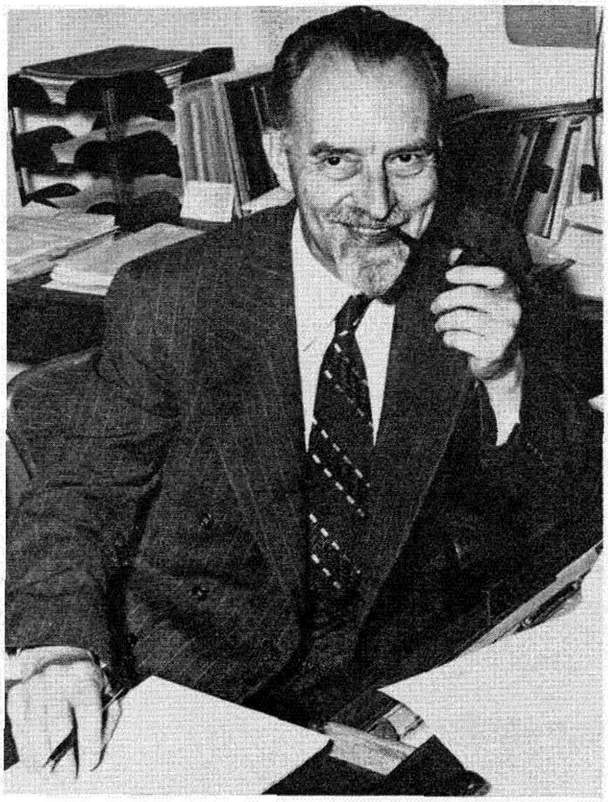


This? In this hypothetical geographical area, communications could be supplied with one large telephone switching office and a network of cables (left), or with three smaller offices and a different network (right). Many other combinations of offices and cable networks might be possible. This situation, although hypothetical, is typical of the complex telephone engineering problems that are being solved with the aid of computer programs designed at Bell Laboratories. **Or this?**



ROMEO RAOUL MARTEL

1890 - 1965

Romeo Raoul Martel, professor of structural engineering and faculty member at Caltech for 42 years, died on February 28, at the age of 74. He joined the faculty in 1918, when the campus was surrounded by orange groves, and retired as professor emeritus in 1960. A native of Iberville, Quebec, R. R. Martel graduated from Brown University in 1912 and taught civil engineering at Rhode Island State College and at the Mechanics Institute in Rochester, New York, before coming west to work for the Atchison, Topeka & Santa Fe Railroad in Amarillo, Texas. In 1918 he joined the Institute faculty and became a full professor of civil engineering in 1930.

Professor Martel was an inspiring teacher who made a lasting impression upon his students. In the classroom and in his office he delighted in subtly unfolding the recalcitrant brains of embryo engineers. He was an artist in knowing what not to say, and what not to explain. He was a master of the short and trenchant remark that might lie dormant for years before developing the brain in which it was lodged. It was his delight to coax, swindle, or frustrate a young mind into thinking for itself, and many of his students are now themselves teaching at universities and are, in turn, trying to influence their students similarly. Many of his former students are playing important roles in the practice of engineering in California, and others are responsible for important engineering works all over the world.

R. R. Martel was a pioneer in the earthquake-resistant design of structures and in earthquake engineering research. He was largely responsible for the earthquake provisions in the first issue of the Uniform Building Code in 1927, and he was active on building code committees for the City of Pasadena, the California State Chamber of Commerce, the State Division of Architecture, and the American Standards Association.

In 1926 he was a delegate to the Council on Earthquake Protection at the Third Pan-Pacific Science Congress in Tokyo, and attended the World Engineering Congress in Tokyo in 1929 in a similar capacity. He was a member of the Advisory Committee on Engineering Seismology for the United States Coast and Geodetic Survey, and was one of the founding members of the Earthquake Engineering Research Institute.

He and his students were responsible for much of the early research on the effects of earthquakes, and the results of this work are embodied in present-day building codes. It is indicative of his interests and influence that much of the knowledge built up in engineering seismology, and most of the provisions against earthquakes in the California Building Code can be traced back to him, or to persons who had come under his influence.

The technical literature on destructive earthquakes is full of the names of his students and many of his students have played active roles in the design of structures to resist earthquakes. He was instrumental in organizing the first meetings of structural engineers in southern California. These developed from a group of 12 men into the Structural Engineers Association of Southern California with 800 members, and later the Structural Engineers Association of Northern California with 400 members, and the Structural Engineers Association of Central California with 200 members. These associations have had a profound influence upon the development of structural engineering in California.

He was a member of numerous engineering and scientific organizations and derived particular pleasure from his membership in the Societé des Ingénieurs Civils de France and the International Association of Bridge and Structural Engineers.

R. R. Martel served as consultant on the design and construction of many important and novel structures. He was consultant on the design and construction of the Mt. Palomar telescope and on the design of the pumps for the Metropolitan Aqueduct, which were unusual in size and capacity. He was consultant on the construction, in 1921, of the Pasadena-San Rafael Bridge and later consulted on the designs of the Linda Vista and Colorado Street bridges. He was consultant to the cities of Pasadena, Glendale, and Los Angeles, to private companies, and the State of California on the design and construction of bridges, dams, reservoirs, gas and oil refineries, and power plants; and to the U.S. Army Engineer Corps in Los Angeles and the cities of Glendale, Burbank, and Riverside on flood-control structures. He served as consultant on the earthquake design of many buildings, in particular the First Trust Building in Pasadena, which is probably the first building in the United States to receive a rational design against earthquakes.

Professor Martel served for many years as Secretary of the Faculty and was succeeded in this position by his son, H. C. Martel, associate professor of electrical engineering at the Institute. In addition to his son, he is survived by his wife, Mildred Pray Martel, his daughter, Nancy C. Martel, and five grandchildren.

