as soon as absorption of alimentary matters begins, certain nutritive matters are taken up in quantity by these vessels, and their contents are known under the name of chyle.

In the human subject and in carnivorous animals, the chyle, taken from the lacteals near the intestine, where it is nearly pure, or from the thoracic duct, when it is mixed with lymph, is a white, opaque, milky fluid, of a slightly saline taste and an odor which is said to resemble that of the semen. The odor is also said to be characteristic of the animal from which the fluid is taken; although this is not very marked, except on the addition of a concentrated acid, the process employed by Barreul to develop the characteristic odor in the fluids from different animals. Bouisson has found that the peculiar odor of the dog was thus developed in fresh chyle taken from the thoracic duct.

The reaction of the chyle is either alkaline or neutral. Dalton noted an alkaline reaction in the chyle of the goat and of the dog; and a specimen of chyle taken from a criminal immediately after execution, examined by Rees, was neutral. Leuret and Lassaigne obtained the fluid from the receptaculum chyli in a man that had died of cerebral inflammation, and found its reaction to be alkaline.

The specific gravity of the chyle is always less than that of the blood; but it is very variable and depends upon the quality of the food and particularly upon the quantity of liquids ingested. Lassaigne found the specific gravity of a specimen of pure chyle taken from the mesenteric lacteals of a bull to be 1013, and the specific gravity of the specimen of human chyle examined by Rees was 1024.

The differences in the appearance of the chyle in different animals depend chiefly upon the food. Colin found the chyle milky in the carnivora, especially after fats had been taken in quantity; while in dogs that were nourished with articles containing but little fat, its appearance was hardly lactescent. Tiedemann and Gmelin found the chyle almost transparent in herbivora fed with hay or straw. They also observed that the chyle was nearly transparent in dogs fed with liquid albumen, fibrin, gelatine, starch and gluten; while it was white in the same animals fed with milk, meat, bones etc.

It is impossible to give an accurate estimate of the entire quantity of pure chyle taken up by the lacteal vessels. When it finds its way into the thoracic duct, it is mingled immediately with all the lymph from the lower extremities; and the large quantities of fluid which have been collected from this vessel by Colin and others give no idea of the quantity of chyle absorbed from the intestinal canal. No attempt will be made, therefore, to give even an approximate estimate of the absolute quantity of chyle; but it is evident that this is variable, depending upon the nature of the food and the quantity of liquids ingested.

Like the lymph, the chyle, when removed from the vessels, undergoes coagulation. Different specimens of the fluid vary very much as regards the rapidity with which coagulation takes place. The chyle from the thoracic

duct generally coagulates in a few minutes. The first portion of the fluid collected from the human subject by Rees—the chyle was collected in this case in two portions—coagulated in an hour. Received into an ordinary glass vessel, the chyle generally separates more or less completely after coagulation, into clot and serum. The serum is quite variable in quantity and is never clear. Its milkiness does not depend entirely upon the presence of particles of emulsified fat, and it is not rendered transparent by ether. It contains, also, a number of leucocytes and organic granules.

Observations have been made with reference to the influence of different kinds of food upon the chyle; but these have not been followed by any definite results that can be applied to the human subject. It is usual to find the chyle fluid in the lacteals and in the thoracic duct for many hours after death; but it soon coagulates after exposure to the air. Although the entire lacteal system is sometimes found, in the human subject and in the inferior animals, filled with perfectly opaque, coagulated chyle, the fluid does not often coagulate in the vessels.

Composition of the Chyle.—Analyses of the milky fluid taken from the thoracic duct during full digestion by no means represent the composition of pure chyle; and it is only by collecting the fluid from the mesenteric lacteals, that it can be obtained without a very large admixture of lymph. In the human subject, it is rare even to have an opportunity of taking the fluid from the thoracic duct in cases of sudden death during digestion; and in most of the inferior animals which have been operated upon, it is difficult to obtain fluid from the small lacteals in quantity sufficient for accurate analysis. In operating upon the ox, however, Colin has succeeded in collecting pure chyle in considerable quantity.

