Spring 1956

Artificial Limbs

A Review of Current Developments

PROSTHETICS RESEARCH BOARD

National Academy of Sciences

National Research Council

When, on December 1,1955, the former Advisory Committee on Artificial Limbs **was** dissolved and reorganized as the Prosthetics Research Board (page 39), it was decided to publish in calendar year 1956 two issues only of ARTIFICIAL LIMBS, one in the spring and the other in the autumn. This issue (Volume 3, Number 1), together with that for Autumn 1956 (Volume 3, Number 2), will thus constitute Volume 3 in its entirety.

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VOL. 3 SPRING 1956 NO. 1

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NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

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Lesson in Lesions

C. LESLIE MITCHELL, M.D.[1]

The human integument, with its complex structural and functional organization, is one of the most remarkable packaging materials in the world. Unlike inanimate wrappers however elaborate, it has under ordinary circumstances the extraordinary facility of regenerating itself, of adapting to the local environment, and of resisting attack by all kinds of agents—chemical, physical, and biological. The reason for this situation lies in the fact that living skin, as is the case with other living tissues, undergoes continuous metabolism, with consequent growth and decay.

But in addition to its mechanical function—that of providing a tough, protective outer covering for the body—the skin has many important but little-recognized physiological properties, among these being its ability to function as a respirator in the exchange of oxygen and carbon dioxide; as a regulator of body temperature by means of sweat glands under control of the sympathetic nervous system; as an agent in the conservation of water and electrolytes; as a sensory organ to record heat, cold, pain, and touch; as a corridor for the reception of vitamins and hormones; and as a barrier against infection. Despite all these indispensable services, the integrity of the skin is so much taken for granted by almost everybody that usually no attention is directed to it until some deviation from the normal develops. Its numerous functions are poorly understood by most laymen, if not indeed by many physicians. Yet neglect of its proper care can result in serious consequences.

Proper functioning of the skin is dependent on many factors, such for example as freedom from constriction and irritation, adequate exposure to air, prompt removal of waste products from its surface, and avoidance of extremes of heat and cold. Whenever the skin is subjected to abnormal insults, the problem of skin care is multiplied many times. Since the wearing of a prosthesis, particularly on the weight-bearing lower extremity, unavoidably creates most of the conditions—constriction, excessive moisture, increased heat, mechanical irritation, and undue pressure—conducive to poor skin health, it quite naturally places upon the skin of the stump a set of demands far in excess of the normal. And not only that. Having lost one of his principal heat-

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radiating "fins," and being at the same time required to exert in locomotion more energy than does the normal person, the leg amputee commonly perspires more freely than normal, and hence his needs for skin hygiene are more acute than are those for one who walks on two natural legs.

The basic requirements of a lower-extremity prosthesis are to provide comfort, function, and appearance. Of these, comfort is unquestionably of chief importance, for without comfort the amputee will fail to obtain satisfactory function, or appearance, or both, and will ultimately either limit use of the prosthesis or else find it impossible to wear it at all. In a large percentage of cases of difficulty or failure, skin lesions of one type or another involving the stump are found to be the cause of discomfort, thus preventing the amputee from wearing the limb. Prophylaxis is, therefore, a *sine qua non* in this regard, and only through adequate knowledge of skin physiology can these disorders be anticipated and thus prevented.

Although disabling skin lesions on the stump of the leg amputee have constituted a serious complication ever since prostheses were first used for the lower extremity, full appreciation of the problem and suggestions for solution have not been forthcoming until recently. As has been typical with most problems in medicine, little was accomplished until a concerted effort was made to understand normal function and to investigate reaction to the abnormal. It is encouraging to note that there is now well under way, with the sponsorship of the Prosthetics Research Board of the National Academy of Sciences—National Research Council, a systematic attack aimed at solution of the cutaneous problems of the leg amputee.

Because even the most satisfactory lower-extremity prosthesis is of no avail if the amputee is deprived of wearing it, and because painful skin lesions in a leg stump have so frequently been the cause of inability to use an artificial leg properly, the then Prosthetic Devices Research Project at the University of California, Berkeley (now the Lower-Extremity Amputee Research Project), in conjunction with the Department of Dermatology at the University of California Medical School in San Francisco, organized in the autumn of 1954 a skin-study group to investigate the cutaneous difficulties of the lower-extremity amputee. In the course of the succeeding two years there has been accumulated a considerable body of new knowledge, not only on the nature and physiology of healthy skin but also on some of the specific clinical manifestations of skin disorders in amputees. Since the proper management of cutaneous disturbances is so essential to lower-extremity function, this issue of ARTIFICIAL LIMBS is devoted to a presentation of some of the information gathered thus far. In the first of two articles, a dermatologist discusses the anatomy and physiology of normal skin and what is to be expected when healthy skin is subjected to unfavorable conditions. In the second, another dermatologist characterizes the common skin maladies of leg amputees and offers suggestions for prevention and treatment.

An interesting observation is that proper care of the stump skin is found to be the responsibility not only of the attending physician and the prosthetist but, and even more important, of the amputee himself. Nevertheless, simple attention to good practices of daily hygiene is not enough. A considerable number of skin disorders peculiar to the lower-extremity stump present themselves despite all precautions. Some are common to all leg amputees. Many are the result of individual skin idiosyncrasies or of climatic conditions. Some are so intractable as to be amenable to cure only by total excision.

While the newer understanding has in recent years appreciably decreased the incidence of serious skin lesions in leg amputees and has made it more readily possible to deal successfully with some of those that do occur, it is obvious that much work remains to be done. For the complete etiology of many of the characteristic disease states yet remains to be elucidated. It is to be hoped that the initiative taken by the pilot study group at the University of California may prove to be a stimulus for similar investigative work at other centers of medical research throughout the world. The lesson is here for us to learn. Unless skin problems can be eliminated once and for all, there can be no true rehabilitation of the lower-extremity amputee.

Skin Health and Stump Hygiene[1]

GILBERT H. BARNES, M.D.[2]

Literally the word "hygiene" connotes a state or condition of health. But adequate hygiene, or good health, of the human skin presents a complex problem involving much more than a casual acquaintance with soap and water, the concept which usually comes to mind when hygiene is mentioned. The functional state of our human integument is pretty much taken for granted by most of us. We know that this two-square-yard covering will, in most cases, repair itself in event of local injury, provided infection is avoided. Cheerfully we dissolve it in strong chemical solutions. We broil it in the summer sun until it peels off like old birch bark. We allow it to be rubbed and blistered in tight shoes for vanity's sake. As a nation, we spend millions of dollars on elaborate sun-tan lotions guaranteed to produce in it the beautiful brown of the aborigine and at the same time an equal fortune on lotions and creams which promise to bleach it out to the shade of a sheltered lily.

Even though the skin has remarkable powers of restoration, the conditions of use are occasionally too damaging, or the opportunities for healing between periods of use are too brief for repair and maintenance. In such instances, there may be an acute breakdown of the skin with a severe inflammatory reaction, or the process may be a gradual one, with a progressive deterioration of the skin and a loss of its protective properties. Among individuals in certain occupations, we frequently see both manifestations of such skin reaction. Housewives, mechanics, laboratory workers, and others whose work exposes certain areas of the body, particularly the hands and arms, to prolonged soaking in solutions and solvents, or even in plain water, are prone to recurrent skin irritation and breakdown. In such cases, the chemical and physiological properties of the skin are altered to such a degree that the skin's built-in protective functions are no longer effective. Even in the absence of prolonged soaking, the skin may be injured locally by contact with an irritant, such as a strong acid, or with a sensitizing agent, such as poison ivy.

All of these considerations similarly pertain to amputees who wear some type of prosthesis (Fig. 1), most of which are attached to the stump by means of a snugly fitted socket which excludes circulating air and traps the accumulated sweat against the skin. In the lower-extremity amputee, the effect is aggravated by the added factor of weight-bearing and uneven loading on localized areas of the stump skin, especially in the adductor region of the stump and at other points of contact with the socket rim. Weight-bearing is attended by other mechanical stresses, especially intermittent stretching of the skin and friction from rubbing against the socket edge and interior surface. The latter results in two important and harmful effects on the skin—heat, and abrasion of the skin surface, which in time can, by steady attrition, become highly destructive. Over a long period of time, heat alone may be capable of causing profound changes in the metabolism of living tissues. The stump skin of the amputee is especially vulnerable to the possible irritant or allergic

[1] Based on a lecture presented before the University of California Pilot School in Lower-Extremity Prosthetics, August 25, 1955, at the U.S. Naval Hospital, Oakland, California.

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action of various materials that compose the socket of the artificial leg.

In this situation, then, the state of health of the stump skin is of the utmost importance in determining whether or not the prosthesis can be tolerated. If the skin cannot be maintained in a good functional condition in spite of daily wear and tear, then the weight-bearing prosthesis cannot be worn, no matter how accurate the fit of the socket may be.

It is the purpose of this article to review some of the basic principles of skin biochemistry and physiology concerned in the maintenance of good hygiene in the stump area. Included are some remarks relative to the use of certain disinfectant agents in skin cleansing, and to some of the natural skin defenses against bacterial invasion, because these topics also are germane to the principal subject with which this article is concerned.

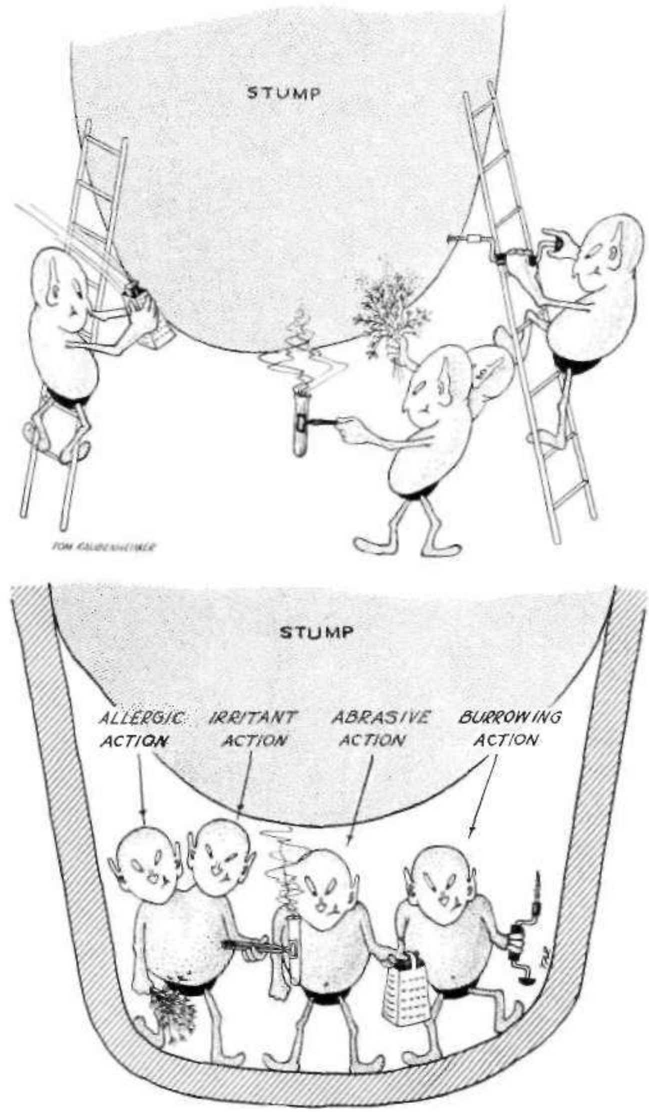


Fig. 1. Injury to the stump skin. The gremlins symbolize some of the common types of damage that may be inflicted upon the stump skin inside the socket of a prosthesis. Injury may be incurred mechanically when parts of the socket abrade the skin or burrow into it. The materials of the socket, coming in intimate contact with the skin, sometimes act as irritants or as sensitizing agents to create a local dermatitis.

THE SKIN AS A VITAL ORGAN

Man cannot live without his envelope of skin any more than he can exist without his heart or his liver. It might seem at first thought that the cutaneous covering of the body performs about the same function as the leather cover of a baseball —and very little more. Actually, the biochemical and physiological activities of the skin are every bit as complex as are those of the liver. The respiratory rate of the main cellular portion of the epidermis, based on oxygen-uptake studies and glycolysis measurements, has been computed to be from two to ten times as high as the rates of other body tissues.

The skin possesses many properties vital to health and life itself. Of particular interest to us from the standpoint of prosthetic design and use is the part it plays in mechanical support of the soft tissues of the stump. It provides a tough, elastic outer covering with a tensile strength of up to 2 kg. per sq. mm. Furthermore, this covering has a tremendous capacity for repairing itself after injury and for strengthening itself at points of mechanical stress, such as those occurring on the lower-extremity stump in association with the wearing of an artificial limb. A familiar example of this is the "lichenification," or leatherlike thickening of the skin over the ischial tuberosity and in the adductor region of the thigh. We know that "calluses," or localized thickenings of the horny outermost layer of the skin, will form at points of repeated pressure. Sometimes a BB-shotlike condensation of horny material will develop over a pressure point, producing the well-known "corn." All of these thickening processes illustrate the defensive reaction of the skin to abnormal mechanical stress by elaborating a natural cushion from its cellular elements.

Mechanical protection, however, is only one of many important services which the skin performs. Its function in the conservation of water and electrolytes, those ionized salts which constitute an essential part of the body fluids, is nearly as indispensable as is the function of the kidneys. The skin is extremely important in the regulation of the body temperature within relatively narrow limits. It possesses certain important electrical and chemical properties. It is also the first barrier, and one of the chief defenses of the body, against infectious diseases.

Many other properties of the skin that are of less immediate importance to the problem of stump hygiene nevertheless have a bearing on human health and welfare. For example, we rely on the sensory organs of the skin for a good part of our information about the world around us. Through nerve endings at or near the surface, the body receives the outside environmental stimuli of heat, cold, pain, and touch. Also important to health is the role of the skin in maintaining a highly complex system of pigment metabolism and in providing a source of vitamins important for growth and nutrition.

Although there are other vital functions of the skin, those cited serve to illustrate the importance and variety of the services the normal skin performs. Some of these are described at greater length in the following portions of this paper.

THE ANATOMY OF THE SKIN

Plate I shows in semidiagrammatic form the principal structures of the skin concerned in stump hygiene. The skin is seen to consist of two distinct layers—the epidermis and the dermis, or true skin. These two layers are joined by a system of fingerlike projections, the rete pegs, which protrude down from the epidermis and interlock with the papillae, which project up from the dermis. This device furnishes a relatively large surface area at the dermal-epidermal junction, thus providing a strong bond between the two layers.

The most superficial layer of the epidermis is the so-called "horny layer," consisting of a material called "keratin," which is very similar to animal horn. Scattered over the surface of the skin are numerous deep pockets, called "follicles," into which sebaceous, or oil, glands discharge their contents. From the follicles protrude the hairs of the skin.

Two other types of glands in the skin have an important bearing on the subject of stump hygiene. They are the eccrine, or small sweat glands, which lie in coils near the base of the dermis, and the apocrine, or large sweat glands (not shown in Plate I), which are similarly situated but are more localized in distribution than are the eccrine glands. The watery sweat secretions pass to the surface of the skin by way of the sweat ducts, discharging on the surface through the sweat-duct opening, or pore.

Deep to the dermis lies the subcutaneous zone. Here, cushioned in masses of fat cells, are the large blood vessels which serve the skin. From the arteries, smaller vessels rise, becoming narrower as they branch, until they terminate in fine capillary nets in the papillae of the dermis. Blood from the papillary nets returns again by a venous collecting system to the large veins in the subcutaneous tissue.

RELATION OF SKIN STRUCTURES TO DISEASE

All of these structures are vulnerable to damage from prolonged wear of a prosthesis. Injury to each different anatomical site results

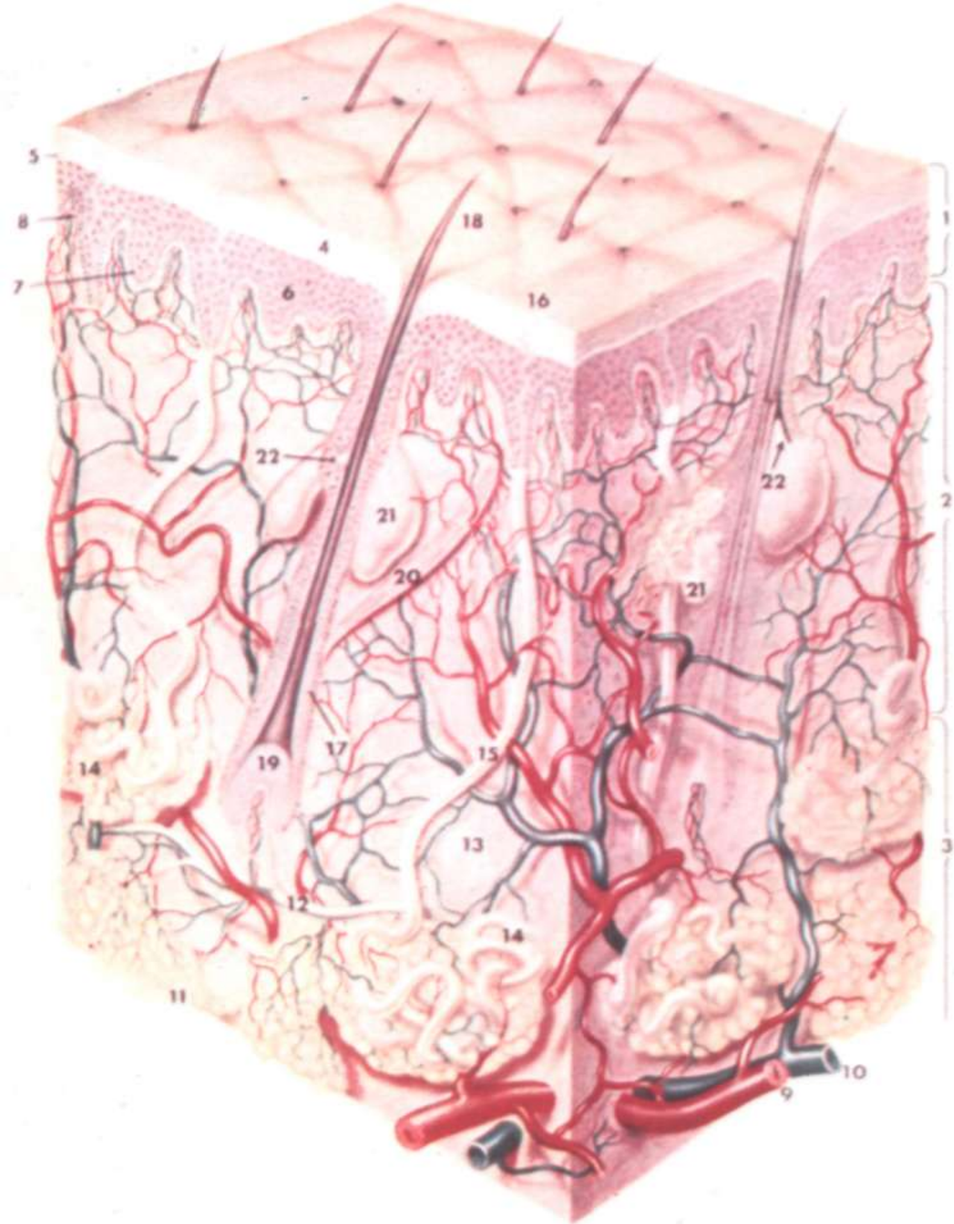


Plate 1. A section of normal human skin. 1, Epidermis; 2, true skin; 3, subcutaneous tissue; 4, horny layer; 5. clear layer; 6, granular layer; 7, germinativc layer; 8, capillary network; *9*. artery; 10. vein; 11. lobules of fat; 12. nerve; 13, corpuscle of Vater; 14. sweat gland; 15, duct of sweat gland; 16, pore of sweat gland; 17, hair follicle; 18, hair shaft; 19, bulb of a hair; 20, arrcctor muscle; 21, sebaceous gland; 22, duct of sebaceous gland. *Courtesy White Laboratories, Inc., KenilKorth, .V. J.*

in a specific disease complex of the skin. For example, excessive heat and moisture may result in a local blocking of the sweat-duct pores. We are familiar with this condition in the form of what is known popularly as "prickly heat," a common malady in warm, humid climates; and the same disorder can occur over stump skin under similar environmental conditions.

