Progress in Prosthetics

A summary under sponsorship of the Prosthetics Research Board of the National Academy of Sciences— National Research Council, prepared under contract with U.S. Department of Health, Education, and Welfare, Office of Vocational Rehabilitation, Washington 25, D.C.

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AUTHOR'S FOREWORD

As a newspaper reporter in Washington for a quarter of a century, first for the Associated Press and later for the New York Times, I have been largely concerned with the fields of health, education, and welfare.

Because of that fact, and because I reported on the campaign in Congress for scientific research and development of artificial legs and arms during World War II, I was requested by the Prosthetics Research Board of the National Academy of Sciences-National Research Council, to undertake this summary of the progress in prosthetics since that time.

It was completely an individual venture. I stipulated that the method I would use would be precisely the same that I employ in newspaper reporting. I spent my vacation month of 1958 making the coast-to-coast visit to cooperating agencies by air. A few weekends rounded out the field work. The text was written on my own time.

Any conclusions drawn or opinions set forth in this book are my own and are not expressed on behalf of those units of the Academy—Research Council concerned with prosthetics research; nor of the newspaper for which I worked while writing this text, which was completed June 30, 1959.

BESS FURMAN

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CHAPTER I

A New Era for Amputees

Amputation is one of the oldest problems of mankind. The skeletal remains of a late Neanderthal man found in a remote cave in far-off Iraq by Smithsonian scientists in 1957 testified to an amputation 45,000 years ago. The ancient bones included a withered right arm amputated just above the elbow. This caveman had managed to survive to the age of about forty, fending for himself with his left arm. However, he obviously also had the aid of his front teeth which were worn down well below the level of the back teeth in an excellently preserved skull. The teeth are still useful in solving some of the everyday problems of persons with artificial arms.

Very early in history man made for himself some substitute for the limb he lost in battle or by accident. References to artificial limbs are found in many records left by the ancients. Picturesque examples of intricate legs and arms produced by the medieval makers of armor are preserved in museums and pictured in textbooks on prostheses. Forward spurts in limbmaking have ever been linked with war, as each new conflict has brought its dramatic new crop of hero-amputees. Yet in modern history, civilian amputees have always far outnumbered those maimed in battle. The present rough estimate for the United States is a half-million civilian amputees as against 40,000 veteran amputees of all wars.

Know-how in the making of artificial legs and arms belonged between the wars to a few highly competitive craftsmen who were quick to patent saleable mechanisms. Purchasers had no standards to guide them.

An early step toward a better situation was taken in October 1917, when the Surgeon General of the Army called to Washington the limbmakers of the country to discuss the problem of supplying artificial limbs to veterans of World War I. That meeting resulted in the organization of the Association of Limb Manufacturers of America, to exchange information and improve service.

But only since World War II has scientific research been broadly and intensively brought to the aid of those who have lost—or been born lacking—limbs or parts of limbs.

It was in 1945 that a cooperative research and development program was launched by the highest scientific body engaged in the war effort—the National Academy of Sciences—National Research Council—at the request of the military. It was a move spurred by Secretary of War Henry B. Stimson himself. Veterans had been vigorously protesting the prostheses with which they had been furnished.

This research and development program has been continuously carried foward by the National Academy of Sciences— National Research Council through the committee of experts that was then set up. It was first designated as the Committee on Prosthetic Devices, then as the Committee on Artificial Limbs. More recently it has become the Prosthetics Research Board.

The first decade of this research was of the patient, painstaking basic type which usually precedes dramatic discoveries in science. Now, breakthroughs are in sight which could bring prosthetics fully into step with this new age of electronics.

As of January 1958, no hydraulic leg was generally available to this country's amputees, but developments now in progress will soon bring them a choice of five different types of hydraulic leg to lessen the energy drain of walking with a prosthesis. One new leg model, the Henschke-Mauch swing-and-stance control leg, will enable an amputee, for the first time, to bear his full weight on his prosthesis in going up and down stairs.

Up to the present time, an arm amputee could use his shoulder power either to open or to close an artificial hand, but not to do both. A new "reflex" hand has been developed by the Army Prosthetics Research Laboratory wherein one continuous motion of the control cable opens the fingers from the relaxed to the full-open position and then closes the fingers on the object approached.

Adult amputees long have had the advantage of naturallooking, functional artificial hands. But children have had to wear terminal hooks, as artificial hands had never been developed in small sizes. Now hands for both small children and teen-agers are being developed.

Functional principles which have been disclosed by research

on artificial arms and legs, in a series of experiments, have proven highly valuable in developing a new science of bracing the flaccid muscles of polio and stroke victims and also in surgically improving the bony structure and nerve and muscle function of these handicapped persons.

One remarkable technique involves bracing with splints the thumb and two first fingers of an inert hand to simulate the pincer action of the terminal hook of a prosthesis. This mechanism is operated by an exterior apparatus exactly as an artificial arm operates. In some successful cases, this technique has been carried further—by surgically "freezing" the human hand in this functional position, making possible removal of the hand splints.

Such encouraging developments have stimulated even more intensive development in the prosthetics field and kindred areas in the field of bracing.

This turning point in research and development prompted the Prosthetics Research Board to arrange for this summary report of progress in prosthetics since World War II.

In its preparation, I traveled from coast to coast, visiting various agencies cooperating with the Board—research and development laboratories, rehabilitation centers, training schools for rehabilitation teams, testing laboratories, commercial artificial-limb manufactoring plants, and retail outlets where both prosthetics and rehabilitation were the stock in trade.

Perhaps the most striking impression gathered in this trip was of the surprisingly close link between artificial-limb development and the development of aircraft and guided missiles. Many of the scientists and gadgeteers who have helped usher in this jet, atomic, electronic and rocket era have also created devices for improving artificial limbs. It requires the same type of thought processes.

It was interesting, also, to talk in Los Angeles with a man who put this system into reverse. In order to create for himself a hydraulic leg, this mechanical genius invented a seal to hold the oil inside. This same type of seal has made it possible for aircraft to stay aloft for long periods. Without such a seal there could be no jet age. His seal now protects the lubrication systems of eighty percent of the world's airplanes. The hydraulic leg he invented has just gone into mass production in a plant so modern it uses automation in the manufacture of small parts.

A second strong impression is of how completely countrywide in cooperation is today's prosthetics research and development. Artificial hand size No. 1, designed in Washington, D.C., is fabricated in Los Angeles to be tested out by child amputees in Grand Rapids, Michigan, before being graduated into broader field tests. A Yale surgeon, Dr. Charles O. Bechtol, lectured regularly for a year in Los Angeles, commuting by airplane, before settling down on the West Coast as Chief of Orthopedic Surgery at the Medical Center of the University of California at Los Angeles. Bracemakers trained in Warm Springs, Ga., spread their specialized knowledge and pick up new ideas in Los Angeles.

Even more striking is the impact on the observer of world cooperation in this highly specialized field. In Los Angeles, a physician from India had just completed the school which trains prosthetics teams-his aim, to start such a school in India. In Oakland, Captain Thomas J. Canty, M.D., the Navy's famed prosthetics pioneer, had on his drafting board the projection of a rehabilitation center for Mexico City, being planned at the request of the Mexican Government. The absence of a San Francisco surgical researcher was interestingly explained-he was overseas studying daring leg-amputation operations widely accepted in Europe but frowned upon here. All scientists interviewed had given papers abroad. All centers visited were constantly receiving visits from the medical men, prosthetists, and technicians of other countries. In New York, Dr. Eugene F. Murphy, chief of the Research and Development Division of the Veterans' Administration's Prosthetic and Sensory Aids Service, had spent six months in Europe in late 1957 and early in 1958 as first lecturer in prosthetics under the Fulbright cultural exchange program. He prepared the program for the First International School in Prosthetics in which twenty nations took part.

Devices developed in Canada are an accepted part of the U.S. armamentarium—a word used in prosthetics as in medicine to designate the vast variety of scientifically useful devices available for prescription. A young Canadian engineer was launching research at the new rehabilitation center in Chicago and was flying each week across the lake to give the benefit of his counsel to the child-amputee clinic in Grand Rapids.

But by all odds the deepest impression of a trip through America's amputee-land was the ever-astounding accomplishments of the amputees themselves. In the San Francisco Bay area, Jerry Leavy, a man without hands, part-owner of a prosthetics factory, flies his own plane on sales trips for artificial arms. From the time he was a teenager he has served as a tester of all types of arms, hands, and hooks, including a bowling attachment for arm prostheses. He is now thirty-two, and is studying instrument navigation of airplanes at night school.

In Denver, a thirteen-year-old Montana girl, born without arms or legs, was waiting in a wheel chair to have her legs lengthened to catch her up with her recent growth. Her schoolmates had started calling her "Shorty." This sunny Montana miss has been coming to a Denver rehabilitationist each summer since she was three years old. She has no hip joints—she walks by moving her pelvis from side to side. She complained at having to sit still. When her legs were ready, the physical therapist helped her to get used to the increased length. At home, she walks six blocks to school each day, and back again. She plays the xylophone in the school band. She dresses herself, washes her own hair.

She has had the inspiration—as all Denver has had—of Jimmy Wilson, a practicing attorney in the Colorado capital and one of the very few quadruple amputees of World War II. He is highly successful in his profession, has a full family life with his wife and two children, and serves on many civic boards. He is active in every enterprise to aid the handicapped. He has given piano recitals—using two hooks—on television. His personality is so dynamic that Denver has simply ceased to think of him as being "different"—except when some other amputee needs cheering up.

Such dramatic success stories are rare, and to tell them is to become target for the accusation of over-optimism. But there they are—not only in Denver of the exhilarating mountain air, but also in Grand Rapids and New York.

And in equal measure to the courage of the amputees comes the dedication of the scientists. Often they are helping their afflicted fellow men as a hobby when the long day's work in some other field is done. Among them are many who have made tremendous contributions to a life-renewing science without any financial remuneration whatsoever. The members of the Prosthetics Research Board receive only a scant "per diem" for expenses during their lengthy deliberations. Yet a terrific inner drive seems to motivate all concerned in the cooperative projects.

All say they have "only scratched the surface" in producing prostheses in any way comparable to the infinite nuances of motion provided by Nature to mankind.

One scientist declared that artificial-arm research has come to a "dead end" until more sources of power are tapped. Now, in the great majority of cases, there is only the shoulder lift and shoulder shrug to move the artificial-arm apparatus. A single cable controls a limited number of motions of elbow, wrist, and hand or hook.

However, for a number of well-muscled men—and at least one woman in this country—the cineplastic tunnel has proven a better source of power. To make such a tunnel, the biceps muscle is slit and the opening lined with skin to hold a peg which operates a below-elbow prosthesis. The big frontal muscle, the pectoral, is tunneled for an above-elbow artificial arm.

One future project envisages "building an instrument board on the amputee's arm or shoulder by muscle and nerve transplants"—to quote the men who hope to do it. This technique would include "slitting and making several tunnels, thus creating little fingers, each a different source of control."

This prospect revives the possibility of an artificial hand in which all fingers could be electronically operated by a tiny powerhouse carried inside the arm or on the person. The present hand, with only the shoulder source of power, is limited to operation of thumb and two adjacent fingers.

Work on an "electric arm" was abandoned by the Prosthetics Research Board after many years of unsuccessful experiment. The electronic science now has made such rapid strides that new researches are being launched, seeking to utilize sources of power outside the human body.

Cited often as an illustration of how difficult it is to copy what nature does was the twelve-year struggle of Hans Mauch to make a hydraulic leg. Mauch was in charge of the development of the V-1 rocket of World War II—the first successful guided missile of them all. For this feat he was presented with the highest decoration of the German Government. When he came to America in 1946 and resumed work on a hydraulic leg he had started developing, together with Ulrich Henschke, two years before, he predicted, with understandable confidence, that he would produce a prototype in six months.



For the first time a man can stand on an artificial leg with its knee bent. Herbert E. Kramer wears the Henschke-Mauch hydraulic legHe actually did this and gave an amputee demonstration of the leg at the 1948 spring meeting of the Committee on Artificial Limbs in San Francisco. Then the so-called "minor engineering difficulties" started.

Ten years later Hans Mauch appeared before the Prosthetics Research Board and humbly said, "Gentlemen, as one of the men who helped to build the first guided missile in the history of the world, I say to you that building that guided missile was simplicity itself compared to building an artificial leg that closely imitates the functions of its human predecessor."

However, Hans Mauch persevered and is now creator of two types of such legs.

No census of amputees with analysis by age and cause of disability has ever been taken. The Prosthetics Research Board has recommended that such a count be made.

However, the trends are obvious. Amputation is increasingly a problem of the aging. It results in high numbers from cardiovascular diseases, also from diabetes and cancer. Some eighty percent of amputations now are caused by diseases.

However, accidents from power machinery still cause a large proportion of teen-age and middle-age amputations. Farm machinery and automobile accidents are the chief cripplers.

And there is the big and baffling problem of congenital amputees. Children born without a hand or a foot, or minus one, two, three, and even four entire extremities, are increasingly coming to the rehabilitation centers. Some of them have vestigial hands or feet, or other malformations. Many malformed limbs are corrected before children are fitted with prostheses. In other cases, useful vestigial limbs are incorporated into prostheses. Nobody knows whether more congenital amputees are being born, or whether better general knowledge of how very much they can be helped is bringing them in from city hideouts and remote rural places. More than half the cases coming into the child-amputee center in Los Angeles are congenital amputees. To Letterman Hospital in San Francisco, parents brought a three-weeks old quadrilateral amputee. A prosthetics engineer, Professor Charles Radcliffe of the University of California, was called in by the physicians to say the last word on the case. He could confidently assure the parents that this child could grow up to walk and work.

The cost of rehabilitating any child born without either arms

or legs is so great that few parents can carry it. It runs often into some thousands of dollars. Federal, State and private funds are often joined to finance the care of a badly disabled child. But society reaps a rich reward when such children grow up to finance themselves.

Similarly, the investment in providing prostheses for the aged, and training them in the use of artificial arms and legs, pays off when it frees the son or daughter attendant for productive work.

As for rehabilitating amputees of working age, the Office of Vocational Rehabilitation has ample statistics to show that it actually pays. A special OVR study in 1956 shows that 7,118 amputees were fitted with prostheses and retrained that year. Only 2,568 of them were working before rehabilitation, and their total annual earnings were \$5,080,800, or \$1,978 per person. After rehabilitation, 6,133 of these amputees had earnings of \$14,277,700 in their first year of work, an average of \$2,328 per person.

The scientific progress which has brought vastly greater possibilities for amputees to lead rich and productive lives has been in a large measure due to the Prosthetics Research Board and its predecessor committees.

CHAPTER II

Surgeon-Engineer-Prosthetist Pioneering

As an aftermath of World War II, surgeon, engineer, and prosthetist were brought together in a new team type of pioneering in prosthetics.

This was partly a natural evolution. But it was mostly the result of a coast-to-coast outcry of amputees that artificial limbs, especially arms, had made scant progress since the Civil War. Some World War II battle victims threw useless hands on the desks of members of Congress. Others told newspaper reporters that their legs had let them down.

Overwhelmed by the amputee problem right after Pearl Harbor, the Navy set up the first prosthetics research center in the United States Naval Hospital on Mare Island in 1943. Amputees were coming in so fast that hospital authorities could not buy enough prostheses. The Navy had to set up its own shop in the basement of the hospital. It bought up all the willow wood it could find on the market. Soon the West Coast was hearing that the best artificial legs were made at Mare Island.

In artificial arms, also, the Navy was adventurous. Dr. Henry Kessler who had introduced cineplasty into this country in 1939 was called to Mare Island and operated there in 1944 and 1945 with the rank of captain. Many veterans with well-developed biceps and shoulder muscles were offered this operation which makes possible use of muscle tunnels to operate artificial arms.

Almost simultaneously with the opening of the Mare Island amputee center, a surgeon-engineer combination started research on artificial arms in the Los Angeles area. An orthopedic specialist, Col. John Loutzenheiser of Bushnell General Hospital in Utah, enlisted the aid of John K. Northrop, President of Northrop Aircraft, Inc., at Hawthorne, California, to develop lightweight devices for amputees. Northrop set some of his best engineers to work on this humanitarian side line. His designers soon made two marked improvements in artificial arms. One was the development of plastic laminate, a sturdy, lightweight material for socket and armshell fabrication. The other was the conversion of the Bowden cable, used in operating airplanes and automobiles, to the operation of artificial arms, replacing leather thongs. The Bowden cable is a flexible-steel wire cable one-sixteenth inch in diameter encased and operating in a cylindrical flexible metal housing.

These new materials were odorless, easy to keep clean, and moisture-resistant. And when Northrop invented a device which would automatically lock an elbow by a shift of the shoulder, modern engineering prosthetics was on its way. No longer need an artificial arm dangle heavily in space, as they still were doing.

By 1945—a momentous year for prosthetics progress—about fifteen hundred amputees a month were coming from the European theater of war into Walter Reed Hospital in Washington, D.C. And the Pacific Theater was still sending its hundreds to Mare Island.

Veterans found the free-swinging weight of artificial arms and hands intolerable by the end of the day. Due to wartime material scarcities, hip joints were not strong enough, and legs collapsed. A vocal and determined campaign for scientific research and development in artificial limbs got underway. From the start, its leaders had modern engineering in mind. They talked then of hydraulic legs and electrically operated arms—objectives only now beginning to prove feasible.

Remarkably enough, the most effective of these campaigners, due to her strategic position, was a woman, Rep. Edith Nourse Rogers of Massachusetts, in 1945 the ranking minority member of the House Veterans Committee and soon to become its Chairman.

Mrs. Rogers had started visiting veterans in hospitals in World War I and kept right on visiting them. By the closing months of World War II her eyes were sharp and her ears alert as she went through the wards by day or by night.

"Their artificial arms were heavy and their legs were heavy," she recalled of this dreary period, "so heavy that they hurt constantly. Part of it was the weight of the heavy harnesses. But in Germany, veteran leg amputees were wearing suction sockets which required no heavy harnesses."

Mrs. Rogers brought busloads of amputees in from Walter

Reed Hospital—thirty, forty, or fifty at a time—to talk to their Congressmen or to sit in the Congressional galleries as evidence that progress was needed. She did not ease her efforts until she had seen to it that each legless veteran who could drive a car or could learn to do so had his own car, paid for by the Government; nor until a nationwide research program was a really going concern. This took several years.



A strategy conference of Rep. Edith Nourse Rogers of Massachusetts and amputees when she was campaigning in Congress for a prosthetics research program. At left, Jerry Leavy, who now flies his own plane. "I was severely criticized by many of my colleagues for bringing the amputees into the halls of Congress," she recalled. "But I have always felt and still feel that I was right in doing so."

Mrs. Rogers often counselled with one of the Walter Reed convalescents—a man she had known well in quite a different setting. He was Colonel Robert S. Allen of General George Patton's staff. Colonel Allen had been wounded and taken prisoner by the Germans, who amputated his injured right forearm and hand. Before he had been called back to active duty in World War II, Mrs. Rogers long had known him as an outstanding member of the press corps at the Capitol, first as a Washington correspondent of the Christian Science Monitor, then of the Philadelphia Record, and later as co-author of the political column "Washington Merry-go-Round."

Bob Allen now was without his good note-taking, typewriter-pounding right hand. He was having to learn to type all over again. While at Walter Reed, he collaborated on inventing a typewriter with the most used letters pulled together on the keyboard so that it could be used by a one-armed person.

As he thus was trying to make the most of his remaining hand, the artificial arm and so-called "miracle" hand with which he was outfitted by the War Department aroused his deepest ire. He found it not only useless but a daily drag—and impossible to keep clean. When a functional hook was substituted for the hand, he slightingly compared it to the field weapons—"a slingshot in an atomic age." And it was, indeed, powered by a rubber band. This slingshot wisecrack, often repeated, gave impetus to the research which resulted in the APRL hook which operates by an inner spring. It was developed by the Army Prosthetics Research Laboratory of the Walter Reed Army Hospital in Washington, D.C., which Allen helped pressure into being in a decidedly direct fashion.

He took the matter up with the Secretary of War, Henry L. Stimson, whom he knew well from attending his press conferences for many years—Mr. Stimson earlier had been Secretary of State. Allen also recruited to the cause of the amputees Robert Patterson, Undersecretary of War, and Tracy Voorhees, then Special Assistant to the Secretary. The Walter Reed Center was ordered set up late in 1945. It has since won a world-wide reputation under Colonel Maurice J. Fletcher, who is both an engineer and a lawyer.

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"I certainly started at scratch," remembered Colonel Fletcher, who became the officer longest in service at Walter Reel. "I had no money, no staff—except a lieutenant who had been a limbfitter—no building, no experience—I had been inventing small weapons to blow off arms and legs. I had nothing but an A-1 Government priority which Bob Allen kept bird-dogging. I somehow set up shop."

An independent effort of the year 1945 was the publication of a forward-looking textbook, "Amputation Prosthesis," by a pioneering Denver team, Dr. Atha Thomas, Associate Professor of Surgery at the University of Colorado School of Medicine, and Chester C. Haddan, prosthetist, then President of the Association of Limb Manufacturers of America. Included was a chapter on artificial arms and legs for children, on which almost nothing had been written at that time. It was illustrated by the photographs of cases that the authors had rehabilitated. Both congenital and paralytic deformities were shown in which amputation was followed by a successful fitting of a prosthesis.

But by all odds the most important event for the nation's many amputees in that significant year was a meeting in Chicago on January 30 of outstanding surgeons, engineers and prosthetists to explore the prosthetics problem with a view to setting up standards for artificial legs and arms.

This meeting was called through the National Academy of Sciences—National Research Council, a private, nonprofit, highly scientific organization which, when formally requested, stimulates advancement and aids in developing standards in all scientific fields. The Academy has as its headquarters a building designed by Bertram Goodhue close to Lincoln Memorial in Washington. It functions through committees of experts. President Abraham Lincoln signed the charter of the Academy of Sciences when it was set up during the Civil War. That charter required that the Academy act as adviser to the Government in scientific matters, although it is not a Government agency. The National Research Council was established by the Academy in 1916 at the request of President Wilson, to enable scientists generally to associate their effort with that of the limited membership of the Academy.

The required formal request to the Academy to aid in the prosthetics field was initiated by the three top War Department officials whose active interest had been sparked by Robert S. Allen, 14 journalist amputee. As it was a medical request, it was made through the Surgeon General-then General Norman Kirk.

It soon became apparent to the Chicago conference that standards were not available, as the systematic approach of science and engineering common in many fields had never been applied to prosthetics. The conference therefore recommended that a research program be set up, and General Kirk made the formal request for an Academy advisory committee on February 3, 1945. It was a distinguished group. Dr. Paul E. Klopsteg, Director of Research at the Northwestern University Technological Institute in Chicago, was named chairman. Included in its membership was the outstanding astronomer, physicist, and pioneer in guided missiles, Dr. Robert R. McMath, of the University of Michigan; Dr. Paul B. Magnuson, then Chairman of the Department of Bone and Joint Surgery of Northwestern University Medical School; and Dr. Philip D. Wilson, Surgeon-in-Chief of the Hospital for Special Surgery in New York and a world-famed authority on prosthetics since World War I.

The next spring, Dr. Klopsteg went abroad as a member of the Surgeon General's special committee to investigate European prosthetic advances. This resulted in a group of German veterans coming to this country to demonstrate in our amputee centers the control of prostheses through cineplastic tunnels. And it led to the later introduction of the suction-socket leg here.

As amputees left the Army and Navy hospitals for civilian life, the Veterans' Administration became the chief target of the crusaders for more modern artificial legs and arms. Purchases of prosthetic devices by VA were then being handled in the same way as office furniture, contracts going to the lowest bidder. In September and October 1945 a long hearing was held by a subcommittee on Aid to the Physically Handicapped created by the House Education and Labor Committee to investigate complaints of amputees.

While the hearings were still underway, in November 1945, General Omar Bradley, Veterans' Administrator, set up the Prosthetics Appliance Service which has since pushed research in artificial limbs, orthopedic braces and shoes, hearing aids, and aids for the blind. Major General Paul R. Hawley, in charge of the VA Medical Department, called in from Chicago Dr. Paul Magnuson to develop a research program. Dr. Magnuson later succeeded Dr. Hawley as VA Medical Director. In Dr. Magnuson the amputees had an advocate colorful and resourceful. Like Mrs. Rogers, he brought the plight of the more helpless veterans forcefully to the attention of the public and of interested officials. A single example suffices to show how Dr. Magnuson viewed the problem. At Percy Jones General Hospital in Michigan, Dr. Magnuson saw two veterans with both arms off at the shoulder.

"They couldn't feed themselves, or do any of the activities of daily living-they couldn't even blow their noses," Dr. Magnuson said when recalling the year 1945.

"I remember I said at the time that if we should spend \$10,000,000 in Government money so that these men could take care of themselves, it was my belief that the taxpayers would be glad to pay it.

"It was less than two years later that I introduced one of these men to the President of the United States. I had had this bilateral amputee as a buffet-dinner guest at the Army and Navy Club the night before. At dinner he had done everything for himself, including carrying a tray, except to cut his meat.

"President Harry S. Truman stood up behind his desk to receive him. I told the President that this veteran had been so completely rehabilitated by our program that he could get into, and out of, his harness by himself. The President said he did not see how that could be possible.

"The veteran said he'd show him, but he was afraid of scratching the desk.

"'Never mind the desk!' said President Truman, sweeping aside his papers.

"The boy hunched up his shoulders, and wriggled out like a turtle. The President's eyes were moist as he watched him. By the time the veteran shook himself back into his harness, the tears were rolling down Mr. Truman's cheeks.

"I know the President told his wife about it that night because she told my wife.

"Certainly, no one could look with understanding at such cases and not feel that every dollar spent in scientific research was more than justified. I, for one, feel that we never should forget that the thing that really matters is helping human beings."

The setting up of the Committee on Prosthetic Devices by the Academy and of the Prosthetics Service by the Veterans' Administration marked the changeover from criticism into construc-

tive, cooperative effort which has not slackened since. The two programs have worked very closely together.

Congress appropriated prosthetics research funds to the Veterans' Administration, which turned to the Academy Committee in the placing of priorities on the research projects, which were so numerous as to be called a crash research program. One of the big contracts went to Northrop on the West Coast.

And on September 1, 1945, a small contract of \$18,000 was awarded to the San Francisco team which turned out to have the curiosity and the competence to do the basic research in lower-extremity prostheses—Howard D. Eberhart, a well-known engineer, and Dr. Verne T. Inman, an outstanding orthopedic surgeon interested in body mechanics. In early association with this pair of star performers was an engineering professor interested in body mechanics, Eugene F. Murphy. The story of this trio is the story of prosthetics progress, Eberhart and Inman working on basic research in cooperation with the Academy Committee, and Murphy on the staff of the Veterans' Administration working on the practical applications of research. A common interest and a tragic accident had brought them all together in the year 1944.

That spring at the University of California a red-headed medical student, Sanford Rothenberg, from the San Francisco campus, sought out Engineer Eberhart on the Berkeley campus. Rothenberg was a student of Dr. Inman, at that time conducting researches on shoulder motions under a grant from the National Foundation for Infantile Paralysis. Young Rothenberg had taken as his own project research through X-rays on the central rotation of the knee joint. He was baffled by some of the engineering principles involved. At the close of a three-hour session with Eberhart, he asked if he could come again and bring Dr. Inman. He did this, and the three had a long conversation.

"It was a very pleasant talk—Verne was curious then as now," Howard Eberhart remembered. "But that was the last I saw of him until August of that year, when I came out from under an anesthetic to recognize him as the surgeon who had just amputated my leg.

"He was standing in the doorway of my hospital roomthe tiredest-looking man I ever saw. His first remark to me was that he had never expected to see me alive."

Eberhart himself gave details of the accident. "That summer I had been in charge of field research on the B-29's that



Dr. Verne T. Inman inserting in human bones the "targets" making possible the Eberhart-Inman studies in human locomotion.

Patterns like the above evolved in establishing the dynamics of the human leg.

were going to be used to wind up the war. On the runways at Hamilton Field, the airbase here, we had a test track, on which we had rigged up a trailer to simulate the B-29 landing gear, with stress meters and electronic recordings. Truck drivers kept this trailer going twenty-four hours a day. It was outfitted with the biggest tires ever built, seven feet in diameter, the only tires like that in the whole United States. We were racing against time, and when the tires started rimcutting under the increasing weight, we had to repair right there. We'd had three or four blows-outs that day—I had worked too many hours—and on one round I didn't get out of the way of the trailer.

"At 1:30 a.m., right in front of our control tower, I got caught under 200,000 pounds of weight which pinned me down, crushing my lower left leg below the knee and breaking the bone in three places."

Eberhart said that as he convalesced, Dr. Inman got him interested, as a sort of occupational therapy, in the shoulder studies conducted by putting pins on joints so as to have fixed points for measuring motion.

"I worked on the curves," said Eberhart.

Eberhart said that when Dr. Inman and he had gone over to Mare Island and had obtained the best prosthesis then known, he had found it so painful that he turned to another UC engineer, Eugene Murphy, who was especially interested in body mechanics, to help him measure some of the stresses working on this artificial leg. They rigged up miniature stress meters like those used on B-29 landing gears.

"While we were still doing this, Murphy heard that the Klopsteg committee was being formed," Eberhart said. "He suggested that Dr. Inman and I should start a research project, and when he went East to finish his Ph.D. degree, he stopped in Chicago to see Dr. Klopsteg on our behalf.

"Dr. Klopsteg was so impressed with how much Murphy already knew that he tried to hire him on sight, but Murphy went on to get his Ph.D. degree. Murphy sent us back a report, and we sent in our proposal—what was needed was fundamental research. The problem might be to develop an artificial knee. But nobody knew what a knee should do. There could not be much progress on the gadgetry side without knowing the basic principles. We would not do the developmental work that the industrial laboratory was better equipped to do. We would study locomotion and functional anatomy. A few months after we started we got an added \$50,000-then we were off?"

The team of Eberhart and Inman have been the outstanding trailblazers in the field of prosthetics ever since.

The prosthetics program had been going only a year when a full-time administrator, Brigadier General F. S. Strong, Jr., an engineer officer from both World Wars (he returned to military service from business life to conduct important engineering projects in World War II), was put in charge of pushing forward and coordinating the projects. He was won to this cause in 1946 by his close friend, Robert McMath. He took with him into the program his aide in engineering projects, Tonnes Dennison, a graduate engineer.

It was in 1948 that Representative Edith Nourse Rogers in the Eightieth Congress pushed through Public Law 729 which authorized the expenditure of up to \$1,000,000 annually to aid in the development of artificial legs and arms, hearing aids, and aids to the blind. The Veterans' Administration was named to administer the funds. The Administrator of Veterans' Affairs was directed to make the results of such a program available to veterans and civilians alike. The Chief Medical Director of VA requested the National Academy of Sciences, through its Advisory Committee on Artificial Limbs, to collaborate and advise in the supervision and coordination of the prosthetics program.

When the Veterans' Administration set up its Research and Development Program in 1948 under this new law, it put in charge Eugene Murphy, by then a Ph.D., with headquarters in the VA Center in New York City.

This progress almost satisfied even Robert S. Allen. He considered that the appointment of General Strong and the million-dollar annual appropriation gave built-in continuity of research between wars. But he made one more successful drive, winning from Congress an edict that prosthetics research funds continue on from year to year—the unexpended balance does not have to go back into the Treasury as is true of almost all Government appropriations.

The permanent program thus established has grown in strength and scope. But it did not include funds for research on prostheses for children.

