Essentials

of

HUMAN

ANATOMY

Woodburne

OXFORD

Essentials of

HUMAN ANATOMY

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Preface

THE PRESSURE of steadily increasing knowledge in medicine and the other health sciences, and in anatomy itself, has been a stimulus for re-examination of teaching methods in anatomy, as it has in related subjects. A superficial response to such pressure is to reduce the time for and the content of anatomy courses. However, expanding frontiers in clinical and anatomical fields are not likely to be served by teaching less anatomy, though it is highly probable that advances can be made in the efficiency of presentation of the subject. It would appear that one area of anatomical teaching which would profit from improvement lies in the character of the textbooks available to the student. Enlarged by every accretion of knowledge through the decades, their systematic organization is an obstacle to learning when only isolated parts of the body are met by the student as systematic entities.

This text presents the basic concepts of the systems of the body and then examines the body, in detail, regionally. Within each region, the order of presentation is from superficial to deep—the only order in which the body can conveniently be dissected. This has the advantage of a concise and integrated description of the region under consideration, and much time and effort is saved in preparing for or reviewing each portion of the body. The regional method of description carries with it, however, the danger of dissociated learning—failing to relate the regional entity to the rest of the system of which it is a part. This danger is avoided by repeated stress on the continuity of parts, by numerous cross-references, and by illustrations that are designed to be synoptic as far as possible.

This is not an elementary text; in some respects its detail goes beyond that of the currently used textbooks. Its brevity comes from an adherence to the essentials of morphology presented functionally and concisely. The author recognizes that conciseness and brevity can lead to oversimplification and inaccuracy, and every effort has been made to be exact in description. Only the most frequent variations are discussed, for to be complete in the matter of variation places a textbook in the reference category. In the choice of such citations, vascular variations are given more attention than muscle and tendon variations, since information on the former is deemed to be of greater clinical utility.

A revision of anatomical nomenclature was adopted by the Sixth International Congress of Anatomists in 1955. This revision is followed in the present text. Its changes are in the direction of simplicity, consistency, and logic in terminology, and the last of the eponyms have been eliminated. No attempt is made, in the descriptions which follow, to carry the older terminology along in bracketed form. The beginning student has no prejudices or foreknowledge in the matter of names. Others accustomed to the traditional names should encounter no difficulty in making the simple transition in terms required by this revision.

It is a privilege and a pleasure for the author to acknowledge his indebtedness to his predecessors and colleagues in the field of anatomy. Most material contributed by previous workers has been incorporated into the general body of knowledge of the subject and cannot be specifically cited in a work of this kind. Indeed, only the more recent contributions are especially listed. In order, however, that the student may have available to him a list of specific citations and general references in which more detail may be found on such subjects as are especially interesting to him, selected references have been grouped at the end of each chapter. These lists are brief, in keeping with the character of the

book, but should serve to lead the inquiring student into the more detailed sources.

I owe a real debt of gratitude to my colleagues in the Department of Anatomy of the University of Michigan for their careful reading of the manuscript and their constructive criticism of the illustrations; special thanks are due to Dr. Thomas M. Oelrich. I am indebted to my illustrators—Joanna C. Berger, William L. Brudon, David Sterrett, and Cecilia Graham—for the excellence of their work and for their tolerance of continual revision, and to my secretary, Esther L. Vowell, for her care in preparation of the manuscript. A real contribution to the work has been made by my wife, who has helped both in composition and in proofreading. The X-rays used were provided by the Department of Radiology of the University of Michigan Medical School. In grateful recognition of assistance from many, the author nevertheless accepts full responsibility for errors or omissions in the final result.

R. T. W.

August 1957

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ESSENTIALS OF HUMAN ANATOMY

I

General Concepts in Anatomy

INTRODUCTION

ANATOMY is the term usually applied to the study of the human body by the method of dissection. As observation of the tissues of the body has extended to more and more minute parts and as microscopes have been employed, the field of anatomy has been subdivided for convenience into **gross anatomy** and **microscopic anatomy. Cytology, histology,** and **organology** are segments of the general field of **microscopic anatomy,** having reference respectively to cells, tissues, and organs. The special study of the nervous system, **neuroanatomy,** is pursued partly by gross but, for the most part, by microscopic techniques. The developmental aspects of the human organism fall under the heading of **embryology.**