Prolonged use of negative-pressure sockets, and to a lesser degree of conventional sockets, may lead to engorgement of the small blood vessels of the skin, resulting in local areas of rupture and extravasation of blood into the surrounding tissues. The dark pigmentation often seen on the terminal end of the stump is the result of this bleeding under the skin. It is usually accompanied by some degree of edema, a state in which there is an abnormal collection of watery fluid in the soft tissues. Thus the skin disorder here is essentially focused in the circulatory system, whereas the previously cited condition of sweat-duct blockage affects primarily one of the glandular systems of the skin. It follows, then, that the over-all hygiene or good health of the stump skin reflects, among other things, the functional state of each of the anatomical components of the skin.

SKIN GLANDS AND STUMP HYGIENE

In the skin of the lower extremity, three different types of glands produce secretions that are discharged on the surface of the skin. These are the eccrine glands, the apocrine glands, and the sebaceous glands (Plate I). During daily use of a prosthesis, their secretions accumulate inside the socket, where they may become a serious hazard to local stump hygiene.

The Eccrine Glands

The eccrine glands, or small sweat glands, are distributed over the entire surface of the body. They are accessory structures that develop from the epidermis. They are true secretory glands, producing a clear, aqueous fluid, and their functioning is vital to the heat regulation of the body, since these glands are the principal source of sweat. It has been estimated that there are over two million of these glands in the skin of a normal adult and from 500 to 600 per sq. in. over the skin of the thigh and lower leg. It has been reported that the capacity for sweating is considerably less for females than for males. According to Weiner *{23)*, roughly 50 percent of heat sweat comes from the trunk, 25 percent from the head and upper limbs, and 25 percent from the lower limbs.

Sweat Deposits. Eccrine sweat is a clear, watery solution containing 0.5 to 1.0 percent of solids. These solids play an important role in stump hygiene because, in the absence of adequate daily cleansing, their accumulation on the surface of the stump and in the socket interior may serve as a source of irritation and to some extent as a culture medium for the growth of harmful organisms. The eccrine sweat solids include urea (in at least twice the concentration found in blood plasma); creatine and creatinine in minute quantities; uric acid; a variety of different amino acids; ammonia; free choline; occasional traces of glucose; lactic acid and lactate (to the extent of more than 2 grams in 90 minutes of heavy physical labor); many of the water-soluble B-vitamins; traces of dehydroascorbic acid; and the minerals sodium, potassium, calcium, magnesium, sulfates, phosphates, and iron. In addition to the sweat solids, there are the secretions of local oil or sebaceous glands, plus a quantity of nitrogenous material made up of keratin shreds and other cellular debris which has been desquamated from the surface of the skin.

This is the residue which collects on the skin and in the socket under normal conditions. If the skin has been damaged by abrasion against the socket wall, or if an eczematous skin condition is present, there may be "weeping" or oozing of serum over the surface, where it mixes with the sweat, oil, and skin debris. This serous material is deposited on the interior wall of the socket, where it dries and sets almost like glue. Successive laminations are added from each day's accumulation, until a considerable thickness may be attained (Fig. 2). Constant wearing and rubbing against the skin may produce a polished, glassy finish on the surface. In the interests of good hygiene, this deposit should be cleaned out of the socket interior regularly.

The innervation of eccrine sweat glands,

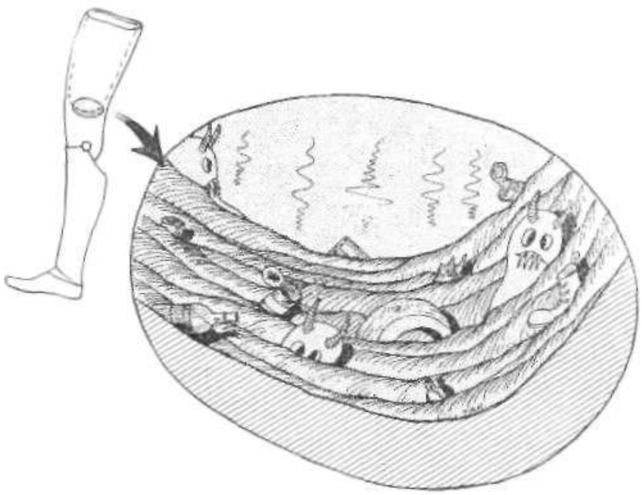


Fig. 2. Debris in the socket. Accumulation of waste in the socket is not favorable to good stump hygiene. Daily waste, consisting of sweat solids, oily secretions, and cellular debris, often combined with serous ooze, is deposited in successive layers that should be cleaned from the socket regularly.

pharmacologically speaking, is parasympathetic or cholinergic. Dale and Feldberg *(10)* demonstrated that the postganglionic nerve fibers liberate acetylcholine at their endings on the receptor cells of the sweat glands. Where excessive perspiration, or hyperidrosis, has been a serious problem, clinical application of this finding has been made by treatment of the patient with an anticholinergic blocking agent to diminish sweating. Drugs like methantheline bromide (Banthine®) and diphemanil methyl sulfate (Prantal®), which are anticholinergic, have been tried.

Such treatment has proved sometimes very helpful, sometimes of slight benefit, and often discouraging. Even though excess perspiration may be reduced, there are not infrequently unpleasant side-effects, such as a sensation oi heat, dryness of the mouth and throat, headache, and urinary retention. In the amputee, who often has an overheating problem in the first place, any further impairment of his cooling mechanism may not be tolerated. In some cases, however, an effort to control excessive sweating may be worth a try; certainly any drying effect that such drug therapy may exercise in the stump area will contribute to the hygienic state of the stump skin.

Eccrine Sweat Retention. In profuse sweating, the sweat is expelled from the eccrine glands onto the surface of the skin at intraductal pressures ranging as high as 250 mm. of mercury. If the outlet at the surface of the skin becomes blocked by masses of keratin, local inflammation, or other obstruction, this pressure may be sufficient to cause rupture of the duct (Fig. 3). If the rupture takes place near the surface at the level of the horny, or keratin layer, the sweat collects in this layer in a raindroplike configuration of little blisters. If the rupture is deeper in the skin, there may be local inflammation, characteristic of "prickly heat." Where the duct is ruptured still more deeply, symptoms are few or none, and the only surface sign consists of small, noninflammatory elevations, or "papules."

Sweat retention may involve most of the skin surface of the body and may be accompanied by pronounced generalized symptoms of fever, headache, and exhaustion, a condition usually confined to tropical climates. More commonly it affects only a localized part of the body. It has been reported in many different types of eczema and in a variety of healing inflammatory lesions. Preliminary investigations of eczematous eruptions of the stump suggest that sweat retention occurs in this area also. The heat and humidity which prevail over the stump skin during use of a prosthesis are factors which encourage the development of sweat-duct blockage and localized sweat retention.

The Apocrine Glands

The apocrine glands, unlike the eccrine glands, develop from the follicular epithelium of the hair, as do the sebaceous glands. Apocrine glands are much larger than eccrine glands, and they are limited in their distribution to the underarm area, the breasts, the midline of the abdomen, and the anal and genital areas. Modified apocrine glands are also found in the external canal of the ear and in the vestibule of the nose.

The apocrine secretion is a turbid, whitish-to-yellowish fluid which dries like glue to form a light-colored plastic. The total number of apocrine glands is greater in women than in men, and axillary sweating starts earlier in adolescent girls than in adolescent boys.

The apocrine glands in the groin and axilla are occasionally the site of a chronic, extremely stubborn disease of the skin called "hidradenitis suppurativa." This disease is characterized by large, burrowing, painful cysts which are filled with a foul discharge. These periodically break down and drain, then heal with scarring, and the process may be repeated indefinitely. Frequently the condition is so severe that surgical extirpation, followed by skin-grafting, affords the only means of controlling it. Rarely, hidradenitis suppurativa is encountered in amputees. In such cases it can cause a really serious handicap, making the use of a prosthesis or crutches impossible.

Innervation of the apocrine glands is exclusively adrenergic, as compared with the cholinergic innervation of the eccrine glands. The apocrine system responds sluggishly or not at all to heat. However, it does respond promptly to emotional or painful stimuli. In the management of this aspect of the amputee's hygiene, therefore, it is important to bear in mind that pain or tenderness in the stump, or an emotional disturbance, may aggravate any existing skin disorders in the groin or underarm regions through stimulation of this specialized glandular system.

Unfortunately, the apocrine glands occur in the areas upon which the amputee must depend for support in the use of a crutch or an above-knee prosthesis. The apocrine glands can be a source of considerable grief, if, through poor hygiene, infection, or other cause, these areas are allowed to become unserviceable for weight-bearing.

The Sebaceous Glands

The sebaceous glands occur wherever there are hair follicles. In addition, there are scattered, free sebaceous glands which are independent of the follicles. Their secretion is an oily liquid composed of fatty acids, alcohols, hydrocarbons, and certain vitamin precursors. This material, called "sebum," becomes solid at about 30°C (86°F), the prevailing skin-surface temperature.

A unique feature of sebaceous-gland secretion is the capacity of the glands to secrete very rapidly onto a defatted skin surface, but at a rate which gradually declines until the new fat layer of the surface reaches a certain critical thickness. When this occurs, sebum production stops or falls to a minimum. If, however, the fat layer is removed, rapid secre-

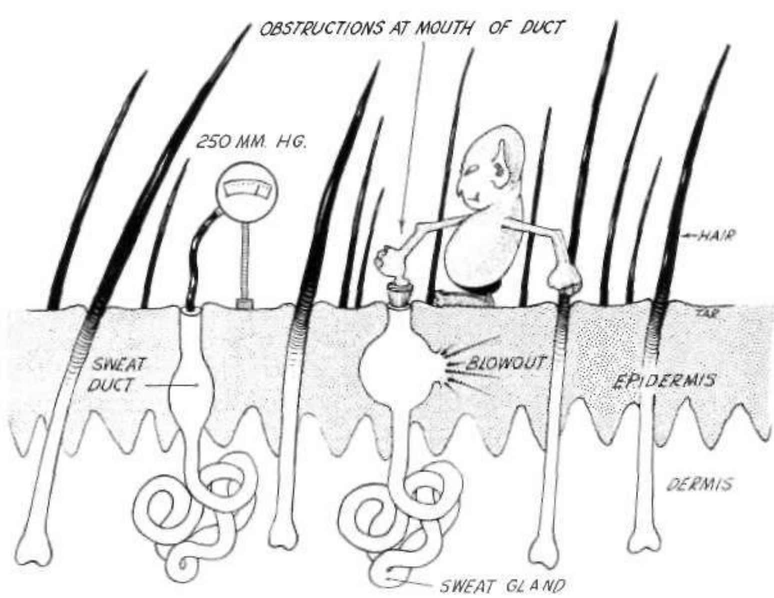


Fig. 3. Pressure in eccrine sweat glands. When an eccrine gland is actively secreting sweat onto the surface of the skin, the pressure in the sweat duct may rise to 250 mm. of mercury. If the opening of the gland becomes blocked, as symbolized by the gremlin, this pressure may be sufficient to rupture the gland duct and allow the sweat to escape into the skin.

tion starts again. The more viscous the sebum becomes, the earlier the sebum expulsion is stopped. As a result, more oil is secreted per unit time at a high environmental temperature than at a low temperature.

Presumably, the counterpressure of the oil film on the surface prevents further production by back-pressure in the gland. There is an interesting fact, however, which is not entirely explained by the back-pressure theory: if the duct of the gland is blocked by sebum only, no pathologic change takes place in the secretory cells of the sebaceous glands, but if the obstruction is caused by masses of keratin or other foreign matter, as in the case of comedones ("blackheads") and various types of follicular keratoses, degenerative changes in the gland set in relatively early.

This phenomenon of controlled oil production is one in which a normal physiologic process appears to work with the amputee rather than against him in the wearing of a prosthesis. Here, the accumulating lipid film under the socket will serve as its own shut-off valve for further secretion, without damage to the sebaceous glands in the stump skin.

HEAT CONTROL AND THE HEALTHY SKIN

Healthy skin exercises a vital role in the thermoregulation of the body, a function in which the skin of the lower extremities normally has an important share. This surface control supplements the central heat-regulatory center in the hypothalamus of the brain. At basal conditions, the heat balance of the normal body is maintained by cutaneous vasomotor adjustment through an environmental temperature range of 25° to 31°C (77° to 88°F), the so-called "zone of vasomotor control." Above this range, at 31° to 32°C (88° to 90°F), when cutaneous blood flow has reached its maximum, sweating sets in—the "zone of evaporative regulation." Between 31° and 36°C (88° and 97°F) and at low humidity, evaporative heat loss easily maintains normal temperature. Below the zone of vasomotor control, the skin temperature falls, and body temperature is maintained chiefly by chills (the "zone of cooling"). If environmental temperature is maintained below a critical level of 31° to 32°C, there is generalized, but grossly invisible, periodic sweating known as "insensible sweating." Consequently, although the principal thermoregulation in this temperature range is vasomotor, there is still an assist from the sweat glands in cooling the skin surface.

The values cited are those reported for the normal. In the amputee, significant areas of cooling surface, along with the component sweat glands, have been subtracted from the total reserve of functional skin surface. In addition, the complex and important system of vascular shunts and arterioles in the amputated limb or limbs has also been lost from the total heat-regulatory mechanism. As a result, a number of characteristic and troublesome disturbances of temperature and heat control are associated with amputation.

Among these is the phenomenon of the poikilothermic stump, which has been studied by staff members of the University of California Medical School *(22)*. In this condition, the surface temperature over the distal part of the stump, and over a considerable portion of the stump proximally as well, tends to become stabilized at the temperature of the surrounding air, more or less independently of any vasomotor control. Thus it is seen that, in a lower-extremity amputation, not only is part of the original heat-control surface permanently lost but the remaining stump surface is no longer normally effective as part of the heat-control mechanism. Nevertheless, it is important to maintain the hygiene, or good health, of this remaining skin area in order to preserve whatever function it may still possess for heat regulating, and particularly for cooling.

MECHANISMS of HEAT LOSS

Heat loss from the normal skin takes place by radiation, convection, conduction, and evaporation. All of these mechanisms are interfered with, if not entirely abolished, over the stump area when a tightly fitted socket is worn, Excessive local heating of the stump can result (Fig. 4), particularly during warm, humid weather, and a major hygienic problem can arise under such conditions.

Heat loss from the skin by radiation takes place in the form of infrared rays in the range of 5 to 20 m/u. Under normal conditions, radiation accounts for about 60 percent of total heat lost from the body. In the amputee, it

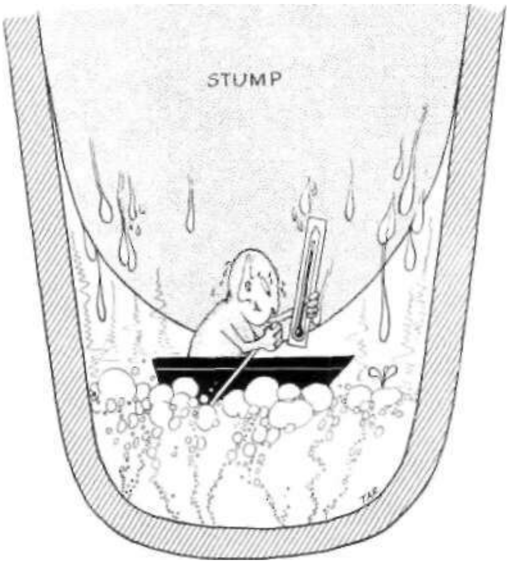


Fig. 4. Overheating of the stump. Since air cannot circulate inside a snugly fitted socket, the stump is usually bathed in sweat.

seems probable that loss of heat from the stump area by this mechanism is greatly restricted by the socket of the prosthesis. We do not at present, however, have any data to confirm this supposition.

Convection depends upon the transfer of energy by means of moving air and thus is negligible as a means of heat loss from the stump when a prosthesis is worn.

Conduction, the transfer of heat between two media in direct contact, is of great importance to the amputee. As the socket becomes warmed to skin temperature, it acts as an insulator against further dissemination of heat from the surface of the stump. It appears probable also that in the vicinity of principal loading, especially along the medial, anterior, and posterior segments of the socket rim, heat is generated by the friction resulting from shearing action between the skin and the socket rim. The insulating effect of the socket would, of course, tend to maintain any such local elevation of temperature. We are initiating a clinical study of this question, employing thermistors for the direct reading of skin temperatures while the prosthesis is being worn under various conditions of normal use.

Just how significant increased local heating of the skin may be in adversely affecting skin hygiene and metabolism over a long period of time we cannot say at present. It is known that an increase in environmental temperature elevates the oxygen and nutritional requirements of most tissues. At the same time, the blood supply to the skin of a lower-extremity stump, if changed at all by the active use of a prosthesis, is probably reduced. One might speculate here whether the predilection of these weight-bearing sites for the development of recurrent "pressure sores" may not be related to increased local heat plus diminished nutrition, as well as to mechanical damage and to maceration from sweat. Certainly this area of stump hygiene merits further investigation.

REFLEX SWEATING

If, in the normal person, the environmental temperature is raised above a critical level between 31° and 32°C (88° and 90°F), there is a sudden, visible outbreak of sweating over the whole body. A similar response, termed "reflex sweating," may be observed when only a portion of the body surface is heated. Whenever there is excessive heating of the stump, the conditions favor reflex sweating, even though the environmental temperature of the rest of the body is below the critical level necessary for visible sweating. Certainly a valuable contribution, both to the comfort of the amputee and to the improvement of his stump hygiene, would be the development of new socket materials and designs which would provide for more rapid heat transfer by conduction and radiation to the outside air.

Loss of heat by evaporation from the stump is negligible in the case of the suction socket. Where the conventional socket is worn with a wool stump sock, however, the wicking action of the sock may well provide an avenue for evaporation and consequent cooling. A light stump sock for use with the suction socket may prove feasible. If so, the cooling effect, as well as the added support and protection afforded the stump skin, would be of benefit in maintaining a healthy stump.

According to Rothman *(15)*, sweating which is elicited by exercise begins at a lower skin temperature than does sweating produced by external heat. Bazett (2) suggested that there may be, deeply situated near vascular plexuses, thermal receptors which are warmed by the working muscles. These receptors may in turn activate the sweat glands of the skin. Whatever the true explanation may be, the combination of excessive sweating (Fig. 5) and increased energy requirements for locomotion is all too familiar to the lower-extremity amputee.

