branes, are the simplest and least active of all known glands. They consist solely in the fatty degeneration of ordinary epidermic epithelial cells.

Coil-Glands.[1] *Development.*—By far the largest mass of glands which the corium contains, is found in the shape of globular or oval coils in the subcutaneous tissue or embedded in the deepest layer of the corium proper. They make their appearance in the fifth fœtal month, first on the palms of the hands and soles of the feet, in the form of epithelial processes standing very close together and growing in a conical shape into the corium. Their situation relative to the ridges of the first-formed papillary layer is a very definite one. We have already seen that at first elevated ridges of connective tissue are separated from each other at regular intervals by epithelial processes, and that the papillæ are developed upon the tops of the ridges, the epithelium here also penetrating downwards. Between two rows of papillæ which have thus been separated from each other, the epidermis now penetrates still further at tolerably regular intervals, and in the course of the sixth month forms long thin cones which traverse the entire thickness of the corium, and assume a slightly bulbous shape at their lower extremities. Just above this blind end there is suddenly developed in the seventh month, the first trace of a lumen which extends rapidly towards the epidermis, after reaching which an opening is formed (from within outwards), *the sweat-pore.* At the same rate at which this lumen is developed, the subsequent cuticula also makes its appearances. At this time the lower end of the gland has usually already assumed a hooked shape, and the coil is now developed by an irregular rolling-up, the gland meanwhile steadily increasing in size. In contrast to the glands of the hair-follicles, the development of the coil-glands has, near the end of fœtal life, reached a point beyond which it does not afterwards go.

Large and Small Coil-Glands.—Another step in the development of the coil-glands, which, however, still goes on after birth, is their continued growth in certain parts of the body to larger varieties which present important structural differences from the ordinary small glands. These large ones occur in the axillæ and folds of the groins, around the anus and in the areola of the nipples, and in the external auditory canal. In the axilla, large and small glands are irregularly scattered through the layers of the skin, the large ones being confined to the hairy portions. In the groin, the small glands are seated superficially, the large ones deep down in the subcutaneous cellular tissue.

The circumanal glands form a single row, $1\frac{1}{4}$ to $1\frac{1}{2}$ cm. from the anus (Gay). On the mammary areola also, which contains only large glands, they form a closed circle near its outer edge. The coil-glands of the auditory canal, which secrete the cerumen, lie in the cartilaginous portion as an almost continuous layer, mainly on the upper and under surfaces. Finally, the glands of Moll in the eyelids must also be classified with these varieties of coil-glands. They are really only broad convoluted tubes without coils, lined with large cylindrical epithelial cells, and provided with strong muscles, which empty with diminished calibre into the follicles of the ciliæ. Waldeyer has demonstrated transitional forms between these "modified coil-glands" and the ordinary variety, in the caruncula lachrymalis.

Histology of the Small Glands.—Histologically, the smaller glands present tolerably uniform appearances. The coil bears a simple cubical epithelium which is cloudy in its external portion, where it shows a striation radiating towards the centre of the canal (Ranvier). Internally it is provided with a clear border, which, according to the same

[1] The author substitutes the name "Knäueldrüse" for the familiar term "Schweissdrüse" (sweat-gland). Where the former, which I have translated "coil-gland," is used, the sweat-gland is always meant. (Translator's note.)

observer, may be thrown off, and in fact viscid, clear protoplasmic débris is found in the secretion of the glands. Upon these secreting cells are seated, externally, muscular fibres which run parallel with or spirally around the canal. I find (agreeing with Sappey, Heynold, Hörschelmann, and Ranvier, but in opposition to Leydig and W. Krause) that the muscular fibres are in direct contact with the epithelium, and that they both together are surrounded by a distinct membrane of connective tissue, a so-called membrana propria. Fig. 14, taken from the coil-glands of the palm of the hand, shows the muscular fibres in cross-section passing in between the epithelial cells, and in an oblique section running parallel to the canal at certain distances from one another. This very figure also shows, however, that the canal of the coil, just before it passes into the excretory duct, sometimes bears not a cylindrical, but a cubical epithelium, arranged in layers. The cells are, moreover, not completely cemented together, the cavity of the canal penetrating between them in many places, as far as the membrana propria. According to Ranvier, the muscular cells are formed from the ectoderm, an inner layer of epithelial cells being transformed into the secreting glandular cells, an outer into muscle cells.

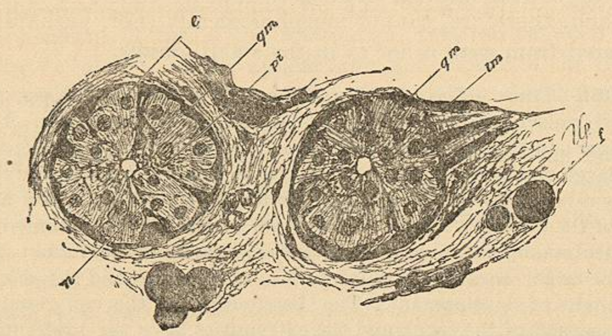

FIG. 14.—Cross-section through the point at which the coil passes into the duct of a coil-gland. *q m*, muscle in cross-section; *l m*, muscle in longitudinal section; *e*, epithelium of the coil; *n*, nerves of the coil; *f*, fat-cells: *p i*, pigment.