All of these branches of anatomy are concerned with various approaches to human morphology, but they are distinguished by special techniques and differing foci. There are no actual boundaries between the several parts of anatomy, and the discussions which follow will occasionally draw from all of them without regard to precise limitations. However, it is the anatomy as seen by the unassisted eye that is the focal point of this description, and it is to general aspects of the gross structure of the human organism that our attention is directed. Some of its special phases are designated **topographic,** or regional, **anatomy, radiographic anatomy, applied anatomy, surgical anatomy.**

Description requires the body to have a standard orientation. Thus the **anatomical position** is an erect one with eyes forward and the palms of the hands to the front. This position of the hands is not an entirely natural one, it is a position of **supination;** the opposite, with the palms down or backward, is one of **pronation.** Description also uses standard reference terms (fig. 1) based on the **anatomical position.** The **median plane** is a vertical plane through the body reaching the surface at the midline in front and behind. This plane is also known as the **midsagittal plane** of the body and, with the exception of the unpaired viscera in the trunk cavities, divides the body into symmetrical halves. Other anteroposterior vertical planes parallel to the median, or midsagittal, plane are called **sagittal planes.** The **coronal plane** is a vertical one directed from side to side and thus is at right angles to the midsagittal plane. It gives its name to the coronal or frontoparietal suture of the skull and may also be designated as a frontal plane. The term **horizontal,** or transverse, **plane** refers to any plane at right angles to the vertical planes; it is a cross section. Fundamental terms for the front and back of the body are, respectively, **ventral** and **dorsal.** Since adult man stands erect, ventral is equivalent to **anterior** and dorsal is the same as **posterior. Cranial** and **caudal,** referring respectively to the head and tail regions of the trunk, are also useful directional terms. It is frequently necessary to stipulate that an object is **medial** and thus near or nearer the median plane of the body, or, conversely, **lateral** and thus farther away from the median plane. **Proximal** and **distal** contrast positions nearer the root of a limb and farther along its length. **Superficial** and **deep** are terms frequently used in describing a dissection and have their usual meaning of nearer or farther from the surface.

THE ORGANIZATION OF THE BODY

As one observes one's fellow man it is apparent that he makes his impress on you as a sentient, reacting organism. He feels, sees, and hears; he moves and responds to stimuli and adapts to the conditions of his environment. He is thus a

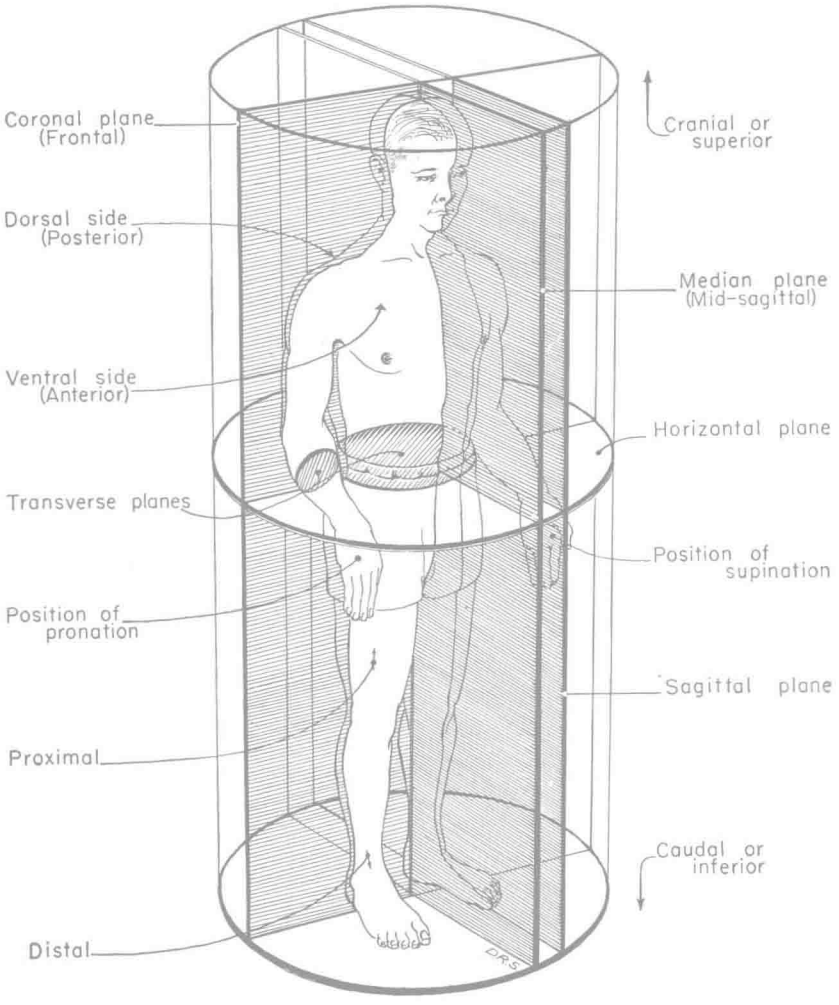

FIG. 1 The planes of the body and terms of direction and orientation.

