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Rose Technic Staff

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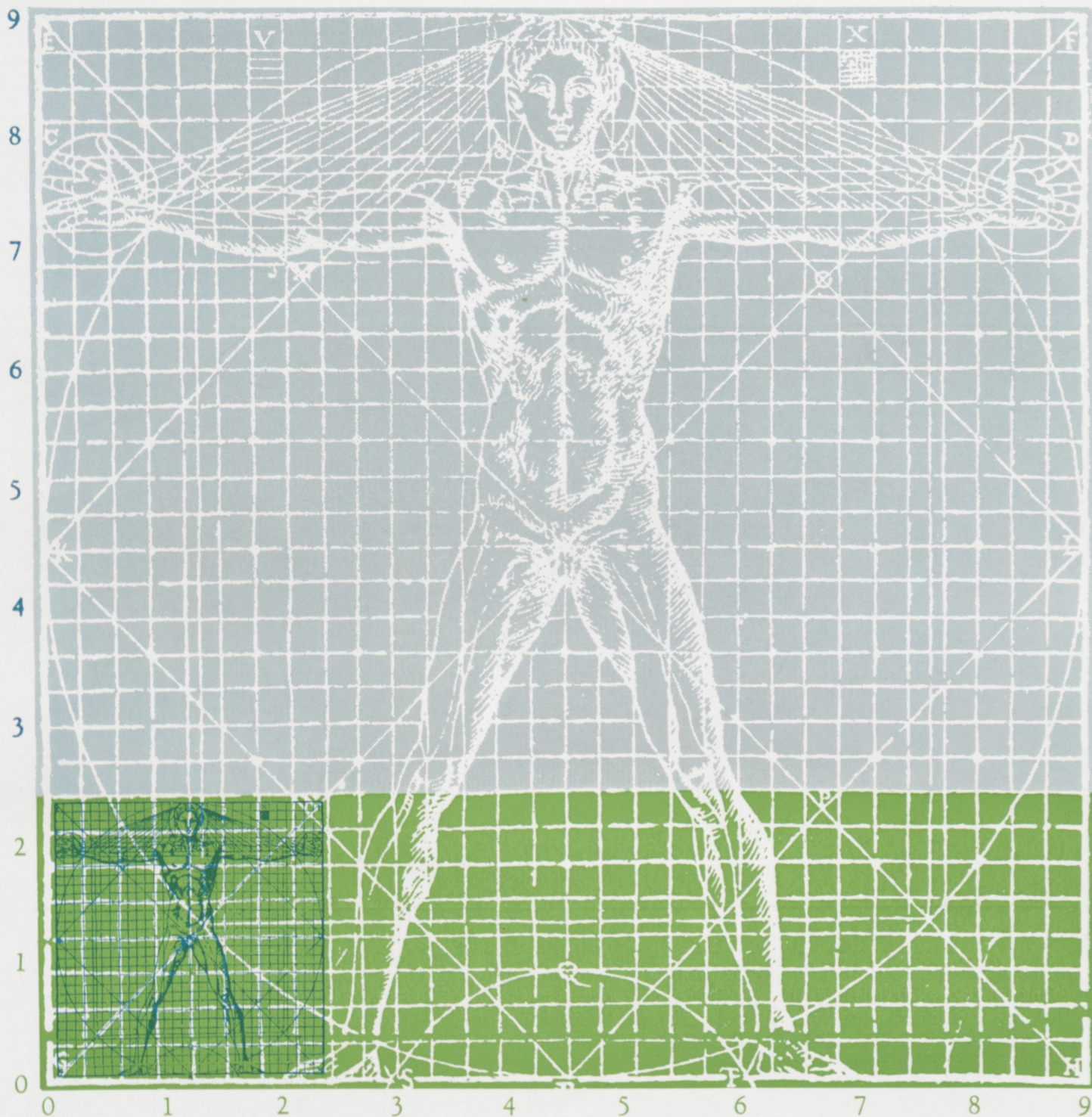
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Rose Technic

April 1964

50c



SPECIAL BIOLOGY ISSUE



Polaris missiles are fired by Westinghouse launching systems



Polaris subs are powered by Westinghouse-designed atomic reactors

Twenty Polaris submarines have gone to sea. Each carries 16 Polaris missiles. They give the U.S. a deterrent force that no enemy can hope to strike out of action.

These subs can travel to any ocean in the world and stay hidden under water for

months, because they are nuclear powered.

Their atomic reactors were developed and designed by Westinghouse, under the direction of and in technical cooperation with the Naval Reactors Branch of the Atomic Energy Commission.

The subs can fire their Polaris missiles from far below the surface. A remarkable deep-water missile launching system, developed and built by Westinghouse, makes this possible.

You can be sure if it's Westinghouse



For information on a career at Westinghouse, an equal opportunity employer, write L. H. Noggle, Westinghouse Educational Department, Pittsburgh 21, Pa.



Is it news that a leading maker of spacecraft alloys had a hand in dolling up Mildred Kinne's potting shed?

It isn't really surprising that a single U.S. corporation provided the metal for the outer skin of Mercury space capsules. It's perfectly natural to be called in on that kind of a job when you lead the nation in developing a line of alloys that resist extreme heat, wear and corrosion.

You'd also expect that a leading producer of petrochemicals could develop a new base for latex paint—called "Ucar" latex—since paint makers are among its biggest customers. Now Mildred Kinne can paint right over a chalky surface without priming. It's dry in minutes. And her potting shed will look like new for many New England summers and winters.

But it might indeed be surprising if both these skills were possessed by the same company. Unless that company were Union Carbide.

**UNION
CARBIDE**

Union Carbide also leads in the production of polyethylene, and makes plastics for packaging, housewares, and floor coverings. It liquefies gases, including oxygen and hydrogen that will power rockets to the moon. In carbon products, it has been called on for the largest graphite shapes ever made. It is the largest producer of dry-cell batteries, marketed to millions under the trade mark "Eveready." And it is involved in more atomic energy activities than any other private enterprise.

In fact, few other corporations are so deeply involved in so many different skills and activities that will affect the technical and production capabilities of our next century.

It's already making things a great deal easier for Mildred Kinne.

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Divisions: Carbon Products, Chemicals, Consumer Products, International, Linde, Metals, Nuclear, Olefins, Ore, Plastics, Silicones, Stellite and Visking

ABOUT THIS ISSUE

After more than two months of preliminary planning, the *Technic* is proud to publish this special bioengineering issue. It is a cooperative effort by the *Technic* staff and the Faculty Biology Committee, in particular Dr. Robert M. Arthur.

Included in this issue are articles on several phases of applied biology including biomechanics, biological warfare, medical electronics, bioastronautics, and cybernetics.

In addition to our regular features, the *Technic* now has color. This is being tried as an experiment. We believe color can add much to the attractiveness of the magazine.

Cover Note

This month's cover, especially commissioned by the Faculty Biology Committee, is by Garrett Boone, of the DePauw University art faculty.

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Rose Technic

April 1964

AMERICA'S OLDEST ENGINEERING COLLEGE MAGAZINE IN
CONTINUOUS MONTHLY PUBLICATION — 1891-1964

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ROSE



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TERRE HAUTE, INDIANA

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ROSE POLYTECHNIC
INSTITUTE
TERRE HAUTE, INDIANA



The President Comments

For a number of years scientists have been predicting that the next major scientific breakthroughs would come in the field of biology. These predictions are now being vindicated as research workers successfully probe into the basic chemistry and physics of life itself.

One of the most promising of these new developments has been the co-operation between engineers, scientists and medical research groups in the use of engineering techniques and devices as effective research tools; an unexpected by-product of this cooperation has been a better understanding of life processes because of analogies in the fields of mechanics, electrical and mechanical engineering. As an example, George Gallup (in his recent book, "The Miracle Ahead") claims that the most valuable contribution of the modern digital computer has not been high speed computation, but the provision of a basic understanding of how the brain operates.

A recent article in the *New York Times* states that a French scientist, Dr. Marcel C. Bessis of the National Transfusion Center in Paris, was given an ovation at the Third Plenary Session of the American College of Physicians in Atlantic City when he described revolutionary new techniques for the study of single cells. The President-Elect of the College described the report as "one of the most exciting experiences in the facts of life we have ever had." In developing this new approach, Dr. Bessis made use of a combination of light microscopy, electron microscopy, time-lapse cinematography, closed-circuit television, special chemical stains and laser rays — all products of modern engineering.

At Rose we are as yet doing little more than exploring, in a tentative way, the potential of bioengineering as an area of specialization. From the point of view of man's insatiable curiosity about life and the possible returns in terms of health and well-being, bioengineering appears to offer an unequalled opportunity for the future. It should receive serious consideration as our next degree-granting area.

Julia A. Logan

BIOLOGY AT ROSE

by Dr. Robert M. Arthur, C.E. Dept.

Much of the popular and technical literature of today contains articles about the growing relationship between the physical and life sciences. This special issue of the *Technic* is ample evidence that this relationship is establishing itself at Rose. However, an inspection of the original Articles of Association of the Terre Haute School of Industrial Science, later renamed Rose Polytechnic Institute, indicates that this relationship was always present. The articles state that "instruction shall be provided therein from time to time based on the practical mathematics and the application of the physical sciences, to the various arts, manufactures, agriculture, horticulture, etc." and that studies to which prominence shall be given will include botany, horticulture and agriculture among others. It is evident that the advantages stemming from a combination of the physical and the life sciences was appreciated even during the early days of our college.

During the Spring semester of 1963, Dr. Logan, upon the request of the faculty, named a temporary committee on Applied Biology and Bioengineering to investigate the establishment of a program in biology including pre-med, pre-dent and pre-vet courses. The Committee was to establish the limits of the program, consider staff and space requirements and investigate cooperative arrangements with other

schools in our area. The Committee, after due consideration of the above, made the following recommendations to the faculty during the Fall semester of 1963. The Committee recommended;

- (1), that the Institute not enter into a formal pre-med, pre-dent, pre-vet program at this time and that further study was required before a final recommendation could be made. The Committee recognized that requirements for entrance to medical schools include both lecture and laboratory work in biology. At present Rose cannot offer the laboratory work because of lack of space and laboratory equipment. However, the Committee did suggest that every effort be made to provide the opportunity for a student to take lecture and laboratory courses in biology at a cooperating college.
- (2), that a permanent committee on Applied Biology and Bioengineering be named to continue the study of establishing a comprehensive biological program, said Committee to be interdisciplinary in that it will have a representative from each of the degree granting departments.
- (3), that, because of the growing interest in biological phenomena by engineers and scientists, three lecture or project

courses in biology be offered. These courses to include, a first course in biological science with emphasis placed on a study of the cell, its structure and function, a second course in biophysical science in which the study of mechanisms is stressed, and a third course in which a student may work on a special project in biology.

- (4), that, in an effort to determine the amount of interest by faculty and students in the area of bioscience and bioengineering, a series of seminars on these subjects be presented during this year.

These recommendations were approved by the faculty on December 12, 1963.

The articles included in this issue of the *Technic* indicate the broad aspects of the combination of biology and science or engineering. The authors of these articles include a physiologist, an electrical engineer, a civil engineer, a chemical engineer, and a mathematician. In addition we could have included articles by physicists, chemists, or mechanical engineers. It is clearly evident that every branch of physical science and engineering can profit from, or contribute to, the area of biology. It is therefore necessary that our program at Rose be broad enough to stimulate the interest of students from all of the various disciplines. This is exactly our intention in the undergraduate

program. Specialization in any particular area of bioscience or bioengineering can be best accomplished at the graduate level.

Although it is readily recognized that bioscience includes the areas of biophysics, biochemistry and biomathematics, the areas of bioengineering are not clearly defined. In an effort to clarify our thoughts on this subject we have prepared a definition of bioengineering as shown in the figure. To be noted is the fact that bioengineering consists of four major areas including bionics, applied biology, biomedical engineering and environmental health engineering. The definition of each of these areas is as follows:

1. Bionics—The application of the knowledge gained from a study of biological phenomena to determine how the mechanism of the system can be used in engineering design to create hardware.
2. Applied Biology—The use of biological systems to create

new products by synthesis.

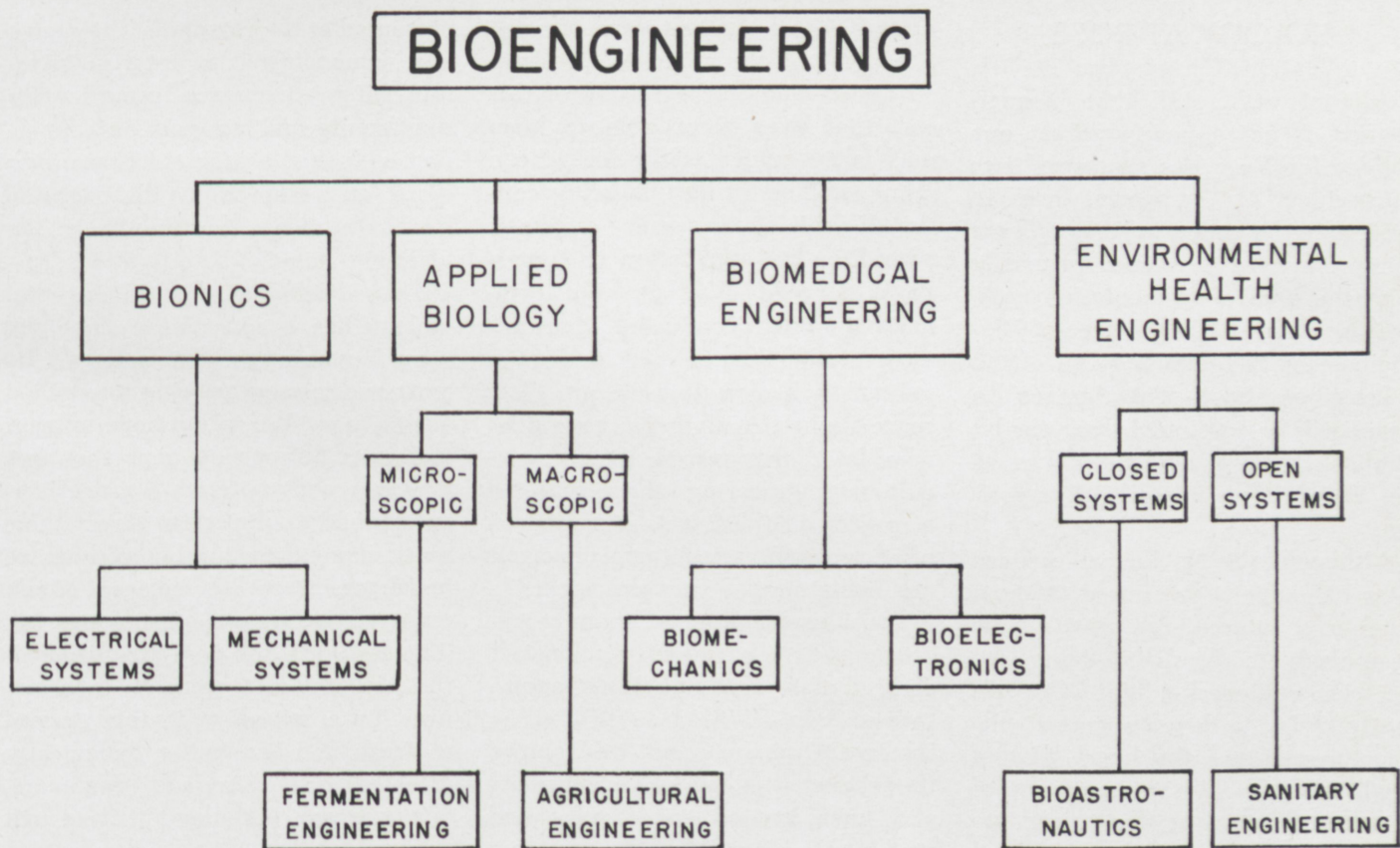
3. Biomedical Engineering — The application of engineering to medicine to:
 - a. Provide electrical-mechanical replacements for damaged structure.
 - b. Provide instrumentation to study function.
4. Environmental Health Engineering — To use engineering principles to control an environment which is optimum for life.

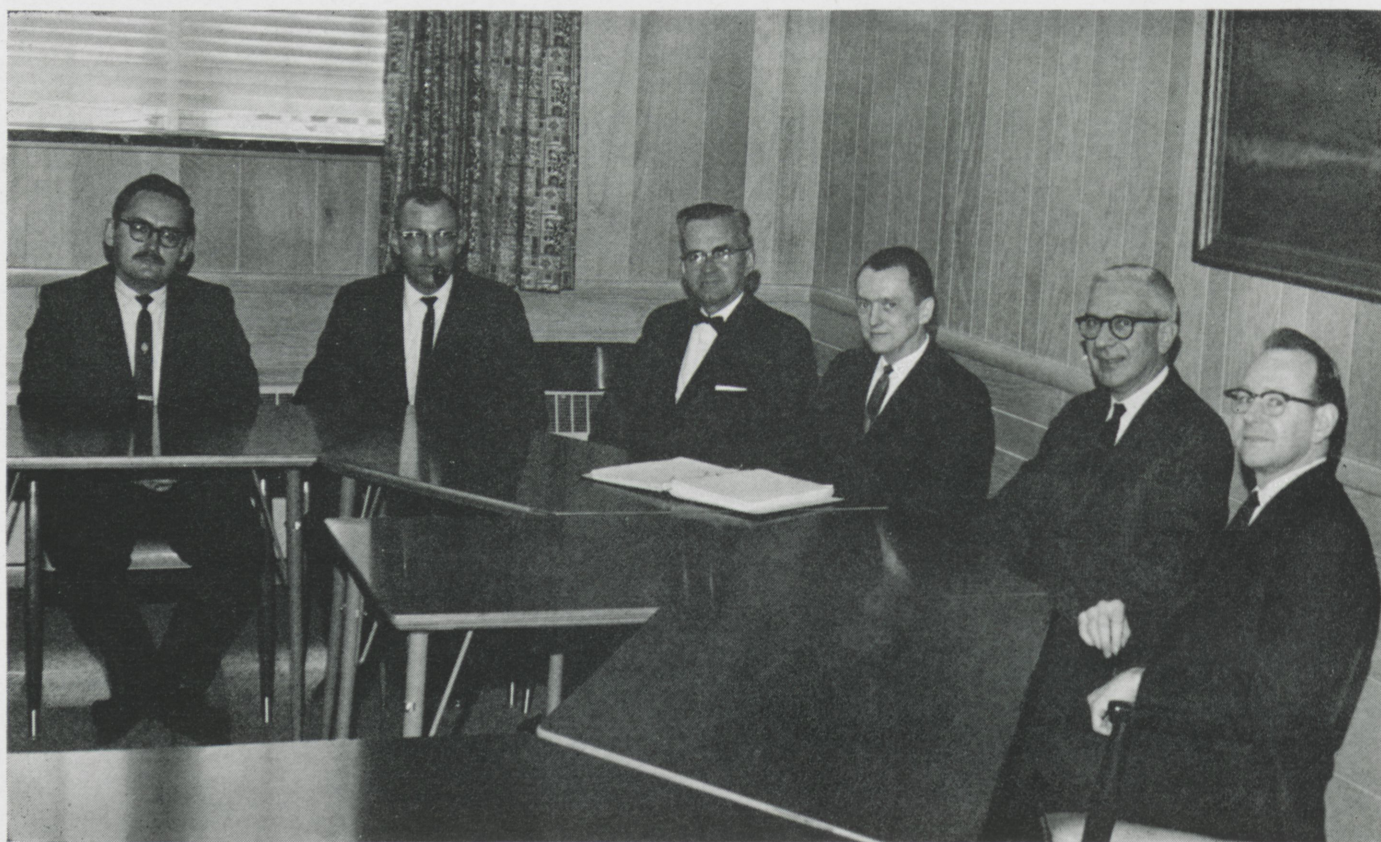
The entire area of bioengineering can be defined as: The application of the knowledge gained by a study of the physio-chemical phenomena of biological systems so that both biology and engineering may be more fully utilized for the benefit of man. From the above it is evident that any breed of engineer can find an area of interest in bioengineering.

In accordance with the recommendations of the Committee, a series of six seminars are being presented during the first and second

semesters of this year. The first two seminars were conducted by two medical doctors from the staff of Methodist Hospital, Indianapolis, Indiana. Dr. Jack Hall, Director of Medical Education, presented the first seminar on "Medicine in Science and Engineering?" The second was presented by Dr. Frank Lloyd, Director of Medical Research. His topic was, "Mechanical Replacement of Body Parts". The third seminar was presented by Prof. Herbert R. Lissner, Coordinator, Biomechanics Research Center, Wayne State University. His topic was, "Biomechanics Research". Lt. Col. Jack Steele, and M.D. from Wright-Patterson Air Force Base, Ohio, presented the fourth seminar on "Bionics." Col. Steele is the originator of the word Bionics. The fifth speaker is to be in the area of applied biology and the sixth in the area of environmental health engineering, particularly, bioastronautics. The latter two speakers have not been confirmed as of the date of this writing.

