ing to the observations of Beaumont and Silliman, was 1005; but later, F. G. Smith found it in one instance, 1008, and in another, 1009. There is every reason to suppose that the fluid, in the case of St. Martin, was perfectly normal, and 1005 to 1009 may be taken as the range of the specific gravity of the gastric juice in the human subject.

The gastric juice is described by Beaumont as inodorous, when taken directly from the stomach; but it has rather an aromatic and a not disagreeable odor when it has been kept for some time. It is a little saltish, and its taste is similar to that of "thin, mucilaginous water slightly acidulated with muriatic acid."

It has been found by Beaumont, in the human subject, and by those who have experimented on the gastric juice of the lower animals, that this fluid, if kept in a well stoppered bottle, will retain its chemical and physiological properties for an indefinite period. The only change which it undergoes is the formation of a pellicle, consisting of a vegetable, confervoid growth, upon the surface, some of which breaks up and falls to the bottom of the vessel, forming a whitish, flocculent sediment. In addition to this remarkable faculty of resisting putrefaction, putrefactive changes are arrested in decomposing animal substances, both when taken into the stomach and when exposed to the action of the gastric juice out of the body.

There are on record no minute quantitative analyses of the human gastric juice, except those by Schmidt, of the fluid from the stomach of a woman with gastric fistula; and in this case there is reason to suppose that the secretion was not normal. The analysis of the gastric juice of St. Martin by Berzelius was not minute. The analyses of Schmidt give less than six parts per thousand of solid matter, while Berzelius found more than twelve parts per thousand. In all the comparatively recent analyses, there have been found a free acid or acids, a peculiar organic matter, generally called pepsine, and various inorganic salts.

The following analysis by Bidder and Schmidt gives the mean of nine observations upon dogs:

COMPOSITION OF THE GASTRIC JUICE OF THE DOG (BIDDER AND SCHMIDT).

Water	973·062
Ferment (pepsine)	17·127
Free hydrochloric acid	3·050
Potassium chloride	1·125
Sodium chloride	2·507
Calcium chloride	0·624
Ammonium chloride	0·468
Calcium phosphate	1·729
Magnesium phosphate	0·226
Ferric phosphate	0·082
	1,000·000

In another series of three observations, in which the saliva was allowed to pass into the stomach, the proportion of free acid was 2·337, and the proportion of organic matter was somewhat increased.

Organic Constituent of the Gastric Juice.—Pepsine is an organic nitrogenized substance, which is peculiar to the gastric juice and essential to its digestive properties. When the gastric fluid was first obtained, even by the imperfect methods employed anterior to the observations of Beaumont and of Blondlot, an organic matter was spoken of as one of its constituents.

Experiments on artificial digestive fluids, by Eberle, Schwann and Müller, Wasmann and others, have demonstrated that acidulated extracts of the mucous membrane of the stomach contain an organic matter, first isolated by Wasmann, on which the solvent powers of these acid fluids seem to depend. Mialhe, who has obtained this substance in great purity by the process recommended by Vogel, described the following properties as characteristic of the organic matter in artificial gastric juice: Dried in thin slices on a plate of glass, it is in the form of small, grayish, translucent scales, with a faint and peculiar odor and a feebly bitter and nauseous taste. It is soluble in water and in a weak alcoholic mixture, but is insoluble in absolute alcohol. A solution of it is rendered somewhat turbid by a temperature of 212° Fahr. (100° C.), but it is not coagulated, although it loses its digestive properties. It is not affected by acids but is precipitated by tannin, creosote and a great number of metallic salts. This substance dissolved in water slightly acidulated possesses, in a very marked degree, the solvent properties of the gastric juice; but it has been found by Payen and Mialhe not to be so active as the substance extracted from the gastric juice itself, which is described by Payen, under the name of gasterase. In the abattoirs of Paris, Mialhe collected from the secreting stomachs of calves as they were killed, between six and ten pints (2·8 and 4·7 litres) of gastric juice; and from this he extracted the pure pepsine by the process recommended by Payen, which consists merely in one or two precipitations by alcohol. This substance he found to be identical with the substance obtained by Payen from the gastric juice of the dog. Its action upon albuminoid matters was precisely the same as that of pepsine extracted from artificial gastric juice, except that it was more powerful.