—George W. Housner

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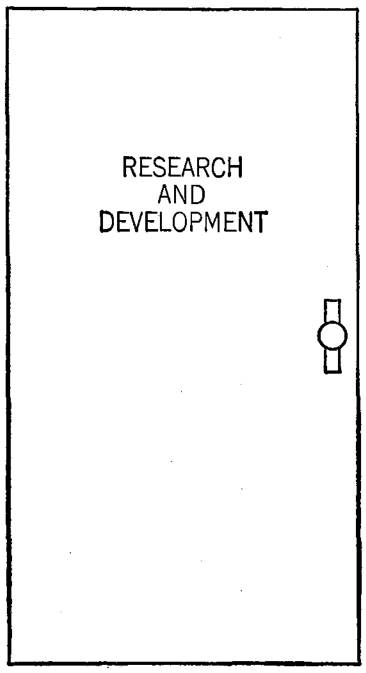

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The Month at Caltech

Royal Society

Gerald B. Whitham, professor of aeronautics and mathematics at Caltech, has been elected a fellow of the Royal Society, Britain's top scientific body. He is one of two United States scientists to receive the honor this year – the other being John Ward, physicist at Johns Hopkins University.

Whitham, who is chairman of Caltech's committee for applied mathematics, is interested in the structure and propagation of waves. His current work involves the mathematical investigation of the structure of plasma shock waves.

Leader of America

Simon Ramo, president of The Bunker-Ramo Corporation, research associate in electrical engineering and a member of the Caltech board of trustees, will be on campus April 7, 8, and 9 as a YMCA-sponsored Leader of America. Ramo will discuss the impact of technology on society in informal meetings with students and faculty and in an evening lecture in Beckman Auditorium. To illustrate one aspect of his advice to young scientists and engineers – "participate in cultural activities" – Ramo plans to bring his violin and an accompanist for some of his campus appearances.

The next Leader in the series will be John Ciardi, poetry editor of the *Saturday Review* and director of The Bread Loaf Writers Conference, who will be at Caltech May 10 to 12.

Sloan Foundation Grants

Four Caltech men are among the 91 young scientists selected to share $1,400,000 in basic research grants from the Alfred P. Sloan Foundation: Fred C. Anson, associate professor of analytical chemistry, who is studying the chemical changes produced by the flow of electrical currents through solutions; Sunney I. Chan, associate professor of chemical physics, investigating the interacting forces of molecules in gases and liquids; Alan T. Moffet, research fellow in radio astronomy, mapping the structures of celestial sources emitting radio energy; and Hugh P. Taylor, Jr., associate professor of geology, studying the processes of formation and temperatures in igneous and metamorphic rock.

Choices in Vietnam

"Choices in Vietnam," a one-day institute sponsored by the Caltech YMCA, the American Friends Service Committee, and the Friends Committee on Legislation, will be held on the campus on April 3. Speakers and discussion leaders will include Jason Finkle, professor of public administration at USC; Stanley Sheinbaum, from the Center for the Study of Democratic Institutions; Herbert Alexander, professor of history at Los Angeles City College; Joel Edelman, of The RAND Corporation; J. Stuart Innerst, chairman of the China committee of the AFSC; and George Noronha, professor of political science at San Francisco College for Women.

An evening address, "Toward a Peaceful Solution in Vietnam," will be given in Beckman Auditorium by Gilbert F. White, professor of geography at the University of Chicago, consultant to the Lower Mekong Co-ordination Committee, and national chairman of the AFSC.

McGeorge Bundy

McGeorge Bundy, special assistant to the President for national security affairs, will be at Caltech April 20 and 21, under the auspices of the Institute Assemblies and Programs Committee. Bundy, who went to his present position from Harvard, where he was professor of government and Dean of the Faculty of Arts and Sciences, will give an evening address in Beckman Auditorium, and will speak at the humanities division seminar on national security.

Community Affairs

Robert W. Oliver, associate professor of economics at Caltech, faces a runoff election April 1 for the Pasadena Board of City Directors. Although he polled more votes than either of his two opponents

continued on page 26

from the Fifth District in the March 11 election, Oliver must rerun against his nearest contender, incumbent Clarence Oakley, because he did not receive a simple majority of the total vote.

Ernest B. Hugg, assistant director of Caltech's physical plant, is a candidate for member of the Pasadena Board of Education in the May 11 election. Hugg served on three Citizens Staff Advisory committees to study school needs. In 1959 he was given the Pasadena Education Association's Distinguished Service Award.

Television Director

Mrs. Rose Blyth has returned to Caltech as director of television, radio, and film activities to develop and distribute program material to TV stations, schools, and other organizations.

Mrs. Blyth worked at Caltech from 1955 to 1962, when she left to help organize the new Los Angeles educational television station, KCET. In 1964 she won the Robert Eastman Award as "Outstanding Woman in Broadcasting."

Putnam Winners

A Caltech team of three undergraduate students has won the 25th annual William Lowell Putnam Mathematical Competition, against 219 teams from United States and Canadian colleges.

Sponsored by the Mathematical Association of America, the contest consisted of a six-hour written examination on general college math and was given December 5 at each of the competing schools simultaneously. Winners were announced this month. The Massachusetts Institute of Technology placed second and Harvard third.

Computer Debate

The role of Caltech's 7040 and 7094 computers was expanded to include programming for the invitational debate tournament held on campus February 19 and 20. It was the first tournament of its kind in the country in which the machines were used entirely to schedule debates and to determine results.

Fed the necessary statistics by the tournament committee, the machines scheduled the six preliminary rounds involving complicated juggling of the 104 students and the 26 judges taking part; computed the results of the ratings; and, finally, scheduled the three elimination rounds for the eight teams involved. The winner — Washburn University, Topeka, Kansas.