(Continued on page 8)





The Faculty Committee on Applied Biology and Bioengineering. From left: Profs. Derry, Schmidt, and Hooper, Dr. Arthur, Prof. Blake, Dr. Guthrie.

BIOLOGY AT ROSE

(Continued from page 7)

Alumni will recall that bioengineering is not a new word at our college for Rose has sponsored two Bioengineering Symposia, one in 1953 and the other in 1955. These Symposia were concerned primarily with the area of fermentation engineering. Since then the area of Bioengineering has embraced all of the areas given above. The Symposium series will be continued this year by publishing the series of seminars as the Third Bioengineering Symposium.

Although the biological science class has only been offered twice, a number of interesting projects have been conducted by the students. An electrical engineering student is presently trying to develop instrumentation to measure the heart beat of small animals with a minimum of distortion. During this past year two civil engineering students conducted

a study on the submersion of mice in water and the effects of pressure on mice. One of the results of this was that they were able to keep mice alive under water for fifteen minutes. This project is being continued this year with emphasis placed on its application to hyperbaric surgery. Another civil engineering student conducted a preliminary study on a closed ecological system such as will be required in space flights. A mathematics major, who later transferred to an agricultural engineering school, initiated a project on the effects of sound on plant growth. Additional projects are being started this semester.

Considerable interest in our program has been expressed by the staff of Methodist Hospital, Indianapolis, Indiana. In addition to presenting the two seminars mentioned above, they have attended other seminars and have invited our faculty and students to attend the the seminars

presented at the Hospital. They have also demonstrated an interest in establishing a research program for our faculty and students. In connection with this, a program of summer work on research at the Hospital for our students is presently in the planning stage.

This article has pointed out that biology has been at Rose since the very beginning of the college. Its existence is merely being intensified at this time. We do not hope to train biologists but we do hope that this program will motivate physical scientists and engineers to direct their particular talent to the solution of problems in the life sciences. Much must yet be done to bring the life sciences up to the analytical level of the physical sciences and engineering. If we can assist in this pursuit of truth by developing biologically oriented scientists and engineers, our program in Biology at Rose will have succeeded.

EQUAL OR EQUITABLE?

What would your reaction be if you were told that you were, indirectly, providing money for the use of some individual or group which gave you nothing in return? What would you say if you discovered that someone else was enjoying their hobby at your expense? Of course, your thoughts would probably depend upon who the person or group was. If you were to find out that the guy who lives three doors down from you in your dorm was using your money to enhance his enjoyment of his leisure time, I doubt that you would be undisturbed. Unless you were aware of the situation and thought that for some reason the poor guy deserved some help, you would probably become aroused enough to try to find out exactly what was going on. Now then, suppose that at the same time you made this revelation, you also discovered that you were receiving something of definite material value at no expense to yourself. If the worth of this "gift" was approximately equal to the amount you were "giving away", and you valued it at all, you might be inclined to think, "Oh well, I'm not losing anything, so what do I care?" You shouldn't care at all, if you consider only yourself. But if you take from Frank and give the same amount to Hank, the *net* result is that Hank is taking that amount away from Frank. Maybe this doesn't bother you, but how would you feel if you were Frank? Or for that matter, wouldn't you feel a little guilty if you were Hank?

Now you may ask what this little hypothetical analysis has to do with you or with Rose Poly. I have presented it because it is analogous to a situation not at all hypothetical but very real which exists on the Rose Campus today. This situation is involved in the disbursement of the Student Fund among the various clubs and organizations recognized by the Student Council. Each semester, every Rose student pays along with his regular tuition a \$15 activities fee. Thirty per cent of this, or \$4.50 per student goes into the Student Fund, the distribution of which is the responsibility of the Student Council. The organizations which receive portions of the Student Fund fall into two general categories: (1) hobby or interest clubs, such as the Camera Club and Radio Club; and (3) the four student publications, the *Modulus*, the *Technic*, the *Explorer*, and the *Student Handbook*. For the past few semesters, the combined allotments to the *Modulus* and the *Technic* alone have totalled more than 50% of the total Student Fund. In contrast, clubs like the Camera Club and Radio Club rarely receive more than \$70 per semester, or less than 3% of the total amount of money allotted. Pity the poor little interest clubs? I should hope not. Let's take a closer look into the situation before we jump to conclusions.

The Student Activity Fee was not created so the school could collect more money from the students. Supposedly, the fee is merely a convenient way for the student to pay for the benefits he receives from the

organizations to which the money goes. The 70% of the total activities fees collected which does not go to the Student Council goes into the Athletic Fund. In this way, the students pay for the pleasure of attending all home athletic contests without having to pay a gate admission charge. This method of indirect payment seems perfectly reasonable to me, and I have yet to hear any complaints about it.

The situation is much the same with the student publications, all of which except the *Modulus* are distributed to students free of charge. In the case of the *Technic*, approximately 500 issues are distributed four times a semester to students. Last semester, the *Technic* received \$650 from the Student Fund. If our average printing cost was 32½¢ per issue, we would have broken even. The cost of printing one copy of the magazine is approximately 40¢. Hence, even if the student should pay no more than the printing cost for a *Technic*, this magazine still loses at least \$100 a semester by distributing copies to students free of charge.

On the other hand, what reason is there for allotting money to hobby or interest clubs? Admittedly, some of them, such as the Rifle Club (in the personage of the Rifle Team) do provide something for the school, and for the student body, in return. Other groups may argue that they contribute something to the school, but do they really contribute anything to the *students*? Take a look at the list of clubs which receive allotments from the Student Fund, and ask yourself what each one of them does for you as a student. If I pay 10¢ a semester to most such organizations on this campus, it is 10¢ worth of pure charity to the members. Yes, this is a very small amount to argue over, but look at an even smaller amount, namely *absolute zero*, which is given to organizations such as Blue Key and R-Men's Club. The primary purpose of these, outside of recognition, is service to the school. The Student Council handles their finances, yet they are not included in the Council budget, and hence receive no money in return for their services. Of course, Blue Key does not expect or even desire such. But what right does the Camera Club or the Radio Club or the Astronomy Club or the Flying Club have to request the students' money in order to finance their "services to the student body?"

Due only to lack of space, I will pass by discussion of the most ridiculous example of "relief request", that of the Glee Club asking for \$500 from the *Student Fund*. The point I hope I have made is this: before you jump to conclusions that you might draw from looking at only figures in a budget, think about what the situation really is. What kind of distribution are we looking for, equal or equitable? I hope that it is the latter, and that in the future we shall get it.

R T K

DEVELOPMENT OF THE HEART PACEMAKER

by Carl V. Hays
Applications Engineer
General Electric Co.

This article written by Carl V. Hays, Advanced Medical Products Applications Engineer of the General Electric Company in Milwaukee, Wisconsin, illustrates the close working relationships between the medical profession and engineers in industry in developing the General Electric Cardiac Pacemaker — a truly life-saving product that rescues the patient from death caused by heart blockage.

Engineering and medicine have cooperated to produce a new type of device — a heart stimulator or pacemaker as it is called. The cardiac pacemaker, implanted completely inside the body, is an interesting development primarily because it is so different from any product existing before. Its development is an example of combining modern electronic components and know-how for the purpose of medical therapy.

The pacemaker is a miniature implantable energy pulse generator providing a stimulus which replaces the natural nerve signal that has failed. This stimulus causes the heart muscles to contract in a normal fashion at a stabilized rate and to provide the necessary blood pumping action. The pacemaker is used for patients with advanced heart block.

Heart block is the result of destroying conductive ability of the "bundle of His" (pronounced hiss). A patient suffering from heart block has a very slow heart beat—20 to 30 beats per minute are not uncommon. In this condition, Stokes-Adams seizures may occur, which cause further slowing of the heart, very erratic beating, and sometimes complete stoppage. Heart block alone, if the heart rate is high enough, may

not be sufficiently serious to require an electronic pacemaker, but coupled with Stokes-Adams seizures, the need for a pacemaker becomes acute.

The normal electrical stimulus for the heart originates in a bundle of tissue called the sino-auricular node, located near the top of the heart. Stimulus comes by the sinus nerve from the brain which varies the heart rate in response to physical and emotional stress. This electrical pulse spreads through both auricles causing the auricles to "contract". The electrical signal is collected at the septum which is the division between auricular and the ventricular regions in what is called the atrio-ventricular node. This node delays the signal, amplifies it, and sends it down a conductive muscular tissue called the 'bundle of His' to the lower tip of the heart. There it spreads out and upward through the heart muscle or myocardium causing the ventricular contraction, or the ordinary heart beat. It is at the bundle of His that heart block occurs.

Although most heart block patients are over 55 years of age, damage to the bundle of His to cause heart block can occur in any age group and from a variety of causes. Chiefly, heart blocks occur in children as a result of surgery in the

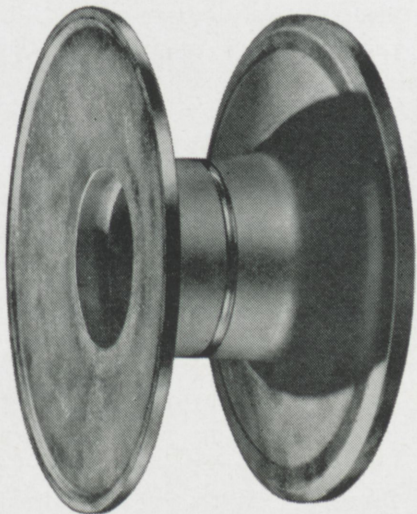
heart. This can occur with only minor myocardial damage elsewhere.

The extent of myocardial damage affects the amount of activity the patient can sustain after implanting a pacemaker. In most cases the damage is minor and the patient may lead a nearly normal life; in others where it is very severe, the patient cannot sustain life very long even with the heart being pulsed by the pacemaker. The abilities of the patient vary, then, in accordance with his heart condition after the implant is made.

The first development of the pacemaker began in 1952 when Dr. Paul M. Zoll of Boston's Beth Israel Hospital and engineers of the Electrodyne Company developed an artificial pacemaker which pulsed energy through electrodes from outside the chest wall to stimulate the heart. The first pacemaker required such high energy to stimulate the heart from the surface of the body that it caused chest muscles to contract, burns on the skin, and made sleeping difficult for the patient.

Next, Dr. C. Walton Lillehei, a noted heart surgeon at the University of Minnesota School of Medicine, decided to attempt to hook the electrodes to the heart muscle itself and connecting them to a power supply

(Continued on page 32)



**FORGINGS
ELIMINATED
REJECTS ON
THIS
EARTHMOVER
HUB . . .
*and cut cost 16%***

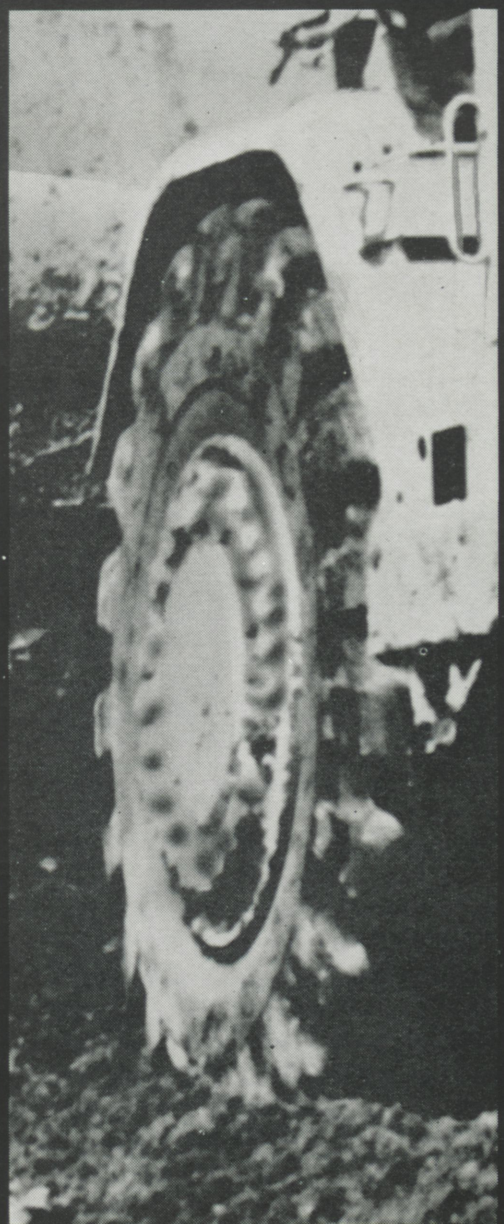
Originally, this earthmover wheel hub was not a forging. Now it is **forged** in steel. Here's why . . .

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.

**DROP FORGING
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When it's a vital part, design it to be



A PHYSIOLOGIST LOOKS AT ENGINEERING

The following article is adapted from an address delivered in Chicago in November 1962 at the 15th Annual Conference on Engineering in Medicine and Biology and is reprinted with permission from "Science", Vol. 140, 3 May 1963.

by Dr. John S. Gray
Professor of Physiology
Northwestern U. Medical School

The collision of two dissimilar air masses generates a meteorological front, marked by turbulence, murkiness, and precipitation. The meeting of two different scientific disciplines creates a frontier, likewise characterized by turbulence, murkiness, and precipitation. One who lacks the prudence to come in out of such weather is apt to get lost in the fog, buffeted by currents, and dashed with cold water. He is also likely to experience a curious mixture of exhilaration and frustration. Eventually, however, when the mental kaleidoscope rotates a fraction, a brilliant new pattern of ideas and outlook is likely to emerge.

I have been asked to talk about what happens to a physiologist when he ventures across the frontier into engineering. Based upon my own experience, the result can be expressed in two sentences. The physiologist is not apt to become an engineer, for, as the saying goes, you cannot make a silk purse out of a sow's ear. But the physiologist can learn from engineering an enormous amount of pure physiology not otherwise available. This may sound like a paradox, but I would like to explain why a paradox it is not.

One hears a great deal today about the burgeoning new field of bio-medical engineering. No one seems to like the term, but it does

encompass a bewildering variety and an impressive range of activities, from the most applied to the most abstract, from the design of electronic instruments to the exploration of living systems, from automatic data analysis in the laboratory to diagnosis-by-computer in the clinic, from mathematical modeling to the development of medical prostheses.

One of the most active of these areas has been the exploration of living systems. For this area, at least, there is an ancient and honorable name at hand—physiology. For centuries it has been the avowed goal of physiology to understand how the living organism works, or functions. This was the goal when the only available tools were the naked eye and a scalpel. It remained the goal when the manometer of the physicist and the test-tube of the chemist became available. It is still the goal today, when the engineer's instruments, techniques, and concepts are brought to bear on the age-old problem of understanding how the living organism functions. There is one difference, however; this latest addition to the armamentarium promises better than its predecessors to help physiology attain one of its goals.

In spite of faithful and persistent efforts physiology has found one of its goals to be exceedingly elusive.

What this goal is may be illustrated by a parable. Imagine a race of brilliant but primitive jungle-dwellers who have just captured from our strange civilization a television set. They organize a Manhattan Project to investigate this wondrous thing with the goal of understanding how it works or functions. With great enthusiasm they dissect it into its elementary components, which their expert taxonomists find they can neatly classify into conductors, resistors, capacitors, and inductors. Teams of researchers are then assigned to study each of these classes to exhaustion. Eventually, having learned absolutely everything there is to know about these components, they declare a national holiday to celebrate the triumphant attainment of their goal of understanding how the television set works.

Laugh, if you wish, at these poor aborigines, who have so egregiously missed the boat, for we know that they have learned **nothing** about the television set. We know it to be a **system**—an organized arrangement of interacting components, whose unique circuitry confers capabilities utterly lacking in any of its isolated components.

What is obvious in the case of the television set is no less ob-

(Continued on page 41)



■ Reuben C. Gooderum, BSME Wisconsin, 1962, is shown examining combustion liners after a thermal paint engine test at Allison Division, General Motors, Indianapolis, Indiana. Thermal paint, developed by Allison, is used to determine temperature gradients existing on engine parts.

Gooderum is one of the young engineers at Allison assigned to design and development of air-cooled turbine engine hardware. This work involves rig testing of turbine engine parts to determine optimum configurations. Parts later are endurance-tested on engines to prove the design.

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BIOLOGICAL WARFARE

by Curt Jones, Sr., Ch.E.

Biological warfare (BW) is, by no means, a new concept in military circles. Evidence shows that Germany possessed biological agents during WW I, but did not employ them because they feared that the Allies would retaliate with similar weapons. The Japanese are believed to have waged small scale biological warfare in Southeast Asia during WW II. Biological warfare possibilities, however, were not systematically explored until some time after WW II. Yet, to the public, biological weapons are particularly mysterious and indecent. They are regarded, along with chemical and radioactive weapons, as unthinkably barbaric—something never to be used except in retaliation. Obviously, government silence has left the public uninformed and unprepared for the advent of biological weapons, either for them or against them. This silence has similarly infected the military establishment, leaving it relatively unprepared to wage biological warfare or defend against it. The concept of biological warfare should not be taken so lightly, for it may very well be the deciding factor in any future war.

Biological warfare is defined as the intentional use of living disease agents or their toxic products to cause disease or death to man, his animals, or his food crops. The type of biological agent employed is determined by the effect wanted and the type of target, whether human, animal or plant. Chemical and radiological weapons would most likely be used in conjunction with biologi-

cal agents because they break down normal barriers to germs and increase susceptibility to disease. The three concepts combined will also make it very difficult to diagnose and treat the resulting disease.

Certain characteristics are desirable in all BW agents for maximum effectiveness, regardless of the target under consideration. These micro-organisms should be highly infectious, hardy, easily mass-produced, lethal or incapacitating when applied in small amounts, and difficult to identify. They should also remain potent when stored or dispersed, reproduce quickly, and possess a slow rate of natural decay. The diseases caused by these micro-organisms should not be preventable by simple sanitary precautions or customary practices of immunization, easily identifiable, or curable by customary drugs or antibiotics. The ideal condition to complement some of these characteristics is a population of minimal immunity.

Recent advances in microbial genetics make production of variants possible, some of which may be even more suitable than naturally occurring strains. Modified strains have already been successfully produced and employed in various vaccines. These strains are modified to possess high virulence and high infectivity through techniques or recombination, and production and selection of mutants with desired characteristics. Therefore, the available antigenic strains could not be counted upon—especially those of labile antigenic structure with a natural tendency

toward antigenic modification.

Scientists have found that pathological effect of inhaling micro-organisms depends strongly upon the size of the particles. Very small particles (1-5 microns in diameter) are not retained by the hairlike structures in the breathing tract which catch larger particles. Smaller micro-organisms thus can penetrate into the lungs where infection occurs. This size factor, or course, would only be important for micro-organisms being dispersed in a medium that would be inhaled by the victim.

The ultimate goal in the development of biological warfare systems and disease-producing agents is that of being able to select the proper agent and accurately predict the amount of agent necessary to produce the desired overall effect. With this knowledge, an aggressor or defender could select micro-organisms in proper dosages to produce: (1) high fatality rates, (2) prolonged incapacitation with low fatality rates, (3) temporary illness or, (4) reduction of food supplies. There are many different factors which complicate any such prediction of results. In the first place, comparatively little is known about the pathological effects of mixing various micro-organisms. Secondly, and one of the most significant factors is that of existing meteorological conditions that affect the dissemination of biological agents and their subsequent survival. Finally, other external factors, such as land terrain, demand attention.

(Continued on page 34)

BIOMECHANICS PAST, PRESENT AND FUTURE

by Tom Terry, Sr. C.E.

To discuss the topic of biomechanics, one must first be clear on what biomechanics really is. Biomechanics is an interdisciplinary science that involves the macroscopic study of organic bodies with the application of engineering principles. The science is "interdisciplinary" because it involves not only the engineer's knowledge of the physical laws of science but also his knowledge from a biological aspect, for he must understand the "organic bodies" with which he is working.

The science of biomechanics is actually not a new one, but considering the recent strides being made in the field, it is still considered to be in its infancy. Although this science is not limited to any particular species of animal, most of the work being done has the human body as its "organic body." For a more complete report, we will look at what has been done in the past, what is being done at present, and what can be done in the future as far as biomechanics is concerned.

