CHAPTER X.

ABSORPTION—LYMPH AND CHYLE.

Absorption by blood-vessels—Absorption by lacteal and lymphatic vessels—Physiological anatomy of the lacteal and lymphatic vessels—Lymphatic glands—Absorption by the lacteals—Absorption by the skin—Absorption by the respiratory surface—Absorption from closed cavities, reservoirs of glands, etc.—Absorption of fats and insoluble substances—Variations and modifications of absorption—Mechanism of the passage of liquids through membranes—Lymph and chyle—Properties and composition of lymph—Origin and uses of the lymph—Composition of the chyle—Microscopical characters of the chyle—Movements of the lymph and chyle.

DIGESTION has two great objects: one is to liquefy the different alimentary substances; and the other, to begin the series of transformations by which these are rendered capable of nourishing the organism. The matters thus acted upon are taken into the blood as fast as the requisite changes in their constitution are effected; and once received into the circulation, they become part of the nutritive fluid, supplying the loss which the constant regeneration of the tissues from matters furnished by the blood necessarily involves. The only constituents of food which possibly do not obey this general law, as regards their absorption, are the fats. Although a small portion of the fat taken as food may pass directly into the blood-vessels of the intestinal canal, by far the greatest part finds its way into the circulation by means of special absorbent vessels which empty into large veins. In whatever way fat enters the blood, it is not dissolved but is reduced to the condition of a fine emulsion.

ABSORPTION BY BLOOD-VESSELS.

That substances in solution can pass through the walls of the capillaries and of the small veins, and that absorption actually takes place in great part by blood-vessels, are facts which hardly demand discussion at the present day. Soluble substances which have disappeared from the alimentary canal have been repeatedly found in the blood coming from this part, even when the lymphatics have been divided and communication existed only through the blood-vessels; and it has been shown that during absorption, the blood of the portal vein is rich in albuminoids, sugar and other matters resulting from digestion.

In the mouth and œsophagus, the sojourn of alimentary matters is so brief and the changes which they undergo are so slight, that no considerable absorption can take place. It is evident, however, that the mucous membrane of the mouth is capable of absorbing certain soluble matters, from the effects which are constantly observed when the smoke or the juice of tobacco is retained in the mouth, even for a short time. In the stomach, however, absorption takes place with great activity. A large proportion of the ingested liquids and of those constituents of food which are dissolved by the gastric juice and converted into peptones is taken up directly by the blood-vessels of the stomach. It may, indeed, be assumed, as a general law, that alimentary matters are in great part absorbed as soon as their digestive transformations in the alimentary canal have been completed.

In the passage of the food along the intestinal canal, as the digestion of the albuminoids is completed, these matters are absorbed, and their passage into the mass of blood is indicated by an increase in its proportion of albuminoid constituents. The greatest part of the food is absorbed by the intestinal mucous membrane, and with the alimentary substances proper, a large quantity of secreted fluid is reabsorbed. This fact is particularly marked as regards the bile. The biliary salts disappear as the alimentary mass passes down the intestine, and undoubtedly are absorbed, although they are so changed that they can not be detected in the blood by the ordinary tests. In this portion of the alimentary canal, it will be remembered, an immense absorbing surface is provided by the arrangement of the mucous membrane in folds, forming the valvulæ conniventes, and by the presence of villi, which are found throughout the small intestine. A certain portion of the gaseous contents of the intestines is also taken up, although it is not easily ascertained what particular gases are thus absorbed.

ABSORPTION BY LACTEAL AND LYMPHATIC VESSELS.

The history of the discovery of what is ordinarily termed the absorbent system of vessels, from the vague allusions of Hippocrates, Galen, Aristotle and others, to the description of the thoracic duct in the middle of the sixteenth century, by Eustachius, and finally to the discovery of the lacteals by Asellius, in 1622, is more interesting in an anatomical than in a physiological point of view. The history of the anatomy of the absorbent system dates from the discovery of the thoracic duct; but from the discovery of the lacteals, by Asellius, dates the history of these vessels as the carriers of nutritive matters from the intestinal canal to the general system.

In 1649, Pecquet discovered the receptaculum chyli and demonstrated that the lacteals did not pass to the liver, but emptied the chyle into the thoracic duct, by which it is finally conveyed into the venous system. In 1650–'51, the anatomical history of the absorbent vessels was completed by the discovery, by Rudbeck, of vessels carrying a colorless fluid, in the liver and finally in almost all parts of the body. Rudbeck demonstrated the anatomical identity of these vessels with the lacteals. They were afterward studied by Bartholinus, who gave them the name of lymphatics.