Visible sweat secretion and heat loss can also occur independent of thermoregulatory needs. For example, sweating can be elicited with ease at air temperature below 31°C (88°F) by the ingestion of hot drinks, probably through a viscerocutaneous reflex. A variety of other nervous impulses unrelated to heat control may produce sweating. One of the most important of these is "emotional sweating," which may at times affect most of us to some degree. In dermatologic practice, we sometimes see patients in whom this condition has become so severe as to be almost incapacitating. Serious limitations affecting social contacts and employability result. The same disturbance of sweat mechanism may be experienced by amputees. Although the emotional factor may be important in some amputees who have a troublesome hyperidrosis, it is apparent from some of the known physiologic mechanisms for sweating that there may be other reasons for such an increase.

Fig. S. Excessive sweating. An amputee using an artificial leg may complain more of general bodily discomfort from heat and excessive sweating than would a normal individual undergoing similar exertion.

STUMP HYGIENE AND GERMS

It has been a matter of frequent observation that the normal skin is not a sterile skin. Such a condition simply does not exist. Normal skin teems with immense numbers of unseen organisms, some harmless and some pathogenic, that is, capable, under the right combination of circumstances, of causing an infection of the skin. Normally, the harmful bacteria and fungi are held in check by a number of different forces. Most of the time we live in some measure of harmony with this enveloping horde. But when resistance to infection is lowered by local skin damage, the presence of some generalized disease, a metabolic disturbance such as diabetes, or any one of numerous other causes, then this harmonious balance is destroyed and the avenue of invasion is opened. Two different classes of bacteria exist on normal skin under average conditions—the resident bacteria, which remain fairly constant, and the transients, which may be almost anything (Fig. 6). In addition, a variety of fungi come and go, chiefly members of the yeasts and molds, although other types, such as those which cause ringworm of the feet and body, may be present.

Evans *et al. (11)* have studied the resident bacterial flora in 146 sample scrapings from the skin of 17 adults over an eight-month period. They found that the anaerobic bacteria (those which grow in the absence of free oxygen) outnumbered the aerobic bacteria (those which require free oxygen) by a ratio that ranged between 10:1 and 100:1. In most of the cases, one species of anaerobic bacteria predominated, the so-called "acne bacillus," *Propionibacterium acnes (Corynebacterium ac-*

nes). Of the aerobic bacteria, two species were observed regularly: *Micrococcus epidermidis* and *Staphylococcus albus {Micrococcus pyogenes),* the latter a skin pathogen The observation was made that, at least in cultures, some types of bacteria inhibited the growth of others. This finding might constitute one explanation for the overgrowth of certain bacteria, especially the acne bacillus, at the expense of the others. It was also found that the sebaceous glands were the major site of growth of bacteria on the skin and that exercise with sweating caused a transient minor increase in skin flora.

What effect might the wearing of an occlusive prosthesis be expected to have on common skin pathogens trapped under the socket? How might the normal defenses of the skin be affected by the conditions attendant upon the use of a prosthesis? To answer these questions, let us consider four common groups of organisms which are likely to cause skin infections in the region of the amputee's stump—the gram-negative organisms like *Escherichia coli,* the staphylococci, the beta hemolytic streptococci, and *Proteus,* some strains of which are secondary wound invaders.

We know that the normal skin surface has two important natural defenses against bacterial invasion—first, the ordinary drying action on the surface, facilitated, where the skin is uncovered, by the movement of air currents; second, the presence of unsaturated fatty acids (particularly oleic acid), which are components of the sebum, or oily secretion from skin oil glands.

Gram-negative organisms, that is, those organisms which do not retain the selective blue dye used in the Gram staining technique, are particularly sensitive to drying. This alone is effective in killing or inhibiting their growth. Unfortunately, the dry state never exists for any length of time over the stump skin during the use of a prosthesis.

Both the drying and the action of the fatty acids are slightly to moderately inhibitory against the staphylococcal organisms. In other words, neither factor offers sure protection

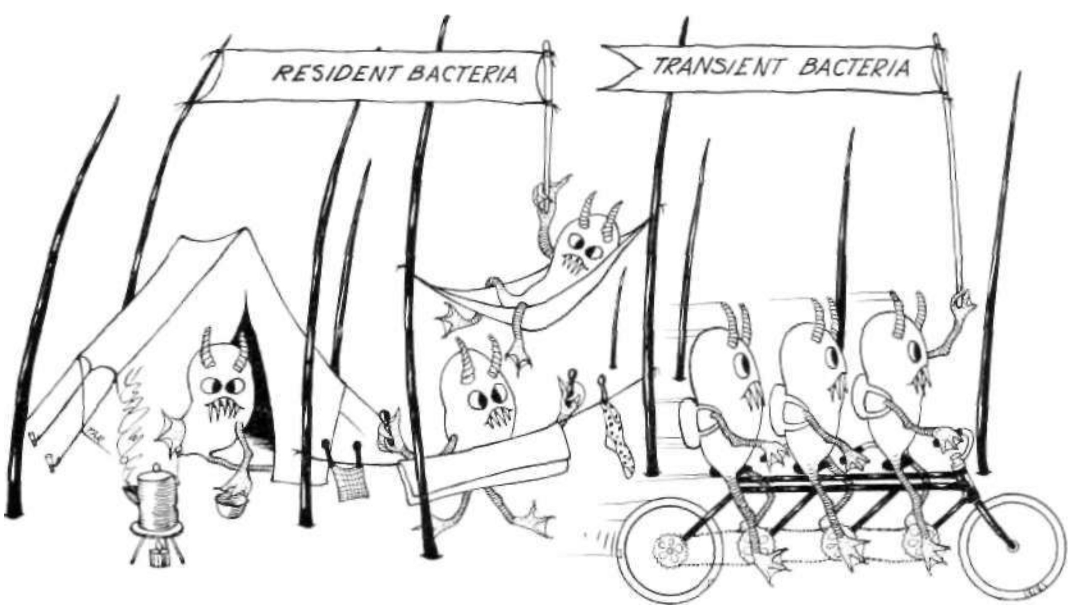


Fig. 6. Flora of the skin. Of the teeming numbers of microorganisms on the normal human skin, some are resident bacteria, which are found on the skin more or less constantly, while others are transient bacteria—only temporary visitors. Common among the residents are *Corynebacterium acnes,* the so-called "acne bacillus"; *Micrococcus epidermidis;* and *Micrococcus pyogenes,* a skin pathogen.

against invasion by this group of germs, but both have deterrent value in the normal skin. Again, the moist state which usually exists under the socket tends to encourage the growth of staphylococci.

Although the beta hemolytic streptococcus is unaffected by drying, it is destroyed by oleic acid. But streptococci will grow in serous exudate, such as may be seen in a weeping eczematoid dermatitis of the stump, because the albumin in the exuded serum neutralizes the oleic acid, the chief natural antagonist of the streptococci. This relation of exudative lesions of the skin to secondary infection underlines the importance of adequate hygienic care in routine management of minor abrasions and irritations of the stump area. Furthermore, it should be apparent that there are times when the continued use of a prosthesis on a stump which is the site of a dermatitis, especially where a serous discharge is present, will prevent healing and is almost certain to invite a secondary infection.

The *Proteus* strains—the fourth group of organisms mentioned—multiply rapidly in a moist environment. Any occlusive dressing or cover, such as the socket, which tends to increase local moisture on the skin will favor a heavy overgrowth of *Proteus*.

Thus we see that, in all four of the examples cited, the use of a prosthesis may be expected in some measure to interfere with the defensive mechanisms of normal skin in its resistance to disease. This interference is augmented by prolonged or strenuous use of the prosthesis and by the presence of any pre-existing lesions, however minor they may seem to the amputee.

ELECTRICITY AND THE SKIN

The electrical behavior of the skin plays an important part in the preservation of good health. Normally, there is a negative electrical charge in the superficial layers of the skin. When an alkaline condition prevails, this electrical negativity is increased owing to adsorption of negatively charged hydroxyl ions. An acid condition of the skin, however, causes a discharge of this normal negativity, which is complete between pH 3 and pH 4. As the relative acidity of the skin increases, there is eventually a reversal of the charge, the skin surface becoming electrically positive. Furthermore, investigators have reported that scarring of the epidermis *(14)* and prolonged soaking in water or concentrated salt solutions *(13)* tend to cause a discharge of the normally negative charge of the skin. Both of these abnormal conditions may develop over the stump as the result of use of a prosthesis.

Just what effect socket wear has on the normal electrical behavior of the stump skin, or how significant this may be in maintaining a healthy condition in the stump area, we do not know at the present time. This is, however, another problem that should receive further investigation. We do know that the negativity of normal skin can be a factor in the defense of the body against pathogenic organisms, which are also negatively charged and which tend to be repelled from, or bound to, the surface of the skin according to variations in the electrical charge on the latter (Fig. 7). It is of interest, incidentally, to note here that in muscle the relationship of negative-positive electrical charges to normal and damaged tissue, as here described for the skin, is just reversed.

STUMP HYGIENE AND LOCAL pH or THE SKIN

Blank *(3)* has confirmed earlier observations that the pH of healthy skin is always on the acid side, falling usually between 4.2 and 5.6. Furthermore, both eccrine sweat and apocrine

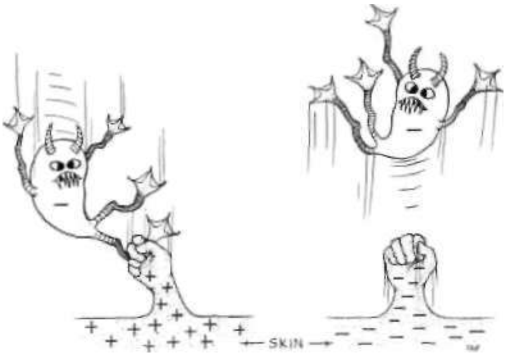


Fig. 7. Electrical charge on the skin as a defense against germ invasion. Germs, which are negatively charged, tend to be repelled from the normally negative surface of the skin but are attracted to the skin when this charge is reversed.

sweat are normally acid. These facts have given rise to the concept of the so-called "acid mantle" of the skin, which is cited by some investigators as one of the body's natural defenses against disease. Schmid *(17)* found a significant shift toward the alkaline side in the surface pH of the skin in cases of eczema and in seborrheic dermatitis, an inflammatory disorder involving especially the hairy and more oily regions of the skin. In general, an even greater shift toward the alkaline side takes place in these inflammatory diseases if the intact skin is broken and neutral in charge or if alkaline extracellular fluid diffuses through, as in any acute, weeping dermatitis of the stump. With healing, the original acid pH returns.

BUFFERING ACTION OF NORMAL SKIN

Another important property of the skin is its buffering action. If the skin surface is exposed to dilute acids or alkalies, there is normally a corresponding shift of the pH locally; but this is temporary, and the former acid pH is rapidly restored. This behavior represents the neutralizing capacity of the skin. Probably the most important agents in this neutralizing property are the sweat constituents, especially the lactic acid-lactate system and the amphoteric amino acids. Any local damage to the sweat mechanism, such as might be caused by socket irritation, could conceivably impair this important function of the skin in the involved areas. Burckhardt *{7,8)* and others have established that there is a definite correlation between the acid and alkali neutralizing capacity of the skin and its tolerance for acids and alkalies.

Pursuing a discussion of acid-base balance brings to mind several unanswered questions with regard to the amputee's problem of stump hygiene. We would like to know, for example, what happens to the normally acid pH of stump skin during the daily wearing of an airtight socket. Does stump skin possess the same pH and buffering properties as the skin of an intact limb? What effect do different socket materials have on the pH of stump skin? Does an interior finish which gives an alkaline reaction necessarily cause more damage to the skin than does one with an acid reaction? These are questions which should receive further investigation in the light of their vital relationship to stump hygiene.

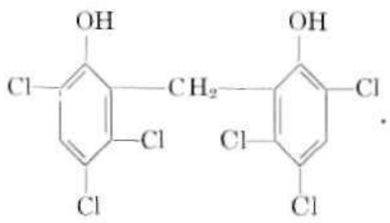
It might seem from the foregoing that the cutaneous surface which gives an acid reaction denotes a healthy skin, resistant to invasion and disease, while an alkaline-reacting skin surface denotes the presence of some disease state. Unfortunately it is not quite so simple. Some organisms grow readily on an acid medium. Pathogenic fungi, for example, flourish on certain media at pH 4.9. Nonetheless, in general, it is desirable to maintain the surface of the skin at least slightly on the acid side.

Washing, even with plain water, causes moderate hydration of the horny layer, with a drop, according to Szakall *(21),* from pH 6.3 to pH 5.3 in 30 minutes. This information may also have some application to lower-extremity prosthetics, since the stump skin becomes soaked with sweat in most cases shortly after the prosthesis is put on. Furthermore, a single washing with soap removes about 50 percent of the surface lipid film, thereby facilitating the outward diffusion of carbon dioxide, the acid reaction of which helps to neutralize an alkaline state on the surface of the skin.

SURFACE pll AND DEGERMING OF THE SKIN

Control of surface pH is also important in degerming the skin. Blank, Coolidge, and others *(4,5,6),* in an extensive study of the surgical scrub, have investigated many different germicidal agents and techniques of cleansing. Among the agents studied were the quaternary ammonium compounds, like Ceepryn® and Zephiran,® which are widely used in surgical cleansing of the skin. While these compounds do exert a bacteriostatic or bacteriocidal effect, Blank *et al. (6)* found that they also have the property of binding the bacteria to the skin. It was demonstrated that, at a pH a little higher than the isoelectric point of keratin, the quaternary ammonium compounds change the normally negative charge on the surface of the skin to positive. Since the bacteria are negatively charged, they are attracted to the skin. If the pH is then increased considerably, for example by rinsing with an alkaline soap, the charge on the skin will revert to negative and the bacteria will be released from the skin, as has been confirmed experimentally by analysis and culture of the rinse water.

Another germicidal agent commonly used in disinfecting the skin is G-ll,® or hexachlorophene. Chemically it is 2,2'-methylenebis (3,4,6-trichlorophenol):



This compound has the double advantage of accumulating on the skin when used daily and of not being inactivated, as most germicides are, when combined with a detergent. If used only at infrequent intervals, G-ll is no more effective as a disinfectant than any nonmedicated soap. If used regularly, however, within five to seven days there will develop in the skin a concentration sufficient to cause a definite reduction in the bacterial flora. One contraindication to the use of this agent is the presence of a serous ooze, such as we see not infrequently on the stump in various types of eczematous skin conditions. Seastone *(19)* has reported that as little as 1.0 percent of sterile serum will reduce the bacteriostatic effect of this agent.

Hexachlorophene is available commercially in combination with various soaps and liquid detergents, in strengths varying from 0.75 to 3.0 percent. These include such brand names as Dial® soap, Gammaphen® soap, pHisoHex,® and Septisol.® Another useful preparation of G-ll is an alcoholic solution containing 0.1 percent of G-ll, with 0.5 percent of cetyl alcohol added as an emollient. This solution may be used as a two-minute rinse following soap-and-water cleansing of the stump.

A useful cleansing agent for stump skin has been found to be pHisoHex, especially where superficial infection is a problem. It consists of an emulsifying agent known as pHisoderm,® to which 3 percent of G-ll has been added. Chemically, pHisoderm is sodium octylphenoxyethoxyethyl ether sulfonate, plus lanolin cholesterols, lactic acid, and petrolatum. Its pH is 5.5, approximately that of normal skin. It lowers the surface tension of water and is an active emulsifier.

There are many other agents for degerming the skin, many of which are too irritating for the type of regular use necessary to routine stump care. One of the more readily available of these is alcohol, which remains a useful bacteriocidal preparation. Isopropyl alcohol, for example, is germicidal up to 50-percent dilution. Too-frequent use of such solvents, however, will dry the skin excessively and may do more harm than good. Furthermore, any marked depression of bacterial flora over the stump skin cannot be maintained for long during use of the prosthesis.

SELECTIVE ABSORPTION AS A PROTECTIVE BARRIER

The healthy cutaneous envelope of the body is constantly active as a physicochemical barrier against the outside world, retaining some substances and passing others through (Fig. 8). As early as 1904, Schwenkenbecher *(18)* showed that the intact skin is permeable to fat-soluble substances and to certain gases but is practically impermeable to water and most electrolytes. Most substances which are soluble in both water and lipids penetrate the skin and pass into the general circulation at rates comparable even to gastrointestinal or subcutaneous absorption. Phenolic compounds, lipid-soluble vitamins, and hormones penetrate rapidly. This property of the skin conceivably could be of serious import in the indiscriminate use of socket materials or finishes capable of liberating absorbable toxic fractions which could be taken up by the stump skin.

In rare instances, individuals have demonstrated a peculiar sensitivity, known as an "idiosyncrasy," on first exposure to certain drugs and chemicals applied to the skin. Alexander *(1)* described a case of iododerma, a form of iodine reaction, resulting in the death of a 37-year-old woman following routine preoperative cleansing of the surface of the skin over the abdomen with iodine. This is not

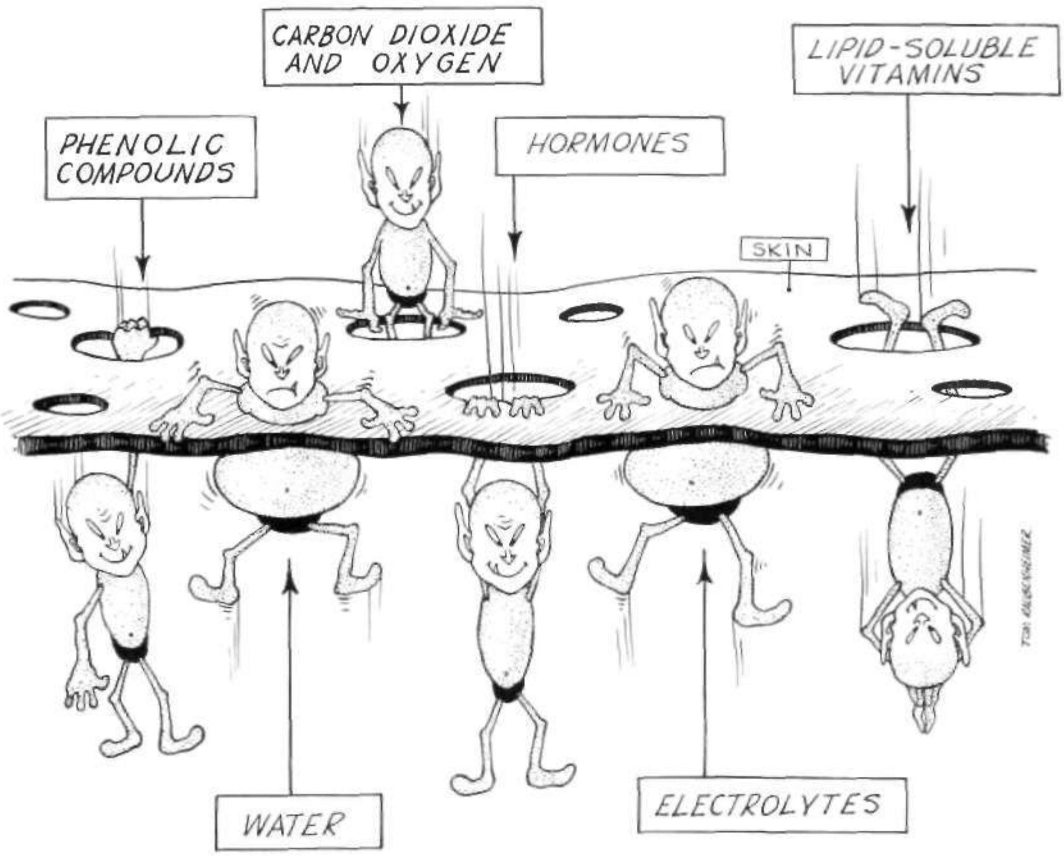


Fig. 8. The skin as a protective physicochemical barrier. The skin conserves in the body some substances like water and electrolytes by selectively barring their outward passage. Other substances, for example the gases carbon dioxide and oxygen, are passed freely through the skin. Lipid-soluble vitamins and hormones likewise readily penetrate the skin barrier. Unfortunately, certain materials which are potentially toxic, such as the phenolic compounds, may also be freely absorbed by the skin. Care should therefore be taken to avoid prolonged intimate contact with such materials.

intended to suggest that any similar hazard exists in the use of present-day, conventional socket materials. It does, however, emphasize the fact that the skin may be, in certain rare cases, an open portal to the systemic circulation.