Honors and Awards

William H. Pickering, director of Caltech's Jet Propulsion Laboratory, received three awards this month in connection with the Ranger program. In Paris on March 4, he was awarded the Galabert International Prize for astronautics; in London on March 8, he was presented with a silver replica of Ranger VII, by the British Interplanetary Society; and in Washington on March 19, he received the Robert H. Goddard Memorial Trophy for 1965 from the National Space Club.

Harris M. Schurmeier, Ranger project manager, received the National Space Club's astronautics engineer award for contributing to the success of the Ranger VII lunar photography mission.

Aron Kuppermann, professor of chemical physics at Caltech, has been appointed to the editorial advisory board of *The Journal of Physical Chemistry,* a monthly publication of the American Chemical Society.

Henry Dreyfuss, associate in industrial design and a member of Caltech's board of trustees, was given an Ambassador Award for Achievement at the Royal College of Physicians in London this month for his "unrivaled contribution to industrial design in human terms." The award was presented by Princess Margaret.

Roy W. Gould, professor of electrical engineering and physics at Caltech, has been elected a fellow in The Institute of Electrical and Electronics Engineers, Inc., for "contributions to the theory of microwave tubes."

Theodosius Dopzhansky, professor at The Rockefeller Institute in New York, and one-time assistant professor of genetics at Caltech, (1929-1936) received the National Medal of Science from President Johnson last month, along with ten other distinguished scientists, for "their outstanding contributions to knowledge in the physical, biological, mathematical or engineering sciences."

Kenneth V. Thimann, Higgins professor of biology at Harvard, and formerly instructor of biochemistry at Caltech (1930-35), has been named provost of College III and a professor of biology at the University of California at Santa Cruz.

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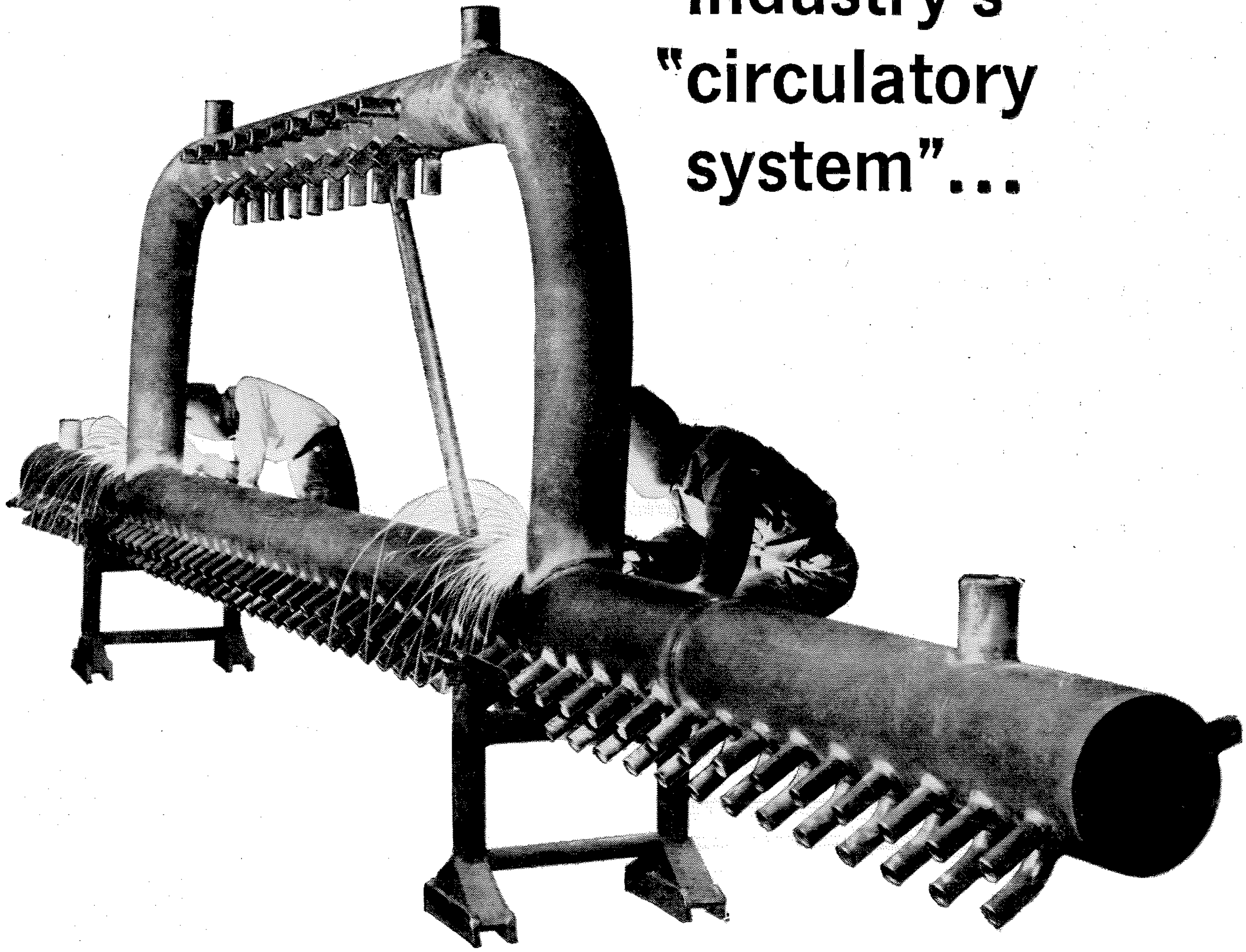
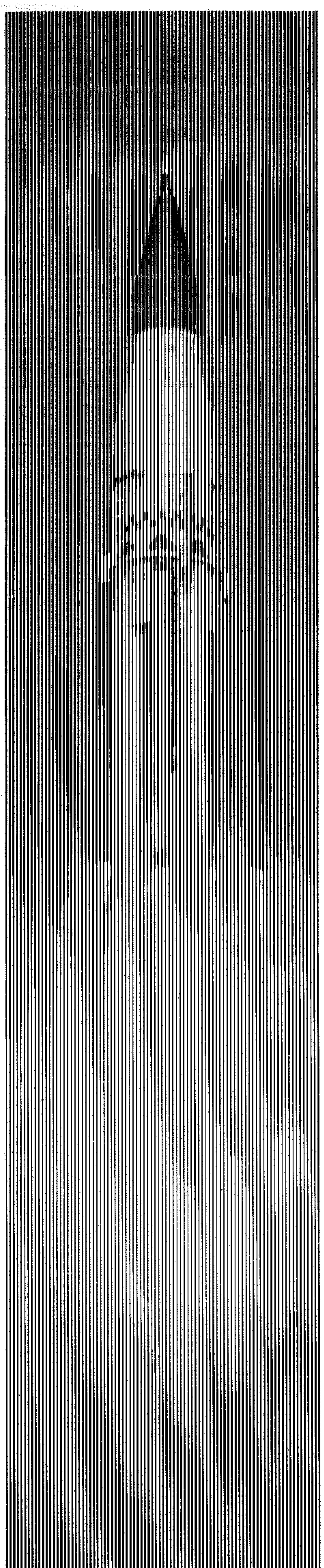




