THE SECRETORY FUNCTION OF THE SKIN.

The fluid secretions of the skin are the sweat and the sebum.

The solid substances thrown off from the skin consist of the cells of the epidermis, which are removed mechanically by rubbing, washing, etc., after the horny layer has been macerated by warm bathes, warm and moist applications, diaphoretic procedures, etc. The most superficial layer of the epidermis, by virtue of its hygroscopic properties, swells up, and it can then be rubbed off.

THE SECRETION OF SWEAT.

The sweat is chiefly secreted by the sudoriferous glands. That the sebaceous glands have some share cannot be denied or affirmed. It is not impossible that some sweat is secreted from the lymph-spaces directly through the sudoriferous ducts, and also that gases and watery vapor are thrown off in this way.

Krause endeavored to show that the surface of evaporation of the entire sudoriferous apparatus is only sufficient for the separation of one-eighth to two-ninth of the entire perspiration. The remainder must, therefore, pass through the epidermis itself.

Against this view it must be said that an accurate estimate of the superficial area of the sweat-glands and ducts is impossible; also that the evaporating surface is largely increased by the spreading-out of each drop of sweat upon the skin.

Erismann has shown that a much greater amount of water can be evaporated by the sweat-glands than Krause estimated. Furthermore, he has shown that the surface of the dead body excretes only one-sixth to one-fifth of the amount thrown off by the living body. In other words, at death the activity of a special organ ceases—an organ which in life has the power, on the one hand, constantly to deliver up water; on the other, to increase in a high degree its evaporating surface. As the epidermis is not changed at death, this organ must consist of the glandular organs of the skin, particularly the sweat-glands.

The sweat is a watery, almost colorless and clear fluid, of acid or alkaline reaction, salty taste, and a peculiar odor varying with the locality and the individual. The sweat contains volatile fatty acids (formic acid, acetic acid, butyric, propionic acids, etc.), and also neutral fats in small amount (palmitin and stearin), and cholesterin.

There can scarcely be a doubt that the sudoriferous glands have an active share in lubricating the epidermis, and that the secretion of the sebaceous glands is especially for the oleaginous needs of the hair.

According to the general view, the reaction of the fresh sweat is normally acid; if a profuse secretion is artificially induced by jaborandi, or other diaphoretics, and be kept up for some time, the reaction becomes neutral or even alkaline. The reaction also changes if the secreted sweat is allowed to stand a long time, in this case there being a decomposition of the nitrogenous constituents, especially urea, with the formation of ammoniacal salts.

Luchsinger and Trümpy found the reaction of the fresh sweat constantly alkaline when that part of the skin examined is first carefully cleansed of the sebum. The acid reaction of the sweat from the uncleaned skin depends, according to Luchsinger, upon the admixture of the uniformly acid sebum. The reaction of the sweat in the vola manus, where there are no sebaceous glands, is constantly alkaline.

It must not be forgotten, however, that Luchsinger and Trümpy examined only the sweat-secretion artificially increased and therefore not perfectly normal. Urea is a normal constituent of sweat and exists in the proportion of about 0.1–0.2 per cent. Whether

variations take place under normal conditions remains still to be determined. Under pathological conditions, for example, in anuria in the course of nephritis scarlatinosa and cholerica, and nephritis suppurativa from nephrolithiasis, the excretion of urea may be so increased that upon evaporation of the sweat, crystals appear upon the surface of the skin.

The presence of other nitrogenous bodies as normal constituents of the sweat has not so far been uniformly observed.

Leube found in profuse sweat a small amount of albumin. Schottin found a rose-red pigment precipitated by alcohol, and turned bright-green by oxalic acid. Finally Favre found an acid containing nitrogen (hydrotic acid).

The inorganic salts in sweat exist, according to Funke, in the proportion of 0.099–0.629 per cent (average 0.329 per cent). The principal ones are the alkaline chlorides, especially chloride of sodium. In less amount are the alkaline and earthy phosphates and the oxide of iron.

The amount of water in sweat varies from 977.40 (Schottin) to 995.573 (Favre). These variations depend upon the amount and duration of the sweating, the food, the amount of water taken during the sweating, etc.

The process of secretion is periodic, being determined by certain causal conditions.