The idea, which dates from the discoveries of Asellius and Pecquet, that the lacteals absorb all the products of digestion, was disproven by the experiments of Magendie and of those who experimented after him upon vascular absorption. It is now known that fats in the form of a very fine emulsion are absorbed by the lacteals, and that these are the only constituents of food taken up in great quantity by this system of vessels. It becomes an important question to determine, however, whether the lacteals be not concerned, to some extent, in the absorption of drinks, the albuminoids, saline and saccharine matters, etc. This question will be taken up after a consideration of certain points in the anatomy of the lymphatic system.

Physiological Anatomy of the Lacteal and Lymphatic Vessels.—The lacteals are the intestinal lymphatics; and during the intervals of intestinal

absorption they carry a liquid which is identical with the contents of other lymphatic vessels. In their structure, also, the lacteals are identical with the general lymphatics.

Owing to the exceeding tenuity of the walls of the small lymphatics and the existence of great numbers of valves which prevent injection from the large trunks, the anatomy of these vessels is studied with some difficulty; and still greater difficulty is presented in the study of the vessels of origin of the lymphatic system in different tissues and organs. The origin of the lymphatics in the intestinal villi has already been considered, and it remains to study the origin of these vessels in other parts.

Comparatively recent investigations, particularly those of Von Recklinghausen and his followers, have entirely changed the views of anatomists with regard to the mode of origin of the lymphatics of various parts; but the results of these investigations are so definite and positive and have been so fully confirmed, that they are now almost universally adopted. According to these results, the lymphatics have several modes of origin.

In the connective tissues, which are so widely distributed in the body, there are always found, irregularly shaped, stellate spaces, which communicate

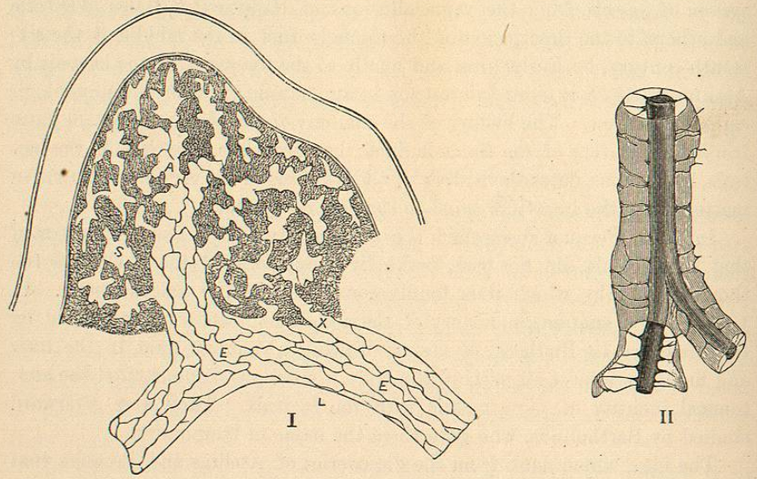

FIG. 82.—*Origin of lymphatics* (Landois).

I. From the central tendon of the diaphragm of the rabbit (semi-diagrammatic): S, lymph-canals communicating by X with the lymphatic vessel L; A, origin of the lymphatic by a union of lymph-canals; E, E, endothelium.
II. Perivascular canal.

with each other by branching canals, that can properly be called lymph-spaces, or "juice-canals." These spaces contain a liquid and large numbers of leucocytes. The leucocytes in these spaces may be called lymph-corpuscles, as they eventually find their way into the true lymphatic vessels; but they are thought to be white blood-corpuscles which have passed through the stomata of the capillary blood-vessels. The connective-tissue lymph-spaces, by certain of their branches, finally communicate with the so-called lymph-

capillaries, through what have been regarded as the stomata of these vessels. These anatomical *data* have led to the following view with regard to the relations between the blood, the lymph and the tissues.

Nutrient matters are supplied to the parts by transudation through the walls of the capillary blood-vessels; and the effete matters pass from the lymph-spaces into the true lymphatic vessels, to be finally carried to the venous system. In certain tissues and organs, however, such as the cornea and fibrous membranes, the lymph-spaces or canals supply the nutrient fluid; and in the glands they probably supply part of the material used in the formation of the secretions.