Transfer of gases across the skin barrier may take place with ease in either direction. The biological significance of the movement of oxygen and carbon dioxide through the skin, which was once thought negligible, is given more importance now. Shaw and others *(20)* found that oxygen was given off through the skin when the oxygen content of the ambient air was reduced to about 2 percent and that it was absorbed more rapidly when the skin was surrounded by a gaseous mixture containing about 37 percent of oxygen than when surrounded by air. According to Chambers and Goldschmidt *(9),* if the total skin surface is surrounded by nitrogen gas instead of air, there may be a compensatory, increased uptake of oxygen by the lungs.

Hediger *(12)* reported that, from a water chamber containing the dissolved gas, carbon dioxide passed into the skin as long as the water contained more than 4 percent of carbon dioxide. When the concentration dropped below 4 percent, carbon dioxide diffused outward through the skin, as it does constantly under physiological conditions. Measurements cited by Rothman and Schaaf *(16)* showed that over a 24-hour period 7 to 9 grams of carbon dioxide escaped from the total skin surface, less that of the head, of an adult male. The amount suddenly increased when the temperature was raised to the critical temperature of visible sweat secretion.

Cleansing of the skin with organic solvents such as ether, benzene, and, to a lesser degree, alcohol, enhances percutaneous absorption, that is, absorption across the skin barrier. Since such solvents are used frequently in the cleansing of the stump, as well as of the interior of the prosthetic socket, this effect upon the skin's absorption should be borne in mind. Moisture, almost constantly present in the wearing of a prosthesis, also promotes transepidermal absorption by an unexplained mechanism.

SUMMARY

Through the use of improved prostheses, many amputees have been able to return to relatively normal physical activity and to take again their rightful place in business and social life. It must be remembered, however, that the use of a prosthesis places upon the leg amputee new and heavy demands, including not only muscular and emotional readjustments but also the infliction of unaccustomed wear and tear upon his stump skin. Daily, for the rest of the amputee's life, his stump will be subjected to an abnormal environment that combines heat, moisture, and darkness with chemical and mechanical irritation. It becomes imperative then, in restoring the amputee to full activity, to make certain that he understands the importance of systematic skin care. An adequate appreciation of the necessary requirements for good stump hygiene must be based on a knowledge of the functions and limitations of normal skin.

The skin provides for the other tissues a highly effective, tough and elastic outer covering, which has a great capacity for strengthening itself at points of stress and for repairing itself after injury. But this capacity of the skin for mechanical protection, the limits of which are of special interest in prosthetics design, is only one of its many important functions. The skin possesses, in addition, a variety of anatomical structures, including the eccrine, apocrine, and sebaceous glands, the normal function of which is necessary for the preservation of good skin hygiene. The eccrine glands are indispensable in the heat control of the body. All of the glands produce secretions, some of which are exceptionally copious. This normal function poses an important sanitary problem for the amputee and makes routine cleansing of both the skin and the prosthesis essential.

The natural defenses of the skin against germs depend upon good hygiene. Conditions inside the socket tend to impair the resistance of the skin to infection, but through adequate cleansing, frequent airing, and intelligent care of early lesions, serious infection may be avoided.

Knowledge is increasing concerning the electrical and chemical buffering properties of the skin and their role in the maintenance of skin health. There is usually a negative charge in the superficial layers of normal skin. It is, however, discharged by injury or by prolonged soaking in water or salt solution. Similarly, normal skin is slightly acid, but in the presence of inflammation of the skin a shift to the alkaline side usually occurs. The sweat constituents contribute largely to the capacity of the skin to neutralize or buffer dilute acids and alkalies to which it is exposed. Whether or not these properties are retained intact by the stump skin of amputees and, if so, how they are affected by the conditions of use of a prosthesis are important areas for further research.

Although the skin serves as a protective barrier, it is readily penetrated by certain substances. For this reason the stump should be protected from contact with materials potentially toxic. Similarly, the stump skin may be subject to a variety of local injuries—mechanical, chemical, or allergic in origin. Again the importance of early and close attention to minor lesions and to good preventive hygiene must be emphasized.

There have been two chief aims in this discussion of basic principles. The first was to impart an awareness of the complex nature of the problem of stump hygiene and the second to emphasize that good stump hygiene, far from being an academic matter, is one of the utmost importance to the amputee. Like the proverbial dispatch rider whose horse was crippled for want of a horseshoe nail, the amputee may suffer discomfort and serious disability because of neglect of a seemingly insignificant lesion or failure to follow a simple cleansing routine.

ACKNOWLEDGMENTS

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The Skin Problems of the Lower-Extremity Amputee[1]

S. WILLIAM LEVY, M.D.[2]

Since the establishment, in the autumn of 1954, of the skin-study group of the Lower-Extremity Amputee Research Project at the University of California, other physicians within the Project have referred to us for observation and treatment those amputees having cutaneous problems associated with the wearing of a prosthesis. Out of this nidus, specific information regarding the various clinical problems has been assembled and correlated in an effort to benefit the individual amputee. Some of the clinical problems have aroused interest in basic dermatologic research, so that investigation has not been of a purely clinical nature.

The cutaneous difficulties associated with the wearing of a leg prosthesis have been evaluated in more than 200 patient-visits, and every effort has been made to classify cutaneous disorders specifically. Approximately the same number of above- and below-knee amputees have been carefully screened and examined. Complete histories have been taken, and physical examinations of the skin have been performed. Skin biopsies have been obtained in many instances, and histopathologic sections have been examined carefully in an effort to determine the course of a specific disorder. Other laboratory aids, such as skin scrapings for fungi or patch tests for contact dermatitis, have been utilized. Stump hygiene is important in relation to many clinical disorders of the skin, and accordingly a specific hygienic program for the care of the stump is being developed.

Skin lesions, however minute they may appear, are nevertheless of great importance since they may be the beginning of an extensive cutaneous disorder that may be mentally, socially, and economically disastrous to a given individual. It is best to view any minor irritation as a potentially dangerous symptom and to deal with it as early as possible. Once the skin problem has begun, it should not be ignored in the hope that it will heal of its own accord. Nothing can be more frustrating to the lower-extremity amputee than to be told to remain off his prosthesis or to go on crutches because he has neglected a minor skin eruption.

This article is devoted to the common skin problems and danger signals associated with the wearing of a lower-extremity prosthesis. Most of our experience has been gained with the above-knee amputee using the suction-socket suspension, but it is believed that the same or similar problems arise in patients using the more conventional types of suspension.

STUMP HYGIENE

Hygienic measures are of the utmost importance in the daily care of amputation stumps and in the use of prostheses. A neglect of cleanliness can easily result in damage to the skin and thus open the door to a number of cutaneous disorders which can require temporary removal of the prosthesis. There is no

[1] Based on a lecture presented before the University of California Pilot School in Lower-Extremity Prosthetics, August 25, 1955, at the U.S. Naval Hospital, Oakland, California.

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unanimity of opinion on exactly what measures should be employed routinely. Amputees have come to us with many varied and weird ideas. Some have used strong soaps and alkalies on their stumps, some alcohol, and others formaldehyde. These hygienic measures have been handed down from one person to another and frequently without reason or logical explanation. Some patients fail to wash either the stump or the socket, thereby giving rise to maceration and malodor.

A simple hygienic program using a sudsing detergent has in many instances prevented or eliminated a cutaneous disorder, and hence we frequently request an amputee to follow a given routine. He is advised against the use of any preparation which would leave a deposit in the socket or any solvent which might affect the interior finish. A simple procedure for cleaning the socket is to wash the inner surface with a lukewarm, soapy cloth or one containing a detergent, remove the soapy residue with a clean wet cloth, and then dry out the socket with a towel. The prosthesis should not be put on for several minutes so that it may have an opportunity to dry completely.

For the stumps of most individuals, a bland soap or liquid detergent provides a good cleansing without irritating the skin. Soaps or detergents containing hexachlorophene provide a bacteriostatic action, in addition to cleansing, and may aid in reducing the danger of infection. An amputee is frequently advised to purchase a plastic squeeze bottle of pHisoHex,® an item available in every drugstore, relatively inexpensive, and to be had without a prescription. He is instructed to spread over the amputation stump a small amount of this antibacterial sudsing detergent containing hexachlorophene. A little water is added and the material worked into a lather. More and more water is added to increase the amount of sudsing. He is told to avoid washing off the suds until ready for thorough rinsing. When well cleansed, the site is then rinsed off with lukewarm water, and the stump is dried by patting rather than by vigorous rubbing. This simple routine should be followed nightly, or every other night, depending upon the rate of perspiration, the degree of malodor, and the bathing habits of the individual. In the treatment of some persistent eczemas of the stump, this simple hygienic program was found to be curative.

CLINICAL PROBLEMS

Some amputees go along for months or years without difficulty or irritation of the stump skin. In others, the skin is a weak tissue, and frequent difficulties arise. Persons concerned with amputees should be aware of certain pathologic conditions—certain danger signals—which are frequently the forerunners of seriously incapacitating cutaneous disorders. Early recognition and treatment of these conditions can avert much mental anguish and loss of social or economic activity. It should be remembered that, once on a prosthesis, the amputee desires to stay on, and it is of vital concern to the physician and prosthetist to prevent any disorder which may return him to crutches or bed rest. What, then, are some of these danger signals?

STUMP EDEMA SYNDROME

When an amputee first starts wearing a suction-socket prosthesis, he can expect to see edema or swelling and reddish-brown pigmentation, roughening, and drying of the skin of the terminal portion of the stump (Fig. 1). These changes are the almost inevitable result of the altered conditions forced upon the skin and subcutaneous tissues. They are relatively innocent, do not usually require therapy, and are partially prevented by gradually compressing the stump tissues with an elastic bandage prior to use of the prosthesis. An incorrectly fitted socket may predispose a leg amputee to this disorder.

In several of our patients the edema has been massive, and distal pigmentation has followed, with the formation of hemorrhagic papules and nodules. Superficial erosion of the skin in these regions is not uncommon, and, in rare instances, deep ulcers can result from the poor cutaneous nutrition (Fig. 2). Multiple biopsies have been taken in order to determine the pathogenesis of this disorder. Special staining of the sections revealed that the pigmentary changes were due to the blood pigment, hemosiderin, within the tissue (Fig. 3).

The collagen of the dermis was thickened by newly formed fibrous connective tissue, and there was an abnormal proliferation and dilatation of blood vessels. It may be that this kind of disorder is vascular in origin and that a venous and lymphatic congestion is productive of the edema and hemorrhage. It is hoped that the basic pathogenesis will be clarified as more patients with this syndrome are studied.

Edematous portions of the skin of the distal part of the stump may become pinched and strangulated within the socket (Fig. 4). Such areas may ulcerate or become gangrenous owing to impaired blood supply.

CONTACT DERMATITIS

Contact dermatitis (Fig. 5) is caused by contact of the skin with a chemical that acts either as a primary irritant or as a specific allergic sensitizer. As defined by Schwartz *(10),* "A PRIMARY CUTANEOUS IRRITANT is an agent which will cause dermatitis by direct action on the normal skin at the site of contact if it is permitted to act in sufficient intensity or quantity for a sufficient length of time." Again using Schwartz' definition *(10),* "A CUTANEOUS SENSITIZER is an agent which does not necessarily cause demonstrable cutaneous changes on first contact but may effect such specific changes in the skin that, after five to seven days or more, further contact on the same or other parts of the body will cause dermatitis." Contact dermatitis may be acute, subacute, or chronic, and moderately severe to severe itching is present in most forms. In the acute and subacute types, diffuse erythema, edema, oozing, and crusting predominate. In addition, vesicles are often present if a specific allergic sensitizer is the cause. In chronic forms, erythema, scaling, and lichenification (thickening) prevail.

We have seen a number of patients with contact dermatitis of the amputation stump. In order to understand the problem, we have had to learn about the plastics and resins used in the external and internal finishes of the different types of prostheses. In some instances, we found only by carefully taken history that the use of a new cream, lubricant, or cleansing agent coincided with the onset of the dermatitis. Some amputees use a foam-rubber cushion, others a plastic-covered pad on the bottom of their socket. These are also capable of producing a contact dermatitis of the skin weeks, months, or even years after use (Fig. 5, *A* and *B).*

On patients exhibiting the clinical manifestations of contact dermatitis, every attempt has been made to determine the exact contactant. Patch tests (Fig. 5, *C* and *D)* have been most informative with respect to specific substances as the cause of the dermatitis. In diagnostic patch-testing, a small amount of the suspected substance is applied to a site of normal skin on the patient. It is covered with an innocuous, impermeable material such as cellophane, which is then sealed to the skin by adhesive plaster. It is usually sufficient to leave the patch on for 24 to 48 hours. Upon removal of the patch, a positive reaction is signified by erythema, vesiculation, or blister formation at the site of application.

Because patch-testing with strong concentrations of known primary irritants will result in reactions on any skin, solutions of such substances are first diluted according to published lists *(11)* in order to prevent a false positive reaction and possible injury to the skin. A generalized eruption following the patch test indicates a high degree of sensitivity, but fortunately such eruptions are rare. Experience and good clinical judgment are necessary in choosing the correct chemical concentration of the irritant and the proper time for performing the patch test.

The sockets of leg prostheses are commonly finished on the inside by the application of a varnish or lacquer and on the outside by coating with plastics and resins. These complex organic substances are capable of causing a contact dermatitis in a given individual who has become sensitized. This sensitization is similar to that produced by poison oak or poison ivy, and the intensity of reaction may vary under different conditions of heat, humidity, and friction. The epoxy resins *(8),* if incompletely cured in their manufacture, may, in addition to being a specific allergic sensitizer, produce a primary-irritant dermatitis. These resins are frequently used to improve the appearance of a socket and to render it impervious to external agents. In the uncured state at room temperature they are viscous, amber-colored liquids. Curing agents, known as catalysts or hardeners, are added to solidify the plastic material. These agents are organic amines of various types and, when left in excess by incomplete baking or curing at high temperatures, are able to produce a primary-irritant dermatitis.

We have had several patients with proven contact dermatitis to Ambroid,® C-8 epoxy resin, polyethylene, foam-rubber pads, and plastic-covered cushions. Removal of the suspicious contactant resulted in a cure, and subsequent patch-testing proved the diagnosis.

In those instances of contact dermatitis where the irritant has not been obvious and the patch tests have been inconclusive, temporary therapy has alleviated the symptoms. Cool compresses, bland antipruritic lotions, and the topical use of hydrocortisone or fluorohydrocortisone preparations have been most beneficial.

POST-TRAUMATIC EPIDERMOID CYSTS

Young *(15),* in 1951, described the appearance of multiple cysts in the skin of an amputee's thigh in association with the wearing of an artificial limb. Other authors *(2,3,6,13,14, 16,17,18)* have described similar nodules in the skin under the rim of the socket. In the typical case (Fig. 6), the cysts do not appear until the patient has worn an artificial limb for months or possibly years. They occur most frequently in above-knee amputees in the areas covered by the upper medial margin of the prosthesis but have also been described in below-knee amputees.

Characteristically, in the above-knee amputee small follicular keratin plugs develop in the skin of the adductor region of the thigh along the upper edge of the prosthesis. In the beginning they appear as small lumps or nodules and will, at times, disappear when the prosthesis is removed temporarily. Under the constant friction and pressure of the prosthesis, they become larger and more numerous. Some become pea-sized, round, or oval swellings deep within the skin. Gradually, with enlargement, they become sensitive and tender to the touch. The skin may break down and erode or ulcerate. With continued irritation by the prosthesis, the nodular swelling may suddenly burst and discharge an opaque, purulent fluid. The discharging sinus may become chronic and thus make it impossible for the patient to use his prosthesis. In other instances, the break may take place within the deeper portion of the skin, and subcutaneous intercommunicating sinuses may develop.

The larger nodules become especially tender and necessitate removal of the prosthesis. These should not be confused with ordinary furuncles or boils (Fig. 7), which may occur on any portion of the stump. Surgical excision of the chronic, isolated, noninfected nodule may give relief, but no completely satisfactory method of treatment is known. In the acutely infected phase, hot compresses and antibiotics are indicated. As the process localizes, incision and drainage may be beneficial temporarily. *Micrococcus pyogenes (Staphylococcus aureus)* is frequently a secondary bacterial invader and at times resistant to many antibacterial agents. In some of the cystic lesions, the contained fluid is sterile.

The cysts range in size from microscopic papules to large nodules that can be palpated with the fingers. The microscopic picture, therefore, is variable, depending upon the size of the lesion and the extent of secondary irritation or infection. In the earliest phase, a keratin plug is seen to form. Later this plug invaginates the epidermis, and pockets of keratin appear in the subepidermal region of the skin. The invaginated epidermis containing keratin may be superficial or deep within the corium. As the keratin cyst enlarges and becomes secondarily infected, acute, subacute, and chronic inflammatory cells are seen. Foreign-body giant cells and newly formed capillaries and fibroblasts are not uncommon about the disintegrating cyst wall.

Many authors have written extensively on the cause of these so-called "prosthetic nodules and abscesses," so frequently the concern of the physician, the limbfitter, and the amputee. Their occurrence is not restricted to wearers of the suction-socket prosthesis, since amputees complained of these inflamed swellings long before the suction socket came into widespread use. In the first third of this century, German investigators *(6,14,16,17,18)* ascribed the lesions to foreign bodies and wrote of finding "chamois-leather" particles, fine hairs, talc, and amorphous substances in the giant cells of the fully developed cyst. Other writers *(2,3,15)* disputed these foreign bodies as the cause and attributed the formation of the nodules to pressure and irritation from the socket and to epidermal keratin forced inward by this pressure. Some present-day investigators *(12,13)* regard the cysts as sebaceous adenomata and speak of sebaceous adenitis as being of frequent occurrence in the adductor region of the thigh stump. These and similar lesions have also been described in the hands and fingers following trauma (5).

Although our studies have been limited, and although we are only now beginning to see these nodules in various stages of development, it appears that the condition is one in which the surface keratin and epidermis becomes invaginated, acting as a "foreign body." Under the influence of friction and pressure from the prosthesis, the keratin plug and its underlying epidermis are displaced into the corium. The result is the production of nonspecific inflammatory tissue and implanted epidermoid cysts. These can remain quiescent for a long period of time or can, with secondary bacterial invasion, become abscessed and produce the characteristic clinical and pathologic picture previously described.

