Essentials of Human Anatomy

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Preface to the Sixth Edition

The continued popularity of this concise text has been the stimulus for its progressive refinement. In this effort illustrations have been added and many have been re-done or corrected to ensure pictorial accuracy. More precise and accurate descriptions of muscle actions, especially in their interactions in the living subject, reflect the many electromyographic studies of recent years. Occasional errors have been corrected.

Though the thoughtful student will recognize that in the general breadth of medicine and in the minute concerns of its specialties, almost no fact of anatomy will fail to have application, certain more obvious applications are not only interesting but instructive in demonstrating how the structure of the body relates to the practice of medicine. References to these clinical applications have been expanded in this edition, and they are placed in context with the anatomical descriptions to which they pertain. Note especially under nerve injuries, dislocations, and fractures.

Radiology is a branch of medicine in which anatomy and its alterations are related visually to the living subject. A tremendous recent advance in such visualization is the technique of computerized tomography. This technique provides a radiogram of a selected level or transverse section of the body so that the radiologist can concentrate his diagnostic efforts on a particular organ or body area unobscured by overlying or intervening structures. Examples are given in Figures 166 and 332. The analysis of such computerized tomograms (C.T. scans) depends directly on the radiologist's knowledge of transverse sections of the body (compare Figures 331 and 332). In view of this rewarding new technique radiologists are re-studying anatomy as seen in cross sections and students would do well to give greater attention to this very useful way of studying anatomical detail and anatomical relations. The author's interest in this manner of study has resulted in a considerably broader representation of cross sections of body levels in this text than in most others available.

The author wishes to acknowledge and thank colleagues and students who have brought to his attention ways in which the text might be improved. He also acknowledges gratefully the assistance of his medical artist, William L. Brudon, whose contributions go far beyond simple rendering of illustrative material. It is the author's hope that the sixth edition will advance the text still closer to students' needs not only for their immediate course requirements but also for reference in subsequent studies.

R.T.W.

Ann Arbor, Michigan
March 1977

Preface to First Edition

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 privelege 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—Joanne 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.

August 1957

R. T. W.

Foreword

To the student beginning his studies and observations in human anatomy: This text is designed as a teaching instrument dedicated to the development of an understanding of the human body. Details are present—and indeed the amount of detail in human anatomy is almost overwhelming—but the author has attempted at all times to simplify, to correlate, to explain, to integrate, and to describe in such a way that the student will understand the body as well as be informed about it. As a teaching instrument the book is not traditional but pragmatic. Its information is specific and accurate, related to the cadaver and checked by dissection. The illustrations are especially designed to illuminate the information in the text, and the student should refer to them constantly. It will be to the student's advantage if he colors the black and white illustrations as he goes along. This is advised in the belief that thoughtful and constructive coloration of the various tissues in any regional illustration adds to the learning process.

The text presents a logical analysis of regions, an analysis which follows the necessary sequence of dissection, but which gives emphasis to the central features of each region. The student will be aided if he recognizes this logical analysis and if he discerns the organization under which all description is made. Organization of material is an important aid to the learning of material, and the student should note and use organization at every step. Although the book is designed regionally, the student must also derive from his studies an adequate understanding of the systems of the body. To this end, the author has taken every opportunity to relate the specific regional entities to the systems of which they are parts. It will contribute to learning if the student will strive for both regional and systematic knowledge.

Anatomy is a laboratory subject. No one has ever been able to derive a satisfactory understanding of the human body by textbook reading alone. The subject is learned by the patient uncovering of structure after structure, cleaning each one to make a clear picture, and relating each to surrounding objects. A textbook should be used in the laboratory; information read should be correlated with information seen, and information seen should be used to check what is read.

Not all of the learning, however, can be done in the laboratory. There are important requirements for the review of material in the learning process; there are also important requirements for the introduction to that material.

There is a 'preview' phase of learning which is exceedingly useful for the learning of anatomy. This may consist of looking over in advance the topic to be dissected during the next laboratory period, examining the textbook organization, looking at its illustrations, seeing what these objects look like or in what terms they are described. This provides an overview of the material which will facilitate and enhance the laboratory examination. A lecture assists in the same preview sense, but pre-reading of the textbook serves as a useful introduction.

Review of the material, later, is another essential part of the learning process, and review within the textbook, within the atlas, and again on the body is important. Visualization should be stressed. One must see in the mind for both understanding and retention. Here the cadaver is paramount, but the atlas and textbook illustrations supplement the observations on the body. Learning is not done at once or in one step. It is produced by a number of contributory stages, and at every one of these this textbook will be useful.

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is the beginning of medical science

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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 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,** and **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, his behavior is that of a sentient, reacting organism. He feels, sees, and hears; he moves and responds to stimuli and adapts to the conditions of his environment.