Free Acid of the Gastric Juice..—The character of the free acid of the gastric juice has long been a question of uncertainty and dispute. In former editions of this work, the different views of chemists with regard to the nature of this acid were fully discussed. It may now be stated that almost all physiologists adopt the view that the gastric juice contains free hydrochloric acid, with possibly a very small quantity of lactic acid. It is admitted, however, that the degree of acidity of the gastric juice is variable, and that the normal acid may be replaced, without loss of the digestive properties of the fluid, by lactic, oxalic, acetic, formic, succinic, tartaric, citric, phosphoric, nitric or sulphuric acid.

Saline Constituents of the Gastric Juice.—It has been shown that artificial fluids containing the organic matter of the gastric juice and the proper proportion of free acid are endowed with all the digestive properties of the normal secretion from the stomach, and that these properties are rather impaired when an excess of its normal saline constituents is added or when the relation of the salts to the water is disturbed by concentration.

Boudault and Corvisart evaporated 6·76 oz. (200 c. c.) of the gastric juice of the dog to dryness and added to the residue, 1·69 oz. (50 c. c.) of water. They found that the fluid thus prepared, containing four times the normal proportion of saline constituents, did not possess by any means the energy of action on alimentary substances of the normal secretion. These facts have led physiologists to attach little importance to the saline constituents of the gastric juice, except sodium chloride, which is thought to be concerned in the production of hydrochloric acid.

Action of the Gastric Juice in Digestion.—Certain of the substances most readily attacked by the gastric juice are acted upon by weak, acid solutions containing no organic matter; but it is now well established that the presence of a peculiar organic matter is a condition indispensable to actual digestion. It has also been shown that fluids containing the organic constituent of the gastric juice have no digestive properties unless they also possess the proper degree of acidity; and it is as well settled that fluids containing acids alone have no action on albuminoids similar to that which takes place in digestion, and that when these substances are dissolved by them it is simply accidental.

The presence of any one particular acid does not seem essential to the digestive properties of the gastric juice, so long as the proper degree of acidity is preserved, and it is undoubtedly important that the normal acid can be replaced by other acids; for in case any salt were introduced into the stomach which would be decomposed by the acid of the gastric juice, digestion would be interfered with, unless the liberated acid could take its place. It can readily be appreciated that transient disturbances might occur from this cause, were the existence of any one acid indispensable to the digestive properties of the gastric juice; while if only a certain degree of acidity were required, this condition might be produced by any acid, either derived from the food or secreted by the stomach.

In studying the physiological action of the gastric juice, it must always be borne in mind that the general process of digestion is accomplished by the combined as well as the successive action of the different digestive fluids. The act should be viewed in its *ensemble*, rather than as a process consisting of several successive and distinct operations, in which different classes of alimentary matters are dissolved by distinct fluids. The food meets with the gastric juice, after having become impregnated with a large quantity of saliva; and it passes from the stomach to be acted upon by the intestinal fluids, having imbibed both saliva and gastric juice.

When the acts which take place in the mouth are properly performed, the following alimentary substances, comminuted by the action of the teeth and thoroughly insalivated, are taken into the stomach: muscular tissue, containing the muscular substance enveloped in its sarcolemma, blood-vessels, nerves, ordinary fibrous tissue holding the muscular fibres together, interstitial fat, and a small quantity of albuminoids and corpuscles from the blood, all combined with a considerable quantity of inorganic salts; albumin, sometimes unchanged, but generally in a more or less perfectly coagulated condition;

fatty matter, sometimes in the form of oil and sometimes enclosed in vesicles, constituting adipose tissue; gelatine and animal matters in a liquid form extracted from meats, as in soups; caseine, in its liquid form united with butter and salts in milk, and coagulated in connection with various other matters, in cheese; vegetable nitrogenized matters, of which gluten may be taken as the type; vegetable fats and oils; sugars, both from the animal and vegetable kingdoms, but chiefly from vegetables; the different varieties of amylaceous substances; and finally, organic acids and salts, derived chiefly from vegetables. These matters, particularly those from the vegetable kingdom, are united with more or less innutritious matter, such as cellulose. They are also seasoned with aromatic substances, condiments etc., which are not directly used in nutrition.

The various articles described as drinks are taken without any considerable admixture with the saliva. They embrace water and the various nutritious or stimulant infusions (including alcoholic beverages) with a small proportion of inorganic salts in solution.

