Notice the thin fanlike mesentery, holding the coil of intestine in place. Notice the blood tubes running across it. Open the intestine for a few inches to show the folds of the valvulæ conniventes.

44. The villi are too soft and too small to be seen without a specially prepared specimen. A magnifying power of 50 will show them.

Examine also a specimen of the liver, using at first a power of 100 diameters. Notice the capillaries converging toward central veins. The bile ducts are too fine to be seen.

Next use a power of 400 diameters, and examine the cells carefully. Notice their large size, and that they sometimes have more than one nucleus. Make a sketch of a villus and of the liver cells.

45. Pour some oil into a bottle of water. Shake well, and notice that the two cannot be made to mix. Now add a small pinch of *pancreatine*. Shake once more, and notice that the oil now forms an emulsion with the water.

Explain that the pancreatine contains the ferment of the pancreatic juice, and that it has the same action outside the body that it does inside.

46. Make a little starch paste. While it is warm stir in a small pinch of pancreatine. In a few minutes the paste becomes fluid from the conversion of starch to sugar.

47. Procure some bile. That from a chicken's gall bladder will do. Pour some into a bottle with oil and water, and notice that it forms an emulsion.

REVIEW TOPICS

1. Describe the intestine and its various divisions — the small and the large intestine, the cæcum, the vermiform appendix, the colon, the mesentery, and the omentum.
2. Describe the pancreas.
3. Describe the liver.
4. Describe the bile and its uses.
5. Describe the pancreatic juice and its three ferments, and their uses.
6. Describe the intestinal juice and its use.
7. Describe the peristalsis of the intestine.

CHAPTER IX

ABSORPTION AND ASSIMILATION

122. Absorption of food. — Digested foods which become part of the body are *peptone*, *glucose*, and *emulsified fat*. While they remain in the intestine, they are still outside of the body proper. In order to nourish the body, they must dialyze through the wall of the intestine and become part of the blood. The process of taking any substance into the blood is *absorption*.

The bodies of most cells are semi-fluid and jellylike. The peptone and glucose, dissolved in water, will soak into the soft epithelial cells lining the intestine, while the original albumin and starch or sugar will not. Blood tubes run so near the inner surface of the wall of the intestine, that only a layer of epithelium and the capillary wall, both together thinner than the thinnest paper, separate the blood from the food in the intestine. The food soaks through the epithelial cells and the walls of the blood tube, and is washed away by the blood stream. So there is a steady flow of digested food through the epithelial cells toward the blood tube; while the undigested food remains behind. The cells are alive, however, and to a degree select what they transmit. Common salt is necessary in the process, and bile greatly aids it. Peptone and glucose are thus absorbed from the intestine by every point of its mucous membrane. The millions of villi projecting into the intestine greatly increase the surface for absorption,

while their thin walls are especially designed for the easy passage of fluid.

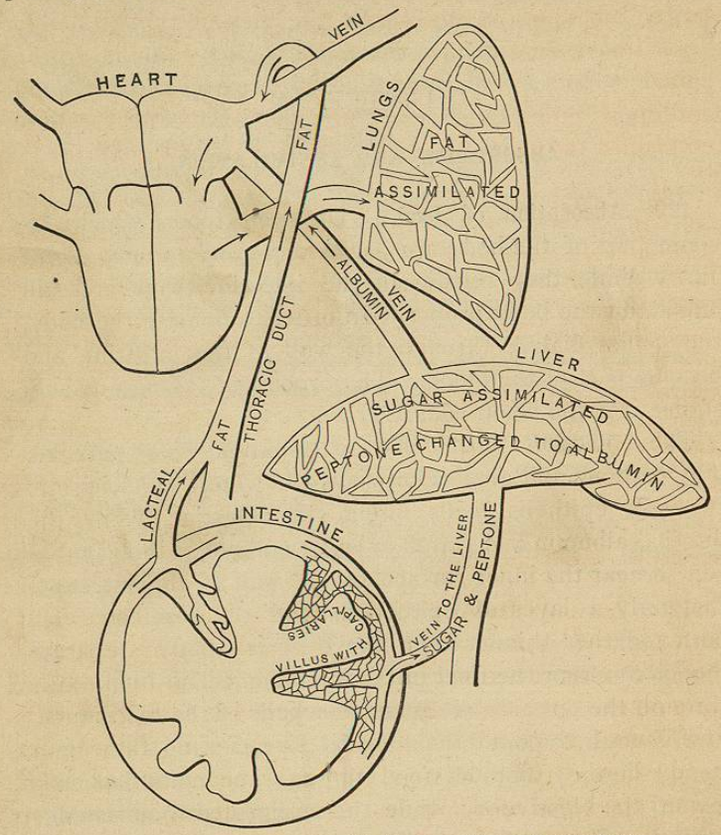

Diagram of the course of food in its absorption and assimilation.