In the analysis by Rees, the fluid was taken from the thoracic duct of a vigorous man, a little more than an hour after his execution by hanging. The subject was apparently in perfect health to the moment of his death. The evening before, he ate two ounces (56·7 grammes) of bread and four ounces (113·4 grammes) of meat. At seven A. M., precisely one hour before death, he took two cups of tea and a piece of toast; and he drank a glass of wine just before mounting the scaffold. When the dissection was made, the body was yet warm, although the weather was quite cold. The thoracic duct was rapidly exposed and divided, and about six fluidrachms (22·2 c. c.) of milky chyle were collected. The fluid was neutral and had a specific gravity of 1024. The following was its approximate composition:

COMPOSITION OF HUMAN CHYLE FROM THE THORACIC DUCT.

Water	904·8
Albumin, with traces of fibrinous matter	70·8
Aqueous extractive	5·6
Alcoholic extractive, or osmazome	5·2
Alkaline chlorides, carbonates and sulphates, with traces of alkaline phosphates and oxides of iron	4·4
Fatty matters	9·2
	1,000·0

Of the constituents of the chyle not given in the ordinary analyses, the most important are the urea, which in all probability is derived exclusively from the lymph, and sugar, coming from the saccharine and amylaceous articles of food during digestion.

The difference in chemical composition between the unmixed lymph and the chyle is illustrated in a comparative examination of these two fluids taken from a donkey. The fluids were collected by Lane, the chyle being taken from the lacteals before reaching the thoracic duct. The animal was killed seven hours after a full meal of oats and beans. The following analyses of the fluids were made by Rees:

COMPOSITION OF CHYLE AND LYMPH BEFORE REACHING THE THORACIC DUCT.

	Chyle.	Lymph.
Water	902·37	965·36
Albuminous matter	35·16	12·00
Fibrinous matter	3·70	1·20
Animal extractive matter soluble in water and alcohol	3·32	2·40
Animal extractive matter soluble in water only	12·33	13·19
Fatty matter	36·01	a trace
Salts, { Alkaline chlorides, sulphates and carbonates, with traces of alkaline phosphates and oxide of iron. }	7·11	5·85
	1,000·00	1,000·00

The above analyses show a very marked difference in the proportion of solid constituents in the two fluids. The chyle contains about three times as much albumen and fibrin as the lymph, with a larger proportion of salts. The proportion of fatty matters in the chyle is very great, while in the lymph there exists only a trace. The individual constituents of the chyle given in the above tables do not demand any farther consideration than they have already received under the head of lymph. The albuminoid matters are in part derived from the food, and in part from the blood, through the admixture of the chyle with lymph. The fatty matters are derived in greatest part from the food. As far as has been ascertained by analyses of the chyle for salts, this fluid has been found to contain essentially the same inorganic constituents as the plasma of the blood.

The presence of sugar in the chyle was first mentioned by Brande, who described it, however, rather indefinitely. Glucose was first distinctly recognized in the chyle by Trommer, and its existence in many of the higher orders of animals has since been fully established by Colin.

Microscopical Characters of the Chyle.—The milky appearance of the chyle as contrasted with the lymph is due to the presence of a large number of very minute fatty granules. The liquid becomes much less opaque when treated with ether, which dissolves many of the fatty particles. In fact, the chyle of the thoracic duct is nothing more than lymph to which an emulsion of fat in a liquid containing albuminoid matters and salts is temporarily added during the process of intestinal absorption. The quantity of fatty granules in the chyle varies considerably with the diet, and it generally di-

minishes progressively from the smaller to the larger vessels, on account of the constant admixture of lymph. The size of the granules is pretty uniformly $\frac{1}{25000}$ to $\frac{1}{12500}$ of an inch (1 to 2 μ). They are much smaller and more uniform in size in the lacteals than in the cavity of the intestine. Their constitution is not constant; and they are composed of the different varieties of fat which are taken as food, mixed with each other in various proportions. The ordinary corpuscular elements of the lymph, leucocytes and globulins, are also found in variable quantity in the chyle.