The Federal Children's Bureau, in cooperation with the Michigan State Crippled Children's Service, sponsored the first child-amputee program. Later, that Bureau added to the children's service a project at the University of California at Los Angeles; and one in New York University, which statistically combined testing experience at a dozen children's hospitals.

The Inman-Eberhart researches were further supported, as they went into related fields, by the National Institutes of Health and the Office of Vocational Rehabilitation.

The whole concept of scientific teams, now accepted both as the most effective way of doing research work and of giving many services to mankind, was itself pioneered in the Veterans Administration prosthetics program. When it had proved broadly useful for putting amputees back on jobs, the entire service of training prosthetic teams was taken over by the Office of Vocational Rehabilitation and its curriculum was broadened. Teams of physicians, prosthetists, physical and occupational therapists are now being taught at New York University, the University of California at Los Angeles, and Northwestern University.

Coordinating work is carried forward by three committees— Prosthetics Research and Development, Child Prosthetics Problems, and Prosthetics Education and Information. Developmental devices and techniques progress through four phases—basic research, model development and evaluation, clinical and field studies, and production by the limb industry.

Taken all in all, this close-meshing effort in behalf of amputees constitutes an amazing example of cooperation between many Government agencies and many nongovernmental institutions.



On this glass walkway, the subject, wearing pin targets to establish how his bones moved as he walked, was photographed from all angles in the Inman-Eberhart studies.

CHAPTER III

San Francisco— The Biomechanics Laboratory

The ever-colorful San Francisco area has one claim to fame of which far too little is known. Here was born modern prosthetics.

The fundamental research project in that field, which started in September 1945 with a grant of a mere \$18,000 from the Federal Government, had grown into the great Biomechanics Laboratory of the University of California by July of 1957.

This laboratory emerged through the teamwork of two creative scientists, Howard D. Eberhart, the Professor of Civil Engineering who lost a leg in an accident due to the pressures of World War II, and his surgeon, Dr. Verne T. Imman, Chairman of the Department of Orthopaedic Surgery at the University of California Medical School. Two university departments, the School of Engineering and the School of Medicine, cooperated to make this research possible.

Here is a laboratory where more than a decade of research has gone purposefully forward on a subject as old an mankind indeed, the mechanism of man himself. The initial investigations of Eberhart and Inman took place at the School of Engineering in Berkeley. Both men held responsible full-time posts in their respective schools. Their joint prosthetics research was a challenging supplemental activity, pursued with the zeal often given to an engrossing hobby.

Strange-looking gadgets and measuring devices appeared on the roof at the University of California Engineering Materials Laboratory. At first there was a level walkway, ramps, and stairs. Then came an elevated glass walkway, with underneath reflection mirror, where the human gait could be photographed from all angles simultaneously, including from below. There were still cameras, fast-motion cameras, slow-motion cameras.

Helping Eberhart and Inman in their early work were Prof. A. S. Levens of the Department of Mechanical Engineering; Dr. John B. de C. M. Saunders, Professor of Anatomy at the Medical School; Dr. T. C. McCowen, Associate Professor of Anthropology, and Don O. Horning, engineer on leave from Consolidated Vultee Aircraft Corporation at San Diego.

Gradually a new health science was created—biomechanics. Its field—as used here—is man as operator of—and affected physically and psychologically by—the prop of his prosthesis. This science seeks to ascertain the effects of limb loss on a person, physically, mechanically, and psychologically, with a view to the restoration of as much of that loss as is currently possible or may be made possible as science itself advances. The University of California formally recognized this new science by setting up the Biomechanics Laboratory in 1957 with more than a score of investigators operating under a Biomechanics Research Board of which Dr. Inman is Chairman and Professor Eberhart is Vice-Chairman.

To observe the complete workings of the Biomechanics Laboratory, it is necessary to go to the Engineering School on the Berkeley campus; to the Parnassus Heights all-medical campus in San Francisco; and then, because the engineering aspects outgrew the space available at Berkeley, to laboratories made available by the Navy Prosthetics Research Laboratory, U.S. Naval Hospital, at Oakland. These farspread activities are kept unified by a highly mobile administrative official, Brig. Gen. Edwin L. Johnson, an Army officer who chose on his retirement the tangy atmosphere of San Francisco. There he encountered the dynamic personalities of Prof. Eberhart and Dr. Inman, and the work they were doing caught and held him. He considers his present position as interesting as any of his varied tours of duty while in the service. General Johnson conducted the tour of the Laboratory.

At Berkeley, where some of the early apparatus still remains on the roof, Professor Eberhart reminisced on the early days of the experiments. He recalled that at the first meeting held in Chicago to spur improvements in artificial legs and arms, there were almost as many ideas of what should be done as there were people. Some fifty specialists were present.

"When this conference formed the Committee on Prosthetic Devices, no one knew what that meant," he said, with a smile. "I have sometimes thought that they chose the word 'prosthetics' for that precise reason. If no one knew what it meant, the amputees would not put the steam on us for results.

"Verne and I felt that where developmental ideas were so diverse there would have to be fundamental research. 'Do doctors and anatomists really understand how man uses normal legs?' was the question we asked. We pointed out that this could be determined with the help of photographic and electronic equipment. We indicated that this would take seven years. Soon we received an adequate amount to work with, as a result of the greatly increased appropriation for prosthetics research made by Congress. With thirty persons working full-time we had our twovolume report of fundamental research completed in 1947, just two years after our small start in 1945.

"Much of this material now is of as much worth in other areas as in the field of prosthetics. It should be reevaluated for what it could contribute to brace problems, to rehabilitation after paralysis, and to pain of all sorts.

"It was a difficult problem for scientists of various disciplines to work together as a team. The engineers sometimes thought the doctors were dictatorial, and the doctors considered the engineers temperamental. But it was extremely successful because of the quality of the men involved.

"Despite our determination to leave development to the independent laboratories, we soon found ourselves having to develop not only our own research apparatus but also the prosthetic devices which were indicated by our findings. The independent laboratories had ideas of their own to develop and were slow to take an interest in ours."

Professor Eberhart chuckled as he recalled how one piece of apparatus was perfected to do the fundamental research.

"We needed a force plate to be used in measuring floor reactions during the walking cycle on the foot of normal subjects and amputees," he said. "We had been in close touch with Northrop Aircraft Company, which had been working on artificial arms for some time. Verne had turned his shoulder studies over to Northrop. So we asked them to design a force plate. They did, but they never could get it to work. At least they told us it was impossible to get the bugs out of it. We had it shipped here. We completely redesigned it and had it working in three months!"

With this type of get-up-and-go and general gusto, the work at the University of California proceeded. Some of the early experiments were varied and interesting. To measure the rotation of bones in the lower limbs while walking, the team employed the pin technique which Dr. Imman had introduced in his earlier shoulder studies. This technique was necessary because the positions of the joints could not be determined accurately by surface markings due to the relative motion between the skin and bone during walking. Under local anesthesia, and using sterile precautions, stainless-steel pins were threaded firmly into the cortices of the various bony prominences adjacent to the hip and knee joints of volunteer subjects. To these pins were attached targets which would show up in still and motion pictures—each target consisting of a sphere attached to the end of a light wooden rod.

Twenty-eight volunteers, ranging in age from eighteen to forty years, where photographed wearing these pins while walking on the level, up and down a ramp, and up and down stairs. This research revealed such facts as:

While on the level, the average magnitude of the rotation of the pelvis during the walking cycle is eight degrees; of the femur, or thigh bone, fifteen degrees; of the tibia, the inner of the two bones between knee and ankle, nineteen degrees. When the knee is locked—that is, fully extended—inward rotation of the femur occurs; unlocking of the knee results in external rotation of the femur.

A still camera and the interrupted-light technique were used to measure quantitatively both the normal gait of the average person and the deviation from that gait of amputees. The subject walked in front of the open lens of a camera while wearing a small light bulb over the center of rotation of the joints of his leg. The field of view of the camera was interrupted at shorttime intervals so the pattern on the film seemed to be small lights moving along the path of each joint. High-speed motion pictures also were used to analyze the walking patterns of both normal subjects and amputees.

Ankle-rotation studies were made by dissection and mechanical experiments with twenty-one cadaver ankles. The designing of the glass walkway made it possible to obtain information through camera studies regarding the relative motions of the leg segments and the foot, and of the motions of the foot itself. A force plate was introduced in this walkway to measure the dynamic forces between shoe and floor. These fundamental studies indicated that some form of ankle rotator would be a desirable feature in the prosthetic device. Otherwise, the rotation originating at the ankle point travels upward through the unyielding artificial leg, causing friction and skin irritation on the stump. Several models of ankle rotators have now been designed by the Biomechanics Laboratory.

The great importance of pelvic motions in locomotion was learned through studies made on the glass walkway. Measurements of pelvic tilt, twist, lateral and vertical displacement were made possible by construction of a special frame which was attached to the pelvis of the volunteers. The normal subjects were found to walk with symmetrical displacements of the pelvis, the amputees with irregular and unsymmetrical displacements. Various artificial legs were evaluated by the characteristics of the pelvic displacements they caused and new types of artificial legs were devised to lessen the jerky motions.

Since the forces which activate an artificial leg come from the muscles in the stump, the muscle-group patterns in locomotion were studied with the aid of electrodes. This study was explained as follows: "It has long been known that muscular contraction is accompanied by minute changes in the electric potential of each of the many fibres which constitute the muscle mass. By means of an electromyograph, these muscle potentials can be amplified, recorded, and analyzed to reveal action patterns from the major muscle groups of normal subjects during various walking activities." The leg muscles of 10 normal male subjects were thus studied as Dr. Inman and Professor Eberhart worked out their early fundamental studies in human locomotion.

This investigation not only provided a firmer basis for evaluating the mechanical behavior of the stump of the amputee, but also suggested surgical procedures for the improvement of the functioning of a prosthesis. Stumps better tailored to artificial limbs through improved surgery have been developed during the last ten years, and offer great future hope in prosthetics.

This rectangular type of socket best fits the human ischium. The ischium is the bony protuberance on which one sits, and which, when the amputee is standing, is supported by the edge of the socket into which the stump is thrust. Having ischium and socket well adjusted to each other counts greatly for the comfort of the amputee, whether walking or resting.

Engineer Eberhart and Surgeon Inman were the team selected by the National Academy of Sciences' prosthetics committee to test out the suction socket for use in this country. As early as 1863, a suction socket for above-knee amputees had been patented in the United States. However, it failed to gain use, and the conventional above-knee prosthesis continued down the years to be an artificial leg which had a pelvic hinge and an allsuspension harness fastening it onto the body by an abdominal belt. In the early 1900's German limbmakers took up the suctionsocket technique, and it was widely used in the United States Zone of Occupation at the end of World War II.

The Commission on Amputations and Prostheses, which was sent overseas by The Surgeon General of the Army in the spring of 1946, took note of this scientific advance and raised the question as to why the suction socket was not used more in this country. They saw many advantages in it and recommended that the subject be gone into. The first experiments were made by the prosthetics committee of the National Research Council itself. Soon, however, the responsibility of the suction-socket program was transferred to the cooperating Berkeley group of researchers.

Under Eberhart and Inman, suction-socket artificial legs were extensively and thoroughly tested out and found to be indeed advantageous. They were put through their paces on the roof-top walkways, were photographed in action at all angles and in comparison with conventional prostheses. Doing away with hinge and harness meant more freedom of motion, lessened skin irritation, and better fit for clothing. Wearers said that the new type of leg seemed more a part of themselves and could be used more actively and accurately.

In October 1947, the Advisory Committee on Artificial Limbs convened in Berkeley at the University of California to launch a series of "suction-socket schools." The Prosthetic Devices Research Project, headed by Eberhart and Inman, was appointed to coordinate these schools, which were held in strategic cities all over the country.

A final report on all the "suction-socket schools" made in September 1950 by Dr. Augustus Thorndike and Howard Eberhart showed that of a total of six hundred and six patients fitted, seventy-three percent continued to wear the new type of prosthesis routinely; fourteen percent alternated it with an artificial limb outfitted with pelvic belt; and thirteen percent were considered failures. The Veterans' Administration added the suction socket to 28 its approved list of appliances for purchase by veteran amputees.

The suction-socket technique is now the basis for all the above-knee prosthetics schools. It is used very widely, except for the aged, who have lost the necessary muscle tone, and small children, whose muscles are still not well enough developed to wear a suction socket.

In using the suction-socket method, the artificial leg is held on by a small amount of suction created in a closely fitted socket by the action of the stump. The fit must be tight enough to maintain an air seal, but not so tight as to restrict the stump muscles which, without aid of harness, must control all motions of the leg. The stump as it operates in the socket is bare. However, a thin sock is used to draw the stump down into the socket by pulling off the sock down through the inside of the socket and out through a small round valve-hole. The hole is then plugged up by screwing into it a suction valve, thus preventing air from entering the socket, but allowing air to be expelled, thus setting up the suction which holds the leg on when it is lifted from the ground.

Into the prosthetics picture, during the work on the suction socket, came a brilliant young designing engineer, Charles W. Radcliffe, now Associate Professor of Mechanical Engineering. He made a major contribution to its development.

With the arrival of the suction socket, alignment of the entire leg became more important. No longer was position fixed by a metal pelvic hinge. In order to make certain of precision of alignment, along with the new freedom of the suction socket, the University of California researchers developed both an adjustable artificial leg and an alignment-duplication jig, with designer Radcliffe taking the leading role. These necessary tools are now on duty in prosthetics laboratories from coast to coast.

The amputee first is fitted in standing and walking positions to correct height and body balance by using the adjustable leg. The dynamic alignment is determined. This leg, an exact measurement, is then laid horizontally in the jig for precise duplication and cosmetic covering.

Recalling these advances, Professor Eberhart commented:

"It was quite remarkable to see the improvement which resulted merely from the proper fitting of a limb. To our surprise, we learned that alignment, fit, and comfort mean far more to most amputees than what an artificial leg may be able to do mechanically.

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"If you are concentrating on a mechanism, you are not likely to recognize the person who is to wear it and his problem.

"Some of the knee designs developed were wonderful jobs, technically. But when we put them on amputees, they said they were too complicated. We could train them to use a complicated knee, but if they got careless at any time, or took one drink, the knee buckled and the amputee fell over. The use of any part of a prosthesis has to become involuntary, or the amputee may land on his back at the bottom of the stairs. We had to change our ideas of advancement."

Happily, the Berkeley engineering group did succeed in making an important new knee development—a polycentric knee which changes the position of the center of the knee motions at various phases of the walking cycle. This knee is both simple in action and stable-feeling.

The projects thus far described were mainly engineering fundamental studies done with medical consultation. Equally clamoring for solution were medical fundamental studies to be done with engineering consultation. Here Dr. Inman was the creative genius.

Dr. Inman spends his working days at the great University of California Medical Center in San Francisco where the Biomechanics Laboratory now occupies a part of the West Wing. His is a clock-around kind of day, pursued with intense enthusiasm. At the lunch hour he usually may be found at a table in the faculty dining hall in consultation with a group of his investigators. By waiting until the most recent obstacle has been analyzed and a way around it figured out, it is possible to obtain some of his well-formulated findings, in essence as follows:

Man as a biological organism reacts to loss of limb with many malfunctions beyond that loss alone. Skeletal changes take place as a result of the amputation. In an above-knee amputation, for instance, the contact or support point of the torso is shifted to the ischium from the hip joint. As the result of this weight shift, the hip joint may show degenerative changes. There may be decalcification of the residual bone and of portions of the pelvis.

Skin disorders often arise from friction of prosthesis on stump, and are heightened by the excess perspiration which besets the amputee who has lost the cooling effect of evaporation from



A chart of one patient's phantom sensations in Dr. Inman's pain studies. Injection of a salt solution in the hip resulted in the swift reappearance of a large portion of the phantom leg, followed, however, by relief from the tingling of the phantom foot.





The Eberhart-Inman studies resulted in the development of the artificial leg, left, and the alignment jig, above, tremendously improving the fit and comfort of artificial legs. the lost arm or leg. Changes in musculature also take place, and changes in the circulatory and nervous systems.

Initial inquiries were made into all these matters in the early investigations.

There are deep psychological problems, too, Dr. Inman pointed out. The human mind must adjust to the loss of a leg. The individual must determine to live fully in spite of it. The difference between use and non-use of an artificial limb often lies in human motivation. But the university investigator who starts studying amputee psychology is likely to find himself with a weighted sampling on his hands. The amputee who has adjusted well is on a regular job—the maladjusted man is left free to volunteer as a subject of study. Dr. Inman advocated that an amputee census of the entire San Francisco Bay area be made as prelude to obtaining a true cross section for psychological studies of amputees.

Going back to the early experiments, Dr. Inman recalled that the first medical problem to hit the investigators with great impact was stump pain, sometimes so severe as to make it impossible for the amputee to wear a prosthesis. A study of painful stumps was made with a view to finding out, if possible, how much of the pain might be eased by improving the prosthesis and how much was due to deep-seated disturbances in nerves and tissues.

Challenging the investigators then-and still remaining to be solved-was the elusive haunting phenomenon of phantom pain.

Almost all amputees, usually with lessening frequency, have the sensation that the cut-off limb, or part of it, is still a part of them. Phantom pain is sometimes felt in the nonexistent limbpain often so severe that it prevents amputees from carrying on normal activities or completely incapacitates them.

The early Inman-Eberhart studies went deeply into the phenomenon of the phantom limb and phantom pain. Their findings were that the phantom limb is a normal phenomenon in the sense that most amputees have it, but that it is pathological in the sense that the amputee perceives something that actually does not exist.

Researchers dealing with child amputees say that the phantom phenomenon has never been reported by children who are congenital amputees or who have lost a leg or an arm at a very early age.
Dr. Inman explained this in terms of the body image. The adult has his concept of his exterior image firmly fixed. From many years of daily living, touching thousands of things, walking and sitting at routine work, the adult is subconsciously accustomed to the whereabouts of his fingers and to the wriggling of his toes.

Often with the leg amputee the phantom of the toes fades last. Phantom toes and ankles are reported more frequently than any other phantom parts. In rare cases the sensation is of toes seeming to reside within the stump itself. Thus the adult mind clings to the most familiar part of the body image.

About 80 percent of all amputees are substantially free of pain, the Inman and Eberhart report on lower-extremity studies stated. Of the remaining group, possibly half are faced with severe intermittent or persisting pain.

"Because of persistent incapacitating pain," the report continued, "approximately ten percent of all amputees never get into a limbshop, never get out of the doctor's office. Where pain enters the phantom syndrome, it may assume large clinical importance. If it is excruciating and persists for long periods, it may take a devastating toll of the whole personality and physical well-being."

Recalling these studies, Dr. Inman said: "Pain can't be calibrated. It can't even be described, except figuratively. It is a 'shooting' pain or a 'stabbing' pain. It feels 'like ants crawling' or 'like a hammer hitting.' In seeking the causes of pain, we found no conditions common to all, or even to most, of our painbeset patients. I sometimes think what is most needed in this field is a good hypothesis—and then prove or disprove it."

Changes in shape of the phantom with some alleviation of pain were produced by injections of saline solution into the interspinous ligaments of volunteers. In eighteen amputees, saline was injected into the spine and ilia (upper pelvic bones). But on that effort the report was that further experiment must be made even to explain the effects produced.

The investigators found other stump pains than phantom pain. There were "trigger" spots of great sensitivity and deepseated "referred" pains felt in areas apart from the site of irritation.

As a preventive of stump pain, Dr. Inman stressed proper preparation of the stump—"a total-bearing stump, non-tender, of adequate length, good skin, not adherent, no tender spots." Some of his own recent operations have been pointed to as marvels of surgical smoothness.



Human energy studies at the University of California. Leigh Wilson, above-knee amputee, goes through his paces as Lee Russell, laboratory technician, jots down observations. Energy expenditure is measured by the knapsack on the back. Other body reactions, including heart action, are relayed to the control room beyond. "Because pain takes such toll of personality and productive power, it is highly important that pain studies, both physical and psychological, of amputees be continuously pushed forward," Dr. Inman said.

"It is clear that before every fifth amputee can be rehabilitated, we must be able to control pain far better than we know how to at present," he added.

Dr. Inman said that the early studies into human locomotion had led inevitably into energy studies which he considers the most important now going on in the Biomechanics Laboratory from the medical standpoint. For the energy a crippled man has to use just to get around is a tremendously important factor in his life.

"The forces that are used in walking are so powerful, and yet so carefully controlled by Nature, that they challenge the most careful consideration," he said.

He made his meaning clear by showing the study now in progress on energy expenditure. This takes place in a large room a bit reminiscent of a television studio with a control room. The large exterior room consists of rectangular track on which a man, with an instrument-carrying pack on his back, goes his repeated rounds at various paces. He breathes through a mouthpiece into the apparatus on his back which is measuring his pulmonary ventilation. A pliable cord feeding down from an overhead boom to the knapsack carries various recordings into the control room. Thus a visitor may see this subject's heart action being electronically recorded as he walks.

At the far end of the room is a treadmill, on which further energy studies will be made. Data have been completed on the energy studies of amputees walking with crutches, pylons, and prostheses in comparison with the normal gait. And now Dr. Gregory Bard, Assistant Professor of Physical Medicine, is supervising studies of the energy expenditure of hemiplegic patients. These are victims of stroke or accident in which one side of the body has been paralyzed.

"Nature is interested only in the energy consumed by the crutch, the pylon, the prosthetic device—not in the cadence of walking and how closely it simulates the gait of the normal person," said Dr. Inman. "Nature recognizes only one principle—to get from here to there in the easiest way. "I first got an inkling of the importance of this fundamental fact while watching our amputee subjects between experiments, as they relaxed and did what came naturally to them. They would assume a remarkably normal gait while on display on the walkway—only to slouch along as soon as they were off duty.

"This brought up the question: How much of a work burden is imposed by trying to improve the walk of the person wearing bracing or a prosthesis?

"We have assumed that if we impose a normal gait on an individual with an artificial leg-make him look better to usthat we inevitably are doing him a favor.

"Maybe an unusual gait could be normal for that amputee. Conservation of energy is a fundamental law of physics.

"In all cases the amputee must use more than normal energy. The energy put into the artificial leg on the straight level is five to eleven percent greater than normal. The energy put into the pylon is higher, and that put into crutches is away up higher."

Dr. Inman recalled a situation in which a physician was about to prescribe that a man return to crutches on the theory that his artificial leg was too tiring. When told about the San Francisco studies he changed his mind.

"Crutches are very exhausting," said Dr. Inman. "Their demands are very high. To put a man of advanced years on crutches is hazardous to the heart—a burden that ought not to be imposed on him."

Particularly for older people, Dr. Inman said, energy expenditure in the operation of a prosthesis should be measured, as it "definitely could make a difference in the life span." The University of California engineering department closely evaluates energy expenditure when developing and recommending any new prosthetic device.

One of the great recent accomplishments of the design laboratory headed by Professor Radcliffe was the development of the SACH foot, first described in the OAIMA Journal in the summer of 1957. Spelled out, SACH means Solid-Ankle, Cushion-Heel foot. This foot became popular so quickly that more than 20,000 of them were produced in 1958.

Professor Radcliffe said the foot was designed to provide shock-absorption and ankle-action characteristics equivalent to the normal ankle without the use of an articulated ankle joint. It









(Top of page) Engineers Howard D. Eberhart (right) and Charles W. Radcliffe fit the new below-knee prosthesis to Albert B. Pennington. Below that is a crosssection sketch of the important development, the SACH (solid-ankle, cushion-heel) foot. At left above is Professor Eberhart and at left below is Professor Radcliffe. was particularly welcomed by women who wanted ankle pliability and yet have sheer hose stretch smoothly over the artificial leg. The developer described this device in part as follows:

"The action of the SACH foot is accomplished by the use of two functional elements: a properly shaped wedge of cushioning material built into the heel, and an internal structural core or keel, shaped at the ball of the foot so as to provide a rocker action. . . . The action of the foot is very smooth and the amputee is not conscious of sudden changes in resistance. . . . The distance from the ankle center forward to the toe break is shorter than in many conventional feet. This has been found desirable as one means of reducing the energy cost of walking, especially up inclines."

With the SACH foot accomplished, Professor Radcliffe turned to a problem which long had been a matter of deep concern to Professor Eberhart—the below-knee artificial leg. Eberhart wished to free the below-knee amputee from heavy harness to the extent that the above-knee amputee had been freed by the suction socket. He held that there should be further development of the "muley leg" which is attached by a single strap; and more end-bearing limb fittings in which weight is borne on the distal surface of the stump.

Professor Radcliffe, with Dr. Norman Johnson, Oakland orthopedic surgeon, as medical consultant, tackled this task with a laboratory team. He said it wasn't easy, and that it required the interaction of all the skills possessed by the research team.

"The below-knee amputee has a poor anatomical stump to carry weight," Professor Radcliffe explained. "A conical stump goes into a container with a wedging action. The wearer often suffers severe skin irritations and breakdown of the tissues.

"As prosthetists and engineers, we have to find out what the forces are. To the medical men, these are forces which the stump must withstand to be sound economically. In this strange field, we don't just work in our so-called disciplines. Engineers work as prosthetists and vice versa. Doctors work as engineers and vice versa."

From such involved teamwork, a new type of below-knee prosthesis has now been developed. For the below-knee amputee, the SACH foot had provided some ankle rotation, but not enough. The new types of ankle rotators solved the problem. Using this rotator, the below-knee amputee can stand flat on the floor and turn his body to the side just as he can when using his own ankle on the other foot. The new below-knee leg is held on by a single small strap at the top.

Professor Eberhart, who has a tender stump, has been fitted with the new below-knee leg and has said that it presents no problem, and indeed feels as if he had his own leg. A pilot school held by the University of California in June 1959 to teach physicians, prosthetists and therapists the use of this leg was completely successful. Full-scale schools were immediately scheduled to start in December 1959.

Old-timers in the prosthetics field predict that the new below-knee leg will have a greater impact in the prosthetics field than the suction socket or the SACH foot. Below-knee amputees are harder to fit than above-knee amputees. In the past most below-knee prostheses have been attached with a thigh lacer.

So much future hope is being placed on end-bearing stumps, with their possibility of greater stability for older people, that the Biomechanics Laboratory is starting a project in that field. Dr. Henry E. Loon, supervisor of the End-Bearing Team, expects to make recommendations which will shorten field trials as the result of spending a year in Europe studying various amputation techniques being used there.

The Biomechanics Laboratory will standardize selected surgical procedures to produce end-bearing and will test them on a series of patients fitted with that type of artificial limb.

The mere fact that a stump is enclosed in a socket may create skin problems which may become incapacitating. The team of Inman and Eberhart, therefore, launched a special study of skin disorders of amputees which is now in its fourth year at the San Francisco laboratory. This fundamental and very comprehensive inquiry has been of the greatest value to physicians all over the country who see but a few amputees and need the experience of experts who know the entire field.

The two dermatologists heading this study, Dr. S. William Levy and Dr. Gilbert H. Barnes, now have a collection of more than seven hundred and fifty colored photographic transparencies of the skin disorders of amputees. Included are swellings, irritations, nodules, hemorrhages and the pigmentation resulting from them, and ulcerations. Allergic reactions to shellac, plastic, resin, or cushioning used in the socket of the prosthesis are also included in this collection. At one national medical meeting, these slides won first prize in a competition of exhibits. They have been shown at many medical meetings all over the United States.

"Our most pressing problem is cyst formation, which may lead to draining sinuses and dangerous infections," said Dr. Levy. "The cysts may be caused, we think, by the socket rubbing the groin or thigh of the above-knee amputee, or the calf or shin of the below-knee amputee. When such cysts develop into large abscesses, the amputee is forced to remove his prosthesis and become disabled.

"We are now experimenting to find out if such cysts can be artificially induced by a rubbing instrument. Healthy volunteers at San Quentin prison are wearing small gadgets that rub against skin as they walk. Volunteer amputee groups at the Old People's Home are used for similar experiments."

Studies in nerve patterning at the Biomechanics Laboratory are headed by Dr. Malcolm R. Miller. They are so complex and detailed that it is projected to do some of them with an electron microscope. The philosophy is that certain patterns of receptors are seen in all tissues of the body. If these patterns were fully understood it would be a step forward toward solving the secret of pain. The investigators are trying to find out such things as: the exact nature of nerve endings; the number of the various types of nerve endings in skin structure, muscle and bone; the sizes and types of nerve fibers supplying these endings; how many nerve endings are associated with one sensory neuron; and the correlation between anatomical structure and sensory function. Much of this study involves animal experimentation, but many specimens of human tissues have been studied as well.

"Spinal Cord Responses to Sensory Nerve Impulse" is the title of one group of investigations under Dr. Benjamin Libet, physiologist. This study delves into mechanisms in the spinal cord that relay incoming sensory nerve impulses into the nerve pathways that lead to the brain. In such studies eventually may lie a better understanding of the pain problems associated with the abnormal sensory input resulting from amputation.

There are also studies into how much pain may be caused by the possible cross firing between adjacent motor and sensory nerve fibers in a stump in which the nerves have been severed and the ends have formed neuromas, or clusters. Prior to the Eberhart-Inman research, sites of amputation had been rather arbitrarily set at certain fixed lines on the limb as agreed upon by surgeons and limbfitters. The researches revealed that as much healthy bone and tissue as possible should be saved—and this is now general practice.

Conditioning for the artificial limbs fitted as part of the studies of the Biomechanics Laboratory is done by the physical therapists of the University Hospital under the same far-spreading roof. The parallel bars between which the amputee learns to walk again are very stable. The rails are wide apart so that the patient will press down, not up. The incline of the ramp he learns to ascend is gradually raised until it reaches a 37.5-degree angle. Then he can climb San Francisco's hills. He learns to mount an eight-inch curb, common in many cities.

Lucile Eising, M.D., Director of Physical Medicine, said that the oldest person she had ever trained to use an artificial leg was one of the quickest to learn.

"He was a 78-year-old prospector," she said. "He walked out of here in two weeks with a lovely gait."

Long-range rehabilitation takes place at the May T. Morrison Rehabilitation Center in downtown San Francisco, closely associated with the University of California Medical Center. Dr. Bard is its Medical Director. This building, a solidly constructed lace factory of years gone by, adapts well to the sturdy type of rehabilitation offered. Ingenious are the devices there to train in everyday jobs—loading, lifting, pushing and pulling, hoisting sacks and climbing ladders. More ordinary types of occupational therapy, such as ceramics, weaving, painting and typing, are offered too. And in the basement is a sheltered workshop producing many small articles, including beautiful jewelry made from hand-polished California redwood.

The officials in charge said that they rely chiefly on Canadian occupational therapists as they are "more geared to the industrial type of therapy." On the wall is a definition which they pride themselves in following: "Occupational Therapy is any activity, mental or physical, prescribed by a physician for its remedial value."

While the rehabilitation center itself is engineered with a view to making it easy for the patients—even those in wheelchairs—to take care of themselves, much training in getting along independently in ordinary rooms is also given. The practice sitting room, kitchen, bedroom and bath are what would be found anywhere.

"Most of these people live in rented apartments," it was explained. "They must learn to get along in ordinary rooms."

In the large working areas, there are many little clumps of people, playing a game together or working together on some kind of project.

"We do a lot of group work here," one therapist said. "Often when we can't solve a personality or a psychological problem as a staff, the patients do it for each other.

"We also get a tremendous amount of help from volunteers, who come in and take our patients on field trips."