It is a true secretion dependent mainly upon nervous influence, and is analogous in many points to the secretion of saliva.

The centres for the sudoriferous nerves are situated in the spinal cord as far up as the medulla oblongata, which latter contains a general centre containing the spinal centres (Luchsinger).

The peripheral paths of the sweat-nerves follow the rami communicantes to the sympathetic, and then pass into the mixed nerves of the extremities. Some fibres pass directly to the extremities (Vulpian, Adamkiewicz), though this is denied by a competent observer (Nawrocki).

The terminations of the sweat nerves upon the sudoriferous glands have been demonstrated by Coyne by the gold method. Whether they pass into the cells and how is as yet unknown.

Irritation of the mixed nerves containing sweat fibres excites in animals secretion of sweat within the distribution of the nerve. Pilocarpine, muscarine, and other alkaloids stimulate secretion by acting upon the periphery. For example, they will excite sweating after section of the nerve trunk from its centre.

The secretion of sweat is increased through reflex and central stimulation by changes in the temperature and composition of the blood, especially by increase of its heat and by venosity, poisoning with strychnine, picrotoxine, camphor, ammonium aceticum.

The glandular activity is diminished or even entirely suspended by cooling the skin, cutting off the supply of arterial blood, separation of the glands from the central nervous system, finally by too long activity, and apparently also by too long rest.

Simple venous stasis without dyspnœic condition of the blood does not stimulate the sweat-glands; neither does active hyperæmia up to the point of inflammation. Similarly a simple increase in the arterial pressure is without effect, as, for example, when a large amount of water is taken into the system, unless the blood is heated by the imbibed fluid, or by a high temperature of the surrounding air, or by prevention of heat-radiation and water-evaporation from the skin, or by muscular activity. The secretion of sweat is so far independent of the blood-vessels and the vaso-motor nerves that it can

still be excited by irritation of a nerve trunk even when the limb is severed from the body (Kendall and Luchsinger), but it is accompanied by dilatation of the blood-vessels and increased by a powerful flow of arterial blood.

Atropine causes a diminution or even cessation of the sweat-secretion by paralyzing the glandular nerves, while, as Rossbach has apparently shown, the specific irritability of the glandular substance persists and can even be excited by pilocarpine, although the strongest electrical irritation of the nerve is ineffectual.

Medical experience confirms the power of atropine to check perspiration, *e. g.*, in the profuse sweats of phthisical, rheumatic, and other patients. In a less degree, morphine acts in the same manner, both in physiological experiment and with the sick.

Chloroform, chloral hydrate, ether, and curare do not lessen the activity of the sweat-glands even in the largest doses. The existence of inhibitory sweat-nerves in the sympathetic has lately (Vulpian) been announced, but not confirmed.

THE SEBACEOUS SECRETION.

Sebum consists in healthy individuals of a fluid fat, which, passing out insensibly from the sebaceous glands, lubricates the epidermis and hair, though not giving them a noticeably oily appearance. Herein, however, there are many variations within the limits of health, especially as regards increased secretion and abnormal consistency—too solid or too fluid. In these cases one notes either that the skin and hair always present an oily appearance, that the mouths of the ducts on the nose and vicinity gape; or, if the consistency of the sebum is increased, that it appears at the openings of the ducts in white, tallow-like masses.

The microscopic examination of the sebum shows, besides free fat, more or less fatty cells, cell debris, cholesterin crystals, and epidermic scales.

The chemical composition of the sebum and allied secretions, the ear-wax, smegma preputii, and secretion of the Meibomian glands has been incompletely studied. The constant constituents are: water, fats (palmitin and olein), palmitic and oleic acid, soaps, a casein-like albuminoid, cholesterin, and inorganic salts (chlorides and phosphates of the alkalies and earths).

C. Schmidt examined an old and rancid accumulation of sebum of gigantic size, which, on account of its age, did not represent the normal secretion, and found: water 31.70%; fatty acids (butyric, valerianic, and caproic), 1.21%; palmitin with a trace of cholesterin, 4.16%; epithelium and albuminate, 61.75%; mineral salts, 1.18%.