Movements of the Lymph and the Chyle.

Compared with the current of blood, the movements of the lymph and chyle are feeble and irregular; and the character of these movements is such that they are evidently due to a variety of causes. As regards those constituents which are derived directly from the blood, the lymph may be said to undergo a true circulation; inasmuch as there is a constant transudation at the peripheral portion of the vascular system, of fluids which are returned to the circulating blood by the communications of the lymphatic system with the great veins. The constituents of the lymph, however, are not derived entirely from the blood, a considerable portion resulting from interstitial absorption in the general lymphatic system; and the chyle contains certain nutritive matters absorbed by the lacteal vessels. These are, physiologically, the most important constituents of the lymph and chyle; and they are taken up simply to be carried to the blood and do not pass again from the general vascular system into the lymphatics.

As far as the mode of origin of the lymph and chyle has any bearing upon the movements of these fluids in the lymphatic vessels, there is no difference between the imbibition of new matters from the tissues or from the intestinal canal and the transudation of the liquid portions of the blood; for the mechanism of the passage of liquids from the blood-vessels is such that the motive power of the blood can not be felt. An illustration of this is in the mechanism of the transudation of the liquid portions of the secretions. The force with which fluids are discharged into the ducts of the glands is very great and is independent of the action of the heart, being due entirely to the processes of transudation and secretion. This is combined with the force of imbibition, and with it forms one of the important agents in the movements of the lymph and chyle. These movements are studied with great difficulty. One of the first peculiarities to be observed is that under normal conditions, the vessels are seldom distended, and the quantity of fluid which they contain is subject to considerable variation. As far as the flow in the vessels of medium size is concerned, the movement is probably continuous, subject only to certain momentary obstructions or accelerations from various causes; but in the large vessels situated near the thorax and in those within the chest, the movements are in a marked degree remittent, or they may even be intermittent. All experimenters who have observed the flow of lymph or chyle from a fistula into the thoracic duct have noted a constant acceleration with each act of expiration; and an impulse synchronous with the pulsations of the heart has frequently been observed.

The fact that the lymphatic system is never distended, and the existence of the valves, by which different portions may become isolated, render it impossible to estimate the general pressure of fluid in these vessels. This is undoubtedly subject to great variations in the same vessels at different times, as well as in different parts of the lymphatic system. It is well known, for example, that the degree of distention of the thoracic duct is very variable, its capacity not infrequently being many times increased during active absorption. At the same time it is difficult to attach a manometer to any part of the lymphatic system without seriously obstructing the circulation and consequently exaggerating the normal pressure; but the force with which liquids penetrate these vessels is very great. This is illustrated by the experiment of tying the thoracic duct; for after this operation, unless communicating vessels exist by which the fluids can be discharged into the venous system, their accumulation is frequently sufficient to rupture the vessel.

The general rapidity of the current in the lymphatic vessels has never been accurately estimated. As a natural consequence of the variations in the distention of these vessels, the rapidity of the circulation must be subject to constant modifications. Béclard, making his calculation from the experiments of Colin, who noted the quantity of fluid discharged in a given time from fistulous openings into the thoracic duct, estimated that the rapidity of the flow in this vessel was about one inch (25·4 mm.) per second. This estimate, however, can be only approximate; and it is evident that the flow must be much less rapid in the vessels near the periphery than in the large trunks, as the liquid moves in a space which becomes rapidly contracted as it approaches the openings into the venous system.

Various influences combine to produce the movements of fluids in the lymphatic system, some being constant in their operation, and others, intermittent or occasional. These will be considered, as nearly as possible, in the order of their relative importance.