Recurrent and secondarily infected nodules may require the attention of a dermatologist or a surgeon. Some lesions necessitate incision and drainage. For others, total excision of the cyst under local anesthesia is the treatment of choice. These methods, however, do not solve the entire problem and may only succeed in alleviating an acute phase. The chronic problem can, in some instances, be mitigated or successfully eliminated by proper fit and alignment of the prosthesis.

At the present time we are attempting the clinical trial of topical agents in an effort to prevent or retard the formation of the keratin plug, which may be the precursor of the epidermoid cyst. We are endeavoring to develop a stump sock or adductor rim sock for use with the suction-socket prosthesis to prevent cyst formation, but to date this effort has been of an experimental nature only. In our experience, there is no completely satisfactory method of treatment, and each amputee with the problem offers a therapeutic challenge.

FOLLICULITIS AND FURUNCLES

Folliculitis, usually caused by staphylococci, is a superficial bacterial infection of the hair follicle in which the primary lesion is an inflammatory papule or pustule. In contrast, a furuncle (Fig. 7) is a larger, more deep-seated, painful, bacterial infection of the pilosebaceous apparatus and is invariably caused by a staphylococcus or a streptococcus. Whereas folliculitis typically consists of multiple, small. itching, red papules, the furuncle, or "boil," is usually a tender, deep-red nodule which eventually rises to the surface of the skin and discharges its necrotic core.

Folliculitis is a commonly encountered problem in the amputee, particularly in dark-complexioned, hairy persons with an oily skin. The condition is aggravated by the use of an artificial leg (Fig. 8). It is usually worse in summer, when increased warmth and moisture from perspiration promotes maceration of the skin, which, in turn, favors invasion of the hair follicle by bacteria. Ordinarily this process is not serious, but sometimes it progresses to boil formation, cellulitis, or an eczematous, weeping and crusted, superficial pyoderma *(1).*

Folliculitis and boils may follow upon poor hygiene of the stump or the socket or both. In several patients, chronic recurrent folliculitis was essentially cured by having the amputee adhere to the routine hygienic program using pHisoHex.® The hexachlorophene in this product is a hundred times more effective than is soap in eliminating skin bacteria, and that circumstance possibly accounts for the effectiveness of this program. In other instances, therapy may require the use of wet dressings, the incision and drainage of boils after localization, the oral or parenteral use of antibacterial substances, and the application of local bactericides, but we do not subscribe to the use of epilating doses of roentgen-ray therapy, which has been reported by Heller *(4).* Since these conditions of the stump are frequently chronic or recurring, it is best to choose relatively nonsensitizing substances for topical application.

Fig, 1. Stump edema syndrome. *A,* In a 33-year-old male above-knee amputee wearing a suction-socket prosthesis. Note the swelling of the *end* of the stump, with pigmentation and hemorrhage into the skin. *B,* Enlarged view of *A.* showing hemorrhagic nodules with superficial erosion. *C,* In a 38-year-old male above-knee ampulee wearing a suction-socket prosthesis, with swelling and hemorrhagic plaque. No erosion or ulceration has occurred. *D,* Same patient as in C, showing socket-rim pigmentation and irritation.

Fig 2 Chronic ischemic ulcer, in a 43-year-okl male below-knee amputee. Poor prosthetic fit with venous obstruction was productive of this lesion

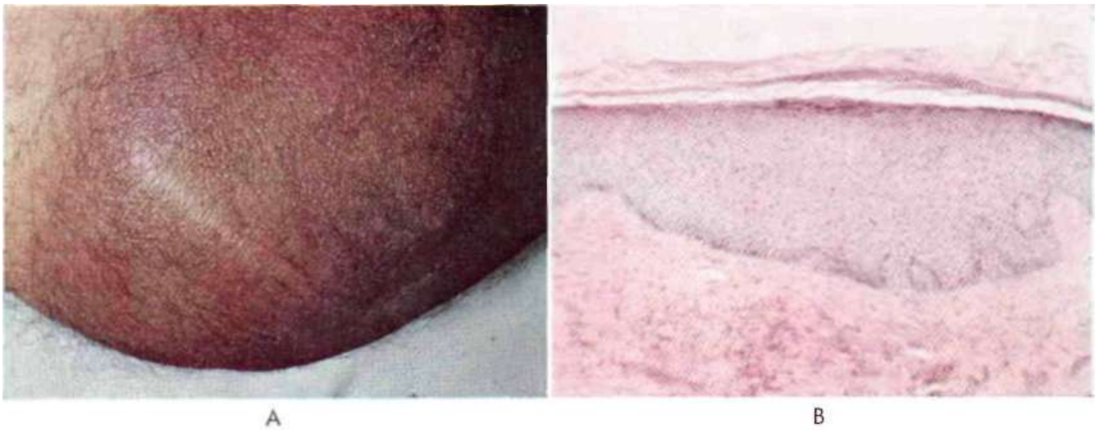


Fig. 3. Pigmentation following stump edema syndrome. *A*, Brown pigmentation of the skin of the distal portion of the stump. *B*, Microscopic section of .1, showing a marked increase in the thickness of the epidermis, with sclerosis of collagen and infiltration of pigment-laden cells.

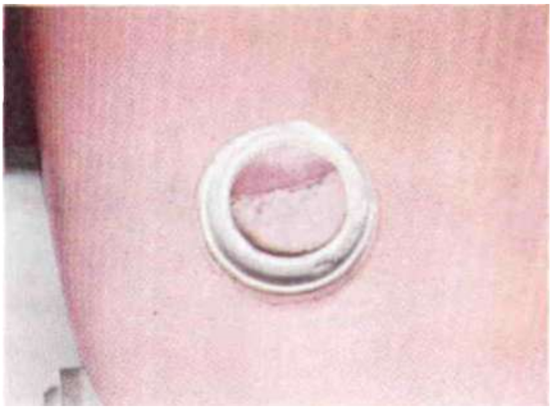
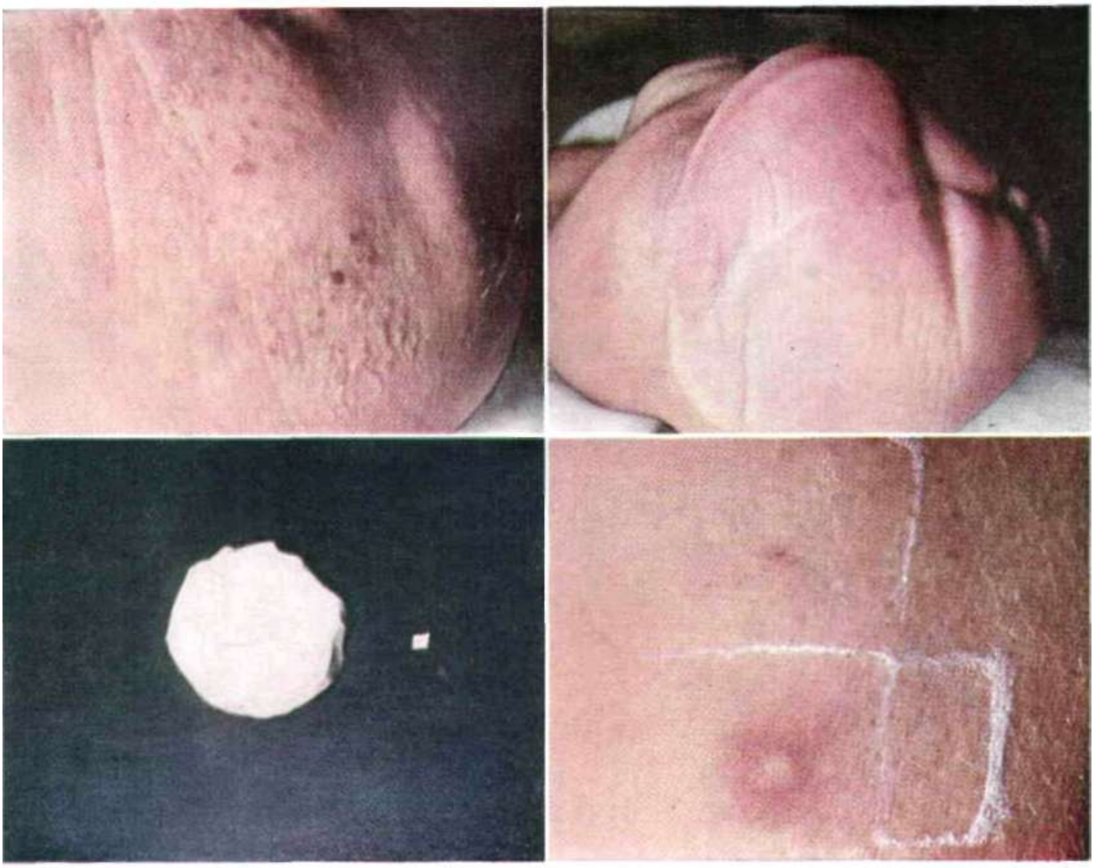


Fig 4 Strangulated skin. Unusual view, showing the distal stump skin resting on the foam-rubber cushion, as seen through the valve opening of a suction-socket prosthesis. A portion of the skin has become partially strangulated, resulting in stasis, edema, and pain.

A B



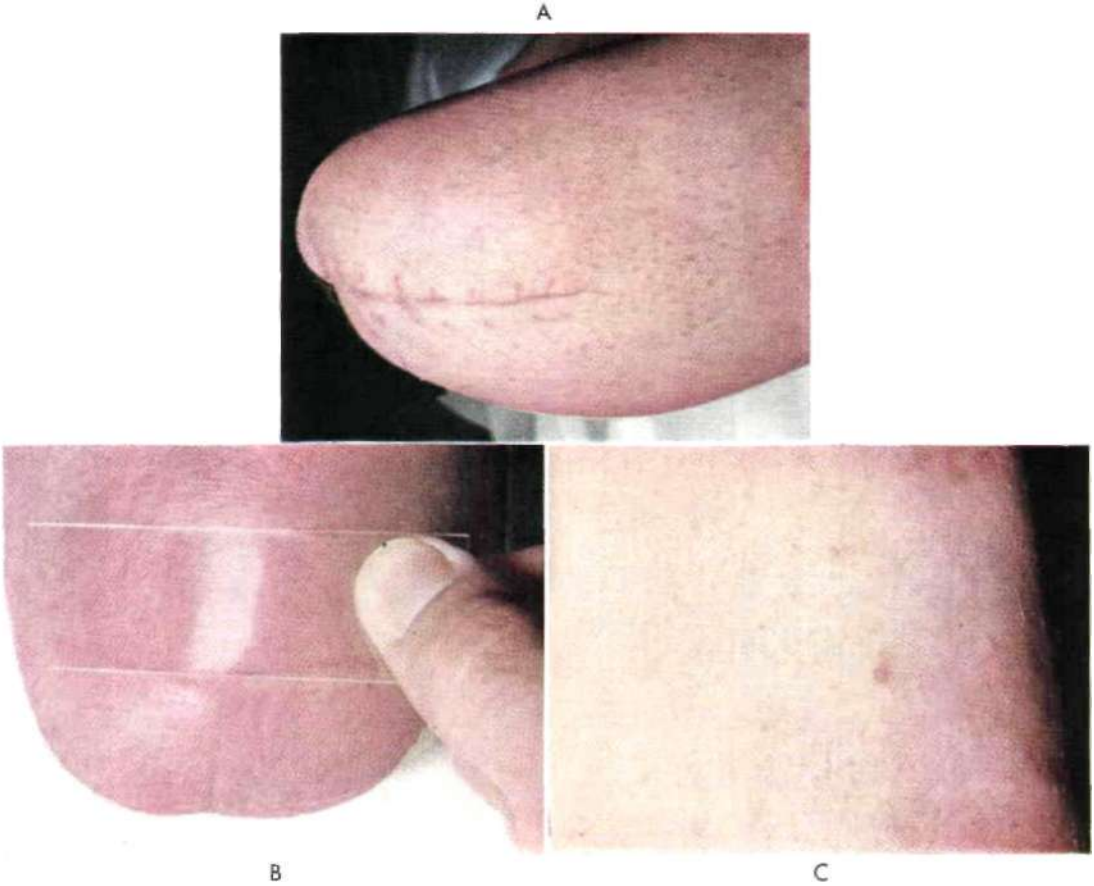
C D

Fig 5 Contact dermatitis. *A,* Chronic, of the distal stump skin, due to contact with a plastic-covered cushion on the bottom of a suction socket. Removal of the cushion provided complete clearing in one week. Patch tests were positive for allergic sensitivity to the plastic *B,* Of the distal stum]) skin, due to contact with a foam-rubber pad on the bottom of a prosthetic socket. Note the circular zone of erythema and edema. Rapid clearing and disappearance of itching followed removal of the pad C, Left, the foam-rubber pad removed from the socket of the patient in *B;* right, the small piece of the material (4 mm in diameter) used in patch-testing *D,* Skin of the upper arm of the same patient as in *B,* showing a positive reaction to foam rubber, A

B C

Fig. 6. Post-traumatic epidermoid cysts. *A,* Early phase, in a Negro patient. Tiny follicular keratin plugs have developed in the skin of the adductor region. Some have enlarged to form tender nodules. *B,* Slightly later phase, in a 15-year-old white female. *C,* Still later phase, in the adductor region of a white male, where the nodules are larger and have become firm, tender, and cystic.

Fig. 7. Furuncle, or boil. Subsiding, on the distal stump skin of a below-knee amputee,

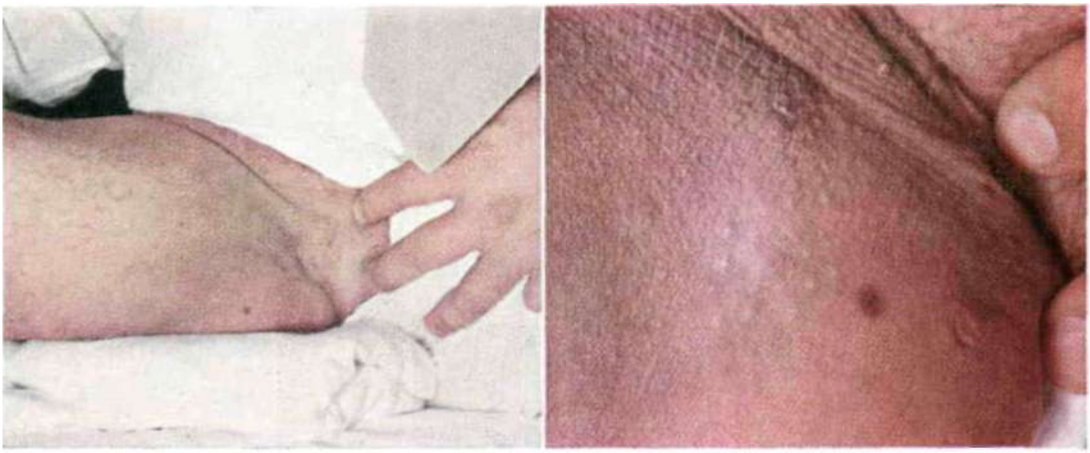


Fig, 8. Skin changes acompanying the early use of prosthesis *A. B,* and *C* show the skin of the same below-knee amputee. .1, Normal stump skin before the prosthesis was worn. *B,* Reactive hyperemia with itching and tingling, shortly after the prosthesis was used for the first time. Compare the flush with the normal skin color, which returns under pressure by the glass slide *C.* Small areas of folliculitis on the skin, which began to develop after wearing of the prosthesis,

Fig 9. Erosion and eczematization ot the stump skin from poor prosthetic fit and alignment.

A B

Fig. 10. Nonspecific eczematization. *A,* Of three months' duration on the stump skin of a 32-year-old above-knee amputee who presented unusually poor stump cleanliness. *B,* Enlarged view of *A,* showing erythema, edema, and vesiculation. After a simple hygienic program with a sudsing detergent containing hexachlorophene, the eczematous process disappeared completely.

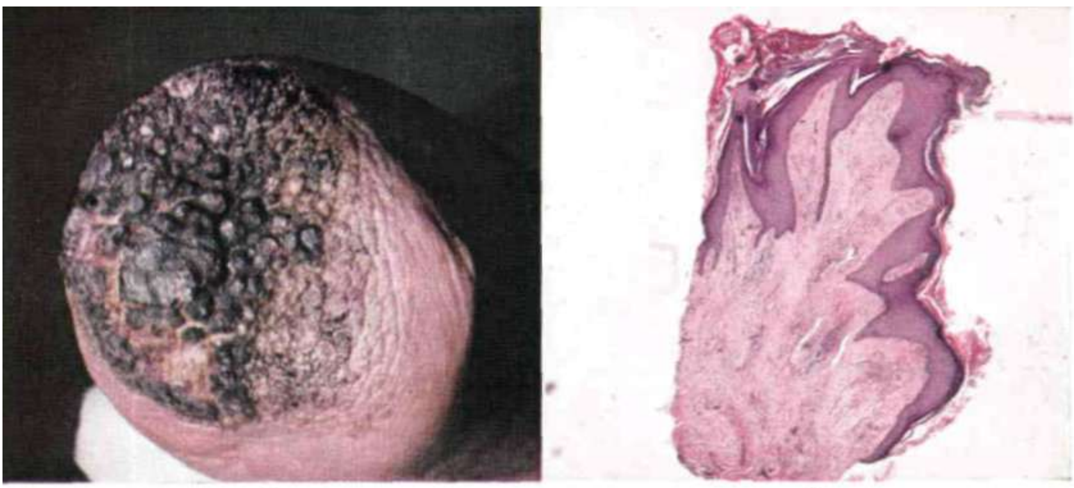


A B

Fig. 11. Skin irritation in the crotch area. *A,* Chronic, resulting from continued friction and pressure from the socket. *B,* Enlarged view of *A,* showing thickened (lichenified) and pigmented skin containing the early phase of post-traumatic epidermoid cysts. The skin of this area may become eroded or ulcerated. In some instances, these problems may be corrected by proper prosthetic fit and alignment.

Fig. 12. Scar tissue of several years' duration on the distal stump skin. Through repeated years of wear and tear from using a prosthesis, the skin has become adherent to the underlying tissue. Such abnormalities are capable of causing repeated infection, erosion, and ulceration. This below-knee amputee .was treated by surgical revision of the scarred area.

Fig. 13. Cutaneous horn of several years' duration in a below-knee amputee. Local excision of the lesion was curative.



A B

Fig. 14. Verrucous hyperplasia of the distal stump skin. *A,* Distal view, showing the warty nature of the skin. This hyperplastic condition was felt to be secondary to an underlying vascular disorder, bacterial infection, and poor prosthetic fit and alignment. *B,* Microscopic section of a warty nodule in *A.* Note the hyperplasia of the epidermis, with sclerosis of the collagen and chronic inflammation.

ADDITIONAL CUTANEOUS PROBLEMS

Fungous Infections

Superficial fungous infections of the stump may be difficult to eradicate completely because of continued moisture, warmth, and maceration of the skin within the enclosed socket of the artificial leg. Tinea corporis *(9)*, or ringworm of the nonhairy portions of the skin, is characterized by oval to round, scaly, erythematous, itching lesions, usually appearing only on the part of the stump enclosed by the socket. The diagnosis is confirmed by microscopic demonstration of the fungal filaments in scales or vesicles removed from a lesion. Therapy consists of the application of fungistatic creams and powders over an extended period.