sensorimotor mechanism in outward behavior. He is also, however, an organism that is inconspicuously but incessantly preoccupied with maintaining his own life processes. The respiratory, digestive, and excretory needs of his body are carried on more or less automatically and continuously. He has an internal regulation that is due partly to endocrine gland secretions and partly to the activities of his nervous system. Finally, his genital apparatus provides for the continuity of the race.

Man is at once both complex and simple, for his manifold abilities and functions are made possible by rather extreme specialization in his tissues, and yet these tissues are fundamentally merely collections of single cells. Essentially, all the functions of the body are expressed in the qualities of the single cell. As **cells** of similar type are aggregated and become organized into **tissues** and as tissues of like and diverse character are collected and fabricated into **organs**, and organs into **systems**, the main subdivisions of the body take shape. The body can be described under headings designating its component systems with economy of space and homogeneity of subject matter. That this approach is not followed in this text is due to the fact that dissection is necessarily performed region by region and not system by system. The **system** represents, however, such a valuable organizing and simplifying concept that an initial acquaintance with the systems of the body is imperative. As usually listed these are: the **skeletal system**; the **muscles**; the **articulations**; the **circulatory system**; the **nervous system**; the **skin** and **organs of special sense**; and the **visceral systems—respiratory, di-**

gestive, urogenital, endocrine. Most of these systems find representation in all or several regions of the body, although the visceral systems occupy the trunk almost exclusively. Among the **regions** of the body that may be usefully designated are the **upper limb,** the **head and neck,** the **back,** the **chest** or **thorax,** the **abdomen,** the **perineum,** the **pelvis,** and the **lower limb.**

As a conceptual basis for dissection in any of the regions of the body a general knowledge of the more basic systems is invaluable. In developing such an understanding of the whole organism it may be advantageous to return to the sensorimotor aspect of Man's organization and begin consideration of his systems with a description of the skin. This is also the initial site of dissection in any region of the body.

THE SKIN AND ITS APPENDAGES

The skin, or common integument (fig. 2), is a tough, pliable covering of the body which grades over into the more delicate mucous membranes of the body cavities at the mouth, the nostrils, the eyelids, and at the urogenital and anal openings. That it is infinitely more than a surface covering is shown by a consideration of its varied functions. The skin is an extensive **sensory organ,** supplied with a host of nerve endings which provide sensitivity to touch and pressure, temperature changes, and painful stimuli. Indeed, skin is the principal source of these 'general' sensations. The skin is a **protective** layer of considerable importance. Not only is it a strong, flexible covering but it also prevents loss of body fluids. Appreciation of this function comes especially as one considers the importance of skin grafts in covering raw, denuded, or burned areas of the body. The integument is especially significant in **temperature regulation.** As a warm-blooded (homeothermic) animal, Man's internal temperature is kept constant through external changes of 100° F. or more. Reduction of body temperature is a special function of skin, for heat loss through radiation, convection, and evaporation (from skin and lungs) accounts for approximately 95 per cent of the total heat dissipated from the body. Sweating is initiated by the effect of blood heat on brain centers and is mediated through cutaneous nerves reaching the sweat glands. Sweating also serves the **excretory functions** of the body, for if sweating is copious, up to one gram of nonprotein nitrogen may be eliminated per hour. The skin is concerned in the production of **vitamin D** through the action of the ultraviolet rays of the sun on its sterols. Studies of percutaneous transmission of drugs, vitamins, and hormones indicate that the skin has an important **absorptive** function when such substances are applied to it in a suitable vehicle.

Basic to effective functioning in all these metabolic aspects is the large **surface area** of the integument in the adult of 1.8 sq. meters (approximately a 6′ by 3′ sheet). The surface area increases about sevenfold from birth to maturity. The skin ranges in thickness from 0.5 mm. over the tympanic membrane and the eyelids to 6 mm. over the upper back, back of the neck, palm of the hand, and sole of the foot. It tends to be thicker on the posterior and extensor surfaces than on the anterior and flexor surfaces and generally approximates 1 to 2 mm. in thickness. The skin is loosely applied to underlying tissues and may be displaced and elevated in most regions of the body. Contrarily, it may be firmly attached to periosteum (as over the subcutaneous surface of the tibia) or to cartilage (as in the ear) or tightly bound to deep fascia or joint capsules (as seen in the flexion creases of the palm of the hand and digits).