Ear-wax is a mixture of the secretions from the sudoriferous and sebaceous glands of the external auditory meatus. Microscopically the formed elements of these two secretions can be recognized.

So far as has been determined, the secretion of sebum is continuous and is increased by increase of vascular supply and of temperature. The central layer of the gland-cells is filled with fat-drops, the cells rupture after coalescence of the drops of fat, and free fat is formed.

The analogy between the sebaceous and lacteal secretion justifies the view that the contractility and permeability of the membrane for fats, demonstrated by Stricker and Schwarz[1] for the colostrum cells, exists also for the cells of the sebaceous glands, so

[1] Sitzungberichte der k. k. Akademie der Wissenschaften zu Wien, Mathem.-naturwiss. Kl., ii. Abthlg., Bd. liii., S. 184.

that the freeing of the fat from the cells does not necessarily imply that the cell is broken up.

THE FUNCTION OF HEAT REGULATION.

The regulation of the amount of heat lost from the surface of the body is essential to the preservation of a constant temperature of the blood, and thereby to the preservation of life.

The heat lost from the cutaneous surface passes off by radiation and conduction, as well as by the evaporation of water. Increase or decrease of the surrounding temperature gives rise, through reflex excitation of the vaso-motor centres, to a narrowing or widening of the cutaneous blood-vessels, and a relaxation or contraction of the smooth muscles of the skin. It cannot be denied, *a priori*, that these effects may be brought about in part by indirect excitation of the smooth muscular fibres of the vessels through temperature changes without the intervention of the nervous system.

In cooling the skin, the amount of blood sent to it is enormously decreased through narrowing of the blood-vessels. By the contraction of the muscles of the skin, also its superficies is reduced to a minimum. In this way, the heat lost from the body surface is not only diminished, but the cooling of the blood itself is lessened. On the other hand, with increase of external temperature, the blood-vessels are dilated, the skin muscles relaxed, consequently more blood circulates in the surface, the superficies of which is at the same time increased. The sweat secretion is of fundamental importance in certain degrees of temperature increase in order to prevent heating of the blood. On account of the passage of drops of sweat from the ducts out upon the surrounding skin, a great amount of heat is rendered latent.

THE FUNCTION OF THE SKIN AS A SENSORY ORGAN.

The function of the skin as a sensory organ depends upon the integrity of the peripheral nervous end-organs and upon the unbroken continuity between these end-organs and the nerve centres. The subject is discussed in Vol. XII. under the head of "Diseases of the Peripheral Nerves."

THE FUNCTION OF THE SKIN AS A PROTECTING ORGAN FOR THE SURFACE OF THE BODY.

The horny layer of the epidermis limits the evaporation of water from the surface which otherwise would go on continually. On the other hand, it opposes strongly the passage of caustic and poisonous fluids, of electricity, and of very high or low degrees of heat, and, to a certain extent, the entrance of poisonous gases when the surface is sufficiently lubricated with sebum.

The elasticity and toughness of the cutaneous tissue are also a protection against injuries of all kinds. The hair, especially that of the head, acts as a protection against thermal and mechanical injuries.

THE DISTURBANCES OF THE GENERAL FUNCTIONS OF THE SKIN.

Covering the skin with an impermeable layer (varnish, oil-paint, etc.) acts very differently upon different animals. In rabbits, varnishing, after removing the hair, sooner

or later produces death. The fatal termination occurs more rapidly the smaller the animal and the more completely the cutaneous surface is covered. It is sufficient, in most cases, to cover only a third of the body in order to produce death, and even varnishing a sixth part may prove fatal.

The symptoms are those of an acute febrile disease, which, after great diminution in temperature, ends fatally. At first, one observes weakness, increased rapidity of the circulation and respiration; soon these latter become slower, the temperature falls, the animal is apathetic, insensible to irritations; albuminuria, convulsions, and paralyses follow, and a fall of temperature to 19°–20° C. (in the rectum) results, the CO_2 exhalation sinks (even to one-half of the normal), and death takes place.

According to the recent experiments of Ellenberger and others upon larger and less sensitive animals, the effects of varnishing are decidedly less marked than is the case with rabbits.

