friction; and this is particularly marked when the weather is cold and dry. The electricity thus excited is negative. Sections of the shaft of the hairs show that they are oval, but their shape is very variable, straight hairs being nearly round, while curled hairs are quite flat. Another peculiarity of the hairs is that they are strongly hygrometric. They readily absorb moisture and become sensibly elongated, a property which has been made use of by physicists in the construction of delicate hygrometers.

Roots of the Hairs, and Hair-follicles.—The roots of the hairs are embedded in follicular openings in the skin, which differ in the different varieties only in the depth to which they penetrate the cutaneous structure. In the downy hairs, the roots pass only into the superficial layers of the true skin; but in the thicker hairs, the roots pass through the skin and penetrate the subcutaneous cellulo-adipose tissue.

The root of the hair is softer, rounder and a little larger than the shaft. It becomes enlarged into a rounded bulb at the bottom of the follicle, and rests upon a fungiform papilla, constricted at its base, to which the hair is closely attached.

The hair-follicles are tubular inversions of the structures that compose the corium, and their walls present three membranes. Their length is $\frac{1}{12}$ to $\frac{1}{4}$ of an inch (2·1 to 6·4 mm.). The membrane that forms the external coat of the follicles is composed of inelastic fibres, generally arranged longitudinally. It is provided with blood-vessels, a few nerves and some connective-tissue elements, but no elastic tissue. This is the thickest of the three membranes and is closely connected with the corium. Next to this, is a fibrous membrane composed of fusiform, nucleated fibres arranged transversely. These resemble non-striated muscular fibres. The internal membrane is structureless and corresponds to the amorphous layer of the true skin. The papilla at the bottom of the hair-sac varies in size with the size of the hairs and is connected with the fibrous layers of the walls of the follicle. It is composed of amorphous matter, with a few granules and nuclei, and it probably contains blood-vessels and nerves, although these are not very distinct.

Although the different membranes of the hair-follicles are sufficiently recognizable, it is evident that the hair-sac is nothing more than an inversion of the corium, with certain modifications in the character and arrangement of its anatomical elements. The fibrous membranes correspond to the deeper layers of the true skin, without the elastic elements; and they present a peculiar arrangement of its inelastic fibres, the external fibres being longitudinal and the internal fibres transverse. The structureless membrane corresponds to the upper layers of the true skin, which are composed chiefly of amorphous matter. The hair-papilla corresponds to the papillæ on the general surface of the corium.

The investment of the root of the hair presents two distinct layers called the external and internal root-sheaths. The external root-sheath is three or four times as thick as the inner membrane, and it corresponds exactly with the Malpighian layer of the epidermis. This sheath is continuous with the bulb of the hair. The internal root-sheath is a transparent

membrane, composed of flattened cells, generally without nuclei. This extends from the bottom of the hair-follicle and covers the lower two-thirds of the root.

Structure of the Hairs.—The different varieties of hairs present certain peculiarities in their anatomy, but all of them are composed of a fibrous structure forming the greater part of their substance, covered by a thin layer

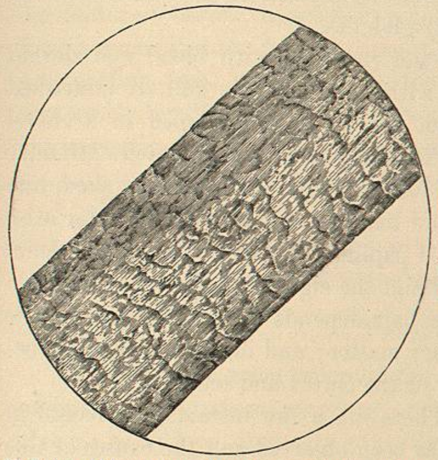

FIG. 109.—*Human hair from the head of a white child; magnified 370 diameters* (from a photograph taken at the United States Army Medical Museum).

This figure shows the imbricated arrangement of the epidermis of the hair.

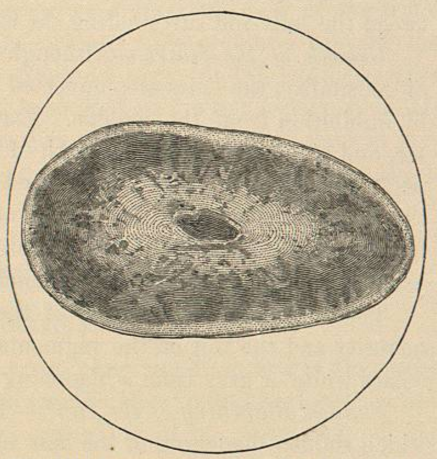

FIG. 110.—*Transverse section of a human hair from the beard of a white adult; magnified 370 diameters* (from a photograph taken at the United States Army Medical Museum).

of imbricated cells. In the short, stiff hairs, and in the long, white hairs, there is a distinct medullary substance; but this is wanting in the downy hairs and is indistinct in many of the long, dark hairs.