The 'flesh color' of the skin is due to the blood color reflected through the epidermis. The color varies according to the thickness of the epidermal layers through which the reflected light rays pass, the state of constriction or dilation of the subpapillary vessels, and the degree of oxygenation of the blood. Variations in color from individual to individual and from race to race also depend on pigmentation. Pigmentation of skin is due to the presence in the deepest layer of the epidermis of so-called 'clear cells' which have branched processes extending into more superficial layers. Under appropriate enzyme action these cells form **melanin** and distribute this pigment as granules throughout their cell bodies and processes. Tanning from exposure to sunlight is due to a physiologic increase in pigment formation. Certain areas of the body exhibit constantly deeper pigmentation: the areola of the mammary gland, the external genital regions, and the axilla.

In areas transitional to mucous membrane, the skin lacks hair, has a ruddy color, and has a moistness or oiliness of surface which is evidence of a gradient toward mucous membrane. Such skin is

typical of the lips, the nostrils, the external genitalia, and the anal region.

Observation of the skin, the dorsum of the hand as an example, clearly shows that **delicate creases** extend across the surface in various directions, intersecting one another and delineating irregular, diamond-shaped segments of the integument. Hairs typically emerge at points of intersection of these creases. Such creases represent flexion lines for the skin; they increase in frequency and depth as regions of free joint movement are approached. Certain of them are differentiated into definite **flexure lines.** These are lines of relative immobility and firm anchorage while the skin on either side of the line is folded passively toward it to accommodate the bending.

Clearly discernible on the pads of the fingers and toes, but extending over the palmar and plantar surfaces of the hand and foot, is a series of alternating **ridges** (cristae cutis) and **sulci** (sulci cutis). These friction ridges function to prevent slippage in the grasp and they result from the large size and specific arrangement of the dermal papillae under the epidermis. Ducts of sweat glands open along the summits of the ridges and hairs and sebaceous glands are absent on these surfaces. The ridges and sulci are, in detail, highly individual and their whorls and patterns form the basis for identification through fingerprints (dermatoglyphics).

Structure

The skin is composed of a surface layer, the epidermis, and an underlying thicker lamina, the dermis (fig. 2). **Epidermis** is epithelium of the stratified squamous variety especially characterized by cornified surface layers. It is typically only a fraction of 1 mm. in thickness and is composed of many layers of cells. The cells in the deeper layers are living and proliferate actively; the cells produced pass gradually to the surface, becoming cornified as they approach it, and ultimately are shed by rubbing on clothing and other surfaces. The epidermis is nonvascular but is penetrated by sensory nerve terminals. On its deep surface the epidermis sends prolongations into the dermis, and irregularities of the dermis also interlock with the epidermis. These interlocking finger-like projections are called, respectively, **epidermal pegs** and **dermal papillae.**

