element of cost or the ease of procuring frequently determines the relative amount of the three classes of food stuffs in the daily diet. Thus, in countries where meat is plentiful, as in South America, proteid food is consumed in much larger proportion than above, whereas in some Asiatic countries, the prevalence of rice, cereals, and fruits leads to a daily diet in which non-proteid foods are especially conspicuous, and the proportion of proteid is reduced to the minimum necessary for life. Further, for similar reasons, the ratio of fat to carbohydrate undergoes wide variation among different races or in different countries. Thus, in the far north, fat (animal) constitutes the greater proportion of the non-proteid part of the diet, while in countries where cereals abound, carbohydrates, mainly in the form of starch, make up the greater portion of the non-nitrogenous food.

For the ordinary purposes of food analysis, the amount of proteid present is usually ascertained by determining the content of nitrogen, and multiplying this figure by the empirical factor 6.25, on the assumption that proteids contain on an average 16 per cent. of nitrogen. In recognition of the fact that the value so obtained is not always an accurate measure of the amount of true proteid present, the word "*protein*" is employed as an arbitrary term to designate a group assumed to include all the nitrogenous matter of the food except the nitrogenous fats. True proteids contain 15 to 17 per cent. of nitrogen and 50 to 54 per cent. of carbon. It is very difficult, however, to determine accurately the amount of true proteid in a mixture, and so chemists are practically forced to rely upon the content of nitrogen as a measure of the amount of proteid present. The above variation in the percentage of nitrogen in different proteids, however, introduces a possible error when the nitrogen content is multiplied by 6.25. This error is probably less, however, than that which comes from the fact that in some food stuffs, as in meat for example, there is a certain amount of nitrogen in the form of amido-acids, etc. Still, even here the error is probably not very great. Thus, beef entirely freed from fat contains, when dried, 49.6 per cent. of carbon, 15.3 per cent. of nitrogen, and 5.2 per cent. of ash.[22] While protein is thus seen to be not strictly equivalent to proteid, yet the content of so-called protein gives, as a rule, a fair measure of the amount of true proteid present. In special cases, however, it is necessary to make use of more elaborate methods of analysis, and to differentiate between the nitrogen of proteid and the nitrogen of amids and amido-acids, etc.

Under the head of fats is included the total ether extract of the food. This is ordinarily made up of neutral fats, but free fatty acids are sometimes present, likewise such phosphorized fats as lecithin and protagon, and also bodies like cholesterin and pigments.

Carbohydrates are usually determined by difference, after the ash and water have been estimated, although frequently starch, sugar, and cellulose are determined separately by direct analysis.

Equally important with chemical composition is the determination of the heat value of food stuffs. This is done by multiplying the number of grams of proteid, fat, or carbohydrate by a number, ascertained by direct experiment, representing the amount of heat produced by the oxidation of 1 gm. of the fat, carbohydrate, or proteid, to water and carbonic acid and to urea. Taking the calorimetric observations of Rubner as a standard, it is found that 1 gm. of proteid on an average, when oxidized to urea, yields 4,124 calories or gram degrees of heat (small calories), or 4.1 kgm. degrees (large calories). Similarly 1 gm. of fat, oxidized to carbonic acid and water, yields 9,321 gm. degrees of heat (small calories), or 9.3 kgm. degrees (large calories), while 1 gm. of carbohydrate, as starch, yields 4,116 small calories, or 4.1 kgm. degrees of heat.

The following table gives the percentage composition of a few common foods, together with the heat values expressed in the form of kilogram degrees of heat (large calories) per pound.

	Water, per cent.	Protein, per cent.	Fat, per cent.	Carbohydrate, per cent.	Ash, per cent.	Heat value per pound, calories.
Lean beef, fresh loin	58.2	17.1	11.1	....	0.9	785
Beef, loin, very fat	44.9	16.0	29.1	....	0.8	1,525
Canned boiled beef.	51.8	25.5	22.5	....	1.3	1,425
Lean breast of veal, fresh	53.3	16.1	4.3	....	0.9	480
Salmon, fresh	40.9	15.3	8.9	....	0.9	660
Codfish, fresh, steaks	72.4	17.0	0.5	....	1.0	335
Oysters, solid	88.3	6.0	1.3	3.3	1.1	230
Hen's eggs, uncooked	73 7	13.4	10.5	....	1.0	720
Butter	11.0	1.0	85.0	....	3.0	3,605
Cheese, American, pale	31.6	28.8	35.9	....	3.4	2,055
Milk	87.0	3.3	4.0	5.0	0.7	325
Hominy, uncooked	11.8	8.3	0.6	79.0	0.3	1,650
Oatmeal "	7.3	16.1	7.2	67.5	1.9	1,860
Wheat flour, entire wheat	11.4	13.8	1.9	71.9	1.0	1,675
White bread, Vienna	34.2	9.4	1.2	54.1	1.1	1,230
Lima beans, fresh	68.5	7.1	0.7	22.0	1.7	570
Fresh beets	87.5	1.6	0.1	9.7	1.1	215
Potatoes, raw	78.3	2.2	0.1	18.4	1.0	384
Sweet potatoes, raw	69.0	1.8	0.7	27.4	1.1	570
Green peas	74.6	7.0	0.5	16.9	1.0	465
Apples	84.6	0.4	0.5	14.2	0.3	290
Bananas, yellow	75.3	1.3	0.6	22.0	0.8	460
Oranges	86.9	0.8	0.2	11.6	0.5	240
Strawberries	90.4	1.0	0.6	7.4	0.6	180

Taken from Atwater and Bryant. Bulletin No. 28, Revised. United States Department of Agriculture.