PAST

Although biomechanics has just come into bloom in the last twenty years, the history leading to its present development is a long, interesting one. The first known studies relating to biomechanics were mostly by men in the field of medicine, because the law of motion (Newton's three laws) had not been "discovered." The first of these men was Aristotle (384-327 BC) who wrote about the motion of animals and tried to subject their actions to geometric analysis. After a long

lapse of more than 1000 years the studies of the actions of the human body were continued by Leonardo da Vinci (1452-1519). Leonardo suggested that the actions of the muscles could be studied by attaching cords to a skeleton in order to simulate the origins and insertions of the muscles. He also described the actions of certain muscles as a person sits, stands, and walks. It was then Alfone Borelli (1608-1679) who postulated that the bones of the body serve as levers and the muscles move the levers in accordance with mathematical principles. Borelli also studied the forces caused by certain muscles, and for his work he is sometimes called the "father of biomechanics." Studies then shifted from the bones and muscles to the primary flowing fluid of the body—the blood. William Harvey (1578-1657) proved that the blood circulated and Poiseuille (1790-1868) defined the viscosity of the blood. After Newton (1642-1727) formulated his three laws of motion, the external forces in the body could be related to the internal forces in the muscles. This was done specifically by Ernst and Wilhelm Weber (1800-1890), who mathematically studied the movement of the human center of gravity. From 1900 until the present date the motion of the body has become a special field in itself — kinesiology.

But as defined above, biomechanics is more than the study of the motion of the body, for dynamics is only one of the "engineering principles." In fact it is in the other facets

of biomechanics that more emphasis is being placed today.

PRESENT

Biomechanical studies in the United States today are primarily an outgrowth of the studies of the mechanism of concussion in the human head due to accidents in the automobile. These studies were begun about 20 years ago by Herbert R. Lissner of Wayne State University in Detroit. Since then the importance of the field of biomechanics has been recognized and more diversified studies of all types of mechanisms of the body are being made.

In order for these studies to take place there must be people qualified to understand and logically solve the problems involved. As was stated before, most of the men in the past were medical men with a little knowledge in the principles of engineering. Now the trend has been to let the doctors specialize at the microscopic levels of bio-physics, and bio-chemistry, and to let the engineer attack the problem on the macroscopic level (which agrees with our definition of biomechanics.) There is however a definite lack of engineers with the proper background to indulge in such studies, so one of the big problems is to produce the qualified people.

The need for a good educational program for the development of people competent to study biomechanics has just been recognized recently and strides are being made to provide the necessary background for

(Continued on page 30)

MAN IN SPACE

by

Bill Kovacs
Sr., Ch.E.

As man is sent beyond the fringes of our atmosphere into space he must be adequately protected from the peculiar hazards of space travel and sustained in a fashion similar to his terrestrial environment. When the astronaut rises above the ionosphere he loses the protective layer of the atmosphere and is subjected to the temperature extremes of space. The unprotected astronaut would find that the side of his body facing the sun would be red hot, while the other side would be freezing. He would also discover an acute oxygen shortage, and would be faced with the possibility of having his body fluids vaporized.

These problems are readily apparent, and were vital factors in the design of the first space vehicles. In Project Mercury, the United States' manned satellite program, there was a need for a closed ecological system. The capsule was equipped with the necessary supplies of food, water, and oxygen and the waste material was stored, to be disposed of on Earth. Since the flights were planned to be of one day duration, the major problems were acceleration and vibration.

When man is accelerated in the direction of his head, acceleration forces, or "G" forces, cause the blood to pool in the abdominal cavity and lower portions of the body. The heart cannot support the column of blood to the brain and he loses consciousness. This problem has been minimized by utilizing a form-fitting couch, positioned such that the astronaut's back is in a plane per-

pendicular to the accelerative force, with his legs slightly elevated. In this position the blood can no longer pool in the lower portions of the body, and the heart is not required to pump against high hydrostatic pressure; consequently no "black out" is experienced.

Vibration is a major problem because different parts of the body have a natural frequency at which they resonate. For the intestines this frequency is 5 vibrations/second. The spine and ribs frequency is 11 vibrations/second, the eyeballs at 75 vibrations/second, and the jaw at 100 vibrations/second. Experiments on volunteers have shown that there is extreme discomfort when a person is subjected to vibrations at low frequencies, particularly at the natural frequency of a particular organ. A suggested method of eliminating this problem is to stiffen the boosters and capsule so that they vibrate at higher frequencies.

Project Mercury has served to whet man's appetite for further space exploration. The Congress of the United States has set the landing of men on the moon as a national goal. Thus for a voyage of this type, which would take weeks, or months, a new type of space vehicle must be designed. This vehicle must carry with it the total environment and all of the materials needed for man's existence throughout the entire mission. The only possible external source of material would be energy from the sun.

The pioneer flights of both the United States and the U.S.S.R. have provided few answers to the prob-

lem of living in space. The biological stresses involved during escape and re-entry had actually been anticipated and countered by techniques developed for pilots during World War II. One important result of these flights is that it has been determined that the astronaut must have the ability to fly the vehicle.

C. B. Westbrook, an Air Force engineer, studied the reliability of automatic systems of control. His calculations, based on the current system of attitude control, indicated that there was only a 22 per cent chance of the system working satisfactorily during a ten day journey. If the astronaut could take control when necessary, he would have a 70 per cent chance of keeping the vehicle steady, and if he could make repairs when necessary, his chances of maintaining control would increase to 93 per cent. These results indicate that the astronaut must remain alert, in good physical condition, and mobile to function as both a skilled pilot and mechanic.

On orbital flights of several days the psychological effects of prolonged tensions and isolation become apparent. If man's destination were the moon, these effects would be compounded by the problem of purification and regeneration of the atmosphere and by the effects of radiation.

Long periods of weightlessness remains as another questionable aspect of the journey. The orbital flight of the Soviet dog Laika in Sputnik II proved that long periods of weightlessness *per se* do not disrupt the main process of vital activity. However, our own tests, based

on relatively short periods of weightlessness (9-10 hours), have indicated that there is an orthostatic rise in heart rate and fall in systolic blood pressure during the twenty-four hours after landing. This hemodynamic phenomena may force the moon bound astronaut to engage in a rigorous exercise program.

Each of these problems will affect the design of the vehicle, and must be solved before man can attempt the journey. Perhaps the most important of these is the problem of purification and regeneration of the atmosphere. In order to approach this problem, a decision must be made as to what type of atmosphere to use.

The Russians use a normal concentration of oxygen and nitrogen at approximately 14-15 pounds per square inch. The United States currently favors a 100 per cent pure oxygen atmosphere at a reduced pressure of 5-6 pounds per square

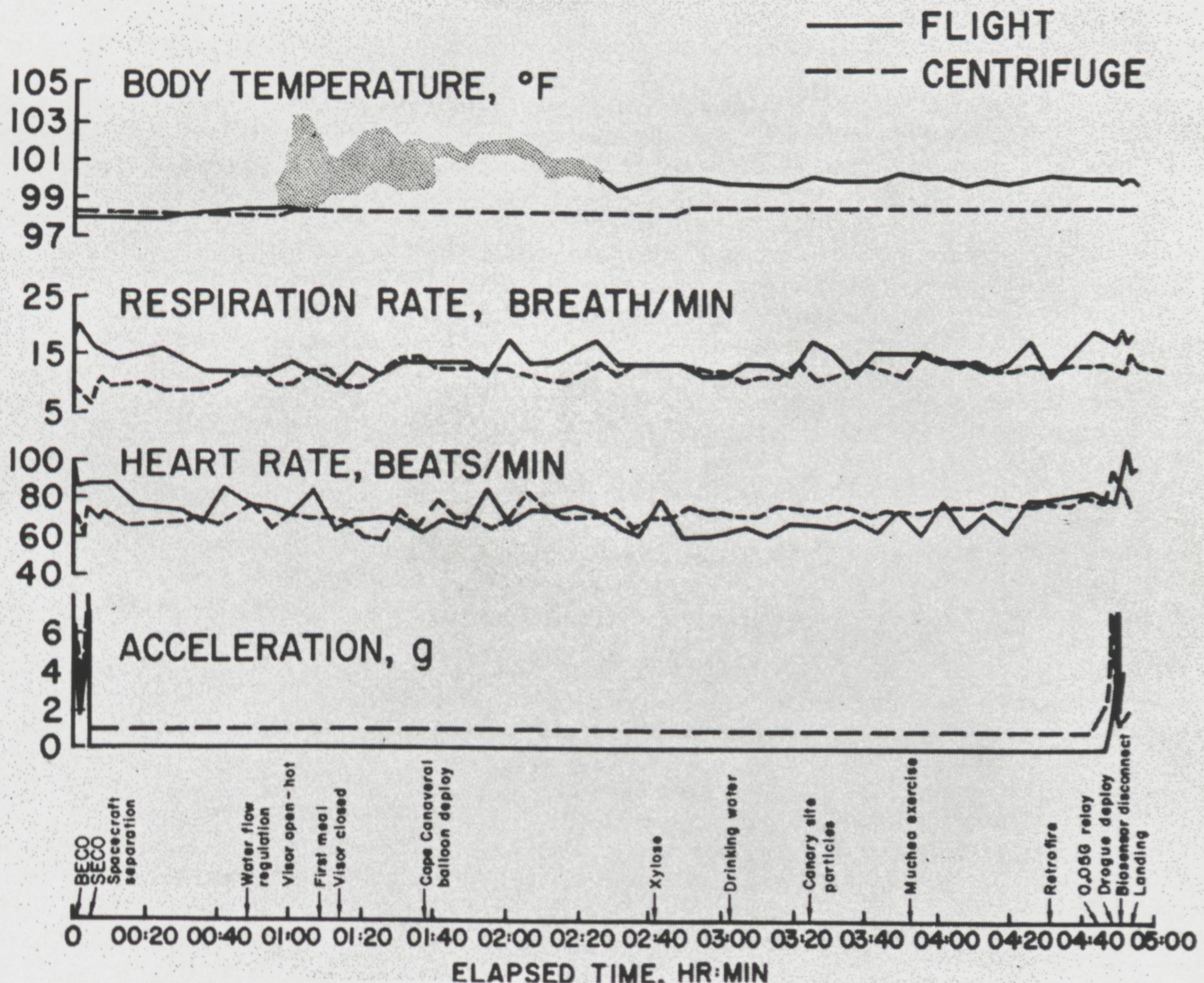
inch. The advantage of the Russian system is its close similarity to the terrestrial atmosphere. The main disadvantage is the high pressure, which would increase the amount of leakage. This would in turn introduce a need for a nitrogen producing source to replenish that which is lost. There is also a factor of increased weight with the high pressure system. The advantages of the American system are reduced weight, minimized leakage, and a single gas composition. The main disadvantage appears to be physiological. Men who have been subjected to this type of atmosphere for long periods have been found to have some degree of aletactasis, or collapse of the alveoli. This is also exaggerated in men subjected to increased acceleration for long periods. A possible method of minimizing aletactasis is to have the astronaut engage in physical exercise.

Once the type of atmosphere has

been chosen, it must then be maintained in such condition that men can live and work in it. Normally the air which surrounds a living, breathing body is carried up by its own warmth and consequent lightness, thus allowing fresh air to take its place. In space, however, weightlessness prevents dust and aerosols from settling, since there are no convection currents. Without air circulation, heat discharged from the body would remain close to the body, causing intense perspiration, which in a saturated atmosphere would not evaporate. The body would also soon become enveloped in expired air.

Air motion imparted mechanically by a fan or other stirring mechanism is a necessary part of the air purification system. One proposed system consists of an activated carbon filter, a millipore, or deep bed filter, and a chemical train for specific materials, through which the

(Continued on page 36)



CYBERNETICS

by Grady Wallace, Jr. Math

Many books have carried the title "Theory of Machines," but usually these books contain information about mechanical things, about levers and cogs. Cybernetics, too, is a "theory of machines," but it treats, not things but ways of behaving. It does not ask "what is this thing?" but "what does it do?" Thus it is very interested in such a statement as "this variable is undergoing a simple harmonic oscillation", and is much concerned with whether the variable is the position of a point on a wheel, or a potential in an electric circuit. It is essentially functional and behavioristic.

Cybernetics started by being closely associated in many ways with physics, but it depends in no essential way on the laws of physics or on the properties of matter. Cybernetics deals with all forms of behavior in so far as they are regular, or determinate, or reproducible. The materiality is irrelevant, and so is the holding or not of the ordinary laws of physics. "The truths of cybernetics are not conditional on their being derived from some other branch of science." Cybernetics has its own foundations.

Cybernetics stands to the real machine — electronic, mechanical, neural, or economic — much as geometry stands to a real object in our terrestrial space. There was a time when "geometry" meant such relationships as could be demonstrated on three-dimensional objects or in two-dimensional diagrams. The forms provided by the earth-animal, vegetable, and mineral — were larger in number and richer in properties than could be provided by elementary geometry. In those

days a form which was suggested by geometry but could not be demonstrated in ordinary space was suspect or unacceptable. Ordinary space dominated geometry.

Today the position is quite different. Geometry exists in its own right, and by its own strength. It can now treat accurately and coherently a range of forms and spaces that far exceeds anything that terrestrial space can provide. Today it is geometry that contains the terrestrial forms, and not vice versa, for the terrestrial forms are merely cases in all-embracing geometry.

The gain achieved by geometry's development hardly needs to be pointed out. Geometry now acts as a framework on which all terrestrial forms can find their natural place, with the relations between the various forms readily appreciable. With this increased understanding goes a correspondingly increased power of control. Cybernetics is similar in its relation to the actual machine. It takes as its subject-matter the domain of "all possible machines", and is only secondarily interested if informed that some of them have not yet been made. What cybernetics offers is the framework on which all individual machines may be ordered, related and understood.

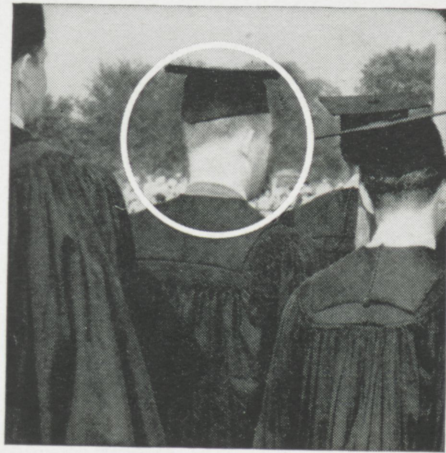
The basic hypothesis of cybernetics is that the chief mechanism of the central nervous system is one of negative feed-back. The field of study is not, however, restricted to feedbacks of the negative kind. Secondly, cybernetics makes the hypothesis that the negative feedback mechanism explains "purposive" and "adaptive" behavior. Support for this striking hypothesis,

which is of fundamental importance, is to be found both in rather general resemblances between organisms and electronic machines and in resemblances of more special kinds. The hypothesis seems to be due mainly to Ashby and Wiener, though others had written on some of the resemblances. It was Wiener who introduced the word cybernetics in his book in 1948; he coined it from the Greek for a helmsman.

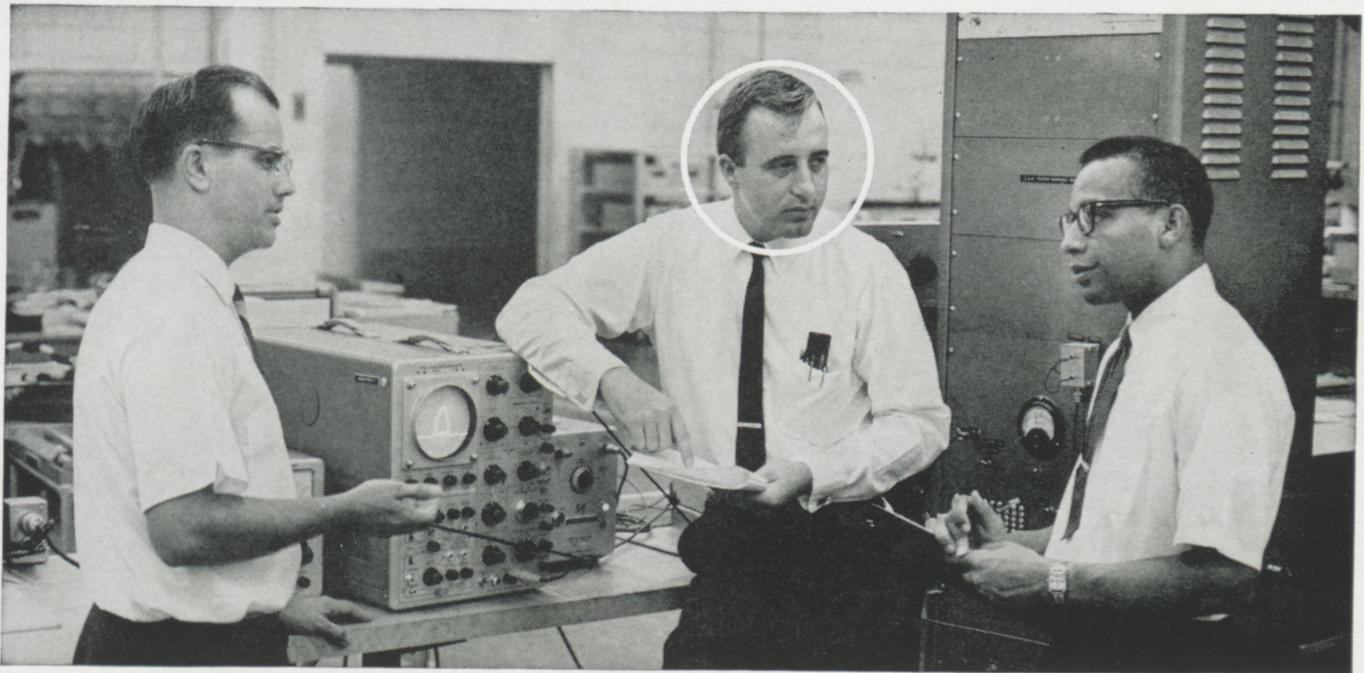
Cybernetics typically treats any given, particular machine by asking not "what individual act will it produce here and now?" but "what are all the possible behaviours that it can produce?" It is in this way that information theory comes to play an essential part in the subject; for information theory is characterized essentially by its dealing always with a set of possibilities; both its primary data and its final statements are almost always about the set as such, and not about some individual element in the set. Cybernetics envisages a set of possibilities much wider than the actual, and then asks why the particular case should conform to its usual particular restriction. In this discussion, questions of energy play almost no part — the energy is simply taken for granted. Even whether the system is closed to energy or open is irrelevant; what is important is the extent to which the system is subject to determining and controlling factors. So no information or signal or determining factor may pass from part to part without its being recorded as a significant event. Cybernetics might, in fact, be defined as "the study of systems that are open to energy but closed to information and control" — systems that are "information-tight."

After this bird's-eye view of cybernetics we can turn to consider some of the ways in which it promises to be of assistance. I shall confine my attention to the applications that promise most in the biological sciences. The review can only be brief and very general. Many applications have already been made and are too well known to need description

(Continued on page 38)



Tom Huck sought scientific excitement



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After graduation, Tom immediately began to work on the development of electronic switching systems. Then, in 1958, Tom went to the Bell Telephone Laboratories on a temporary assignment to help in the advancement of our national military capabilities. At their Whippany, New Jersey, labs, Tom worked with the Western Electric development team on computer circuitry for the Nike Zeus guidance system. Tom then moved on to a new assignment at WE's Columbus, Ohio, Works. There, Tom is working on the development of testing circuitry for the memory phase of electronic switching systems.

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Here April's Miss Technic, Jane Kenner, is doing what she likes — having fun by doing things. A freshman at Indiana State, Jane is active in her sorority (AO 3.14159), studies (nursing), and outdoor sports. One of this girl's favorite sports is driving her little red sports car around her native city of Terre Haute.

She has been actively preparing for Rose Poly during her 19 years. Her exams were graded at 120 # with bonus points for her 34-23-34. Jane welcomes personal thank you's for her appearance in this issue.





miss technic for may

MEDICAL ELECTRONIC SYSTEMS

by R. W. Hodgers
Rose B.S.E.E. '43



About the Author—

R. W. Hodgers, Jr. is presently Manager of General Electric Company's Medical Electronics Systems Operation at Milwaukee, Wisconsin. He graduated (with highest honors) in 1943 with a B.S.E.E. degree from Rose Polytechnic Institute. Included in his many important engineering and management assignments in the General Electric Company was a three-year assignment as Manager of Engineering for the X-Ray Department.

This first article on Medical Electronics Systems describes the broad applications of electronic systems equipment to medicine in those areas dealing with information sensing, processing, analysis, display and control, primarily for diagnosis and patient care.