The fibrous substance of the hairs is composed of hard, elongated, longitudinal fibres, which can not be isolated without the aid of reagents. They may be separated, however, by maceration in warm sulphuric acid, when they present themselves in the form of dark, irregular, spindle-shaped plates. These contain pigmentary matter of various shades of color, occasional cavities filled with air, and a few nuclei. The pigment may be of any shade, between a light yellow and an intense black; and it is this substance that gives to the hair the great variety in color which is observed in different persons. In the lower part of the root the fibres are much shorter, and at the bulb they become transformed, as it were, into the soft, rounded cells found in this situation, covering the papilla.

The epidermis of the hair is very thin and is composed of flattened, quadrangular plates, overlying each other from below upward. These scales, or plates, are without nuclei, and they exist in a single layer over the shaft of the hair and the upper part of its root; but in the lower part of the root, the cells are thicker, softer, are frequently nucleated, and they exist in two layers.

The medulla is found in the short, stiff hairs, and it is often very distinct in the long, white hairs of the head. It occupies one-fourth to one-third of the diameter of the hair. The medulla can be traced, under favorable conditions, from just above the bulb to near the pointed extremity of the hair. It is composed of small, rounded, nucleated cells, which frequently contain dark granules of pigmentary matter. Mixed with these cells are air-globules; and frequently the cells are interrupted for a short distance and the space is filled with air. The medulla likewise contains a glutinous fluid between the cells and surrounding the air-globules.

Growth of the Hairs.—Although not provided with blood and devoid of sensibility, the hairs are connected with vascular parts and are nourished by imbibition from the papillæ. Each hair is first developed in a closed sac, and at about the sixth month of intraüterine life, its pointed extremity perforates the epidermis. These first-formed hairs are afterward shed, like the milk-teeth, being pushed out by new hairs from below, which latter arise from a second and a more deeply seated papilla. This shedding of the hairs usually takes place between the second and the eighth month after birth.

The difference in the color of the hair depends upon differences in the quantity and the tint of the pigmentary matter; and in old age the hair becomes white or gray from a blanching of the cortex and medulla.

Sudden Blanching of the Hair.—There are a few instances on record in which sudden blanching of the hair has been observed and the causes of this remarkable phenomenon fully investigated by competent observers; and it is almost unnecessary to say that a single, well authenticated case of this kind demonstrates the possibility of its occurrence and is important in connection with the reported instances which have not been subjected to proper investigation. One of these cases has been reported by Landois. In this instance the blanching of the hair occurred in a hospital in a single night, while the patient, who had an acute attack of delirium tremens, was under the daily observation of the visiting physician.

The microscopical examinations by Landois and others leave no doubt as to the cause of the white color of the hair in cases of sudden blanching; and the fact of the occurrence of this phenomenon can no longer be called in question. All are agreed that there is no diminution in the pigment, but that the greater part of the medulla becomes filled with air, small globules being also found in the cortical substance. The hair in these cases presents a marked contrast with hair that has gradually become gray from old age, when there is always a loss of pigment in the cortex and medulla. How the air finds its way into the hair in sudden blanching, it is difficult to understand; and the views that have been expressed on this subject by different authors are entirely theoretical.

The fact that the hair may become white or gray in the course of a few hours renders it probable that many of the cases reported upon unscientific authority actually occurred; and these have all been supposed to be connected with intense grief or terror. The terror was very marked in the case reported by Landois. In the great majority of recorded observations, the sudden blanching of the hair has been apparently connected with intense mental emotion; but this is all that can be said on the subject of causation, and the mechanism of the change is not understood.

Uses of the Hair.—The hairs serve an important purpose in the protection of the general surface and in guarding certain of the orifices of the body. The hair upon the head and the face protects from cold and shields the head from the rays of the sun during exposure in hot climates. Although the quantity of hair upon the general surface is small, as it is a very imperfect conductor of caloric, it serves in a degree to maintain the heat of the body. It also moderates the friction upon the surface. The eyebrows prevent the perspiration from running from the forehead upon the lids; the eyelashes protect the surface of the conjunctiva from dust and other foreign matters; the mustache protects the lungs from dust, which is very important in persons exposed to dust in long journeys or in their daily work; and the short, stiff hairs at the openings of the ears and nose protect these orifices. It is difficult to assign any special office to the hairs in some other situations, but their general uses are sufficiently evident.

