

oblique. The fibres of connective tissue are very abundant and unite the vessels to the surrounding parts. The internal and the middle coats are closely adherent to each other; but the external coat may readily be separated from the others. Blood-vessels have been found in the walls of the lymphatics, and the existence of vaso-motor nerves is probable.

The walls of the lymphatic vessels are very closely adherent to the surrounding tissues; so closely, indeed, that even a small portion of a vessel is detached with great difficulty, and the vessels, even those of large size, can not be followed out and isolated for any considerable distance.

In all the lymphatic vessels, beginning a short distance from their plexus of origin, are semilunar valves, generally arranged in pairs, with their concavities looking toward the larger trunks. These folds are formed of the middle and inner coats; but the fold formed from the lining membrane is by far the wider, so that the free edges of the valves are considerably thinner than that portion which is attached directly to the vessel. The valves are most abundant in the superficial vessels. The distance between the valves is one-twelfth to one-eighth of an inch (2 to 3 mm.), near the origin of the vessels, and one-quarter to one-third of an inch (6 to 8 mm.), in their course. In the lymphatics situated between the muscles the valves are less abundant.

They are always relatively few in the vessels of the head and neck and in all that have a direction from above downward. Although there are a number of valves in the thoracic duct, they are not so abundant here as in the smaller vessels.

In their anatomy and general properties, the lymphatics bear a close resemblance to the veins. Although much thinner and more transparent, their coats have nearly the same arrangement. The arrangement of valves is entirely the same; and in both systems, the folds prevent the reflux of fluids when the vessels are subjected to pressure.

The lymphatics are very elastic; and it is generally admitted that the larger vessels and those of medium size are contractile, although the action of their muscular fibres, like that of all fibres of the non-striated variety, is slow and gradual.

One of the most important points in connection with the physiological anatomy of the lymphatic vessels is the question of the existence of orifices in their walls, which might allow the passage of solid particles or of emulsions. Anatomical observations have indicated the existence of stomata, of variable size and irregular shape, in the smallest vessels; and a strong argument in favor of the existence of these orifices has been the fact of the actual passage, through the walls of the vessels, of fatty particles, the entrance of which can not be explained by the well known laws of endosmosis. The anatomical evidence of the existence of openings is derived mainly from preparations stained with silver nitrate. It is assumed



FIG. 91.—Valves of the lymphatics (Sappey).

that silver nitrate stains the solid parts of tissues and the borders of the endothelial cells; and that non-nucleated areas which do not present any staining are necessarily open. In preparations of the lymphatics, the solution of silver is seen staining the tissues and the borders of the cells lining the vessels; but there are areas between these cells where no staining is observed and in which no nuclei are brought out by staining with carmine.

Lymphatic Glands.—In the course of the lymphatic vessels, are small, lenticular bodies, called lymphatic glands. The number of these is very great, although it is estimated with difficulty, from the fact that many of them are very small and are consequently liable to escape observation. It may be stated as an approximation that there are six or seven hundred lymphatic glands in the body. Their size and form are also very variable within the limits of health. They generally are flattened and lenticular, some as large as a bean and others as small as a small pea or even a pin's-head. They are arranged in two sets; one superficial and corresponding with the superficial lymphatic vessels, and a deep set, corresponding with the deep vessels. The superficial glands are most abundant in the folds at the flexures of the great joints and about the great vessels of the head and neck. The deep-seated glands are most abundant around the vessels coming from the great glandular viscera. A distinct set of large glands is found connected with the lymphatic vessels between the folds of the mesentery. These are known as the mesenteric glands. All of the lymphatic vessels pass through glands before they empty into the great lymphatic trunks, and most of them pass through several glands in their course.

The perfect, healthy glands are of a grayish-white or reddish color, of about the consistence of the liver, presenting a hilum where the larger blood-vessels enter and the efferent vessels emerge, and are covered, except at the hilum, with a delicate membrane composed of inelastic fibres, a few elastic fibres and non-striated muscular fibres. Their exterior is somewhat tuber-