Electronics — the glamour technology of the space age has teamed up with a new partner — medicine. Medical electronics includes the application of electronic equipment to any phase of medical science or medical facilities. It not only includes the use of electronics for diagnostic and therapy equipment, but in its broadest sense can include the use of electronic equipment such as closed circuit television, radio paging and entertainment television in a hospital or medical institution (Figure 1) as well as nurse-call and other hard wire intercommunication systems.

The important thing to remember is that more and more the medical profession is teaming up with the engineer and the scientist to apply their combined knowledge to the diagnosis and treatment of human ills. This first discussion is confined, primarily, to a description of the latest electronic-type systems used for medical diagnosis and patient care. The second article covers electronic therapy devices used for stimulation — such as the heart pacemaker.

All medical diagnosis is concerned with the functions of sensing, transformation and display of information. This is true of the simple mercury thermometer as well as the x-ray or the electrocardiogram. Thus the problem of diagnosis is a problem of information gathering and handling. Medical electronic systems are concerned with the performance of one or more of these functions.

This can best be seen by viewing the functional areas of a hospital from the viewpoint of an integrated patient information system. (Figure 2). This system includes the use of electronic systems around the total spectrum, from patient diagnosis and monitoring to patient accounting and billing. If the requirements for a total system are kept in mind during the planning of the systems and procedures for one or more of the areas shown in Figure 2, each one will be compatible with other areas and the total hospital information system will be a truly integrated one which is optimized from a cost and performance viewpoint.

Key parts of this total system are the medical electronic equipments associated with surgical and diagnostic procedures. Requirements for electronics here are two-fold — to display needed physiological data to the medical specialist during a procedure and often to record information for later analysis, study or teaching.

Diagnostic and Surgical Procedures

One of the best known and time tested electronic diagnostic tools is the x-ray. But even it has a face-lifting. Today the radiologist can sit behind leaded glass, (Figure 3), use normal room lighting, handle his patients remotely, view internal organs on closed circuit television and record a series of x-ray photographs on film for later viewing and study. This gives a brightness gain over previous fluoroscopy methods and a significant information gain, so that



Figure 1. The latest in Audio-visual patient communication equipment in use at the new Southwest Texas Methodist Hospital, San Antonio, Texas.

the systems cuts patient x-ray exposure by 80%. As shown (Figure 3), the system includes a 180° angulating table with a 30" longitudinal and 10" lateral power travel, a 9" image intensifier, a 16mm synchronous film camera and an 8" or larger television monitor.

More and more, however, hospitals of today require unique diagnostic equipment designed for special requirements. One example is a heart catheterization system developed for the University of Oregon Medical School. It consists of a special procedure room (Figure 4) and a control room (Figure 5).

In the procedure room, the equipment design has been focused around the patient and the procedure to be performed. In this case a catheter or tube is inserted into an artery or vein and run into the heart. Radio opaque fluid is then injected and the complete action is recorded via x-ray. An x-ray tube is permanently fixed in the base of the special-procedure table with a dual magnification image intensifier located directly above, but suspend-

ed from the ceiling. The procedure table top moves in both directions of the horizontal plane with 50 inches of longitudinal motion and approximately 10 inches of lateral motion.

Physiological monitoring leads go from the patient to connections on the sides of the table top, thus eliminating leads draped from the patient to other equipment in the procedure room. Intravenous stands, radiopaque injectors and other special equipment can be mounted on rails at any point on either side of the table. The primary method of displaying the x-ray is by use of a high scan line, closed-circuit television although direct viewing is available.

This particular television system uses 875 scan lines per frame and 1:1 aspect ratio, thus providing balanced horizontal and vertical resolution. The line (motion picture) camera included with the image intensifier takes x-ray films which are synchronized with the pulsed x-ray generator at speeds of 60, 30, 15 and

7½ frames per second while viewing either directly or via television. Automatic brightness control is included to insure proper film exposure as well as minimum patient dosage during operation. The system also includes the ability to take standard x-ray pictures in two planes; i.e., a bi-plane film changer can be moved into position and the patient properly placed over the bi-plane unit by moving the table top. This bi-plane unit takes up to 8 frames of film per second in each plane and can be synchronized with other equipment and with the electrical signal generated by the heart during each beat. More specifically, the radiopaque injector, the x-ray generator and the bi-plane unit can be programmed to take radiographs—at precise moments during the heart beat cycle.

Multi-pulse x-ray exposures synchronized with the injection of radiopaque fluids can provide information on blood velocity and acceleration — information badly needed in the treatment of heart disease.

INFORMATION HANDLING IN MEDICINE

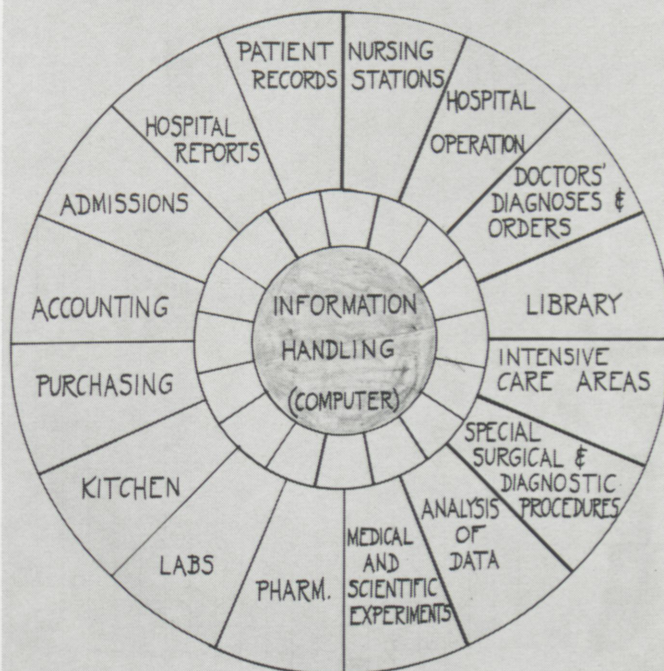
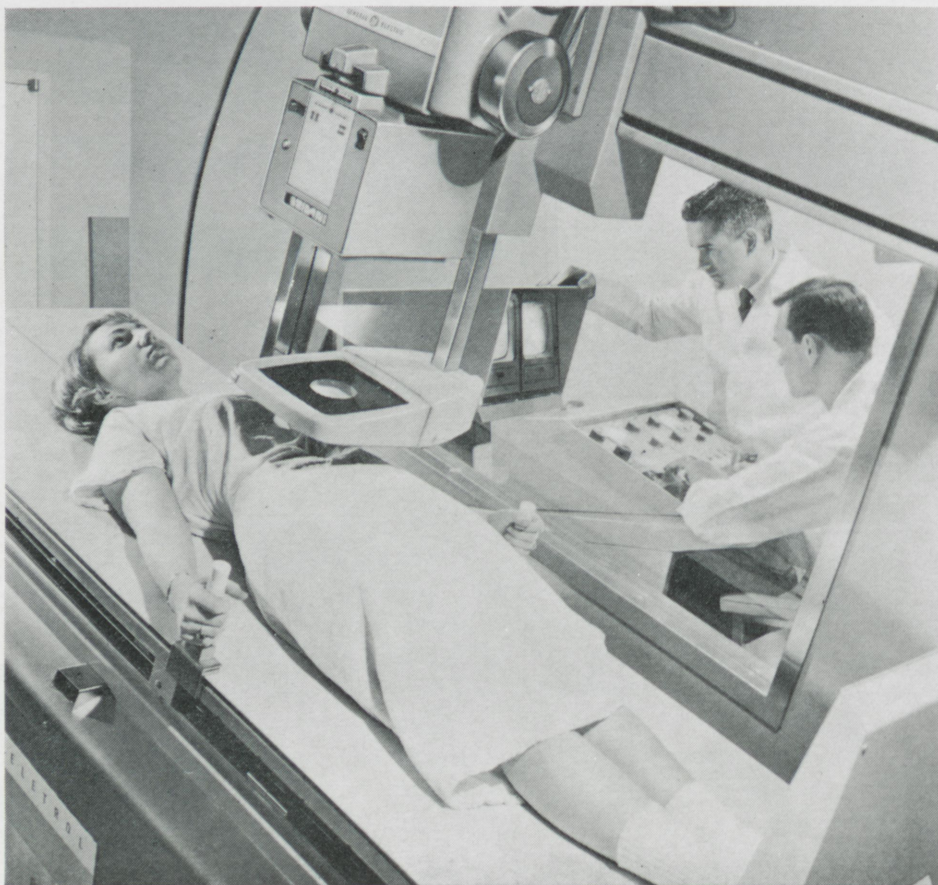


Figure 2. Schematic of an integrated hospital information system showing the main functional blocks.



Figure 3. Electronics now is an integral part of modern x-ray equipment used in viewing, communication and control. View of x-ray apparatus from radiologist side.

Figure 3A. Patient positioning can be done remotely. View taken from patient side.



All information processing, storage and display drivers, as well as remote operation controls, are located in the control room console (see Figure 5). The main upright portion of the console contains program set-up controls, information recording and display equipment. The desk part of the console contains x-ray, image intensifier, fluid injector, audio and recorder controls. The preamplifiers for the physiological data are located in the upright console with their outputs being distributed to different recording and displaying devices through a changeable patchboard system.

Presently, the information can be distributed to a magnetic analog tape recorder, a magnetic video tape recorder with analog recording provisions, an 8-channel hot stylus oscillograph, an 8-channel photographic oscillograph, a kinescope recorder with 4-channel data recording capabilities, and to the physiological data oscilloscopes.

Any number of these devices can be connected in without affecting the signal level. The kinescope recorder will synchronize physiological data with the x-ray information as well as supplementary patient information. This synchronized information will allow the medical group to examine any one frame of a 16mm film or a 4x5 Polaroid spot film and see the exact time relationship of the x-ray exposure with respect to the physiological data. X-ray information, recorded on video tape, can be played back either in real time, at 1/60th the rate of real time, or the motion can be stopped to allow the medical team to look at any one field of video information for a period of time.

In the system, all physiological functions, as well as x-ray image information, are recorded on magnetic tape in such a manner that the tape can be automatically searched at high speed for any event marked previously and then played back on the console and the procedure room displays. This allows the medical procedure team to review time-synchronized x-ray and physiological data recorded previously. It also al-

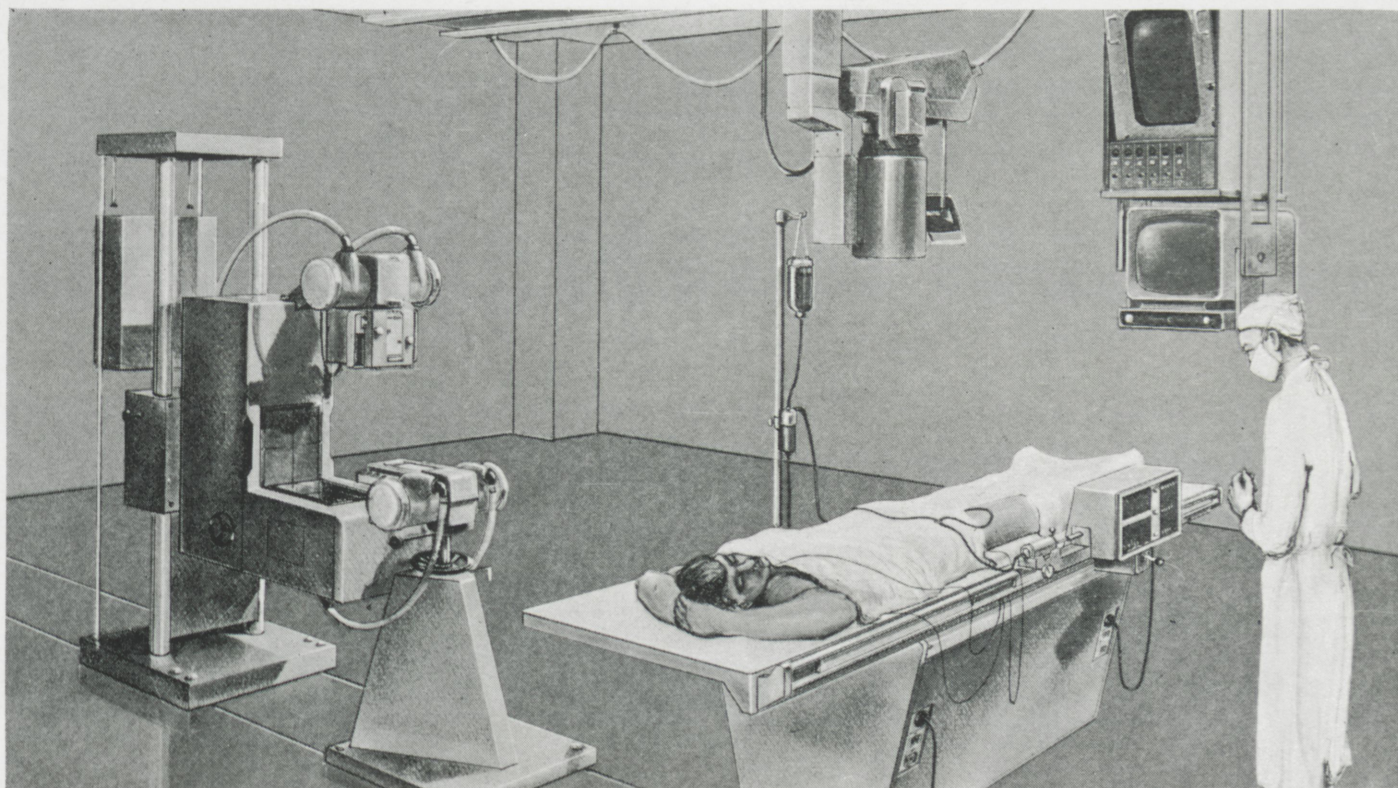


Figure 4. Artist's visualization of the heart catheterization procedure room for the U. of Oregon Medical School showing each piece of equipment.

lows a physician to review the patient's case after the patient has been discharged or use the tape recordings for teaching purposes.

This heart catheterization equipment can be integrated with a central computer during the procedure for immediate analysis or conversion of analog to digital data for display, or the information can be fed into the computer later for study and analysis.

Intensive Care

The ultimate problem in the care of any critical patient is to maintain an adequate supply of oxygenated blood to the body organs, such as the brain, heart and kidneys. All other medical problems are less critical from the point of view of time factors. In a coronary patient, for example, this problem of maintaining a supply of oxygenated blood is particularly difficult because the pump itself, the heart, has been damaged by an attack. The heart is operating at a disadvantage and may cease to perform its pumping function with little or no advanced warning. It is because of this potentially rapid onset of emergency conditions that Coronary Intensive Care units and equipment systems

are valuable parts of a hospital information system.

The prime function of a Coronary Intensive Care unit is to detect the emergency condition and take prompt remedial action. The sum and substance of the problem is time. As implied, the problem is twofold, detecting the emergency condition, and doing something about it. The physician defines the conditions which are to be regarded as emergencies and the action to be taken to correct them. The execution of these functions normally resides with the nursing staff. Equipment to implement or supplement the performance of detection and correction must be blended into the over-all nursing care system of the Coronary Intensive Care unit.

Operation of a Coronary Intensive Care unit varies from the private duty nurse approach to the specialized nursing team approach. The specialized nursing team approach for 4 to 20 patients offers the greatest opportunity for an integrated information and communication system within the intensive care area. Here (Figure 6) one nurse is assigned to monitor all patients using a multiple patient console with shared displays.

Prescribed emergency conditions or physiological limits are set for each patient by the doctor. As long as each patient remains within the limits set, nothing happens. The nurse can switch to any one of the patients connected to the console and view or record on strip charts any of his physiological data. When limits are exceeded an alarm is triggered and aid rushed to that patient. This, of course, requires that each intensive care patient have sensors attached to pick up critical physiological data as prescribed by the physician.

Once again, data can be fed into a central computer on a real time basis or put into the system later as part of a patient history analysis.

Doctors Orders

The mainspring for the remaining areas in the integrated hospital information system is the medical order or the doctors' order system. The doctors' order system provides the flow of information and instructions by which each physician plans and carries out the effective medical management of his patient. It includes all the instructions which the physicians place for patient care, including the medication schedule,

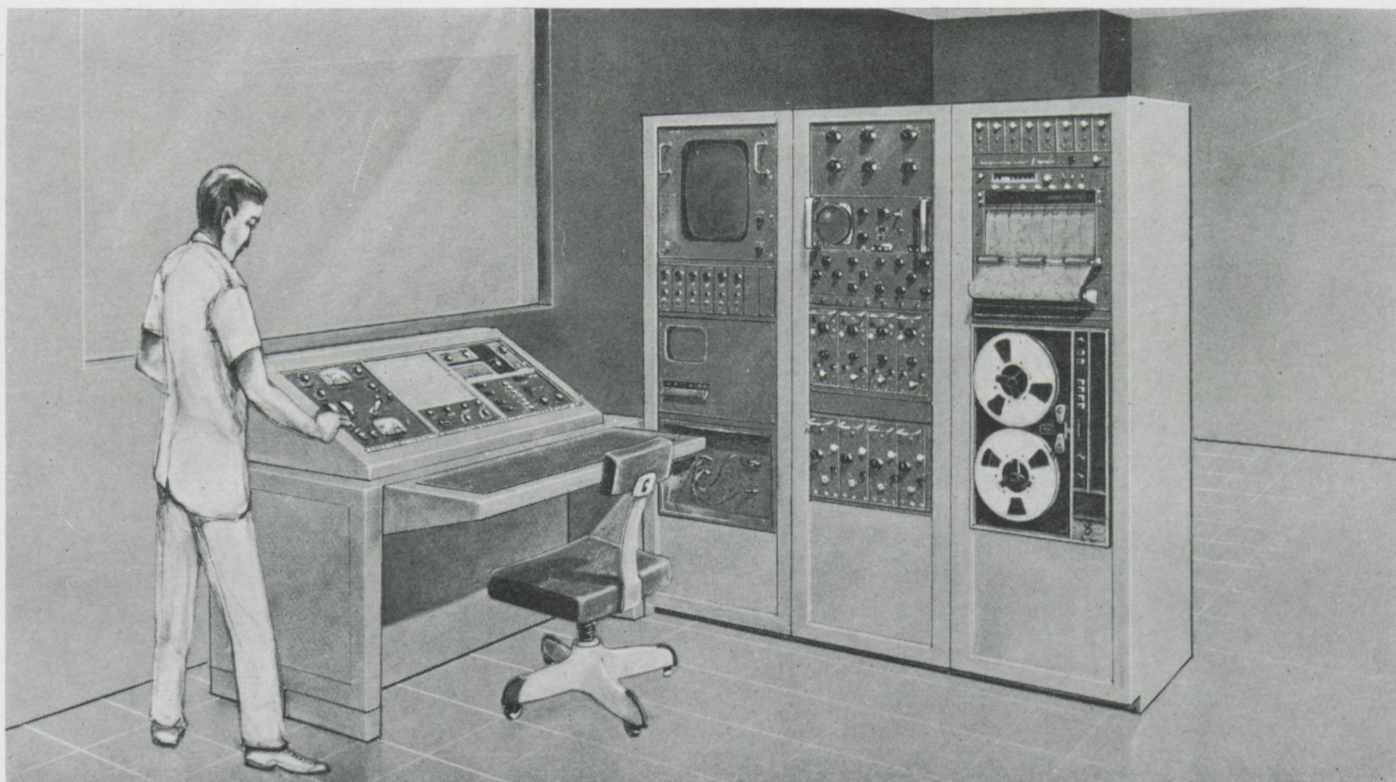


Figure 5. Artist's visualization of the heart catheterization control room for the U. of Oregon Medical School.

special diet instructions and laboratory tests.

The information is so logged and processed that it becomes a two-way system, one which not only placed orders on the pharmacy, kitchen, laboratory and nurses' station, but also provides each doctor with a running log of patient treatment and response. At the same time, as a by-product, it provides the office with data for billing purposes. Once stored in the information center, individuals records can be recalled for later use to compile patient statistical reports.

Adequate computer, peripheral and communication equipment is available today for a doctors' orders system. Yet to be developed is a set of standard procedures which will give each physician adequate flexibility of operation and, at the same time, be standardized sufficiently to fulfill the requirements of automated data handling equipment. This job requires agreement among the hospital medical staff and the acceptance by the physician of a certain amount of procedural rigidity. Once the system is in existence, technical staffs will have more free

time for patient attention, a lot more detailed patient information will be available, and each nurse will be able to spend less time compiling detailed log books and more time on patient care.