Senator has recently investigated this question anew, and has sought to determine whether the results upon animals can be applied to man. The single observation which illustrates the deleterious effect of varnishing upon man is, as Senator shows, not a strong evidence. At the installation of Pope Leo X., a poor boy was gilded over his entire skin. The child was taken sick and died the following night. Senator rightly contends that this shows nothing, since we are not told what symptoms occurred, and whether the substances used in gilding were not poisonous. The fact of death occurring so suddenly speaks against its being due to the gilding, reasoning from the mode of death in lower animals, since dogs survive varnishing for several weeks.

Senator has made a number of experiments, partly upon febrile (typhoid) and partly upon non-febrile adults. He applied to the skin an impermeable coating of adhesive plaster, collodium ricinatum, or tar, and allowed it to remain several days. This did not produce any morbid symptoms, much less fatal results. Decrease of the internal temperature did not once take place if cooling of the surface, from long exposure or evaporation of ether, was prevented.

Hence it appears that covering the cutaneous surface with an impermeable coating is, in man, or at least in adults, not dangerous.

Covering the entire skin with tar and tar preparations produces indeed some morbid symptoms, but no dangerous results. If more than a third of the body is covered with tar, there is produced a high fever with distress, malaise, headache; in vomiting, a dark-brown fluid is sometimes thrown up, and the fæces have sometimes a dark-brown color; most constantly, the urine has a greenish-black appearance, due to the presence of tarry constituents. Whether these enter the blood by the skin or lungs is not yet determined. At all events, we are justified in assuming that these morbid phenomena are due not to suppression of the perspiration, but rather to absorption of the constituents of the tar.

THE ABSORPTIVE POWER OF THE SKIN AND ITS LIMITS.

The horny layer of the epidermis is that part of the skin which, lubricated by the sebum, reduces to a minimum the absorption of substances applied to it in solution. If the epidermis is removed, the papillæ exercise a powerful absorptive capacity. Small excoriations and abrasions of the epidermis allow soluble substances to be taken up. But the question whether and to what extent the uninjured epidermis possesses an absorptive power is not yet finally settled. The practical importanceof this matter is apparent in view

of the daily application of ointments, liniments, etc., to the skin. Physiology is not less interested in the scientific aspect of the question.

As regards the paths of absorption, the cutis, with its rich supply of juice-spaces and lymph-vessels, and the subcutaneous tissue to a still greater extent, offer favorable conditions for absorption.

The epidermis alone, particularly the horny layer, presents obstacles. In experimentation, it must be first carefully ascertained that no excoriations, cuts, or lacerations are present; that the openings of those canals which are covered with mucous membrane (vagina, urethra, prepuce) are not included in that portion of the skin examined; finally, that the absorption of volatile substances by the lungs is excluded.

The histological structure of the epidermis does not exclude, *a priori*, its permeability to fluids and gases. The superficial horny layer alone forms a firm layer only interrupted at the mouths of the hair-follicles and sweat-glands. But here, indeed, there is an opportunity for fluids to enter the deeper layers of the epiderm towards the stratum lucidum without calling into play any absorptive capacity of the glandular substance itself.

V. Wittich has contended strongly of late that between the cells of the horny layer in the septum lucidum there are spaces communicating with each other, and filled with granular cement substance which probably communicate with the juice-canals of the cutis, and constitute the path of communication between the surface and the fluids of the body. They would also allow nourishing juices to pass from the papillary layer to the superficial parts of the epidermis, and carry off the watery and gaseous constituents of the perspiration; it could, on the other hand, under favorable circumstances, assist in absorption of fluids and substances in solution.

These paths contain the star-shaped wandering cells of Biesiadecki which reach with their processes into the corium, and serve for the passage of gases and easily soluble substances between the epidermis and cutis.

The above description harmonizes completely with the phenomena of vesication resulting from thermic and chemical irritation.

The filtration capacity of the epidermis is, according to V. Wittich's experiments, extremely small, although not entirely absent. But its permeability can be increased at any time by soaking the horny layer and loosening its texture. This especially occurs when substances are pressed into the orifices of the glands and distend them.

We will first consider the simplest condition of absorption.

Water, applied to the uninjured skin, is not absorbed. The experiments with long-continued baths give indeed an increase in the body weight, but this depends in all probability upon imbibition of water by the epidermis, not upon water absorption. All experiments at least in which the water of the bath contained in solution substances which could be easily detected in the excretions or secretions, have given negative results; provided the necessary precautions were used.