The forces of endosmosis and transudation are undoubtedly the main causes of the lymphatic circulation, more or less modified, however, by influences which may accelerate or retard the current; but this action is capable in itself of producing the regular movement of the lymph and chyle. It is a force which is in constant operation, as is seen in cases of ligation of the thoracic duct, a procedure which must finally abolish all other forces which aid in producing the lymphatic circulation. When the receptaculum chyli is ruptured as a consequence of obstruction of the thoracic duct, the vessel gives way as the result of the constant endosmotic action, in the same way that the exposed membranes of an egg may be ruptured by endosmosis, when immersed in water.

The situations in which the endosmotic force originates are at the periphery, where the single wall of the vessels is very thin, and where the extent of absorbing surface is large. If liquids can penetrate with such rapidity and

force through the walls of the blood-vessels, where their entrance is opposed by the pressure of the fluids already in their interior, they certainly must pass without difficulty through the walls of the lymphatics, where there is no lateral pressure to oppose their entrance, except that produced by the weight of the column of liquid. This pressure is readily overcome; and the valves in the lymphatic system effectually prevent any backward current.

In describing the anatomy of the lymphatic system, it has already been stated that the large vessels and those of medium size are provided with non-striated muscular fibres and are endowed with contractility. This fact has been demonstrated by physiological as well as anatomical investigations. Béclard stated that he often produced contractions of the thoracic duct by the application of the two poles of an inductive apparatus. It is not uncommon to see the lacteals become reduced in size to a mere thread, even while under observation. Although experiments have generally failed to demonstrate any regular, rhythmical contractions in the lymphatic system, it is probable that the vessels contract upon their contents, when they are unusually distended, and thus assist the circulation, the action of the valves opposing a regurgitating current. This action, however, can not have any considerable and regular influence upon the general current.

Contractions of the ordinary voluntary muscles, compression of the abdominal organs by contraction of the abdominal muscles, peristaltic movements of the intestines and pulsations of large arteries situated against the lymphatic trunks, particularly the thoracic aorta, are all capable of increasing the rapidity of the circulation of the lymph and chyle.

The contractions of voluntary muscles assist the lymphatic circulation in precisely the way in which they influence the flow of blood in the venous system; and there is nothing to be added regarding this action to what has already been said on this subject in connection with the description of the venous circulation.

Increase in the flow of chyle in the thoracic duct, as the result of compression of the abdominal organs or of kneading the abdomen with the hands, was observed by Magendie, and the fact has been confirmed in all recent experiments on this subject. The same effect, though probably less in degree, is produced by the peristaltic contractions of the intestines.

When a tube is introduced into the upper part of the thoracic duct, it is frequently the case that the fluid is discharged with increased force at each pulsation of the heart. This was frequently observed by Dalton in his experiments on the thoracic duct, and he described the jets as being "like blood coming from a small artery when the circulation is somewhat impeded." This impulse is due to compression of the thoracic duct as it passes under the arch of the aorta. Its influence upon the general current of the lymph and chyle is probably insignificant.

While the *vis a tergo* must be regarded as by far the most important agent in the production of the lymphatic circulation, the movements of fluids in the thoracic duct receive constant and important aid from the respiratory acts. This fact has long been recognized; and in the works of

Haller there is a full discussion of the influence of the diaphragm and of the movements of the thorax upon the circulation of chyle. Colin always found marked impulses in the flow of chyle from a fistula into the thoracic duct, which were synchronous with the movements of respiration. With each act of expiration the fluid was forcibly ejected, and with inspiration the flow was very much diminished or even arrested. These impulses became much more marked when respiration was interfered with and the efforts became violent. The impulses were sometimes so decided, that the pulsations were repeated in a long elastic tube attached to the canula for the purpose of collecting the fluid.

From all these considerations, it is evident that although there are many conditions capable of modifying the currents in the lymphatic system, the regular flow of the lymph and chyle depends chiefly upon the *vis a tergo;* but the vessels themselves sometimes undergo contraction, and they are subject to occasional compression from surrounding parts, which, from the existence of valves in the vessels, must favor the current toward the venous system. The alternate dilatation and compression of the thoracic duct with the acts of respiration likewise aid the circulation, and they are more efficient than any other force, except the *vis a tergo.* The action of the valves is precisely the same in the lymphatic as in the venous system.