Nonspecific Eczematization

Nonspecific eczematization of the stump skin has been seen in a number of instances (Figs. 9 and 10). Here the amputee presents a weeping, itching, nonhealing plaque of dermatitis over the distal portion of the stump. The lesion is dry and scaly and then suddenly becomes moist without reason. It waxes and wanes over a period of months to years and may be a major source of mental anxiety.

We have tried to find the cause through either history, physical examination, or laboratory tests, or through studying the clinical course of the eczematous process. At times we have been able to elicit a significant history of recurrent allergic eczema or to demonstrate active eczematous lesions on other portions of the body to account for the eruption on the stump. In other instances, the eczema was secondary to edema and congestion of the terminal portion of the stump, so that only with the alleviation of these problems did the condition clear. Drug sensitivities from the internal use of an agent such as penicillin may present themselves on the amputation stump. Ideally, whenever possible, the cause of the eczema should be found and removed. Temporary symptomatic treatment with topical hydrocortisone or fluorohydrocortisone preparations is effective, but the condition will frequently recur unless the cause is eliminated.

Generalized Disorders

The localization of other skin disorders on the amputee's stump is not an uncommon occurrence. We have seen patients with acne vulgaris of the face and back develop acne lesions of the stump. We have seen similar localizations in patients with seborrheic dermatitis, folliculitis, and eczema. There are recorded instances of psoriasis and lichen planus developing on the stump skin with few lesions present elsewhere on the body *{9)*. Here again, it is important to diagnose the generalized cutaneous disorder and to treat it dermatologically in order to improve the stump condition.

Intertriginous Dermatitis

An intertriginous dermatitis is an irritative condition of those skin surfaces which are in constant apposition and between which there is a hypersecretion and a retention of sweat. This situation usually occurs in the crotch (Fig. 11), but on occasion it occurs in the folds at the end of the stump where two regions of skin rub each other and where the protective layer of keratin is removed by the friction. A chronic disorder may develop, with deep, painful fissures and with infection and eczematization. Hygienic measures to cleanse the apposing folds and the use of drying powders are beneficial. At times, it may be necessary to re-excise the bulky, infolded stump skin in an effort to provide a linear scar which would preclude this form of disorder.

Adherent Scars

With repeated infection and ulceration of the skin, the scar may become adherent to the underlying subcutaneous tissues (Fig. 12), a condition which invites further erosion and ulceration. Long wear and tear from the use of a prosthesis may necessitate surgical revision in order to free the scar in the bound area.

Chronic Ulcers

Chronic ulcers (Fig. 2) of the stump may result from bacterial infection or from poor cutaneous nutrition secondary to an underlying vascular disorder. In every instance, the underlying cause should be investigated and appropriate treatment provided. Malignant ulcers have developed within old, persistent stump ulcerations, and hence every effort should be made to diagnose the condition before it becomes chronic.

Tumors

Tumors of the stump may be malignant or benign. We have seen innocent hyperkeratosis, or callus formation, and have removed verrucae, or viral warts, from the stump skin. Simple "skin tags," or cutaneous papillomas, are easily removed dermatologically under local anesthesia. A cutaneous horn (Fig. 13) on an amputation stump has been recorded (7), and we have removed one from a below-knee amputee wearing a conventional prosthesis.

Extensive verrucous hyperplasia (Fig. 14) of the entire terminal stump skin has been seen in one instance. A surgical biopsy failed to reveal the pathologic picture of viral verrucae. This hyperplastic condition was felt to be secondary to an underlying vascular disorder, bacterial infection, and poor prosthetic fit and alignment. Treatment to date has consisted of adequate control of the bacterial process and gradual end-bearing maneuvers to improve the vascular stasis. A new prosthesis is being manufactured to correct the fit and alignment. Here is an example of the need for the services of the entire clinic team to provide the maximum benefit to the individual amputee.

Malignant tumors of the stump skin have been recorded by others, but we have not as yet encountered any primary cancers in our series of patients.

SUMMARY

The cutaneous problems of the lower-extremity amputee are many and varied. They are real problems, which can begin insidiously without creating additional disability and then, through neglect and mistreatment, seriously threaten the social and economic rehabilitation of the amputee. A variety of skin disorders are found to localize on the skin of the lower-extremity stump because of the many new insults to which it is subjected when a prosthesis is worn. These disorders may require dermatologic consultation for either diagnosis or treatment.

In the past year, the cutaneous difficulties associated with the wearing of a leg prosthesis have been evaluated during more than 200 patient-visits to the Lower-Extremity Amputee Research Project at the University of California Medical Center in San Francisco. Hygiene is important in relation to many skin disorders of the stump, and consequently a specific hygienic program is being developed, The danger signals and the clinical problems which have been found to require medical attention include the stump edema syndrome, contact dermatitis, post-traumatic epidermoid cysts, folliculitis and furuncles, superficial fungous infections, nonspecific eczematization, intertriginous dermatitis, chronic ulcers, and tumors of the stump.

The skin-study group is a comparatively recent addition to the Lower-Extremity Amputee Research Project of the University of California. It is hoped that, through this study group, the varied cutaneous disorders associated with the lower-extremity amputee will, over a period of time, be fully classified and thereby be prevented.

ACKNOWLEDGMENTS

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Technical Notes from the Artificial Limb Program

This section of ARTIFICIAL LIMBS *is intended as an outlet for new developments in limb prosthetics which, though not deserving of a long feature article, nevertheless ought to be brought to the attention of the readers of this journal. Notes may vary in length from a single paragraph to several pages of manuscript, as appropriate. Illustrations also are acceptable.*

Below-Elbow Training Arm

At the Army Prosthetics Research Laboratory there has recently been developed a simple and inexpensive method of making a device that can be used by an instructor in demonstrating the various mechanical hands and hooks. Although "training arms" as such are not particularly new, the method of construction worked out at APRL represents a significant advance in this field.

The APRL training arm consists of a modified F-M wrist disconnect (ARTIFICIAL LIMBS, January 1954, p. 18), a formed "Royalite" (United States Rubber Company) forearm cuff with a grasping handle just above the wrist disconnect and a holding strap near the proximal end of the forearm, and a figure-eight harness with inverted Y-strap (ARTIFICIAL LIMBS, September 1955, p. 28), the open end of the figure-eight being attached to a Bowden cable (ARTIFICIAL LIMBS, September 1955, p. 27) to furnish means for operating the terminal device.

The forearm section is made of 3/16-in. "Royalite" sheet, trimmed according to a pattern (see cut) so designed as to produce a piece that will encase a half section of the normal forearm and yet allow easy insertion and withdrawal. The sheet is heated in an oven at 250°F until it is pliable, and the material is then formed over a mandrel to the shape of the forearm. The distal end is bent at right angles to the forearm section, and the grasping handle is put into place and formed with the hand until a comfortable hold is obtained.

Modification of the F-M wrist disconnect consists of removing the knurled laminating flange. A washer with a 1-in. center hole and an outside diameter equal to that of the F-M disconnect is then fashioned. The disconnect is assembled to the forearm shell by removing three alternate screws in the faceplate and drilling the holes on through the "Royalite." With a suitably smaller drill, corresponding holes are made through the washer, and these holes are then tapped out to receive the screws which hold the disconnect to the arm shell.

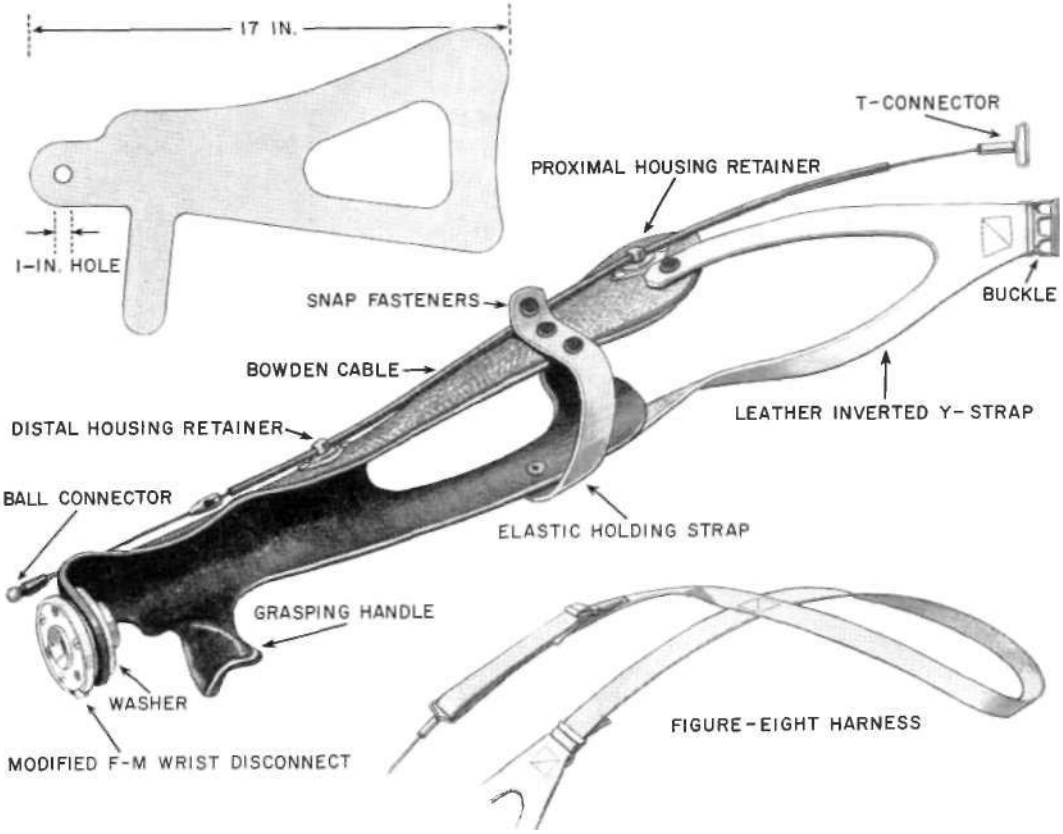
The cable housing and operating cable with ball connector are now installed in place and connected to the figure-eight harness. The fork of the inverted Y-strap is riveted in place on the arm shell, and the other end is attached to the harness by a buckle. Finally, the holding strap, which is made of elastic webbing, is riveted in place.

The completed training arm is shown in the cut. All adjusting straps should be made long enough to accommodate persons of various sizes, but of course it may be necessary in certain cases to modify the size of the arm when it is intended for persons of exceptionally small or exceptionally large build.

The drawing accompanying this note is the work of George Rybczynski, free-lance artist of Washington, D. C.

Improved Harness Material

As is common knowledge among prosthetists, there are about six basic requirements for a fabric tape for use in harnessing upper-extremity prostheses. It must have a comparatively high tensile strength for a given weight of weave; it must exhibit good dimensional stability under load; it must be readily washable without significant shrinkage and later stretch on reapplication of load; it must be nonirritating to the skin and comparatively resistant to the deteriorative effects of perspiration; it must have good workability on the sewing machine and a minimum tendency to curl; and it must be of such color as to be appropriate for a piece of apparel to be worn in intimate contact with the body. Heretofore, the materials most nearly meeting all of these demands have been vinyon and, better still. boiled-off nylon.



BELOW-ELBOW TRAINING ARM, APRL DESIGN—A useful device that can be constructed easily and economically, The model shown is for a right arm, and the pattern is drawn to exact scale.

In an attempt to discover an even more suitable harnessing material, the Army Prosthetics Research Laboratory carried out extensive studies[1] of the stretching, shrinking, and washing characteristics of a number of commercially available fabric tapes, including those of cotton, vinyon, nylon, dacron, and certain Fiberglas-vinyon combinations. Of these, boiled-off dacron and the Fiberglas-vinyon tapes were found to be the most dimensionally stable, both wet and dry. Although the Fiberglas-vinyon tapes showed properties equivalent to those of dacron, materials containing Fiberglas were ruled out because of the possibility of skin irritation from continued contact with glass fibers. The accompanying table summarizes the average results obtained on application of tensile loads four times up to 150 lb. using a Baldwin-Southwark Universal Testing Machine.

[1]APRL Technical Reports 5302, 5318, 5423, and 5430.

Load (lb.)	Stretch in Percent of Original Length							
	Dacron (dry)	Dacron (wet)	Nylon (dry)	Nylon (wet)	Cotton (dry)	Cotton (wet)	Vinyon (unracked)	Vinyon (racked)
50	0.4	0.5	2.5	4.8	4.5	7.5	5.5	2.3
100	0.9	1.2	4.0	7.7	6.2	10.1	9.7	3.7
150	1.3	1.7	6.3	10.1	7.4	11.7	15.0	6.9

It may be seen that the dacron tape stretched the least by a considerable margin. Even with loadings up to 150 lb., far in excess of what is normally required for operation of an arm prosthesis, the dacron tape stretched only 1.7

percent when wet. After removal of the load, recovery to the initial length was immediate. The shrinkage of boiled-off dacron tape after washing in warm water was found to be a minimum. An additional advantage disclosed was that holes to receive buckle tines may be made in dacron tape using a heated awl, and, just as in the case of vinyon, the ends of the tape may be burned to eliminate fraying.

Because of the favorable results obtained, APRL requested that the Prosthetic Devices Study at New York University conduct further laboratory studies as well as amputee tests on the actual usefulness of dacron tape for harnessing upper-extremity amputees. A number of above- and below-elbow amputees who had been wearing vinyon or nylon harnesses were fitted with harnesses of dacron. After some five months of wear, the opinions of the amputees and of the fitters were solicited. Amputee reactions were highly favorable because of the color (which does not contrast with that of the shirt or undershirt), because of the ability of the tape to lie smoothly, because of the absence of stretching and relative absence of rolling of the tape under the axilla, and because of its excellent ability to withstand laundering. The prosthetists also favored dacron because of the low stretch characteristics, which eliminates the need for prestretching, and because of a lowered tendency toward fraying at buckle perforations.

The new material tested was furnished by the Bally Ribbon Mills, Bally, Pennsylvania. It is catalogued as "1-in. Dacron, Pattern 7928, S/O 6219, natural, boiled-off." The material is also available in the half-inch width.

Digest of Major Activities of the Artificial Limb Program

This section of ARTIFICIAL LIMBS *is intended to present a summary of principal news events of interest in the Artificial Limb Program during the several months preceding issue. Stories of activities in the various laboratories and associated agencies, reports of meetings, photographs, and items about individuals all are acceptable.*

New Prosthetics Research Board

In an effort to provide for continuity of the Artificial Limb Program, the Advisory Committee on Artificial Limbs, functioning as such since 1947, and before that as the Committee on Artificial Limbs, successor to the Committee on Prosthetic Devices, was officially dissolved on December 1, 1955, and reconstituted as the Prosthetics Research Board. Membership, which is on a rotational basis, is now as follows: Brig. Gen. F. S. Strong. Jr., Chairman; Chester C. Haddan, of Gaines Orthopedic Appliances, Inc., Denver; Paul E. Klopsteg, Associate Director of the National Science Foundation, Washington; Paul B. Magnuson, formerly Chief Medical Director of the Veterans Administration; Robert R. McMath, of the McMath-Hulbert Observatory, University of Michigan, Pontiac; C. Leslie Mitchell, of the Division of Orthopaedic Surgery, Henry Ford Hospital, Detroit; Howard A. Rusk, Director of the Institute of Physical Medicine and Rehabilitation, NYU-Bellevue Medical Center, New York; Augustus Thorndike, Chief Surgeon to the Department of Hygiene, Harvard University; and Tracy S. Voorhees, prominent attorney, Washington. Col. Robert S. Allen continues to serve as consultant to the new Board.

Col. Gerald R. Tyler has accepted the position of Executive Director of PRB. Having served with the Army's Corps of Engineers in various important posts during World War II, including duty at Los Alamos with the Manhattan District in the development of the atom bomb, Col. Tyler has more recently been associated with the Armed Forces Special Weapons Project (guided missiles) until his retirement in July 1955. Mr. A. Bennett Wilson, Jr., continues as Executive Secretary.

The new Board held its first meeting in Washington last December 5 and its second at NYU-Bellevue's Institute of Physical Medicine and Rehabilitation in New York on February 20.

Schools in Above-Knee Prosthetics

Early in 1955, the Prosthetic Devices Study at New York University was asked to offer a series of courses in above-knee prosthetics for physicians, surgeons, therapists, and prosthetists. Following a pilot school last summer at the U. S. Naval Hospital, Oakland, California, for the training of faculty personnel (ARTIFICIAL LIMBS, September 1955, p. 65), preparation was begun for the New York schools. Some 5000 sq. ft. of space were obtained in the NYU Dental School at the corner of First Avenue and East 26th Street. This space was completely remodeled and redecorated and fully equipped for the proposed courses.

On Monday, March 5, the first course for prosthetists began with an enrollment of 10 limbfitters from the Metropolitan New York area. Three days later, on Thursday, March 8, 11 therapists, also drawn chiefly from the Metropolitan New York area, began the first section of the therapists' course. On Monday, March 12, the initial group of 13 physicians and surgeons began their course.

The courses for all three groups were completed on Friday, March 16. In evaluation sessions held on the final day with each of the three groups, considerable enthusiasm for the courses was expressed. Apparently, for all those participating, the courses had met a long-felt need.

The second course in the series began on Monday, April 2. It had an enrollment of 12 prosthetists, 23 therapists, and 24 physicians and surgeons, the students being drawn from the New England States, Upper New York State, Chicago, and Washington, D. C. Again considerable enthusiasm was expressed concerning the course.

NYU SCHOOLS IN AK PROSTHETICS—Start of a new series. Above, William E. Hitchcock, President of the Boston Artifical Limb Company and member of the instructional staff of the New York University Schools in Above-Knee Prosthetics, instructs a class in use of the alignment duplication jig (ARTIFICIAL LIMBS, May 1954, p. 25) during the first course, March 5 through 16, at NYU. Below, George A. Scoville, of the Winkley Artificial Limb Company, Hartford, Connecticut, and another member of the teaching staff, demonstrates use of the adjustable leg (ARTIFICIAL LIMBS, May 1954, p. 23). The wall charts, used as teaching aids, are blowups of pages from the lesson material furnished the students.