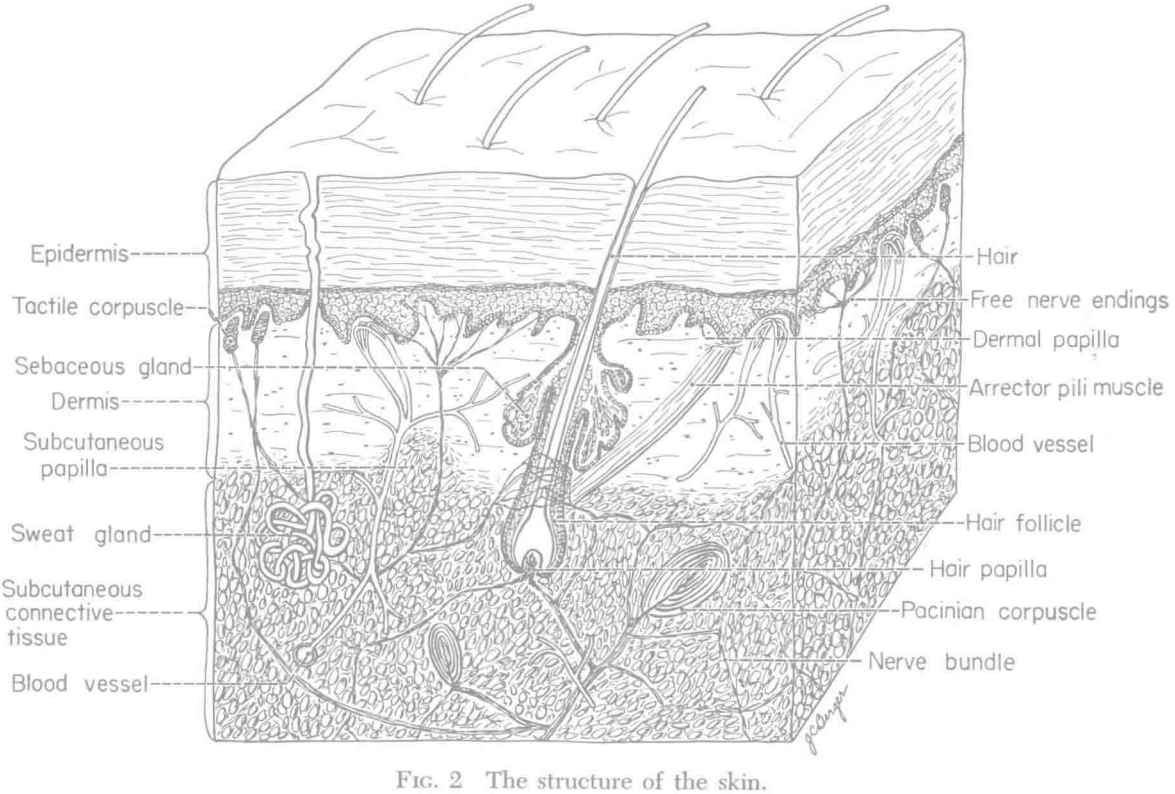

Fig. 2 The structure of the skin.

Dermis is the deeper interlacing feltwork of connective tissue fibers which constitutes the greater part of the total skin thickness. It has a finely textured papillary layer, and a deeper, thicker, coarsely textured reticular layer which in turn grades over into the subcutaneous connective tissue. The **papillary layer** gives rise to the dermal papillae which may number 100 per sq. mm., their concentration varying from region to region. Most papillae enclose capillary tufts, thus bringing the blood into close relation with the epidermis. Some of them accommodate tactile corpuscles, numerous in areas of acute tactile sensitivity, scanty where such sensitivity is poor.

The deeper layer of the dermis, the **reticular layer,** is a dense mass of interlacing white (collagenous) and elastic connective tissue fibers. This layer accounts for the toughness and strength of skin and, when commercially processed, is the substance of leather. Its fibers run in all directions but are mainly tangential to the surface. The predominant orientation of fiber bundles in relation to the surface differs in different regions of the body, and study of these fiber arrangements has resulted in the description of patterns designated as **Langer's lines.** Surgical incisions in the direction of these lines run parallel to the principal fiber bundles and have less tendency to gape. The dermis contains a small quantity of fat, numerous blood vessels and lymphatic channels, nerves, and sensory nerve endings. Hair follicles, sweat and sebaceous glands, and smooth muscles are present in the layer. The underside of the dermis is invaginated by tufts of subcutaneous connective tissue similar to but larger and more dispersed than the dermal papillae of the papillary layer. The spacing and size of these invaginations is reminiscent of pig-skin, and the pig-skin appearance of the under surface of the dermis is a guide to the proper plane of separation between it and the subcutaneous tissues. These invaginations serve for the entrance into the skin of blood vessels and nerves.

The **subcutaneous connective tissue** (fig. 2) is composed of loose-textured, white fibrous connective tissue with which fat and slender elastic fibers are intermingled. It is of the type of 'areolar' connective tissue, so named by the ancients because of its gas-containing spaces in decomposing bodies. In its relation to epidermis and dermis, it is correctly designated **hypodermis** (hypo = under). The subcutaneous fat varies in amount in different parts of the body but is absent in only a few regions, such as the eyelids, penis, scrotum, nipple, and areola. Where the fat layer is very prominent the hypodermis is designated **panniculus adiposus.** Fat is unequally distributed in the male and female and its local differences constitute a secondary sex characteristic. The fat is supported by strands and sheets of white fibrous connective tissue and in the scalp is firmly held in locules among the dense connective tissue fibers of the subcutaneous layer. The hypodermis varies in thickness but is generally much thicker than the overlying dermis. It contains blood and lymph vessels, the roots of hair follicles, the secretory portions of the sweat glands, cutaneous nerves, and sensory endings, especially Pacinian (pressure) corpuscles.

Subcutaneous bursae, single or multilocular spaces, exist in the subcutaneous tissue over joints that undergo marked bending, as at the elbow or knee. They contain a small amount of fluid and facilitate the movement of the skin.