Alumni News

Board Nominations

The Board of Directors of the Alumni Association met as a Nominating Committee on February 23, 1965, in accordance with Section 5.01 of the By-Laws. Eight vacancies will occur on the Board at the end of the fiscal year, June 1965. Four of these vacancies will be filled by the Immediate Past President, President, Secretary, and Treasurer, ex officio, and four will be filled by direct election. The present members of the Board, with the years their terms expire are:

James L. Adams '55	1966	David L. Hanna '52	1965
Donald S. Clark '29	1965	John L. Mason '47	1966
William H. Corcoran '41	1965	John T. McGraw '38	1966
Patrick J. Fazio '53	1966	Richard P. Schuster, Jr. '46	1965
John R. Fee '51	1965	Peter V. H. Serrell '36	1965
Sidney K. Gally '41	1966	Herbert M. Worcester, Jr. '40	1965

The following nominations have been made:

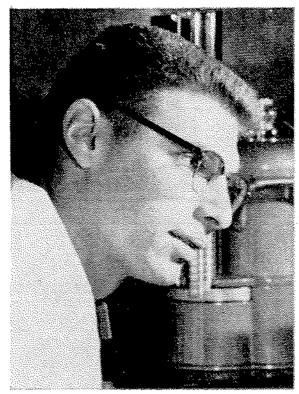
Presdent – Richard P. Schuster, Jr. '46	(1 year)
Vice-President – Sidney K. Gally '41	(1 year)
Secretary – Donald S. Clark '29	(1 year)
Treasurer – John R. Fee '51	(1 year)
Director – Theodore C. Combs '27	(2 years)
Director – Robert W. Lynam '54	(2 years)
Director – Paul D. Saltman '49	(2 years)
Director – Fred T. Selleck '49	(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*

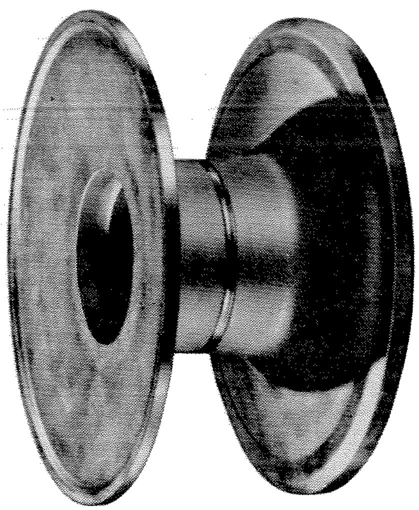
ROBERT W. LYNAM received his BS in mechanical engineering in 1954. He spent the next three years with the U.S. Air Force – including one year of graduate work in meteorology at Oklahoma A&M in Stillwater. Since 1957 he has been superintendent and project manager for various engineering contractors in the Los Angeles area. He is now field superintendent for the Long Beach division of the Sully-Miller Contracting Company. Last year he was a member of the program committee for the Alumni Seminar.



PAUL D. SALTMAN received his BS in chemistry in 1949 and spent a year of study and research at the College de France in Paris. In 1953 he received his PhD in biochemistry from Caltech and joined the faculty of the University of Southern California. He is now professor of biochemistry there. In 1960 he was appointed Career Investigator by the National Institutes of Health and was in Copenhagen for a year studying transport mechanism in cells. He served as a member of the program committee of the Alumni Seminar in 1956.

THEODORE C. COMBS received his BS in civil engineering in 1927, and has worked in city management, building materials research and technical promotion, fabrication of structural elements, construction, and engineering sales work. He is now engaged in property development and management. He served the Alumni Association as president in 1940 (with time out for military service in Europe and the Pacific), and as editor of *Engineering and Science*. He has been program committee chairman and arrangements committee chairman of the Alumni Seminar and is general chairman this year.

FREDERIC T. SELLECK received his BS in chemistry in 1949, after interrupting his education to serve with the U.S. Air Force three and one-half years. Following a year with Standard Perlite Corporation in Pasadena, he became a research assistant in Caltech's chemical engineering laboratory, working in fluids research. In 1953 he joined the Fluor Corporation in Los Angeles, where he is now process methods and data engineer in applied thermodynamics and physical chemistry. He was a member of the Alumni Seminar committee in 1961 and assistant general chairman in 1962 and 1963.



FORGINGS ELIMINATED REJECTS ON THIS EARTHMOVER HUB...

and cut cost 16%

Originally, this earthmover wheel hub was not a forging. Now it is **forged** in steel. Here's why . . .