As to the amount of food required by an adult during twenty-four hours, much depends upon the condition of the body, and especially upon the amount of muscular work being done. Voit, in Germany, has given for a man of 150 pounds body weight, doing ten hours of muscular work, the following diet as requisite:

105 gm. assimilated proteid .. × 4.1 = 430 large calories.
56 " fat .... × 9.3 = 520 " "
500 " carbohydrate ...... × 4.1 = 2,050 " "
3,000 " "

Atwater,[23] in this country, from a large number of observations, considers a somewhat more liberal allowance of proteid desirable, and a little larger heat value for a man doing severe muscular labor; say 125 gm. proteid and a total heat value of 3,500 large calories. Laying aside minor points of variation, it is safe to assume that a healthy workingman, of average body weight, requires in his daily diet at least 100 gm. of pure proteid, together with sufficient fat and carbohydrate to give a heat value of 3,000 large calories. No doubt, a man can maintain himself in perfect health on a somewhat smaller allowance of proteid, but in order to do this he must increase very greatly the amount of non-proteid food taken, especially carbohydrates.

Taking the above diet of Voit's, and assuming that in order to obtain the 105 gm. of assimilable proteid 118 gm. of proteid food would be required, we find that this means a daily consumption of 18.03 gm. of nitrogen and at least 328 gm. of carbon. Further, since the 118 gm. of albumin contain but 63 gm. of carbon, it is plain that there would be required 265 gm. of carbon, in the form of fats or carbohydrates.[24] The following table gives the number of grams of several common foods necessary to furnish the daily requisite of carbon and nitrogen:

For 18.3 Gm. Nitrogen.	Gm.	For 328 Gm. Carbon.	Gm.
Lean meat	538	Lard	450
Wheat flour	796	Corn	801
Eggs (18)	905	Wheat flour	824
Corn	989	Rice	899
Rice	1,868	Eggs (43)	2,231
Milk	2,905	Lean meat	2,620
Potatoes	4,575	Potatoes	3,124
Lard	4,796	Milk	4,652

It is thus evident that no one of these substances is in itself a proper food. Lean meat, for example, must have added to it fat or carbohydrate, or both; while potatoes, as an example of a carbonaceous food, require an admixture of nitrogenous matter. Hence a judicious mixture of all the alimentary principles from both the animal and vegetable kingdoms constitutes the food best adapted to the wants of mankind. Finally, emphasis must be laid upon the great difference in heat value between fats on the one hand, and proteids and carbohydrates on the other; fats having per gram a heat value more than twice that of proteids or carbohydrates.

R. H. Chittenden.

[1] Wurtz: Chimie biologique, chapters i., ii., 1884.
[2] Hoppe-Seyler: Physiologische Chemie, p. 28.
[3] Hermann's Handbuch der Physiologie, vi., 347.
[4] Philosophical Transactions, 2, 494.
[5] Zeitschrift für Biologie, ix., 387.
[6] Aronstein: Pflüger's Archiv für Physiologie, viii., p. 75. Alex. Schmidt: Pflüger's Archiv, xi., p. 1.
[7] Zeitschrift für Biologie, vol. ix., 1873.
[8] Weiske: Zeitschrift für Biologie, vol. vii., pp. 179 and 333.
[9] Forster: Zeitschrift für Biologie, vol. xii., p. 464.
[10] Comptes Rendus, 1872, 64, p. 1353.
[11] Compare Homburger: Zeitschrift für physiolog. Chem., vol. ii., 191.
[12] Bunge: Zeitschrift physiol. Chem., ix., p. 49.
[13] Bunge: Lehrbuch d. physiol. u. pathol. Chem., 1889, p. 100.
[14] Hermann's Handbuch der Physiologie, vi., 260.
[15] Ibid., vi., 388
[16] Zeitschrift für Biologie, viii., 297.
[17] Text-Book of Physiology, p. 467.
[18] Zeitschrift für Biologie, xv., 261.
[19] Atwater and Benedict: Bulletin 69, United States Department of Agriculture.
[20] Chittenden, Mendel, and Jackson: Amer. Journ. Physiol., i., p. 164.
[21] Chittenden and Richards: Amer. Journ. Physiol., i., p. 471.
[22] Argutinsky: Pflüger's Archiv f. Physiol., lv., p. 345
[23] See Atwater and Woods: Bulletin No. 46, United States Department of Agriculture, p. 63.
[24] Voit: Hermann's Handbuch der Physiologie, vi., 497.