PERSPIRATION.

In the fullest acceptation of the term, perspiration embraces the entire action of the skin as an excreting organ and includes the exhalation of carbon dioxide as well as of watery vapor and organic matters. The office of the skin as an eliminator is undoubtedly very important; but the quantity of excrementitious matters with the properties of which physiologists are well acquainted, such as carbon dioxide and urea, thrown off from the general surface, is small as compared with what is exhaled by the lungs and discharged by the kidneys. If the surface of the body be covered with an impermeable coating, death occurs in a very short time; but the phenomena which precede the fatal result are difficult to explain. All that can be said upon this point is that death takes place when the heat of the body has been reduced to about 70° Fahr. (21° C.), and that suppression of the action of the skin in this way is always followed by a depression of the animal temperature. Warm-blooded animals die usually when more than one-half of the general surface has been varnished. Rabbits die when one-fourth of the surface has been covered with an impermeable coating (Laschkewitsch). Valentin and Laschkewitsch found that when the temperature was kept at about the normal standard by artificial means, no morbid symptoms were developed. The cause of death in these experiments has never been satisfactorily explained; and it is not easy to understand why coating the surface should be followed by such a rapid diminution in the general temperature. The experimental facts, however, indicate that the skin probably possesses important uses with which physiologists are unacquainted. Urea and some other effete products have been detected in the perspiration, but it is probable that some volatile matters are eliminated by the general surface, which have thus far escaped observation.

Sudoriparous Glands.—With few exceptions, every portion of the skin is provided with sudoriparous glands. They are not found, however, in the skin covering the concave surface of the concha of the ear, the glans penis, the inner lamella of the prepuce, and unless the ceruminous glands be regarded as sudoriparous organs, in the external auditory meatus.

On examining the surface of the skin with a low magnifying power, especially on the palms of the hands and the soles of the feet, the orifices of the sudoriferous ducts may be seen in the middle of the papillary ridges, forming a regular line in the shallow groove between the two rows of papillæ. The tubes always open upon the surface obliquely. In a thin section of the skin, the ducts are seen passing through the different layers and terminating in rounded, convoluted coils in the subcutaneous structure. These little, rounded or ovoid bodies, which are the sudoriparous, or sweat-producing structures, may be seen attached to the under surface of the skin when it has been removed from the subjacent parts by maceration. A perspiratory gland consists, indeed, of a simple tube, presenting a coiled mass, the sudoriparous portion, beneath the skin, and a tube of greater or less length, in proportion to the thickness of the cutaneous layers, which is the excretory duct, or the sudoriferous portion.

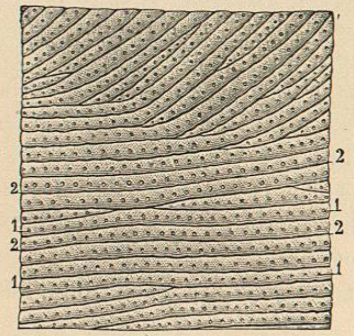

FIG. 111.—*Surface of the palm of the hand, a portion of the skin about one-half an inch* (12·7 *mm.*) *square; magnified* 4 *diameters* (Sappey).

1, 1, 1, 1, openings of the sudoriferous ducts; 2, 2, 2, 2, grooves between the papillæ of the skin.

The glandular coils are $\frac{1}{125}$ to $\frac{1}{25}$ of an inch (0·2 to 1 mm.) in diameter; the smallest coils being found beneath the skin of the penis, the scrotum, the eyelids, the nose and the convex surface of the concha of the ear, and the largest, on the areola of the nipple and the perineum. Very large glands are found mixed with smaller ones in the axilla, and these produce a peculiar secretion. The coiled portion of the tube is about $\frac{1}{340}$ of an inch (0·07 mm.) in diameter, and presents six to twelve turns. It consists of a sharply defined, strong, external membrane, which is very transparent, uniformly granular and sometimes indistinctly striated. The tube is of uniform diameter throughout the coil and terminates in a very slightly dilated, rounded, blind extremity. It is filled with epithelium in the form of finely granular matter, usually not segmented into cells, and is provided with small, oval nuclei. The glandular mass is surrounded by a plexus of capillary blood-vessels, which send a few small branches between the convolutions of the coil. Sometimes the coil is enclosed in a delicate fibrous envelope.