In the serous membranes and in other analogous structures, there are large numbers of openings into the cavities; and the peritoneum, pleura, pericardium, tunica vaginalis testis, chambers of the eye, labyrinth of the internal ear and subarachnoid space are to be regarded as great lymph-sacs, the contained fluids being lymph, without, however, presenting the so-called lymph-corpuscles.

The relations between the blood-vessels and the smallest lymphatics are very close in certain parts. In the cerebro-spinal centres, Robin and His have demonstrated a system of canals which surround the small blood-vessels and are connected with the lymphatic-trunks or reservoirs described by Fohmann and found under the pia mater. The capillary blood-vessels thus float in surrounding vessels filled with liquid. These vessels surrounding the blood-vessels are called perivascular canals, and the contained liquid is true lymph, containing leucocytes, or lymph-corpuscles. They exceed the blood-vessels in diameter by $\frac{1}{1250}$ to $\frac{1}{400}$ of an inch (20 to 62μ). Since the perivascular canals of the nerve-centres have been described, similar vessels have been found in the retina and in the liver.

The true capillary lymphatics have been studied in various parts by means of mercurial injections, but the presence of valves in the small trunks renders it necessary to make these injections from the periphery. The vessels have been injected in certain situations with mercury, by simply puncturing with a fine-pointed canula the parts in which the plexus is supposed to exist, and allowing the liquid to gently diffuse itself. Following the course of the vessels, the injection passes into the larger trunks and thence to the lymphatic glands. The regularity of the plexus through which the liquid is first diffused and the passage of the injection through the larger vessels to the glands are proof that the lymphatics have been penetrated and that the appearances observed are not the result of mere infiltration in the tissue. It does not appear that the vessels composing this plexus vary much in size. They are quite elastic, and after distention by injection, they return to a very small diameter when the fluid is allowed to escape.

By the method above indicated, it is possible to inject the superficial lymphatics of the skin, the deeper vessels situated just beneath the skin, and vessels in the serous membranes, glandular organs, lungs, tendons etc., in addition to the larger trunks, such as the thoracic duct. The lacteal system presents essentially the same anatomical characters as the general lymphatics,

and the vessels are filled with colorless lymph during the intervals of digestion. In many situations the lymphatics present in their course little, solid structures, called lymphatic glands, although, as regards structure and office, they are not true glandular organs. The smallest capillary lymphatics have a diameter of about $\frac{1}{300}$ of an inch (83 μ). This may be taken as their average diameter in the primitive plexus. This plexus, when the vessels are abundant, as they are in certain parts of the cutaneous surface, resembles an ordinary plexus of capillary blood-vessels, except that the walls of the vessels

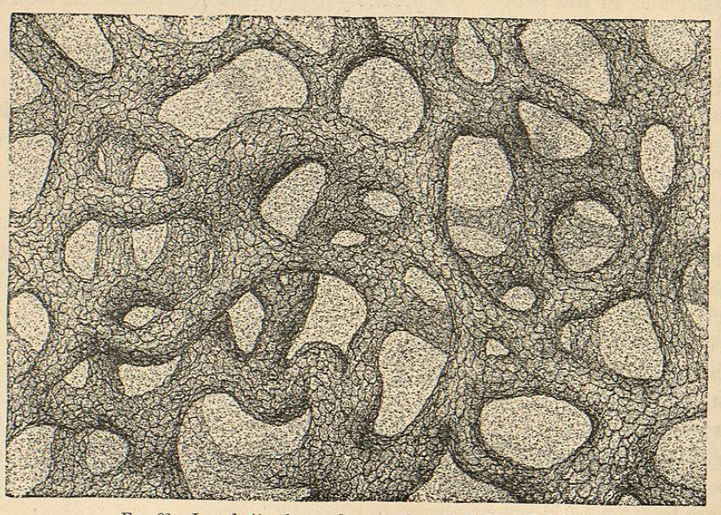

FIG. 83.—*Lymphatic plexus, showing the endothelium* (Belaieff).

are thinner and their diameter is greater. The vessels are lined by endothelial cells, the borders of which are brought into view by the action of silver nitrate, as is shown in Fig. 83.

The smallest lymphatic vessels are by far the most abundant. They are arranged in the form of a fine plexus, very superficially situated in the skin. A second plexus exists just beneath the skin, composed of vessels of much greater diameter. The skin is thus enclosed between two plexuses of capillary lymphatics. A plexus analogous to the superficial plexus of the skin is found just beneath the surface of the mucous membranes. These may, indeed, be classed with the superficial lymphatics. The deep lymphatics are much larger and less abundant, and their origin is less easily made out. These accompany the deeper veins in their course. They receive the lymph from the superficial vessels.