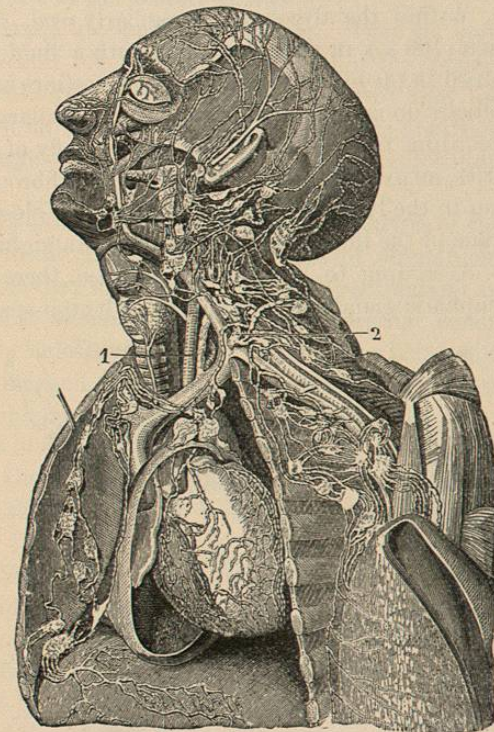


FIG. 92.—Lymphatics and lymphatic glands (Sappey).
1, upper extremity of the thoracic duct, passing behind the internal jugular vein; 2, opening of the thoracic duct into the internal jugular and left subclavian vein. The lymphatic glands are seen in the course of the vessels.

culated, from the projections of the follicles just beneath the investing membrane. The interior of the glands is soft and pulpy. It presents a coarsely granular, cortical substance, of a reddish-white or gray color, which is one-sixth to one-fourth of an inch (4 to 6 mm.) in thickness in the largest glands. The medullary portion, which comes to the surface at the hilum, is lighter colored and coarser than the cortical substance. Throughout the gland, are found delicate fasciculi of fibrous tissue connected with the investing membrane, which serve as a fibrous skeleton for the gland and divide its substance into little alveoli. The structure is far more delicate in the cortical than in the medullary portion.

Within the alveoli, are irregularly oval, closed follicles, about $\frac{1}{250}$ of an inch (100 μ .) in diameter, filled with a fluid and with cells like those contained in the solitary glands of the intestines and the patches of Peyer. These follicles do not seem to occupy the medullary portion of the glands, which, according to Kölliker, is composed chiefly of a net-work of lymphatic capillaries, mixed with rather coarse bands of fibrous tissue. The follicular structures in the lymphatic glands resemble the closed follicles in the mucous membrane of the intestinal canal and the Malpighian bodies of the spleen.

According to Von Recklinghausen, there exist in the substance of the lymphatic glands great numbers of lymph-spaces or canals, which are proba-

bly lined with endothelium; and these spaces communicate with the efferent vessels, by the stomata. The afferent vessels, two to six in number, penetrate the gland, and probably empty their contents into the lymph-spaces. The lymph is then collected from the lymph-spaces, by the vasa efferentia, one to three in number, which are always larger than the afferent vessels.

The lymphatic glands are supplied with blood, sometimes by one but generally by several small arteries, which penetrate at the hilum. These vessels pass directly to the medullary portion and there break up into several coarse

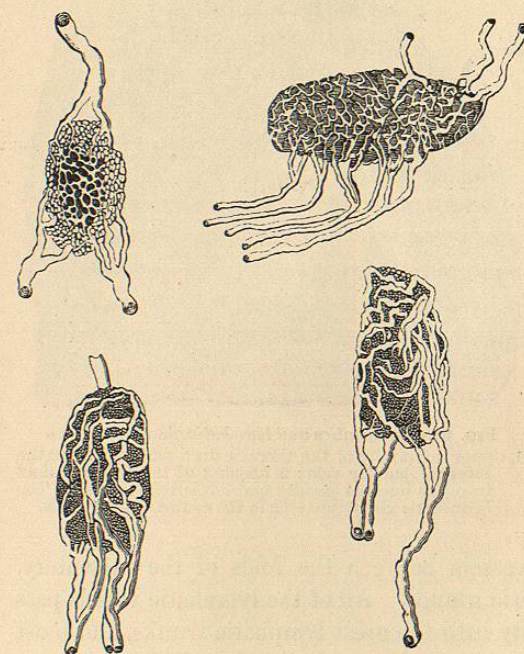


FIG. 93.—Different varieties of lymphatic glands (Sappey).

branches to be distributed to the cortical substance, where they ramify in a delicate, capillary net-work with rather wide meshes, in the closed follicles found in this portion of the gland. This capillary plexus also receives branches from small arterial twigs which penetrate the capsule of the gland

at different points. Returning on themselves in loops, the vessels unite to form one or more large veins, which generally emerge at the hilum.