Most experiments have been made with the salts of iodine. The careful experiments of Braune gave invariably negative results.

Fleischer has lately made very careful experiments. He inclosed a limb in a glass vessel containing water kept at an even temperature. By means of a communicating pipette he determined the level of the fluid, after covering it with a layer of oil to prevent evaporation. If now the skin absorbed any water, the height of the fluid in the pipette would sink. After several hours this took place to such a small extent that Fleischer concluded that the epidermis imbibed some water, but that none was absorbed.

The skin similarly does not absorb alcoholic solutions of various substances if the tinctures are simply brushed upon the skin.

On applying to the skin various watery solutions by means of the spray-apparatus, Röhrig found iodine in the urine and saliva after twenty minutes. After one to two hours he found ferrocyanide of potassium in the urine. V. Wittich and I, who repeated this experiment with slight modifications, constantly obtained negative results. It is, therefore, doubtful at least whether absorption takes place after simple spraying.

The case is somewhat different in rubbing upon the skin substances dissolved or suspended in fat or oil. In some cases absorption then takes places apparently through the mouths and ducts of the glands into which the fat is pressed. But in most cases nothing is absorbed.

Lassar[1] holds the view, based upon observations upon rabbits, that fats and the substances contained in them are absorbed to an unlimited extent, probably at the mouths of hair-follicles. Fleischer obtained negative results with ointments of potassium iodide, morphine and veratrine, while the results were sometimes positive, sometimes negative, with ointments containing salicylic acid.

It cannot be doubted that mercury rubbed upon the skin in the form of an ointment is absorbed. How and in what form mercury is taken up by the skin is a question regarding which there is not yet harmony of opinion. Röhrig thinks that the greater part is absorbed in the form of mercurial vapor. Others believe that the mercurial particles enter through the mouths of the hair-follicles or sebaceous glands (Neumann) or pass through the superficial layers of the epidermis (Rindfleisch, Fleischer). According to v. Bärensprung, the oxide of mercury, which is always present in mercurial ointment, can alone be absorbed and become active. This is dissolved by the free acid of the sweat, and so is absorbed.

Gases and substances which easily become volatile at relatively low temperature pass through the skin with considerable readiness.

The diffusion of gases through the epidermis takes place most easily of all. This has long been proven experimentally with regard to hydrogen sulphide, carbonic oxide, carbonic acid gas, chlorine, prussic acid, and other gases. Röhrig has lately obtained positive results in experiments with these gases and with chloroform, illuminating gas, etc. He has also shown that baths, if the water is saturated with these gases, produce characteristic symptoms of poisoning.

The absorption of volatile substances, such as turpentine, camphor, etc., very readily takes place through the intact epidermis.

The circumstance that the difficulty of absorption is increased by the presence of an oily stratum upon the skin is one of importance, and absorption is aided by the removal of this layer by means of ether, alcohol, or chloroform. According to my experiments, based on those of Röhrig, the solutions of pilocarpine, apomorphine, salicylic acid, etc., in ether or oil of turpentine, powerfully sprayed upon the skin, were absorbed to the greatest extent when the skin had first been washed with soap or ether. The quantity of the substances which can be taken up in this way, however, is so small that no practical significance can be attached to it as a method of administering drugs.

Although it is certain that watery solutions of organic and inorganic salts are not

[1] Lassar, Virchow's Archiv, Bd. 67, 1.

absorbed by the uninjured skin, yet therapeutics receives compensation in the doctrine of the irritating action of saline solutions upon the ends of the peripheral nerves and, by means of centripetal conduction upon the central nervous system and upon the metabolic processes.

We can further affirm that the absorption of gases and volatile substances by the skin takes place. Should it be further established that medicinal substances dissolved or suspended in these easily volatilized substances (alcohol, ether, oil of turpentine, etc.) are also taken in by diosmosis, the limits of epidermic therapeutics will be somewhat, though for practical purposes not very greatly, enlarged.

Finally, the absorption of substances dissolved or suspended in fats when mechanical pressure is employed cannot be denied.