A final visit in San Francisco was to a modern retail prosthetics shop. Its various departments dealt with specially built shoes, brassieres, and braces, as well as with artificial legs and arms. In a half-dozen private fitting rooms, equipped with parallel bars and mirrors, customers could make sure of fit and cosmetic appearance, and become accustomed to the new device before taking it out. One woman customer enthusiastically reported that she'd won a game of tennis playing on her new muley leg. The saleslady brightly answered, "I wear a muley, too."

This is typical of retail outlets for artificial limbs to be found in cities throughout the United States. They are equipped with the latest scientific materials and devices and are ready for the further improvements continuously coming out of the research laboratorics, such as the just-developed below-knee prostheses with the ankle rotator.

CHAPTER IV

Oakland—Navy Prosthetics Research Laboratory

Captain Thomas J. Canty, a picturesque surgeon, prosthetics pioneer and administrator, is in charge of the Navy Prosthetics Research Laboratory at Oakland, California. For Navy personnel and their dependents, he devises all types of prostheses. But the chances of war caused this laboratory to specialize in the lower extremities as the Army laboratory has tended to specialize in the upper extremities and the improvement of their terminal devices. Captain Canty has been developing prostheses at the Navy laboratory since early in World War II when it was located on Mare Island near Vallejo, California.

When I arrived to tour the laboratory, Captain Canty was sitting behind a huge desk in a large office filled with decorations, citations, and mementos of his unusual type of service to his country. He was at work on a big blueprint of a proposed prosthetics and rehabilitation center in Mexico. His office was just off an entrance hall which was filled with exhibits of a long series of Navy "firsts" in the prosthetics field. On the counter of the reception desk, handy to visitors, was a scrapbook of newspaper and magazine clippings, further documenting the interesting developments of this laboratory down the years.

The Captain recalled that he had learned his cineplastic surgery from Dr. Henry H. Kessler, who introduced the technique into this country just prior to World War I, and who now heads the Kessler Institute of Rehabilitation at Orange, N.J. Canty worked under Kessler in 1944 and 1945 at Mare Island.

In 1950, Dr. Canty moved with the laboratory into the U.S. Naval Hospital in Oakland, commonly called Oak Knoll.

More amputees have been treated at this Navy medical center, Captain Canty said, than in any other place in the country. During its first fifteen years, he added, the amputees served there totalled more than seven thousand. While the great majority of them were young men who had served in World War II, they ranged in age from the congenital-amputee babies of sailors and marines to aging World War I and even Spanish War veterans.

"The oldest man we ever fitted with an artificial leg, more than ninety years old, was with Dewey at Manila," he said.

Captain Canty recalled that he had conducted one of the early suction-socket schools in December of 1947.

"The first report in American medical literature on suction sockets was published in the U.S. Naval Medical Bulletin in March 1949," he said. "It reflected the experience in fitting the first one hundred such sockets produced in this laboratory."

Captain Canty said that about ninety percent of all aboveknee amputees fitted at the Navy center are routinely given suctionsocket prostheses.

Captain Canty recently has been concentrating on a soft socket to cradle the lower end of the amputee's stump and thus make walking easier for him. He said that he has been able to work this out for both below-knee and below-elbow amputees. In this process, the stump is supplied with a cushion of foam rubber, which is covered with a thick, soft, easily cleaned plastic such as is sometimes used in covering couches. For the below-knee amputee, no hollow space is left between the end of the stump and the place where the solid but pliable foot is attached. The prosthesis provides a form-fitting cushion for the stump end.

From the first, Captain Canty said, he has been tremendously impressed with the possibility for the vast variety of plastics in the improvement of artificial limbs. In fact, he added, entire limbs, legs, and arms may now be made of plastic.

"When willow wood was scarce in World War II," he said, "I noticed the Navy plastic gun covers—'cocoons' the men called them. They were used to encase and protect guns going into icy Arctic waters. It struck me that plastic of a similar type might serve for human shins."

Captain Canty said that in 1942 the Navy laboratory called in a chemist from the Bakelite Corporation and in the next three years turned out six hundred plastic shins which were fitted to battle amputees.

"Some of them were still in use ten years later when I sent out a questionnaire on the subject," he said. "The average life of a prosthesis is five years."

Talking as rapidly as he walked, Captain Canty started a tour of the many work centers in the large laboratory. His first stop was the shin shop, in which one machine can attach ankle blocks to the shank part of eight legs at the same time.

In 1945, he said, the Committee on Artificial Limbs sponsored a project of measuring normal legs and arms to collect statistical data on length, transverse diameters, and circumferences of both arms and legs.

"The data collected on legs were used by this Center in connection with the sizing of new metal molds for new shin shapes," he said.

Dramatically he threw open the doors of a floor-to-ceiling wall cabinet containing, row on row, shelf on shelf, graduated sizes and shapes of molds for plastic shins.

"You see here," said Captain Canty, "fifty sizes of limbs which will fit ninety-eight percent of adults and also forty sizes for children. In case of a national calamity, plastic legs except for socket and fittings could be produced in large volumes for thousands of people. We have worked out the methods of getting into operation quickly."

In other laboratories he showed how the process of producing plastic shins had been speeded up by the development of plastics which can be molded at room temperature, instead of having to be heated; and skin color achieved by the use of plastic pigments which may be mixed into the plastic itself before it sets. When the work first started, dyes had to be used to simulate the color of the skin.

Again he referred to his blueprint for a prosthetics center in Mexico, on which he said he was helping as a matter of good will between nations.

"One of the things we are going to do down there is to teach how to make plastics," he said. "Think of how much this less time-consuming, less expensive method might mean to whole nations which have many needy people and little money."

To think of large numbers of persons in great need of aid all at once is no feat of the imagination for Captain Canty. He recalled that Mare Island had eight hundred amputees at one time during World War II. And five hundred and eighty-six frostbite cases from the Chosen Reservoir blizzard in the Korean conflict became his charges at Oakland. Colored photograph transpar-

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encies of their injuries are part of the exhibit in the entrance hall. Ten percent of the frostbite cases had injuries so serious as to require the amputation of toes or fingers. Captain Canty's published studies on these patients advanced medical knowledge on the management of frostbites, one of the essentials being to allow time for recovery of as much tissue as possible before determining the level of amputation.

A fellow scientist later commented that these frostbite cases also had shown Captain Canty to be a great humanitarian.

"He not only knew the name of every man, and the details of his case, but also what was worrying him," this scientist said.

Captain Canty showed consultation and fitting rooms for patients. He explained Navy training in the classroom for teaching the arts and sciences involved in the making of artificial limbs. There was a feeling of the world-wide service of the Navy in this place where the students worked and learned. Souvenirs from many countries were classroom "props." The chief conversation piece was a remarkably contrived prosthesis that a Japanese soldier of World War II had made for himself. When he became a United States prisoner, a better one was made for him.

There were metal shops, too, turning out the mechanical parts of prostheses, and brace parts made from new aluminum alloys. The Captain highly praised titanium—"lighter than steel, stronger than aluminum—won't oxidize." He told of the Navy's development of an early hydraulic leg, which, however, "cost too much, made too much noise." He told of its successful "geriatric leg," requiring much less effort and giving more stability than the legs made for young men; of the Navy functional-ankle joint; functional artificial knee; and new plastic whole foot.

Experimentation in plastics has gone on and on, he said. The flexible plastic lacer has replaced leather for below-knee prostheses. A flexible plastic cosmetic covering has been developed for women's artificial legs.

"The entire artificial leg may now be made of plastics," Captain Canty said. "The first plastic arm and the first plastic leg were developed by the U. S. Navy."

But by all odds the closest thing to science fiction in the Navy plant was the laboratory of specially bred, registered, dietfed beagles, all of them literally as alike as identical twins. As

current magazines have well explained to the public, tissue transplants—grafted nerves and muscles—are rejected by the human body unless they come from the person himself—or if he happens to have one—an identical twin. But they continue normal growth in the same person or his twin from the same human cell.

Captain Canty's dog colony makes possible experiments in limb grafting—a possible forerunner to the "limb banks" which may one day operate alongside the blood banks in our hospitals. And new plastics are considered promising for such operations as bone sealers or bone extenders. The late Dr. Craig Taylor and his hand. The gifted Dr. Taylor devised this cage for observing prehension patterns in three dimensions simultaneously. The hand position, of course, is the pincer—two first fingers opposite thumb—to which the amputees are limited in artificial hands and terminal hooks.





CHAPTER V

Los Angeles—New Chapters in Cine-plasty, Team Teaching, and Child Prosthetics

A new prosthetics team is getting under way at the University of California at Los Angeles. This team has as its locale both a new medical center and an almost-new engineering building on an all-modern campus with a mountain view. UCLA is located in the charming residential suburb of Westwood, beyond Beverly Hills. The atmosphere of the place is lively as well as learned.

The Chief investigators of this prosthetics team are Dr. Charles O. Bechtol, who has in recent years refined the cineplasty operation, and Dr. John Lyman, Ph. D. in psychology, who for many years served as chief aide to the late Dr. Graig Taylor, the gifted UCLA professor who pioneered modern upper-extremity prosthetics. Dr. Lyman's present field is human engineering.

The suburban campus with its great medical center was only a dream when Craig Taylor started his researches into the engineering problems involved in artificial arms and hands. As Professor of Engineering and Physiology at UCLA, Dr. Taylor became recognized throughout the world as one of the great modern researchers in the field of human biomechanics. He was one of the principal contributors to upper-extremity prosthetics for more than a decade. He was also well-known for his pioneer investigations of the influence of environmental conditions on the physiological processes of the human body. In work conducted for the U.S. Air Force, he once demonstrated, by himself serving as the subject, that normal man can exist in an environmental atmosphere some fifty Fahrenheit degrees above the boiling point of water. He has since been referred to as one of the leaders in the field of space medicine. His early experimental work was done in temporary buildings on the site selected for the new campus.

Dr. Taylor made time-and-motion analyses of normal arms in action. He established such fundamental concepts as that the arm is a crane to place the terminal device in position. He figured out precisely what was needed in the mechanism controlling a prosthesis in order to perform this function with a minimum of effort. By physiological studies, he established that the functions of twenty-five groups of muscles disappear with the amputation of a forearm.

He analyzed the workings of that complex, intricate, really amazing device when you stop to think about it—the human hand. Stripped down to engineering fundamentals, divested of all its nuances of motion, the hand is a pincer at the end of the previously defined crane. The pincer essentially consists of the thumb working against the two first fingers, as in holding and writing with a pencil. The other two fingers just go along for the ride. As anyone who has known a really adept bilateral arm amputee can testify, almost all the really necessary activities of daily life can be done with this simple tool.

Remarkably enough, the power which is left to an amputee to work a terminal device when his hand has been amputated is just enough to operate this tool. A single source—the shrug of a shoulder—can be used to open, and then close, the pincers or vice versa, or—and only very recently—close and then open them in one continuous motion.

When an artificial hand is so constructed that all the fingers may be moved, added power lines, muscular, electric or pneumatic, must be used. And this must be done with a device so simple in the using that it will become almost automatic, and not require the concentrated attention of the wearer. Dr. Craig Taylor solved many problems, but he left the problem of finding the forces for all five fingers of an artificial hand to his successors when he died in April of 1958.

Dr. Lyman accepted the top position which Dr. Taylor had held in the UCLA Biotechnology Laboratory and indicated his interest in going on with the work in artificial arms. Earlier, the University had called in Dr. Bechtol to teach orthopedic surgery in the new Medical Center. As a private physician in Oakland, California, Dr. Bechtol had been part of the nationwide prosthetics program, serving as a consultant to the Veterans' Administration. In collaboration with Craig Taylor, Dr. Bechtol had com-

bined the cineplasty operation with the modern prosthesis and had taught it to a score of interested surgeons over the country. For a full academic year, as mentioned earlier, he regularly lectured on his orthopedic specialty at both Yale and UCLA, flying across the continent frequently. He then accepted a full-time position at UCLA, which includes working closely with Dr. Lyman on the upper-extremity research program.

Dr. Bechtol and Dr. Lyman have set out to solve the problem: "How can greater control be added to an artificial arm?"

Said Dr. Bechtol: "Scientific developments of very recent years for a destructive purpose—guided missiles—can help us. The electric arm made earlier in the national prosthetics program by the International Business Machines Corporation was abandoned because it required too much attention from the amputee. There are five different methods of control of the guided missiles in use today. Of these, the method used years ago to control electric arms has proven the least successful. That leaves Dr. Lyman with four better possibilities to explore. We will supply the medical help. We will try nerve transplants and muscle transplants—making things just as simple as possible.

"It seems to us logical to separate surgically the powerlines leading to a prosthesis by setting up—as replacement for a single shoulder shrug—a 'control box' on the shoulder—a fanshaped muscle that can be hooked onto a number of different places, say five to ten different control pulls. These can be trained to obey the subconscious mind, as when an autoist wants to go faster and, without conscious thought, steps on the accelerator. When the subconscious mind says 'I want to close my finger' the connection could be a cineplastic tunnel—a very tiny procedure. It seems to me that would be a really big breakthrough. Other than some real solution such as that, we are just gadgeteering."

Said Dr. Lyman, "A really mobile artificial arm and hand must use the missile techniques. But there are terrific engineering problems to be solved. A remote manipulator to handle atomic wastes demonstrates beautifully coordinated multiple controls. But it can weigh twenty tons in order to have all the engineering apparatus necessary to make its finely calculated motions.

"There is no reason that we can't make use of 'outside power' in the manipulation of artificial fingers. But weights must

be reduced to a small fraction of what now is possible, even if transistors are used to supply electric power."

Dr. Lyman said that in spite of the prosthetics developments since World War II, "this field is still one of our cruder technologies."

"It presents fantastic problems," he said. "We need to externalize the controls connecting the machine to the man, to bring materials out through the surface of the skin that will permit skeletal attachments. This could make possible transplanting of limbs, and a Limb Bank. We may eventually know enough about growth processes to start experiments in regrowing human body parts. We need more studying of stumps, the resilience of flesh, the coefficient of friction in the pressures exerted against the socket. And what would happen if the stump were surgically changed in shape so as to lock better into a socket?"

Dr. Lyman said that working closely with Dr. Bechtol would make it possible for engineering aims to have some influence on surgical concepts. He added, "The engineer and the surgeon have to get together, instead of the engineer just taking what the surgeon gives.

"Together we need to look at man—look at the functional capabilities he will have left after an amputation. We need to look at the congenital amputee with an anomaly and find out how much power there may be in his vestigial finger or 'lobster claw' and find out how it can be used.

"The long tradition of physical research done by the Russians, particularly in Pavlov's time, should not be ignored. And we should know what is being done in physical medicine and engineering in Russia at the present time." He referred, of course, to Russian scientist, Ivan Pavlov, who established in experiments with dogs the principle of association. A bell was rung whenever a dog was given food. Soon the dog's saliva would start on the bell ring, with no food given. Recently there has been renewed interest in such experiments in this country. At Columbia University, human subjects have been taught to twitch their thumbs at a certain hum on an entirely subconscious level.

"Plastic laminates, light but strong, helped the upperextremity socket problem, and revolutionized artificial arms," Dr. Lyman continued. "Only plastic arms are being used now. If we could bring a bone extension out through the skin, a stronger, more sophisticated prosthesis could be produced. It is a matter of getting a seal of alloys, or of plastics, that would be compatible with flesh. If such a sealing technique could be worked out, it would make sockets completely obsolete. The prosthesis would attach right on to existing bone.

"Until that happens, there are exciting possibilities in reshaping arm stumps to get stability. Successful experiments along that line are now being conducted in lower-extremity research. The arm, too, might be reshaped by the surgeon to meet the requirements of current technology and add to the comfort and ease of amputees. Ways of making socket pressure measurements are important to this work."

Dr. Lyman laid great stress on the fact that motion is by no means all that is lost when a hand is severed. Man learns an enormous lot from the information fed back to his brain through his nerves by the sense of touch. That sense of touch no longer is available to him.

"We need to orient deeply into neuro-control and sensory feedback," he said. "An amputee's brain has not changed. The natural possibilities are still there. It is like having knowledge in a book and not being able to read. It is a very touchy problem to get hold of these nerve possibilities and make them do something useful."

The Biotechnology Laboratory headed by Dr. Lyman is of much broader scope than upper-extremity prosthetics research, giving that project the advantage of many scientific facts learned in other Man-Environment-Equipment experiments. Engineers are trained in this laboratory to deal with problems in the design and structure of machines where human characteristics become limiting factors. Its permanent special equipment includes, among other things, an environmental chamber for human exposures in which temperature, humidity, and altitude can be accurately controlled over a wide range; scales for measuring human weight loss during exposure; photographic equipment for motion and time studies and equipment for amplifying and recording bioelectric phenomena such as muscle and nerve potentials; and strain gauge and computer equipment for human force and movement studies.

Besides serving as collaborator in prosthetics research with Dr. Lyman and as professor of orthopedic surgery in the UCLA Medical School, Dr. Bechtol is chief lecturer for the UCLA prosthetics and orthotics school. This school trains orthopedic physicians, orthotists, prosthetists, and physical and occupational therapists in working togther as teams in fitting prostheses and braces. Only this year the orthotics, or bracing, school was added to its curriculum. The field of functional bracing for people who have lost, or partially lost, the use of arms, legs, or spinal column, has lagged far behind prosthetics, and rehabilitationists are eager for it to catch up.

The UCLA prosthetics and orthotics schools are supervised by Dr. Miles Anderson, Ed. D. in educational psychology, a man of conviction as to teaching aims and methods. Dr. Bechtol goodhumoredly submits to Dr. Anderson's rule governing this school: "If the student hasn't learned it, the professor hasn't taught it." And then it is taught all over again. Dr. Bechtol also puts his every lesson through Dr. Anderson's ACID test, which he spells out this way:

A-get ATTENTION

C-arouse CURIOSITY

I-get the INTEREST

D-awaken the DESIRE to learn.

"From there on," decrees Dr. Anderson, "use methods of instruction sixty-five percent visual, leaning heavily on the simple old Lesson Plan."

Dr. Bechtol said that he not only plans his lessons, but has his class writing along with him on illustrated work sheets as he instructs at the blackboard, thus impressing each lesson on their minds in two ways.

Charles A. Hennessy, who teaches precisely how to fit artificial arms and legs at the prosthetics school, and how to brace ineffective muscles at the orthotics school, follows the same teaching methods. However, he learned his highly technical skills by experience. Until he was drafted as an educator by UCLA, he had been for thirteen years a teacher in his own prosthetics shop on the old person-to-person apprenticeship plan.

Charles Hennessy was run over by a streetcar when he was a boy. He has had a total of thirty-six operations since, thirty-five of them as a below-knee amputee. At last he had to have his leg still further shortened, to become an above-knee amputee. So many operations kept him current with the latest ideas on the subject. As soon as prosthetics research got underway on the West Coast, he became an enthusiast for the latest scientific methods.

His limbshop, a short auto ride away from UCLA, is more than modern—it is imaginative. His child customers step through a Mother Goose mural of the Old Woman Who Lived in a Shoe to get their limbs fitted. But that will soon come down, for he is enlarging his plant again. Two years ago when he accepted the full-time teaching job at UCLA, he could confidently turn over the routine running of the shop to the men whom he had trained. He still finds time to fit the difficult cases. He gave as his credo about a prosthesis: "If it is gold plated and doesn't fit, it isn't worth a penny." Picking up a suction socket he showed what he meant by fit—to the minuscule fraction of an inch, 'actually measured.

At UCLA, in his own limbshop, and even sitting beside their own swimming pools, Mr. Hennessy recalled, he has fitted some very famous persons. One was a movie actress and TV star, who had a very beautiful cosmetic leg created for her at UCLA. Sponge rubber just under the surface made it soft to the touch. It made no sound when it happened to hit against the leg of the table when she sat on a "panel of experts" before the television cameras. It was trim of ankle enabling her to continue her motionpicture roles. She suffered from bone cancer, but her career was extended for a few happy years by this handsome device. A very famous song writer also was fitted by Mr. Hennessy. An injury he suffered more than twenty years ago resulted in osteomyelitis, which finally required amputation of a leg. This man, who had made all of America more gay with his many melodies, gave Mr. Hennessy a lift of spirit too. But the case that has given him the greatest joy, he said, was a pretty little girl, born without legs, whom he has been fitting ever since she was two years old. She now is cight.

"She rides a bicycle and she can skate backwards," he said. "When any unilateral amputee comes in here feeling sorry for himself, I show him my photographs of this little girl in action, and I get the response, 'I'll never say another word.'"

Mr. Hennessy said that in his estimation the greatest change in the prosthetics field in recent years is that more is being done for children.

"Pediatricians with their special training catch many more birth defects than the general practitioner used to," he said. "And many more children come to us as a result of the school health programs. The school nurses note what is wrong and tell the parents that something could be done. A few years ago a child's need of a leg brace, for instance, was considered strictly the parents' business. The parent may argue, 'So-and-so had just such a condition and grew out of it.' but the school nurse will answer, 'Why take a chance?' " In daily use at his own shop are the how-to-do-it charts that he uses as a member of Dr. Anderson's staff at UCLA.

Dr. Anderson was one of the leaders in the vast vocational education program of World War II. From this experience he derived his firm ideas that intensive courses in techniques must be made simple and visual. He converted this type of training to prosthetic purposes when he helped launch the school at UCLA. Its classes run early and late, and sessions are held for six days each week. The students of this special school can't afford to spend much time away from their regular work.

Dr. Anderson recalled that the prosthetics school was started in January 1953 with the Veterans' Administration paying the costs. Its purpose was to teach physicians, prosthetics, and therapists employed by the Veterans' Administration to serve veteran amputees. When the VA had enrolled its trainees, it permitted the University to fill up the classes with civilians.

"The Veterans' Administration deserves great credit for setting the pattern and permitting civilians to share in the benefits," said Dr. Anderson. "And when the time came that the Office of Vocational Rehabilitation took over the sponsorship of the schools, the Veterans' Administration turned over all its equipment, asking only that its trainees be allowed to take the classes free of charge. There has been no bureaucratic competition."

When the students have had prosthetic techniques demonstrated to them through lectures, film strips and motion pictures, each then does the actual fitting of limbs under the supervision of the experts on the faculty.

"We try very hard not to permit our students to make even one mistake," said Dr. Anderson. "We stay right with them until they have done enough correct fitting to enable them to do it themselves."

The short-term prosthetics school is followed by a shortterm orthotics school. The UCLA faculty looks forward to the

time, not many years hence, when undergraduates can be given a four-year course leading to a Bachelor of Science degree in both prosthetics and orthotics.

Dr. Anderson wrote the UCLA textbook on orthotics. He derived his text from a several weeks' stay at the nationally famous Rancho Los Amigos Hospital at Downey, California, another Los Angeles suburb. There, spectacular pioneer work in bracing has been conducted under a brilliant, 40-year-old Canadian-born surgeon, Dr. Vernon L. Nickel. He was described by one admirer in the prosthetics field as "that genius who does a spinal fusion as casually as most surgeons do an appendectomy."

Dr. Nickel is assisted by a woman orthopedic surgeon, Jacquelin Perry. The light, metal, ultramodern braces that they recommend are invented and fabricated under the direction of Roy Snelson, an orthotist who had ten years' experience with a commercial company before joining the Rancho staff about two years ago. The Rancho orthotics laboratory now has fifteen trained technicians at work, under the direction of Jack Conry, who came in 1954 from the Georgia Warm Springs Foundation where he was trained in the science of making braces.

When started back in 1887, Rancho Los Amigos was Los Angeles County's poor farm. As Old Age and Survivors Insurance and public assistance programs took over much of the financing for the aged, it was converted into a nursing home for chronic diseases. Few diseases are more chronic than the aftermath of polio. In that great population center, Los Angeles County, longterm respirator cases began accumulating at Rancho Los Amigosthe really "hard core" of past epidemics. These were patients regarded as hopeless and helpless, even requiring aid to breathe.

A program to restore them to function, begun in 1944, gained great momentum when the National Foundation for Infantile Paralysis, in 1952, provided funds for establishment of a Rehabilitation Center there. In less than a decade, it has come to be recognized as one of the best places in the country in the rehabilitation field.

Just to step inside it and see the wheelchairs purposefully going their daily rounds was to catch a spirit of hope. This spirit was not dissipated later when walking through the wards with Dr. Jacquelin Perry, talking to bright-eyed bed patients. One woman, A surgeon adapts a lesson learned in prosthetics. Dr. Jacquelin Perry, surgeon at Rancho Los Amigos Hospital, helps Hollis W. Nelson, whose hand has been useless, to master the pincer movement by bracing two fingers opposite the thumb. She then performs an operation which freezes the hand into this pincer position, shown in photo at right. Finger splints are no longer necessary.







"Artificial muscle" is being experimentally used to operate the "feeders" of Dorcas Clark, polio patient at Rancho Los Amigos Hospital. A small tank of compressed gas, held in place by the loop over her leg, furnishes the power to operate the "muscle." Note the jointed spoon which stays level all the way to the lips.

attached to a respirator machine, was faithfully doing her finger exercises.

Under the intensive care given at this highly specialized hospital, patients who had been inert and waited upon for five or more years have been so improved that they have been discharged to home and a job. Now many of the long-time inmates are out-

patients, coming back in for check-ups from time to time. As the polio situation improved, the same type of surgical corrections and intensive care that had freed polio patients from the hospital was extended to persons suffering from other types of severely disabling conditions—spinal-cord injuries, severe arthritis, multiple sclerosis, muscular dystrophy, neurological disorders, strokes, and amputations.

"Have you ever seen a cough machine?" asked Dr. Perry, pointing to a waist-high, tank-like apparatus on wheels. "The biggest hazard in respiratory cases is having the lungs get stagnant. This machine, which causes a patient to cough, has cut down pneumonia and reduced the death hazard."

She led the way to a ward in which the hands of several paralysis victims were being surgically revised to make them functional.

"The Easter Seal Research Foundation gave us around \$40,000 to search the literature on braces and get started on orthotic research," said Dr. Perry. "Meanwhile, we just go right ahead. When we look at these people here, we can't understand the philosophy of not doing anything because we don't know everything. If we can figure out anything that will help, we do it."

In Dr. Perry's philosophy, the function of the surgeon extends far beyond the operating room. She considers him an important factor in the ultimate rehabilitation of the patient, responsible for the early splinting which makes possible later functional bracing. The surgeon has the duty of initiating the early physical therapy which keeps joints that are still mobile from becoming gnarled and seriously deformed.

At Rancho Los Amigos, the same engineering principles are applied to the paralyzed human hand that Dr. Craig Taylor worked out for prostheses.

"We brace the two fingers opposite the thumb with splints, and then surgically fuse them into function," said Dr. Perry. "We then extend a small brace up the arm to where there is a functioning muscle to furnish the power to work the pincer. But our patients have one great advantage over the amputee. A hand with finger pads is better than a slick hook in picking up a glass of water."

Practice with this splint-supported skeletal device gradually brings into use whatever latent power is left in the fingers, and

sometimes the splints can simply be taken off, she explained. Again, there may not be enough latent power left for the device ever to work without bracing. In that case if useful function remains in the less important third and fourth fingers, nerve and muscle transplants from those fingers are used to restore function to thumb and first fingers. When these transplants have been healed, the splints are taken off.

"Shoulder fusions have also been used to restore function," said Dr. Perry. "We have in our outpatient department several housewives who have been rehabilitated and who put on their upper-extremity lacer splints for an hour or so a day for certain household tasks. One instance is the use of an arm-support with elbow lock in order to iron with body motions."

"Our aim is to replace the essential function," she further explained. "We don't try for normal nor get too elaborate. Patients are not gadgeteers."

At Rancho Los Amigos polio cases with severely involved upper extremities come to the table in wheel chairs and use "feeders" to help them eat. These are laced-on braces which support the entire arms in an eating position. The patient uses a longhandled spoon with a bowl so attached that it maintains a level position as the food is carried to the mouth. Two patients have been provided with the power to eat through the use of an experimental "artificial muscle" operated by a small tank of compressed carbon dioxide attached to the lower part of the wheel chair. A very slight pressure exerted by the patient's leg releases a control valve which permits the carbon dioxide gas to fill the tubing and cause it to contract, thus transferring energy to the thumb and forefinger. This energy is of normal handgrip intensity.

"Dr. Joseph McKibben, a research worker at the Los Alamos atomic energy installation, who had a teen-age daughter with a severe case of polio, devised the artificial muscle on paper," explained a technician from the orthotics shop. "It consists simply of nylon braid in helical weave with a rubber bladder inside which contracts when the bladder is filled with gas.

"Only a year ago, we worked out a prototype 'artificial muscle' here and demonstrated its feasibility. Cooperative grants have now been given to six rehabilitation centers for further developments of 'artificial muscle.' It is hoped that this device may be refined by research so that the gas tank can be carried in a

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coat pocket. Carbon dioxide is very cheap, and could be used constantly to amplify the muscle potential. Of course, the person who uses it would be fully trained by the occupational therapist in the care of the gas tank before being allowed to take it home."

Doris Clark, one of the polio patients who had been having her noon-day meal with the aid of the "artificial muscle," smiled and volunteered the information that it has been a great help to her.

Because artificial-arm development centered in Los Angeles, the Federal Children's Bureau provided funds to help finance a child-amputee demonstration center there. Its aim was to develop and test artificial arms, terminal hooks and attachments in children's sizes. Among the devices developed with the aid of the UCLA engineering department have been the infant passive hand, a resilient below-elbow infant prosthesis, a plastic hook, a violin-bow holder, a piano-playing device, a baseball-glove holder, a nyloncable liner, an outside-friction elbow, a passive, upper-extremity prosthesis for small fingers, and an elbow-lock lever for vestigial fingers. With the aid of the engineering department of UC at Berkeley, the first bucket device for a small child born without legs was developed there, and many other lower-extremity devices have been fashioned for UCLA child cases who could not be fitted with conventional artificial legs.

The work on lower, as well as upper, extremities has taken place because eighty percent of the children who have been brought to this center have been congenital amputees. Many such amputees have multiple amputations and deformities, affecting legs as well as arms. Indeed, so many lower-extremity problems arose that in April 1957 a regular monthly conference was set up, with Charles W. Radcliffe or an engineer on his staff flying down from San Francisco to give advice or to take measurements back to the Oak Knoll laboratory for working out a device.

Just as the child center—as a physical matter—has taken in the child's whole body as the only sensible thing to do, so—as a matter of psychology—it has taken in the child's whole family. The team of experts in charge there has become increasingly convinced that this method brings the best rehabilitation results.

Dr. Milo B. Brooks was called in from private pediatric practice in the Los Angeles suburb where UCLA is located to head the project. Dr. Robert Mazet, Jr., serves as surgeon. Wilma Gurney, Senior Medical Social Worker, has had the duty of draft-62 ing its many reports and has herself been author of articles on the needs of parents of child amputees. These UCLA publications have had wide use all over the country.

Among the problems being frankly faced and scientifically worked on are: the psychological shock to parents at the birth of an amputee; the necessity of accepting the situation; the danger of the mother's over-solicitude for the amputee doing psychological damage to her normal children; the importance of enlisting the whole family in the vigorous discipline involved in training a child to use a prosthesis; and the great need of starting this rigorous education early.

"No baby is too young to be referred to an amputation center, and the sooner they come the better," said Dr. Brooks. "We first saw one child when he was only ten days old. He had been born with no arms whatever. His parents already had taken him to a surgeon, and had been told that maybe when the child was ready to go to school something could be done. That it is ever necessary to wait for so long certainly is no longer true. It might have been in some cases before children's prosthetics were so well developed. And such advice dooms the parents just to sit and wring their hands and wonder what to do.