Business Data

Other parts of the integrated information system are concerned with business routines comparable to those in industry which are being computerized. These include inventory control, customer billing, accounting, payroll, business statistics and analytical studies. In these areas, routines compatible with the total system are required.

Information Processing Center

In order to integrate this information a computer is needed which has real-time processing capability. Process computers, originally developed to monitor and control industrial processes can handle all the requirements of the system. These computers can accept analog electrical signal inputs which vary in response to changes in temperature, pressure, rate, or other conditions. In process computers, large numbers of analog inputs can be scanned on a pre-arranged schedule, answers to

complex equations computed almost instantly, appropriate signals given or even corrective action initiated, electrically.

Systems of "priority interrupts" (Figure 7) as shown on the left are incorporated to allow an emergency condition detected by the computer to override, momentarily, a routine calculation the computer may be making, such as those shown on the right. After the interruption, the calculation is automatically resumed at the point where it was set aside. Because there is the need to perform several tasks in parallel, process computers also have the capability to accept input data and issue output data in such rapid sequence that they are, in effect, operating simultaneously. All these features of process computers make it possible to apply them directly both to the monitoring of medical situations and to the data handling operations of a hospital.

The second computer concept important to medicine is the application of both basic data processing techniques and continuous on-line operation to the transmission of messages among widely separated stations.

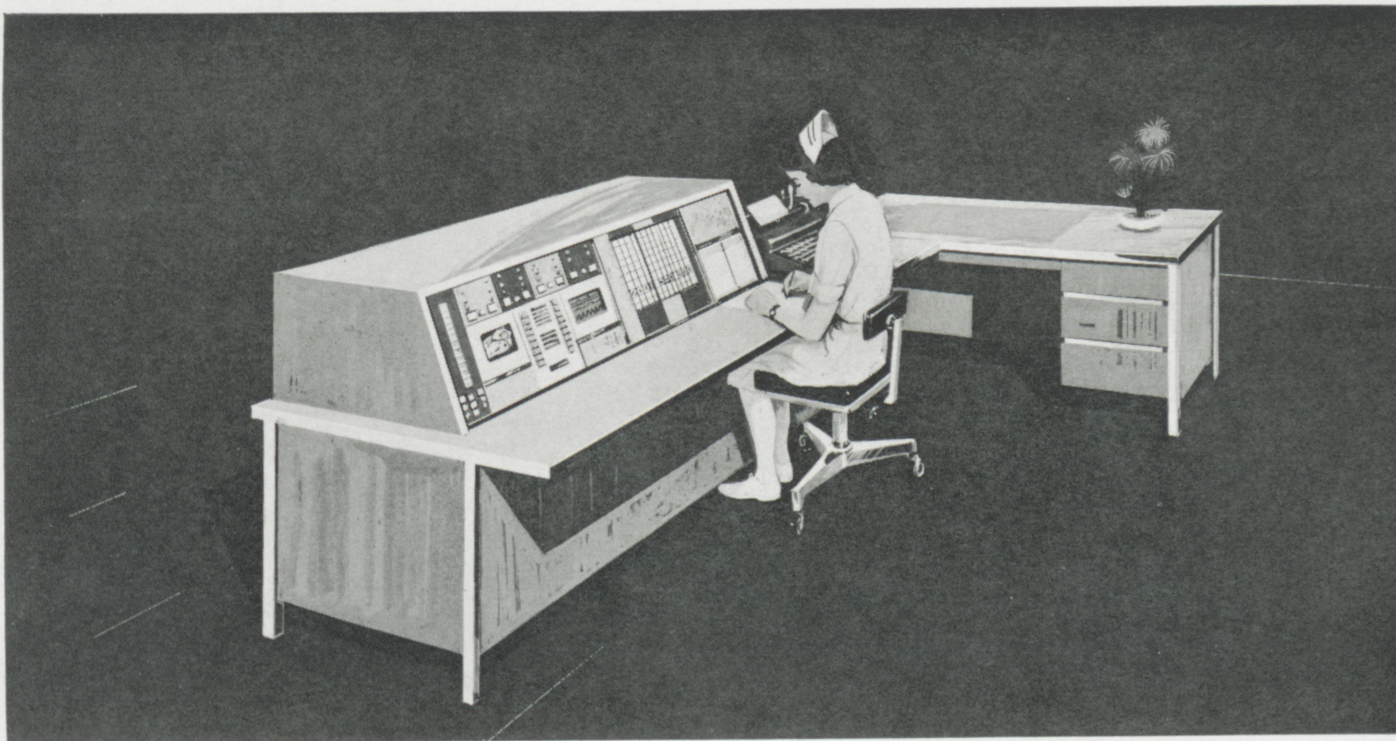


Figure 6. A coronary intensive care console can be used to monitor a number of patients with one nurse.

Equipment is now available for complete data communications centers, each capable of handling many remote stations, storing, dispatching, recording and checking messages in all directions. These units can be used to communicate with computers, thus making the computer's capabilities available to many areas in one building, several buildings or even several cities.

No complete system such as described, is in operation today. However, parts of the system are in operation and most of the equipment required for the system is available. Work must be done to determine what information should be recorded for maximum benefit to the physicians and medical specialists on the hospital staff. Effort is then required to standardize and codify this information. Systems engineering and programming talent is available from industrial developments but medical skills must still be applied to determine what information is significant and agreement reached on what is desired.

It can readily be seen that much can be done by the engineer to aid the medical profession in their work. This teamwork will save many lives and develop many more ways to treat human ills.

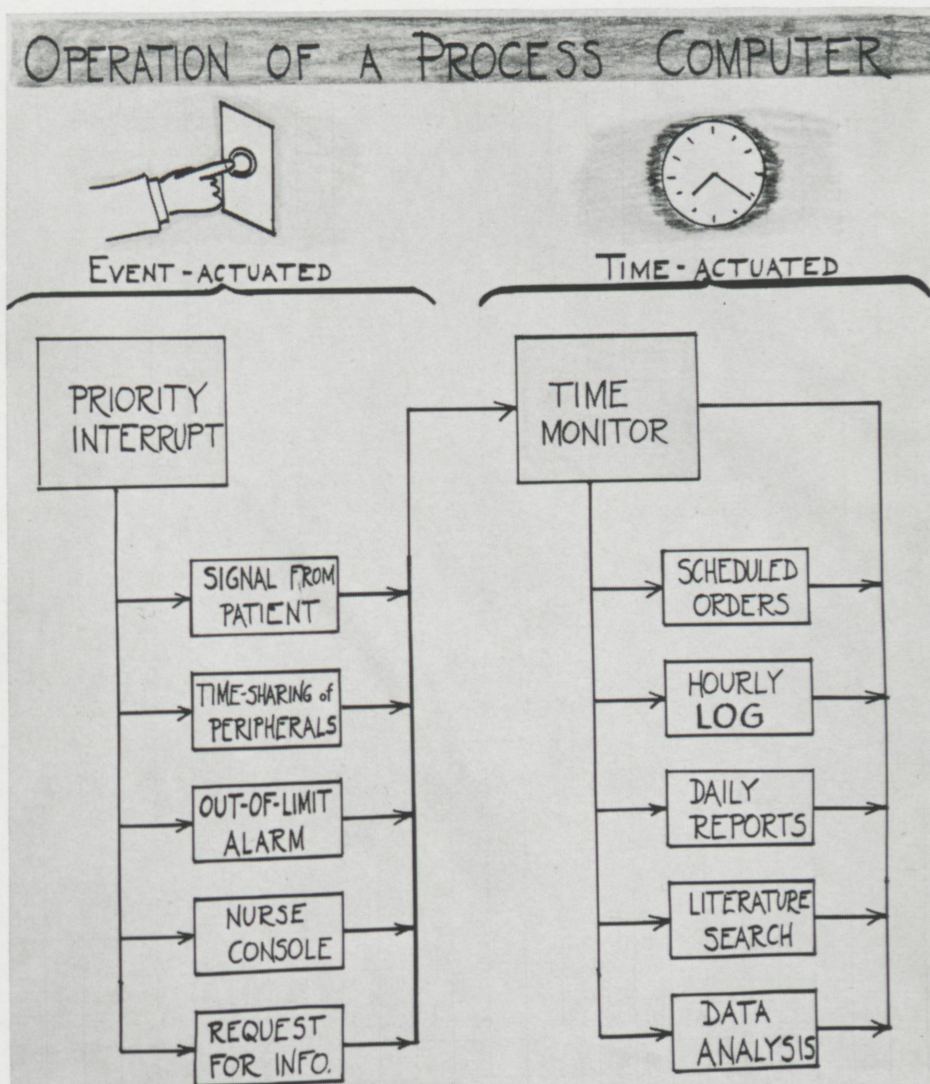
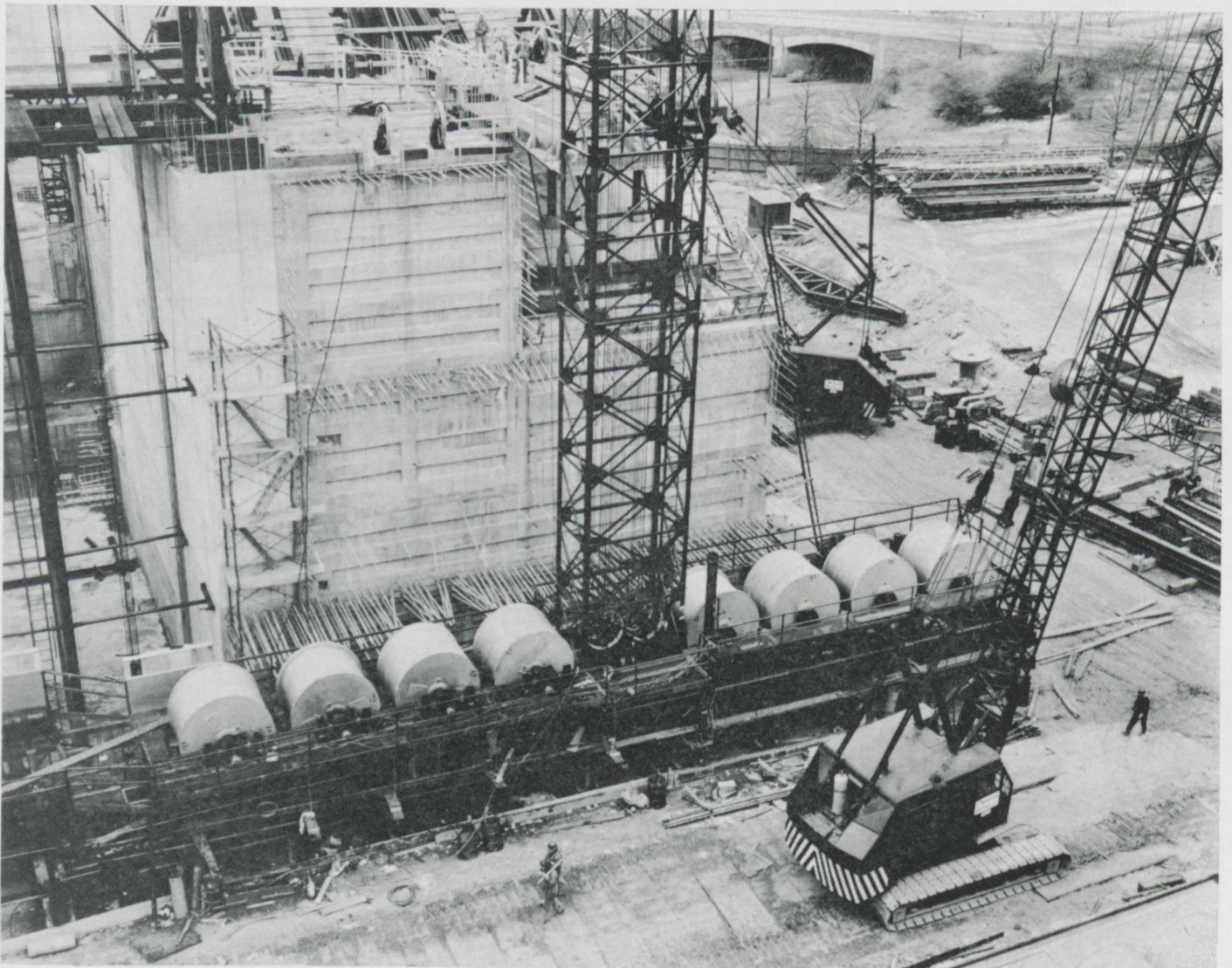


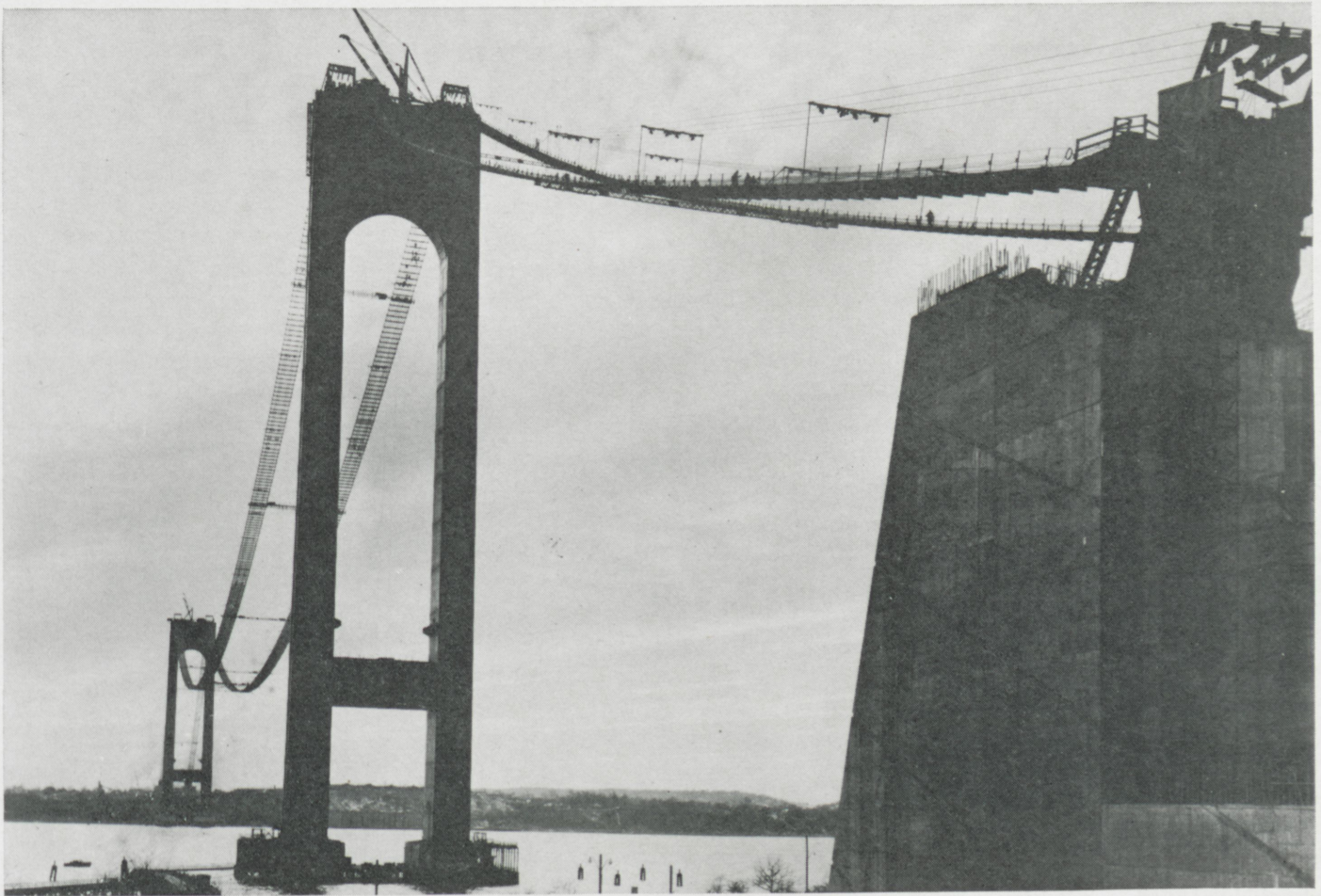
Figure 7. Schematic of the operation of a process computer in handling an integrated hospital information system.

INDUSTRY ON THE MOVE

Edited by
Chuck Hague
Soph., E.E.



Eight reels of pencil-thick galvanized steel bridge wire are shown in position at the Brooklyn anchorage of the Verrazano-Narrows Bridge as preparations for the start of cable spinning were completed. Some 1,600 reels such as these, each containing 24 tons of wire will be used in spinning the bridge's main cables.



Above: This photo looking from the Brooklyn anchorage toward Staten Island, shows the 20'-wide catwalks that will serve as work platforms during the cable spinning operations. Each measuring 6,948 feet in length, the catwalks are completed and support tramways to carry the spinning wheels that will position the 142,500 miles of galvanized steel wire making up the four main cables.



Left: The sweep of the 20 foot wide catwalks built between the towers of the Verrazano-Narrows Bridge is dramatized by the late-afternoon sun that also silhouettes a cargo vessel passing through the Narrows. The spinning of the four main cables began on March 7.

BIOMECHANICS

(Continued from page 15)

a person so interested. For obvious reasons the best educational facilities are where both engineering and medical facilities are present. Therefore large universities are doing most of the ground work today in establishing the proper educational opportunities. In order to see more clearly what exactly is being done, we will look into the programs offered by a few schools.

At Wayne State University, under the guidance of Herbert Lissner, students of civil, mechanical, electrical, and aeronautical engineering are doing graduate work in the field of biomechanics. To understand the problems of the body it is obvious that a thorough knowledge of the anatomy and physiology of the body is needed. At Wayne this is accomplished by the engineering students taking courses at the university's medical center. The students then do extensive laboratory work with human as well as other animal cadavers. They learn some

techniques such as the use of stress-coat, applying strain gages to bones, and attaching accelerometers. Then they become assistants to someone doing a research project which gives him an opportunity to work with cadavers and also to apply and increase his knowledge of instrumentation. The student then is probably ready for his own research project for his master's degree.

At Brooklyn Polytechnic Institute, Dr. Victor H. Frankel of the Hospital for Joint Diseases, is teaching an undergraduate course in Biomechanics. Dr. Frankel believes that since most of the material known about biomechanics comes from empirical data, that a firmer medical knowledge is needed by the engineering student. He suggests that the engineer should study biology, organic chemistry, and comparative anatomy in addition to anatomy and physiology.

Last fall the University of Michigan School of Engineering undertook a program in "Bio-Engineering", which is supposed to give the

engineering students a good background for studies in biomechanics and other related fields.

These are a few of the schools recognizing biomechanics' great potential and doing something about it. There are, I am sure, others also engaging in similar programs, but the above mentioned are to be taken as a cross-section.

Of course progress, besides the educational programs, is being made by people already in the field. Studies are being made investigating the production of a safe airplane seat which will absorb the impact of a slow moving (150 mph) plane on landing and taking off. It is during these critical times where the most accidents occur. Investigations on dash board padding for automobiles continues with new improvements being continually made. Another interesting study is the possibility of a hospital patient riding on an "air cushion" instead of lying in bed. This would eliminate the pressure on injured or burned parts of the body. This type of device has

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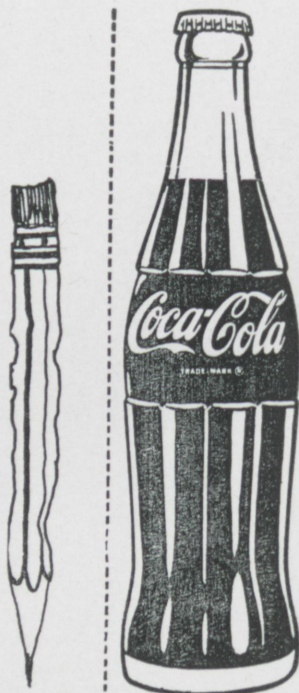
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many evident parameters, and until all of them are fully understood, combining medical knowledge with engineering "know-how", the problems will remain unsolved. The above-mentioned are but a few of the problems being investigated at the present time.

FUTURE

The number of problems being investigated in the present is being limited by the present number of investigators. It is evident today that there is a definite shortage of qualified people in the field of biomechanics. Therefore if the present shortage is considered, it is easily seen that a person's future in biomechanics is rather secure. But more important is the fact that new and exciting problems are being encountered and will continue to be encountered in biomechanics. One only has to look at the federal government's space program to see the possibilities. Therefore as the number of problems increases, the number of qualified people needed in the future will be even greater than the amount needed today. To get a

better idea of what the future of biomechanics is, let us see what men in the field say.