The twitching of the skin of the horse and other four-footed animals gives evidence of **subcutaneous voluntary musculature.** Widely distributed in lower animal forms, this type of muscle is restricted in Man to the scalp, face, and neck where a subcutaneous sheet of muscle is differentiated into the **facial group of muscles.** It is concerned with the movements of facial expression. The palmaris brevis muscle in the hand is a vestigial, subcutaneous, voluntary muscle. Certain **involuntary,** or smooth, **muscles** also exist in the subcutaneous connective tissue. The dartos muscle of the scrotum and muscular tissue of the areola and nipple of the mammary gland are of this type. Subcutaneous muscle inserts into the overlying dermis.

Hair

Hair (fig. 2) is distributed widely over the body, being absent only over the palm of the hand, the sole of the foot, the dorsum of the distal segment of the digits, the red portion of the lips, the glans and prepuce of the penis, the inner surfaces of the labia majora, the labia minora, and the nipple. Hairs vary as to thickness and length. The very delicate **primary hair,** or **lanugo,** of the fetus and infant is succeeded by secondary hair or

down hair. **Down hair** is, in turn, partially replaced by terminal hair. **Terminal hair** is present over much of the body, notably in the scalp, eyebrows, eyelids, vestibule of nose, and at the entrance of the external acoustic meatus. It is also prominent after puberty over the pubes and in the axilla, and as the beard in men.

The portion of the hair projecting from the surface of the skin is the shaft; the portion under the skin is the root. The root is enclosed in a tubular **hair follicle** which extends deeply into the dermis. A connective tissue papilla projects into the bottom of the follicle and conducts blood vessels into it. Hairs tend to be placed in groups, three being a common grouping, and they are implanted in the dermis obliquely to the surface rather than vertically. Such oblique directions are regional, forming hair-tracts in which the hairs have a common direction, as whorls in the scalp. The shaft of the hair is circular in cross section, although curly hair has a more oval cross-sectional form. Hair color is due to pigment in the hair cells (melanin and a soluble red pigment) and to air in the shaft of the hair. The life of a hair is from 2 to 4 years on the head but only from 3 to 5 months in the eyelashes; they are intermittently shed and replaced.

Each hair is associated with one or more **sebaceous glands.** These lie in the obtuse angle between the slanting hair follicle and the skin surface and their ducts open into the neck of the hair follicle. The angle in which the sebaceous gland lies is crossed by a slender smooth muscle, the **arrector pili** (fig. 2). This muscle attaches to the connective tissue sheath of the follicle at about its midlength and inserts at its other end in the papillary layer of the dermis. Contraction of the muscle erects the hair, squeezes out the secretion of the sebaceous gland, and, as a spasmodic phenomenon, creates the familiar 'gooseflesh.'

Nails

The nail consists of an approximately rectangular horny plate on the dorsum of the terminal segment of the fingers and toes. The dense **nail plate** is composed of closely welded, horny scales or cornified epithelial cells. Its semitransparency allows the pink of the highly vascular **nail bed** to show through. The nail is partially surrounded by a fold of skin, the **nail wall,** and adheres to the subjacent nail bed, where the staunch vertical fibers ending in the periosteum of the distal phalanx give the firm attachment necessary for the prying and scratching functions of the nails. The distal edge of the nail is free; the proximal edge constitutes its root. The nail is formed from the epithelium of the proximal part of the nail bed, an area in which the epithelium is particularly thick and which extends about as far distally as the whitened lunula. Developing from this **nail matrix** the nail moves out over the longitudinally parallel dermal ridges of the nail bed, growth being approximately 1 mm. per week. Sensory nerve endings and blood vessels are abundant in the nail bed.

Skin Glands

The glands of the skin are the sebaceous, the sudoriferous, or sweat, glands, and the mammary glands. (The mammary glands are described with the pectoral region.)

Sebaceous Glands The sebaceous glands (fig. 2) are associated with the hairs and hair follicles. They exist throughout the body except in the skin of the palms and the soles and the dorsum of the distal segment of the digits. They are also found in certain areas where hair does not exist, such as the lips, the corner of the mouth and adjacent submucosa, the glans penis, the internal fold of the prepuce, the labia minora and clitoris, the areola and nipple. In these locations the duct opens directly on the surface. The glands vary from 0.2 to 2 mm. in diameter. The largest exist on the ala of the nose where the size relationships are such that we might say that the hairs are accessory to the glands. Typically the sebaceous glands lie in the dermis with one to six glands grouped in relation to a hair and with the single duct opening into the neck of the hair follicle. The secretory segment is flask-shaped, the form being designated as alveolar. Several convergent alveoli may combine in a grape-like mass. The polyhedral cells of the sebaceous gland are continuously destroyed and renewed in the production of its oily secretion, which is known as **sebum.** The **ciliary glands** of the eyelid are modified sebaceous glands.