"We admitted the baby at once, assuring the parents of our backing on a long-term program to provide their child with arm function. We saw the baby again at two months and at four months gave it what we call a 'work up'—an analysis by our entire prosthetics team which includes project director, orthopedic surgeon, engineer, pediatrician, psychologist, social worker, occupational therapist, physical therapist, and secretary-stenographer to keep the records. When we had completed the 'work up,' we showed the parents what they could do as a means of exercising the child's shoulders to build up the muscles in preparation for a prosthesis.

"They did this so well that when the child was seven-anda-half months old we brought it in here and made both movies and still photographs to show other parents and medical personnel how well a baby can function without arms. We now have a real 'head start' on fitting that baby with arms as soon as he develops independent standing balance. And we also have with us a cooperative and hopeful attitude on the part of the parents."

Miss Gurney added that family attitude is considered so important that only outpatients are accepted at the UCLA Child

Center. The father, brothers, and sisters of the amputee, as well as the mother, are encouraged to come to Westwood and stay at a nearby motel while the child is being conditioned and fitted to a prosthesis.

"It is cheaper to keep the family in a motel than to hospitalize the amputce and pay for a baby sitter at home for the other brothers and sisters while the mother is away," said Miss Gurney. "A child is home-centered, more home-centered than most people realize. We intend to keep it that way. We are pleased when father, brothers, and sisters can come here and be part of the family adjustment to the whole problem. Often the child just older than the patient presents more of a behavior problem than the patient does. This older youngster has been penalized by the amputee's extra claim on his mother's attention. The older youngster is expected, without explanation, to understand the absorption of his mother and still like his baby brother. We are here not only to care for the amputee, but also to provide a service for the family so that when the amputee goes home we will have the home-team working with the team that is working here-and not working at cross-purposes with us."

At work with an occupational therapist at the center, in one of its cheerful, toy-filled playrooms, was a lone exception to this family rule—an eleven-year-old boy. He seemed shy, but he was making progress in using his hook to zipper up his pants. Dr. Brooks told of how he had found this boy in an institution for mentally retarded children, and had established by tests that he was not, and never had been, mentally retarded.

"When this boy was born, the attending obstetrician advised his mother never to see him," Dr. Brooks said. "He was a bilateral, congenital arm amputee, with some facial deformities. It was assumed he was feeble-minded. You can see how well he is beginning to use his arm prostheses. The facial deformities are getting attention. And if the scars of rejection are not too deep on his soul, we can get him a stabilized home."

Miss Gurney said this boy had experienced, in a very extreme degree, the reaction of rejection often present in parents of babies born without one or more limbs. "What is the meaning of the congenital amputation to the parent?" she asked. Often it is: 'I am not able to produce a whole baby. I can't accept this substitute.'"

But, as the great possibilities for normal living for most of these amputees become better known, she added, people won't think about the situation as being so strange. The child wearing a hook for an arm will be accepted by parents, brothers, and sisters, school and community, as easily as though he were wearing glasses or hearing aids.

"But at present school often is pretty tough for a child amputee to take," she said. "The book, *Peter Pan*, may be just delightful whimsy to some people but, frankly, we wish that Peter Pan had never met Captain Hook."

In their desire to make the helpful hook a matter-of-course part of daily living, the child experts at the Center now are considering equipping babies with blunt, plastic-covered hooks instead of with the passive hands which they have been long using as a first prosthesis.

"We have fitted seven or eight youngsters under fifteen months of age with plastic-covered hooks," Dr. Brooks said. "The hooks furnish support in crawling, just as the plastic hand does, and also are used by the babies to pull themselves up on the playpen.

"The very young child needs to develop an awareness that this thing they are using can hold. A fake hand can't compare with a good, honest hook.

"But with teen-agers the case is quite different," Miss Gurney hastened to add. "When the time comes for them to start going to dances, they need a hand that is just as cosmetic as it can possibly be made."

At present, no supply of cosmetic, functional hands is available to teen-agers.

My tours through all the prosthetics installations in and around Los Angeles were conducted by Colonel Earl J. Murphy, the retired Army officer serving as West Coast coordinator for the Prosthetics Research Board. In charge of its office suite in Beverly Hills, Colonel Murphy keeps in close touch with San Francisco activities through his old friend of many years in the service, Brigadier General Edwin L. Johnson. In addition to doing intensive advance planning and record-keeping on projects, these seasoned administrators serve as hosts and guides to an endless stream of scientists seeking to learn more about prosthetics and orthotics.

CHAPTER VI

Suburbia— Those Fascinating Factories

Among the small industries dotting the West Coast are the fascinating factories from which a large proportion of this country's artificial limbs come, as a whole, or in parts. These are not many-storied, central city structures, but low-lying and pleasantlooking plants in suburban settings.

An unusual combination of prosthetics factories on the peninsula below San Francisco would be classified by old stage troupers as a "brother act." The A. J. Hosmer Corporation at Santa Clara is run by Lloyd W. Brown. The D. W. Dorrance Company at San Jose is run by his brother, Noel J. Brown. Hosmer turns out artificial arms and, since the UCLA orthotics school got going, functional braces. Dorrance turns out the terminal devices for the artificial arms. The brothers put out a joint catalog.

Nationally circulating salesman for their wares and partowner of the Hosmer plant is Jerry Leavy, the exceptionally ambidextrous bilateral amputee mentioned earlier. Being able to fly hither and yon in his own airplane at will, Jerry Leavy brings the customers into close contact with the factories. From his long experience as a tester of experimental arms, he was personally acquainted with most of the people in that field before he took his present position. As a boy he worked for a prosthetics firm in Kansas City. He was one of the early testers for the Northrop project in California. He tested, too, for the Army Prosthetics Research Laboratory in Washington, D.C. He served as "guinea pig" for five of the schools held by UCLA, and for two conducted by New York University.

Visitors who have made no study of prosthetics often are amazed at the broad range of service offered in the modern factories. In the plastic shop at the Hosmer plant, for instance, skin colors for upper arms and forearms include Caucasian, Mexican, 66 Oriental, light Negroid, medium Negroid and dark Negroid. The number of metal devices offered for the widely varying needs of amputees is amazing to anyone who has not seriously considered what it would mean to lose an arm. There are quick-change wrists, friction wrists, elbows with seven positive-locking positions, cable controls, nylon harnesses, suction-socket valves, and scores more.

Business has been growing rapidly in recent weeks in Hosmer's new line for which a separate catalog has been issued— Robin Aids—functional arm braces named for George Robinson of Vallejo who did the designing.

"We took this book 'Functional Bracing of the Upper Extremities' by Miles H. Anderson of UCLA and tooled up and designed bracing so it can be manufactured in parts—the newest thing in the prosthetics field," said Lloyd Brown. "We have 'kits' available."

"Just like a tinker-toy set," volunteered a customer who had just come in. "If you need a locked elbow substituted for a free elbow, the part fits right on."

This owner of a prosthetics shop was enthusiastic over the new bracing system based on Dr. Anderson's text resulting from the research of UCLA and the practical experience of Rancho Los Amigos. He said he had just supplied functional bracing to a boy with paralyzed arms.

"Had this lad in for a fitting," he said. "Took me three hours to get it all set right. The little guy took right to mastering the whole thing.

"The next day I went out to see him. He had two six guns and could bring them together at a ninety-degree angle. He could pick up two small rubber balls and swing sideways—then, opening his hooks, throw them across the room. He wrote his name with his right one. He could get a spoon up to his mouth. I wouldn't have believed it if I hadn't seen it."

In the bracing system devised at Hosmer, a Dorrance hook is nestled right in the palm of a flail hand, held in place by plastic straps across the palm of the hand and around the wrist. This was the method which enabled the little boy to hold his guns and throw his balls.

Mr. Brown's customer went on to another case, that of a man who had not been able to light his own cigarette for three years. He had fitted this man with functional bracing.

"That same day he was able to get a cigarette to his mouth and get it lit," he said. "You should have seen his eyes light up when he told me about it."

The Hosmer plant was started in 1941 at Los Angeles by Dr. A. J. Hosmer, a man who had lost his own arm. He was a pioneer in prosthetics and was awarded one of the early prosthetics research contracts. His plant was bought by Brown in 1952.

D. W. Dorrance, founder of the plant which still bears his name, lost his right arm in an accident in the year 1909. Until that happened arm amputees had only a single hook as a prosthesis—the kind that Captain Hook wore. Dorrance was so irked with the limited scope of this tool that he turned all his thought and inventive ability to working out something better. The result was the double hook which opens and closes. With missionary zeal, he went all over the country, selling his invention to limbshops. Sometimes Dorrance was so down on his luck in this venture that he had to "ride the rods" of freight trains. However, his long-range success was so complete that the Dorrance factory now supplies a major portion of all the terminal hooks worn in the United States.

Surely there are few stranger and yet more stimulating spectacles than a factory filled with this one product—hooks to serve as substitutes for human hands. Hooks in all stages of being turned out by machines and assembled by technicians. Hooks for heavy duty and for light. Hooks sized for big men on down to babies. One multi-purpose, heavy-duty hook is shaped to hold a shovel handle at its broadest part; to grasp a chisel at its narrow portion; to pick up nails with its pincer end, and to hold a thin knifeblade with a small upper hook. A hook for a very young child carries an inner lining of neoprene which allows a firmer grip on orange-juice glasses and doorknobs.

The terminal devices known as APRL hooks and APRL artificial hands were invented by Colonel Maurice J. Fletcher at the Army Prosthetics Research Laboratory near Washington, D.C. On Colonel Fletcher's specifications, they are produced at the Sierra Engineering Company in the Los Angeles area, as an outgrowth of the early prosthetics work done by Northrop Aircraft. Sierra, which occupies a series of small buildings and large warehouses in Sierra Madre, some of them converted residences, makes oxygen masks for the crews of jet airliners and breathing equip-
ment for survival in space. It makes anesthetizing apparatus for hospitals.

But it is best known as the home of Sierra Sam, the Space-Age Test Man. He is a 200-pound dummy, manufactured in multiple, whose chestbox is crammed with electronics which tell what happened to him on each hurling-forth—from upper air, or in experiments staged on Utah's great salt flats to test escape systems in wind blasts at high speeds. His flesh is foam rubber. He wears a crash helmet, orange jacket, padded pants, and heavy leather shoes.

The engineers who show visitors through Sierra—as far as visitors may go under Government security regulations—say that the extensive output in upper-extremity prosthetics and a large proportion of the Space-Age devices are results of the two strikingly different types of fundamental research initiated and painstakingly carried through by the same man—Dr. Craig Taylor of UCLA.

They tell of how Dr. Taylor sat for hours in the environmental chamber he designed in which temperature, humidity and altitude can be accurately controlled, taking notes on a pad on his knee on the effects of atmospheric changes on the human body, and on how much heat, cold, and pressure the human body can be expected to stand.

They tell, too, about a dedicated junior scientist, Colonel John Paul Stapp, who served as human guinea pig for Dr. Taylor in the human factors field, setting the practical limits of human bodies to endure acceleration and deceleration.

When the Northrop Aircraft company was carrying on experimental work in artificial arms, Sierra was serving as a subcontractor to Northrop. And when Northrop closed out its prosthetics contracts, Sierra took over the Northrop line of devices and several of its top engineers and continued with development of devices. Naturally, they thus took over very close relations with Dr. Taylor, UCLA's authority on upper-arm prosthetics. One of the most difficult of engineering tasks undertaken by Sierra was the manufacture of Colonel Fletcher's Hand Size No. 1, for very young children, because all the necessary parts had to be fitted into so tiny a space. On the first twenty such hands the Sierra engineer worked under the supervision of Dr. Craig Taylor. This was Dr. Taylor's final contribution to the prosthetics field.

This entire nation, as well as every amputee wearing an

artificial arm, owes a special debt of gratitude to Dr. Craig Taylor, engineer-physiologist extraordinary, who built his own torture chamber to establish new Space-Age frontiers—who concerned himself with the building of a baby's hand.

Arcadia is the place where Dr. Franklin Page, Jr., holder of many patents, and a former engineer for Sierra, impartially advances both the Henschke-Mauch hydraulic legs and a hydraulic leg of his own. He makes the tools to make the Henschke-Mauch swing-control unit. Mauch does the assembly himself, in Dayton, Ohio. The Page hydraulic leg will compete with the Henschke-Mauch leg in the open market.

In his small establishment filled with the most complicated machines, the DuPaCo, close to the Santa Anita Race Course, big, genial Dr. Page amiably compared all the hydraulic legs soon to come on the market. He contended there would be plenty of consumer demand for all of them, and that they will be competitive only in the sense that automobiles are competitive. "Some like Fords and some like a Chevrolet," was the way he phrased it. "And don't let anybody tell you that their cost will make them prohibitive for amputees. None of them will cost as much as a good hi-fi."

He led the way to a corner of his shop where the leg he invented had just gone through 3,019,252 walking cycles in a testing machine without breakage or loss of function.

"In that cycling machine that leg has been walking 8 to 10 hours a day, six days a week, for the last eight months," he said. "It has been going at a medium fast walk, 80 steps a minute. Now I am going to take it down and dissect it—see what condition it's in. I want it to be worn from three to five years before having to go back into the factory for replacement of the hydraulic unit. That unit has to be sealed—it can't be fieldrepaired."

Automation already is doing a sizeable share of the work at Jay Greene's new prosthetics plant in Glendale—the U.S. Manufacturing Co. The youthful and enthusiastic proprietor claims for his factory two "firsts"—the first use of clock-controlled automation in the field of prosthetics, and the first plant to get tooled up for quantity production of a hydraulic leg—the Stewart leg. One clock-controlled machine is a tester of the performance of artificial legs, with walking cycles continuing day and night—no stop-

ping until the test is finished. Other such machines turn out the small parts for artificial legs, arms, and functional braces.

Jay Greene had a Spanish translation made of the fifteenminute motion picture which he uses to demonstrate his prosthetic appliances to certified prosthetists, and also of the half-hour motion picture which he uses in demonstrating modern scientific bracing to qualified orthotists. These Spanish-speaking films, he said, were made for showing at such gatherings as the South American Prosthetics Congress held in 1958 in Caracas, Venezuela, where a 500-bed rehabilitation hospital had just been built. The U.S. Veterans Administration is helping set up a prosthetics and orthotics laboratory at the request of the Venezuelan government.

"The man in charge of all this used to be President of Venezuela," Greene said. "Governments of many other countries are interested in the neglected field of prosthetics and bracing."

It then became quite evident that Greene had used "U.S." in naming his firm because he hopes to serve the world and wants the world to know his product was made in the United States. He spoke of visits to Puerto Rico, Panama, and Guatemala. He said he would help Captain Canty in his program in Mexico, where the government wants to manufacture and fit right in a new rehabilitation center.

"From the Far East surgeons come and are trained in prosthetics, U.S. style," he said. "They go back—and find no prosthetics industry. We can go into such countries and teach doctors how to take the measurements and do the fittings."

Jay Greene in his travels has become convinced that Captain Canty's plan for plastic legs in Mexico could be carried to the Far East—"places where the plastics fit the financial brackets," he said. In this country wood, mostly willow, is customarily used for artificial legs. In England metals are favored.

Greene said that he had gone into the prosthetics field by working with the Kessler and Northrop investigations in 1945 and 1946. He said that the important findings of the later Prosthetics Research Board investigations should be included in the curriculum of medical schools so that all surgeons could have the benefit of them, and that foreign students particularly could learn them at any medical school.

"No engineer carries on without instruction," he said. "A

machinist refuses to do work unless he is a qualified fitter. The same should hold true for stump surgery."

At the time of the author's visit to the U.S. Manufacturing Company, engineering and testing had been completed on the Stewart leg, the first two hundred such legs were in the works, and the factory was tooling up for quantity production. Jack Stewart, who had sold his invention outright to Jay Greene, was almost ready to return to his native New Zealand to live. But he was spending a great deal of his time at the plant, taking great satisfaction in seeing his long-cherished dreams come into reality.

"Jack will be buying from us," explained Greene. "He will be assembling Stewart legs for the South Pacific market.

"Of course, this type of leg is only for above-knee amputees, and we sell as a unit only up to the knee. The prosthetist has to make and fit the socket, and Jack will do the assembling in that area."

Jack Stewart came into the conversation to explain, "The Stewart leg is basically made for the active type of man." He rose, and strode swiftly across the floor to demonstrate the brisk action of his leg.

"I claimed in this leg thirty-nine basic patents," he said. "It is really a hydraulic shin which controls both the knee and the foot. See—it bends the knee before the foot lifts off the ground. It causes the toe to rise by picking up the foot, so that there is no danger of stumbling or of stubbing the toe."

Stewart said that he had started work on his hydraulic leg in 1940 in Pasadena.

"I had come from New Zealand with a friction-knee device of my own," he said. "I had been on a motorcycle racing team with boys from Pasadena before I had the accident which cost me my leg, and I knew they would direct me to people who would help me solve my problem.

"I was not satisfied with the friction leg, and had decided to do it hydraulically. In 1941 I built a machine to duplicate the human walk. My difficulty was retaining oil within the system. You can't carry in your pocket the oil supply to operate a hydraulic leg, nor can you let oil leak out as you walk. A seal was an important problem.

"By 1943, I had a working model with a seal. I took it to

Lockheed and had it tested, and Lockheed said I had a great thing and should see Vickers in Detroit. Such a seal was greatly needed by the airplane industry. When the P-38's were out only between 50 and 250 hours they had to land for lack of a better seal in the hydraulic system.

"So I went to Detroit—took my leg-work along—and saw Harry Vickers. He was interested—he spent \$300,000 of his own money on my leg proposition and on perfecting the Vickers seal for the hydraulic systems in airplanes. Now Pan American World Airways flies a seal 4,200 hours as against 250 hours—all because of a motorcycle accident. Planes the world over are more reliable because a man needed a seal for his artificial leg."

There are, of course, more such factories in this and in other geographical areas. These are merely the ones I saw in passing on a tour arranged to show man's ingenuity in behalf of man.

CHAPTER VII

Denver— Individual Enterprise Rehabilitation

The luxury airliners flying from Los Angeles to Denver circle down from the last of the Rockies to the spectacular plateau airport of the Mile High City. Denver's very pattern from the air indicates that here is a community of individual initative and imagination. Its newer suburbs are not regimented but spread out from the central city in patterns that swing and curve.

Downtown Denver, too, has the air of being creatively at work on a cooperative, community-building basis. The new skyscrapers are not duplicates of either East Coast or West Coast architecture. The tall new building of a long-established department store includes a single-story glass building as showcase—a jewel box really—for its imported goods. It gives a touch of variety as charming in the Denver business district as the skating rink in Rockefeller Center does in the heart of New York.

It is really not surprising to find that rehabilitation in its most modern concepts is available as a retail item in downtown Denver. The establishment where it is sold is one of the many illustrations of how problems are independently solved at the Great American Grass Roots.

Chester C. Haddan is the rehabilitationist who owns and runs Gaines Orthopedic Appliances, Inc., at 1633 Court Place. He draws his customers not only from miles around, but from whole States around—Wyoming, the Dakotas, Nebraska, Kansas, and Texas.

In the showcase and office portion of the shop, customers come tripping in as casually as to the nearby jewelry shops selling well-designed items made from the semi-precious stones found in the Colorado mountains. They buy cosmetic corsets, brassieres, braces, prostheses—the whole line of items helpful to less than perfect human beings.

Mrs. Haddan works with her husband in the supervision

of the establishment from one of the office desks. Mr. Haddan has a quiet inner office, where people feel free to tell him their troubles. He himself is an amputee—a matter not at all noticeable as he walks, but which nevertheless quickly establishes rapport with his customers. Behind his office are the fitting rooms for artificial legs and arms, and the mirror-reflected exercise bars and ramps where his physical therapist trains amputees in the use of these devices. Still farther back in the long building are the plastic, metal, and woodworking shops, widely known for exemplifying the finest in workmanship.

To serve his community, Mr. Haddan joined forces with an outstanding orthopedic surgeon, Dr. Atha Thomas, professor at the University of Colorado School of Medicine at Denver, years before the "team approach" was formalized as a rehabilitation procedure. As mentioned earlier, these two authorities published a textbook which included important pioneering work in children's prosthetics the very year that broad scientific research into prosthetics was launched. They were quick to see the great vista opened by bringing the science of engineering to bear on prosthetics problems. They have continued their collaboration on scientific articles in the field.

Chester Haddan became a member of the Prosthetics Research Board when it was formed and remained a Board member. He also served on the National Advisory Council to the Office of Vocational Rehabilitation. For him it is routine to report on call at a conference on either coast. It is only a matter of a few hours from the mile-high airport, either way.

Although obviously an individual operator, Mr. Haddan is an eloquent exponent of the prosthetics-team philosophy. He counts as members of his team not only his own skilled staff, but also the orthopedic and general surgeons of his area and the medical social workers and vocational rehabilitation experts of Denver, a State capital. He also works very closely with the Children's Hospital there. With all these resources available, he contends, a midland city can compete with the great population centers on both coasts in offering a full range of service—for teamwork is not a matter of organizational charts but of mutual confidence and respect, without which there can be no real teamwork.

"It is not necessary for all members of the team to sit down around the patient at the same time in order to have real teamwork

in operation for him," said Mr. Haddan as he settled down for a chat in his office.

"A self-constituted team which confers personally when necessary, but more often by telephone across the city, or even across States, is just as surely doing teamwork as does that in the conference room of a big city rehabilitation center."

His own philosophy, he said, is that rehabilitation is a part of independent, everyday living—and that as soon as an amputee has so adjusted as to go forward, independently and successfully in his community, he ceases to be disabled and should not be counted in a census of the disabled.

Such a triumph over disability, he said, has been proven possible even to a quadruple amputee. He paid tribute to Denver's outstanding attorney, Jimmy Wilson, who lost both arms and both legs in World War 11.

"His remarkable triumph over disability had been a matter of inner spirit. Nothing counts so much in rehabilitation as the person's own motivation. That is the difference between the leg or arm used, and the leg or arm left in a closet," Mr. Haddan said.

He said he counted Jimmy Wilson as the outstanding member of the Denver rehabilitation team though he plays none of the long list of roles given in discussions of rehabilitation teams.

"He is a forceful personality," said Mr. Haddan. "He has been a tremendous inspiration. If someone is clear down in the mouth and can't adjust, we ask him in. We don't do this to the point of making it too much of an imposition on him. We respect the really tremendous load he is carrying in the whole civic life of Denver, as well as in his own profession. But he can explain, as no one else can, how not to be bothered in the least when people stare at those hooks. It is only curiosity, which soon will be satisfied. It has long since got so that the people around him most pay no attention to his prostheses and accept him completely as a person."

Haddan then spoke of that bright, smiling 13-year-old quadruple amputee who sat in the outer office waiting to have her legs lengthened.

"She has been coming down here summers from Montana since she was three years old," he said. "Last summer we made her new arms. "From growth studies made by the Child Research Council of the University of Colorado, sponsored by the Federal Children's Bureau, we have arrived at a set of rules as to arm length and body length in proportion to body build. Thousands of normal children were measured in working out these growth tables. From time to time as she grows, we make her legs and arms normal for her. To bring her to her present normal height, five feet two inches, we have just inserted two-and-a-half inches in each artificial leg.

"In about twenty minutes, the work will be all polished off, and I'll let you take a look at how the physical therapist goes about helping her get adjusted to the new length.

"She has never been to any special school. I agree with the philosophy of our social workers here, who have helped so much on her case. There is more of her that is normal than is abnormal. She has to live in a world of normal people when she grows up. We are now literally helping her to grow up. We must also prepare her to live, not in a sheltered, but in a normal environment.

"The crippled children's program of her State, with its matching Federal funds, pays for her prostheses—that merely starts her out a little bit even with the world. But when anyone around here feels moved to buy clothes for her that her parents can't afford, I won't let them. Her father sends her money for clothes. I will not have her feeling that she is a charity case.

"We have here in this shop a caseload of 177 children who are amputees, and none of them are on any socialized program. The children go to public and parochial schools in Colorado, Wyoming, Montana, Nebraska, and New Mexico.

"On congenital malformations where amputation is the treatment of choice, the doctors in these States ask my advice. I tell them that if there is a deformity, get rid of it at the earliest stage—don't wait until children grow up and have deep habit patterns as well as physical deformities to change.

"I tell these physicians to teach the parents to do as much as they can. They can go for advice to the rehabilitation director of their State. The mother can learn to do therapy—and so can the other members of the family. The sooner this is done, the sooner the child is accepted as a member of the family and of society."

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Again he referred to the 13-year-old quadruple amputee. He told of what a remarkably well-trained and resourceful young physician she had had as a family doctor and of his wonderful "teamwork" even though he is situated more than a thousand miles from Denver.

"Her mother has helped with her therapy," he said. "And so she is no extra burden when she comes down here in the summer and stays at a boarding home. She dresses herself. She combs and washes her own hair. She walks to the table like anybody else, and eats like anybody else."

Mr. Haddan said that he also advised the doctors in his territory to be patient and not expect too much, adding, "if we can prevent amputees from getting worse as the years go by, that is progress. As the result of the amputation, they may inherit many other problems, such as spinal maladjustments."

As much a part of the rehabilitation as learning to use a prosthesis is the adjustment of the family to the situation, Mr. Haddan said.

"Sometimes the conflicts are so fundamental that one partner in a marriage may have to take over the whole burden of the rehabilitation and be content if the other partner will even give consent," he said. "There was the somewhat understandable case of a star athlete, whose son was born minus an arm. The whole pride of his life had been in his own perfect body. His mind utterly rejected this situation and he absolutely refused to face the fact that his son needed help. The mother had to do the facing up to things while her husband was at work."

Mr. Haddan said that more than once in his experience the family conflict resulting from a congenital amputation has caused the separation of parents. In such cases, he said, he quietly stands by, respecting confidences, but not hesitating to set before both parents the truth of the matter as he sees it affecting the best good of both the child and the family. But the decisions, he contended, must be left to the parents themselves.

He held that people gain confidence and self-respect by having to cope with their own problems, however difficult. Sometimes the problem is merely a financial one. He told of one farm family which has been on his books, because of the complicated type of prostheses required by the son, since the year 1947.

"By the time they get their debt almost paid off, he has

grown again, and another extension is necessary. But year after year, they cheerfully come in and pay up as far as they can when the wheat crop is sold," he said.

"These are the kinds of people who made America great. Take from them the privilege of caring for their son—give him his care as charity—and you would take from them the most precious thing that they have.

"People who earn their own prostheses treat them more kindly and make them last longer than do those whose prostheses are given to them. That is a proven fact."

The longest-lasting prosthesis he ever heard of, Haddan said, belonged to one of his favorite customers of all his years in business.

"She was a 97-year-old woman with an 1890 leg," he continued. "She taught school on it for half a century before she retired to almost as active a life. It was an excellent leg in the first place—with a knee not much different from many being sold today, and a rubber foot—no ankle joint—mechanically and functionally no different from the SACH foot of today. Year after year I kept it in good shape for her.

"Always she came to the shop by herself—never once let me send for her. Once, when she was well past ninety, I looked her prosthesis over and told her I was sorry, but it would have to stay in the shop a couple of days for a rather major repair. I asked her to let me drive her home.

"'No, just give me a pair of crutches, and I'll go home by myself,' she answered. She walked out of my door on her crutches, got into a cab, and went home."

We watched Miss Montana mastering her lengthened legs. Then we went into the front office for a chat with Mrs. Haddan. In from the street breezed a beautiful girl, with shapely legs. I would not have known that one of them was artificial had I not been told. She had a brief consultation with Mr. Haddan and went out again, smiling.

"Her mother had her take modeling lessons," said Mr. Haddan. "Now she wants to be an airplane hostess. I told her I saw no reason why not. I'll take it up with United."



This ingenious device, working something like a pantograph, was developed at the Rehabilitation Institute of Chicago to diagram forces between socket and floor and thus achieve more precision in alignment.

CHAPTER VIII

Rehabilitation Under One Roof

Dr. Paul B. Magnuson, orthopedic surgeon and medical statesman, is founder and honorary chairman of the Board of Directors of the Rehabilitation Institute of Chicago. According to the old saying that an institution is the lengthened shadow of a man, Dr. Magnuson merits analysis as background to inspecting the establishment he founded.

Now seventy-four years old and writing his memoirs at his home in Washington, D.C., Dr. Magnuson is one of the most vigorous campaigners in this country for the intensive kind of medical care which makes it possible for seriously disabled individuals to become helpful members of society.

He is tall, spare, and dynamic. He is proud of his record, of "wearing no man's color," of saying precisely what he thinks in public debate, and of tossing out any timeworn traditions which might block scientific progress.

Dr. Magnuson has served his country as Medical Director of the Veterans' Administration, and also as Chairman of The President's Commission on the Health Needs of the Nation in the Truman administration. In the first capacity, he organized a medical system which brought to veterans the medical advice of the great teaching hospitals in the universities. In the second post, throughout the year 1952, he conducted an intensive study into every phase of the Nation's health needs. Thirty all-day panels in Washington were followed by eight regional panels throughout the country. One result was more than 11,000 pages of testimony on U.S. medical needs. Another was a series of reports and recommendations, then considered controversial, but since widely accepted.

In between his two tours of national duty, Dr. Magnuson slipped out to his home city of Chicago and quietly raised a quarter of a million dollars in less than ten weeks to start the Rehabilitation Institute.



A new type of elbow is being adjusted as part of the process of making an artificial arm at the Rehabilitation Institute of Chicago. Said Dr. Magnuson, "I sold the proposition of the rehabilitation center on the basis of making a self-supporting, self-respecting, tax-paying unit out of the unhappy, dependent tax-absorbing unit which had previously attempted to meet the need. I consider this economically, physically and spiritually sound business and politics alike. Businessmen bought this idea quickly, which explains the original contributions so promptly given."

A member of the Prosthetics Research Board from its beginning, Dr. Magnuson continues to keep abreast of progress the world over in this particular branch of rehabilitation. Only last summer, he made a trip to Europe to study advances. He came back reporting that he had seen both electrically and gas-controlled artificial arms in use in both Germany and France.

Immediately he started urging a still more intensive research program in this country, with a view to using external power to operate both artificial arms and body braces.

"Of course, the electric and gas arms in Europe aren't perfect yet," he said. "But they are working. A cylinder of carbon dioxide gas, with valves which are connected to the various parts of the arm apparatus with tiny tubes, operates the pneumatic prosthesis commonly called the Heidelberg arm. The electric arm is operated by three little batteries, each not more than three-anda-half inches long."

When reminded that complaints have been made in this country that the pneumatic, or Heidelberg, arm makes too much noise, Dr. Magnuson fairly snorted, "So what! If it does the work who cares about noise—with all the noise we've got around us!"

Dr. Magnuson particularly urged external power to help operate the braces worn by child victims of poliomyelitis and other forms of paralysis.

"We have been putting heavy braces on poor little halfparalyzed arms and legs that didn't have enough muscles in them to move their own bones," he said "We have loaded them down with steel and leather until these children can hardly lift their braces by straining all the rest of their muscles.

"We must develop light materials and we must motorize many of these parts so that these afflicted children can use their arms and legs much better than they have ever been able to in the past."

The same sort of research, he added, must be pushed for-

ward for the rapidly increasing numbers of older persons disabled by strokes.

Characteristically, Dr. Magnuson vented his impatience at the slow pace of the development of external-power devices.