123. Absorption of fat. — Fat also diffuses in the alkaline solution contained in the intestine. Under the microscope, particles of emulsified fat may be seen inside the epithelial cells of the villus. Only a small part enters the blood tube of the villus, while its greater part enters the *lacteal* tube. These lacteals unite to form larger and larger tubes, which run across the mesentery, and finally open into a single tube, the *thoracic duct*, running up the spinal column. This is a tube as large as a goose quill, and opens into a large *vein* at the root of the neck, where emulsified fat from the intestine first reaches the blood.

124. Completion of digestion. — Reckoning the amount of saliva as two pints a day, of gastric juice as eight pints, of pancreatic juice one and a half pints, and bile as two pints, and of food three pints, the liquid introduced into the intestine daily amounts to two gallons at least, and nearly the same amount is absorbed. More and more of this liquid is absorbed as the food passes down the intestine, until, about twelve hours after eating, what is left of the food and digestive fluids reaches the large intestine in a semi-solid state. In the large intestine absorption and peristalsis are so very much slower, that from twenty-four to thirty-six hours are required for the remains of food to traverse it. Its water and digested food and some of the bile are absorbed, while the rest of the bile and its other waste products and undigested matter are left behind. In health the intestine expels the waste matter regularly at least once a day.

125. Assimilation of fat. — Changing the digested food into the various fluids and tissues of the body is assimilation. The thoracic duct pours the digested fat into a large vein on the left side of the neck, whence it is carried with the venous blood to the lungs. Little or no fat can be found in the blood leaving the lungs unless it has been eaten in excessive quantities. It is probably oxidized at once to carbonic acid and water, an ounce requiring three ounces of oxygen. It is unlikely that any fat from the food is stored up, but the fat in the body is probably derived from the albumin of the cells. The oxidation of fat produces *heat*, and the heat may be changed to power, or be used simply to warm the body.

126. Assimilation of glucose. — Glucose enters the blood in the villi, and is carried from there to the *liver* by means of a large vein called the *portal vein*. As the blood emerges from the liver, it contains almost uniformly $\frac{1}{1000}$ part of glucose, no matter what amount of sugar is in the portal vein. The liver contains a sugarlike substance called *glycogen*, which increases in amount after digestion, and almost disappears a few hours after eating. So it is thought that glucose is stored in the liver as glycogen, and given up to the blood in a steady stream.

In the blood the glucose is all oxidized to carbonic acid gas and water, giving out heat and energy. One ounce of glucose requires about one and one fifth ounces of oxygen to oxidize it completely.

127. Assimilation of peptone. — Peptone is a *poison* to the body and must be changed immediately after entering the circulation. It is carried directly to the liver by the portal vein, and there all becomes changed back to forms of albumin which will not diffuse through a blood tube, except under pressure. The liver further makes the albumin a living part of the blood. Some albumin is oxidized in the liver, but a large part is carried to the cells of the body. Each cell in the body is thus bathed in albuminous food brought to it by the blood.

Like an ameba, each cell chooses as much of the albumin as it needs for food, and, taking it in by any part of the surface of its body, makes it a living part of itself. Finally, even the living albumin of the cell is oxidized, an ounce requiring one and one half ounces of oxygen.

128. Absorbed poisons thrown out by the liver. — Fermentation in the intestine produces injurious substances, and the bile brings in waste matter. Decayed food, too, contains poisons. All these substances may be absorbed and carried to the liver, which either destroys the poisons or sends them back to the intestine along with the bile. In this way the liver is a continual protection to the body.

129. Summary of the work of the liver. — The liver serves as the *regulator* of the body. The bile which it produces is to the intestine what the acid is to the stomach. It aids the action of the digestive ferments and hinders other forms of fermentation. It smooths the passage of food down the intestine, and aids diffusion into the blood tubes. The liver changes digested albumin and sugar and fits them for use in the blood, and intercepts poisons which may be circulating in the blood. Its work goes on constantly, and upon its perfect action depends the well-being of the body.

130. Biliousness. — If the liver acts imperfectly, a part of the peptone remains unchanged; other poisons, too, brought from the intestine by the blood are not destroyed; and the glucose is not properly assimilated and oxidized. A coated tongue, headache, loss of appetite, and an unconquerable feeling of dullness follow, and are symptoms of what is known as *biliousness*.

In fevers there is a poisoning of the body by the cause of the disease. As the liver is one of the principal organs which remove poisons from the blood, it may soon be able to get rid of them, and thus cure the fever. But often the task is too great for it, and then all the symptoms of a severe bilious attack are added.

131. Liver medicines. — Certain drugs, like *mercury* or *podophyllin*, have the power to increase the action of the liver. In proper doses they cause a great outpouring of bile which carries with it the poisons of the body. The drugs also cause the liver cells to assimilate the food more perfectly. Thus nature is *assisted* by the drugs and the biliousness is soon overcome.

132. Intestinal indigestion. — When the stomach is overworked and acts imperfectly, its work is thrown upon the intestine. Digestion there is imperfectly accomplished, and

fermentation takes place, with the development of poisons. The gas from the fermentation causes the abdomen to swell or bloat. The liver is imperfectly nourished, and is overworked in throwing out the poisons; so it fails to make the proper changes in food. Then the whole body, including the stomach, is weakened, and biliousness is produced. At last nature brings on severe sickness, and compels the overworked organs to rest.