The *duct* is composed of an ordinary cubical pavement epithelium, arranged in two rows, the inner of which bears a cuticle which was discovered by Heynold. Outside of this epithelium is a thick layer of connective tissue, which borders on it by a membrana propria and has no muscular fibres. The epithelium of the coil has a clear border, which is not always blackened by osmium, whereas the epithelium lining the duct has a border which is always stained by it, probably in consequence of its imbibition of the excreted fats and fatty acids.

The duct runs more or less spirally through the corium, and loses, at its junction with the epithelium of the surface, its connective-tissue sheath externally and its cuticular border internally, so that for a short distance in the prickle-layer the strongly convoluted lumen is surrounded only by ordinary prickle-cells. But immediately beyond this part of the duct, well-developed granular cells draw near its lumen, much earlier than in other portions of the prickle-layer; then basal, next superbasal horny cells, etc. (see Fig. 3), so that one may say that all the layers of the epidermis sink down, in the shape of a funnel, into those next below them, to form the wall of the canal. At the point at which the wall of the canal is composed of basal horny cells, it shows a decided slit-like contraction.

Sweat-pore.—It follows from the relation of the duct to the epidermis that it really terminates in the basal prickle-layer, and that the corkscrew-like spiral canal in the epidermis which seems to be its direct continuation, does not belong to it alone, but also to the open juice-spaces of the epidermis which surround it. It is, therefore, proper to sharply distinguish this portion of the canal under the old name, *sweat-pore*, from the rest of the duct of the coil-gland, in view of the fact that the fluids which pass upwards in them are not identical. The sweat makes its appearance externally at the sweat-pore, but we have no right to maintain that it comes from the duct (at least entirely) and eventually from the coil. This is also the reason why we have wholly ignored the misleading name, *sweat-glands*, and have reintroduced the older and better term, *coil-glands* (*Meissner*).

Histology of the Large Coil-Glands.—The large glands are distinguished from the small ones, aside from their often great thickness and length, mainly by the fact that they present irregular dilatations and constrictions. As a rule, the widened portions with a large lumen are lined with one layer of cylindrical epithelium and also have bundles of muscular fibres externally, even if they already constitute a part of the duct, as is often the case in the axillary glands; the narrower parts of the duct between them are again lined by several layers of pavement epithelium without muscles. The duct and the coil in the large coil-gland, therefore, cannot morphologically (nor, perhaps, physiologically) be so simply separated from each other as in the small glands.

Secretion of the Coil-Glands.—The secretion of the coils is composed in part of albuminoid, viscid cellular débris with nuclei, containing drops of fat and pigment granules. In the small glands it is almost always clear and transparent, except in old age, when much pigment is also found in it. The secretion of the large glands is often also clear, but is usually darker, containing fat and pigment. A great many mixtures intermediate between these two extremes are also met with. To regard the secretion of the coils as a simple watery fluid is entirely unwarranted, and we must admit, from an anatomical standpoint, that the different coil-glands of the human skin, from the smallest on the trunk to the larger ones on the palms and soles, those around the anus, etc., appear like links in a complete chain of development. The distribution of the coil-glands over the surface shows that the flexor aspects of the trunk and the extremities have the preference over the extensor, and that the larger collections of coil-glands are confined to the surfaces of contact of the joints, and the mammary and anal regions. In man, as in the animal, the higher development of this glandular apparatus is associated with the surfaces of contact in the broadest sense which most require lubrication; we also recognize the periodical presence of fat in all the coil-glands, and its constant presence in the larger ones, and, finally, during fœtal life, when the body has most need of lubrication, we find the same apparatus at the highest point of its development and activity. On the other hand, no one would seriously speak of the sweating of the fœtus.

Function of the Coil-Glanas.—We must return to the view advocated in 1856 by Meissner, that the whole apparatus of the coil-glands is destined *solely for the oiling of the body*. That it is, on the whole, better adapted to this purpose than the glands of the hair-follicles is clear from the standpoint of anatomy: according to the older Krause, there are more than two million (according to recent estimates still more) coil-glands tolerably uniformly distributed over the body (with a preference for the surfaces of contact). On the other hand (according to W. Krause), there are only about one hundred thousand hair-follicles with sebaceous glands, of which about eighty thousand are crowded together upon the hairy scalp alone. Finally, no sebaceous glands are found on the palms of the hands and soles of the feet, which certainly require lubrication and are never without it. The secretion of the sebaceous glands, the greater part of which is still inclosed in cells, is deposited directly upon the cornified surface of the funnel of the hair-follicle, whereas the secretion of the coil-glands is placed at the disposal of the lower layers of the epidermis. There is much more warrant for ascribing a lubrication of the surface to the

"sebaceous glands of the mucous orifices" than for the view generally held as to the function of the glands of the hair-follicles. These acinous glands would then also physiologically occupy a place midway between the glands of the hair-follicles and the coil-glands.