The excretory duct is simply a continuation of the glandular coil. Its course through the layers of the true skin is nearly straight. It then passes into the epidermis, between the papillæ of the corium, and presents, in this layer, a number of spiral turns. The spirals vary in number according to the thickness of the epidermis. Six to ten are found in the palms of the hands and twelve to fifteen in the soles of the feet (Sappey). As it emerges from the glandular coil, the excretory duct is somewhat narrower than the

tube in the secreting portion; but as it passes through the epidermis, it again becomes larger. It possesses the same external membrane as the glandular coil and is lined generally by two layers of cells.

In a section of the skin and the subcutaneous tissue, involving several of the sudoriparous glands with their ducts, it is seen that the glandular coils generally are situated at different planes beneath the skin, as is indicated in Fig. 112.

Sudoriparous glands in the axilla have been described which do not differ so much from the glands in other parts in their anatomy as in the character of their secretion. The coil in these glands is much larger than in other parts, measuring $\frac{1}{25}$ to $\frac{1}{12}$ of an inch (1 to 2 mm.); the walls of the tube are thicker, and they present an investment of fibrous tissue with an internal layer of longitudinal, non-striated muscular fibres; and finally, the tubes of the coil itself are lined with cells of epithelium. These glands are very abundant in the axilla, forming a continuous layer beneath the skin. Mixed with these, are a few glands of the ordinary variety.

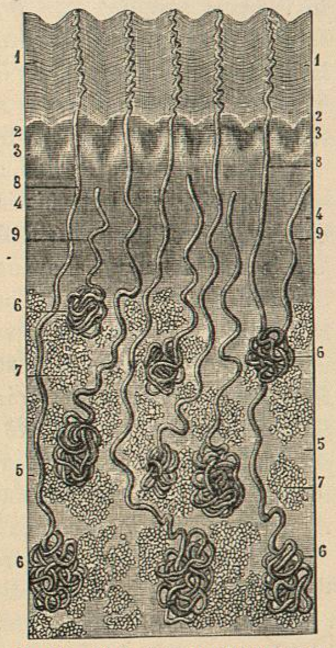

FIG. 112.—*Sudoriparous glands; magnified* 20 *diameters* (Sappey).

1, 1, epidermis; 2, 2, mucous layer; 3, 3, papillæ; 4, 4, derma; 5, 5, subcutaneous areolar tissue; 6, 6, 6, 6, sudoriparous glands; 7, 7, adipose vesicles; 8, 8, excretory ducts in the derma; 9, 9, excretory ducts divided.

Estimates have been made of the number of sudoriparous glands in the body and the probable extent of the exhalant surface of the skin, but they are to be taken as merely approximate. Krause found great differences in the number of perspiratory openings in different portions of the skin; but taking an average for the entire surface, it was estimated that the entire number of perspiratory glands is 2,381,248; and assuming that each coil when unravelled measures about $\frac{1}{16}$ of an inch (1·8 mm.), the entire length of the secreting tubes is about $2\frac{1}{3}$ miles ($3\frac{3}{4}$ kilometres). It must be remembered, however, that the length of the secreting coil only is given, and that the excretory ducts are not included.

Mechanism of the Secretion of Sweat.—The action of the skin as a glandular organ is continuous and not intermittent; but under ordinary conditions, the sweat is exhaled from the general surface in the form of vapor. With regard to the mechanism of its separation from the blood, nothing is to be said in addition to the general remarks upon the subject of secretion; and it is probable that the epithelium of the secreting coils is the active agent in the selection of the peculiar matters which enter into its composition. There are no examples of the separation by glandular organs of vapor from the blood, and the perspiration is secreted as a liquid, which becomes vaporous as it is discharged upon the surface.

The influence of the nervous system upon the secretion of sweat is important. It is well known, for example, that an abundant production of perspiration is frequently the result of mental emotions. Bernard has shown that the nervous influence may be exerted through the sympathetic system. He divided the sympathetic in the neck of a horse, producing as a consequence an elevation in temperature and an increase in the arterial pressure in the part supplied with branches of the nerve. He found, also, that the skin of the part became covered with a copious perspiration. Upon stimulating the divided extremity of the nerve, the secretion of sweat was arrested. The local secretion of sweat after division of the sympathetic in the neck of the horse was first observed by Dupuy, in 1816.