Very little is known regarding the distribution of nerves in the lymphatic glands. A few filaments from the sympathetic system enter with the arteries, but they have never been traced to their final distribution. The entrance of filaments from the cerebro-spinal system has never been demonstrated.

It is evident, from the structure of the lymphatic glands, that they must materially retard the passage of the lymph toward the great trunks; and it is well known in pathology that morbid matters taken up by the absorbents are frequently arrested and retained in the nearest glands.

The uses of the lymphatic glands are somewhat obscure. They are supposed, however, to have an important office in the elaboration of the corpuscular elements of the lymph and chyle; and it has been observed that the lymph contained in vessels which have passed through no glands is relatively poor in corpuscles, while the large trunks and the efferent vessels contain them in large numbers.

Absorption of Albuminoids by the Lacteals.—Comparative analyses of the lymph and chyle always show in the latter fluid an excess of albuminoid matters; and it is natural to infer that the excess of nitrogenized matters in the chyle is due to absorption of albuminoids from the intestinal canal. Lane collected the chyle from the lacteals of a donkey, seven and a half hours after a full meal of oats and beans, and compared its composition with that of the lymph. The analyses were made by Rees, who found that the chyle contained about three times as much albumin and fibrin as the lymph. While by far the greatest part of the products of digestion of the albuminoids is absorbed by the blood-vessels, there can be no doubt that a small portion is also taken up by the lacteals.

Absorption of Glucose and Salts by the Lacteals.—What has just been stated regarding the absorption of albuminoids applies to saccharine matters and the inorganic salts. Small quantities of sugar and sometimes lactic acid have been detected in the chyle from the thoracic duct in the herbivora; and the presence of sugar in both the lymph and the chyle has been determined by Colin. While the products of the digestion of saccharine and amylaceous matters are taken up mainly by the blood-vessels, a small quantity is also absorbed by the lacteals. In the comparative analyses of the chyle and lymph by Rees, the proportion of inorganic salts was found to be considerably greater in the chyle. The great excess in the quantity of blood coming from the intestine, and the rapidity of its circulation, as compared with the chyle, will explain the more rapid penetration by endosmosis of the soluble products of digestion.

Absorption of Water by the Lacteals.—There can be no doubt that a small portion of the liquids taken as drink finds its way into the circulation by the lacteals, although the greatest part passes directly into the blood-vessels. This has been proved by experiments of a most positive character. When an animal has taken solid food only and is killed during digestion, the thoracic duct contains a very small quantity of chyle; but when the animal has taken liq-

uids with the food, the thoracic duct and the lacteals are very much distended (Leuret and Lassaigne). In an experiment by Ernest Burdach, a dog was deprived of food and drink for twenty-four hours, after which he was allowed to drink water, and in addition, half a pound (227 c. c.) was injected into the stomach. The animal was killed a half-hour after, and the thoracic duct was found engorged with watery lymph, which contained a very few lymph-corpuscles.

Aside from the entrance of gases into the blood from the pulmonary surface, physiological absorption is almost entirely confined to the mucous membrane of the alimentary canal. It is true that liquids may find their way into the circulation through the skin, the lining membrane of the air-passages, the reservoirs, ducts and parenchyma of glands, the serous and other closed cavities, the areolar tissue, the conjunctiva, the muscular tissue, and, in fact, all parts which are supplied with blood-vessels; but here the absorption of foreign matters is occasional or accidental and is not connected with the general process of nutrition. It is now well known that all parts of the body, except the epidermis and its appendages, the epithelium, and some other structures which are regularly desquamated, are constantly undergoing change, and the effete matters which result from their disassimilation are taken up by what is called interstitial absorption, and are carried by the blood to the proper organs, to be excreted. It seems probable that the vessels of these parts would also be capable of absorbing soluble foreign substances; and this is, indeed, the fact with regard to all parts in which the nutritive processes are even moderately active or where the structures covering the vascular parts are permeable.