"Too many of us medical men are trying to make records for ourselves when we ought to be thinking what we can do to make sick people well and disabled people function again," he grumbled. "Too many of us are looking for glory in our own ideas. Unless we quickly take the best ideas wherever in the world we find them, we will be so far behind in this country that we won't catch up in twenty years."

But he quickly conceded that the application of external power involves tremendous problems in materials, physics, chemistry, and mechanics, to say nothing of surgery and psychology.

He spoke of bracing as another field badly in need of development. He said that the Federal Government could well put a million dollars annually into bracing research. He said this new research in the field of orthotics should be channeled through the Children's Bureau for boys and girls, and through the Office of Vocational Rehabilitation for older people, as has been done through the Veterans' Administration for some years in the field of prosthetics.

Dr. Magnuson's keen interest in rehabilitation dates back to 1917–18 when he served as a major in the Medical Corps in the first World War. When he returned from that war to Chicago where he had been in surgical practice since 1908, he was instrumental in setting up in the Northwestern University Medical School what probably was the first college rehabilitation course in the country.

The rehabilitation center which he founded four years ago is close to the downtown lakeside campus of that great medical center. Both its new research department in the field of prosthetics, and its new school for the training of prosthetics teams are under the sponsorship of Northwestern.

The Rehabilitation Institute of Chicago at 401 East Ohio Street was once a sturdy commercial printing plant. When Dr. Magnuson first saw it he noted its many advantages. Its floors were built for heavy loads, such as the therapeutic whirlpools and hydrotherapy tanks which now are installed on its upper floors. Air-conditioning was installed between the floors of this building by lowering the too-lofty ceilings. Even the covered driveway, built to protect the great rolls of paper as they came into the plant, has its use for protecting incoming patients from winter weather on a lake front. The high upper windows, now in patients' rooms, commanded a magnificent view of Lake Michigan.

Dr. Magnuson himself arranged the option on this building. Gradually it was converted to a rehabilitation center as public-spirited Chicagoans added to the fund that he started. As soon as the work had gone far enough so that a few patients could be admitted, they were allowed to come in and the Institute went on growing around them.

The old printing plant has now become the most modern, inviting place imaginable. At its entrance is a small conservatory—artificial, but looking very real. Its every room is a symphony in restful pastel colors—at least three different colors being used in each room. This is as true for the upper rooms occupied by patients as for the large first-floor areas where the staff meets incoming patients, their families, visitors from abroad—and occasionally the interested public in an open house. For the Institute keeps up a close connection with the community it serves.

The little conservatory, the many cheerful yet restful color schemes, and the comfortable, modern furniture are part of the rehabilitation, setting a high and hope-filled standard for everyday living. The interior decoration was done as part of the community enterprise by Chicago's largest department store, Marshall Field.

The Institute operates as a service to the practicing physicians of Chicago and the surrounding area. Patients are accepted only upon referral by their physicians or by a recognized health agency. The Institute assumes responsibility for the evaluation and treatment of the rehabilitation problem only. But its service is broad. The ultimate responsibility for the operation of the Institute rests upon the Director, Bernard J. Michela, M.D. He is guided by a Medical Advisory Committee comprised of twelve physicians appointed on recommendation of the Chicago Medical Society to consider all problems of a professional nature; and by a Board of Directors, rehabilitation-minded Chicago citizens concerned with all nonprofessional activities of the Institute.

The Institute can accommodate about seventy-two inpatients as they gradually learn to manage normal living again. Treatment and training can be given daily to about seventy-five additional patients who come to the Institute as out-patients. These patients are on regular programs of treatment and exercise while continuing to live at home. Others come in for periodic follow-up after successfully completing treatment at the Institute.

Dr. Clinton L. Compere, orthopedic surgeon, a pioneer in prosthetics and now on the faculty of Northwestern University Medical School, serves on both the professional and citizen groups. As a lieutenant colonel in World War II, Dr. Compere was chief of amputee surgery at McGuire General Hospital in Richmond, Va. He held one of the first prosthetics research grants, a \$40,000 study on the use of light airplane metals in artificial legs. Later he conducted in Chicago the first city-wide—and very successful—experiment in the introduction of plastic artificial arms. Three or four times a year he makes use of the Institute as a largescale clinic to demonstrate to Northwestern University medical students the modern methods and latest trends in prosthetics. He has given great impetus to the Institute, and is the responsible academic advisor of the new school to train prosthetics teams.

It was Dr. Compere who most forcibly called attention to the fact that with the lengthening lifespan in this country the big amputee problem to be faced now and in the foreseeable future lies in the older age group. He said that a very large proportion of the more than five hundred amputees which the Institute has cared for in its four years of operation has been in the older age group.

"The Office of Vocational Rehabilitation sends the oldsters in here so that we can teach them to care for themselves, and not be a drag on an able-bodied person," he said. "Older people never have to sit around in wheel chairs just because they have lost a leg. There always has to be some other seriously complicating factor if this really is necessary."

Dr. Compere said that at one time when a check was made, seventy percent of the patients of the Institute had been sent in by OVR. The younger ones were there to get themselves in physical shape to go back on a job. The older ones were learning to take care of themselves.

Dr. Compere said that the rehabilitation problems of the aging will continue to be the chief specialty of the Center. But all ages will be served there, including children, so that the prosthetics teams from all over the Middle West which will be trained at the school just opened on an upper floor of the Institute will have the full range of training. On my arrival at the Institute, Miss Merrian Passarelli, coordinator, greeted me and accompanied me on my tour of the Institute. The upper floors are reserved for in-patient living quarters. Here mirrors are tilted slightly away from the walls enabling a wheel-chair patient to have full view. Bathtubs are equipped with grab bars so that patients can help themselves to get in and out under their own power or with stand-by aid. Face bowls are extended from the walls, again enabling a wheelchair patient to get closer than he could if the bowl were flush against the wall. Lavatories are likewise equipped with grab bars and are extra wide.

Our inspection went on through the Personal Counseling Department, which includes Clinical Psychology, Vocational Counseling and Medical Social Service. Psycho-social problems are not an uncommon factor in the lives of many who come to the Institute. The Personal Counseling Department works closely with the other departments in helping a patient toward acceptance of disability and adjustment—to make the most of what he has left.

We continued to the Occupational Therapy clinic, where Mr. Frederick Sammons, department chief, described how various arts and crafts are used in training amputees to use prostheses. Here lower-extremity amputees are given a type of work closely allied with their skilled trade. Standing tolerance is built up and adjustment from one work situation to another carefully noted. Arm amputees are taught heavy lifting and gross and fine manipulations of the hook in work situations.

"It is marvelous what they can do with hooks," I commented.

"But we have learned that they do more here than they ever do at home—and so our rehabilitation team sees to it that they get the maximum here," was the reply.

In the weaving area one of the patients at a loom was just completing an exquisite tapestry. He was a Catholic priest, with sparkling eyes and a friendly smile. His loom had been adapted to supply resistance, making it harder to operate. Certain muscles needed strengthening and his loom had been adjusted to make him use the amount of effort which would further his recovery.

Activities of daily living are carried out by patients under supervision of the therapists in the Physical and Occupational

Therapy departments and the patient is taught how best to meet the problems of physical adaptation to everyday activities.

In the Physical Therapy area where patients were taking their highly varied, prescribed exercises, Miss Hildegarde Myers, chief of the department, explained the various applications of physical therapy. A discharged patient breezed in just to brag about his progress. This 54-year-old leg amputee said that he had just finished painting his own house, climbing up on a tall stepladder every day. He walked swiftly across the floor to show the improvement he had made in his gait.

One of the staff pointed out that age was no deterrent in the prescription of a prosthesis, informing me: "One of our most delightful cases was a little old lady of eighty-six who weighed only ninety pounds. Her children and grandchildren had agreed that this sprightly person shouldn't just sit. By putting a manual lock on her artificial knee to give it stability, the prosthetics team got her going beautifully. It took about three weeks."

Patients join each other at mealtimes in the cafeteria which is located on the first floor. Where necessary, aides carry trays to tables but each patient selects his own food. If he is on a diet, he is cautioned not to choose foods not in line with his treatment. A consultant dietitian makes out special diets as ordered by the physician for those cases complicated by diabetes, obesity and any other diagnostic factor calling for specific attention and control.

Eating can be a problem for some patients and one may observe in action a functional device, constructed in occupational therapy, which helps a patient hold a fork or spoon in order that he may feed himself. It may be that he hasn't fed himself in weeks, even months, and it may take him a little longer than if someone fed him but this, too, is part of the rehabilitation process—the restoration of independence.

Amputee Clinic, a direct outgrowth of the amputee program at the Institute, is held every other week. After pre-clinic examination, a new amputee is presented for prosthetic evaluation by a team of orthopedic consultants. The amputation, contributing factors, present condition of the limb, type of prosthesis best suited to the patient's physical and vocational future are all taken under consideration in open discussions before the prosthesis is actually prescribed.

Representatives from approved commercial limbshops are present at these clinics. They confer with the members of the 88 Prosthetics Research laboratory. Once the prescription for a prosthesis is written it is sent to the limbshop designated by the patient. If a research problem is present, the prosthetics research team will begin work in conjunction with the limbshop that is to fabricate the standard part of the prosthesis.

After completion, prostheses prescribed by the consultants are brought to clinic and again the patient is checked to insure the proper fit of the prosthesis. If there are no adjustments to be made the patient's training is begun. He is checked periodically. Daily training at first is a general rule, then a tapering off to three times a week, perhaps twice a week for lesser periods of time and, finally, discharge. However, this is not the end of the amputee program for a patient. Where it is felt necessary, patients are asked to return for re-check examinations at clinic after a specified time which may extend from two weeks to one year, and all patients leave with the knowledge that they can consult the Institute should a problem of prosthetic adjustment arise.

Dr. J. Warren Perry, a Ph. D. in Psychology from Northwestern University, is head of the new Prosthetics Education School of Northwestern University Medical School. This prosthetics school is supported by a teaching grant from the Office of Vocational Rehabilitation. It gives to the central portion of the United States the same advantages that are available on the West Coast through the UCLA prosthetics school and on the East Coast through the prosthetics school of New York University.

"We will be following the lines of the other two schools, offering courses ranging from one week to four for physicians, prosthetists, therapists, and rehabilitation counselors," said Dr. Perry.

"Each student will receive practical training in his own discipline. Experience will be gained in working together as a clinic team to fit' a patient with a prosthesis and train him in its use."

Certificates from Northwestern University Medical School will be given for each course completed.

The Prosthetic Research Center of Northwestern University Medical School operates under a grant from the Veterans' Administration, with Dr. Compere as the responsible medical investigator. It has as its director a young Canadian engineer, Colin McLaurin. He explained the Center's purpose and its connection with the Institute, and described some of the current projects at the Center.

"The Center is ideally located for clinical research and par-89 ticipation in the amputee programs of the Institute," he said "We participate in the clinic team by advising on biomechanical problems, helping to organize all pertinent information on prosthetics treatment, keeping a systematic pictorial and written record of this information, evaluating and interpreting it in a manner useful for fabricating the prosthesis. We come in contact with amputees of all ages—particularly geriatrics—and certainly with varied medical complications, so the properly organized records of these patients lend invaluable criteria for us in the design of new devices."

McLaurin said that the Center is currently investigating a half dozen projects which he described as follows: "An arm for the above-elbow amputee has been devised which is controlled by a single cable. It is a separated control device which can be switched from the independent operation of the terminal device to the independent operation of the forearm lift, or vice versa, by means of a system of pulleys and cables in the elbow unit. A multi-position wrist disconnect unit is incorporated in this arm.

"We employ a cast-taking technique in which the hydrostatic action of wet plaster distributes force evenly. The plaster and the stump are separated by a diaphragm clamped to the top of the container. A pressure-gauge reading is taken. With the records of stump size and shape taken by this technique we can correlate them with socket size and shape. This is a simple method of defining stump shape which affords consistently accurate results. An adjustable leg is being made to try out the sockets.

"In connection with this we have developed a graphic method of locating prosthetic knee centers for obtaining a more comfortable fit in the sitting position while retaining good alignment in the standing position. This chart is simply a geometric tool stating how to alter the position of the prosthetic centers once the desired alignment has been determined.

"Another new development is the above-knee tracer which records the shape of the socket. Such tracings are being made of all above-knee and below-knee sockets seen here at the Institute. It is hoped that we will develop a second machine to record the functional characteristics of the leg.

"Finally, there is a multi-position locking shoulder joint which is in the early stages of development. It's a tool for preliminary investigation on the desirability of multi-position shoulder joints for disarticulation and forequarter amputees." 90

CHAPTER IX

Grand Rapids—Pioneer Child Amputee Center

Into a unique clinic in a hospital in Grand Rapids, Michigan, came a pretty young woman with a radiant but obviously greatly handicapped little girl. The woman seemed somewhat hesitant, as though the place was strange to her. The little girl, however, unquestionably felt right at home there.

She made a swift although stiff-legged dash for the jar of lollipops sitting on a table beside the orthopedic surgeon who was conducting the clinic.

"My mom-mom-momma's got a new-new-new dress!" she delightedly called to him.

The surgeon and many of the other specialists at this regular and routine clinic of the Michigan Crippled Children Commission in its Area Amputee Program, knew that this was the remarkable little Jessica Weaver of Davenport, Iowa. They knew that her mamma was new, and that her last name of Weaver was new, too—and that for Jessica to have someone she could call "Mom—mom—momma" was a triumph indeed.

Her delicate face was framed in fine, light hair. Her blue eyes had great appeal. But it had not always been so. The surgeon quietly explained to visitors to the clinic that here was a really severely disabled child who nevertheless was making great progress. He said that soon she would have all four of her prostheses sufficiently mastered and she could be given lessons in the speech clinic to overcome her repetitive habit.

Mrs. William C. Weaver, the foster mother, gave a proud report on Jessica: "She wears her arms all day, except at naptime, and her legs all day long." Actually wearing a prosthesis is the acid test of its success.

"Very good," approved the surgeon. "She handles herself well. She has excellent standing balance. Any troubles?"



This appealing and hopeful photograph of Jessica Weaver, a quadruple congenital amputee, won first prize in the Iowa newspaper photographers' contest of October 1958. Jessica, an Iowa child, was fitted with artificial arms and legs at the Area Amputee Center of the Michigan Crippled Children Commission in Grand Rapids through funds furnished by the Federal Children's Bureau. "One elbow gets red when it rubs against the prosthesis," said the mother. The surgeon and the engineering and prosthetics experts of the clinic made a little circle around Jessica and her lollipop as they studied her arms and legs. They conferred together at some length. Then the conductor of the clinic sat down in his chair, pulled up the mouthpiece of the dictaphone which sat on the floor beside him, and dictated what was to be done to her prostheses in the two days before she would go back to Iowa. The inner arm would be hollowed out a bit, so it would not rub the tender skin above her elbows. The leg sockets would be cut down, so she could get her feet closer together and not have to walk so stiff-legged.

As Jessica was going over to rejoin her foster mother, she fell down. Gamely she got herself right up again. Impressed by the sturdy spirit of this frail, fey, Iowa child, I struck up a conversation with a man whom I had observed arriving with her and and her foster mother. He identified himself as Leon Lyle, superintendent of the Iowa Anna Wittenmyer Home which holds the legal custody of Jessica and probably will continue to do so until she reaches legal maturity at age twenty-one. From him I obtained Jessica's strange story.

"She belongs to the State of Iowa," he said. "However, she has been cared for since birth by an assortment of Federal, State, local, and private organization funds. The foster home she now has was made possible by the Catholic Charities of the Davenport Diocese, and as a crippled child she is entitled to Federal-State grants-in-aid under the Social Security Law. She also receives, because of the death of her natural father, Social Security funds which are banked and used for extraordinary needs such as special clothing. The regular boarding-home care payments are made by the Anna Wittenmyer Home."

Mr. Lyle said that the records showed that her father and mother were divorced a month before she was born on May 2, 1954. Her mother abandoned her in the hospital where the birth took place when she saw that both of Jessica's legs were absent from the knees, that her right arm was absent from the elbow, and that all fingers except the index finger were absent from her left hand. The hospital accepted this abandonment as inevitable in view of the fact that the mother, evidently in very poor health, already had three older normal children to care for and support.

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Jessica was kept in the hospital for four months while welfare workers searched in vain for a foster home for her.

"Every person who knew something about the situation hoped that someone else would do something quickly," said Mr. Lyle. "Nobody did, and soon those who had been arguing that the State children's home was no place for Jessica were the most insistent in their arguments that we must take her in. The unspoken attitude was, 'Please take this bundle quickly off our hands.'"

Thus it was that a seasoned old Children's Home, which had been doing its worthy works for more than ninety years, took over the care of the unwanted waif. The home was founded in 1863 under the leadership of Mrs. Annie Wittenmyer, a nurse, to care for Civil War orphans. An Act of Congress of January 22, 1866, turned over to this home a Civil War fort. The Joint Resolution of Senate and House stated "that the buildings, sheds, furniture and other property now in Camp Kinsman, near Davenport, Scott County, Iowa, be and the same are hereby donated to the Soldiers' Orphans' Home of Iowa."

Superintendent Lyle said he turned to a nearby hospital for help for Jessica. When he sent her there for observation she was returned within two days with advice that she should be given exercises from six months to a year before any prosthesis for her could even be considered. Months later, when a few weeks' treatment was secured for her in a children's ward, other children shrank from her. She formed the habit of playing by herself and became very possessive of her toys. It was noted that she was afraid of men, but only when they had their hats on. It finally dawned on one of the nurses that in Jessica's cloistered way of life she had never seen men with hats on. Her appetite was poor. She had frequent colds and fever flare-ups.

Then a very small incident took place which changed Jessica's life. Mr. Lyle said that he just happened to see, in the spring of 1956 when Jessica was almost two years old, a little item about the Michigan Crippled Children Commission. Appropriately it was printed in a current events paper for very small children, "Two to Five World News." It said that the Michigan Commission was offering to treat child amputees from any part of the United States, and that the program was made possible by a special grant from the Children's Bureau.

"Mention was made of the importance of starting treatments early, as young as two years of age, so that the child could be started on the way to adjustment before going to school," said Mr. Lyle. "Jessica was two.

"It said that for nine years the Amputee Center had been operating in the Mary Free Bed Guild Children's Hospital and Orthopedic Center in Grand Rapids as testing ground for the National Research Council in trying out new types of prostheses.

"Best of all, it said that nearly 100 percent of the children treated there for leg amputations had learned to wear leg prostheses, and that 85 percent of child arm amputees were successfully fitted with artificial arms. We decided to inquire about the possibility of care for Jessica."

Right there, he said, was when a marathon correspondence about the case of one child started. This file on Jessica now totals more than 150 letters. The first thing he learned was that the request would have to be made through the Iowa State Crippled Children's Services to the Crippled Children's Services of the State of Michigan. It took several months to work out all the details of interstate and Federal-State cooperation; to give Jessica the physical, psychological and intelligence tests preparatory to her treatment; and even to choose carefully the toy of which she was most fond which would go with her to Grand Rapids. But on January 1, 1957, Jessica, newly outfitted, was on her way.

"In the course of all this concentration on Jessica, nobody could remember exactly when she learned to walk," said Superintendent Lyle. "It just suddenly occurred to us that she had been getting around for some time when someone mentioned having observed her going down the hospital hall on her stumps helping to pick up the toys. She stood, crawled, and jumped on her stumps. A special, curved spoon was given her to feed herself with her lone finger, and she became dexterous with it.

"The psychologist who was jotting down observations to send on to Michigan noted that Jessica smiled, laughed, played peek-a-boo, waved bye-bye, picked up articles, handed them to the psychologist, and said, 'Hi.'"

In February 1957, the report on Jessica, made from Grand Rapids, Michigan, to Davenport, Iowa, ran: "Jessica has her legs and is very proud of them, particularly of the pretty socks and shoes. She is being trained in walking. . . . In the dormitory she does not seem nearly as fearful. She is now able to join a group of children her age. . . . Everyone here is interested in this child, and also quite encouraged."

Arm fitting and training followed leg fitting. Jessica remained in the Grand Rapids hospital for many months-close to a year, in fact.

And when she returned to Iowa, she aroused the interest and affection of the attractive woman who agreed to take her into her home.

"It is working out very well," said Supt. Lyle. "Her foster parents love her and want to give her a permanent home."

And a nurse-physical therapist at the Mary Free Bed Hospital added: "The really remarkable thing is that it is possible to predict that Jessica probably will be able to earn her own living when she grows up. She is an intelligent, adaptable, and capable child."

The Federal Children's Bureau has made possible the rehabilitation of amputee cases involving extreme disability and therefore very high costs, such as Jessica's, by a special allocation to the Michigan Grippled Children Commission of Federal funds which do not have to be matched by State funds. The Grand Rapids program has been so highly praised because of its remarkable results that more money has been made available for it. It was given \$55,000 in Federal funds in the fiscal year 1958. This was raised to \$87,725 in fiscal 1959, and is expected to continue at around \$85,000 annually for some years.

Part of this money is spent in the training of physical and occupational therapists to work with amputee children. Both New York State and Georgia, for instance, have sent physical therapists to Grand Rapids along with severely handicapped child amputees so that the therapists could learn the intensive rehabilitation regime which enables the multiple amputees to join other children in work and play. More than seventy children from other States have been rehabilitated at Grand Rapids since the Children's Bureau designated the Michigan project an "Area Amputee Program" in the year 1955.

It was in the year 1935 that the Michigan Crippled Children Commission started utilizing the services of the Mary Free Bed Convalescent Home as the Orthopedic Center of Western Michigan. Here was a case where a great hospital had already grown from a single bed. The Mary Free Bed Guild began in 96 1891 with the endowment of a free bed—one that could go to a charity case—in one of the general hospitals of Grand Rapids. The Guild raised the money "by asking contributions from all women with the given name of Mary," so its leaders explain today, and so says its literature. With this quaint start in the voluntary services health field, the Mary Free Bed Guild went right ahead. In 1911 it was incorporated as a Benevolent Association. In 1920 it sponsored the first Crippled Children's Clinic in Western Michigan. In 1938 the Guild set up a brace shop; in 1942 a dental clinic. It was in character for this institution to house the first amputee center in the United States devoted exclusively to children.

After it took on the program for training amputee children in 1946, it added special programs for children who were victims of cerebral palsy, rheumatic fever, and spinal-cord lesions. A big, new addition emphasized the hospital phase of its work, and its name was changed in 1953 to the Mary Free Bed Guild Children's Hospital and Orthopedic Center. So many badly disabled children have to spend many months there that a complete school. from the first grade to the twelfth, is conducted daily under its roof. It is located at 920 Cherry Street, S.E., Grand Rapids.

In one of its brochures, the Guild sets forth the theory that "a magnetic something" in the very air of the place "has attracted to us the finest physicians, nurses and therapists, and the support of men and women who have found this institution a splendid channel for helping children to triumph over disease and handicaps."

The Area Amputee Clinic conducted by the Michigan Crippled Children Commission occupies a semi-basement section in a hospital wing with its own outside entrance on an automobile areaway. This is a great convenience to out-patients and their parents as they can roll up almost to the entrance and walk down a ramp. Show windows along the ramp are lined with manikins, each wearing a different type of prosthetic device of an upper and a lower extremity. The clinic area itself is equipped with movable partitions. The day I visited, it was set up with a very large room where the clinic was being held, and several little rooms for the taking of records and leaving of wraps and taking off blouses and shirts for the showing of arm prostheses.

Ten years of highly successful operation have given swift, smooth functioning to the prosthetics team in charge. Heading

this team are two orthopedic surgeons, Dr. George T. Aitken and Dr. Charles H. Frantz. Either one or both are present at all clinic sessions. Individually or in collaboration Drs. Aitken and Frantz have produced a sizable amount of the scientific literature in the child-prosthetics field.

At Grand Rapids it was established that the proportionally large number of congenital arm amputees with below-elbow stumps were greatly improved functionally by a prosthesis and that it was harmful to children to hobble on crutches on the theory that they should "wait until they were older" to be given artificial legs.

The below-elbow arm amputation is the most common congenital type. In a series of 76 congenital arm amputations, 49 children, or 64 percent, had the below-elbow amputation. It was found on the left side in a three-to-one ratio in the observations at Grand Rapids. Many parents felt that these children could do well without a prosthesis for the left hand, as they used their stumps well. Nearly all could thread needles, and could hold objects in the crook of the elbow. It was often hard to fit a prosthesis when stumps were short. But it was done with a figure-eight harness and a forearm shell with a child's size Dorrance hook as terminal device. These children soon were demonstrating that they could do everything better—make beds, sweep floors, dress and undress, handle books, erasers, pencils, checkers and toys. They are regarded as but slightly handicapped, with no need for special privileges in school or at home.

The pioneering work on artificial legs and arms for children at Grand Rapids ran all the way from routine to most severe cases, and from infants on through the growing years.

Taking notes at this particular clinic session with his "terminal device" was John Steensma, a bilateral arm amputee who became Prosthetics Instructor when the Grand Rapids clinic became Michigan's Juvenile Amputee Training Center in 1946. Mr. Steensma is the author of a 30-page manual recently published by the Michigan Crippled Children Commission, "A Guide for Parents of Child Amputees." This handbook has been sent all over the United States in response to the queries of parents, and has been distributed to all State crippled children's agencies. His work soon assumed even wider scope when he accepted an assignment with the Church World Service to establish a prosthetics program in Korea.

Advising on engineering problems at the Michigan clinic

was Colin A. McLaurin, quoted in the previous chapter in his role of director of prosthetics research at the Rehabilitation Institute of Chicago. Mr. McLaurin thinks nothing of flying across Lake Michigan early in the morning to size up the forces to be withstood by the prostheses of children at play. His expert knowledge has been especially valuable in devising prostheses for exceptionally difficult cases.

Present with the individual records in her hand was Mildred I. Lineberger, both a registered nurse and a physical therapist, who is in general charge of the child-amputee center. Other participants were Mrs, Irene Ferrell, the medical social worker, who takes the family histories of the children and interviews their mothers when they come in; and Mrs. Shirley Ferguson, medical secretary.

Teen-agers coming in to report didn't dash for the lollipops. But each was ready to reach out for friendly attention. An 18-year-old farm boy from the Upper Peninsula said he wanted to use a bulldozer and needed a heavier hook. He got it. Born with a flail hand, this lad had chosen to have it amputated and to be equipped with something functional. He was glad that he had done so.

A score of children with greatly varying degrees of disability went through the clinic that morning. Children grow. Prostheses get wear and tear. Some small or large alteration had to be made for every one. Only one case had never been there before—a little baby from the Upper Peninsula. The treatment was mostly for the mother—assurance that she did not cause her child to be born without a hand. She had thought it was due to a fall she had before he was born. The surgeon took her to a wall board and showed her the prostheses that children successively wear, starting with a passive mitt. She looked at them closely—and at the happy children at the clinic wearing them. She seemed cheered.

Watching the entire morning's work with evident satisfaction was a frequent clinic visitor, Dr. Carleton Dean, of Lansing, the Director of the Michigan Crippled Children Commission. It was Dr. Dean who initiated modern children's prosthetics in this country. Dr. Dean told of how he had happened to turn crusader in the amputee field.

"I went up into the North Woods one day to attend a field clinic," he said. "A young lad brought in-carrying it in a box

and not wearing it—a sculptured, artificial arm which our Commission had provided for him as one of those on the Federal-State crippled children's program. His father was with him—a strong-faced, grizzled man. I'll never forget the look on the face of that father as he lifted the heavy arm from the box and tried to manipulate it.

"'Take it back with you,' he said, 'It is of no use to us." And he was right."

Dr. Dean said that he had had a survey made of Michigan children arm amputees and had learned that seven out of eight were not wearing their prostheses.

"This was due partly to lack of proper fitting," he said. "But it was basically due to the lack of suitable functional prostheses for the various types of amputation.

"In addition, there were no facilities or procedures to determine whether a child was physically conditioned to accept a prosthesis; or to provide him with instruction and training for its use; or to follow through with care, adjustment, repair and replacement when needed."

Dr. Dean made trips to Washington and enlisted the cooperation both of the then new committee on prosthetics research under Brigadier General F. S. Strong, Jr., and of the Federal Cooperative arrangements were made under Children's Bureau. which research and development on children's artificial arms would be done in Los Angeles: developmental work on children's legs would be done in San Francisco; and the creation of a child hand would be taken on by Colonel M. J. Fletcher at the U.S. Army-Prosthetics Research Laboratory, Walter Reed Army Medical Center, Washington, D. C. And Dr. Dean himself took on the task of starting a child-amputee training center where all the prostheses to be developed would be tried out. Success has been scored on all these fields, and the child hand is now in the testing stage. There are definite high acceptance signs from child-amputee wearers.

From 1946 through 1957, a total of 447 child amputees were treated in the Grand Rapids clinic. Slightly over half of them, 225, were congenital amputees. In 49 of these congenital cases, surgical conversions were performed to make it possible to fit the children with prostheses. The rest of the cases were traumatic, resulting from accidents or from disease.

Because the human havoc of accidents is so unceasingly 100

impressed upon them, the clinic carries on a constant campaign to get parents to guard their small children from disabling accidents and to teach the older boys and girls how to protect themselves. It is pointed out that modern civilization has brought the high-powered automobile, hazardous alike for child passengers and children at play along the highway. It has brought the basement powertool and the powermower on the front lawn. Children ride bicycles on busy highways. On farms they are around mechanized vehicles which do not have adequate safety devices. And firearms go off unexpectedly, resulting in mangled limbs requiring amputation.

An analysis of 300 Michigan children with noncongenital amputations over a nine-year period showed that over 65 percent were traumatic. Slightly over 40 percent were necessitated by railroad, powertool, and vehicular accidents; and 20 percent were the result of explosions and gunshot wounds.

Congenital amputees now being seen in the clinic are usually in the younger age groups, particularly as parents increasingly learn the benefits of getting started early with training in using prostheses Amputations because of accidents are mostly among the older boys and girls.

The records of the boys and girls who have been fitted with prostheses at the Area Amputee Center and who continue to return there from time to time to keep their artificial legs and arms in line with their growth and development are amazingly complete. Each child has his own series of photographs showing progress. Their prostheses, and the changes in them from time to time, are painstakingly diagrammed. Cost accounting is done, not only on these prostheses but also on all the services given each child in the clinic.

One folder shows that a child, born December 28, 1953, was first fitted with an extension pylon. Thus she became used to an arm length like other children. Just the extra length was a help to her in handling things. The passive pylon soon was followed by an active hook, and at four years of age she was adept in its use—could play an accordion, guide a tricycle. Another folder contains photos and records of the first child ever to wear the plastic mitt, sanitary and useful, which was developed by Colonel Fletcher.

A whole series of devices has been developed at the Clinic to help teach little amputees to walk. In the files were photo-



Michigan Montage—Illustrations of the remarkable work being done to rehabilitate children at the Mary Free Bed Children's Hospital and Orthopedic Center in Grand Rapids. The Area Child Amputee Center of the Michigan Crippled Children Commission is located in this hospital. graphs of children using them. There was an arm swing to hold upright babies born without feet—so that they could get a sense of balance. There were stand-up tables, mobile walkers, weighted chairs with casters, and parallel bars.

The arm amputees are taught two-handed dexterity in dozens of ways, but particularly in play. Grade-school boys and girls make the most rapid progress, the records show. They have nearly 100-percent success in learning agility with their artificial arms. Where rehabilitation is well done in childhood, the prosthesis is likely to seem to the child to be as much a part of himself as shoes are to all children. This is not true of the adult amputee.