Function of the Sweat-Pores.—It would hardly seem possible, therefore, that the sweat has hitherto been believed to come from the coil-glands, if it were not for the fact that sweat-pores are direct continuations of these glands. But now that we know that the intercellular passages of the epidermic cells open into the sweat-pores and furnish a means of escape externally for the tissue-fluid of the epidermis, this circumstance has lost all its value as a proof. Just as we cannot ascribe the formation of all the ingredients of the urine to the Malphigian bodies alone, just so surely is the sweat only in small part the production of the coil-glands. *The sweat-pores are the conditio sine qua non of sweating.* The dog does not sweat because he has no sweat-pores, although he has coil-glands which open into the hair-follicles.

Coil-Glands and Subcutaneous Cushion of Fat.—While we must, therefore, ascribe the work of lubricating the epidermis only in very small part to the sebaceous glands, and by far the largest to the coil-glands, we also assign to the latter the formation of the subcutaneous cushion of fat. The anatomical relation between these two becomes evident even during fœtal life. They appear simultaneously, in the fifth month, first on the palms and soles, and progress at the same rate in their development. At birth the panniculus is so highly developed that (allowance being made for extent of surface and bodily weight) it is about five times as thick as the subcutaneous fat of a stout adult. The fat is comparatively firm, of a grayish-white color, crumbles readily, and when cut into allows no oil drops to escape (Langer). At the same period the coil-glands occupy a relatively large part of the skin (see Fig. 1). Their product, which we find in the vernix caseosa mixed with epidermis, is firmer and contains more stearin than in the adult. After birth, the coil-glands and clusters of fat begin to concentrate at certain points, and we there find the connection between the two reproduced, collections of fat being found even in the thinnest individuals at the points provided with large coil-glands, and a typical cushion of fat is always present in those parts which have the most coil-glands (palms, soles, hairy scalp). The fatty secretion of the coil-glands and the fat of the subcutaneous tissue both change at the same time their chemical constitution, appearance, and consistence. Both kinds of fat become softer and more oily, and the stearin diminishes as compared with the palmitin and the greatly preponderating oleïn.

Topographically, however, the relation between the two structures can be followed still further. The majority of the coil-glands penetrate into the subcutaneous stratum, or they remain in the larger fissures of the corium. In the former case, their form becomes round and regular, and they become gradually closely surrounded by fat-tissue; the coils which remain in the corium assume flatter and more angular shapes, are not surrounded by fat-tissue, *but the latter regularly advances towards them in columns.* The prolongations of the subcutaneous fat into the corium always run towards single coil-glands or towards several united in a group. Those coil-glands which seem to have no connection with the fat-tissue, as is often the case in lean individuals, always present scattered between their loops at least a few heaps of fat-cells. A small but a very typical portion of these cutaneous columns of fat which pass upwards at the site of the hair-follicles (see Fig. 1) has recently been described by J. Collis Warren under the name of columnæ adiposæ, but their connection with the coil-glands has entirely escaped this author.

Fat-tissue.—With Flemming, we distinguish in the subcutaneous fat of the adult, which is developed by a process of partial atrophy from that of the new-born child, three kinds of collections of fat, which may be described according to their relations to the vascular system of the skin. The "true fat-lobules" are supplied by large blood-vessels of their own, which break up in them to form a close capillary network surrounding the individual fat-cells. Flemming applies the term "fat-columns" to those masses which lie along the larger vascular branches of the subcutaneous tissue and are but scantily supplied with capillaries. "Fat-islands," finally, are entirely isolated small groups of fat-cells without blood-vessels of their own; they occur but seldom in the human subject.

Histology of the Fat-tissue.—The fat-cells are developed from ordinary, flat branching connective-tissue cells, some of which take up fat in fine drops. While these drops increase in number and become confluent, the protoplasm of the cells also grows, and the cells assume a rounded shape. These young fat-cells are now changed, by the continually enlarging drops of fat, into large globular bodies; the protoplasm containing the nucleus is pushed to the periphery, and thus gradually assumes the appearance of a membrane. A real membrane is not an essential attribute of the fat-cell; only in old fat-cells does the protoplasm sometimes become condensed into a membrane-like covering.

The globular drop of fat of the mature fat-cell presents certain peculiarities which render it probable that it consists of a mixture of fat with other products of the disintegration of protoplasm. Thus, when stained with picro-carmin, it often assumes at certain points a pale red color, and also presents more deeply stained red granules at such places. Here are also most frequently found those fatty crystals which probably are formed during the cooling of the skin after death. The drop of fat frequently contains vacuoles with thin-fluid contents.