No valvular arrangement is found in the smallest lymphatics; but the vessels coming from the primitive plexuses, as well as the large vessels, contain valves in great numbers. These valves, being so closely set in the vessels, give to them, when filled with injection, a peculiar and characteristic beaded appearance.

The course of the lymphatics is generally direct. As they pass toward the great trunks by which they communicate with the venous system, they

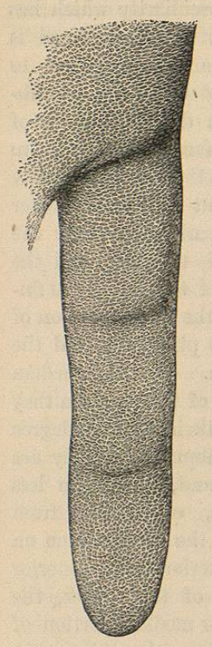

FIG. 84.—*Superficial lymphatics of the skin of the palmar surface of the finger* (Sappey).

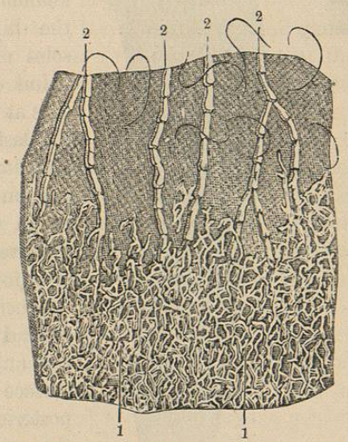

FIG. 85.—*Deep lymphatics of the skin of the finger* (Sappey).
1, 1, deep net-work of cutaneous lymphatics; 2, 2, 2, 2, lymphatic trunks connected with this net-work.

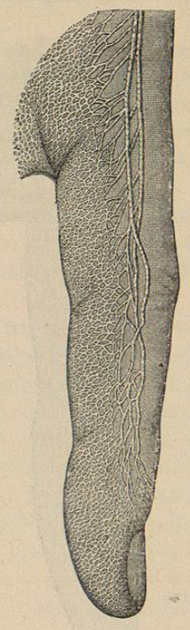

FIG. 86.—*Same finger, lateral view, showing lymphatic trunks connected with the superficial net-work* (Sappey).

present a peculiar anastomosis with the adjacent vessels, called anastomosis by bifurcation; that is, as a vessel passes along with other vessels nearly parallel with it, it bifurcates, and the two branches pass into the nearest vessels on either side. These anastomoses are quite frequent, and they generally occur between vessels of equal size. In their course, the vessels pass through the so-called lymphatic glands.

A notable peculiarity in the lymphatic vessels is that they vary very little in size, being nearly as large at the extremities as they are near the trunk. In their course, they are always much smaller than the veins and do not progressively enlarge as they pass on to the great lymphatic trunks. The largest vessels that pass from the skin are $\frac{1}{25}$ to $\frac{1}{12}$ of an inch (1 to 2 mm.) in diameter, and the larger vessels, in their course, have a diameter of $\frac{1}{12}$ to $\frac{1}{8}$ of an inch (2 to 3 mm.). As in the case of the smallest lymphatics of the primitive plexuses, the elasticity of the walls of the vessels renders their diameter greatly dependent upon the pressure of fluid in their interior. Many anatomists have noticed that vessels which are hardly perceptible while empty are capable of being dilated to the diameter of half a line (about 1 mm.)

or more, returning to their original size as soon as the distending fluid is removed.

In the lymphatics of the skin, the only important peculiarity which has not yet been mentioned is that the vessels appear to be very unequally distributed in different parts of the surface. According to Sappey, they are particularly abundant in the scalp over the biparietal suture, the soles of the feet and the palms of the hand, the fingers at the lateral portion of the last phalanges, and the scrotum. In the median portion of the scrotum they attain their highest degree of development. They are also found, though in less number, originating from around the median line on the anterior and posterior surface of the trunk, the posterior median portion of the extremities, the skin over the mammæ, and around the orifices of the mucous passages. Sappey has injected lymphatic vessels in the anterior portion of the forearm, the thigh and the leg, and in the middle portion of the face, although they are demonstrated with difficulty in these situations. If they exist at all in other portions of the cutaneous surface, they are not abundant.