While reviewing costs of the original part, the earthmover manufacturer discovered that: (1) Cost of the hub was too high; (2) rejection rates during machining were high because of voids and inclusions; and (3) hidden flaws required costly salvage operation.

By converting to **forged** steel hubs, the manufacturer has saved 16%, has completely eliminated rejects and repairs of parts in process, has achieved 100% reliability of the part.

Forgings have greater inherent reliability and strength because they:

1. Are solid, void-free metal
2. Have higher resistance to fatigue
3. Are strongest in withstanding impact and sudden load
4. Have high modulus of elasticity
5. Have low mechanical hysteresis
6. Have unique stress-oriented fiber structure

Memo to future engineers:

"Make it lighter and make it stronger" is the demand today. No other metalworking process meets these two requirements so well as the forging process. Be sure you know all about forgings, their design and production. Write for Case History No. 104, with engineering data on the earthmover hub forging shown above.

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When it's a vital part, design it to be

FORGED

Personals

1918

MUNSON J. DOWD died of cancer February 22 in El Centro. He was 68. A longtime expert on water resources, he was chairman of the Colorado River Board of California and executive officer of the Imperial Irrigation District. He leaves his wife, Neva; a son, Munson; and two daughters, Mrs. Helen Hearns and Mrs. Neva Jurkovich.

1922

HOWARD G. VESPER is now a director and vice president of Standard Oil Company of California, with headquarters in San Francisco. He is principally concerned with the company's worldwide marketing interests. For the past seven years he has been president of Western Operations, Inc., chief operating subsidiary of Standard Oil of California.

RUSSEL H. KOHTZ died suddenly last July in Studio City, where he made his home. He had been an insurance agent and broker for the past 30 years, with offices in a building he owned and had constructed. He is survived by his wife, Cecille; a stepdaughter, June M. U'Ren; and a stepson, Robert B. Jones.

HAROLD S. OGDEN retired on February 1 from the General Electric Company's locomotive and car equipment department in Erie, Pennsylvania, after 42 years of service. He was presented with an original painting by John Gould of the PSIC Silverliner, the first modern high-speed AC multiple-unit car with static propulsion control, which was pioneered through his efforts. Ogden's son, Hugh, is a doctoral candidate and teaching fellow at the University of Michigan, and his daughter, Elizabeth, is married to a GE engineer.

EDMUND T. GROAT died February 28 of a heart attack in Tucson, Arizona, where he had been visiting his son, Russell. Earlier in the month he had retired as coordinator of mining sales for the General Electric Company in Chicago, after some 40 years with the company. He and Mrs. Groat were en route to southern California to visit friends and relatives. He is survived by his wife, Margaret; two sons, Russell and Leonard; and two daughters, Mrs. Vern Baldwin and Mary Frances Groat. Groat was one of Caltech's most outstanding athletes. As an undergraduate he won 10 letters in four sports – football, track, baseball and basketball.

1925

MARKHAM E. SALSBURY, chief engineer for the Flood Control District of Los Angeles County, will retire next month after nearly 40 years of service. He started in 1925 with the County Surveyor's staff, but transferred to the Flood Control District in 1927 as an assistant engineer. He became chief engineer in 1959.

ROLLAND R. PEARSON retired last month from his position as chairman of the science department and psychometrist at Lincoln High School in Los Angeles, after 36 years of teaching high school math and science. He was graduated from Lincoln in 1918, began teaching vocational electricity there in 1929, transferred to Manual Arts High School in 1947 to teach math and physics, and returned to Lincoln in 1954 in his present capacity.

1926

ERNST MAAG is recovering from recent major surgery and expects to be fully active within the month. Maag retired December 1, 1964, from the Office of Architecture and Construction of the State of California, where he was principal structural engineer in charge of the southern California office of the school section.

1927

JAMES BOYD was named 1964 "Copper Man-of-the-Year" by the Copper Club, a nationwide organization of experts in the field. The award was given for his contributions to the copper industry as corporation president, educator, government official, and geologist. Boyd is president of the Copper Range Co. of New York City; a former vice president of Kennecott Copper Corp. in charge of their worldwide exploration programs; a former director of the United States Bureau of Mines; and a former faculty member and dean of faculty at the Colorado School of Mines.

1931

JOHN F. McGARRY, MS '32, has retired from lecturing at the University of California at Berkeley, to devote more time to consulting work and managing his private interests.

GEORGE E. LIEDHOLM retired last month after 31 years with Shell Development Company, where he was head of the petroleum processing department of the company's research center at Emeryville, California. During the 1930's and 40's Liedholm was part of a team that developed Shell's first commercial fluid-bed catalytic cracking plant. The Liedholms will continue to live in Berkeley, but plan to travel for the first year or so of his retirement.

1932

JOSEPH SHEFFET, MS '33, is the new vice president of the Consulting Engineers

Association of California, an organization with a membership of 212 firms and 356 individuals. Sheffet is a structural engineer with the firm of Joseph Sheffet. Inc., in Los Angeles.

1935

FRANCIS R. GAY writes from Oakland that he and his wife have a year-old son, born February 7, 1964. An older son is at Piedmont Junior High School and a daughter is at Arizona State University. Gay is in the window-shade business. He was ranked No. 3 in Senior Veterans Tennis of northern California for 1964.

1939

CARROL M. BEESON, PhD, is the newly appointed chairman for the division of engineering of California State College at Los Angeles, where he will head the second largest college undergraduate engineering program in the West. The appointment is effective September 1. Beeson goes to Cal State L.A. from the University of Southern California, where he has been chairman of the department of petroleum engineering, and a faculty member since 1948.