CHAPTER XI.

SECRETION.

Classification of the secretions—Mechanism of the production of the true secretions—Mechanism of the production of the excretions—Influence of the composition and pressure of the blood on secretion—Influence of the nervous system on secretion—Anatomical classification of glandular organs—Classification of the secreted fluids—Synovial membranes and synovia—Mucous membranes and mucus—Physiological anatomy of the sebaceous, ceruminous and Meibomian glands—Ordinary sebaceous matter—Smegma of the prepuce and of the labia minora—Vernix caseosa—Cerumen—Meibomian secretion—Mammary secretion—Physiological anatomy of the mammary glands—Mechanism of the secretion of milk—Conditions which modify the lacteal secretion—Quantity of milk—Properties and composition of milk—Microscopical characters of milk—Composition of milk—Variations in the composition of milk—Colostrum—Lacteal secretion in the newly-born—Secretory nerve-centres.

THE processes of secretion are intimately connected with general nutrition. In the sense in which the term secretion is usually received, it embraces most of the processes in which there is a separation of matters from the blood by glandular organs or a formation of a new fluid out of materials furnished by the blood. The blood itself, the lymph and the chyle, are in no sense to be regarded as secretions. These fluids, like the tissues, are permanent parts of the organism, undergoing those changes only that are necessary to their proper regeneration. They are likewise characterized by the presence of certain formed anatomical elements, which themselves undergo processes of molecular destruction and regeneration. These characters are

not possessed by the secretions. As a rule, the latter are homogeneous fluids, without formed anatomical elements, except as accidental constituents, such as the desquamated epithelium in mucus or in sebaceous matter. The secretions are either discharged from the body, when they are called excretions, or after having performed their proper office as secretions, are absorbed in a more or less modified form by the blood.

Physiologists now regard secretion as the act by which fluids, holding certain substances in solution, and sometimes containing peculiar ferments but not necessarily possessing formed anatomical elements, are separated from the blood or are formed by special organs out of materials furnished by the blood. These organs may be membranes, follicles or collections of follicles, or tubes. In the latter instances they are called glands. The liquids thus formed are called secretions; and they may be destined to perform some office connected with nutrition or may be simply discharged from the organism.

It is not strictly correct to speak of formed anatomical elements as products of secretion, except in the instance of the fatty particles in the milk. The leucocytes found in pus, the spermatozoids of the seminal fluid, and the ovum, which are sometimes spoken of as products of secretion, are anatomical elements developed in the way in which such structures are ordinarily formed. For example, leucocytes, or pus-corpuscles, may be developed without the intervention of any special secreting organ; and spermatozoids and ova are generated in the testicles and the ovaries, by a process entirely different from ordinary secretion. It is important to recognize these facts in studying the mechanism by which the secretions are produced.

Classification of the Secretions.—Certain secretions are formed by special organs and have important uses which do not involve their discharge from the body. These may be classed as the true secretions; and the most striking examples of such are the digestive fluids. Each one of these fluids is formed by a special gland or set of glands, which generally has no other office; and they are never produced by any other part. It is the gland which produces the characteristic constituent or constituents of the true secretions, out of materials furnished by the blood; and the matters thus formed never pre-exist in the circulating fluid. The office which these fluids have to perform is generally not continuous; and when this is the case, the flow of the secretion is intermittent, taking place only when its action is required. When the parts which produce one of the true secretions are destroyed, as is sometimes done in experiments upon living animals, the characteristic constituents of this particular secretion never accumulate in the blood nor are they formed vicariously by other organs. The simple effect of such an experiment is absence of the secretion, with the disturbances consequent upon the loss of its physiological action.

Certain other of the fluids are composed of water, holding one or more characteristic constituents in solution, which result from the physiological wear of the tissues. These matters have no office to perform in the animal economy and are simply separated from the blood to be discharged from the