These courses and others to be offered in the series are sponsored jointly by the College of Engineering and the Post-Graduate Medical School of New York University. The participating faculty included Ernst W. Bergmann, M.D., Associate Clinical Professor of Orthopedic Surgery, Post-Graduate Medical School, New York University; Donald A. Covalt, M.D., Associate Professor of Physical Medicine and Rehabilitation, College of Medicine, New York University; Sidney Fishman, Ph.D., Project Director, Prosthetic Devices Study, College of Engineering, New York University; Charles Fryer, M.A., Supervising Physical Therapist, Beekman-Downtown Hospital, New York City; Henry F. Gardner, Certified Prosthetist, Veterans Administration Prosthetics Center, New York City; William E. Hitchcock, Certified Prosthetist, Boston Artificial Limb Company, Boston, Mass.; Alvin Hulnick, M.D., Associate Clinical Professor of Orthopedic Surgery, Post-Graduate Medical School, New York University; Hector W. Kay, M.Ed., Assistant Project Director, Prosthetic Devices Study, College of Engineering, New York University; Allen S. Russek, LRCPS (Edinburgh; Glasgow), Associate Professor of Clinical Physical Medicine and Rehabilitation, College of Medicine, New York University; Warren P. Springer, B.S., Assistant Engineering Scientist, Prosthetic Devices Study, College of Engineering, New York University; George A. Scoville, Certified Prosthetist, Winkley Artificial Limb Company, Hartford, Conn.; Walter A. L. Thompson, M.D., Professor of Orthopedic Surgery and Chairman, Department of Orthopedic Surgery, Post-Graduate Medical School, New York University; William A. Tosberg, Certified Prosthetist, Institute of Physical Medicine and Rehabilitation, New York University-Bellevue Medical Center; M. Larry Villalobos, M.A., Staff Physical Therapist, Institute of Physical Medicine and Rehabilitation, New York University-Bellevue Medical Center; and Irene E. Waters, M.A., Instructor, Physical Therapy Department, Institute of Physical Medicine and Rehabilitation, New York University-Bellevue Medical Center. In addition, there were several visiting lecturers.

Those enrolled in the first two schools were as follows:

FIRST SCHOOL

PHYSICIANS AND SURGEONS

Course 741A
March 12 through 16

JOHN CLINTON ALLEN, M.D.
West Hartford, Conn.

HOWARD D. BALENSWEIG, M.D.
New York City

SIGMUND CHESSID, M.D.
Brooklyn. N. Y.

BERNARD CHROMOW, M.D.
Teaneck, N. J.

ROY R. CICCONE, M.D.
Passaic, N. J.

GEORGE D. DORIAN, M.D.
Short Beach, Conn.

ALFRED EBEL, M.D.
Bronx, N. Y.

EARL F. HOERNER, M.D.
West Orange, N. J.

JEROME LAWRENCE, M.D.
Brooklyn, N. Y.

JAMES MCATEER, M.D.
New York City

CAMILLO MUELLER, M.D.
Chevy Chase, Md.

RALPH G. ROHNER, M.D
Newark, N. J.

BERNARD STOLL, M.D.
Bronx, N. Y.

THERAPISTS

Course 742A
March 8 through 16

DAVID S. BILOWIT
East Orange, N. J.

THEODORE F. CHILDS
Brooklyn, N. Y.

SISTER E. DE ST. PIERRE
Port Jefferson, N. Y.

G. A. Di NUBILA
New York City

HERBERT H. JONES
Rocky Hill, Conn.

ALAN KAMENSHINE
Brooklyn, N. Y.

FLORENCE S. LINDUFF
Washington, D. C.

JOSEPHINE MCCARTHY
Port Jefferson, N. Y.

MORRIS PECKERMAN
Newark, N. J.

MORRIS VOGEL
Bronx, N. Y.

OSCAR C. WALKER
New York City

PROSTHETISTS

Course 743A
March 5 through 16

GERHARD BEIL
Newark, N. J.

ARTHUR L. BOLAND
Paterson, N. J.

MARTIN DUREC
New York City

FRED J. ESCHEN
New York City

JOHN GALLO
New York City

FRED GREIMEL
Brooklyn, N. Y.

KONRAD HOEHLER
New York City

Louis IULIUCCI
New York City

JOSEPH A. MARTINO
New York City

WILLIAM SPIRO
Hempstead, N. Y.

SECOND SCHOOL

PHYSICIANS AND SURGEONS

Course 741B
April 9 through 13

SAMUEL BRHDGHAM, M.D.
Rumford, R. I.

LEON R. BURNHAM, M.D.
Augusta, Me.

BRADLEY W. CARR, M.D.
Evanston, Ill.

BENNETT W. CAUGHRAN, M.D.
Fayetteville, Term.

BERNARD J. DOYLE, M.D.
Newton, Mass.

OTTO A. ENGH, M.D.
Alexandria, Va.

JAMES D. FISHER, M.D.
Springfield, Mass.

WILLIAM H. GEORGI, M.D.
Buffalo, N. Y.

OTTO G. GOLDKAMP, M.D.
New Haven, Conn.

EVERETT J. GORDON, M.D.
Washington, D. C.

EDWARD HARDING, M.D.
Brookline, Mass.

THOMAS F. HINES, M.D.
Branford, Conn.

ROBCLIFF V. JONES, JR., M.D.
Fairfield, Conn.

LEON M. KRUGER, M.D.
Springfield, Mass.

JAMES F. KURTZ, M.D.
LaGrange, Ill.

JOHN J. LORENTZ, M.D.
Boston, Mass.

COLMAN J. O'NEILL, M.D.
LaGrange Park, Ill.

EUGENE E. RECORD, M.D.
Boston, Mass.

ANNA K. ROSSILIANO, M.D.
Rocky Hill, Conn.

LOUIS SCHWARTZ, M.D,
Chicago, Ill.

EDWARD SCULL, M.D.
Hartford, Conn.

GEORGE A. SOTIRION, M.D.
Springfield, Mass.

ARTHUR A. THIBODEAU, M.D.
Boston, Mass.

JOHN TRAPUZZANO, M.D.
Hartford, Conn.

THERAPISTS

Course 742B
April 5 through 13

JAMES ARDIZZONE
Washington, D. C.

SALLY BASSETT
Boston, Mass.

ROBERT BECKER
Arlington, Va.

DOROTHY BROWNELL
State of Rhode Island

JEANNE CLEVERLY
Jamaica Plains, Mass.

BAELA DRACH
Montreal, Can.

MARIAN A. ELDEN
Boston, Mass.

HAZEL GRIGSBY
Boston, Mass,

IRJA R. HOFSCHIRE
Springfield, Mass.

CHARLOTTE A. HOPPE
Hartford, Conn.

CARMEN JULIEN
Hartford, Conn.

PRUDENCE M. KUHRT
Newington, Conn.

WILFRED A. MACNEIL
Saranac Lake, N. Y.

NANCY MAHER
Springfield, Mass.

NATALIE A. MCFEE
Hines, Ill.

HILDEGARDE MYERS
Chicago, Ill.

EDITH L. NYMAN
New Haven, Conn.

ROBERT F. SCHAEFER
Malone, N. Y.

ROBERT B. SCHERF
Hartford, Conn.

MARY M. SHOREY
Chicago, Ill.

FLORIAN SURDYK
Chicago, Ill.

Lotus M. TINGHINO
West Orange, N. J.

ROWENA WALDEN
Portland, Me.

PROSTHETISTS

Course 743B
April 2 through 13

CLIFFORD ANTHONY
Braintree, Mass.

JOSEPH C AVENI
Melrose, Mass.

RAYMOND BEALES
Fairfax, Va.

ROLAND DANIEL
Buffalo, N. Y.

RALPH DEGAETANO
Bronx, N. Y.

ALFRED DENISON
Cicero, Ill..

WILLIAM DICKINSON
Watervliet, N. Y.

JEROME S. KESSLER
Cranford, N. J.

JOSEPH MARTINO
Boston, Mass.

WALDEMAR SCHOENE
Chicago, Ill..

JOSEPH E. TRAUB
Buffalo, N. Y.

EWALD UNTERBURGER
Middle Village, N. Y.

The next New York course in above-knee prosthetics is to be held early in the fall of 1956.

Anatomy for Prosthetists and Orthotists

Last autumn the School of Medicine and the Department of Medical Extension of the University of California at Los Angeles inaugurated a series of 15-week courses in anatomy especially designed for prosthetists and orthotists. Under the direction of Dr. Robert W. Bailey, Assistant Professor of Surgery (Orthopedics) at the UCLA Medical School, the classes meet for a period of three hours every Wednesday evening for 15 weeks, thus providing for each course a total of 45 hours of instruction. The fee is a nominal $1 per hour, or $45 for the entire course; classes are limited to 40 students; and two units of credit are given for successful completion.

The first section, which ran from October 5 through January 25, was devoted to lectures on the normal anatomy. A comparatively new approach, called "regional anatomy," was tried out, and the results were gratifying. Instead of presenting all of the bones of the body, then all of the muscles, then all of the blood vessels, and so on, the instructors took up single "regions" of the body and discussed each in its entirety. Included were the shoulder; the elbow; the forearm; the hand; the back, neck, and trunk; the hip; the thigh; the knee; the leg; and the ankle. In *The Shoulder,* for example, all of the bones, joints, muscles, nerves, and blood vessels that make up the shoulder were studied in relation to one another.

The second section, which ran from February 22 through June 6 (less May 30), was concerned with pathological anatomy for prosthetists and orthotists. The schedule was as follows:

February 22	Orientation to pathology: degenerative processes, circulatory disturbances, inflammation, healing, infection, growth, tumors, etc. ROBERT S. STONE, M.D.
February 29	Pathology of the nervous system: herniation of the nucleus pulposus, virus diseases of the nervous system, multiple sclerosis, muscular dystrophies. CHRISTIAN HERRMANN, JR., M D.
March 7	Pathology of the nervous system: vascular lesions of the brain, lesions of the spinal cord, syphilis, cerebral palsy. HARRY C FANG, M.D.
March 14	Peripheral vascular diseases: arteriosclerosis, Buerger's disease, varicosities, and related conditions. JACK A. CANNON, M.D.
March 21	Bone infections, tumors. J. VERNON LUCK, M.D.
March 28	Osteoporosis, Paget's disease, and related metabolic bone conditions. MARSHALL R. URIST, M.D.
April 4	Fractures, dislocations, and sprains (I). ROBERT W. BAILEY, M.D.
April 11	Fractures, dislocations, and sprains (II). ROBERT W. BAILEY, M.D.
April 18	The arthritides. PAUL E. MCMASTER, M.D.
April 25	Poliomyelitis. VERNON NICKEL, M.D.

May 2	Pathological conditions of muscles, tendons, and bursae; fibrosis, myositis ossificans, tenosynovitis, bursitis. THEODORE A. LYNN, M.D.
May 9	Amputations of the upper extremities: causes, sites, stump pathology. CAMERON B. HALL, M.D.
May 16	Amputations of lower extremities: causes, sites, stump pathology. ROBERT MAZET, JR., M.D.
May 23	Congenital deformities: club foot, flat foot, bow leg, knock knee, dislocation of hip, scoliosis, lordosis, kyphosis, congenital absence of extremities. ROBERT W. BAILEY, M.D.
June 6	Summary, discussion, final examination. ROBERT W. BAILEY, M.D.

Section three, to be devoted to various aspects of the principles of limb prosthetics, will begin this autumn.

The organizers of these important courses have performed a service worthy of emulation in other parts of the country. They were fortunate in being able to enlist for the teaching staff a group of outstanding physicians and surgeons, many from the UCLA Medical School itself, others from private practice in the Los Angeles area. All of the lectures were recorded on tape with the idea of later using some of this valuable material in the Prosthetics Education Program.

Additional information about the UCLA extension program may be obtained from Dr. Thomas H. Sternberg, Assistant Dean for Postgraduate Medical Education, University of California Medical Center, Los Angeles 24, California.

New Film on Canadian Prosthesis

A new 16-mm. color motion picture covering the fabrication and fitting of the Canadian hip-disarticulation prosthesis was completed early this year by the Prosthetics Education Project at the University of California, Los Angeles Campus, under the supervision of Dr. Miles H. Anderson, Educational Director, and Raymond E. Sollars of the PEP staff. Embracing the entire process from the first examination of the amputee to the final fitting, complete with cosmetic covering, the film was directed, shot, edited, and titled by Anderson and Sollars, both of whom have extensive experience in this field. Included in the coverage is an x-ray of the pelvic area of the subject, ample indication of the general physique, and studies of the gait pattern with the completed limb.

Because it was anticipated that the film would best be shown silent, with live commentary appropriate to the class or audience viewing it, *The Canadian Hip Disarticulation Prosthesis* carries no sound, but it contains sufficient titles to elucidate the subject matter. In order to provide for mechanical narration or commentary where required, all prints have been ordered with single perforations only, so that magnetic stripping may be added on the unperforated edge.

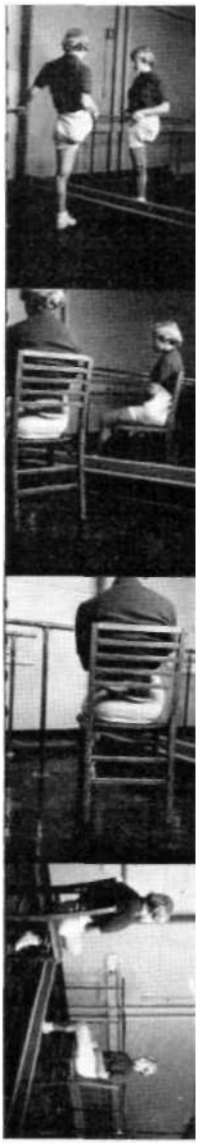
An interesting fact about *The Canadian Hip Disarticulation Prosthesis* is the speed (and hence economy) with which it was produced. Almost 4000 feet of "Kodachrome A" were shot in less than five days. A work print was made and edited, titles were written and filmed, and final prints were delivered—all within about 40 days after shooting began. The completed film, with titles, totals 2796 feet, with a running time of one hour and 45 minutes.

James Foort, chemical engineer on the staff of the Lower-Extremity Amputee Research Project at the University of California, Berkeley Campus, appears in the film as the "prosthetist." Actually, Foort is not a prosthetist at all, but he made it his business to learn as much about fitting and alignment, anatomy, and gait analysis as was needed in order to utilize his knowledge of plastics to best advantage. Since the film was made almost within days after Foort had completed development work on the over-all procedure, it was not only expedient, but necessary as well, to use him as the demonstrator in the film. A report, covering the same subject matter as the film but going into greater detail, has been prepared by Foort and Charles W. Radcliffe, also of the Berkeley group. Copies of this brochure may be had free of charge by addressing a request to the Lower-Extremity Amputee Research Project, University of California, Berkeley.

The hip-disarticulation amputee seen in *The Canadian Hip Disarticulation Prosthesis* is Miss Gretchen Van Dyke, of Dana Point, California, and it is to her that ARTIFICIAL LIMBS is indebted for permission to use the accompanying photographs. Now 22 years old, she became an amputee at the age of 14 as the result of bone infection following injury in a sand-lot baseball game. She became the pilot study subject for hip-disarticulation prostheses with the Berkeley project while she was a student at the University of California there and has continued the association since leaving the University. She may be classified as a true hip-disarticulation case, since no part of the femur remains on the amputated side. Although she is very little more than five feet tall, Miss Van Dyke is an athletic individual and takes part in such sports as water-skiing. She has excellent neuromuscular coordination and gait.

The hip-disarticulation prosthesis shown in the film, commonly referred to as the "Canadian type," was originally developed by Colin A. McLaurin, an engineer formerly with the Department of Veterans Affairs of Canada. As seen in the film, it utilizes McLaurin's principles, but with the addition of certain fitting and alignment modifications and certain plastics-fabrication procedures developed by the Berkeley group. The original design has been published previously in ARTIFICIAL LIMBS (September 1954, p. 30).

Two copies of this new and informative motion picture are available on loan. One resides in the library of the Audio-Visual Department of the University of California at Los Angeles. It may be borrowed upon written request to that department. The other has been placed with the Veterans Administration. It may be obtained upon request addressed to William M. Bernstock, Prosthetics Education Specialist, Prosthetic and Sensory Aids Service, U. S. Veterans Administration, 252 Seventh Avenue, New York City.



NEW HD MOVIE—Some typical shots of the amputee subject before fitting. *Courtesy University of California at Los Angeles.*

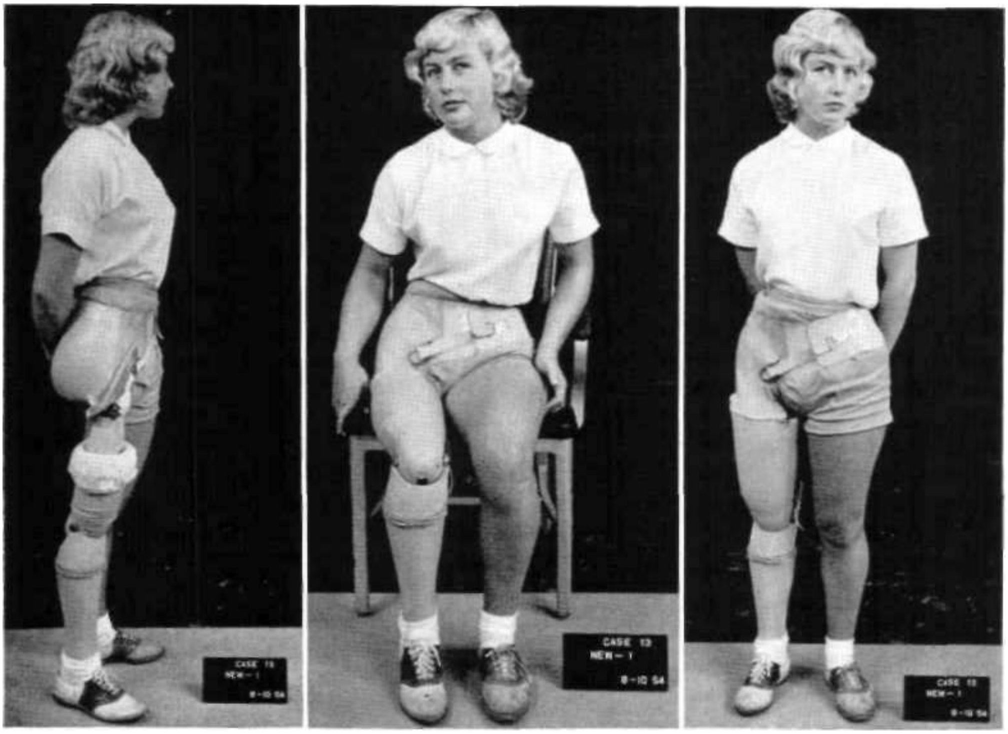
Training Courses for Prosthetic Representatives

In most regional offices of the Veterans Administration key prosthetics personnel, known as "Prosthetic Representatives," serve as Chiefs of Prosthetic and Sensory Aids Units. There are approximately 65 such Prosthetic Representatives, who in turn receive guidance from seven Area Chiefs, the latter being on the staffs of the seven Area Medical Directors throughout the country. Each Prosthetic Representative and Area Chief is a user of a major prosthetic appliance. Practically all of those presently assigned are amputees.

Prosthetic Representatives are responsible "for all activities, other than purely professional activities, pertaining to prosthetic appliances, terminal devices, sensory aids, cosmetic restorations, and/or medical accessories at the station concerned." They serve as "technical and administrative advisers to the professional medical staff regarding all appliances."

It has long been recognized that the Prosthetic Representatives need formal technical training to help them discharge their important responsibilities. Most of them have been trained "on the job" for more than eight years, acquiring technical information in varying degrees and in an unsystematic manner. The disadvantages of this fortuitous method of amassing knowledge have been quite apparent, but budgetary considerations did not permit any organized training program until fiscal year 1956.