1940

DAVID BONNER, PhD, who founded the department of biology at the University of California at San Diego and served as professor of biology there from 1960 until his death last May, is to have the new biology building at UC San Diego named in his memory. David was a brother of James Bonner, professor of biology at Caltech.

1942

ROBERT A. COOLEY, PhD, has joined Monsanto Research Corporation as a senior research group leader at its laboratory in Dayton, Ohio. He was formerly with Fuel Cell Corp. in St. Louis, Missouri.

ARCHIE M. KAHAN, MS, is executive director of the University of Oklahoma's Research Institute and recently announced two new projects to be undertaken by the institute – one to deal with the properties of frozen soil, sponsored by the U.S. Army Cold Regions Research and Engineering Laboratory, and the other on thermodynamics and transport theory, sponsored by the U.S. Air Force Office of Scientific Research.

1944

ERIC WEISS died of a heart attack on January 29 in La Jolla. He was 44. He had been an independent consultant for computer systems there for the past three years. Prior to that time he was involved in the logical design of computers and computer systems for several firms. He is survived by his wife and a son, Ray '64, who is now a graduate student at the University of California at San Diego.

1947

ROBERT C. WHITE, MS, has been appointed manager of Geophoto Resources Consultants in Brisbane, Australia, where he has been assistant manager for two years. White joined Geophoto in 1951 and has served the company in the United States, Alaska, Guatemala, Libya and Colombia. In Australia he has been involved in the geological evaluation of the country's sedimentary basins.

CHAROEN VADHANAPANICH, MS '48, writes from Bangkok that he has changed his surname and should now be addressed: CHAROEN CHAROEN-RAJAPARK.

1950

ADAM F. SCHUCH, PhD, was elected a fellow of the American Physical Society recently. He is a staff member and alternate group leader in the low temperature physics group with the Los Alamos Scientific Laboratory, New Mexico.

ED REINECKE, the newly elected United States Congressman from California's 27th Congressional District, is now settled in Room 1239, Longworth House Office Building, Washington, D.C.

1951

EUGENE N. PARKER, PhD, professor of physics at the University of Chicago, has received the annual Space Science Award of the American Institute of Aeronautics and Astronautics "for distinguished individual research on the causes and properties of solar wind." The award was made in New York in January at the Institute's Aerospace Sciences meeting.

1952

ROBERT S. DAVIS, MS '53, announces that he and an associate, Peter Spitz, have formed a new company, Chem Systems, Inc., in New York City. The firm provides a new concept in technical consulting for management in the field of petro-chemicals. Davis formerly was director of development at Scientific Design Co. Inc. in New York.

1953

GEORGE W. SUTTON, MS, PhD '55, received the 1964 Arthur S. Flemming Award for "significant contribution in advising the Director of Development Plans on the scientific quality and engineering merit of new research and development programs," and for his unique contributions to the fields of heat protection of hypersonic re-entry vehicles and magnetohydrodynamic power generation. The presentation was made by the Honorable Arthur J. Goldberg, Associate Justice of the United States Supreme Court. Sutton is scientific advisor for the Directorate of Development Plans, DCS/Research & Development, Headquarters United States Air Force, Washington, D.C.

WILLIAM GARDNER is the new president of the City Engineers Association of Riverside and San Bernardino Counties, having just finished a year's term as president of the American Society of Civil Engineers of the same counties. Gardner recently became a licensed land surveyor, in addition to being a civil engineer. He is an ardent horticulturist, and will be staging chairman for the Riverside Flower Show in April. He writes that during the Christmas holidays he got together with JACK WALKER, DAVE KNAPP, DOUG INGLIS, BOB EASTON (all '53) and SAM VODOPIA '54.

ROBERT L. BIXLER, PhD '57, will be responsible for the commercial development of a series of new chemicals in his new job as manager of special projects for the Dow Chemical Company's chemical sales department. He has been with Dow since 1957 in the nuclear and basic research department, and as manager of marketing research for the chemicals department.

GIL PEPPIN, senior scientist for Northrop Corporation's division in Ventura, is working on generation of hypervelocity particles, equation of state of materials and shock phenomena. The Peppins have three children, a girl 6, and boys 5 and 4 years old.

1954

JOHN G. GOETTEN has joined Toups Engineering Incorporated, consulting civil engineers in Santa Ana. He had been senior civil engineer in charge of the Orange County road department's planning section.

1958

MICHEL EBERTIN, MS, is senior research engineer at the data systems division at Autonetics, in Anaheim, and is doing research in special purpose computers and requirements for real-time multiple computer systems. The Ebertins have a son, George Michel, seven months old.

RICHARD TANAKA, PhD, was general chairman last fall of the Joint Computer Conference in San Francisco, which involved nearly 11,000 persons. Tanaka is senior member for computer research at Lockheed Missiles & Space Co.'s electronic sciences laboratory in Palo Alto. He and his wife have what Tanaka calls a "wellprogrammed family: boy/girl/boy, 8, 6, 2 respectively."

1959

WILLIAM K. CLARKSON, MS, is the new manager of the systems integration section at the Aerospace Corporation in El Segundo. He has been with the company since 1960.

WILLIAM O. McCLURE, who completed work on his PhD at the University of Washington, Seattle, last November, is now at The Rockefeller Institute in New York City, working on some aspects of immunochemistry. He reports that GARLAND MARSHALL '62, DAVE LANGE, '58 and STAN SAJDERA '63, also are in New York – all well and happy.

1960

MARTIN CARNOY and his wife announce the birth of their first child, a son, David Alexis, on December 7 in Washington, D.C.

1962

GEORGE ROBERT ROOT, MS '63, is one of the research engineers at the Hycon Manufacturing Corp. in Monrovia, who collaborated on the development of a device that will artifically stimulate the heart for as long as 30 years. The instrument is being used in heart patients at the City of Hope Medical Center in Duarte, California. It is implanted in the heart muscle and uses batteries rechargeable from the outside.