The mature fat-cell may persist in this form for any length of time without undergoing any visible alteration. But a real permanence of its component parts is not probable, particularly as the fat-tissue is extraordinarily rich in blood-vessels. It is therefore probable that a constant transformation and reproduction of the fat takes place. If the former predominate over the latter, the various forms of atrophy result.

In the human subject, "serous atrophy" is most frequently met with, characterized by the disappearance of the drop of fat alone, the cavity thus left in the interior of the cell being filled with a serous fluid, and the fat-cell thus at first retains its original size. If the atrophy progress, the fat-cell diminishes in bulk and finally becomes reduced to a mass of protoplasm, lying in the interior original cell near the globule of fat, and surrounding the nucleus. During these processes, the connective-tissue cells between the fat-cells become filled with very minute drops of fat, and it is possible (?) that free finely-divided fat is also deposited between them. A constant phenomenon during the course of the atrophy is the appearance in the fat-cells, and adjacent connective-tissue cells, of "*secondary drops,*" which grow in the fat-cells as the primary drop disappears, usually differing from it in consistence and color. They are therefore certainly not produced by its disintegration, but are the result of a secondary new-formation. Much more rarely are the two other varieties of atrophy met with: "*simple atrophy,*" in which the protoplasm diminishes concentrically with the fat-globule; and "*atrophy with growth,*" in which multiplication of nuclei and cell-growth coincide with the atrophic process. Instead of the cell being reduced to the status of the connective-tissue cell, it may either entirely disappear (as in the skin of old people) or groups of daughter-cells with fibrillary

connective tissue may be formed. The disappearance of the fat is ultimately followed by atrophy of the surrounding capillary network.

Besides the blood-vessels and very scanty fibrillary connective tissue, only ordinary connective-tissue cells are found between the fat-cells within the large lobules, in inverse proportion to the quantity of fat-cells already present, because they themselves become fat-cells if the layer of fat increase in thickness. The fat-tissue, like the larger and firmer connective-tissue columns of the subcutaneous tissue, contains a large number of holes and juice-spaces, but is entirely destitute of lymph-channels with independent walls.

We have considered the fat-tissue in connection with the coil-glands, for the reason that it is only a dependent of the latter, a portion of the corium which, owing to the activity of these glands, has undergone a peculiar transformation. Despite its early appearance in fœtal life, the fat-tissue does not belong to the typical constituents of the skin, since skin in most parts of the body may be well developed, yet without a cushion of fat, under physiological conditions.

The Coil-Glands produce the Fat-Cushion.—We have already seen that the products of the coil-glands consist of fat and other things (fat-formers, fatty acids, soaps). These are all steadily pushed onwards towards the epidermis by the action of the smooth muscular fibres of the coil-glands. As is well known, the muscles alternate quite regularly with the epithelium, so that the entire secreting epithelium comes directly in contact by half its surface with the lymph-spaces around the coils which extend into the connective-tissue sheath of the latter. The muscles are, therefore, really destined to further an exchange and reflux between the secreting epithelial cells and the lymph which flows around them. In this they are aided by the above-mentioned arrangement of the oblique muscles of the skin, which exert an expulsive influence only upon the contents of the duct, and a retarding one upon the glandular products in the interior of the gland, as upon its circulation. This arrangement seems a highly practical one, because heat, which relaxes the vessels, calls forth, by causing a hyperæmia of the whole papillary layer, a profuse watery alkaline sweat, and at the same time, by relaxing the oblique muscles of the skin, opens wide the way for the passage of the fatty products of the coil-glands to the surface, thus counteracting the unpleasant effects of the alkaline tissue-fluids upon the epidermis by means of the acid and fatty products of the glands. On the other hand, every increase in the tension of the framework of the skin by its oblique muscles, must lead to a retention of the secretion of the coils, and thus facilitate the passage of the products from the naked coils into the surrounding lymph-spaces.

We must at any rate imagine the lymph which streams away from the coils to be loaded with fatty products. This lymph has, however, no lymphatic vessels of its own, but is taken up in part by the few lymphatic vessels coming from the corium, but mainly by the cutaneous venous trunks. The lymph, while being thus taken up, must, of course, be filtered in such a way that its fatty elements are left behind in the subcutaneous tissue and accumulate there. By this process, I explain the storing-up of fat by the cells of the subcutaneous tissue and their conversion into fat-cells.