"... we believe that the area is unlimited I have been asked to list areas of research which we might engage in and I have had no difficulty in proposing 25-30 projects that might be started immediately. When you consider the number of injuries and deaths due to the automobile alone, and consider what might have been done to improve the chances of the occupants of automobiles to survive crashes by proper structural design, you can begin to appreciate the tremendous field that biomechanics encompasses. Our own (Wayne State) students are very sought after, and we can place ten times as many graduates as we have without the slightest difficulty in excellent positions."

S. R. Lissner

Wayne State University

"I believe that the future of biomechanics is a secure one for there is a great lack of knowledge based on definite measurements. Much that has been done . . . has not been

founded on measurement techniques but rather on empirical data."

Victor H. Frankel, M.D.

Hospital for Joint Diseases
(N.Y.)

"I think that body mechanics (biomechanics) must be a research field and not an arm chair occupation for a long time to come, although no doubt there should be clues of human significance that might come from research on (bio) mechanics."

W. T. Dempster

University of Michigan

It can be seen that by the comments made by the people actually in the field, those who should know, that biomechanics has a very bright future for those ready to accept its challenge. The rewards are great and the chances for rewards are greater as the number of investigators remain small. But with the present trend in the educational field some of the need for qualified people will be fulfilled. Then "those getting into the field in its infancy will grow with it and have the greatest opportunity to make outstanding contributions."

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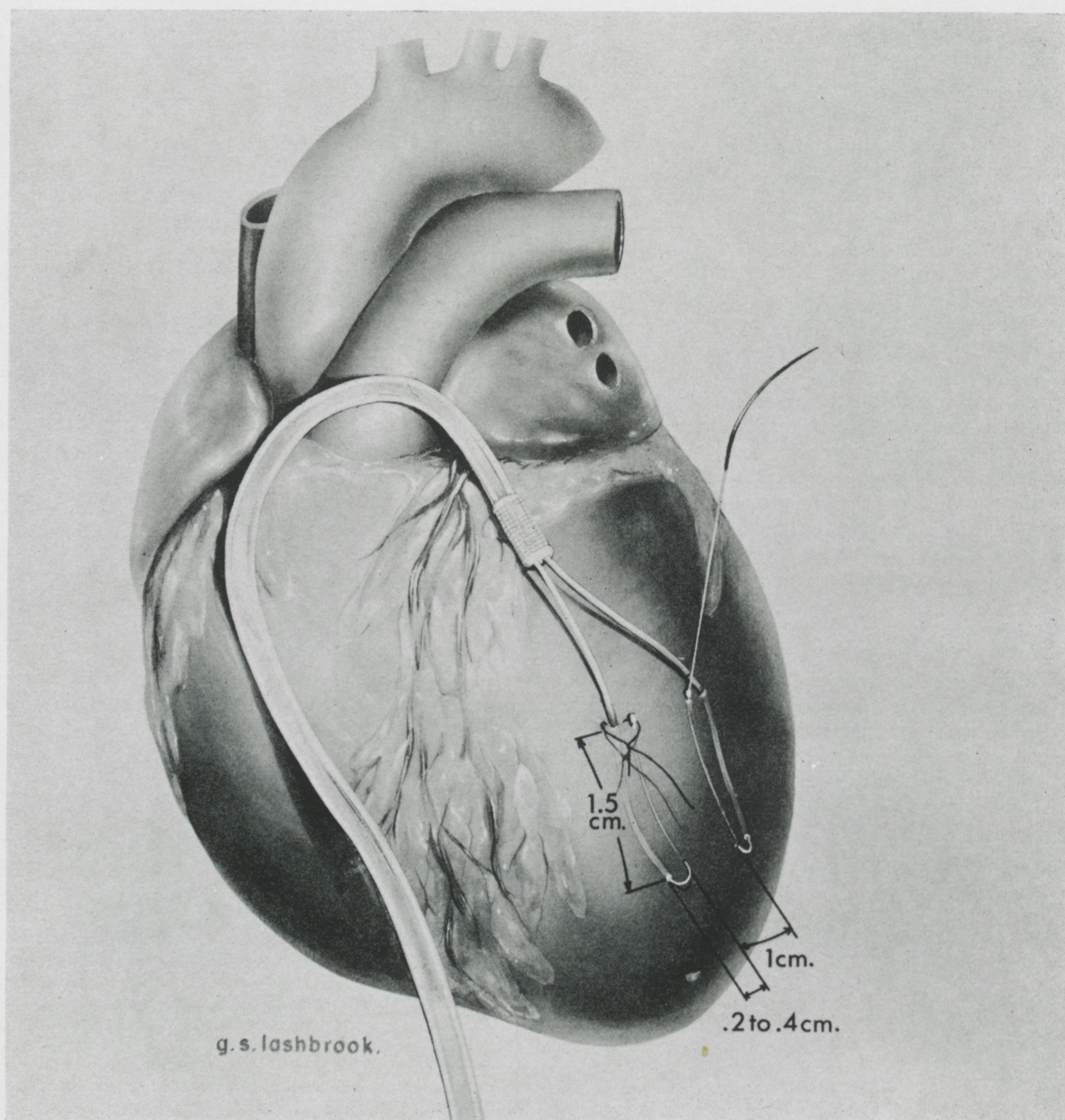
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HEART PACEMAKER

(Continued from page 10)

outside the body. Engineers again developed a smaller energy power supply and in 1957, Dr. Lillehei began installing the external pacemaker with heart electrodes. Many of these were used, but infection through the wire entrance into the body, and the difficulty of taking a bath and exercising with an ex-

ternal pacemaker left more to be desired. Also, the external apparatus kept many patients from feeling normal again, leading to psychological problems.

At this point, several teams of medical researchers and engineers began independently to conceive a pacemaker which could be implanted in the body. Wilson Greatbatch, an electronic engineer, collaborated with Dr. Chardack of Veterans Ad-

ministration Hospital, Buffalo, New York, to build a completely implantable pacemaker. After several iterations of developing circuits and testing them, pacemakers were implanted in patients. This effort became the pacemaker now provided by the Medtronic company.

At about the same time, Dr. Adrian Kantrowitz of the Maimonides Hospital, Brooklyn, New York, began to discuss with friends in the

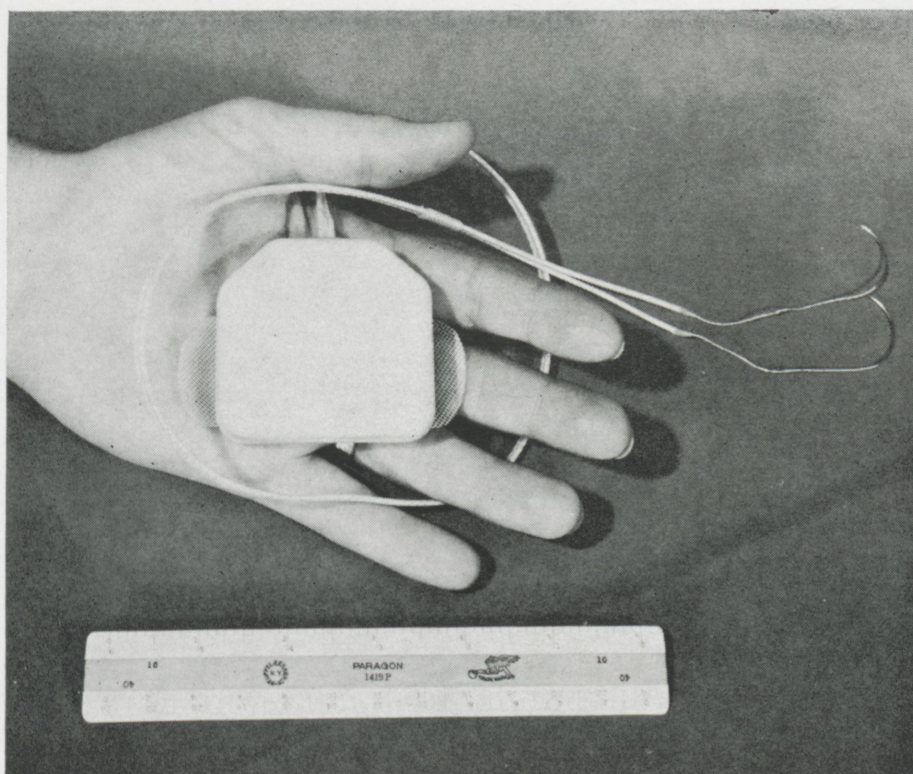


Figure 2. Implantable Pacemaker with leads.

General Electric Electronics Laboratory in Syracuse the possibility for developing an implanted pacemaker. Several engineers in the Electronics Laboratory began working on the problem.

From their background in miniature pulse generators for space missiles and satellites, they suggested the unique circuit shown in Figure 1. This circuit produced a differentiated pulse which is bi-phasic (as much energy in the negative condition as the positive pulse). This type of pulse was found to be the one developing the least heart tissue reaction to the electrical signal.

The research leading to the development of the pacemaker established that the heart is an energy-sensing organ requiring five microjoules of energy for stimulation. This threshold energy must be delivered with a minimum of approximately two volts but is also dependent on sufficient energy produced by voltage and current flow for a certain pulse length. The minimum required threshold of five microjoules is observed to increase to approximately 15 microjoule threshold over a long period of time after implanting.

To achieve reliable heart stimulation, it is desirable to approximately double the voltage and energy required by the heart. The pulse height is established, therefore, at about 3.7 volts. This results in a pulse energy input of 65 microjoules at the base rate of 70 pulses per minute, or approximately four times the required energy.

This energy is supplied by five mercury batteries. The batteries are chosen for the high standards of reliability; therefore, failure due to premature battery rundown is rare.

As another innovation, the General Electric engineers developed an

external rate control which is inductively coupled to the implanted pacemaker. For greater activity or periods of stress, this external rate control may be applied by the patient to temporarily raise the rate to any desired level between 75 and 120 pulses per minute. Removal of the external control automatically returns the pacemaker to its original rate. This control allows many patients to return to their normal activities and even to participate in sports such as bowling and hiking.

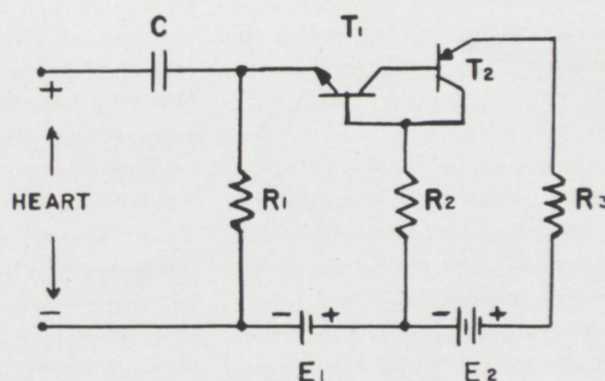
Implanted pacemakers (see Figure 2), at first curiosities in the medical field, are now well accepted and have been implanted in over 4,000 patients.

To develop new medical stimulators, close coordination is necessary between the engineer and the doctor. The process is one of mutual education and understanding of problems to both fields. Since few people have a complete understanding of both medicine and technology, a joint team approach is necessary.

Normally a product application engineer advises customers how to apply the product. In the pacemaker this advice must be given by a medical doctor since the application involves highly specialized surgery.

The intimate relationship between the medical specialist and the engineer, each recognizing the competence and contribution of the other, promises to accelerate the development of medical electronic equipment that will be direct aid to improving and maintaining human health.

Figure 1
Circuit
Diagram
of
Implantable
Pacemaker



BIO-WARFARE

(Continued from Page 14)

All these conditions are so exacting that the prediction of military effects is far from certain.

Since meteorological conditions cannot be controlled, efforts are being made to predict the effect of given doses of particular micro-organisms or combined micro-organisms, provided that they all reach the target area. The individual infective dose for particular micro-organisms, with few exceptions, is not known at the time. The general terms massive and minimal are used with no baseline figures as reference points. Infective or lethal doses for man are obtained by extrapolating the corresponding infective or lethal doses for animals. Much inaccuracy is inherent in this procedure.

The prediction of individual epidemics is a complex problem. The use of the mathematical probability theory to improve the predictability in the inception and development of an epidemic has been rather unsuccessful. These stochastic models of epidemics work best only when applied to small groups, and they fail with larger groups because of the increased number of variables. The "threshold theorem" is quite unsatisfactory for strictly a quantitative determination. It asserts that the introduction of infective cases into a community of susceptibles would not cause an epidemic, and the disease would ultimately disappear, if the density of susceptibles were below a certain critical value. If the critical value were exceeded, the resultant epidemic would reduce the density of susceptibles as far below the threshold as it originally was above. An estimate of morbidity and mortality resulting in a group of susceptibles simultaneously exposed to an "adequate" dose of these agents in a single BW attack may be made with some accuracy; but the prediction of a progressive epidemic is not nearly so accurate as similar predictions for nuclear weapons. Biological weapons are so unpredictable in scope and effect that any national

power using BW agents would be acting with great imprecision, which, aside from its disadvantages as a military weapon, could have grave ecological consequences.

Waging biological wars could conceivably disturb the fine ecological balances, achieved as a result of evolution over eons of time, among human, animal, and plant life, and between such life and their micro-organisms. Sudden disbalances in numbers or insertion of new infective elements, if in excess, could produce an unrecognizable and unmanageable world from the standpoint of communicable disease.

The useful agents for biological warfare are classified as bacterial, rickettsial, viral, fungal, and toxic.

Viruses are unable to grow and multiply outside of living cells. The parasitic nature of viruses gives rise to the following consequences: (1) Cultivation requires prior cultivation of specific hosts. Viruses must be cultured in human or animal tissue whereas bacteria may be cultured on synthetic media which are easily attained. (2) Their survival depends entirely on the intrinsic stability of the materials composing them, since they are unable to repair any damage to their substance by metabolic processes. (3) They reside inside cells of the host and are largely protected from immunological defenses. They can thus endow the host with extremely long lasting immunity by continued stimulation of the host's defense system after their initial effects have worn off. (4) Viruses are unaffected by antibiotics. For humans, some of the most useful viral agents would be psittacosis, Russian spring-summer encephalitis, influenza, dengue fever, Rift Valley fever, smallpox, and primary atypical pneumonia. Also included as viral agents are yellow fever, Japanese B encephalitis, and Coxsackie group (B). Smallpox is considered to be the most dangerous of these viral agents. The viral agents used against animals include African swine fever, anthropod-borne viruses, Bovine pleuropneumonia, foot and mouth disease, rinderpest,

Sheepox, Teshen disease, vesicular exanthema, and vesicular stomatitis.

Rickettsiae are taxonomically intermediate between micro-organisms and viruses. They are intracellular parasites; and, in general, unable to grow outside living cells. They will infect insects as well as humans and other mammals. Rickettsiae are susceptible to a number of antibiotics and extremely labile outside their hosts. Their dissemination is restricted to transmission through carriers. Generally, they are not suitable for BW because it is necessary to use non-flying (lice and ticks), and thus inefficiently spreading, insect carriers. Attempts at using mosquitoes as carriers have been unsuccessful. Also, the ease of producing vaccines and the fact that clinical cases are controlled by antibiotics make rickettsiae unsuitable agents. Some diseases induced in humans by rickettsiae are typhus, Q fever, Rocky Mountain spotted fever, and undulant fever.

Bacterial agents used against humans would be anthrax, brucellosis, glanders, melioidosis, plague, tuberculosis, tularemia, diphtheria, and typhoid. Diseases induced in animals would include anthrax, blackleg and other clostridial diseases, brucellosis, and tuberculosis.

Fungal agents would be used primarily to attack fruits and vegetables, but human beings are vulnerable to coccidioidomycosis (Joaquin Valley fever) transmitted by fungi.

Protozoal agents may also be employed to induce amoebic dysentery, malaria, and toxoplasmosis in humans.

Supplementing these living agents are by-products or toxins created by the micro-organisms. Botulism toxin (food poisoning) causes a painful, paralytic, and usually fatal disease.

Fungi, viruses, insects, and bacteria may be directed against crops to cause wheat rust, potato blight, and blast diseases of rice. Air-borne or soil-borne pathogens may be used in attacks on plants. The air-borne pathogens are weather-dependent, but the faster spreading of the two.

Soil-borne pathogens are immensely destructive. Some are capable of rendering land unsuitable for many years. Unfortunately most soil-borne pathogens are limited to certain species of host plants and do not prevent the growing of other crops on the infested land. Soil-borne pathogens could be used very effectively against countries dependent upon a single major crop, as in Russia's dependency upon her wheat crop. In most cases infectious diseases of plants spread too slowly and couldn't be introduced in sufficient quantities to influence the outcome of a war.

Biological weapons are particularly well adapted to aggression and sabotage. Most of the agents are more suitable for strategic use than tactical use. Strategic implies the capability of producing a major effect of widespread proportions either through morbidity, mortality or economic disruption. The term tactical implies usage restricted to selected areas for a limited objective. The reasons for their strategic suitability are: (1) The delay between infection and outbreak of disease makes BW agents ineffective as tactical weapons on the battlefield. (2) The most important asset of BW agents is the possibility of covering large target areas. Since BW is a more useful strategic weapon, it is more likely to be used against civilian populations, not troops.

The overt methods of dissemination of BW agents are generally of two classifications, aerosol sprays and very finely ground powders or dusts. These sprays and dusts may be sprayed into favorable winds which carry them to their target area, or delivered by bombs and conventional artillery shells. Since meteorological conditions are not accurately predictable, BW agents, presumably stabilized to withstand atmospheric exposure, might remain active for long periods and ultimately fall anywhere. The aggressor would then risk the chance of being exposed to his own BW agents. The biological cloud (aerosol or dust) is

invisible, odorless, and tasteless. It permeates most structures, and searches out and infects all targets permeable or breathing. It can establish new foci of contagious disease in animals, insects, birds, and people, and contaminates hospitals, food supplies, water, milk, kitchens, restaurants, and warehouses. The duration of such biological attack would be governed by the nature of the germs, density of the germs, susceptibility of the population, weather, terrain, and other conditions. Some biological agents stay alive and potent for years. Another means of overt dissemination would involve carrying, parachuting, or ballooning infected animals and insects deep into enemy territory.

The covert means of dissemination through saboteurs are almost endlessly practical. BW agents could be easily introduced into air conditioning systems, centralized food-processing industries, and drug producing industries. Numerous other avenues of covert attack are also feasible. Incredibly dangerous dosages could be easily concealed and disseminated because they require little bulk. For instance, a single ounce of toxic agent which causes J fever would be sufficient to infect twenty-eight billion people. Obviously, BW lends itself quite well to dissemination from within the victimized country.

Biological warfare presents several advantages over conventional and nuclear weaponry. BW agents are cheaper than standard warfare agents and can largely be used with existing and projected weapons, thus requiring little capital outlay for elaborate new delivery systems. For comparable results, BW agents are less bulky and heavy. Their research, development and production require a relatively small fraction of national effort and resources. These weapons can seek out the enemy whether he is widely dispersed, underground, or in fortifications. BW agents offer a very wide range of effects, from temporary to persistent, from mildly incapacitat-

ing to highly lethal. They can be employed alone or in conjunction with high explosives or nuclear weapons. BW agents can mount an attack which is ultimately directed against all the portals of the body and thus extremely difficult to defend against. It can neutralize, without destroying, valuable facilities which will be needed intact; and provide captive labor to man these facilities. Finally, biological warfare requires use of the minimum force necessary to accomplish a military mission, causing a minimum of blood spilling, prolonged physical suffering, and disfigurement. It may be used as a deterrent against future wars.

The defenses against biological warfare are all relatively useless without early detection. Instruments have been developed for the detection and measurement of the bacterial content of air. These instruments are not, however, presently adapted to large scale detections. Other defense measures are quick identification, protective masks and clothing, shelters, air filters, public health measures, means of decontamination of equipment, food, and water supplies, and mass immunization. Russia is already attempting the mass immunization of her armies and civilian population.

The greatest threat to the United States with the advent of a biological war will be the lack of an informed public. People must realize that biological warfare is no longer a mysterious weapon of the future. They must take measures to educate themselves and be prepared for this now imminent danger, for they will surely bear the brunt of a BW attack. Biological warfare is no longer considered an indecent form of aggression. Biological agents are perhaps the most humane of all types of weaponry, if any instrument of war can be considered humane. Every citizen should, in the interest of the perpetuation of humanity, make an effort toward understanding the effects of and defenses against biological warfare.

MAN IN SPACE

(Continued from page 17)

turbulent air from the cabin would be passed. It appears that temperature control, air motion development, removal of particulate matter, elimination of odors, and control of microorganism populations may be adequately handled through the use of existing commercial equipment.