Absorption by the Skin.—It is universally admitted that absorption can take place from the general surface, although at one time this was a question much discussed by physiologists. The proofs, however, of the entrance of certain medicinal preparations from the surface of the body are now entirely conclusive; and the constitutional effects of medicines administered in this way are frequently as marked as when they are taken into the alimentary canal. The question which is of most importance in this connection relates to the normal action of the skin as an absorbing surface. Looking at this subject from a purely physiological point of view, absorption from the skin, under ordinary conditions, must be very slight, if, indeed, it take place at all. There are, nevertheless, facts which render it certain that water may be absorbed by the skin. In a series of experiments by Collard de Martigny, in 1821, it was shown that water could be absorbed in small quantity by the skin of the palm of the hand. In one experiment, a small bell-glass filled with water was applied hermetically to the palm. This was connected with a tube bent in the form of a siphon, also filled with water, the long branch of which was placed in a vessel of mercury. After the apparatus had been applied for an hour and three-quarters, the mercury was found sensibly elevated in the tube, showing that a certain quantity of the water had disappeared. In a series of observations upon the absorption of water and soluble substances, by Wille-

min (1863), it was shown that water is absorbed in a bath, and that various medicinal substances may be taken up by the skin in this way and can be detected afterward in the urine.

It has been frequently remarked that the sensation of thirst is always least pressing in a moist atmosphere, and that it may be allayed to a certain extent by baths. It is true that in a moist atmosphere the cutaneous exhalations are diminished, and this might account for the maintenance of the normal proportion of fluids in the body with a less amount of drink than ordinary; but one could hardly account for an actual alleviation of thirst by immersion of the body in water, unless it were assumed that a certain quantity of water had been absorbed. A striking example of relief of thirst in this way is given by Captain Kennedy, in the narrative of his sufferings after shipwreck, when he and his men were exposed for a long time without water, in an open boat. With regard to his sufferings from thirst, he says: "I can not conclude without making mention of the great advantage I derived from soaking my clothes twice a day in salt-water, and putting them on without wringing. . . . There is one very remarkable circumstance, and worthy of notice, which was, that we daily made the same quantity of urine as if we had drunk moderately of any liquid, which must be owing to a body of water absorbed through the pores of the skin. . . . So very great advantage did we derive from this practice, that the violent drought went off, the parched tongue was cured in a few minutes after bathing and washing our clothes; at the same time we found ourselves as much refreshed as if we had received some actual nourishment."

Absorption by the Respiratory Surface.—Animal and vegetable emanations may be taken into the blood by the lungs and produce certain well marked pathological conditions. Many contagious diseases are propagated in this way, as well as some fevers and other general diseases which are not contagious. With regard to certain poisonous gases and volatile matters, the effects of their absorption by the lungs are even more striking. Carbon monoxide and arsenious hydride produce death almost instantly, even when inhaled in small quantity. The vapor of pure hydrocyanic acid acts frequently with great promptness through the lungs. Turpentine, iodine and many medicinal substances may be introduced with great rapidity by inhalation of their vapors; and the serious effects produced by the emanations from lead or mercury, in persons who work in these articles, are well known. Not only have vapors introduced in this way been recognized in the blood, but many of the matters thus absorbed are excreted by the kidneys and may be detected by their characteristic reactions in the urine.

As would naturally be expected, water and substances in solution, when injected into the respiratory passages, are rapidly absorbed, and poisons administered in this way manifest their peculiar effects with great promptness. Experimenters on this subject have shown the facility with which liquids may be absorbed from the lungs and the air-passages, but it must be remembered that the natural conditions are never such as to admit of this action. The normal office of the lungs is to absorb oxygen and sometimes a little ni-

trogen from the air; and the absorption of any thing else by these surfaces is unnatural and generally deleterious.

Absorption from Closed Cavities, Reservoirs of Glands, etc.—Facts in pathology, showing absorption from closed cavities, the areolar tissue, the muscular and nervous tissues, the conjunctiva and other parts, are sufficiently well known. In cases of effusion of serum into the pleural, peritoneal, pericardial or synovial cavities, in which recovery takes place, the liquid becomes absorbed. It has been shown by experiment that warm water injected into these cavities is disposed of in the same way. Effusions into the areolar tissue are generally removed by absorption. In cases of penetration of air into the pleura or the general areolar tissue, absorption likewise takes place; showing that gases may be taken up in this way as well as liquids. Effusions of blood beneath the skin or the conjunctiva or in the muscular or nervous tissue may become entirely or in part absorbed. It is true that these are pathological conditions, but in the closed cavities, the processes of exhalation and absorption are constantly going on, although not very actively. As regards absorption from the areolar tissue, the administration of remedies by the hypodermatic method is a familiar evidence of the facility with which soluble substances are taken into the blood, when introduced beneath the skin.