The first collection of fatty lymph, in the embryo as in the adult, exercises an irritating influence and attracts capillaries from the nearest blood-vessels, whose venous branches take up all the lymph except its fatty portions, the arterial furnishing the oxygen used in the elaboration of the fat. The lymph-corpuscles which, as usual, become separated from the current of blood, collect around the fat-lobules. The fact of their accumulation when fat-tissue is first formed, cannot, however, be utilized to explain the origin of the fat-tissue, in view of the absence of any transitional forms between wandering and fat-cells. In places where the budding of the sanguineous capillaries is less abundant, the fat which has been filtered out at first remains behind on all the larger venous branches and their attendant lymphatic vessels, around which the "fat-columns" are then formed, which so often accompany these vascular tracts. Between the coil-glands and the fat-layer proper, fat-islands, fat-columns, and single clusters of fat mark the course of the fat-laden lymph. If the latter become exhausted, atrophy of the fat-lobules (Flemming) begins, *externally* of course, and thence progresses concentrically inwards, towards the absorbing blood-vessels. In this way the association of coil-glands with fat-tissue is fully explained.

It still remains to cast a brief glance at the vascular and nervous trunks which grow from within outwards into the corium.

Blood-Vessels.—Tomsa has shown that both the size and form of the individual vascular trunks which supply the different portions of the corium with blood, are subject to great variations. On the extensor surfaces of the extremities and trunk, the territories supplied by single arteries are much larger than on the flexor surfaces; the vascular trunks are most numerous in the palms of the hands, the soles of the feet, and the face. Their form is dependent upon the local cleavage. While in parts of the skin where the cleavage is not uniform, the vascular trunks are very tortuous, and run almost vertically upwards, and the area of distribution of their very crooked branches is of a rounded shape, in parts with uniform cleavage they are crowded together, by the bundles of fibres tightly stretched in one direction, into flat *circulatory planes.* According to Tomsa, the best way to find such a circulatory plane is to make *oblique sections* through the corium, *parallel to the hair-follicles,* and therefore at right angles to the direction of cleavage. Fig. 1, however, shows that the horizontal ramifications may be completely exposed by a section made *vertically* and at the same time parallel to the direction of cleavage and of the hairs. Between the horizontal, oblique, or vertical planes of circulation there are, of course, some parts of the corium which are relatively poor in vessels.

The horizontal distribution of the vessels which in part run obliquely, in part vertically upwards occurs principally in two regions of the skin—at the border between the corium and the subcutaneous tissue, and at that between the former and the papillary layer.

Papillary Circulation.—Underneath the papillary layer we find a wide-meshed arterial network, composed of narrow tubes, the longitudinal axes of which run in the direction of the grooves of the epidermis. This network sends upward a tortuous arterial capillary to each vascular papilla, which bends over in the shape of a loop to form the still more tortuous venous capillary. All the venous capillaries of the papillary layer again unite to form a close, narrow-meshed venous capillary network at the same level as that in which the arterial lies, and from this larger veins arise, which run through the corium in the same direction as the arteries.

All the vessels of this papillary vascular system and the larger branches in the corium connected with them consist only of an endothelial tube, which is joined, near the subcutaneous tissue, by a very insignificant media and adventitia. They are therefore mainly of a capillary nature. The arteries are narrow, the veins comparatively very wide.

In three places, the papillary vessels present dilatations in the deeper portions of the corium. In the first place, they furnish the flat vascular networks of the hair-follicles which lie between their middle and external sheaths and the basket-like plexuses

of the sebaceous glands. The oblique muscles of the skin also receive their vascular supply from this source, and a third branch-plexus accompanies the excretory ducts of the coil-glands downwards. Minor deviations are found in some parts of the skin. Thus in very short papillæ the ascending papillary loops are often entirely wanting, giving place to irregular plexuses; on the external ear, the alæ nasi, and around the lips, the whole subpapillary vascular net is transformed into a series of large lacunæ, into which the venous capillaries empty from above, and the veins from below (Tomsa).

Circulation of the Coil-Glands and Fat-Tissue.—Below the papillary system is a horizontal area poorly supplied with vessels, which is the broader the thicker the corium; the fibrous bundles of the corium themselves have no capillaries. An exceedingly abundant distribution of vessels is found at the border of the subcutaneous tissue. In the first place, independent branches are here given off by the small arterial trunks, to furnish a capillary loop for each hair-papilla. All the coils of the coil-glands also receive capillary plexuses from this source. If the coils lie close together, a common plexus is formed by their vessels. Finally, the vessels which form dense networks of capillaries inside the fat-lobules take their origin from this point. The vessels of the individual lobules also unite, when the fat is abundant, to form horizontal nets, this usually taking place simultaneously with a corresponding occurrence in the coil-glands. In this way, a vascular plexus is formed at the lower border of the corium also, which occupies a much larger extent of surface than that of the papillary layer.

We may regard the *horizontal* distribution of the vascular trunks as taking place mainly at the two borders of the corium, and may divide it into the *papillary system* (with ascending loops for the papillæ and three kinds of branches in the lower portions of the corium) and the *system of the coil-glands and fat-tissue* (the vessels running upwards to the former, and downwards to the latter).