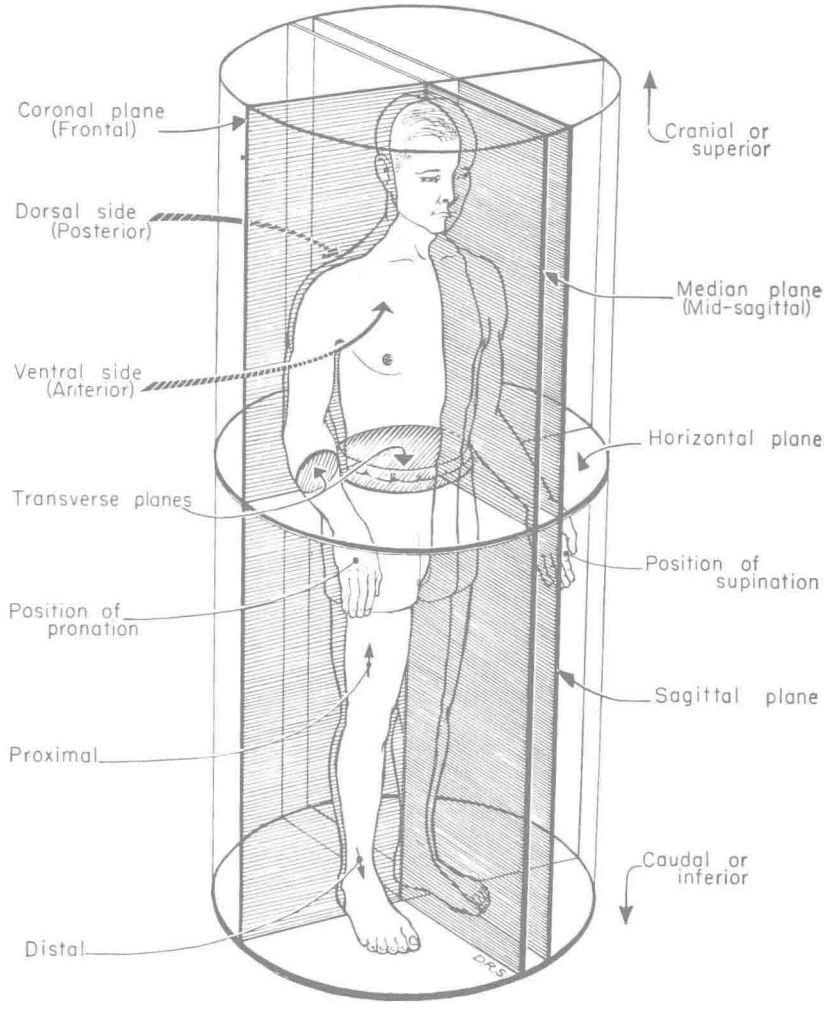

Fig. 1 The planes of the body and terms of direction and orientation.

He is thus a 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, digestive, 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

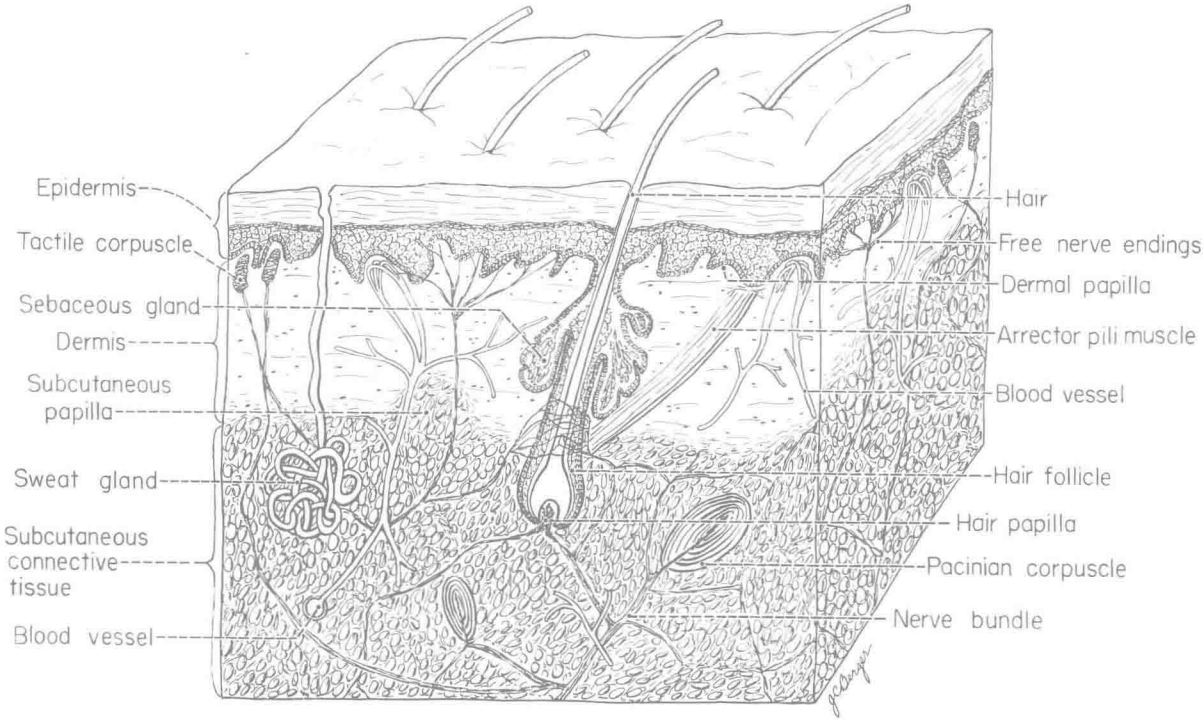

Fig. 2 The structure of the skin.

epidermis. These interlocking finger-like projections are called, respectively, **epidermal pegs** and **dermal papillae.**

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 space 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. These may be called glabrous surfaces. Hairs vary as to thickness and length. The very delicate **primary hair,** or **lanugo,** of the fetus and infant is