There are several possible methods of supplying oxygen for use in the regeneration of the atmosphere. One is to carry the total supply of oxygen in the gaseous form in high pressure containers, or in the liquid or cryogenic state. A second is to derive oxygen from oxygen containing chemicals, such as the superoxides and ozonides. A third method is to produce oxygen with living organisms such as algae. A fourth and theoretically promising method is the disassociation of the carbon dioxide respired into usable oxygen and carbon.

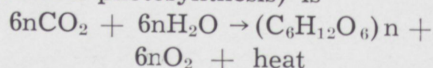
Since the reutilization of all chemicals is necessary, the dual problem of waste treatment and carbon dioxide-oxygen balance is critical. Currently the use of algae culture appears to offer the most promise of solving this problem. The ideal solution would be to use liquid wastes as a source of nutrient in an algae culture. There are certain characteristics which an algae suitable for use in a confined space should have. The species of algae should:

1. Grow efficiently at a high temperature (40-50°C).
2. Give a high growth rate with higher rates of evolution of oxygen.
3. Grow in mass culture without change over long periods by recirculation of media.
4. Be very hardy—resist contaminating agents and inhibiting substances.
5. Be free from toxic substances.
6. Have good food value.
7. Be able to utilize the nitrogen from urine.

The factors which prohibit the use of this type of system at present are the extensive waste treatment

which is required before admission to the culture, and the toxicity of the cultures when they are sick. Work is now being done in trying to develop more suitable strains of organisms.

Another possible method of attaining carbon dioxide conversion is through the development of an artificial photosynthetic cell. A simplified expression for the reaction which is carried out in a living cell (natural photosynthesis) is



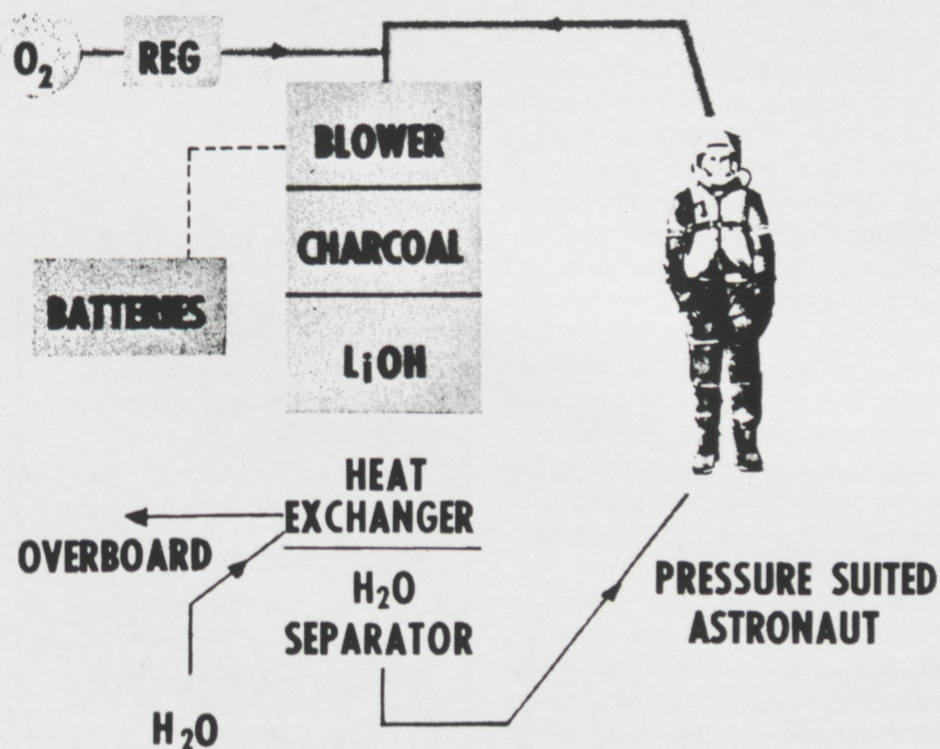
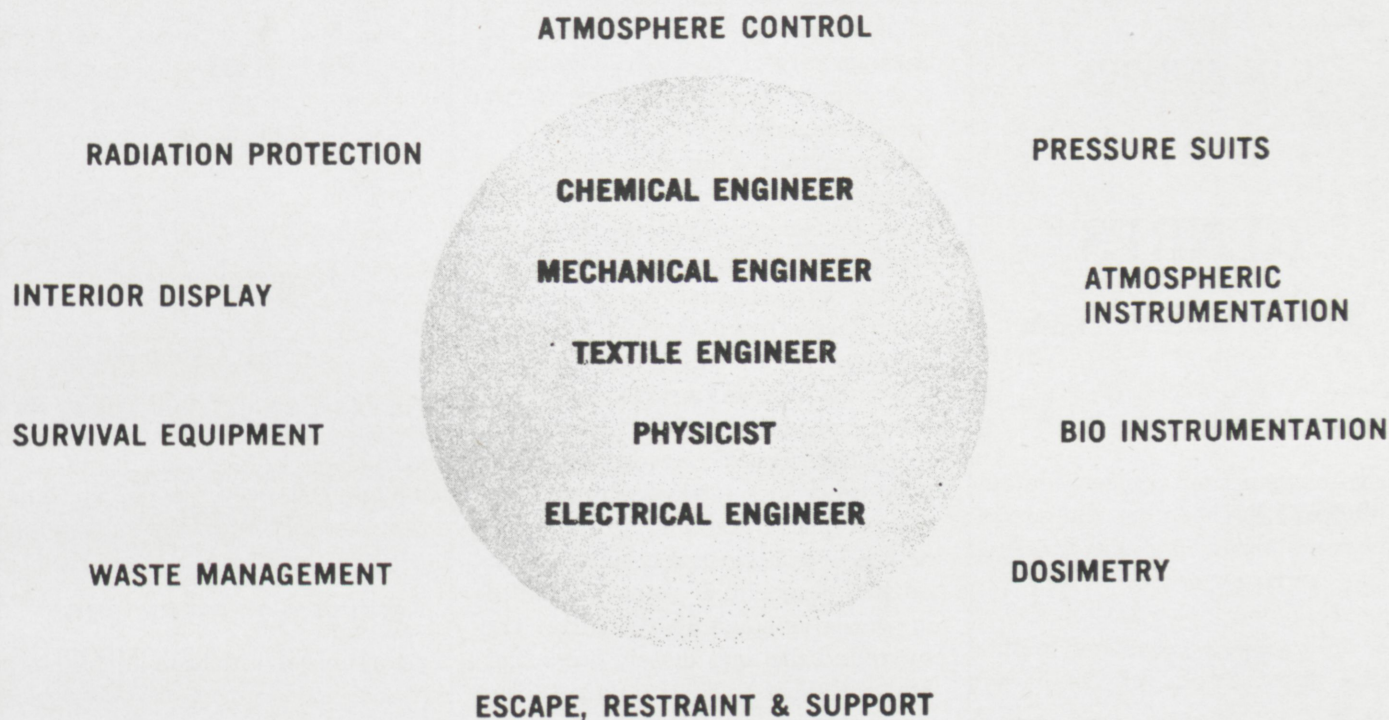
Techniques have been developed to combine the disassociated carbon from carbon dioxide with hydrogen, produced from the hydrolysis of water, to yield methane. Further reactions will convert methane to formaldehyde, and formaldehyde to usable and palatable sugars. The overall reaction closely approximates the one which occurs during the process of photosynthesis. The limitations to this method result from the size and type of the reaction equipment, and the unknown effect of the environment incurred during space flight. The ideal situation would be to have the reaction function as a continuous process, housed in a limited space, thus providing a constant removal of carbon dioxide to the normal level and at the same time supply a constant supply of oxygen and sugar.

Another aspect of space flight is whether to provide an artificial gravity, by allowing the spacecraft to rotate. This would simplify the problem of waste collection, and also provide the familiar up-down orientation for the astronaut. There is, however, one disadvantage of allowing the spacecraft to rotate. When man is slowly spinning, with his head in a plane perpendicular to the direction of rotation, currents are set up in the semicircular canals. The brain interprets these currents as rapid rotation of the entire body. The other physiological detectors, vision and tension in the skeletal muscles, do not indicate much rotation. The result of these conflicting reports is confusion, dizziness, and nausea. It is believed

that rotation of the spacecraft caused the "spacesickness" which the Soviet cosmonaut Titov experienced. Since the presence of gravity would greatly simplify the engineering problems, work is being conducted to develop drugs which would deaden the sensitivity of the semicircular canals.

The final problem which the astronaut would face before reaching the moon is the radiation effect caused by the Van Allen belt. The Van Allen belt is a heavy concentration of protons and electrons extending from approximately 400 miles to about 30,000 miles above the Earth's surface. Radiation shielding has been developed which would protect the astronaut under ordinary conditions. There is, however, the possibility of a solar storm occurring, which cause large concentrations of radiation to be emitted from the sun. It has been suggested that the capsule could be shielded by magnetism during these periods, by utilizing the principles of superconduction in magnetic coils. The effect that the strong magnetic field would have on the astronaut is not known. There is some evidence that they may have harmful effects. It is known that electric and magnetic fields combine to exert a powerful force on chemicals in the free radical state, and it is these chemicals which play a major role in most life processes.

In summary, what I have described in the preceding paragraphs are the problems involved in the design of closed ecological system suitable for space travel, and also some suggestions as to the possible areas in which the solutions to these problems might be found. The problems which I discussed may not be the most critical problems of the entire space program, but they do represent the major problems which the biologist and biological engineer must solve. The conquest of space will undoubtedly open a new era of science and technology, and with this new era is the opportunity to observe the biological sciences mature into very precise and well defined sciences.



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CYBERNETICS

(Continued from page 18)

here; more will undoubtedly be developed in the future. There are, however, two peculiar scientific virtues of cybernetics that are worth explicit mention.

One is that it offers a single vocabulary and a single set of concepts suitable for representing the most diverse types of system. Until recently, any attempt to relate the many facts known about, say, servomechanisms to what was known about the cerebellum was made unnecessarily difficult by the fact that the properties of servomechanisms were described in words common to the automatic pilot, or the radio set, or the hydraulic brake, while those of the cerebellum were described in words common to the dissecting room and the bedside— aspects that are irrelevant to the similarities between a servo-mechanism and a cerebellar reflex. Cybernetics offers one set of concepts that, by having exact correspondences with each branch of science, can thereby bring them into exact relation with one another.

It has been found repeatedly in science that the discovery that two branches are related leads to each branch helping in the development of the other. The result is often a markedly accelerated growth of both. The infinitesimal calculus and astronomy, the virus and the protein molecule, the chromosomes and heredity are all examples of this. Neither, of course, can give proofs about the laws of the other, but each can give suggestions that may be of the greatest assistance and fruitfulness. Cybernetics can provide the common language by which discoveries in one branch can readily be made use of in the others. ,

The second peculiar virtue of cybernetics is that it offers a method for the scientific treatment of the system in which complexity is outstanding and too important to be ignored. Such systems are, as we well know, only too common in the biological world. In the simpler systems, the methods of cybernetics

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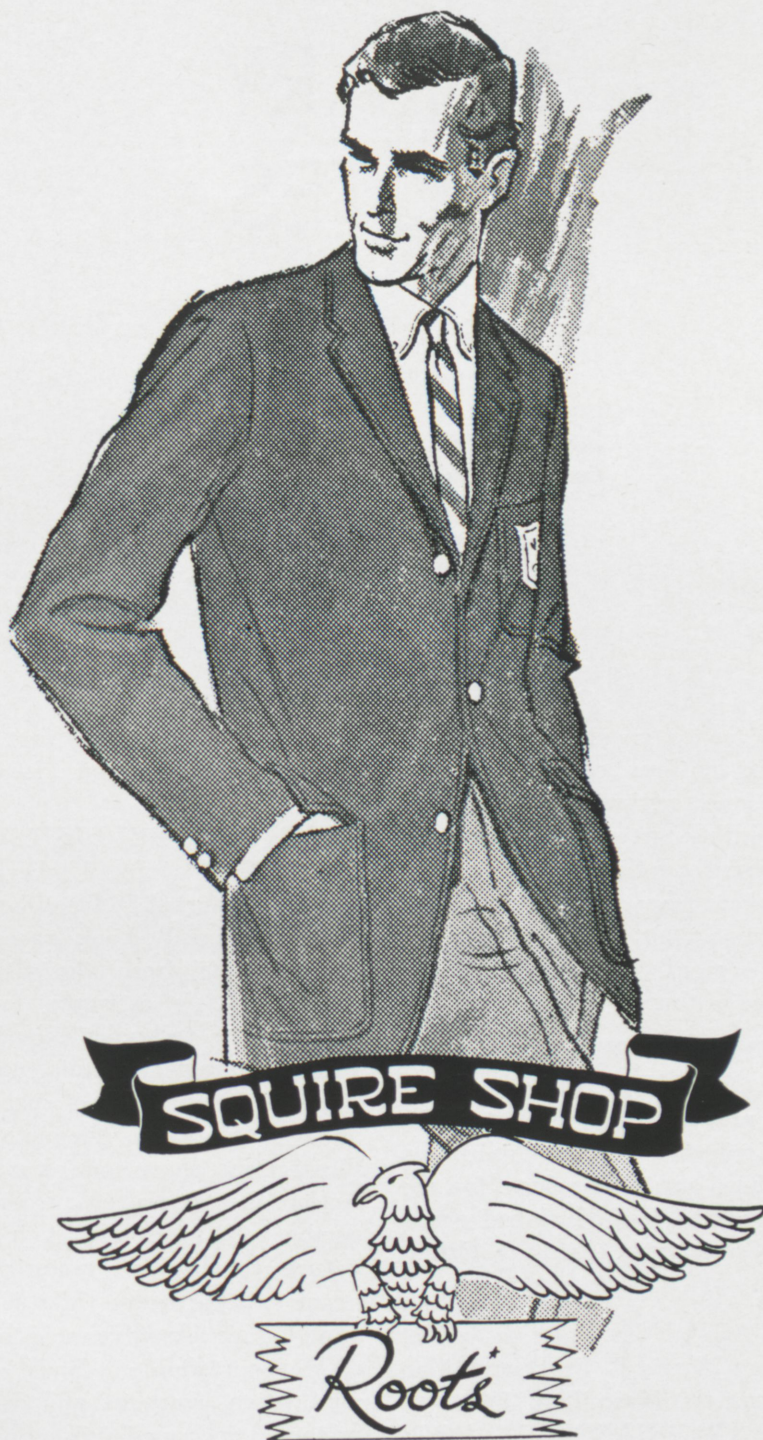
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sometimes show no obvious advantage over those that have long been known. It is chiefly when the systems become complex that the new methods reveal their power.

Science stands today on something of a divide. For two centuries it has been exploring systems that are either intrinsically simple or that are capable of being analysed into simple components. The fact that such a dogma as "vary the factors one at a time" could be accepted for a century, shows that scientists were largely concerned in investigating such systems as allowed this method; for this method is often fundamentally impossible in the complex systems. Until recently, science tended to evade the study of such systems, focusing its attention on those that were simple and, especially, reducible. In the study of some systems, however, the complexity could not be wholly evaded. The cerebral cortex of the free-living organism, the ant-hill as a functioning society, and the human economic system were outstanding in their practical importance and in their intractability by the older methods. So today we see psychoses untreated, societies declining, and economic systems faltering, the scientist being able to do little more than to appreciate the full complexity of the subject he is studying. But science today is also taking the first steps towards studying "complexity" as a subject in its own right.

Prominent among the methods for dealing with complexity is cybernetics. Cybernetics offers the hope of providing effective methods for the study, and control, of systems that are extremely complex. It will do this by first marking out what is achievable (for probably many of the investigations of the past attempted the impossible), and then providing generalized strategies, of demonstrable value, that can be used uniformly in a variety of special cases. In this way it offers the hope of providing the essential methods by which to attack the ills—psychological, social, economic—social, economic—which at present are defeating us by their complexity.



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LIBRARY NOTES

"Some read to think, — these are rare; some to write, — these are common; and some to talk, — and these form the great majority."

Franklin,
Poor Richard's Almanack,
1738.

In order to encourage more individuals on our campus to read more, short reviews are given in this monthly article. The reviews are frequently followed by a list of other recent acquisitions. To vary the format a bit, the list will come first this month. We hope you will try some of these.

SCIENCE, TECHNOLOGY, AND DEVELOPMENT: United States papers prepared for the United Nations Conference on the application of Science and Technology for the benefit of the less developed areas. U. S. Government Printing Office, 1962-63.

PRIVACY: the right to be let alone; by Morris L. Ernst and Alan U. Schwartz. Macmillan, 1962.

THE TWO HANDS OF GOD: the myths of polarity; by Alan W. Watts. G. Brazillier, 1963.

MATHEMATICS: by David Bergamini and the editors of Life. Time, Inc., 1963.

THE LIVING SEA: by Jacques Y. Cousteau. Harper and Row, 1963.

THE CONSUMERS' UNION REPORT ON SMOKING and the Public Interest; by Ruth and Edward Brecher. Consumers Union, 1963.

ORDEAL OF VICTORY: by John Terraine. Lippincott, 1963.

ANZIO: the gamble that failed; by Martin Blumenson. Lippincott, 1953.

THE PICTURE HISTORY OF INVENTIONS: by Umberto Eco and G. B. Borzoli. Macmillan, 1963. This encyclopedic book traces man's achievements from the Stone-age cave dweller's attempts to make tools, to the technological advances which characterize this century's scientists in the fields of space flight and atomic science. The pictures and illustrations show man learning to exploit the natural resources of the earth, and eventually vying with nature to produce materials that never existed before. Man is shown applying his inventive mind to means of transportation, methods of communication, weapons and defensive systems, and machines to replace manual labor. Special emphasis is given to the Renaissance period because of the inventive genius evident at that time, and to the nineteenth century because of its rapid industrial development. The contemporary era is not neglected as all the most recent developments in electronics, nuclear energy, and space flight are covered.

Besides being a chronicle of scientific and technical achievements, these advances are portrayed in

their broad historical context and shows how they have transformed the social, political and cultural patterns of human life over the centuries. In addition to being a valuable reference work, this book affords interesting reading and visual delight with over 800 illustrations.

THE DARKEST DAY: 1814, by Charles G. Muller. Lippincott, 1963.

The subtitle of this book is, The Washington - Baltimore Campaign, and it seems more descriptive than the title itself. The author, using official documents, manuscripts, reminiscences and eye witness accounts from both sides of the conflict, recounts the events that precipitated our "second war of independence." The war was called President Madison's War at first, but the British blockade and militia soon aroused the states to action. The humiliating defeats of the next two years were culminated on August 24, 1814, when Wellington's veterans routed the American militia at Blandensburg, Maryland, then marched into Washington and burned the capital. However, the book does not end on the Darkest Day, since the author culminates his account with the heroic American defense of Baltimore a few weeks later. This successful defense not only contributed to a swift conclusion of hostilities, but also inspired our national anthem.

THE WISDOM OF THE SERPENT: by Joseph L. Henderson and Maud Oakes. George Brazillier, 1963. Man is the only animal who knows he is going to die. This act of mortality, so central to human experience, assumes tremendous significance both in the world of mythology and in modern psychoanalysis. Here, death is viewed as the essential condition for growth and for life. The author explores the meanings and variations of this sense of death in myth and in contemporary experience. He concludes that death is seldom perceived as an end, but invariable as part of an experiential cycle of death and rebirth or of death and resurrection. Death becomes the symbol of the universal experience of initiation. In a case-

study the author illustrates the meaning of death and rebirth for a woman who encounters, interprets, and overcomes her fears of dying. In the rites and mysteries of initiation, which provide the means for growth from one stage of development to another, the author finds two central patterns: the descent into the earth and the magic flight upward.

This book gathers together all the elements contained in the mystic images of death, rebirth, and resurrection and translates them for modern man. The second half of the book is devoted to an extensive selection of myths and illustrations. Here, Maud Oakes has chosen and annotated legends, religious texts, epics, stories and poems from all periods and places which exemplify the themes of death, rebirth and resurrection. Together they present an engrossing journey into the very depths of man's inner struggles with life and death.

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PHYSIOLOGIST LOOKS

(Continued from page 12)

vious in the case of the living organism. The longest recognized fact about the latter is that it is a self-maintaining, self-regulating, self-adapting, self-operating, self-reproducing system. It is the system to end all systems. In fact, we might say that the very secret of life is organization. In order to realize its destiny, physiology must succeed in understanding living systems as well as their isolated components.

The living organism is a hierarchy of control systems organized at a succession of levels. Each component is both a subsystem in itself and an element in a super-system. At the highest level is the organism-as-a-whole; at successively lower levels come organ-systems, organs, tissues, cells, organelles, macro-molecules, and ultimately the particles of physics. At each of the living levels of this series the components are organized as control systems. If the organism is to survive, none can run rampant and uncontrolled; each must operate in the interest of the whole.