The horizontal form of the distribution of the vessels in the adult is due mainly to the increase in thickness of the corium. In the fœtus and new-born child, the obliquely or vertically ascending vessels give off branches irregularly to the nearest epithelial structures. Only after the deposition between them of firm bundles of fibrillæ, are the horizontal terminal branches near the border of the papillary layer crowded together to form a network, and with the descent of nearly all the coil-glands to the lower border of the corium, and the gradual atrophy of the subcutaneous fat, the vascular territories of the coil-glands and the fat-tissue unite to form the broad subcutaneous plexus. The larger vessels of this plexus gradually assume after birth, by the addition of a media and a thick adventitia, the characters of arteries and veins, while the vessels above them retain their indefinite embryonic (capillary) character. When in adult life the subcutaneous fat again attains considerable dimensions, the upper portion of the fat-cushion is supplied by the cutaneous, the lower by the musculo-fascial vessels.

Direct Passage of the Arteries into the Veins of the Skin.—A peculiar arrangement of vessels is found in the skin of the terminal phalanges of the fingers and toes. Hoyer describes it as of a double nature in man. In the first place, branches of the digital arteries empty directly into the wide veins of the nail-bed, and in the second place, after giving off branches for the fat and coil-glands of the skin of the finger, but before the papillary system is formed, empty into numerous small vascular coils, inside which they also pass into veins. Under ordinary circumstances, these direct transitions evidently serve as regulators for the obstructed capillary circulation through the ends of the fingers and toes, in which, aside from their unfavorable situation, the absence of the muscular, and the insufficient development of the elastic elements of the corium come into play.

If we take a general view of the circulation in the skin, we are forced to admit that there is no such thing as a functional division of it into a circulation for respiration, secretion, muscular movements, etc. Its distribution is uniform from the first, and becomes transformed into a double one only by mechanical influences. This latter fact is of great importance, because by it alone many pathological processes in the skin remain confined to the fibrillary circulation and its annexes. The unusual thinness of the walls of the cutaneous and subpapillary vessels is doubtless a consequence of their being embedded in firm papillary tissue; the skin-veins which rest upon a very firm basis even assume the form of blood-sinuses with extremely thin walls. The absence of highly-developed muscles upon the vessels of the skin is in part compensated by the elastic frame-work, which is influenced by the external temperature through the oblique tensors of the skin. The very distensible capillary loops of the papillæ probably possess the power of independent contraction under nervous irritation.

Lymphatic Vessels.—The absorbent lymphatic apparatus of the skin is an unsymmetrical secondary appendage of the vascular circulation with a centripetal direction; it has one peculiarity, however, viz., that large masses of tissue, absolutely devoid of blood-vessels, are embedded in it, *i. e.*, the epidermis and its appendages. Recent investigations have defined with satisfactory clearness the exact course of the lymphatic channels of the skin, but as the statements of authors are often absolutely contradictory, it behooves us to ascertain the real truth of the matter.

It is certain that all parts of the skin contain juice-spaces; on this point there can be no difference of opinion. As the nomenclature of pure unapplied anatomy is insufficient for our purpose, we shall designate as *juice-spaces all those lymphatic channels which do not possess an absolutely free outflow into well-marked lymphatic vessels lined with endothelium, whether they are devoid, as is usually the case, of independent walls or are provided with them; lymphatic vessels, on the other hand, are those channels from which a free outflow into the blood takes place.* Let us now consider from this standpoint the system of juice-spaces of the skin.

Juice-spaces of the epidermis.—The juice-spaces of the epidermis are represented by the interspinal passages of the prickle-cells. These will be most readily understood by imagining a low hall, the roof of which is supported by innumerable columns standing close together. Since Axel Key and Retzius have succeeded in injecting these spaces from the lymph spaces of subcutaneous tissue, it is certain that they are already formed lymphatic passages. I also once observed a natural infiltration of these channels with fat, in which the fat, stained by osmium, surrounded the cells with a black frame (see Fig. 15). But it is another question whether the interspinal passages do not also contain a soft, viscid substance, somewhat analogous to the so-called cement substance of the endothelium.

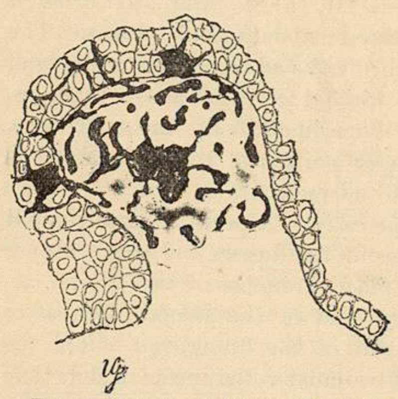

FIG. 15.—Juice-spaces of a papilla and the adjacent epidermis with a natural fat-injection.

That the prickle-cells require no cement to hold them together is clear from the description of their connecting threads.