Sweat Glands The sweat glands (fig. 2) have a wide distribution in the skin of the body, exceptions being the nail beds, the margins of the lips, the concha of the ear, the nipple, the glans penis, the prepuce, and the labia minora. These

glands consist of simple, coiled tubes and generally have a frequency of from 100 to 400 per sq. cm. The secretory portion is a tube folded by several unequal coils into a ball of from 0.3 to 0.4 mm. in diameter. The duct begins at an abrupt narrowing of the tube and is spirally twisted in its course through the epidermis. On the palms and soles and over the flexor surfaces of the digits the ducts open on the summits of the ridges (cristae cutis). Sweat is a clear fluid without cellular elements. Its importance in temperature regulation has been mentioned under the discussion of the function of the skin.

In the armpit and about the anus there are large, modified sweat glands. These are from 3 to 5 mm. in diameter and lie deeply in the subcutaneous layer. Their ducts may open onto the skin surface directly or be associated with a hair follicle. The secretion includes disintegration products of the gland cells. The odor commonly associated with these glands is not inherent in the secretion product but is due to bacterial contamination from the skin. Pigment granules secreted with the axillary sweat provide its slight coloration. These apocrine glands vary with sexual development, enlarging at puberty, and in the female show cyclic changes correlated with the menstrual cycle.

Blood and Lymphatic Vessels

The **arteries** of the skin are derived from vessels in the subcutaneous connective tissue layer which form a tangential network or plexus at the boundary between dermis and hypodermis. Branches from this network supply the fat, the sweat glands, and the deep parts of the hair follicles. Other branches in the dermis form a subpapillary network (fig. 2) from which is supplied twigs to the dermis and fine branches to the loops of the dermal papillae. The epidermis is avascular.

The **veins** show an arrangement similar to the arteries, with a subpapillary plexus, a plexus at the interface between the dermis and hypodermis, and other subsidiary plexuses. The subcutaneous veins pass deeply with the arteries.

The **lymphatics** of the skin begin in the dermal papillae as blind outgrowths or networks and in the papillary layer form a dense, flat meshwork of lymphatic capillaries. From here lymphatic vessels pass to a deeper network at the boundary of dermis and hypodermis. The lymphatic vessels run centrally in company with the cutaneous blood vessels.

Nerves

Cutaneous nerves are of two types. Included are **afferent somatic fibers** mediating general sensation, such as pain, touch, pressure, heat, and cold. There are also **efferent autonomic** (sympathetic) **fibers** supplying the smooth muscle of the blood vessels, the arrectores pilorum muscles, and the sweat and sebaceous glands. **Afferent or sensory endings** have several forms. Free, or naked, nerve endings extend between cells of the basal layer of the epidermis and terminate around and adjacent to the hair follicles. Encapsulated tactile corpuscles (fig. 2) lie in the dermal papillae and mediate the sensation of touch. Pacinian corpuscles (fig. 2) exist in the subcutaneous tissue and are plentiful along the sides of the digits. They appear to be pressure endings. Specific corpuscles for heat and cold have been described but there is not general agreement as to their identity.

THE MUSCLES

In the sensorimotor framework in which we observe man, movement is the second element. It is movement which characterizes animal life from the one-celled organism to the most complex. In the specialization of cells, contractility has become the particular property of muscle.

There are three varieties of muscle in the body (fig. 3): (1) **involuntary muscle,** known also as **smooth, nonstriated,** and **visceral muscle;** (2) **cardiac,** or heart, **muscle;** and (3) **skeletal muscle,** also distinguished as **striated** and **voluntary.** Involuntary, or smooth, muscle typically

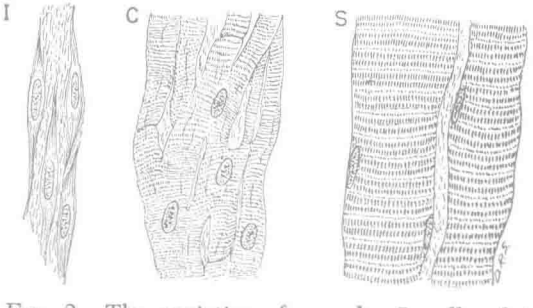

Fig. 3 The varieties of muscle; I—cells of involuntary muscle, C—cardiac muscle, S—skeletal muscle. (Redrawn after Patten.)