Action of the Gastric Juice upon Meats.—There are three ways in which the action of the gastric juice upon the various articles of food may be studied. One is to subject them to the action of the pure fluid taken from the stomach, as was done by Beaumont, in the human subject, and by Blondlot and others, in experiments upon the inferior animals; another is to make use of properly prepared acidulated extracts of the mucous membrane of the stomach, which have been shown to have many of the properties of the gastric juice, differing mainly in activity; and another is to examine from time to time the contents of the stomach after food has been taken. By all of these methods of study it has been shown that the digestion of meat in the stomach is far from complete. The parts of the muscular structure most easily attacked are the fibrous tissue which holds the muscular fibres together, and the sarcolemma, or sheath of the fibres themselves. If the gastric juice of the dog be placed in a vessel with finely chopped lean meat and be kept in contact with it for a number of hours at about 100° Fahr. (37·78° C.), agitating the vessel occasionally so as to subject, as far as possible, every particle of the meat to its action, the filtered fluid will be found increased in density, its acidity diminished, and presenting all the evidences of having dissolved a considerable portion of the tissue. There always, however, will remain a certain portion which has not been dissolved. Its constitution is nevertheless materially changed; for it no longer possesses the ordinary character of muscular tissue, but easily breaks down between the fingers into a pultaceous mass. On subjecting this residue to microscopical examination, it is found not to contain any ordinary fibrous tissue; and the fibres of muscular tissue, although presenting the well marked and characteristic striæ, are broken into short pieces and possess very little tenacity. It is evidently only the muscular substance which remains; the connective tissue and the sarcolemma having been dissolved. These facts have been repeatedly noted, and even on adding fresh juice to the undigested matter, it is not dissolved to any considerable extent, the residue not being sensibly diminished in quantity, and

the muscular substance always presenting its characteristic striæ, on microscopical examination. Bernard, in experiments with the gastric juice of different animals, found the fluid from the stomach of the rabbit or the horse much inferior, as regards the activity of its action upon meat, to the gastric juice of the dog.

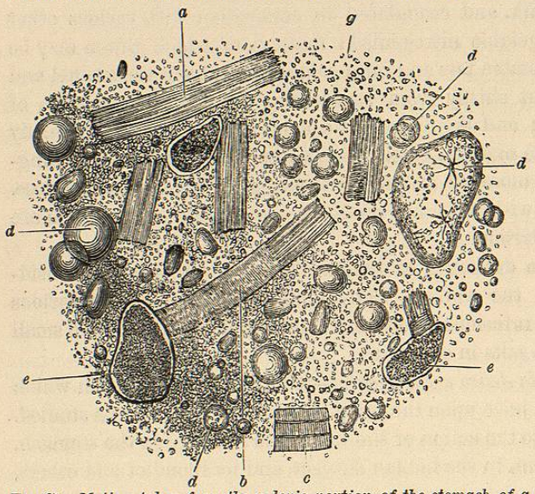

FIG. 65.—*Matters taken from the pyloric portion of the stomach of a dog during digestion of mixed food* (Bernard).

a, disintegrated muscular fibres, the striæ having disappeared; *b*, *c*, muscular fibres in which the striæ have partly disappeared; *d*, *d*, *d*, globules of fat; *e*, *e*, *e*, starch; *g*, molecular granules.

Whether the gastric juice be entirely incapable of acting upon the muscular substance or not, the above-mentioned facts clearly show that muscular tissue usually is not completely digested in the stomach. The action in this organ is to dissolve the intermuscular fibrous tissue and the sarcolemma, or sheath of the muscular fibres, setting the true muscular substance free and breaking it up into small particles. The mass of tissue is thus reduced to the condition of a thin, pultaceous fluid, which passes into the small intestine, where the process of digestion is completed.

The constituents of the blood, albuminoids, corpuscles etc., which may be introduced in small quantity in connection with muscular tissue, probably are completely dissolved in the stomach.

Action upon Albumin, Fibrin, Caseine and Gelatine.—The action of the gastric juice upon uncooked white of egg is to disintegrate its structure, separating and finally dissolving the membranous sacs in which the albumin is contained. It also acts upon the albumin itself, forming a new fluid substance, called albumin-peptone, which, unlike albumin, is not coagulated by heat or acids, but is precipitated by alcohol, tannin and many of the metallic salts. The digestion of raw or imperfectly coagulated albumin takes place with considerable rapidity in the stomach; and the digestion of albumin in this form is more rapid than when it has been completely coagulated by heat. It is a matter of common as well as of scientific observation, that eggs when hard-boiled are less easily digested than when they are soft-boiled or uncooked. The products of the digestion of raw or of coagulated albumin, albumin-peptone, are essentially the same. It is probable that the entire process of digestion and absorption of albumin takes place in the stomach; and if any albumin pass out of the pylorus, the quantity is very small.