Accordingly, a pilot Technical Training Course for Prosthetic Representatives was conducted by the Prosthetic and Sensory Aids Service in its New York offices during the two-week period January 9 through 20. A two-day critique followed the course. Participants were: Voight W. Baker, Area Chief, Prosthetic and Sensory Aids Service, St. Paul, Minn.; William R. Bouldin, Chief, Prosthetic and Sensory Aids Unit, Philadelphia; James Cohen,



SUBJECT OF NEW FILM—Gretchen Van Dyke, 22-year-old hip-disarticulation amputee, is the subject fitted in the new film *The Canadian Hip Disarticulation Prosthesis.* Here she is shown wearing the completed limb, including cosmetic covering. *Courtesy University of California at Los Angeles.*

Chief, Prosthetic and Sensory Aids Unit, New York City; James C. Higgins, Chief, Prosthetic and Sensory Aids Unit, Albany, N. Y.; Wilfred G. Holsberg, Area Chief, Prosthetic and Sensory Aids Service, Boston; James T. Kenny, Chief, Prosthetic and Sensory Aids Unit, Pittsburgh; Harry D. MacBird, Area Chief, Prosthetic and Sensory Aids Service, San Francisco; Leonard J. McCarthy, Area Chief, Prosthetic and Sensory Aids Service, Trenton, N. J.; Nelson McFarland, Area Chief, Prosthetic and Sensory Aids Service, Atlanta; Jack Miller, Chief, Prosthetic and Sensory Aids Unit, Brooklyn; Donald W. L. Smith, Area Chief, Prosthetic and Sensory Aids Service, St. Louis; Albert S. Zuidema, Chief, Prosthetic and Sensory Aids Unit, Boston. Thelma Murray, Rehabilitation Counselor with the New York State Division of Vocational Rehabilitation, attended as a guest.

Because of the limited time available, and because of the wide variety of material to be covered, a survey course was developed. More than 50 discrete topics were included in the curriculum. Anatomy and kinesiology, mechanics, materials, highlights of arm and leg fabrication and fitting, bracing, hearing aids, and orthopedic shoes were covered, as were many other topics ranging from hair pieces to arch supports. The instructional methods used included lectures and bench demonstrations. Time did not permit complete fabrication and fitting of various prosthetic and orthopedic appliances, and it was therefore necessary for the instructors to fabricate a number of items in advance and to describe the steps involved in the fabrication procedure. The wide variety of models and visual aids helped make the lectures more meaningful. A comprehensive Prosthetics Technical Guide, developed prior to the course, was used by the participants as back-up material.

The test-retest method was used as one means of evaluating the effectiveness of the course. A general test (consisting of 64 questions) in technical aspects of prosthetics, a muscle-identification test, and a bone-identification test were administered on the first day of the course. Retests were conducted at the end of the course two weeks later. Every one of the students showed improvement in all three tests. The average gain in the general test was 41 percent, in the muscle-identification test 65 percent, and in the bone-identification test 39 percent.

Significant though these statistics may be, what was more impressive perhaps was the unanimous reactions of the participants that the course was the most valuable they had ever experienced. In response to their comments that they should have had such training eight or nine years ago, it can only be stated that not as much was known then as is known now.

Credit for whatever success the course enjoyed must go in great part to the instructors who participated in it—personnel from the New York Regional Office of the Veterans Administration, from the Research and Development Division and the Prosthetic Testing and Development Laboratory, and from the New York University Prosthetic Devices Study. The two-day critique, held on January 23 and 24, resulted in a number of valuable suggestions which will help to improve future courses.

A second course, for the Prosthetic Representatives in the San Francisco Medical Area, will be held in May in the facilities of the Prosthetics Education Project at UCLA and at VA installations in that area. The curriculum is based on the New York program, and materials and models developed for the pilot New York course will be made available to the West Coast instructional personnel.

In June another course will be conducted in New York, primarily for the Prosthetic Representatives in the Atlanta and Columbus Medical Areas. Courses for the rest of the Veterans Administration's Prosthetic Representatives will be held during fiscal year 1957.

It is the considered opinion of those in the Prosthetic and Sensory Aids Service who are responsible for the education and training of the VA's prosthetics personnel that these basic survey courses are a logical prerequisite for participation in the more advanced courses being conducted under the Artificial Limb Program. As a group, the Prosthetic Representatives are of above-average intelligence; their formal schooling ranges from three years of high school to a master's degree, with an average of one year of college; and, most important, they have an intense desire to learn. With proper planning, it should ultimately be possible to involve them to good advantage in the program of regional courses in prosthetics.

New VA Prosthetics Center

Establishment of a Veterans Administration Prosthetics Center in New York City was announced early in February by Dr. William S. Middleton, VA's Chief Medical Director. The only one of its kind in the country, the Center is located at 252 Seventh Avenue in the same building with the VA Regional Office. Administrative integration of prosthetic activities of the regional office with Central Office units makes for improved administrative efficiency and better service to veterans, Dr. Middleton said.

Combined in the Center are three important elements. One is the Limb and Brace Section, formerly a part of the New York Regional Office. This unit annually manufactures and fits, under close medical supervision, braces and limb prostheses for hundreds of amputees and disabled veterans, particularly problem cases.

Another part of the new organization is the Orthopedic Shoe Center, which was previously supervised directly from Washington. The Shoe Center distributes orthopedic shoes to eligible veterans throughout the United States.

The third constituent of the new Center is the Prosthetic Testing and Development Laboratory, which was formerly operated in New York City under the jurisdiction of VA's Prosthetic and Sensory Aids Service. This laboratory, which previously served as a testing laboratory for prosthetic developments prior to approval by the VA, has consolidated its personnel, testing equipment, and machine shop into the new Prosthetics Center at a considerable saving to the Government.

Chief of the new Center is Anthony Staros, an engineer formerly serving as head of the Prosthetic Testing and Development Laboratory. Professional and technical assistance and supervision for the Center is provided by the

Prosthetic and Sensory Aids Service of VA's Department of Medicine and Surgery in Washington. This Service, headed by Dr. Robert E. Stewart, has offices in both Washington, D. C, and New York City, in the latter together with a large reference exhibit at 252 Seventh Avenue.

MR. STAROS

Medical assistance for veterans with prosthetic problems will continue to be furnished by the New York Regional Office. The Orthopedic and Prosthetic Appliance Clinic Team of the New York Regional Office will continue its close supervision of difficult cases being fitted in the new Center. Closer correlation of VA's research activities in prosthetics with actual fabrication of limbs for amputees and braces for the orthopedically disabled should result in considerably improved services to veterans.

Amputees Alliance, Inc.

For several years, various staff members of the Prosthetic and Sensory Aids Service have delivered talks and held demonstrations at meetings of Amputees Alliance, Inc., in New York. This group, organized in 1948 with headquarters at 1269 York Avenue, New York, has been doing an effective job in helping amputees, particularly new amputees, and in promoting the spirit of good fellowship among its members.

On January 19, Dr. Eugene F. Murphy discussed developments in lower-extremity prosthetics, with emphasis on the Canadian hip-disarticulation prosthesis, now the subject of a motion picture recently completed at UCLA (page 43).

AAOS Instructional Course Lecture

On February 1, Dr. Charles O. Bechtol and Dr. Eugene F. Murphy collaborated in an Instructional Course Lecture on *Surgical Applications of Engineering Principles* at the meeting of the American Academy of Orthopaedic Surgeons in Chicago.

Prosthetics Research at OALMA Assembly

Key figures in prosthetics research were represented in the program of the National Assembly of the Limb and Brace Profession when it convened at New Orleans last October 16 through 19.

Chester C. Haddan, member of the Prosthetics Research Board, joined with Lucius Trautman, of Minneapolis, in presenting a seminar on *Making and Fitting the Lower-Extremity Prosthesis.* Dr. Charles O. Bechtol, Head of the Department of Orthopedic Surgery at Yale University, taught a seminar on *Brace Problems Related to Fracture Healing and Muscle Mechanics.* Dr. Bechtol also participated in a panel discussion of the *Prosthetics Clinic Team Approach* with A. Bennett Wilson, Jr., Executive Secretary, PRB, and Dr. Miles H. Anderson, Educational Director, PRB. *A Survey of New Developments in Prosthetic Appliances for the Child* was presented by Dr. Carleton Dean, Director of the Michigan Crippled Children Commission, and John Steensma, Prosthetics Instructor for the Commission.

Contract arrangements for prosthetic service to veterans were reviewed by a panel of VA officials consisting of Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service; D. M. Zimmerman, Assistant Chief of the Service Contracts Section; and Dr. Eugene F. Murphy, Chief of the Research and Development Division of the Prosthetic and Sensory Aids Service.

A Spotlight Drama on the Life of a Typical Male Amputee was presented by Dr. Jack K. Wickstrom, Head of the Division of Orthopedic Surgery at Tulane University. Dr. Wickstrom's presentation, which featured the individuals actually concerned with the amputee, pointed up the need for the team approach in prosthetic rehabilitation. Dr. Wickstrom was assisted in the presentation by Dr. Edward T. Haslam, of Tulane University, and Thomas Maples, who was the certified prosthetist in the case.

The need and the rewards for effective cooperation between the prosthetic facility and the Municipal Rehabilitation Center were discussed by Ivan A. Dillee, certified prosthetist of Kansas City. Mr. Dillee's paper was printed in the March 1956 issue of the *Orthopedic and Prosthetic Appliance Journal,* and reprints may be had from OALMA.

MR. HARMON

Before adjourning, the Assembly chose W. Frank Harmon, of Atlanta, Georgia, to be President for the year 1956 and selected San Francisco, California, as the site for the 1956 National Assembly. The dates are October 20 through 23.

Prosthetics Section at NRA Meeting

The 1955 conference of the National Rehabilitation Association at St. Louis, November 14 through 16, featured a sectional meeting on *Physical Restoration* arranged by the Orthopedic Appliance and Limb Manufacturers Association. Glenn E. Jackson, Executive Director of OALMA, served as moderator of the program and introduced these speakers: Milton Tenenbaum, New York City, *Cosmetic Devices and Restorations;* Chester C. Haddan, Denver, *Highlights in Today's Research;* Paul E. Leimkuehler, Cleveland, *What Should These Devices Cost?;* and Lester A. Smith, Assistant Director of OALMA, *A Survey of Prosthetic Literature—Selected Reference Aids.* A demonstration of today's physical-restoration devices was introduced by Lucius Trautman, of Minneapolis.

Dr. Edward C. Holscher and McCarthy Hanger, Jr., presented *An Amputee Clinic in Action.* Dr. Holscher called on experienced members of his clinic team to review the procedures. Those participating included Dr. Henry G. Farris, Chief of Physical Medicine at the VA Regional Office; Rose Mary Kelly, Chief Physical Therapist; Lillian T. Carney, Chief Occupational Therapist; Wesley Briscoe, certified prosthetist of the Standard Artificial Limb Company; Robert Reich, certified prosthetist of J. E. Hanger, Inc., of Missouri; and Russell J. Curtis, Chief of the Prosthetic and Sensory Aids Unit of the VA Regional Office in St. Louis.

Mr. Leimkuehler's paper was printed in the November-December 1955 issue of the *Journal of Rehabilitation.*

Among the exhibitors at the conference were the Orthopedic Appliance and Limb Manufacturers Association; the National Society for Crippled Children and Adults; the Standard Artificial Limb Company, of St. Louis; the Bureau of Old Age Insurance; the Pennsylvania Bureau of Rehabilitation; the W. E. Isle Company, of Kansas City; the Liberty Mutual Rehabilitation Center; and the J. E. Hanger Company.

MOALMA Conference

More than 225 prosthetists and orthotists and their guests were registered for the 1956 Prosthetic and Orthopedic Conference held at the Hotel Biltmore in New York City April 27 and 28. Sponsored jointly by the Metropolitan (New York) Orthopedic Appliance and Limb Manufacturers Association and by Regions I and II of OALMA, the conference was planned by a committee headed by Mrs. Mary Dorsch, of the Dorsch-United Limb and Brace Company, and including Fred J. Eschen, Charles R. Goldstine, Mrs. Adele Tenenbaum, and Leo Waller, all members of the New York Association.

For the first time the conference featured a display of scientific and technical exhibits contributed by manufacturers of artificial limbs and related appliances. Selection of the displays was made by Herbert B. Hanger, certified prosthetist and manager of the J. E. Hanger Company of New York.

Dr. Howard A. Rusk, Director of the Institute of Physical Medicine and Rehabilitation of the NYU-Bellevue Medical Center, opened the conference with an address entitled *Crippled People in a Troubled World,* in which he emphasized the importance of rehabilitation in the postwar era. At the conclusion of his remarks, he was presented with an illuminated scroll in recognition of his services in the rehabilitation of the handicapped (see cut).

Presentation of the citation, the first in a series of annual honors to be presented by MOALMA, was made by Milton Tenenbaum, President of the Association, assisted by Karl W. Buschenfeldt and John A. McCann, Directors, respectively, of Regions I and II of OALMA.

A panel of physicians and prosthetists, including Dr. Charles 0. Bechtol, Dr. Donald A. Covalt, Dr. Ralph Rohner, Dr. Allen Russek, Dr. Samuel Sverdlik, Herbert B. Hanger, Arthur L. Boland, William F. Francis, Charles R. Goldstine, and Fred Greimel, reviewed the prosthetic problems of the older age group and discussed the merits of the suction socket versus the conventional socket. Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service of the Veterans Administration, reviewed the efforts of the VA to improve service to the amputee and participated in a question-and-answer session on problems in prosthetic service. In another presentation, Dr. Sidney Fishman, Director of the Prosthetic Devices Study of New York University, said that when the prosthetist has acquired the skill to convey his technical knowledge to other disciplines, and when he understands fully the responsibility of the prosthetics clinic team toward the patient, any difficulties in relationships with the medical and other professional groups will vanish.

Other features of the two-day program included a demonstration of braces by Dr. William B. Snow and Cosmo L. Invidiato, certified prosthetist and orthotist of Paterson, N. J.; a demonstration of the prosthetics evaluation team by Dr. Jerome Lawrence and Fred J. Eschen, certified prosthetist of New York City; a panel discussion on fabrication and joining of metals applicable to orthopedic appliances by John T. Stewart and Herbert B. Leary of Whitehead Metal Products Company, Benedict G. Pecorella, certified prosthetist of Buffalo, and Arthur Pomeroy and Julius Vitarius, certified orthotists of New York City; a demonstration of new devices and techniques, with David E. Stolpe of New York City as moderator; a report on public relations for the brace facility and the artificial-limb establishment by Lester A. Smith, editor of the *Orthopedic and Prosthetic Appliance Journal;* and an explanation of the cost-accounting project to be sponsored by OALMA, presented by Glenn E. Jackson, Executive Director of OALMA. On the evening of April 27, Mr. Jackson served as toastmaster at the annual spring dinner and reception, a traditional feature of the MOALMA Conference.

--*Standard Flashlight, New York City*

MOALMA HONORS RUSK—Dr. Howard A Rusk, Director of the Institute of Physical Medicine and Rehabilitation, NYU-Bellevue Medical Center, and member of the Prosthetics Research Board, reviews the program of the 1956 Prosthetic and Orthopedic Conference of the Metropolitan (New York) Orthopedic Appliance and Limb Manufacturers Association after receiving a citation, April 27, "in acknowledgement of his generous cooperation and in tribute to his inspired efforts in rehabilitating the handicapped." Pictured are (left to right) Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service of the Vetrans Administration; Mrs. Mary Dorsch, of the Dorsch-United Limb and Brace Company and Chairman of the Conference Committee; Dr. Rusk; and Milton Tenenbaum, of Tenenbaum Prosthetics and President of MOALMA, who made the presentation of an illuminated scroll.

New Certification Requirements

In continuation of its efforts to raise the standards of training for prosthetists and orthotists, the American Board for Certification has revised and expanded its application forms required of those persons wishing to be certified. The new form for prosthetist (TRS-P) provides for a detailed statement of all experience during the last 15 years. Time spent on work processes must be recorded in months of actual experience and in percentage of the workday. The questions covering fitting experience call for the amount of time spent on measuring and consulting and on fitting in the following categories: Chopart, Syme, below-knee, knee-bearing, above-knee, hip disarticulation, below-elbow, elbow disarticulation, above-elbow, and shoulder disarticulation.

Questions regarding education cover not only high school but also detailed information about any specialized courses taken since then —college or elsewhere. Applicant must be a graduate of high school or at least obtain a certificate of high-school equivalency. Also required are the signatures of three attesting physicians, one of which must be an orthopedic surgeon.

The application form for orthotist (TRS-O) has been similarly expanded to require a full report on past experience and training.

Copies of the new forms may be obtained from the Executive Director, American Board for Certification, 411 Associations Building, 1145 Nineteenth St., N. W., Washington 6, D. C.

New Officers for NERC

The New England Regional Council of the Orthopedic Appliance and Limb Manufacturers Association has announced new officers for the calendar year 1956. They are as follows: John F. Buckley, President; Edward Hitchcock, Vice-President; John Glancy, Secretary; and Eric Klahr, Treasurer. Further information about the activities of the New England Council may be obtained from the secretary at 691 Boylston Street, Boston.

New OALMA Reprints

The Orthopedic Appliance and Limb Manufacturers Association has made available for distribution two reprints of interest in the field of limb prosthetics. They are titled *Advice to the Amputee* and *What Should Prostheses Cost?*

Advice to the Amputee is an article by Dr. Preston J. Burnham, Clinical Instructor in Surgery, College of Medicine, University of Utah. Dr. Burnham, who is a leg amputee, is a graduate of the School of Medicine of the University of Rochester. He is the author of a number of other articles, including *Amputation of the Lower Extremity* published in *Ciba Clinical Symposia* for September-October 1954. In 1952 he was elected a Fellow of the American College of Surgeons.

Dr. Burnham prepared the article to help new amputees who are worried about their future and who need advice. It has been found useful by orthopedic surgeons and prosthetists who, in the course of their professional duties, are called upon to discuss many problems with the new amputee and his relatives.

What Should Prostheses Cost?, which has been reprinted from the *Journal of Rehabilitation,* is an article by Paul E. Leimkuehler, certified prosthetist of Cleveland, Ohio. It is based upon a talk given by Mr. Leimkuehler before the 1955 National Convention of the National Rehabilitation Association in St. Louis (page 48).

Copies of these reprints may be ordered from OALMA, 411 Associations Building, 1145 Nineteenth St., N. W., Washington 6, D. C. A nominal charge of ten cents for the Burnham reprint and five for the Leimkuehler is made to cover printing and mailing costs.

Correction

Last autumn (ARTIFICIAL LIMBS, September 1955, p. 67) it was erroneously reported that the New England Regional Council of OALMA had established a free central library under the direction of Howard V. Mooney of the Boston Artificial Limb Company, Boston, Mass. Actually, the Council decided at its meeting last June that, in view of the high level of voluntary cooperation between the individual members, no such central repository was needed, since educational media are always exchanged on a personal basis. That no formal system of exchange is required is a credit to the members of the New England Council. ARTIFICIAL LIMBS regrets the faulty reporting.

Amputation Prosthesis

The Office of the Executive Director of the Prosthetics Research Board is badly in need of a single copy, new or used, of Thomas and Haddan's *Amputation Prosthesis* (Lippincott, Philadelphia, 1945). This volume is now out of print, and attempts to obtain a copy from booksellers have proved fruitless. Anyone having a spare or unneeded copy will perform a service by lending it or, preferably, selling it to OED. Communications in this regard may be directed to the editor of ARTIFICIAL LIMBS.

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

The National Academy of Sciences—National Research Council is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare.

The Academy itself was established in 1863 under a Congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental 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 efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government designated by the President of the United States, and a number of members-at-large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.