The question is simply whether or not a more consistent substance is found in them. Such seems to be the case. In treating sections of the epidermis with alkalies, it sometimes happens

that the prickles are bent and broken by the expansion of some interspinal substance, and sometimes injections of the epidermis with chloroform-asphalt fail completely, and they very rarely succeed entirely, although the interspinal spaces are well-developed. These injections would always succeed if some obstruction were not encountered in the majority of cases.

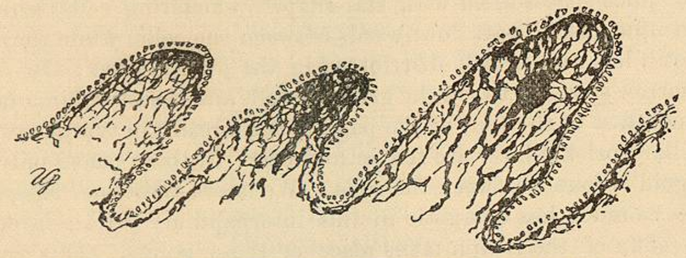

FIG. 16.—Lymph-passages of three papillæ, injected with asphalt.

It is a priori a necessity that the lymph which flows from them should carry off the products of tissue-changes in the prickle-cells; it is possible that there may be among them a readily coagulating substance, capable of obstructing the passages. But even if we assume that the interspinal passages are partially filled with a soft viscid substance, the nutrition of the epidermis would not even then represent a simple process of imbibition, for the interspinal passages are also traversed by fine nerve filaments which often have a capillary cavity around them, and they both, nerve and perineural cavity, always pass through the protoplasm of the cells and terminate in the nuclei.

Even where an interspinal substance is wanting, we always find deposits of lymph in the fresh skin.

The most beautiful specimens are obtained from slightly œdematous skin, treated for

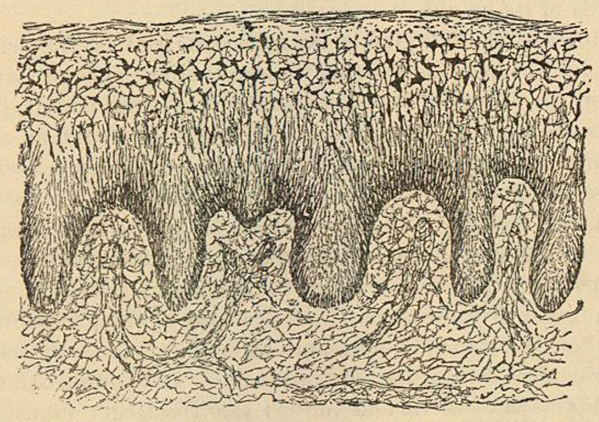

FIG. 17.—Staining with gold of all the lymphatic channels of the papillary layer and epidermis of a slightly œdematous skin.

a short time with the boiled mixture recently recommended by Ranvier, four parts of chloride of gold and one part of formic acid. In specimens thus treated, we see very distinctly, according to the heaviness of the deposits of gold, those passages which are preferred by the current, and those in which stagnation occurs. Fig. 17 shows such a picture from an œdematous prepuce. At the apex of the papilla, a thread of gold corresponds to each intercellular space, and consequently the threads radiate like a tuft of hair from the surface of the corium. In the upper horizontal layers these threads divide, corresponding to the contours of the cells, anastomose, and then present between the granular cells rows of forked ends, from which rows of granules may be followed some distance further, as the last juice-spaces between the horny cells. Below the granular layer we see nearly all the juice-spaces filled with star-shaped wandering cells, which send their branches in part upwards, in part downwards between the cells, while they are otherwise plentifully but still less numerously distributed in the prickle-layer; they are unable to creep into the narrow spaces between the granular cells and therefore stick fast all through this layer. In contrast to the tops of the papillæ the streams of lymph at their bases and in the interpapillary prickle-layer are few in number. In these places only a finely granular deposit of gold is found between the cells. We must, therefore, regard the circulation of the juices as much less energetic in this interpapillary prickle-layer, or, in other words, the slow reflux of the lymph takes place at these points. This conclusion may also be reached from another circumstance. Key and Retzius found, as has already been mentioned, that the sweat-pores can be filled from the cutaneous lymph-passages by way of those of the epidermis. We therefore have in the sweat-pores a means of escape for the lymph circulating through the epidermis, and they are without exception situated in the interpapillary depressions.

Direction of the Current of Lymph in the Epidermis.—The lymph, therefore, flows to the epidermis mainly from the apices of the papillæ, thence spreads in all directions through the former and returns to the corium by way of the interpapillary depressions, through the sweat-pores of which it may, under some circumstances, be discharged externally also.

The papillæ are very uniformly traversed by juice spaces (see Fig. 16). They become confluent near the centre of the base of the papilla, at which point the beginning of a lymphatic vessel is usually found; this passes upwards in the axis of the papilla to a distance of two-thirds of its height.