Fibrin, as distinguished from the so-called fibrin of the muscular tissue, or myosine, is not a very important article of food. The action of the gastric juice upon it is more rapid and complete than upon albumin. The well known action upon fibrin, of water slightly acidulated with hydrochloric acid, has led some physiologists to assume that the acid is the only constituent in the gastric juice necessary to the digestion of this substance; but observations on the comparative action of acidulated water and of artificial or natural gastric juice show that the presence of the organic matter is necessary to the digestion of this as well as of other nitrogenized alimentary substances. The action of water containing a small proportion of acid is to render fibrin soft and transparent, frequently giving to the entire mass a jelly-like consistence. The result of the digestion of fibrin in the gastric juice or in an acidulated fluid to which pepsine has been added, is its complete solution and transformation into a substance which is not affected by heat, acids or by rennet. The substance resulting from the action of gastric juice upon fibrin, called fibrin-peptone, resembles albumin-peptone, but nevertheless has certain distinctive characters.

Liquid caseine is immediately coagulated by the gastric juice, by the action both of the free acid and the organic matter. Once coagulated, caseine is acted upon in the same way as coagulated albumen. The caseine which is taken as an ingredient of cheese is digested in the same way. According to Lehmann, coagulated caseine requires a longer time for its solution in the stomach than most other nitrogenized substances. The caseine of human milk, which coagulates only into a sort of jelly, is more easily digested than caseine from cow's milk (Elässer). The product of the digestion of caseine is a soluble substance, not coagulable by heat or the acids, called caseine-peptone.

Gelatine is rapidly dissolved in the gastric juice, when it loses the characters by which it is ordinarily recognized, and no longer forms a jelly on cooling. This substance is much more rapidly disposed of than the tissues from which it is formed, and the products of its digestion in the gastric juice resemble the substances resulting from the digestion of the albuminoids generally.

Action on Vegetable Nitrogenized Substances.—These substances, of which gluten may be taken as the type, undoubtedly are digested chiefly in the stomach. Raw gluten is acted upon very much in the same way as fibrin, and cooked gluten behaves like coagulated albumin. Vegetable articles of food generally contain gluten in greater or less quantity, or substances resembling it, as well as various non-nitrogenized matters, and cellulose. The fact that these articles are not easily attacked in any portion of the alimentary canal, unless they have been well comminuted in the mouth, is shown by the passage of grains of corn, beans etc., in the fæces. When properly prepared by mastication and insalivation, the action of the gastric juice is to disintegrate them, dissolving out the nitrogenized matters, freeing the starch and other matters so that they may be more easily acted upon in the intestines, and leaving the hard, indigestible matters, such as cellulose, to pass

away in the fæces. The nitrogenized constituents of bread are probably acted upon in the stomach in the same way and to the same extent as albumen, fibrin and caseine.

Peptones.—It has been shown that gastric digestion is not merely a solution of certain alimentary matters, but that these substances undergo very marked changes and lose the properties by which they are generally recognized. That the different products of this transformation resemble each other very closely is also undoubted; but there are certain differences in the chemical composition of the products of digestion of the different constituents of food, as well as differences, which have lately been noted, as regards their behavior with reagents.

The peptones in solution form colorless liquids, having a feeble odor resembling that of meat. They are not coagulable by heat or by most acids, a property which distinguishes them from almost all of the nitrogenized constituents of food. They are coagulated, however, by many of the metallic salts, by chlorine, and by tannin, in slightly acidulated solutions. On evaporating peptones to dryness, the residue consists of a yellowish-white substance, resembling desiccated white of egg. This is soluble in water, when it regains its characteristic properties, but is entirely insoluble in alcohol.

It is evident that the gastric juice, aside from its action in preparing certain articles for digestion by the intestinal fluids, does not simply liquefy certain of the alimentary matters, but changes them in such a way as to render them osmotic and provides against the coagulation which is so readily induced in ordinary nitrogenized bodies. Peptones pass through membranes with great facility.