At each level of this hierarchy of control systems there is a physiology, involving both analytic and synthetic problems. Analysis strives to define the behavior of components isolated from their systems; synthesis strives to deduce the behavior of systems, from a knowledge of their components and organization. Thus analysis moves downward through the hierarchy while synthesis moves upward. But in order to understand a system, at whatever level of organization, one must synthesize as well as analyze. Both are necessary, yet neither is sufficient. Analysis properly comes first, but synthesis must follow.

Although impressive and truly exciting progress has been made in the analytic phase of physiology, we are only on the threshold of an effective synthetic phase.

Further delay, however, invites calamity. For without the organization and assimilation which only synthesis can provide, the accelerating accumulation of analytic knowledge threatens physiology with the frightening fate of the Sorcerer's Apprentice. Guidelines for fruitful physiological synthesis have not, and are not likely to, come from physics and chemistry, for synthesis in these disciplines is restricted to the sub-living level of organization. It has not proved easy for physiology to develop its own guidelines when confronted with systems of baffling complexity. It is simply not the way of intellectual evolution to lick the toughest problem first.

Yet there is a field, traditionally unrelated to physiology, which has long concerned itself with systems, their analysis and synthesis as well as their theory and principles. It was blessed with the good fortune to be able to evolve naturally from the simple to the complex as a growing body of theory and methodology provided the catalyst. That field, of course, is engineering. Its earlier successes, from designing wigwams to keep us warm to building giant machines to amplify our muscle power, have shed little light on living systems. But the present century has witnessed an explosive evolution in engineering. The principle of the closed-loop system, featuring the transmission of information as well as power, has been exploited in the design of devices exhibiting responsive, adaptive, and controlled behavior of a kind hitherto seen only in living things. In a sense, the engineers have unlocked some of the secrets of nature's design principles. The accompanying theory and methodology are precisely those that physiologists have long been seeking as guidelines to the synthetic phase of their own science. It is thus no paradox that engineering has much to offer that is most meaningful to physiology.

One of my most thrilling moments came with the discovery that the principles of control systems so beautifully worked out by engineers can be fairly directly translated into fundamental principles of physiology. They not only shed a penetrating light on the behavior of physiological systems, they guide a more powerful approach and re-orient the outlook in a way that, once captured, influences all one's thoughts, experiments, and teachings in physiology. Take, for example, the concept of homeostasis, so fundamental in physiology. It recognizes that if an organism is to survive, certain critical factors in its internal environment must remain constant within tolerable limits in spite of threats from a host of disturbing factors. It has emphasized this constancy almost to the exclusion of the nature of the mechanism essential to its achievement, which must necessarily involve a system with an actively manipulated variability. The concept of homeostasis is an initial expression of something that has flowered in powerful and illuminating form in engineering control theory. A physiologist can learn more about it from a brief study of engineering sources than from an exhaustive study of classical physiological sources. At the same time he will discover that the concept has been generalized to include the more sophisticated following device, or servomechanism, counterparts of which are also to be found in nature.

Most physiological control systems, whether regulators or servomechanisms, are of the closed-loop variety, which may prove treacherous to one accustomed to thinking in terms of the simpler open-end system. When an open-end system is forced, responses occur only ahead of the point of forcing and the rest of the chain can be conveniently ignored. But the responses of the closed-loop system inevitably involve the entire circuit, no matter where the forcing

is applied, so that no part of the system can be ignored. It follows that any experimental interruption of the circuitry profoundly alters the behavior of a closed-loop system. This affords a most useful means of exploring the system, to be sure, but special pains must be taken to avoid mistaking the modified system for the original. The behavior of components is apt to be quite different in isolation than in circuit; the circuitry may suppress certain responses while exaggerating others. The isolated, piece-meal outlook so comfortable and appropriate for the open-end system can become a booby-trap when unconsciously carried over to the closed-loop system.

I would not want to leave the impression that engineering literature is nicely designed for the casual perusal of the physiologist. On the contrary, it is presented in a fashion best suited to the specialized needs of the designer of systems to be synthesized from simple, known parts to meet predetermined specifications. The problem of the physiologist, however, is to explore unknown systems grown by nature from components often hard to delineate, rarely well understood, and seldom linear. Accordingly, he must pick and choose and digest the engineering material, seeking the most general, ferreting out the specialized restrictions, and translating constantly from the problem of design to that of exploration and from hardware to flesh and blood. In spite of all this, however, the ore is rich in nuggets of pure physiology.

In addition to translatable control principles, engineering has other things to offer, perhaps even more valuable in the long run—a methodology and an attitude. The methodology is the powerful one of systems analysis, which is simply analysis followed by synthesis as the means of exploring, representing, and understanding system behavior. Phys-

iological systems are no different from engineering systems in one fundamental respect; both are mechanisms whose behavior is determined by the nature, number, and circuitry of their components. Each component has some input-output function which it is the goal of analysis to establish. Synthesis of these component functions according to their unique circuitry can then yield the determinate behavior of the whole system.

A key of systems analysis is mathematical modeling, which is merely a new designation for the old practice of representing functional behavior in quantitative mathematical form. The ultimate goal is to achieve a final, valid model which faithfully describes the entire spectrum of system behavior. But this, of course, is an ideal, approachable only as a limit. In the earlier, more realizable stages, mathematical modeling plays two indispensable roles: it summarizes present understanding in a precise form, and it guides further enquiry. Experimentation without modeling may turn random and sterile, for it is insight that both guides the most fruitful experimentation and facilitates recognition of the fruit. On the other hand, modeling without experimentation soon turns into unbridled speculation, a mere exercise in the abstract. It is the continual, intimate interaction of experiment on modeling and of model on experimenting that yields optimal progress. This does not mean that the experimenter and modeler must be one and the same person, but it does imply that each must be responsive to the other.

Physiological as well as engineering systems are dynamic in nature, which is to say that their behavior exhibits time features that are of critical importance. This the engineer fully understands and turns to his own advantage, for it provides the means for a more penetrating analysis of

the system. But the dynamic features of physiological systems have sometimes been ignored, with inevitable confusion resulting from the failure even to differentiate transient and steady state responses. Admittedly the dynamics of non-linear physiological systems pose a more formidable mathematical problem than those of linear engineering systems. This may well justify an initial attack on the simpler steady state phenomena, but even then the experiment must be so designed as to yield proven steady state responses. On the other hand, dynamic analysis, as developed by the engineer, offers a relatively unused but potentially powerful tool for exploring physiological systems.

The engineer resembles the pure physicist and the pure chemist in an important characteristic for which there is no accepted word. They all strive to explore thoroughly and with painstaking logic all the implications of their concepts, to rely on mathematics to guarantee straight thinking in quantitative matters, and to make all assumptions and simplifications explicit in order to facilitate the observance of any restrictions they may impose on the applicability of the result. For lack of a better word, and at the risk of raising the hackles of mathematicians, I shall call this the rigorous attitude. The engineer learned it the hard way when his building collapsed, or his bridge oscillated to destruction in a wind, or his billion dollar rocket fizzled. Physiology needs this attitude even more than most sciences, for the more complex the problem the more, not less, essential a rigorous treatment becomes. Rigorousness demands the application of mathematics, however painful the thought may be.

The successful use of mathematics often presupposes simplification, abstraction, and approximation in the initial attack. Although physiologists have never

hesitated to borrow simplifications from the "exact" sciences ("ideal" gas laws, for instance), they have traditionally insisted that simplification of the complexities that plague their own field must lead only to misleading inaccuracies. But "exact" scientists long ago discovered that it is non-rigorous deduction from confused complexity that is most surely misleading. By contrast, rigorous deduction from ingenious simplification is extraordinarily illuminating and possesses the further crucial advantage that it focuses attention on residual discrepancies that both goad and guide a succeeding round of improvement. This is merely an example of the ancient maxim of research that progress emerges from error far easier than from chaos. The adequate justification for simplification is that it makes rigorous treatment possible. The mastery of the complex comes in steps, but sound, sequential steps are more effective than rickety, haphazard steps.

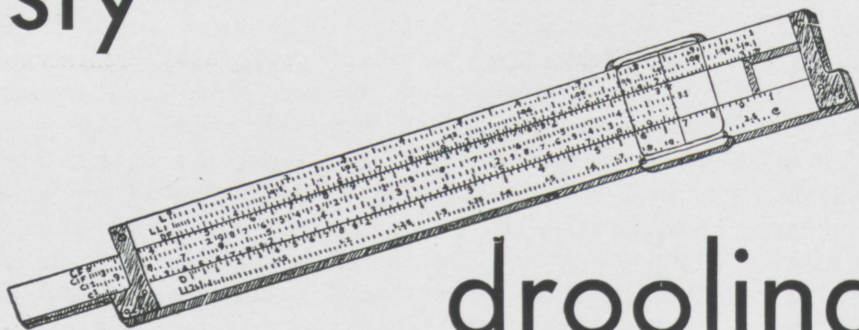
The engineer has developed one device for enforcing an elementary rigorousness that is refreshingly simple and general. This is the block diagram, a qualitative mathematical model, which conveniently displays to the eye, uncluttered with distracting details, all the components and variables of a system together with their circuitry. For each component mechanism of the prototype one draws a box; for each input to the component (there are often several) one draws an entering arrow and for each output an exiting arrow. The system is then synthesized by joining the boxes through those arrows they share in common. We have found this mathematical device to be a boon, not only in our thinking and research, but in our teaching.

On several occasions I have had the opportunity to watch in fascination as a fellow physiologist has attempted to represent in this simple form and at this elementary level the system on which he

is expert. He is usually flabbergasted to discover that his ready knowledge is unequal to the task. He finds he is uncertain about numerous items suddenly revealed for the first time to be of key importance. The usual result is a period of prodigious cerebration, more intense, novel, and cogent than previously accorded the system, punctured by precipitate flights to the library to find answers to questions never before asked. If a workable diagram is eventually formulated, the lights it shed may be absolutely exciting. One can suddenly see physiological flesh and blood as a coherent, determinate, functioning system instead of as a collection of mnemonically ordered facts. This is what physiology has long been striving for.

Over the past centuries physiology has weathered a series of revolutions generated by the introduction of powerful tools and concepts from other disciplines, notably physics and chemistry. On each occasion such infusion of new ideas has enormously strengthened and enriched physiology. Today, the introduction of tools and concepts from engineering promises another revolution with another strengthening and enrichment. Among the things engineering has to offer are some that are closest to the true heart of physiology. These must be adapted and thoroughly integrated into the body of physiological concepts, attitudes, and operations. This presents a challenge which physiologists cannot afford to ignore. It calls for an "operation bootstrap" on the part of those of us long past our student days. It will entail a changing pattern of undergraduate preparation and graduate education for those who will become the physiologists of the coming generation. But a welcome to the challenge and an encouragement of efforts to meet it, will transform this opportunity, as they have previous ones, into another advance in physiology.

sly



droolings

Stolen by Larry MacDonald, Jr. M.E.

Anna sat on an anthill at a picnic with most unfortunate results. She asked her sister to send a telegram to their mother and tell her what happened. The sister, faced with the problem of telling the tale in a way acceptable to Western Union and having only enough money for a six-word wire, came up with this message: "ANACIN HOSPITAL ADAMANT BITTER ASININE PLACES."

* * *

He was a rather undersized freshman at his first college dance, but despite his smallness and bashfulness, he was sure of himself in his own way. He walked over to a beautiful and over-sophisticated girl and said, "Pardon me, Miss, but may I have this dance?"

She looked down at his small size and lack of fraternity pin and replied, "I'm sorry, but I never dance with a child!"

The freshman bowed deeply and said, "Oh, I'm sorry, I didn't know your condition."

* * *

The army reports that its new radar is so sensitive, it can pick up a tank at a distance of ten miles and can identify an enemy soldier three miles away. That is not all. A good operator can tell whether the enemy is male or female. It

seems that the hip movement of a woman causes distinctive blips. The question is how are you going to keep the operator's mind on tanks and troops when a hip blip weaves across the screen.

* * *

A housemother complained to the dean of women that the boys in the fraternity house next door never closed their blinds and that it embarrassed the girls. When the dean went to the room of the particular girls who had made the complaint, she looked out the window and said, "Why, I can't see in their window from here." The girls said, "Oh, you have to stand on that chair."

* * *

"And what kind of officer does your uniform signify?" asked the nosy old lady.

"I'm a Naval surgeon," he replied.

"Goodness, how you doctors specialize these days."

* * *

Confucius say: "A bosom companion sometimes turns out to be a false friend."

* * *

In Paris, it's frankness;
In Panama, it's life;
In a professor, it's clever;
But in the Technic, it's smutty.

Only one man in a thousand is a leader of men. The other 999 are followers of women.

* * *

A canny Scot was engaged in an argument with the conductor as to whether the fare was to be five or ten cents. Finally the disgusted conductor picked up the Scot's suitcase and tossed it off the train just as they were crossing a long bridge. It landed with a mighty splash.

"Hoot mon," screamed the Scot. "First you try to rob me and now you've drowned my little boy."

* * *

Her: "I think dancing makes a girl's feet too big, don't you?"

Him: "Yeah."

(Pause)

Her: "I think swimming gives a girl awfully large shoulders, don't you?"

Him: "Yeah."

(Pause)

Him: "You must ride quite a lot, too!"

* * *

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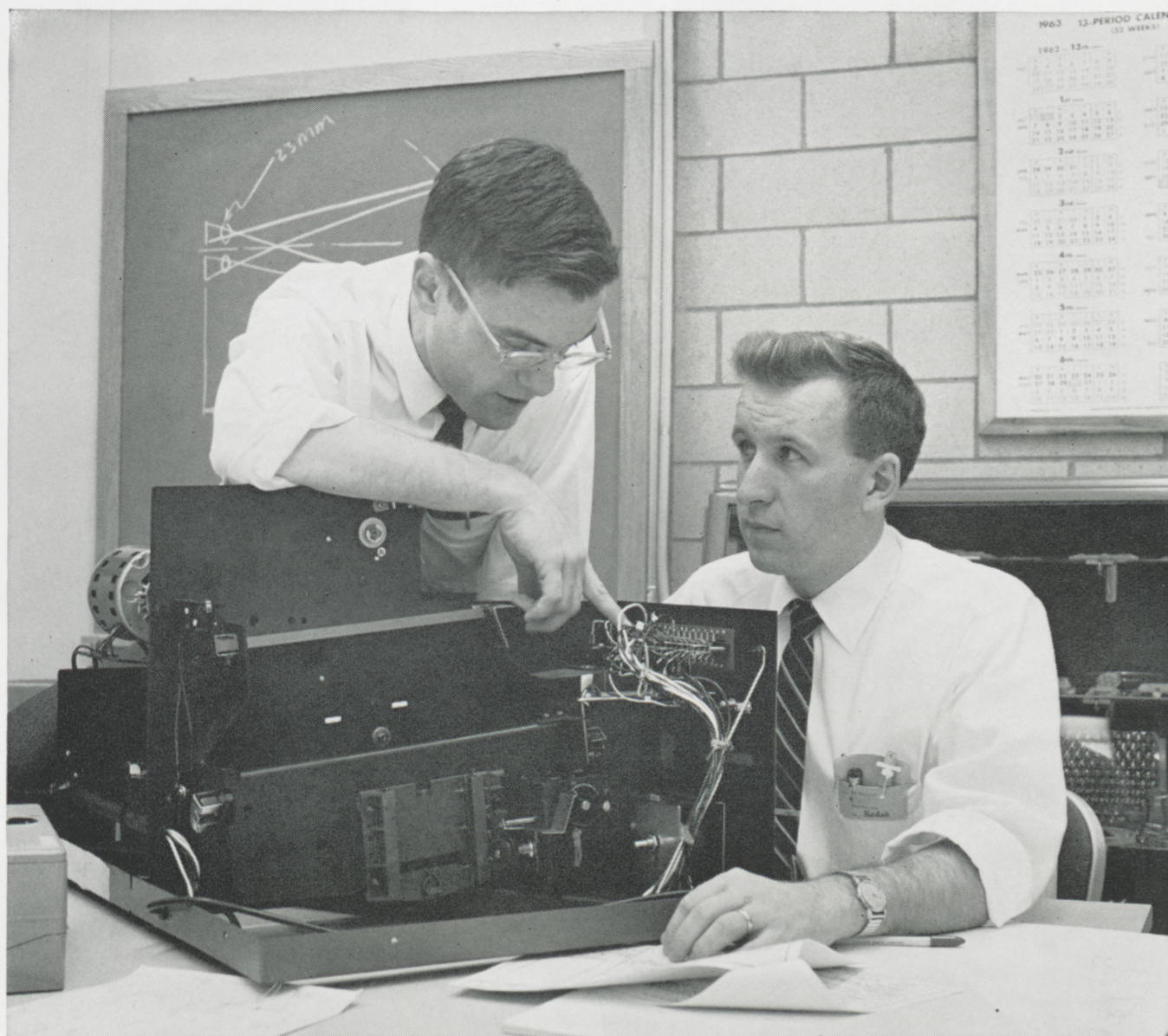
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detail what we have to do to multiply McNair's working model by x , a number chosen by the marketing people. To make the production-run machines work not merely as well as McNair's hand-built one, but better. To decide which parts we should buy and which we should make. To specify the tooling for the parts we make. To specify also the tools for assembly and inspection. To design the fabrication processes. Better than just designing the processes, to see the need for a process which no previous manufacturing engineer had realized was needed and which happens to make the product an irresistible bargain for the ultimate user and a money-maker for us.

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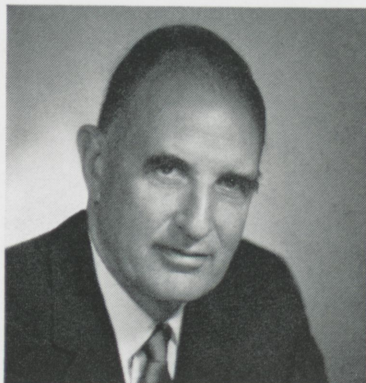
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Define Your Career Objectives!

■ An interview with W. Scott Hill, Manager—Engineering Recruiting, General Electric Co.



W. Scott Hill

Q. Mr. Hill, when is the best time to begin making decisions on my career objectives?

A. When you selected a technical discipline, you made one of your important career decisions. This defined the general area in which you will probably begin your professional work, whether in a job or through further study at the graduate level.

Q. Can you suggest some factors that might influence my career choice?

A. By the time you have reached your senior year in college, you know certain things about yourself that are going to be important. If you have a strong technical orientation and like problem solving, there are many good engineering career choices in all functions of industry: design and development; manufacturing and technical marketing. If you enjoy exploring theoretical concepts, perhaps research—on one of the many levels to be found in industry—is a career choice to consider. And don't think any one area

offers a great deal more opportunity for your talent than another. They all need top creative engineering skill and the ability to deal successfully with people.

Q. After I've evaluated my own abilities, how do I judge realistically what I can do with them?

A. I'm sure you're already getting all the information you can on career fields related to your discipline. Don't overlook your family, friends and acquaintances, especially recent graduates, as sources of information. Have you made full use of your faculty and placement office for advice? Information is available in the technical journals and society publications. Read them to see what firms are contributing to advancement in your field, and how. Review the files in your placement office for company literature. This can tell you a great deal about openings and programs, career areas and company organization.

Q. Can you suggest what criteria I can apply in relating this information to my own career prospects?

A. In appraising opportunities, apply criteria important to you. Is location important? What level of income

would you like to attain? What is the scope of opportunity of the firm you'll select? Should you trade off starting salary against long-term potential? These are things you must decide for yourself.

Q. Can companies like General Electric assure me of a correct career choice?

A. It costs industry a great deal of money to hire a young engineer and start him on a career path. So, very selfishly, we'll be doing everything possible to be sure at the beginning that the choice is right for you. But a bad mistake can cost you even more in lost time and income. General Electric's concept of Personalized Career Planning is to recognize that your decisions will be largely determined by your individual abilities, inclinations, and ambitions. This Company's unusual diversity offers you great flexibility in deciding where you want to start, how you want to start and what you want to accomplish. You will be encouraged to develop to the fullest extent of your capability—to achieve your career objectives, or revise them as your abilities are more fully revealed to you. Make sure you set your goals realistically. But be sure you don't set your sights too low.

FOR MORE INFORMATION on G.E.'s concept of Personalized Career Planning, and for material that will help you define your opportunity at General Electric, write Mr. Hill at this address: General Electric Co., Section 699-10, Schenectady, N. Y. 12305.

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