133. Prevention of biliousness. — Man has it in his power to prevent almost entirely the evils of indigestion. He should eat only plain food, in moderate quantities, and at regular intervals. He should be careful not to eat when he is tired, or heated, or just before or after hard work. His digestive organs would then furnish a continual supply of perfectly digested food, sufficient for all the cells of the body; the influences producing disease would be resisted by well-nourished cells, and sickness would be rare.

134. Regularity of the bowels. — The last act of digestion, or the expulsion of waste matters from the intestine, is as important as eating, and should be performed with the same regularity. The mouth and stomach are endowed with feelings which make known their needs, but the intestine has only slight sensibility, and we are unaware of the digestion which is continually going on in it. Only when some irritating food, or a large collection of gas, greatly increases its peristalsis are we aware of its action. At a regular time every day a healthy person feels that the completing act of digestion should be performed, but the sensation will pass away if it is neglected, and in course of time the sensation will be repeated only once in two, three, or even more days. The retention of waste matter all that time cannot fail to do harm. Even if nature does not give the sensation indicating the need of expelling waste matter, the matters need to be expelled,

and the opportunity should be given daily at a regular time. Even if little food is eaten, the waste matters are still formed, and need expulsion. It should be remembered that it requires two days for food to pass the length of the intestine, so refraining from food only a single day does not make the intestine empty.

When the intestine expels its contents too freely, there is usually some irritating food which it is trying to expel. So a dose of medicine, which will aid in its expulsion, is required rather than something which will restrain the action.

135. Proper food. — The stomach may be able to begin digesting an improper meal, while the intestine is unable to finish the work. Owing to the slowness with which the intestine acts, several meals may be eaten before its failure becomes noticeable. Then the last meal is blamed, instead of the offending meal. So persons may gain wrong ideas about the digestibility of various articles of food.

136. Headaches. — A headache is generally due to disturbances in digestion. Usually when the liver is stimulated by a proper medicine, the headache ceases. Even if the headache is due to overwork, probably it would not have come on if the digestive organs had been performing their work properly.

SUMMARY

1. The peptone and glucose are taken up by the epithelial cells of the villi, and passed on to the blood in the capillaries inside the villi.
2. Emulsified fat is taken up by the epithelial cells of the villi, and passed on to the lacteals within the villi. From there it goes to the thoracic duct, and finally is poured into the large vein at the root of the neck.
3. About two gallons of fluid enter and leave the alimentary canal each day.

4. The fat is carried to the lungs, and is there oxidized to carbonic acid gas and water, each ounce of fat using nearly three ounces of oxygen.
5. The glucose is carried to the liver, and from there is given out in a steady stream and oxidized to carbonic acid gas and water, each ounce using a little more than an ounce of oxygen.
6. The peptone is carried to the liver, and there is changed back to the form of albumin adapted to the blood and tissues of the body.
7. In the liver some albumin is oxidized, and the rest is sent out as a part of the blood to feed the cells.
8. Poisons are often absorbed with the food, and are carried to the liver. But the liver cells separate out the poisons, and either destroy them or expel them with the bile.
9. By intemperate eating the stomach is disordered. Then more work is put upon the intestine, until it fails in its duties. Then the liver has imperfectly digested food and more poisons to take care of. Then a poor quality of bile is poured out. Then the intestine fails still more in its work. So the circle of cause and effect goes on, all depending at first upon intemperate eating.
10. The last act of digestion, or the expulsion of waste matters, should be attended to regularly every day.

DEMONSTRATIONS

48. Show the absorption of food in a young kitten or puppy which had been fed with cream about two hours before being killed. Place the animal in a tight box along with a sponge containing half an ounce of chloroform. In a few moments the animal will be dead. At once open its abdomen and spread out its intestine. Across its fanlike mesentery will be seen white lines. These are lacteals, which

are carrying the emulsified fat from the intestine. The fluid looks like milk, and so the name *lacteals*, or milk tubes, was given to the tubes. (See demonstration 35.)

49. Probably some boy in the schoolroom who is suffering with a bilious attack will be willing to show his tongue to the class. Notice that it is covered with a thick white or yellow fur. Explain that the tongue is a part of the alimentary canal, and that the stomach and intestine are in a like condition. Explain that, when the rest of the alimentary canal is acting well, the tongue is clean and the breath sweet.

REVIEW TOPICS

1. Describe the diffusion of digested food into the blood.
2. Trace a particle of digested fat from the intestine to the blood, and tell what finally becomes of it.
3. Describe how the liver uses digested sugar.
4. Describe how digested albumin becomes a part of the blood, and tell of what use it is to the body.
5. Tell how the liver removes poisons from the absorbed food.
6. Tell how a disturbance of digestion, in either the stomach, intestine, or liver, disturbs each of the other organs.
7. Show that each organ of digestion is perfectly adapted to its own work.