A tour of the Mary Free Bed Hospital, as it is customarily called, followed the clinic. The Superintendent of the Hospital and some of the members of the Guild showed its swimming pool, hydrotherapy tanks, hot paraffin baths, and all the many other pieces of modern equipment which help in rehabilitation. They led through wards where many types of disability were being treated. But they were proudest of a new playroom on the same floor with the attractive cafeteria, which is in itself a benchmark in the conquest of crippling. This used to be the hot-pack room for the treatment of child polio cases. After the Salk vaccine was discovered, the child polio cases became so few that a separate room for hot packs during epidemics was no longer needed. Now, child amputees in the preschool stage play circle games there, and sit in groups, singing songs and listening to stories.

No medical miracle lies ahead for congenital amputees. But fundamental research into human heredity, the genes, and the chromosomes, such as now is being launched on a large-scale basis, may one day disclose the causes of the various types of congenital amputees—and perhaps what might be done to prevent such amputations and anomalies. The hypothesis thus far is that simple, congenital amputations are genetic accidents. However, Scandinavian studies have shown that such anomalies as the splitray hand, commonly called "lobster claw," and buds of hands at the shoulders and of feet below the hips, are hereditary.

The Grand Rapids amputee team has been greatly aided by the Gesell and other growth and development studies which are used widely by educators everywhere. They know that they can completely count on powerful help from Nature—that, at a certain point in his growth and development, because this urge is 103 implanted in the cell from which he starts, every human being will somehow rise upright and, given the tools to do it with, will walk. This life fact accounts for the almost 100-percent results in teaching child amputees how to walk. From the fundamental research on children in the Gesell clinic at Yale, the members of the Grand Rapids prosthetics team also know what to expect in skills from year to year.

The modern prosthetics work for children, started at Grand Rapids, has begun to permeate the children's hospitals of the nation. In August 1958 the twelve hospitals throughout the country handling the largest number of child-amputee cases began cooperative research under the auspices of the Children's Bureau in cooperation with the Prosthetics Research Board. The directors of these hospitals met in a conference at the Grand Rapids clinic and launched a nation-wide program of testing children's prostheses, with the New York University College of Engineering as the tabulating and evaluating center.

These studies will determine the best age for fitting a baby with an artificial arm, how useful the suction socket is for children under ten years of age, whether the SACH foot is adapted to children's wear, and whether the pre-flexed artificial arm is of advantage to children with below-elbow amputations. This preflexed arm, instead of hanging straight down, is flexed to a 20degree angle and requires less energy in lifting.

The child prosthetics clinics taking part in the tests, in addition to the Michigan Area Amputee Center, are:

NEWINGTON HOME AND HOSPITAL FOR CRIPPLED CHILDREN, Newington, Conn.; THE JAMES LAWRENCE KERNAN HOSPITAL AND INDUS-TRIAL SCHOOL OF MARYLAND, Baltimore; DUKE UNIVERSITY, Durham, N.C.; BIRMINGHAM CRIPPLED CHILDREN'S CLINIC AND HOSPITAL, Birmingham, Ala.; CRIPPLED CHILDREN'S DIVISION, Department of Public Health, Atlanta, Ga.; REHABILITATION CENTER FOR CHILDREN, Children's Hospital, Buffalo, N.T.; UNIVERSITY OF ILLINOIS COLLEGE OF MEDICINE, Chicago, Ill.; MEDICAL COLLEGE OF VIRGINIA, Richmond, Va.; INSTITUTE OF PHYSICAL MEDICINE AND REHABILITATION, New York City; THE SHRINERS ORTHOPEDIC HOSPITAL, Philadelphia, Pa.; ARMY PROSTHETICS RESEARCH LABORATORY, Forest Glen, Md.; NAVY PROSTHETICS RESEARCH LABORATORY, Oakland, Calif.

The last two clinics named furnish prosthetics to the amputce children of servicemen.
CHAPTER X

Dayton—A Dream Come True

As World War II drew to its close, the United States Army conducted a highly secret operation which went by the code name "Paperclip."

The German forces in large numbers were falling into American hands. Card catalogues were being kept of their names and full identifications. Both this country and Russia wanted the benefit of the brains of some of the very brilliant scientists engaged in the development of German weapons. When one of these men was catalogued, his card was marked with a paperclip. A few brilliant women scientists were also marked. Thus was derived the code name of the project.

This operation became known to the German scientists, and some chose the "Paperclip" route, with its assurance of freedom of investigation in the United States, rather than risk Russian capture and certain regimentation of scientific investigation.

The story is still told of how Wernher von Braun, who directed the development of the V-2 rocket, took his equipment and hid in the hills until when both armies were approaching he and his staff got into cars and went and surrendered to the American army. U.S. officers escorted them back to get the equipment. Von Braun has since directed development of Army ballistic missiles.

One of the "Paperclip" scientists, Hans A. Mauch, head of the development of the V-1 rocket used in the bombardment of England, also happened to be an expert in technical medicine, particularly prosthetic devices. His rocketry achievement won for him the highest decoration of the German Government.

Indeed, War Department records show that Mr. Mauch was an expert in many things. As a youth, he studied at the Institute of Technology, Stuttgart and Berlin, becoming a Diploma Engineer in Electrical and Mechanical Engineering. From 1930 to 1935, he was chief engineer for technical development at the Zwietusch Works, Berlin. From 1935 to 1939 he was with the





Hans A. Mauch, developer of the V-1 rocket of World War II, who came to this country as a "Paperelip" scientist. He has pioncered in Space-Age research for the Air Force as well as perfecting that remarkable prosthetics advance, the Henschke-Mauch hydraulic leg.

Wooden ser-up including swing-and-stance-control systems of Henschke-Mauch hydraulic leg.

German Air Ministry where he first directed the development of testing installations for propulsion systems, then of airfield equipment, and finally of rocket and jet engines. His initiative in the jet-engine field is considered a major reason for the head start Germany had in this field during World War II.

From 1939 to 1945, he was an independent engineer for developments in half a dozen important fields. These were: (1) Hydraulic, pneumatic, mechanical and electrical equipment used in aircraft and motor vehicles, hydraulic-energy transmitting devices, pneumatic-energy-distribution systems, high-performance mechanical-energy transmissions, electric controls and measuring devices; (2) filters for liquid and gaseous substances; (3) airfield cranes, movable ladders and platforms; (4) high-efficiency heat exchangers having low air resistance; (5) the V–1, the ME 262 jetpropelled fighter, and remote-controlled missiles; (6) technical medicine, especially prostheses.

The Army officer who drew these publishable facts from the still-secret files of Operation Paperclip was moved to remark as he read them off: "This man seems to be able to do almost anything he puts his mind on."

When Mauch came to this country in December 1946, the Air Force claimed him for its experimental work at Wright Field, Dayton, Ohio. He developed protective equipment for extending human endurance at high temperatures. One such article of equipment was the United States Air Force "Air Conditioned Suit" which he invented and which was the subject of an article in Life Magazine. At that time, Hans Mauch firmly refused to permit his name to be used. For Hans Mauch is a philosopher as well as an inventor, and his philosophy, given at that time, was: "Although I admit it gives me great professional satisfaction to make contributions to the society I live in, I don't think it is essential for my work as a scientist to be known to a great many Much rather than to be famous at the end of my days, people. I would like to be able to state that I have had one or two dozen really good friends."

While the work at Wright Field claimed all of Mauch's regular employment time, the Air Force encouraged him to continue his prosthetic research and development work in his spare time. This he did in the basement workshop of his Dayton home. In this country, he had married an Austrian woman "Paperclip" scientist, Tatjana Schmid.

For some years, Mr. Mauch did his prosthetic research in collaboration with another "Paperclip" scientist, Ulrich K. Henschke, now a cancer research specialist at Cornell University. The main results of this work so far are two hydraulic systems for above-knee amputees, the "Henschke-Mauch Hydraulic Swing-Control System" and the "Henschke-Mauch Hydraulic Swingand-Stance Control System." These hydraulic legs, developed under contract with the Veterans' Administration, were accorded by New York University the full-scale testing reserved for highly important developments.

After eleven years of work as a civilian scientist at Wright Field, Hans Mauch resigned. Given as his reason was the fact that private enterprise required his full-time duty. The Air Force immediately appointed him a consultant to enable continuation of his work on the development of a highly advanced environmental test chamber for the simulation of cockpit conditions in supersonic and space vehicles.

The private enterprise to which he could at last devote his energies was the production of hydraulic legs and other scientific inventions in the field of rehabilitative medicine and human-factors engineering. The laboratory building he now has under construction at 3035 Dryden Road, Dayton, will initially have 5,000 square feet of space on two floors and is so planned that it can be expanded to 26,000 square feet.

In the prosthetics field Mauch is also working on a hydraulic ankle and on a chemical power source for upper-extremity prostheses. He conducted the original investigation in Germany on hydrogen peroxide as a possible energy source for artificial limbs. Other activities of his include the development of a reading machine and of guiding devices for the blind, and work on a personal type of air conditioning, an offshoot of his former Wright Field activities. Both the limb prosthetics researches and the aids to the blind are sponsored by the Veterans' Administration.

A visit with Hans Mauch was included in my trip through the Midwest. As pictured by his fellow scientists all over the country, he turned out to be a rare raconteur who, however, abhors sceing his own words in print between quotation marks.

Mauch sees a prosthesis as a device by which man regains lost abilities or provides himself with abilities nature denied him. In this sense, an airplane is a flight prosthesis, a telescope is a vision prosthesis, and an electronic computer is a brain prosthesis. 108 He calls the swing-and-stance control a "hydraulic brain" located in the artificial leg. He says that throughout the twelve years of its development the initial plans remained unchanged— "just making refinements so it will do everything the amputee wants it to do and nothing he doesn't want it to do."

What the amputee wants the leg to do, he notes, amounts to quite a list: He wants the leg to support him—even in its flexed position—when he stumbles. He wants the leg to yield slowly under his weight when he walks downstairs or downhill. He would like the leg to have swing characteristics of the good leg. He would appreciate it if the leg could be locked at any knee angle. He would like it if all the control functions so far listed could be easily adjusted to match his particular gait and his walking habits.

The list of the things the amputee doesn't want the leg to do, Mauch has found out in his researches, is about as long. He doesn't want the leg to make any noises. He doesn't want it to be significantly heavier than a conventional prosthesis or to have an inferior cosmetic appearance. He would prefer it if the leg needed a minimum of maintenance and repair work. Its price should not be too high, and its life expectancy should not be too short.

The list of what an amputee wants has been included in the new hydraulic leg. The list of what he doesn't want has been ruled out. That all this is nearing accomplishment in twelve years of mostly spare-time activity makes the time period appear relatively short, after all.

Mauch says his World War II work on a rocket which hits the target without a man to guide it is akin in its way to the hydraulic leg—both are simulations of the controls of the human brain, a subject which so fascinated him from earliest youth that it has led him to make numerous inventions in the control field.

In an amputation, he points out, the communication system from brain to leg or arm has been cut off. The ideal thing, the path of the future, he says, is to catch the impulses of the nerve ends and channel them into the prosthesis; and to put pressure and position sensors into the prosthesis and channel their signals through the nerve ends back to the brain.

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CHAPTER XI

New York—Testing and Teaching

The tall towers of New York symbolize many things in American life. Not the least of these is the future hope of a better world through a greater interchange of health information and an active campaign to conquer the afflictions of mankind. The President of the United States chose the United Nations as the forum for his plan to make the health sciences a diplomatic instrument for international goodwill. No better groundwork for such a program has been laid than in the field of modern prosthetics.

New York also serves a highly specialized function in the prosthetics of this nation. It is thought of as the national testing laboratory for prosthetic devices; as the eastern center for the training of prosthetic teams; and—more dramatically—as the location of what has been termed "the world's most comprehensive program for overcoming human disability" with the recent affiliation of the New York University—Bellevue Medical Center and the Institute for the Crippled and Disabled founded in 1917 by Jeremiah Milbank. These two great rehabilitation centers on the East Side of Manhattan are in close proximity to the United Nations building. Both serve as training centers for the men and women of many nations.

It is in New York that the two great streams of artificiallimb and bracing development cooperate the most closely. One stream is the work done in behalf of the veterans—the men who risked their lives in this country's wars. This has its focus in the Veterans' Administration Prosthetics Center. The other stream is the work done in behalf of civilians, in which New York University and the Institute for the Crippled and Disabled have taken leadership. The endeavors of NYU and VA are, in a way, an extension of each other. In the testing of devices, they even work in the same building at 252 Seventh Avenue.

The great medical schools, teaching hospitals, and rehabili-

tation centers of New York University are on New York's East Side. Its testing laboratories are on the West Side. Many times each week, Dr. Sidney Fishman, the psychologist in charge of both prosthetics teaching and testing at NYU, threads his way through the heavy, cross-town, wholesale-warehouse traffic in the interest of his fellow man. He is but one among several hundrd rehabilitationists daily at work on the lower part of Manhattan Island. And here it is a case of East Side-West Side-All Around the World so far as the benefits are concerned.

A sturdy old building which functioned as a cloak-and-suit factory before World War II houses the New York Regional Office of the Veterans' Administration, which is host to the Research and Development Division of the VA Central Office's Prosthetic and Sensory Aids Service and the Prosthetic Devices Study of New York University. Its address is 252 Seventh Avenue. During World War II, this building was taken over by the Federal Government for the censorship operation in this country's largest city and seaport. It has been partially occupied by the Government ever since. A sizable portion of it now is devoted to serving disabled veterans under a rather complicated but common-sense administrative setup.

As the Veterans' Administration itself explains it, Eugene F. Murphy, Ph. D., is Chief of the VA Research and Development Division. He and his staff of a half-dozen full-time employees are a part of the Prosthetic and Sensory Aids Service which has its headquarters in the Veterans' Administration building in Washington, D.C., though physically located in the New York Regional Office. Dr. Murphy is responsible "for planning and conducting a broad program of research, development, and education in the field of prosthetic appliances and sensory aids."

Thus, Dr. Murphy carries heavy, national responsibilities for the successful development of prosthetics for the some 250,000 veterans entitled to the Government's free service to all veterans who require such aids.

He never has to step outside the VA section of the building he is in to see a large sampling of the way the program is going in the actual service to veterans. For, in addition to the hearing-aid and plastic-eye work of the New York regional office, the VA Prosthetics Center is right there, functioning under Anthony Staros, a mechanical engineer. Mr. Staros was graduated in engineering from Cornell University. He received his M.S. degree in engineering from Stanford University. He was recruited to his present post by Dr. Murphy, who won him away from Franklin Institute in 1949. By mutual consent and admiration, Dr. Murphy and Mr. Staros work as such a close team that they are usually spoken of in the same breath. Together they explained the workings of the Center, which serves as a national human-aids plant as well as the service center for the disabled veterans in the region which includes New York.

Under Mr. Staros, the Prosthetics Center in its national research, development, and education program carries on many activities. It fabricates and repairs experimental artificial limbs and other appliances used in "shakedown" and service testing. It fabricates limbs and appliances for problem cases referred there from VA field stations all over the country. It conducts pilot studies on materials and fabrication techniques to study their relative economic values, thus guiding the limb and brace industry. It continuously trains technicians in latest approved techniques in limb and brace fabrication in order—as the VA puts it—"to provide a reservoir of trained people for immediate, temporary expansion of prosthetic and orthopedic shops in the event of war or national disaster."

The guiding genius of the research program is Dr. Murphy, who was in on the start of modern prosthetics research on the West Coast and transferred his field of operations to the East Coast.

Just to walk through the VA prosthetics activities in New York is to know that therein works a man who knows so much about one field that he could be queried for weeks without exhausting this information. This is obvious from the looks of the office where he works, crammed chock-a-block with scientific information. He is not writing mere books but encyclopedias, the current tome to be called "Atlas of Orthopaedic Appliances, Vol. II, Prosthetic Appliances." It is further evidenced by an exhibit which accurately depicts the development of prostheses from earliest times to the present. And, as earlier mentioned, Dr. Murphy was the world authority chosen to draft the curriculum of the first international prosthetics school held in Denmark.

Dr. Murphy told how he got into the field in time to help lay the cornerstone of modern prosthetics research.

"In July 1944, I happened to hear a lecture by Dr. Henry Kessler at the Cornell Club in San Francisco," he said. "I was a Cornell graduate in engineering, and was teaching mechanical 112 engineering at the University of California at Berkeley. Already the Dean of the engineering school had suggested the idea of making my classes more interesting by using the human body as illustration of forces in motion. My students told me that this added to the enjoyment of learning.

"Dr. Kessler, at the time a Captain in the Navy, was surgeon at the Mare Island hospital. He was then introducing cineplastic surgery into Navy medicine. His talk was tremendously interesting. Dr. Kessler then was, and still is, an extremely effective speaker on the whole field of rehabilitation. I lingered to speak with him when he had finished, and we talked for a long time on the mechanics of the human body.

"It was the year of the Eberhart accident—in fact that happened only a month later, in August. I don't know whether or not Eberhart told you the full facts on that. The situation was that in his zeal to get B-29 planes into the air to finish up the war he had worked for 72 hours before the accident with only four hours sleep. He was running the final tests on reinforcing materials for runways so the B-29's could land safely—and time was running out on him.

"These tests were conducted at the Hamilton Air Force Base north of San Francisco on an oval race-track-like type of setup for a heavy truck and trailer which carried increasing loads in a pattern operated from a control-tower structure. The strain gauges were placed in the runway under the track. Eberhart was kneeling on the runway looking through a trap-door at a broken strain gauge.

"He failed to hear the signal for him to clear ahead of the truck—or didn't react to it. Another man pulled him almost out of the way—but not quite. The truck ran over his left leg, crushing it."

As previously mentioned, when Professor Eberhart was fitted with the best artificial leg Mare Island then had to offer—and found it painful—Murphy joined with him in trying to figure out the stresses and strains on it so that it could be made more comfortable. They used patterns of strain gauges on a much smaller scale than those used for the B-29 runway. Their efforts soon convinced them that much deeper research was needed. Professor Eberhart already was starting his body-motion studies with Dr. Verne Inman. Murphy returned to study for his Ph. D. degree in Chicago and also to do all in his power on his trip there to

obtain a research grant to further the Inman-Eberhart studies. This included visits to the Committee on Prosthetic Devices, whose headquarters were then in Evanston, Ill. Because of his already extensive knowledge in the new field of body dynamics, he was invited at that time to join the CPD staff. But he continued his own further studies and earned his Ph. D. degree. Later in 1948, he joined the VA Prosthetic and Sensory Aids Service as Assistant Director for Research and Development.

Over a decade has passed since then, with great improvement in leg prosthetics and a real revolution in arm prosthetics. Now, these programs have progressed sufficiently so that Dr. Murphy can turn his constructive attention to the field which affects him personally—bracing. He formerly wore a leg brace and still uses canes, the result of polio in his youth.

In the last ten years, bracing has advanced to the point where it has become a profession called orthotics. Those who practice it are called orthotists. But it has been a halting progress compared to the prosthetics advance spurred on by the World War II clamor of the amputees.

In collaboration with a physician, Dr. Augustus Thorndike (formerly Acting Director of Prosthetics and Sensory Aid Service— PSAS), Dr. Murphy and Mr. Staros prepared an important scientific paper analyzing the then unsatisfactory brace situation and charting future development in orthotics. This work has been carried forward in the New York VA laboratories and in the 28 orthopedic shops in veterans' hospitals throughout the country.

Complaints about leg braces, these three men reported, showed remarkable similarity. The wearers wanted lighter, less bulky appliances. Braces caused excessive clothing damage, lubricant staining, and actual tearing of clothing by the joints of the braces. To protect clothing, the brace wearers did not lubricate their braces—only to be embarrassed by metallic squeaks as they moved. Unlubricated metal rubbed against metal with gradual loss of stability of the appliance. The breakage of braces was all too common. And the brace wearers complained of the inconvenience and cost of repairs.

"There has always been pressure to lower the cost of orthopedic braces," the Thorndike-Murphy-Staros report stated. "All too often the patient himself and his family are restricted in paying for braces because of the high costs associated with the prior illness or other conditions requiring braces. Many public agencies 114 responsible for supplying braces have tended to secure them from the low bidder, with inadequate specifications because of the difficulties of specifying such intangible factors as comfort for the patient and high skill on the part of the bracefitter. Nevertheless, better braces can be produced at less shop cost, more profit to the braceshop, and yet lower cost for both purchase and maintenance to the ultimate consumer.

"The increasing use of stainless, sanitary, and abrasionresistant materials should help to reduce maintenance. In fact, higher first costs for the small amounts of such materials should prove a very good investment. In general, the cost of the materials is only a small fraction of the total cost of the appliance, so that the best materials are none too good."

Studies made in the New York VA laboratories of manufacturing techniques and fabrication methods in orthopedic bracing have shown that the use of prefabricated parts, turned out by mass production as standardized subassemblies, results in braces which are more economical, yet of superior quality to those made from handmade parts.

"The central manufacturer of prefabricated parts can afford an excellent design staff, accurate machining and modern equipment and careful quality control," the report set forth. "Provided with prefabricated parts, the orthotist can select and readily assemble a complete brace to meet the requirements of most orthotic conditions. . . . As a result of saving time at the forge and milling machine, the orthotist will have more time for self-education, clinic meetings, and for solving difficult 'problem cases.'"

"The time has come in this country to start punching prefabs instead of using the old blacksmith-and-forge technique," said Anthony Staros, putting the gist of these scientific findings into the vernacular.

"The gains are great in over-all economy, uniform quality, and greatly reduced repairs. Braces are better designed, more durable, and replacement is easy because the standard parts fit interchangeably."

Mr. Staros said that much more study needs to be given to the special brace requirements for various orthopedic conditions. This is particularly true for polio victims, since any combination of muscles may be affected temporarily or permanently by that disease.

"We are trying to persuade physicians and orthotists that

many patients are being fitted with heavy steel when light aluminum would do better," he said.

"On the other hand, an orthotist, who has dealt chiefly with polio patients and become expert in the use of aluminum, may put braces that are too light on a spastic patient. In spastic conditions due to cerebral palsy or paraplegia, it is generally necessary to prevent unwanted motions while encouraging those considered desirable. Great rigidity is necessary in some sections of the braces as the spastic reacting forces are very high."

More study should be made of plastics in bracing, he added, particularly as component parts in leg and functional arm braces so that aluminum would not rub against aluminum. And he said that there was a great field to be explored in the use of plastics for back bracing, now recognized as being frequently unsatisfactory.

Dr. Murphy cited the back brace studies of Drs. Paul L. Norton and Thornton Brown at the Massachusetts General Hospital in Boston, which showed that no back brace then in use did what it was intended to do—immobilize the spine—after spinefusion operations.

These studies were made by drilling pins in the vertebrae and recording bone motions, the technique devised by Dr. Verne Inman for early shoulder-motion studies, and used also for the Inman-Eberhart leg-motion studies.

"The Boston studies showed that some of the back braces being widely used not only failed of their purpose but also did precisely the opposite of what they were intended to do," said Dr. Murphy. "A patient with a spinal anomaly requires a brace that will provide the necessary immobilization in the involved part, yet will permit the maximum function of the remainder of the body, so that the back will be free to move over as great a length as possible.

"The Boston tests showed that some braces practically reverse the process, tending stringently to limit gross torso movements yet not adequately immobilize the involved segment of the spine. A normal subject, uninhibited by pain, was able to move the critical vertebrae in bending forward against the brace even more than he did in bending forward without a brace. This was possible because the pressure of the brace exerted a force of its own—it was almost a high-resistance exercise!"

The result of the Boston studies was that Drs. Norton and Brown developed a better brace under the VA project, then con-116



Dr. Eugene Murphy, Chief of the Research and Development Division of the VA's Prosthetic and Sensory Aids Service, New York City, as first Fulbright lecturer in the field of prosthetics.

Part of the collection of below-knee prostheses at the VA Prosthetics Center in New York City, showing need for simplification in this field, as was recently accomplished at the Biomechanics Laboratory in San Francisco. tinued, with the aid of a grant from the National Institutes of Health, to study the dynamics of the spine itself. This new and different type of back brace is now being tested out on patients. Dr. Murphy has termed this an encouraging development, but he holds that no single innovation can meet the need.

"The striking variations between back braces and between the individuals wearing them suggest further adaptation to this field of the prescription team which has been so effective in solving prosthetic and orthopedic appliance problems," he said. "The doctor, the bracefitter, the therapist, plus any other necessary consultants, can select and later evaluate the particular appliance logically needed for the individual patient."

Dr. Murphy and Mr. Staros took me through the orthopedic shoe center where the lasts of the 8,442 veterans throughout the United States requiring orthopedic shoes are on file, ready for re-orders at all times. Case on case are filled with boxes containing these lasts, numerically identified.

The orthopedic shoe center, which includes a first-class leather-working shop, has tremendously raised the standards of fitting such shoes for veterans. In each VA field station is an expert on measuring a patient's feet for corrective shoes. These measurements are sent to the New York center where a permanent last is made from them. The center deals with several shoe manufacturers willing to give special attention to custom shoes. The manufacturer makes a pair of shoes, using the special lasts. The shoes are sent back to the field station and fitted by the expert who made the original measurement. If he finds that they are satisfactory, the lasts are stored and later pairs of shoes are made, as needed. If not, adjustments are made until the lasts are satisfactory. Each veteran has two pairs of satisfactory orthopedic shoes at all times, so he will always have another pair to wear when one goes back to the center for repairs.

After the initial fitting, the VA Center in New York acts as a mail-order house, dealing directly with the veteran. Moving from one State to another does not cut him off from his source of supply on custom shoes. If his feet change shape so his shoes no longer fit, he merely goes to the nearest VA field station for a recheck of measurements. It is simple for him to get repairs, and the mass-purchasing by VA reduces the cost. Even with the inflation of recent years, the Government has been able to supply veterans with orthopedic shoes at a cost of only about \$37 per 118 veteran per year. Cost studies have shown that the orthopedic shoe center saves the Federal Government between \$70,000 and \$80,000 a year.

This entire operation, like the national contracts with most qualified artificial-limb facilities, was made possible by a special law, Public Law 85–56, under which the Administrator of Veterans' Affairs may procure prosthetic appliances and special services required in the fitting, supplying, and training and use of prosthetic appliances by purchase, manufacture, contract, or in such other manner as he may determine to be proper, without regard to any other provision of law. In less legalistic terms, gone forever from the entire veterans' prosthetics field is the pernicious provision that contracts for such services—often involving intangible qualities like comfort—should go to the lowest bidder.

No more modern and expert shoe repair and custom-manufacturing shop could be found in the country than the one the New York VA Center maintains as a regional service and as a check on materials and costs in the servicing of veterans with corrective shoes the country over.

My guides took me through laboratories in which prosthetic devices, from stump socks to entire artificial legs, are put through motions similar to human wear to test durability. The VA takes nothing for granted. For any product to be placed and to stay on the VA recommended list means that it stands up under wear.

Most sought out by visitors at the VA offices in New York is the third-floor exhibit. The visiting hours are from 9:00 a.m. to 4:30 p.m. The official title of this unusual display is "Prosthetic and Sensory Aids Reference Exhibit"—and it actually serves as the master reference exhibit on devices in the prosthetics field. It also maintains the most complete collection of books, pamphlets, patents, slides, and films on prosthetics in the United States.

One small item on exhibit is a photograph of the vast, stored collection of strangely assorted below-knee prostheses. On file are literally hundreds of individual makers' different ideas of a substitute leg for the person who has had a low amputation. Every conceivable way to harness on an artificial shank is presented—clear evidence for the need of such research as Professor Charles Radeliffe has been successfully conducting at Oak Knoll to simplify this field.

As significant new advances are made, they are added to

the display. However, in reviewing the prosthetics progress he has witnessed since World War II, Dr. Murphy did not mention latest devices. He mentioned men who were pictured in connection with early embryonic projects and who now have to their credit major achievements.

And he termed the American Board for Certification in the prosthetics field the most noteworthy advance of all because it guarantees to the customer that he is buying a modern prosthesis from an expert professional who knows how to fit it. Any citizen may look for the American Board for Certification insignia on the sleeve of his prosthetist; and for the shop certification on the wall of the place he patronizes. These are assurances of competence. All Veterans' Administration fitters are certified, and so are the shops in which they work.

Obviously, most of the work at the VA Prosthetics Center is linked closely with the correlating efforts of the Prosthetics Research Board. Indeed, the Board serves as the advisory body to VA on all matters pertaining to research, development and education in the field of artificial limbs. The Board also recommends the acceptance or rejection of all experimental limbs, terminal devices or components, developed and evaluated under the prosthetics research program.

This evaluation, conducted under the direction of Dr. Fishman of New York University, goes forward daily in the Seventh Avenue Building, elbow-to-elbow with the workings of the Veterans Administration.

It was set up there for the purpose of testing out on human beings the many devices developed in the early years of the "crash" prosthetics program. Devices were coming in so fast the VA was overwhelmed by them. The only way to appraise their usefulness in keeping with the new scientific philosophy was to subject them to scientific tests in actual use on men. On recommendation of the Advisory Committee on Artificial Limbs, a contract was awarded to New York University to undertake studies in how to evaluate a prosthesis in actual use on an amputce.

Because the man who wears the prosthesis is of chief concern in the rehabilitation process, a psychologist—Dr. Fishman was put in charge when the New York University testing program was set up in August 1948. In the decade since, the Prosthetic Devices Study, Research Division, College of Engineering, New York University, has published 27 major technical reports on as 120



Testing the dynamics of an artificial leg on the elaborate walkway of the Prosthetic Devices Study at New York University.

many significant devices tested under Dr. Fishman's direction, has made available some additional 75 reports dealing with less comprehensive evaluations. The testing starts when a device is in embryonic form, and continues until it is ready for commercial use.

"A few prototypes come to us as a new idea enters what the Prosthetics Research Board calls Phase II—the transition from basic research to development," said Dr. Fishman. "This is for the purpose of discovering early whether the device has sufficient merit to warrant spending money on its ultimate production.

"In this phase of the program two or three models of the device are tested. If these pass the evaluations successfully, a decision is made whether or not the item merits being placed into production. This 'Production Model Phase' is called Phase III. In Phase III we really put it through the paces on a test of 12 to 18 models and we then issue a technical report for the use of 121 prosthetic clinics on each item that is approved for general amputee use." These tests made in the NYU laboratories are among the many projects financed through the \$1,000,000 in prosthetics research funds annually appropriated by Congress to the Veterans Administration.

"Only when the significance of the device warrants it as a notable service to amputees do we conduct field tests.

"In our ten years of experience, we have tested perhaps a hundred items in Phase II, twenty-five to thirty in Phase III, and only about ten warranted field evaluation. These ten include, of course, the Henschke-Mauch hydraulic leg, the Navy aboveand below-knee legs, the APRL hand, the APRL hook, cineplastic procedures, and the University of California above-knee fitting-and-alignment procedures. The new UC below-knee devices are the latest on this list.

In the device-testing process a highly specialized new vocation, open only to amputees, has grown up. This is the expert who is able to aid greatly in the evaluation of legs or arms by wearing many types for comparative comfort, ease of operation, stability, and general performance. Outstanding among such specialists have been Herbert Kramer, of the NYU laboratories, for above-knee leg devices, and—before he went into the artificiallimb business with the Dorrance firm—Jerry Leavy for artificial arms.