JOHN F. McCARTHY JR, PhD. is director of Apollo control systems at the space information system division of North American Aviation in Downey, California. In a recent talk to students of the Massachusetts Institute of Technology's department of aeronautics and astronautics, McCarthy predicted that "home viewers will be able to watch astronauts on the moon in 1969, and the pictures will be of equal quality to those of present-day commercial presentation."

1964

JOSEPH H. WEIS is studying at the University of Bristol, England, on a Rotary Foundation Fellowship.

JOHN F. CLAUSER, teaching assistant in physics at Columbia University, was married in December to Maralee Warren.

Don't forget the date

MAY 8

PLACEMENT ASSISTANCE TO CALTECH ALUMNI

There are two ways in which the Placement Service may be of assistance to you:

(1) To help you seek new employment or a change of employment.

(2) To inform you when outstanding opportunities arise.

This service is provided to Alumni by the Institute. A fee or charge is not involved.

If you wish to avail yourself of this service, fill in and mail the following form:

To: Caltech Alumni Placement Service
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Please send me:

☐ An Application for Placement Assistance

☐ A form to report my field and operation so that I may be notified of any outstanding opportunities.

Name .... Degree (s) ....

Address .... Year (s) ....

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VICE PRESIDENT
David L. Hanna, '52

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Donald S. Clark, '29

TREASURER
John R. Fee, '51

James L. Adams, '55
Wm. H. Corcoran, '41
Sidney K. Gally, '41
John L. Mason, '47
John T. McGraw, '38
Richard P. Schuster, Jr., '46
H. M. Worcester, Jr., '40
Peter, V. H. Serrell, '36

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Vice-President — Philip E. Smith, '39, Eastman Kodak Co., 1712 Prairie Ave., Chicago, Ill.

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Secretary-Treasurer — Thomas G. Taussig, '55, Lawrence Radiation Lab., Univ. of Calif., Berkeley, Calif.

Meetings: 15th Floor, Engineers' Club, 206 Sansome St., San Francisco
Informal luncheons every Thursday at 11:45 A.M.
Contact Mr. Farrar, EX 9-5277, on Thursday morning for reservations.

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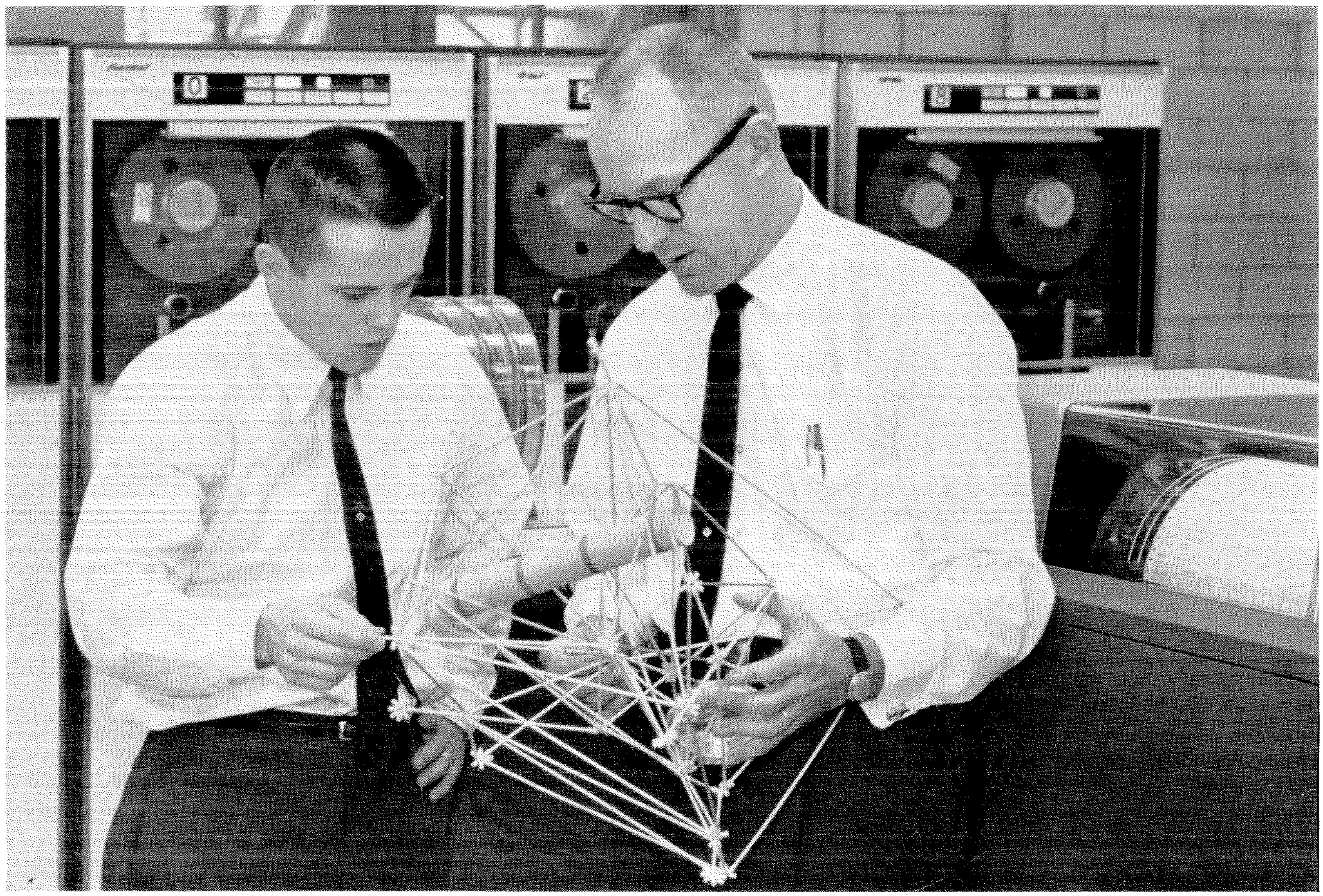
Meetings: University Club, 1319 "K" St.
Luncheon first Friday of each month at noon.
Visiting alumni cordially invited—no reservation.