forms the muscular layers of the walls of our hollow viscera, and of blood vessels. Its cells are elongated and fusiform, and each cell contains a single nucleus. This muscle contracts relatively slowly and less powerfully than striated muscle but can maintain its contraction longer. Cardiac muscle is also involuntary muscle; it is not under the direct control of the will. It exhibits cross striations, however, and is recognized as a separate variety. Cardiac muscle is a syncytium; its fibers branch and anastomose and contraction waves spread through it. Physiologically we say that the heart action is myogenic; that is, its musculature has an automatic, rhythmic contraction which is modified but not initiated by nervous impulses. Skeletal muscle constitutes the largest category of muscle tissue in the body and is the principal subject of the following discussion.

Skeletal muscle constitutes some 40 per cent of the body mass in man. Muscles have various forms, some flat and sheet-like, some short and thick, others long and slender. In the abdominal wall certain sheet-like muscles extend from the bony framework of the back to the midline of the ventral abdominal surface and from the rib margin to the pelvis. The longest muscle of the body, the sartorius muscle of the thigh, is approximately 24 inches long. At the other extreme, within the bone housing the ear there lie the tensor tympani muscle of 2 cm. length and the even shorter stapedius muscle. The length of a muscle, exclusive of its associated tendon, is closely correlated with the distance through which it is required to contract, for muscle fibers have been shown to have the ability to shorten by 57 per cent of their relaxed length. It must be clearly understood that muscles produce movement by shortening; they pull, never push. The pull of a muscle is usually exerted across a joint and draws closer together the bones on either side of the joint, as in bending the elbow or flexing the knee (fig. 7).

Structure

The histological unit of skeletal muscle is a **muscle fiber.** A single muscle fiber is a long, cylindrical, multinucleated cell which varies from 10 to 40 micra in thickness. Its length is given differently by various authors; teased specimens of several inches in length have been isolated. Whole muscles are made up of bundles of these overlapping, interweaving, shorter, individual muscle fibers. The muscle fiber is covered by a thin membrane, the **sarcolemma,** and exhibits alternate light and dark cross striations. The end of the muscle fiber is bluntly rounded or tapered, and a delicate network of collagenous and elastic fibers, the **endomysium** (fig. 4), invests the entire

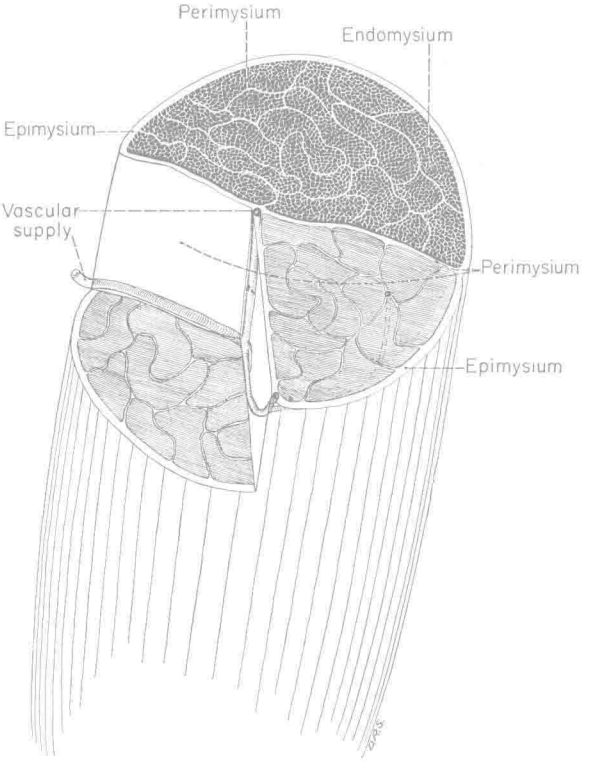

Fig. 4 The organization of a muscle from bundles of muscle fibers and the investing and enclosing connective tissue layers.

muscle fiber. Parallel muscle fibers are organized into bundles and the whole is surrounded by a similar but heavier connective tissue covering, the **perimysium.** A still coarser connective tissue investment, the **epimysium,** surrounds and infiltrates the muscle itself. These intimate connective tissue relations are further exhibited at the muscle-tendon junction (fig. 5) where the sarcolemma at the end of the muscle fiber is fused with the collagenous fibers of the tendon and the collagenous bundles of the endomysium and perimysium pass directly over into those of the tendon. It is through such intimate connective