"During the developmental stage of a device," said Dr. Fishman, "we use only our own staff of sophisticated amputee wearers. For the Phase III testing, we recruit from the community. To these volunteers, we pay nothing but incidental expenses such as the local transportation to this center. We find an ample number of New York amputees interested enough in prosthetics progress and in their fellow amputees to take part in this process. The only reward held out is that if the device the amputee is wearing is satisfactory to him, he may keep it as his own when the testing period is over."

Dr. Fishman said that Phase III testing is not conducted for the purpose of proving a device good or bad, but to establish its adequacy in various respects for different people under different conditions of wear.

"Ours is an effort toward developing prescription principles to aid the physician who is going to use it on a patient—comparable to the way in which new drugs are developed," he said. 122 The broad-scale field tests are for a further purpose—to build up a mass of evidence and educational material which will win wide acceptance for a greatly improved product, somewhat comparable to the field tests used in the development of Salk vaccine.

The 16-person testing staff working under Dr. Fishman is divided into four groups, each working in his own area but with constant collaborations. These are the Engineering Group, the Medical Evaluation Group, the Psychological Group, and the Prosthetic Evaluation Group.

The engineering section of the NYU-VAPC laboratory, with its mirror-reflected walkway, interrupted-light photography and ingenious, electronic measuring devices, attracts a continuing stream of visiting scientists from this country and abroad.

The device which is of the most general interest there has to do with interrupted-light photography. A still camera with a rotating disc mounted in front of the lens is used on subjects on



One of the intricate motion patterns resulting from the interruptedlight photography used in the Prosthetic Device Study.

the walkway. The joints and limbs of the subject are marked with highly reflective tape, Scotchlite. Slots in the rotating disc permit a light beam, reflected from the Scotchlite, to pass through the lens at one-twenty-fifth-of-a-second intervals, producing repetitive, still images on a single frame of the photographic film. The images appear on the film as lines of light giving sequential positions of joints and limbs in space and time in the walking process. These images look like sticks, and the sequences are called "stick diagrams."

Still another NYU development makes possible direct electrical recordings of body speed in a horizontal direction, and the accelerations of the center of gravity of the body in all three planes during walking. This is of great value in the prosthetics field since it indicates the smoothness of gait and the wearing comfort of the prosthesis.

Such devices have made possible highly exact studies of gait in both normal subjects and amputees. Only male subjects have been studied. The studies of female gait are still to be made.

The engineering group has also been active in the development of additional techniques for the analysis of the kinematics and kinetics in human motion. Six of these devices have been described in a new NYU report. One makes possible determination of dynamic load distribution on sockets and sidebars in below-knee prostheses. Another determines pressure between stump and socket in artificial legs. A third test records the amount of body sway and permits determination of the load distribution on the good and prosthetic legs during standing. A fourth tests the ability of amputees to maintain balance on slopes. A fifth tests the ability of amputees wearing particular artificial legs to maintain balance on a rolling platform. The sixth determines the mass center of gravity and mass moment of inertia of living body segments.

The Medical Evaluation Group considers the effects of an experimental device or prosthesis upon the medical condition of the amputee, both as to his general health and as to the condition of the amputation stump. It observes and rates the performance of each wearer with his prosthesis. To obtain comparative data, the subjects are evaluated prior to the use of the experimental item, and again after extended use of the new device. The group records reactions of the wearers as to the comfort, fatigue, and ability to perform of the experimental item. It analyzes the 124 possible anatomical and physiological changes to be expected from a new device. Often, new methods must be devised to make such tests.

A dramatic recent example was the development of the new University of California below-knee fitting which permitted the amputee to do away with thigh laces and metal sidebars. This type of device made drastic changes in weight distribution on the stump, removed the external stabilizing effect of the metal hinges on the knee, and permitted the anatomical knee mechanism to function in a more normal manner.

A Prosthetic Evaluation Group of three certified prosthetists performs the vital role of applying experimental devices or techniques to amputee subjects. Their prime concern is the proper application of the new item so that its effects may be evaluated. However, they also consider it their duty to look at each new device from the viewpoint of the practicing prosthetist. They consider such matters as skill and time requirements of fittings and the frequency and extent of prosthetic service. When called upon to apply a prosthetic technique that is radically different from procedures currently in use, they develop instructional materials for the use of prosthetists.

The psychological group has developed a battery of tests for the screening of amputees to take part in the testing. In order to make the results valid, some volunteers have to be ruled out, such as those not capable of carrying out a long-term plan and those who have nervous habits of tinkering with their prostheses.

More important, however, is the psychological testing of an amputee's reaction to all that goes with being fitted to a prosthesis. In such studies, the psychological puzzle of the phantom limb and of phantom pain looms large. A paper setting forth some challenging ideas on this subject has been published by NYU psychologist, Samuel A. Weiss.

It is his theory that the mind of an amputee clings to the feeling of the presence of a lost limb because of his subconscious rejection of a negative change in his own body image. He may even suffer the feeling of intense pain in the phantom for the assurance it gives him that if the limb hurts it must still be there.

Dr. Weiss sees in these hypotheses some possible positive values for the future development of prosthetics.

"It seems to me that a complex prosthesis, such as a hy-645523 O-62-9 125 draulic leg, may be more readily integrated into the body concept of an amputee," he said. "Give him a wooden or a plastic leg, and he feels that it is artificial. Give him a well-functioning, complicated mechanism and, to some extent, you may approximate the complexity of the natural limb he has lost."

As another practical aspect of this theory, he spoke of the considerable time which now elapses between an amputation and the fitting of an artificial leg.

"This involves the amputee in a conflict between the concept of himself as a whole person and his amputated state," he said. "The longer the period of time between amputation and fitting, the more difficult it will be to restore the original self image of the amputee since neurotic mechanisms will operate during this waiting period. If it were medically feasible to fit the amputee immediately after amputation (although the leg undoubtedly would require changing because of shrinkage and other factors), the feeling of emptiness on the part of the patient would not develop to the extent that it presently does. The amputee would learn to integrate his artificial limb before being compelled to make a revision of the self concept from nonamputated to amputated-from amputated to 'not whole'-and then again from not whole to 'whole-with-prosthesis.' Immediate fitting would eliminate the difficult transitions and enable the amputee to retain the integrity of wholeness and of his former self image."

The field testing service of the NYU group is now chiefly concerned in the analysis of the vast amount of data gathered by the upper-extremity field studies which followed prosthetics schools of 1952–54. This gigantic task will be completed soon.

"These schools and field studies were conceived and carried out by General Strong in his determination to see to it that the Korean veterans who had lost an arm would have no cause for complaint as did the veterans of World War II," said Dr. Fishman.

"When the Korean hostilities opened, there was little chance that any leg amputee would feel that he had a grievance against his Government. The suction-socket prosthesis already had been widely accepted throughout the country, and any fighter who lost a leg knew that the best science then had to offer would be available to him.

"But General Strong had no such assurance as to the general availability of the comparatively light, functional arms which 126 had been developed at Los Angeles. He therefore sent out a prosthetics expert, Howard Thranhardt, of Atlanta, Georgia, to see how closely general practice came to the arm-fitting principles worked out by UCLA. Mr. Thranhardt found a great discrepancy."

Dr. Fishman said that General Strong then came to him with the proposal: "Let's take a city in which the gap is as wide as it is anywhere else, and make it a test case in the improvement of prosthetics practice. Let's see what gains could be made by offering incentives."

"We picked Chicago because Dr. Clinton Compere was there to cooperate with us," said Dr. Fishman. "I was authorized to go to Chicago and invite a group to go in early 1952 to the University of California at Los Angeles at government expense to learn the fabrication, fitting, and training in the use of modern, functional, plastic artificial arms. Included in the group were doctors, limbfitters, and therapists.

"They came back to Chicago and put into practice what they had learned at UCLA. In one year's time, they had completely revolutionized the care of upper-extremity amputees in the city of Chicago."

Dr. Fishman said that this signal success stimulated the holding of similar schools for clinic teams from other large cities.

"We started with arm-prosthesis schools for the thirty clinics of the Veterans' Administration and then opened them for an additional 45 civilian clinics," he said. "This time we offered no travel subsidy. The physicians, prosthetists and therapists already were convinced of the value of the training and were willing to pay their own way to school.

"We held twelve schools in all for 85 clinic teams and had ten field representatives visiting each clinic once each month for two years, checking on the continuing performance of the artificial arms. These schools proved to be of tremendous educational and social value. They changed nation-wide arm prosthetics practice, dramatically for the better, in three years. Nobody wears a heavy wooden arm any more.

"No incentives had to be offered three years later when schools were set up to teach prosthetics teams the leg-alignment techniques worked on at the University of California."

Dr. Fishman said that he had been happy to note that, due to the foresight and imaginative action of General Strong, no complaints with regard to their artificial arms came from the Korean veterans.

"Not that I blamed the veterans of World War II," Dr. Fishman added. "The arms that were fitted to them when they came home were unfortunate things to have to wear."

Because of the special problems involved in prosthetic restoration for the juvenile amputee, a separate but integrated evaluation program has been established under Dr. Fishman through the support of the Children's Bureau, Department of Health, Education, and Welfare and the New York State Department of Health. The patterns of operation of this Children's Evaluation Group of four professional workers follow the previous discussions to a great extent. However, they have been modified so as to take into account the very significant variables of growth, development and coordination, parental attitudes and psychosocial-environmental influences which affect the use of a prosthesis by a child.

The first Medical School of New York University, built in the 1860's and now the Dental School, has somehow found space to accommodate the University's Prosthetics and Orthotics School directed by Dr. Fishman. The stone steps of this sturdy brick at 435 First Avenue are worn by the footsteps of generations of medical students. A historic plaque takes up a large portion of the wall in its entrance hall.

Here, in quarters once occupied by Dr. Jonas Salk in his early polio experiments—with no plaque to mark the spot—Dr. Fishman conducts courses in upper-extremity prosthetics, lowerextremity prosthetics, lower- and upper-extremity orthotics, and body bracing. The courses follow one upon the other, in swift succession, and there always is a waiting list for the next one.

Four types of rehabilitationists come to learn new techniques in prosthetics and orthotics, and how to work in prosthetic and orthotic teams, in these short, intensive courses. They are: physicians and surgeons, prosthetists and orthotists, occupational and physical therapists, and rehabilitation counselors who usually are employed by the Vocational Rehabilitation offices in the various States. These counselors study both prosthetics and orthotics.

The courses are so arranged that when some special technique, such as above-knee prosthetics is being taught, the prosthetists arrive first and have classes for three weeks, the therapists

come for two weeks of classes, and the physicians take a one-week cram course. Each course culminates in the division of these disciplines into a dozen clinics, each in its own cubicle, each with a faculty adviser to help prescribe a prosthesis for some patient with a difficult case. Each prosthetist fits five or six patients with a prosthesis during each course.

The patients who are fitted are paid for their time. They are not permitted to purchase the limbs made for them as limb production is so lively at the New York school it soon would upset the commercial market. Between thirty-five and forty limbs are fitted during each three weeks' short course. When the course is over, the prostheses are dismantled and many of their parts are used again.

Dr. Fishman said that he looks forward in the not far distant future to the establishment of a four-year undergraduate course at NYU for the education of prosthetists and orthotists with the awarding of a B.S. degree in those fields upon graduation. This skilled profession thus would be put on a par with many other comparable professions requiring a scientific education. But until that happens, he said, short and intensive courses will have to be kept available to train new prosthetics personnel and furnish "refresher courses" for those long in the field who wish to keep up with new techniques in a fast-developing science.

In this field in which textbooks are still scarce they are continuously being compiled both at New York University and at the two California universities. Dr. Fishman said that great care is taken on both coasts to make sure that the texts supplement, and do not duplicate, each other. Two texts produced by NYU which have had wide use since they were made available in 1957 are "Notes on the Management of the Above-Knee Amputee" and "Notes on the Diagnosis and Treatment of Above-Knee Fitting Problems."

CHAPTER XII

New York— World-Reaching Rehabilitation

World-known and world-serving is the modern seven-story Institute of Physical Medicine and Rehabilitation of the New York University—Bellevue Medical Center at 400 East Thirty-fourth Street. It is headed by Dr. Howard A. Rusk, physician, educator, organizer, and national and international advisor in the field of physical medicine.

Dr. Rusk is also a member of the Prosthetics Research Board of the National Academy of Sciences—National Research Council. He views the advances made in the prosthetics field since World War II, largely as a result of the activities which the Board has coordinated, as a possible boon to all mankind, particularly in the underdeveloped countries being aided by the Agency for International Development. He contends that making modern artificial limbs and braces available in these countries would dramatically further President Eisenhower's announced policy of promoting peace through international health and medical projects.

The Institute of Physical Medicine and Rehabilitation has grown swiftly since it was started by Dr. Rusk in 1948, aided by the warm interest of such philanthropists as Bernard M. Baruch, Mr. and Mrs. Bernard F. Gimbel, the late Louis J. Horowitz, internationally known builder, and Mrs. Mary Lasker. But its story goes back further than this. Thirteen years ago, on May 12, 1946, the name of Dr. Howard A. Rusk appeared as author of an article in the New York Times Sunday Magazine—a challenging article titled, "Forgotten Casualty: The Disabled Civilian." The subtitle read, "For his rehabilitation a plan is put forward to use the techniques we used in wartime." World War II hostilities had recently come to a swift close after the dropping of the atom bomb. "Daily on the streets we notice the disabled men in uniform," said Dr. Rusk in this article. "Our sympathy is aroused by the campaign ribbons and the Purple Heart which tell the mute story of a missing arm, an amputated leg, or some other type of combat wound. We want to do something for them. We want them to have the best that care and money can provide. Our attention is focused on the veteran, but the disabled civilians have become an accepted part of our daily scene. We see them hundreds of them daily—on the streets of every city. They are part of our pattern of living—commonplace casualties we take for granted."

Dr. Rusk then described the intensive rehabilitation of a veteran who had lost both hands through a land-mine explosion in Normandy.

"The final step was an amputation center, where the hooks that he would learn to use instead of hands were fitted and his classes began," he continued. "That meant practice and more practice. Open the door, pick up a glass, cut the meat, answer the phone, dress and undress. When he had mastered all these and a hundred other things, he was ready to go home. He had learned to replace his disability with a capability, to create in cold, mechanical steel the power to lead an active, useful life."

Dr. Rusk pointed out that there were 17,000 amputees in the Army in World War II and that during that same period there were 120,000 major amputations resulting from accident and disease in the civilian population.

"The sorry truth is that the majority of our disabled civilians, unlike our veterans, have no place to go to re-learn the activities of everyday living and new skills."

As author of that article, Dr. Rusk was starting a new career in answer to his own challenge—one that would take him all over the world.

Before World War II he had been a highly successful young doctor of internal medicine in St. Louis, Mo. As a physician in uniform—a Major in the Air Force—he was confronted with a problem which he set about to solve in a forceful way.

Men whose wounds had been healed, but who had not yet been pronounced fit for strenuous active duty, remained idle in hospitals for weeks and even months. Dr. Rusk instituted a program of physical conditioning and rehabilitation for these soldiers which astonished the nation and changed medical practice. This program demonstrated that long periods of quiescence weakened instead of strengthening the human body. Dr. Rusk was called to Washington as a consultant. Before the war ended, his system had been put into effect in 253 hospitals and 12 rehabilitation centers. It even spread to the maternity wards of civilian hospitals so that the "lying-in"period was cut from three weeks to a few days.

Very soon after the close of hostilities, when Dr. Rusk was facing a decision as to whether to return to his practice or to turn it over to his partners and continue in the new physical medicine field which had come to fascinate him, he met Arthur Hays Sulzberger, the publisher of the New York Times, at a dinner party. In the course of the conversation, he spoke at some length on his idea that the rehabilitation available to veterans should be extended to civilians. Mr. Sulzberger soon thereafter offered Dr. Rusk an editorship through which he might promote his idea.

"I recall," said Dr. Rusk, "that Mr. Sulzberger remarked that he believed the general acceptance of such an idea might be shortened by a decade by having a regular forum through which to reach the people."

Dr. Rusk said that he declined the offer, telling Mr. Sulzberger he was not a writer.

"But every few weeks I received a letter, sometimes not more than a single sentence, saying the offer was still open," said Dr. Rusk. "And soon I accepted and asked Eugene J. Taylor, who had been working with me in the Army Air Forces Program, to join me. I haven't missed writing a single weekly column for the New York Times in the thirteen years since—and I feel that Mr. Sulzberger was right—that public acceptance of rehabilitation has been shortened by ten years through the sustained interest manifested by the New York Times."

In 1948 Dr. Rusk was made Professor and Chairman of the Department which would set up the NYU Institute of Physical Medicine and Rehabilitation.

At New York University, he joined Dr. George G. Deaver who had been his civilian consultant during the Air Force days when the latter was Medical Director of the Institute for the Crippled and Disabled. To round out his team he called in a third man who had been with him in the Air Force program from

its inception, Dr. Donald A. Covalt, founder of the first comprehensive rehabilitation service in the Veterans' Administration.

With alter egos on both jobs, Dr. Rusk could drop down to Washington to give consultative service. He could make trips to European countries, including Russia, and to the far-off underdeveloped lands such as Burma. Always his object was to promote interchange of rehabilitation information between nations.

Starting with only thirty-five beds, the Institute doubled, and then doubled again. In its serene setting of great glass areas and blond woods, human life is highly lively. From entrance hall to roof, the whole place seems to be permeated with the spirit that with intense effort and expert aid it is entirely possible to triumph over any and all disability. This expert aid, of course, includes clinic evaluation by every discipline involved—psychiatrist, surgeon, physicist, prosthetist, and so on. It includes the help of skilled therapists throughout the treatment. Floor on floor wheelchairs roll, people do pushups on exercise mats, bright-eved nurses bustle about, and nonchalant internists of all nationalities are busy on their patient charts.

New York millionaires, famous ballplayers and radio announcers, and waifs from city streets are treated there on a basis of absolute equality, sleep in the same dormitories, follow the same regimens, and share with each other the many small triumphs on the road to getting well. There is no race or color line anywhere.

Dr. Rusk's own beautiful office on the sixth floor has on its walls many plaques in recognition of his services to humanity in this country. Wall cabinets hold many decorations from foreign governments and art objects representative of the many countries where he has given demonstrations of how physical medicine can help humanity.

The chair which Dr. Rusk holds as Professor of Physical Medicine and Rehabilitation has been endowed and named for him. It is seldom that a university chair is named for a man in his lifetime. Louis J. Horowitz specified in his will that the chair be named for Dr. Rusk when he left a half-million-dollar endowment for it. Mr. Horowitz left an additional ten million dollars to the Institute with the stipulation that its income go to paying for the care of patients who cannot afford to pay. Fifty-eight physicians and eleven nurses, prosthetists and therapists from thirty-five foreign countries are now taking longterm training at the Institute. Other foreign physicians, nurses, and therapists who have had short terms of formal training there within the past year bring the number up to well over three hundred. When foreign doctors come to the Institute, they also have access to the rich teaching resources of all the other medical centers conducted by or affiliated with New York University. These include a half-dozen huge city hospitals and fourteen smaller satellite hospitals all over the metropolitan area. Foreign physicians and therapists are rotated through these hospitals to get the specific training that they need to go back to their countries and set up little Institutes all over the world.

This special service to foreign countries has been, to a large degree, financed by the World Rehabilitation Fund, Inc., of which Dr. Rusk is President and Mr. Taylor Secretary-Treasurer. Serving the Fund as honorary chairmen are former Presidents Herbert Hoover and Harry Truman, Bernard M. Baruch, and Dr. Albert Schweitzer. No public appeal has ever been made by the Fund.

It has become Dr. Rusk's custom to hold conferences frequently with the heads of great corporations with large financial stakes abroad to interest them in the program of the World Rehabilitation Fund. Among the firms which have aided the Fund are the IBM World Trade Corporation, Charles Pfizer and Co., Inc., Monsanto Chemical Co., Bulova Watch Co., Smith, Kline and French Laboratories, Radio Corporation of America, Merck and Co., Inc., and the American President Lines. The Sinclair Oil Corporation has created fellowships for training in this country of rehabilitation personnel from Venezueia, and General Foods Corporation through its Franklin Baker Division is supporting a rehabilitation center in San Pablo, the Philippines.

Long-term training has been given prosthetists from Japan, Korea, Burma, the Philippines, Colombia, Guatemala, Portugal, Bolivia, Thailand and Spain.

Dr. Rusk said he got the idea of setting up such a Fund when he went to Poland in 1949 as a consultant for the United Nations. He found there were thirty thousand amputees in that country, more than this country had in all its armed services as a result of World War II. "Although it was shortly before Poland disappeared behind the Iron Curtain, and there was much anti-American feeling among Polish officials, I found them ready to work with me on this common problem and almost pathetically grateful for any helpful suggestion," he said. "I thought then that if Poland and the United States could work together on problems like this, they might one day understand each other and work in peace.

"Again, in 1951, I was forcibly struck with the great potential for international understanding through the field of medicine when I attended the International Congress on the Welfare of Children in Stockholm, Sweden. Three hundred people were expected. Eight hundred came from all over the world. Each nation set up its little display on a card table covered with a white cloth. It was a new social phenomenon of nations sharing with each other the results of their studies in polio, their new ideas in braces and prostheses—anything that they thought might help out. There was never an empty seat in any meeting. And I heard not a single word of religious differences, partisan politics, or bigotry all the while I was there."

Dr. Rusk did not lose his special interest in Poland. He and Mrs. Rusk revisited Poland in 1957 and he provided the rehabilitation services for the Polish women victims of Nazi medical atrocities who were brought to this country in December 1958 to live in Polish families and become out-patients of hospitals in the New York area. These women—several of whom later had professional careers as artists, teachers and physicians—are referred to as "The Ravensbrueck Lapins" because a Nazi surgeon, later executed for his crimes, regarded them as rabbits for experiments in bone grafts for injured German soldiers and for tests of new drugs on bone infections.

The World Rehabilitation Fund got under way in 1954. Since then it has sent prosthetics consultants to Korea, Burma, Thailand, India and Jordan and medical consultants to many countries. It has aided in organizing rehabilitation congresses in Europe and Latin America and international prosthetics training courses in Denmark. It has shipped braces and artificial limbs to the Philippines and South Korea and rehabilitation libraries to Poland, France, Yugoslavia, Egypt, Lebanon, Denmark and Austria. It also supports an international journal, "Prostheses, Braces and Technical Aids," published by the International Society for the Welfare of Cripples and its affiliate in Denmark, the Society and Home for Cripples.

In April of 1958, Dr. Rusk told a writer on the New York Daily News, "I am convinced that we can make a significant contribution to the effective understanding of American ideals of democracy, and the value we place on human worth and dignity, by sharing our advances in artificial limbs with the world."

For this writer, Eckert Goodman, he drew up a list of what \$2,000,000—less than the cost of two experimental ICBMs—could do toward bringing modern prosthetics to the underdeveloped countries in two years. This list included: Sending medical consultants to all parts of the free world to determine most urgent needs; furnishing four mobile prosthetics shops to Southeast Asia, the Near East, North Africa, and South America; setting up permanent rehabilitation centers in key parts of the world; shipping parts to provide artificial limbs to more than 40,000 amputees; bringing 100 additional trainces into the United States; and translating all available technical literature on this subject into the foreign tongues necessary for its international use.

Because of his deep belief in medical science as a potent arm of Western diplomacy, Dr. Rusk helped form a citizens' group, the Committee on Health for Peace, headed by General Omar N. Bradley and Dr. Detlev W. Bronk to support Senator Lister Hill's "Health for Peace" bill which would set up an Institute for International Medical Research in the National Institutes of Health at Bethesda, Maryland.

"The opportunities are unlimited for the good we can do to other peoples and thus generate good will for our own country," he said.

The most recent doubling of the capacity of the Institute of Physical Medicine and Rehabilitation made it possible for Dr. Rusk to initiate a special service to some 150 congenital amputees of the New York area. His interest in this project was quickened by the success of the Institute in the rehabilitation of one of its most famous cases, the Bolivian boy, Juan Iregoyen Yepez, a quadruple congenital amputee. When Juan came to this country, his only means of locomotion was a rapid rolling around the floor. His case became widely known through an article in Newsweek, February 21, 1955.

He had been found in a trashcan on a La Paz street in 1951,

not a deserted baby but a lusty five-year-old. He had been taken to the American Hospital in La Paz by the local Rotary Club, which "adopted" him. Juan's case was unusual in that he had sturdy hands but scarcely any arms, sturdy feet but almost no legs. A young plastic surgeon visiting Bolivia reported his case to Dr. Rusk. The Save the Children Federation of New York volunteered to serve as his guardian while the Institute worked on his problem. An airline flew him from La Paz to New York, with no charge.

He now walks the block and a half to the public school on First Avenue on a remarkable prosthesis which brings him up to normal height and enables him to sit down like other boys. He goes up steps and ramps alone. His own feet fit into stirrups which assist in the locomotion of his artificial legs. His prosthesis is securely locked at hip and knee as he walks. The hip and knee mechanism is controlled by a small wheel, not unlike the steering wheel of an automobile, which comes up high on his chest and is manipulated by his hands. Thus he unlocks hips and knees as he sits down. He wears jodhpurs, a jaunty-looking type of trousers, commodious in just the right place to minimize the "bucket seat" and elaborate mechanisms of the prosthesis. He is making an excellent record in his studies.

"A mental genius—that boy," admiringly said William Tosberg, Chief of the Prosthetic Technical Services at the Institute, who worked out the successive prostheses for Juan until a really satisfactory model was evolved.

"He has had very definite ideas all along, and almost always he was correct. He kept saying, 'Why can't I sit down? We can find a way to do it.' And he kept thinking of ways that he could use his little feet to help propel the prosthesis. He has helped us tremendously with his ideas, not only for himself but for others. Some day he will be a great administrator of a rehabilitation center in his home country of Bolivia."

As I hurried from the Institute to First Avenue to catch a bus for the United Nations, I met a handsome, lively, dark-eyed lad whom I easily recognized as Juan on his way home from school. To him the Institute is as warm and love-filled a home as any Welfare Department anywhere could possibly find. And he needs the daily watchful eye of William Tosberg on the intricacies of his highly prized prosthesis. The Bolivian boy, Juan Iregoyen Yepez, quadruple amputee, walking with the intricate prostheses which he helped design.

A lively below-knee amputee on the run. Both boys were rehabilitated at the Institute of Physical Medicine and Rehabilitation.



Dr. Rusk's article in the New York Times Magazine in 1946 was illustrated by a photograph of a class at the Institute for the Crippled and Disabled in New York, captioned "New skills for a new life." This Institute had trained his Air Forces rehabilitation personnel. A pioneer in comprehensive rehabilitation of the disabled dating from World War I, this Institute, which is headed by Willis C. Gorthy, has just been linked-through a professional affiliation with New York University-with the Institute headed by Dr. Rusk. The Institute of Physical Medicine and Rehabilitation is medically oriented and starts with the in-patient, often when the disability is at its worst. The Institute for the Crippled and Disabled is vocationally oriented and works with out-patients whose rehabilitation must continue for long periods after the hospitalization phase. Plans are complete for a new seven-story building which will include a 50-bed unit for patients who require limited nursing care during their rehabilitation. Together these two Institutes comprise the most comprehensive system for the rehabilitation of civilians that the world has ever seen.

Together they will work under the coordination of the New York University Center for Rehabilitation Services, a newly formed unit which reports to Dr. John Ivey, Executive Vice President of NYU. This is the highest echelon ever accorded to human rehabilitation in any university, described as "on the Dean's level."

The Institute for the Crippled and Disabled occupies an eleven-story building at 400 First Avenue. Bruce Barton is President of its distinguished Board of Trustees. Its affiliation had been with Columbia University and the Presbyterian Hospital in the City of New York until the Institute's Board of Directors voted late last year to affiliate professionally with New York University because of the proximity on the lower East Side of the Institute and NYU and because of the ambitious plans of both institutions in the rehabilitation field.

Mr. Gorthy, an engineer, Institute director for the past ten years, briefly summarized the scope of its operations. The annual patient load is about 5,200, the average number of active patients served is about 700. Five prosthetists and five orthotists are given ten months training each year in its limb and brace shops. (The literature states that a graduate of the Orthopedic or Prosthetics course who had two years of practical experience may qualify for the examinations given by the American Board for Certification of the Prosthetic and Orthopedic Industry.) Four in the current class of ten are foreign students.

Mr. Gorthy told of the way in which the Institute had helped establish the first limbshop in Korea financed by the World Council of Churches. Under the leadership of Reuben A. Torrey, D.D., two prosthetists as well as a physical therapist and a physican received the necessary training to man the first shop, which began operation in 1952. The recent hostilities in Korea made it difficult to ship supplies and equipment for this first shop. The Institute assembled all these items and shipped them to Japan. From there Dr. Torrey managed the trans-shipment to Korea in sampans. Time Magazine, in the issue of February 14, 1955, gave an interesting account of Dr. Torrey's activities.

"Training of foreign students and planning of limb and brace shops in their own countries is done on a down-to-earth basis, realizing the local limitations and needs," Mr. Gorthy said. "We try to make all our education of foreign students fit into the environment they will have when they return home. Not long ago we helped a student from Israel with his plans for building his shop and ordering the materials and equipment needed. This is the first shop established in that country that uses American methods and techniques."

Mr. Gorthy stated that this aspect of the program is appreciated by the foreign students. A current trainee from France, for example, hopes to leave New York this June with a full set of architectural drawings for the construction of a prosthetic shop that will be a part of a rehabilitation center located in Paris.

The fund-raising department of the Institute has 70,000 regular contributors listed in its files. The annual sale of products from its Sheltered Workshop brings in around \$40,000, and the sale of Institute products and services brings in some \$200,000 more.

In this building the American Institute of Prosthetic Research carries on its projects. Dr. Henry H. Kessler, the surgeon who first introduced cineplasty to this country, is its President. Mr. Gorthy is Executive Director and Edward A. Kiessling, mechanical engineer, is Program Director. Mr. Kiessling is now engrossed in a three-year project which is concerned with the development of a pneumatically powered artificial arm and the relationship of this system to orthotics. The research is sponsored by the Office of Vocational Rehabilitation and the first year's grant
amounted to \$40,000. This arm, which makes possible for the amputee much greater motion with much less effort, is regarded as particularly promising in special-problem cases where often there is a lack of muscle power or a limitation of motion.

Donald G. Weiss, Director of Public Relations and Community Education, took me through the plant. We went first to the large room where the Institute's weekly staff case conferences are held, with the professional staff members sitting around long tables. A disabled person who wishes to become active and selfsupporting reports first to this room. There a course of medical rehabilitation, psychological and social rehabilitation, and industrial rehabilitation is prescribed for him.

"Last year we gave 13,000 hours of evaluation in comparison with 25,000 hours of training, roughly a 1 to 2 ratio," said Mr. Weiss. "We gave 2,500 hours in medical examination and 15,000 hours in medical treatments, a 1 to 7 ratio. Obviously, we have learned that it pays to analyze a problem before trying to solve it.

"We have only the seriously handicapped here, and about half of them are seriously handicapped only in the medical field which means that as soon as they are restored to health they can resume their former activities.

"We have no looms, no handcrafts. The tasks our patients do—all of them medically prescribed—are purposeful. A man recovering use of the muscles of his back and shoulders may paint a wall. A housewife uses the muscles she must exercise to perform kitchen tasks. Some utensils are hung high to make her reach for them and stretch the muscles of her back and shoulders while washing dishes will require her to exercise the muscles of her hands.

"Both men and women learning to use an arm prosthesis must be able to do all the everyday operations included on our testing board, such as operating a light switch, turning a doorknob, lifting a refrigerator latch, driving a nail, and so on."