10 years from now he may tire of working with computers

10 years ago he didn't wait for a computer's verdict

People matter more than computers

To lure smart young engineers, we feature up-to-date computer facilities. That's one good reason to have computers. We have even more compelling reasons, not all to be found in our widely advertised product lines like family cameras, film, textile fibers, office equipment, plastics, etc.

What prudence prevents us from publicly spilling is what occupies and fascinates a large corps of mechanical engineers like Edward T. Kern *(right)* and his younger colleague, William S. Walsh. To more colleagues from among the mechanical engineers of the Class of 1965, we hereby offer our persuasive combination of long-haul stability and internal mobility.

We respect an engineer for requesting a chance to broaden himself by a change of assignment. Both men pictured here did so.

When we hired Ed fresh out of college in 1947, we had him spend a year personally running a lathe and doing bench assembly on new production equipment for film manufacture. (We rarely start engineers that way any more.) Then, until 1955, he developed machinery for paper-sensitizing and film-emulsion coating. Next came a stint bossing a 75-man crew that erected, maintained, and repaired buildings and equipment for processing KODACOLOR Prints and other large-volume photographic products. Feeling his feet all too firmly on the ground after three years of this, he decided to grapple with a subtler form of reality than concerns the average pipefitter, electrician, or bricklayer.

This decision he made just in time to join his present team, then forming. For a while he found himself pitching in with proposal preparation, customer contact, subcontract technical co-ordination, customer briefings, etc. Gradually the assignment evolved from communicating *about* technical matters to generating rather fundamental technical content of his own. This he does today, living the life of the systems engineer, surrounded by logic, concepts, and limiting parameters.

Bill, a 1962 graduate, spent his first year in vibration analysis and learned how unimportant is the distinction between an E.E. (which his diploma calls him) and an M.E., under which heading he now ventures on the same frontier with Kern. Before we throw him his retirement party, for all we know, he may win honors as the greatest living expert on knitting machinery. We have many interests.

Drop us a line.

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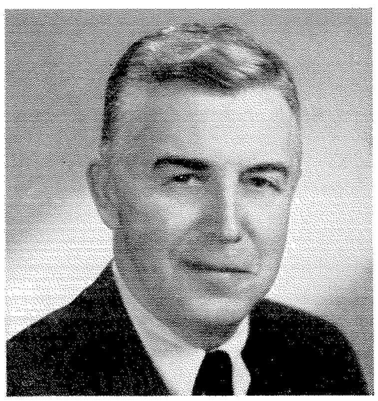
Should You Work for a Big Company?

An interview with General Electric's S. W. Corbin, Vice President and General Manager, Industrial Sales Division.



S. W. CORBIN

■ Wells Corbin heads what is probably the world's largest industrial sales organization, employing more than 8000 persons and selling hundreds of thousands of diverse products. He joined General Electric in 1930 as a student engineer after graduation from Union College with a BSEE. After moving through several assignments in industrial engineering and sales management, he assumed his present position in 1960. He was elected a General Electric vice president in 1963.

Q. Mr. Corbin, why should I work for a big company? Are there some special advantages?

A. Just for a minute, consider what the scope of product mix often found in a big company means to you. A broad range of products and services gives you a variety of starting places now. It widens tremendously your opportunity for growth. Engineers and scientists at General Electric research, design, manufacture and sell thousands of products from microminiature electronic components and computer-controlled steel-mill systems for industry; to the world's largest turbine-generators for utilities; to radios, TV sets and appliances for consumers; to satellites and other complex systems for aerospace and defense.

Q. How about attaining positions of responsibility?

A. How much responsibility do you want? If you'd like to contribute to the design of tomorrow's atomic reactors—or work on the installation of complex industrial systems—or take part in supervising the manufacture of exotic machine-tool controls—or design new hardware or software for G-E computers—or direct a million dollars in annual sales through distributors—you can do it, in a big company like General Electric, if you show you have the ability. There's no limit to responsibility . . . except your own talent and desire.

Q. Can big companies offer advantages in training and career development programs?

A. Yes. We employ large numbers of people each year so we can often set up specialized training programs that are hard to duplicate elsewhere. Our Technical Marketing Program, for example, has specialized assignments both for initial training and career development that vary depending on whether you want a future in sales, application engineering or installation and service engineering. In the Manufacturing Program, assignments are given in manufacturing engineering, factory supervision, quality control, materials management or plant engineering. Other specialized programs exist, like the Product Engineering Program for you prospective creative design engineers, and the highly selective Research Training Program.

Q. Doesn't that mean there will be more competition for the top jobs?

A. You'll always find competition for a good job, no matter where you go! But in a company like G.E. where there are 150 product operations, with broad research and sales organizations to back them up, you'll have less chance for your ambition to be stalemated. Why? Simply because there are more top jobs to compete for.

Q. How can a big company help me fight technological obsolescence?

A. Wherever you are in General Electric, you'll be helping create a rapid pace of product development to serve highly competitive markets. As a member of the G-E team, you'll be on the leading edge of the wave of advancement—by adapting new research findings to product designs, by keeping your customers informed of new product developments that can improve or even revolutionize their operations, and by developing new machines, processes and methods to manufacture these new products. And there will be classwork too. There's too much to be done to let you get out of date!

FOR MORE INFORMATION on careers for engineers and scientists at General Electric, write Personalized Career Planning, General Electric, Section 699-12, Schenectady, N. Y. 12305

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