Another, the most important and the essential change which is exerted by the gastric juice upon the albuminoids, is that by which they are rendered capable of assimilation by the system after their absorption. Pure albumin and gelatine, when injected into the blood, are not assimilable and are rejected by the kidneys; but albumin and gelatine which have been digested in gastric juice are assimilated in the same way as though they had penetrated by the natural process of absorption from the alimentary canal (Bernard and Barreswil). The same is true of caseine and fibrin. These facts, showing that something more is necessary in gastric digestion than mere solution, point to pepsine as the important agent in producing the peculiar modifications so necessary to proper assimilation of nitrogenized alimentary substances. The action of pepsine is essential to the changes which occur in the albuminoid alimentary matters, resulting in the formation of what are known as peptones; and the change into peptones takes place in all nitrogenized substances that are dissolved in the stomach. This may occur even when the albuminoid matters are somewhat advanced in putrefaction; and the gastric juice possesses antiseptic properties, which fact accounts for the frequent innocuousness of animal substances in various stages of decomposition when taken into the stomach.

The change of the albuminoids into peptones in the stomach is not direct. The intermediate processes probably are the following: The albuminoids are

first changed by the gastric juice into an acid-albumin or albuminate; this is farther changed into propeptone, or as it is called by Kühne, hemialbumose; and the final action is a change into the true peptones. These intermediate processes have been studied in artificial digestion, and the acid-albumin and propeptone differ, in some of their chemical properties which it is not necessary to describe in detail, from both albumin and peptone. A temperature near that of the body is necessary to the various changes just mentioned.

Action of the Gastric Juice on Fats, Sugars and Amylaceous Substances.—Most of the fatty constituents of the food are liquefied at the temperature of the body; and when taken in the form of adipose tissue, the vesicles in which the fatty matters are contained are dissolved, the fat is set free, is melted and floats in the form of drops of oil on the alimentary mass. The action of the stomach, then, seems to be to prepare the fats, chiefly by dissolving the adipose vesicles, for the complete digestion which takes place in the small intestine.

The varieties of sugar of which glucose is the type undergo little if any change in digestion and are probably in greatest part directly absorbed by the mucous membrane of the stomach. This is not the case, however, with the varieties of sugar classed with cane-sugar. It has been shown that cane-sugar injected into the veins of a living animal is not assimilated by the system but is immediately rejected by the kidneys. When, however, it has been changed into glucose by the action of a dilute acid or by digestion in the gastric juice, it no longer behaves as a foreign substance and does not appear in the urine. Experiments have shown that cane-sugar, after being digested for several hours in the gastric juice, is slowly converted into glucose. This action does not depend upon any constituent of the gastric juice except the free acid; and a dilute mixture of hydrochloric acid had an equally marked effect. Experiments in artificial digestion have shown that cane-sugar is transformed into glucose by the gastric juice very slowly, the action of this fluid in no way differing from that of very dilute acids. In the natural process of digestion, this action may take place to a certain extent; but it is not shown to be constant or important.

The action of gastric juice, unmixed with saliva, upon starch is entirely negative, as far as any transformation into sugar is concerned. When the starch is enclosed in vegetable cells, it is set free by the action of the gastric juice upon the nitrogenized parts. Raw starch in the form of granules becomes hydrated in the stomach, on account of the elevated temperature and the acidity of the contents of the organ. This is not the form, however, in which starch is generally taken by the human subject; but when it is so taken, the stomach evidently assists in preparing it for the more complete processes of digestion which are to take place in the small intestine.

Cooked or hydrated starch, the form in which it exists in bread, farinaceous preparations generally and ordinary vegetables, is not affected by the pure gastric juice and passes out at the pylorus unchanged. It must be remembered, however, that the gastric juice does not entirely prevent a continuance of the action of the saliva; and experiments have shown that gastric

juice taken from the stomach, when it contains a notable quantity of saliva, has, to a certain extent, the power of transforming starch into sugar.

The changes which vegetable acids and salts, the various inorganic constituents of food and the liquids which are classed as drinks undergo in the stomach are very slight. Most of these substances can hardly be said to be digested; for they are either liquid or in solution in water and are capable of direct absorption and assimilation. With regard to most of the inorganic salts, they either exist in small quantity in the ordinary water taken as drink or are united with organic nitrogenized substances. In the latter case, they become intimately combined with the organic matters resulting from gastric digestion. It has been noted that the various peptones contain the same inorganic salts which existed in the nitrogenized substances from which they were formed.