Miss Thelma L. Wellerson, author of a 123-page manual for the use of therapists in the rehabilitation and training of upperextremity amputees, is in charge of the occupational therapy unit.

"It would be impossible to overestimate the importance of training in the use of arm prostheses," she said. "To put an artificial arm on a patient without instruction is like telling a person to drive a car without lessons. It takes five to ten hours to train

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Every arm amputee must be able to operate with a prosthesis every common household device on this test hoard. The instructor overseeing this test is Thelma L. Wellerson, Director of Occupational Therapy at the Institute for the Crippled and Disabled, New York, and also author of "A Manual for Occupational Therapists on the Rehabilitation of Upper Extremity Amputees." a below-elbow amputee; eight to thirteen hours to train an aboveelbow amputee; and fourteen to nincteen hours to train a shoulderdisarticulation amputee. The minimum training for the average bilateral amputee case requires from 15 to 28 hours."

One of the tests of completed training, she said, is the ability to pick up with a terminal device an ice-cream cone without crushing it.

The "TOWER" system of evaluation developed at the Institute is in active operation at all times on the floor devoted to testing out patients as to aptitudes. "TOWER" stands for Testing, Orientation and Work Evaluation in Rehabilitation. This system is far broader than the mere initial tests. In the last twenty-three years 120 tests have been evolved in thirteen major job areas. A book which describes the origin, development and use of the TOWER System is currently being published by the Institute for the Crippled and Disabled.

The entire TOWER System, priced at less than cost at \$200, is sold as a package to other rehabilitation centers and agencies. The tests are also beginning to be used by business concerns.

Students in tan coats who are being trained to administer the TOWER vocational tests mingle with Institute technicians in the large area where patients are busy at benches, sewing machines, adding machines, typewriters, optical apparatus, sorting troughs, and test boards, finding out what they can do best.

The Vocational Rehabilitation floor where they really settle down to turn out work resembles a series of offices and shops. Among the vocations in which the disabled are being trained are office practices, bookbinding, leather-goods manufacture, the making of precision lenses and other optical goods, and precision crafting of metal jewelry and electronic devices.

Mr. Weiss said that the Institute takes great care not to become static in its training programs. Rather it seeks to anticipate new employment opportunities for the handicapped as changes occur in treatment programs, nature of the caseload and labor market conditions.

The school for training in prosthetics and orthotics operates on the ground floor in three large and elaborately equipped areas a brace shop, a prosthetics shop for the making of both artificial arms and legs, and a leather shop. Charles R. Goldstine, Director, said that his shop too is vocationally oriented—indeed, he has discovered that vocation is a tremendously important consideration in the selection of a prosthesis or a brace. This consideration has convinced him that no one material is best for either purpose—and so he keeps up his stocks of a very wide choice of the latest materials and components.

"As one instance," he said, "leg amputees who work on the fishing boats off Long Island come here for their prostheses. The metal parts of a conventional prosthesis soon become corroded by the salt water, and the leather parts deteriorate. Sand sifts into the ankle mechanism and causes excessive wear.

"We outfit these fishermen with a water-repellent prosthesis, with a solid-rubber foot and plastics replacing leather or metal where possible. If it is not possible, a plastic coating is used as a protection."

As another instance of fitting appliances to the lives of the wearers, Mr. Goldstine remarked: "If an amputee or a bracewearer belongs to a religious faith which requires considerable kneeling, we allow for greater flexion in the knees than is used in conventional prostheses and bracing."

He confided that what he guards against most during the fitting process is over-optimism. As a brace-wearer himself, he considers it cruel to lead a patient to over-estimate what a device will do for him.

The series of braces used by the famous actor, Ralph Bellamy, in the stage play "Sunrise in Campobello" were made in these shops. Mr. Goldstine and his staff created a true reproduction of the early braces used by the late President Franklin D. Roosevelt. Mr. Bellamy trained at the Institute to play the role of a polio patient realistically.

In the research laboratories, Edward A. Kiessling has redesigned the pneumatic arm prosthesis which was brought to this country from Germany by Dr. Kessler.

The pneumatic arm developed by the American Institute of Prosthetic Research has more prosthetic appeal, more economical use of its source of power—carbon-dioxide gas—and is quieter than its predecessor. It is also more rugged.

Both Mr. Gorthy and Mr. Kiessling gravely cautioned against rousing any premature hopes as to pneumatic arms.

Demonstrating with the new prototype he has developed with the aid of U.S. manufacturers, Mr. Kiessling gave a step-bystep account of how new parts had been developed after tests had shown the German-devised arm to be unacceptable for American use.

Energy for the pneumatic arm is supplied by a cylinder of liquid carbon dioxide, an economical material which costs the wearer only a few cents each day. In the German model this cylinder was carried in the forearm sector of a prosthesis made of metal bars, and just about filled it.

"The tests here showed that the tank should never go in the forearm," said Mr. Kiessling. "When the elbow was flexed, the tank up-ended and liquid carbon dioxide often leaked out and got into the prosthetic mechanism, rupturing the tubes used to conduct the gas to the various operative parts. The liquid also ruptured the bellows devices used to move the elbow and open and close the hand.

Mr. Kiessling said that he consulted five manufacturers of containers in this country, and three new container and pressure regulators have been developed. These devices were given his enthusiastic praise. He pulled one from a drawer and showed how much more compact it was than its predecessor.

"This new storage tank is spun from seamless, stainless steel tubing to be carried on a belt around the waist," he said. "It is worn snug against the body. It consists, as you see, of two small tanks each containing 90 grams of liquid carbon dioxide. This about doubles the capacity of the German model.

"The regulators are two-stage, positive-acting, non-leaking equipment with double safety valving which exceed the U.S. Bureau of Standards requirements."

The artificial hand used by the Germans he characterized as "a good hand, with a firm grip and unusually good dexterity."

But American amputees object to its cosmetic appearance," Mr. Kiessling added. "It has an elongated movable thumb operating against two fixed first fingers."

And so a new hand was developed in which the two first fingers move against the thumb as in the Army Prosthetics Research Laboratory hand. It has a forty-pound grip, the developer said, adding "few amputees have more than a ten-pound grip." The rubber bellows within the German hand was found to rupture quite often and was difficult to repair because it was so inaccessible. A pneumatic servomotor was built into the all-metal A.I.P.R. hand.

The elbow of the German arm was bellows-actuated, and was not rugged enough for the daily workloads which are encountered in this country.

"We now have a new elbow under design. The new elbow is approximately three hundred percent more rugged than the German elbow with a relatively small increase in weight," he said.

"It requires only two valves instead of four to operate, being equipped with a dual-acting servomotor designed to be self-locking through pressure equilibrium. The arm is both raised and lowered by gas pressure. It has the ability to lift a hand which is holding a weight of 5 pounds."

The German wrist-rotation unit, Mr. Kiessling said, was bellows-operated through levers and mitre-gears, had no interchangeable parts, and did not adapt well to laminated plastic. Four valves were required to lock, unlock, pronate and supinate. It was possible to raise a drink to the lips with it. But it did not have enough power to open doors or do many kinds of work.

Two different wrists now have been designed with dualacting servos which reduce the number of valves required from four to two, Mr. Kiessling said. Both designs have proven satisfactory.

Fabrication and type testing on the models of the A.I.P.R. arm are being done in the Prosthetic and Orthopedic Appliance Laboratories of the Institute for the Crippled and Disabled and at Kessler Associates, a prosthetics shop operated by the sons of Dr. Kessler.

Thus it is an all-American pneumatic arm which now is beginning to go through the long and detailed developmental process which must prove its worth before it goes on the market.

CHAPTER XIII

Washington—The Famed APRL, the PRB, and the Cooperating Agencies

In a temporary building of World War II at Forest Glen, Maryland, a small suburb of the Nation's Capital, Colonel Maurice J. Fletcher directs a laboratory doing researches into substitute devices for missing parts of the human body.

Not only has the laboratory produced greatly advanced types of terminal hooks and a functional, artificial hand, but also has covered that hand with a cosmetic glove in close simulation of human skin of all the races of mankind. Indeed, the recognition of the outstanding work of this laboratory is greatest in the field of cosmesis.

The cosmetic gloves have been developed in six basic skin tints for the white race and six basic skin tints for other races ranging from Oriental to Negro. The functional hand and covering cosmetic glove have been developed in five different sizes—a small child's hand, a larger child's hand, an adolescent or woman's hand, a small man's hand and a large man's hand. It is handsize No. 1 which is now being tested out on small children, and size No. 4, which is glove size No. 8, which is commercially available. For size No. 4, somewhat small for most men and somewhat large for most women, two skin textures are available, one feminine and one masculine.

There is an urgent need to get the rest of the hand sizes into production, particularly for the age of adolescence when appearance means much. Women amputees, too, are eager for more attractive artificial arms. In future, Colonel Fletcher says, it is entirely possible to make artificial arms cosmetic to the shoulder and of soft-textured exteriors which will not clink against tables, so that women amputees may wear short sleeves as other women do.

While the Army Prosthetics Research Laboratory is most

famed for its hand and arm prostheses, Colonel Fletcher's staff also duplicates facial parts, greatly lifting the morale of many who have been victims of disfiguring accidents and diseases.

The high quality of work done in this field under trying conditions brought a glowing tribute from a Washington woman whose mother had a stubborn case of skin cancer which finally had to be curbed by a drastic facial operation at age seventyseven.

"Day after day, in the hot and humid month of August, I took my mother out to the APRL laboratory," said this woman. "There was no air conditioning, and that low-roofed, frame building was truly insufferable. Yet I completely forgot about the heat, and my mother did too, in the fascination of watching the delicate, artistic work of those scientists, with their plastics and their pigments, as they duplicated a section of the human face."

No laboratory in my travels had a setting which in any way approximated that of Forest Glen. The atmosphere of the early 1900's in which these ultramodern marvels are turned out must



The Hand or the Hook?

Here they may be seen in close comparison—a child's hand holding a child's hook.

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Both, says Col. Maurice J. Fletcher, director of the Army Prosthetics Research Laboratory at Forest Glen, Maryland, a suburb of Washington, D.C. His inventive genius has advanced both terminal hook and artificial hand tremendously.

However, Colonel Fletcher's chief fame lies in his development of cosmetic gloves closely resembling human skin. They fit over five hand sizes also developed in the Army Prosthetics Research Laboratory. Two views, with measurements of the five sizes, are shown below.

Size 1, Child hand. Size 2, Teen-age hand. Size 3, Woman's hand. Size 4, Hand for small man or large woman. Size 5, For large man. Only size 4 is in mass production.





be breathed to be believed. Under the World War II pressures for a place to live and work in Washington, the Walter Reed Hospital, in dire need of a rehabilitation center for its amputees, purchased the acreage and buildings of a once-fashionable young ladies' seminary of the type known as a "finishing school." A rounded culture was the aim. Pseudo-art statuary is scattered all through the woodlands. The cottages for the young ladies, clustered around the great central hall of learning, were—and still are—in the simulated architecture of many forcign lands. The imitation Swiss chalet, Chinese pagoda, English manor house, and others more or less easy to recognize, have long since lost any glamor they derived as picture-book settings for the pretty daughters of wealthy men. Even the Old Grads who for so many years were loyal to them have ceased to return for reunions.

In a building which looks as though it once were the chapel, the Medical History of World War II is now being compiled. The main hall of what was the Administration building contains an elaborate painting of that amazing building and its landscaping, done by a soldier who spent many months being rehabilitated there.

Colonel Fletcher, a man of dry humor, enjoys showing visitors the rococo Grand Ballroom with its three rising tiers of handsome boxes for parental onlookers, when he crosses the campus at noon to get lunch in the cafeteria which now occupies the oncestately dining hall. Then he threads his way back through the statuary to the utterly utilitarian one-story structure, built around an open square, in which he has worked these many years.

On the walls of his office, close to the building entrance, are displayed some of the devices the laboratory has developed. Lying on his desk are the latest models. One of these is the No. 1 size child's hand, difficult to develop as all its parts had to be reduced to such tiny sizes. And its cosmetic glove had to be toughened up by inclusion of nylon net for the hard usage that children give their hands.

On the desk also were the APRL reflex hand, and the APRL reflex hook, both of which open and then close on one pull of the control cable.

"This one-pull principle will eliminate forever the argument over voluntary-opening and voluntary-closing terminal devices," said Colonel Fletcher.

Voluntary-opening devices involve nothing more than a 150

spring clamp. They work like a clothespin. The cable tension opens the device. Springs or rubber bands perform the function of grasping the object, thereby relieving the amputee of strain during the holding phase. It is simple to use but does not adapt to the lifting of very light or very heavy objects.

Voluntary-closing devices open with a spring force and use the cable tension for closing. These require a locking of the grasp and so are more complicated to develop and to operate but give the amputee control over the amount of grasping force exerted.

Colonel Fletcher said that with a one-pull or reflex device an amputee can reach into his pocket, move the cable and open the pocket, a useful, everyday motion hitherto not possible for a terminal hook or hand. With this device, he added, the amputee "can pick up a feather or a brick" with his prosthesis.

As creator of both artificial hands and terminal hooks, Colonel Fletcher has small patience with the debate which runs through the rehabilitation world, "The hand or the hook?" One school of thought holds that the hook is far more functional; that the amputee and his family, therefore, should face reality and make use of it from infancy on up; and that the public should accept it as casually as it accepts hearing aids and eyeglasses. The other school holds that the artificial hand eventually could be made equally useful; that it is necessary for the complete restoration of the self-image so important to the human ego; and that the general public should not rest until the closest possible simulation of a human hand is made possible for the amputee.

Colonel Fletcher's contention is that both the hand and the hook in their present state of development have a proven place in rehabilitation. He therefore is constantly seeking to improve devices which make possible a quick interchange of hand and hook as terminal devices for the same arm prosthesis.

"For small, precise motions, the hook no doubt is better than the hand," said Col. Fletcher. "But if you prefer stability to ease in getting into small places, the hand is better. The worker who grips relatively large objects, as in a coal mine, or the mother who is taking care of a baby does better with a hand. Timeand-motion studies have shown that the precision movements needed for the picking up of very small objects or parts of mechanisms have been overemphasized. Much more of the daily activities of life are concerned with large motions."

As though to back him up, a pretty little nurse came in I51

with the APRL prosthetics expert wanting his advice on the fit of her new pre-flexed arm and APRL hand. Colonel Fletcher decided that the arm should be eased out a bit at the top, which was done then and there by merely trimming the plastic. She said that her specialty was taking care of babies, and so she wanted the hand, even though it was somewhat bigger than her real hand.

Colonel Fletcher said the cosmetic value of a hand often outweighs the added precision advantages of a hook.

"Many parents of congenital amputees who refuse a hook will gladly accept a cosmetic glove which doesn't work for one minute," he said. "All it will do is hold a ruler, move things back and forth, and add to the range of motion of the arm."

Other parents, he said, willingly accept the APRL child's plastic hook, rounded at the end so it can't dig into eyes or ears or catch mouth or nose. It will push, pull or clasp. It is operated by a ribbon of fiberglass instead of a metal cable, and is easy to clean and keep dust-free.

A long and narrow corridor of the APRL laboratory is lined with designs and art studies of prostheses. One series, done by a soldier gifted in art who was convalescing there, depicts the various types of cineplasty in use at Forest Glen following World War II.

On the day I visited, the APRL design section was developing upper-extremity feeders for quadriplegic patients at Walter Reed Hospital and was also working out a prosthesis for an involved hip-disarticulation case.

While the Army Prosthetics Research Laboratory specializes in the upper extremities, there is no type of prosthetics problem it has not tackled, for the Army turns to this laboratory for help in the most difficult cases which cannot be fitted commercially.

One large area of the laboratory is taken over by the pigment shop, with its many special problems of blending blues, greens, yellows, oranges and reds into skin colors that remain steadfast and reasonably comparable to the skin color of the wearer, in sun or shade, in daylight or artificial light.

Impressive is the APRL machine shop, with its lathes, milling machines, drill presses and cycling machines. And surely there is no plastics shop anywhere with problems more complex and delicate than this one, dealing in simulated human skin as well as in shells for arms.

As I completed the tour with Colonel Fletcher, he had a small sermon to deliver-and its subject was safety.

"No matter how far we go forward with new techniques in prostheses," he said, "it would be far better if the people who have them would keep their normal number of legs and arms, hands and feet. The human body is a structural engineering job of the first water. The skeleton of each animal is precisely designed for its own specialties. It should be kept intact, and not mangled by preventable accidents.

"Yet there is an increasing number of what I call compicker hands—farmers try to clean the corn-picker without shutting off the tractor. And farm youngsters fall off and get under mowing machines and hay balers. There should be more safety devices developed for farm machinery—and made mandatory."

Colonel Fletcher was even more eloquent on the hazards of the highway. In addition to advocating much more safety engineering for the automobile industry, he had this very special caution to offer:

"Keep your elbows inside car windows. We have had many cases here recently of shoulder disarticulations—the hardest kind of case to fit with a functional artificial arm—resulting from a disregard of this simple rule.

"Where cars pass each other at very high speeds on the superhighways, such as seems to happen a great deal on the open plains of Texas, the trailer overhang of a passing truck may hit the driver of a passenger car on his extended elbow—and his entire arm will be far behind him down the road before he even realizes he is hit, before he even feels the pain. The amputation is instantaneous."

"What about the sportscar driver?" he was asked.

"Where the amputation is at the neck," was his reply, "there is no need for a prosthesis."

Washington is the headquarters city where plans and policies are made and from which programs are directed. This is true in a thousand fields, and it is true for the many activities which are coordinated by the Prosthetics Research Board.

This probably is principally because Washington is the location of the greatest cooperating agency of them all—Congress. Far too little praise is given to the statesmen in House and Senate who levy the taxes and appropriate the public funds to the good of all the people. Their general good judgment is the top secret 153 of why life in the United States of America has such outstanding advantages. All issues affecting the national good are discussed, deliberated and decided by the duly-elected representatives of the people.

Few citizens realize to what extent the public funds are being spent in cooperation with private agencies working on special projects for the betterment of man. Prosthetics research falls in this cooperative field.

The Prosthetics Research Board is one of many committees of scientists giving valuable time and expert knowledge in the farspreading program of an entirely private agency, the National Academy of Sciences—National Research Council with headquarters at 2101 Constitution Avenue. Although not a part of the Government, the Academy-Research Council is called upon, under its Congressional charter of 1863, to advise the Federal Government upon request in all matters of scientific and technical interest. The great work of the Academy has recently been dramatized by its cooperation with other nations in the International Geophysical Year.

Dr. Detlev W. Bronk, President of the Academy, who also holds the high post of President of the Rockefeller Institute in New York City, testified before a Senate committee in February 1959 that his intimate association with the International Geophysical Year had convinced him that vast possibilities lie just ahead for world cooperation in medical science.

"Powerful new tools we never had before.will open up tremendous new fields," he said. "The great developments in the physical sciences offer medical opportunities so challenging they bewilder one's vision and imagination."

Dr. Bronk cited particularly the prosthetics field as ready for rapid development through the advances that have been made in engineering.

The Prosthetics Research Board, which has as its chairman Brigadier General F. S. Strong, Jr., has its national headquarters in an office of the Academy-Research Council in Washington, D.C. Its remarkable work of pulling all the threads of a scientific and humanitarian endeavor together has been the subject of this entire report.

Everywhere I went to see this process in action I was told that the remarkable progress in prosthetics since World War II had been largely due to the coordinating ability of General Strong. 154 I was told that this had been accomplished with a high degree of creative imagination, as might have been expected from the man who had—when a youth—made one of the highest scholastic records ever attained at the United States Military Academy at West Point. I was told that his later record had included military service in both world wars and varied activities in private life during the intervening years. I was told that his engineering experience, both military and civil, was later brought into play in World War II construction, including the Alaska and Pan American Highways, and the Ledo-Burma Road. I was told that after General Strong retired—and was just preparing to enjoy his retirement—he was persuaded to take up still another career which—in the estimation of my many informants—turned out to be the greatest of them all. He built the Road Ahead for all the amputees.

Working as assistant to General Strong in the Canadian Northwest, and along the Alaska Highway, was another engineer, Tonnes Dennison. He has served General Strong in a similar capacity in the coordinating work of PRB, flying from project to project as the program requires.

Stationed in the Washington PRB office is Dr. Harold W. Glattly, Secretary of the Committee on Prosthetics Education and Information which has recently launched a program to improve amputee services in areas where prosthetics teams are not now available.

Twice a year the Prosthetics Research Board publishes the magazine "Artificial Limbs" which keeps both the cooperating scientists and the industry informed on important developments. Bryson Fleer, one of the most informed men in the country in the field of prosthetics, is editor.

The Government agencies closely cooperating with PRB on the planning level in Washington have been described through their workings in the States. However, a brief recapitulation here may clarify the intricacies of the Federal agencies involved.

The Defense Department has made a great contribution to prosthetics research and development through the Army and Navy research laboratories.

The Veterans' Administration, however has been the tremendous trailblazer, through its Prosthetic and Sensory Aids Service, headed by Dr. Robert E. Stewart. Its offices are in the Veterans' Administration building at Vermont Avenue and I Street, N.W.

Dr. Stewart's administrative assistant, wounded in World

War II, is a bilateral leg amputee. In each of the sixty-two field offices of the Veterans' Administration throughout the United States is a prosthetic specialist who is a rehabilitated disabled veteran. He understands the problems of the amputee and the veteran who requires a prosthetic device because these problems also are his own.

Under Dr. Stewart's direction, the \$1,000,000 annually appropriated by Congress for the research and development of prosthetic and sensory aids is awarded on a contract basis to projects of universities and laboratories. About \$750,000 goes annually for institutional prosthetics research and development, and about \$250,000 to the intramural research and development program. The benefits of the artificial-limb research go to all adult amputees, not only to the veteran amputees of all wars but also to the half million or more amputees in civilian life. The VA has also trained many orthopedic technicians from foreign countries in the VA Center in New York.

The entire VA prosthetics program has served as a powerful upgrading force. The Federal Government pays for the prosthetics of all veteran amputees. All devices sold to the Veterans' Administration must be up to VA standards. Ninety-eight and six-tenths percent of all VA prosthetic devices are purchased from private industry—this in itself being a standard-setting operation.

Three agencies of the Department of Health, Education, and Welfare are concerned in the research and development of prosthetic devices and in the dissemination of knowledge in their use. They are the Office of Vocational Rehabilitation and the Children's Bureau, both located in the HEW building at Fourth Street and Independence Avenue, S.W., and the National Institutes of Health, the great research laboratories of the Public Health Services, located on an extensive acreage in Bethesda, Md., a suburb of Washington.

The Office of Vocational Rehabilitation, headed by Miss Mary E. Switzer, has as its objective getting the disabled off relief rolls onto payrolls wherever possible; and, if not, rehabilitating them for self-care insofar as possible. Naturally, OVR has found it necessary to take on increasing responsibilities for prosthetics and orthotics programs for civilians. OVR now furnishes the Federal supporting funds for the schools that train prosthetics teams at the University of California at Los Angeles, at the Rehabilitation Institute of Chicago, and at New York University. This 156 agency has also sponsored special research projects, such as the one on artificial muscle at Rancho Los Amigos and the pneumatic arm research in The Institute for the Crippled and Disabled in New York.

The OVR has recruited rehabilitation experts to give technical aid to the governments of other nations and has planned for the rehabilitation training here of more than 800 people from more than 60 countries in the last twelve years. Many of these trainees have had a special interest in prosthetics. A recent OVR report stated, "The emphasis on international activities of the Office of Vocational Rehabilitation will be intensified in 1960 since rehabilitation contributes significantly to the over-all efforts of the United States in promoting world peace."

Since the Veterans' Administration by law can serve only adults, the Children's Bureau, with its services for crippled children through fund-matching with the States under the Social Security Act, inevitably was drawn into the child-prosthetics field. The Children's Bureau also has a special fund for services to very greatly disabled children like Jessica Weaver. Dr. Arthur J. Lesser is in charge of this entire phase of the Children's Bureau work. Its research and testing projects are being conducted at the University of California at Los Angeles, at the Michigan Child Amputee Center at Grand Rapids, and at New York University.

A few prosthetics research projects are also carried forward under contracts with the National Institutes of Health. These Institutes, which have made such dramatic advances in cancer, heart, mental health, neurological, and many other medical and health fields, have not as yet made any noteworthy impact in the field of physical medicine and rehabilitation. However, the proposed National Institute for International Medical Research definitely would place a high priority on research and development in prosthetics and orthotics, and would give OVR and the Children's Burcau advisory roles in rehabilitation research.

Still another Washington headquarters which has been highly important to progress in prosthetics and orthotics is that of the Orthopedic Appliance and Limb Manufacturers Association and also of the American Board for Certification in that industry at 919 Eighteenth Street, N.W.

OALMA is the trade organization established as the result of World War I, which has worked very closely with the Pros-

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thetics Research Board from its beginning. Chester Haddan, selected to be a member of the Prosthetics Research Board because of his leadership in the industry, kept the records of OALMA at his Denver establishment until the organization set up headquarters in the nation's capital in 1946.

The American Board for Certification (ABC) is a standards raising program. This Board first granted certification to qualified limb and brace fitters in 1948. Since 1951 ABC has held examinations to certify those entering the profession of prosthetist and orthotist. Many qualify in both fields.

The improved standards of recent years followed a threeyear intensive study by a group of leading orthopedic surgeons, prosthetists and orthotists. This study resulted in the setting up in August of 1948 of the modern program of certification.

The certification board is made up of seven directors three orthopedic surgeons, three men nominated by OALMA, and one director nominated by the Advisory Council of ABC.

This Board maintains a Registry of Certified Prosthetists and Orthotists. Each of these is entitled to wear the insignia of the ABC on his laboratory jacket. Facilities which come up to the high standards of the ABC are also certified. The annual registry of these approved establishments, of which there are about 300 in the United States, is sent out on request. Thus, any person in the United States who wishes assurance that an artificial limb or brace will be fitted by sound anatomical and mechanical principles can obtain the name of the approved facilities in his area by writing to Washington.

Executive Director of both OALMA and ABC is Glenn E. Jackson, a former YMCA director and Civil Defense official, who has been in charge of the Washington headquarters from its start. Lester A. Smith, a former librarian at the U.S. Army Medical Library, is Assistant Executive Director of OALMA and editor of the Orthopedic and Prosthetic Appliance Journal. A. Bennett Wilson, Jr., formerly of the Prosthetics Research Board staff, is Secretary of the Committee on Advances in Prosthetics of OALMA, which promotes the commercial use of the devices developed in cooperation with, and tested out by, PRB. LeRoy W. Nattress, Jr., until recently the course coordinator of the UCLA Prosthetics Education Program, is the Examinations Director of ABC.

This part of the report completed June 30, 1959

CHAPTER XIV

The Future

Obviously the ultimate in the way of an answer to the solution of the artificial-limb problem is elimination of the causes of amputation. It is hoped eventually that safety measures will eliminate most of the accidental amputations, that medical research will annihilate the diseases now requiring the amputation of a limb, that research will reduce drastically the incidence of congenital defects requiring artificial limbs, that procedures can be developed to permit successful reattachment of severed limbs, and even that amputation stumps might be induced to regenerate the missing parts.

All of these avenues are being explored but it is apt to be a good many years before a large degree of success can be expected, and certainly for a long, long time there will be a need for artificial limbs that permit amputees to function at a level as near normal as possible. Though a good deal of progress has been made, there remains a tremendous gap between what an amputee can do and what he should be able to do.

Attachment of the prosthesis to the body is one of the most difficult problems facing those trying to improve the lot of the amputee. One suggested solution is the attachment of a strut directly to the bone of the stump and protruding through the stump tissues in such a manner that a prosthesis can be attached directly. If proven medically feasible, such a technique would provide a stable connection between amputee and prosthesis, thus permitting better control of the limb and eliminating the need for the soft tissues of the stump and other parts of the body to assume forces for which they were not intended. Work is being undertaken in this area but, here too, success cannot be expected for a number of years. In the meantime less spectacular approaches must be pursued.

Through the introduction of new materials and techniques much of the art has been removed from the art-science of limbfitting, yet successful results depend entirely too much upon art, and techniques even simpler than those available are needed, especially in the case of a national disaster. In spite of valiant efforts little has been accomplished for the severely disabled upper-extremity case. Without power generated outside of the body of the patient, very little function can be expected in patients with amputations at high level in both arms. The technology exists, and has been demonstrated, for the design and fabrication of externally powered prostheses but with the present state of knowledge subsconscious control cannot be effected, and though dramatic demonstrations can be given, the patient more often than not finds that the effort required to operate such a prosthesis is not worthy of the functions provided and soon discards it. Experiments on control devices both within the prosthetics program and in space technology are leading the way to an ultimate solution to sensory feedback and automatic control.

From the early days of the prosthetics program it was realized that many of the data and developments should be applicable to the field of orthopedic bracing, orthotics. As funds have become available for research in orthotics, the National Academy of Sciences, through its Committee on Prosthetics Research and Development, successor to the Prosthetics Research Board, has assumed the responsibility of correlating work in this field which is so closely allied to prosthetics. It is felt generally that orthotics is in about the same position that prosthetics was in 1945, and it will be interesting to watch progress in this area in which the problems posed are even more defiant of solution than those in prosthetics.

The initial task undertaken by the research group was to develop devices and techniques for the least complicated cases, otherwise healthy mature adults. As results of the program began to accrue, where possible some were applied, with slight modifications, to child cases, but it soon became apparent that in many cases children had problems of a very special nature and projects were established to investigate these matters. However, amputees in the older age groups also are beset with special problems, and in the past it has not been possible to devote any significant attention to this special group of amputees.

It is expected that considerably more effort will be spent in developing special management techniques for the geriatric amputee. More must be known about the distribution of pressure between stump and socket and about the effect of prosthesis use on the rest of the body before full advantage can be taken of the potential of the geriatric amputee. In the present-day efforts on the part of the United States to render needed assistance to the so-called underdeveloped countries to help them to raise their standard of living, the role that can be rendered by the field of prosthetics must not be overlooked. The Office of Vocational Rehabilitation has demonstrated many times the soundness of amputee rehabilitation programs from an economical viewpoint in that each dollar spent in rehabilitation is recovered many times over in the form of income and other taxes paid by those who would not otherwise be able to work. Prosthetics should therefore be included in any program designed to improve the living standard of any country or area.

Addenda

Since completion of this manuscript in 1959, two developments have occurred that are expected to contribute materially to continued progress in the field of orthotics and prosthetics. These are:

I-Formation of the University Council on Orthotic and Prosthetic Education (UCOPE).

UCOPE was founded in May 1961, with membership limited to the project directors and the medical consultants of the three major university programs at the University of California at Los Angeles, New York University, and Northwestern University. Dr. J. Warren Perry, Assistant Chief of the Division of Training in the Office of Vocational Rehabilitation, serves as the executive secretary of this new group. The primary objectives are a closer coordination among these three programs and a greater standardization of course content.

II—The start of functioning of the Prosthetics and Orthotics Committee of the United States Committee of the International Society for the Rehabilitation of the Disabled.

The initial meeting of this group was in March 1962. The International Society has established this United States Committee on Prosthetics and Orthotics to coordinate and strengthen United States participation in the work of the International Committee on Prostheses, Braces and Technical Aids and to encourage and coordinate United States activity in the international field of prosthetics and orthotics. This committee is composed of sixteen representatives of research, training, medicine, manufacturers and professional organizations involved in this specialized field.

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