The excretory ducts of the coil-glands, the sebaceous glands, the prickle-layer of the hair-follicle and the hair-bed, have the same interepithelial juice-spaces as the epidermis. In the last situation the ascent of pigment in them can often be recognized. The hair papilla, reasoning from analogy, is probably also traversed by lymph-spaces which communicate with the interepithelial spaces of the matrix of the cortex which contain pigment, and with those of the matrix of the medulla, cuticle and root-sheath, which are destitute of pigment, and extend in all directions as far as the horny portions of the hair. The oblique muscles of the skin and the coils of the coil-glands float in distended lymph-spaces, in which respect the latter differ from the sebaceous glands which are surrounded by a much smaller number of juice-spaces. In the case of the arrectores, these lakes of lymph furnish room for their movements, and in that of the coil-glands they supply material for the fabrication of their specific products. The connective-tissue bundles are all ensheathed by lymph-spaces of various forms; also the larger fat-lobules, from whose lymph-sheaths very slender lymph-canals extend between the individual fat-cells.

Lymphatic Vessels.—In contrast with this *infinitely complicated system of juice-spaces*, the skin has only a small number of real *lymphatic vessels*. This system of vessels begins in the upper third of the papillæ with blind extremities into which the juice-canals empty, as they do everywhere else, through holes (Schenk; pseudostomata: Klein) and through the porous cement ridges of the endothelia (stomata). The lymphatic vessels then unite to form a continuous plexus which uniformly permeates with its not very narrow meshes the entire skin. The transverse and vertical connecting branches of this network increase steadily in width as they approach the subcutaneous border, and are scattered through the corium in such a manner that they keep as far from the blood-vessels as possible. Having reached the subcutaneous tissue, they collect into a few larger lymphatic vessels upon which Flemming demonstrated the rudiments of a muscular apparatus. These lymphatic vessels of the skin are relatively few in number. This fact, together with another, viz., that the veins of the skin are of extraordinary width as compared with its arteries, compels us to believe that the greater part of the lymph which circulates through the skin is taken up by the veins. Physiology has already declared in favor of this view, since œdema ef the extremities cannot always be produced by tying all the lymphatic trunks, whereas it always follows ligation of the veins. But while the lymph of the papillary layer and of the epidermis with its appendages always has an assured free outflow into the cutaneous lymphatic vessels, the lymph which comes from the *vessels of the coil-glands and fat-tissue*, although provided with well-developed juice-spaces, has no way of free escape. The lymph which sluggishly flows off from these structures is filtered upon its entrance into the passing cutaneous veins and lymphatic vessels, and this filtration is, as we have seen, the starting-point of the formation of the subcutaneous fat. Lymphatic vessels, as we define them, are found neither in the fat-tissue nor in the subcutaneous tissue which is destitute of fat.

Nerves.—The sensitive twigs of the cerebral and spinal nerves penetrate from below into the skin in larger bundles and at much greater distances apart than the blood-vessels. They first run a longer course horizontally in the subcutaneous tissue, repeatedly breaking up into thin branches, and finally pass through the corium with the ascending vessels. In some parts, these nerves give off, inside the subcutaneous tissue, branches to the corpuscles of Vater (Pacinian). *Corpuscles of Vater.*—These are oval bodies, visible to the naked eye, the principal bulk of which consists of an enormous enlargement of the sheath of Schwann into concentric lamellæ, having nuclei and lined with endothelium. Between the middle layers of these lamellæ, which are everywhere interrupted by transverse septa, there is a large quantity of albuminous lymph by which they are irregularly distended. This thick capsule of connective tissue incloses a much narrower cylindrical cavity filled with a granular indistinctly fibrous substance containing cells and traversed in its centre by the sensitive nerve. This loses its medulla on entering the cavity, although it remains double contoured (Ranvier), and ends either singly or divided in the corpuscle, with one or more bulbous extremities, or passes entirely through it to terminate finally in a single filament in a second or a third Pacinian corpuscle. According to W. Krause, these bodies serve as instruments of touch, which enable us to appreciate pressure or traction by transforming them into hydrostatic pressure. They are especially numerous in the fingers, toes, palms and soles, etc.

After passing through the corium, the nerves again assume a horizontal direction at the lower border of the papillary layer, and here form a true nerve-plexus underneath the epidermis. According to some authors, nuclei or extremely small ganglion-cells are found in these nerves and in those which arise from this point, which are still medullated. The branches which pass still further upwards are in part very short, and break up below the epidermis into fine non-medullated fibrillæ which branch very freely, some branches terminating on the endothelia of the papillary vessels, while others can be found terminating with small bulbous extremities free in the connective tissue (probably these also end in large connective-tissue cell-plates). By far the larger number of them, however, penetrate between the epithelial cells into the interspinal spaces.