Under some conditions, absorption takes place from the reservoirs of the various glands, the watery portions of the secretions being generally taken up, leaving the solid and the organic matters. It is supposed that the bile becomes somewhat inspissated when it has remained for a time in the gall-bladder, even when the natural flow of the secretion is not interrupted. Certainly, when the duct is in any way obstructed, absorption of a portion of the bile takes place, as is shown by coloration of the conjunctiva and even of the general surface. The serum of the blood, under these conditions, is always strongly colored with bile. It is probable, also, that some of the watery portions of the urine are reabsorbed by the mucous membrane of the urinary bladder when the urine has been long confined in its cavity, although this reabsorption is ordinarily very slight. Absorption may take place from the ducts and the parenchyma of glands, although this occurs chiefly when foreign substances have been injected into these parts.

ABSORPTION OF FATS AND INSOLUBLE SUBSTANCES.

The general proposition that all substances capable of being absorbed are soluble in water or in the digestive fluids must be modified in the case of the fats. These are never dissolved in any considerable quantity in digestion, the only change which they undergo being a minute subdivision in the form of a very fine emulsion. In this condition the fats are taken up by the lacteals and may be absorbed in small quantity by the blood-vessels.

In studying the mechanism of the penetration of fatty particles into the intestinal villi, it has been ascertained that the epithelial cells covering the villi play an important part in this process. During the digestion of fat, these cells become filled with fatty granules (Goodsir). Funke, in his atlas of physiological chemistry, figures the appearances of the intestinal epithelium

during the digestion of fat, as contrasted with the epithelium observed during the intervals of digestion, showing the cells, during absorption, filled with fatty granules.

It has not been demonstrated exactly how the fatty particles penetrate the epithelium of the villi, but the fact of such penetration is undoubted. From the epithelium, the particles of emulsion pass into the substance of the villi—probably into the lymph-spaces and canals—and from these they readily find their way into the lymphatic capillaries. It has been shown that fatty emulsion will pass more easily through porous *septa* that have been moistened with bile; and it is probably in this way mainly that the bile aids in the passage of the fine particles of fat into the lacteals.

As a general law, insoluble substances, with the exception of the fats, are never regularly absorbed, no matter how finely they may be divided. The apparent exceptions to this are mercury in a state of minute subdivision like an emulsion, and carbonaceous particles. As regards mercury, it is well known that minute particles in the form of unguents may be introduced into the system by prolonged frictions; but this can not be taken as an instance of physiological absorption. The passage of small, carbonaceous particles through the pulmonary membrane seems to be purely mechanical. The same thing may possibly occur when fine, sharp particles of carbon are introduced

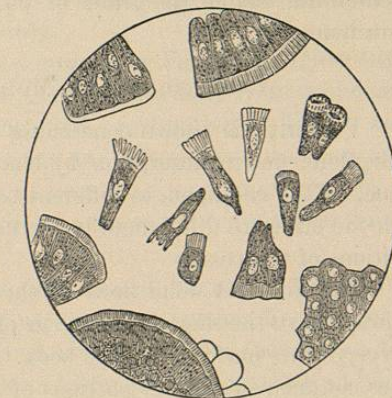


FIG. 94.—Epithelium of the small intestine of the rabbit (Funke).

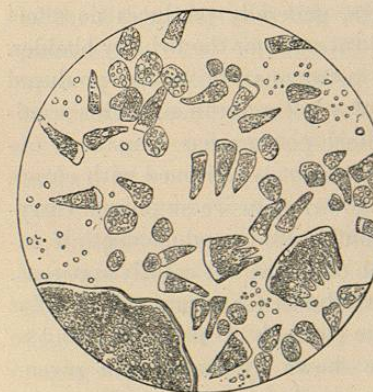


FIG. 95.—Epithelium from the duodenum of a rabbit, two hours after having been fed with melted butter (Funke).

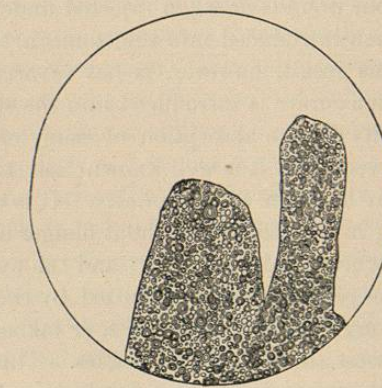


FIG. 96.—Villi filled with fat, from the small intestine of an executed criminal, one hour after death (Funke).

into the alimentary canal; but the experiments of Mialhe with pulverized charcoal, and particularly those of Bérard, Robin and Bernard with lamp-