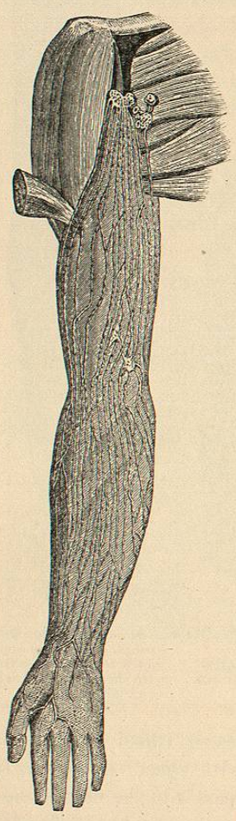

FIG. 87.—*Superficial lymphatics of the arm* (Sappey).

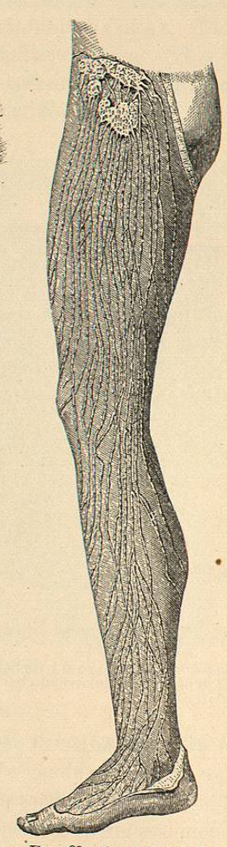

FIG. 88.—*Superficial lymphatics of the leg* (Sappey).

In the mucous membranes the lymphatics are very abundant. Here are found, as in the skin, two distinct layers which enclose between them the entire thickness of the mucous membrane. The more superficial of these layers is composed of a rich plexus of small vessels, and beneath the mucous membrane, is a plexus consisting of vessels of larger size. The superficial plexus is very rich in the mixed structure which forms the lips and the glans penis, and around the orifices of the mouth, the nares, the vagina and the anus. There are certain mucous membranes in which the lymphatics have never been injected. In the serous membranes, lymphatics have been demonstrated in great abundance. Lymphatics have been demonstrated taking their origin in the voluntary muscles, the diaphragm, the heart and the non-striated muscular coats of the hollow viscera, although their investigation in these situations is difficult.

Lymphatics are found coming from the lungs in great numbers. These arise in the walls of the air-cells and surround each pulmonary lobule with a close plexus. The deep vessels follow the course of the bronchial tubes, passing through the bronchial glands and the glands at the bifurcation of the trachea, to empty into the thoracic duct and the great lymphatic duct of the right side.

In the glandular system, including the ductless glands, and in the ovaries, the lymphatic vessels are, as a rule, more abundant than in any other parts of the body. They are especially abundant in the testicles, the ovaries, the liver and the kidneys.

The lymphatic vessels from the superficial and deep portions of the head and face on the right side, and those from the superficial and deep portions of the right arm, the right half of the chest, and the mammary gland, with a few vessels from the lungs, pass into the great lymphatic duct, ductus lymphaticus dexter, which empties into the venous system at the junction of the right subclavian with the internal jugular. This vessel is about an inch (25·4 mm.) in length and one-twelfth to one-eighth of an inch (2 to 3 mm.) in diameter. It is provided with a pair of semilunar valves at its opening into the veins, which effectually prevent the ingress of blood. The vessels from the inferior extremities, and those from the lower portions of the trunk, the pelvic viscera, the abdominal organs generally and the left half of the body above the abdomen empty into the thoracic duct.

In their course, all of the lymphatics pass through the small, flattened, oval bodies, called the lymphatic glands, which are so abundant in the groin, the axilla, the pelvis and in some other parts. Two to six vessels, called the vasa afferentia, penetrate each gland, having first broken up into a number of smaller vessels just before they enter. They pass out by a number of small vessels which unite to form one, two or three trunks, generally of larger size than the vasa afferentia. The vessels which thus emerge from the glands are called vasa efferentia.

The lymphatics of the small intestine, called lacteals, pass from the intestine between the folds of the mesentery to empty, sometimes by one and sometimes by four or five trunks, into the receptaculum chyli. In their course, the lacteals pass through several sets of lymphatic glands, which are here called mesenteric glands.

The thoracic duct, into which most of the lymphatic vessels empty, is a vessel with very delicate walls and about the size of a goose-quill. It begins by a dilatation, more or less marked, called the receptaculum chyli. This is situated upon the second lumbar vertebra. The canal passes upward in the median line for the inferior half of its length. It then inclines to the left side, forms a semicircular curve something like the arch of the aorta, and empties at the junction of the left subclavian with the internal jugular vein.