Some discussion has arisen with regard to the action of the fluids of the stomach upon calcium phosphate and calcium carbonate, salts which are considered nearly if not entirely insoluble. Observations on both natural and artificial digestion have shown that the calcareous constituents of bone are to a certain extent dissolved in the gastric juice. Bones are digested to a considerable extent in the stomach, although the greater part passes through the alimentary canal and is discharged unchanged in the fæces. In the natural process of digestion, the solution of the calcareous constituents of bone is more rapid than in artificial digestion, from the fact that the juice is being continually absorbed and secreted anew by the mucous membrane of the stomach.

Duration of Gastric Digestion.—Inasmuch as comparatively few articles, and these belonging exclusively to the class of organic nitrogenized substances, are completely dissolved in the stomach, it is evident that the length of time during which food remains in this organ, or the time occupied in the solution of food by gastric juice out of the body, does not represent the absolute digestibility of different articles. It is, nevertheless, an important question to ascertain, as nearly as possible, the duration of gastric digestion.

There has certainly never been presented so favorable an opportunity for determining the duration of gastric digestion as in the case of St. Martin. From a great number of observations made on digestion in the stomach itself, Beaumont came to the conclusion that "the time ordinarily required for the disposal of a moderate meal of the fibrous parts of meat, with bread, etc., is three to three and a half hours." The observations of F. G. Smith, made upon St. Martin many years later, gave two hours as the longest time that aliments remained in the stomach. In a case of intestinal fistula reported by Busch, it was noted that food began to pass out of the stomach into the intestines fifteen minutes after its ingestion and continued to pass for three or four hours, until the stomach was emptied.

Undoubtedly, the duration of gastric digestion varies in different individuals and is greatly dependent upon the kind and quantity of food taken, conditions of the nervous system, exercise etc. As a mere approximation, the

average time that food remains in the stomach after an ordinary meal may be stated to be between two and four hours.

Milk is one of the articles digested in the stomach with greatest ease. Its highly nutritive properties and the variety of its nutritious constituents render it very valuable as an article of diet, particularly when the digestive powers are impaired and when it is important to supply the system with considerable nutriment. Eggs are likewise highly nutritious and are easily digested. Raw and soft-boiled eggs are more easily digested than hard-boiled eggs. "Whipped" eggs are apparently disposed of with great facility. As a rule the flesh of fish is more easily digested than that of the warm-blooded animals. Oysters, especially when raw, are quite easy of digestion. The flesh of mammals seems to be more easily digested than the flesh of birds. Of the different kinds of meat, venison, lamb, beef and mutton are easily digested, while veal and fat roast-pork are digested with difficulty. Soups are generally very easily digested. The animal substances which are digested most rapidly, however, are tripe, pigs' feet and brains. Vegetable articles are digested in about the same time as ordinary animal food; but a great part of the digestion of these substances takes place in the small intestine. Bread is digested in about the time required for the digestion of the ordinary meats (Beaumont).

Conditions which influence Gastric Digestion.—The various conditions which influence gastric digestion, except those which relate exclusively to the character or the quantity of food, operate mainly by influencing the quantity and quality of the gastric juice. It is seldom that temperature has any influence, for the temperature of the stomach in health does not present variations sufficient to have any marked effect upon digestion.

As a rule, gentle exercise, with repose or agreeable and tranquil occupation of the mind, is more favorable to digestion than absolute rest. Violent exercise or severe mental or physical exertion is always undesirable immediately after the ingestion of a large quantity of food, and as a matter of common experience, has been found to retard digestion.

The effects of sudden and considerable loss of blood upon gastric digestion are very marked. After a full meal, the whole alimentary tract is deeply congested, and this condition is undoubtedly necessary to the secretion, in proper quantity, of the various digestive fluids. When the entire quantity of blood in the economy is greatly diminished from any cause, there is difficulty in supplying the amount of gastric juice necessary for a full meal, and disorders of digestion are likely to occur, especially if a large quantity of food have been taken. This is also true in inanition, when the quantity of blood is greatly diminished. In this condition, although the system constantly craves nourishment and the appetite frequently is enormous, food should be taken in small quantities at a time.

As a rule children and young persons digest food which is adapted to them more easily and in larger relative quantity than those in adult life or in old age; but ordinarily in old age digestion is carried on with more vigor