The stimulation as well as the division of certain nerves induces local secretion of sweat, but this is nearly always associated with dilatation of the blood-vessels of the part; still, sweat is frequently secreted when the surface is pale and bloodless, showing that dilatation of the blood-vessels is not an indispensable condition. The action of the so-called vaso-dilator nerves will be treated of in connection with the physiology of the nervous system. In experiments upon the cat, excito-secretory fibres have been found to exist in the cerebro-spinal nerves going to the anterior extremities. The fibres for the posterior extremities are in the sheath of the sciatic nerve. In all instances the action of these nerves is direct and not reflex. Experiments upon the cat have been very satisfactory, as this animal sweats only on the soles of the feet, and the secretion can be readily observed.

The so-called sweat-centres are in the lower part of the dorsal region of the spinal cord, for the posterior extremities, and in the lower part of the cervical region of the cord, for the anterior extremities. According to Adamkiewicz, both of these centres are subordinate to the principal sweat-centre, which is situated in the medulla oblongata. Ott has collected a number of cases of disease of the cord in the human subject, which go far to confirm the results of experiments on the inferior animals, with regard to the action of excito-secretory nerves and sweat-centres.

When the skin is in a normal condition, after exercise or whenever there is a tendency to elevation of the animal temperature, there is a determination of blood to the surface, accompanied with an increase in the secretion of sweat. This is the case when the body is exposed to a high temperature; and it is by an increase in the transpiration from the surface that the animal heat is maintained at the normal standard.

Quantity of Cutaneous Exhalation.—The quantity of cutaneous exhalation is subject to great variations, depending upon conditions of temperature and moisture, exercise, the quantity and character of the ingesta, etc. Most of these variations relate to the action of the skin in regulating the temperature of the body; and it is probable that the elimination of excrementitious matters by the skin is not subject, under normal conditions, to the same modifications, although positive experiments upon this point are wanting. When there is such a wide range of variation in different individuals and in the same person under different conditions of season, climate etc., it is possible only to give approximate estimates of the quantity of sweat secreted

and exhaled in the twenty-four hours. Seguin and Lavoisier (1790) estimated the daily quantity of cutaneous transpiration at one pound and fourteen ounces (850 grammes), and the results of their observations have been fully confirmed by recent investigations. It may be assumed that the average quantity is nearly two pounds, or about 900 grammes.

Under violent and prolonged exercise, the loss of weight by exhalation from the skin and lungs may become very considerable. It is stated by Maclaren, the author of a work on training, that in one hour's energetic fencing, the loss by perspiration and respiration, taking the average of six consecutive days, was forty ounces (1,130 grammes), with a range of variation of eight ounces (227 grammes).

When the body is exposed to a high temperature, the exhalation from the surface is largely increased; and it is by this rapid evaporation that persons have been able to endure for several minutes a dry heat considerably exceeding that of boiling water. Southwood Smith made a series of observations with regard to this point upon workmen employed about the furnaces of gas-works and exposed to intense heat; and he found that in an hour, the loss of weight was two to four pounds (907 to 1,814 grammes), this being chiefly by exhalation of watery vapor from the skin. In such instances the loss of water by transpiration is compensated by the ingestion of large quantities of liquid.

Properties and Composition of the Sweat.—An analysis of the sweat was made by Favre, in 1853. After taking every precaution to obtain the secretion in a perfectly pure state, he collected a very large quantity, nearly thirty pints (14 litres), the result of six transpirations from one person, which he assumed to represent about the average in composition. The liquid was perfectly limpid, colorless, and of a feeble but characteristic odor. Almost all observers have found the reaction of the sweat to be acid; but it readily becomes alkaline on being subjected to evaporation, showing that it contains some of the volatile acids. Favre found that the fluid collected during the first half-hour of the observation was acid; during the second half-hour it was neutral or feebly alkaline; and during the third half-hour, it was constantly alkaline. The specific gravity of the sweat is 1003 to 1004. The following is the composition of the fluid collected by Favre:

COMPOSITION OF THE SWEAT.

Water	995·573
Urea	0·043
Fatty matters	0·014
Alkaline lactates	0·317
Alkaline sudorates	1·562
Sodium chloride, (soluble in water)	2·230
Potassium chloride, (soluble in water)	0·244
Alkaline sulphates, (soluble in water)	0·012
Alkaline phosphates, (soluble in water)	a trace
Alkaline albuminates, (soluble in water)	0·005
Alkaline earthy phosphates (soluble in acidulated water)	a trace
Epidermic *débris* (insoluble)	a trace
	1,000·000