ALIMENTARY TRACT.—DEVELOPMENT.—The alimentary tract arises from the inner germ layer, reinforced by the visceral layer of the middle germ layer. The inner germ layer furnishes the epithelium of the entire alimentary tract and its accessory organs, the lungs, liver, pancreas, etc. The visceral layer of the middle germ layer, on the other hand, gives origin to all the muscles and connective-tissue layers, and also to the mesentery and omentum. By a process of folding there is gradually formed a tube which at first is broadly in contact with the dorsal wall of the embryo along its entire length immediately ventrad to the notochord. In this tube we can distinguish three divisions, which have received the names of fore, mid, and hind gut. Neither the fore gut nor the hind gut opens to the exterior at first; they end blindly. During the earlier stages of development the mid gut is connected with the yolk sac (Fig. 69), by a wide communication, but as development progresses this communication becomes more and more constricted. This constriction is brought about by the growth caudad, on the one hand, of the fold which gave rise to the fore gut, and on the other hand by the growth cephalad of the fold which formed the hind gut.

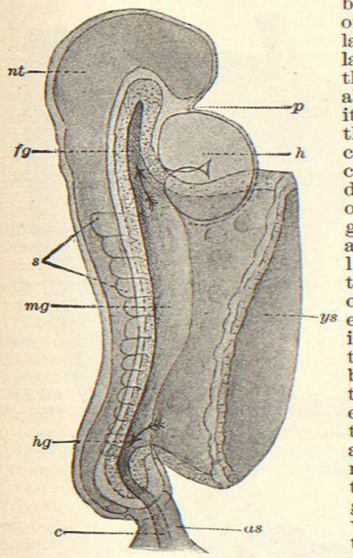

FIG. 69.—Human Embryo, 2.5 Mm. Long. × 30. (After Kollman.) The yolk sac is cut away. The rudiment of the primitive intestines can be seen extending through the embryo. *as*, Allantois stalk; *c*, epithelial tube within the allantois stalk; *fg*, fore gut; *h*, heart; *hg*, hind gut; *mg*, mid gut; *nt*, neural tube; *p*, mouth pit; *s*, somites; *ys*, yolk sac.

By this growth in both directions the previously wide communication of the mid gut with the yolk sac becomes smaller and smaller, until finally there remains only a narrow communication between the mid gut and yolk sac—the vitelline duct or *ductus omphalo-entericus*.

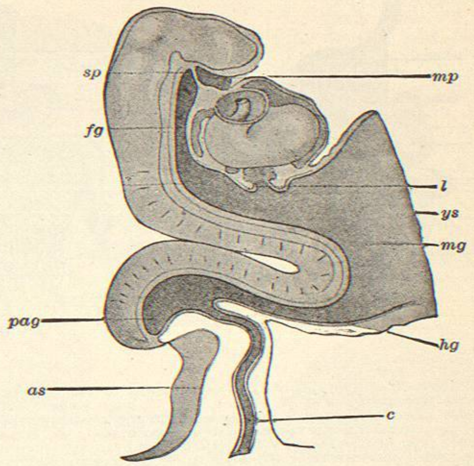

FIG. 70.—Human Embryo, 4.10 Mm. Long. (After His.) *as*, Allantois stalk; *c*, epithelial tube within the allantois stalk; *fg*, fore gut; *hg*, hind gut; *l*, rudiment of the liver; *mg*, mid gut; *mp*, mouth pit; *pag*, post-anal gut; *sp*, Seessel's pocket; *ys*, yolk sac.

On the ventral side of the fore gut the heart is situated, while from the hind gut a diverticulum grows out which forms a thick-walled stalk. This stalk is known as the allantoic stalk, or the *Bauchstiel* of His. In man and other primates this diverticulum always remains narrow, but in the lower vertebrates it forms a free vesicle.

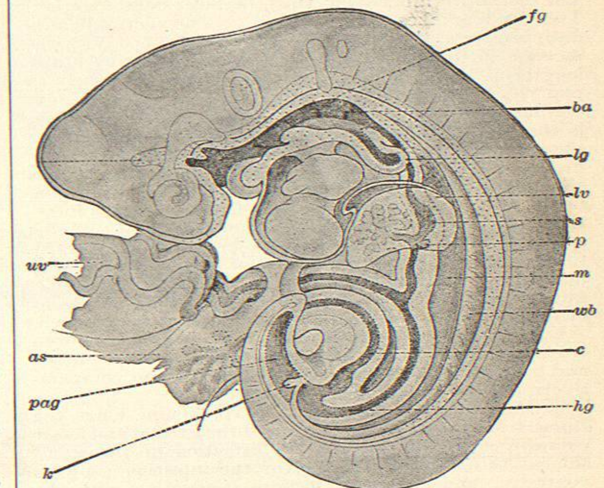

FIG. 71.—Human Embryo, 5 Mm. Long. Sagittal section of a reconstruction. × 15. (After His.) *as*, Allantois stalk; *ba*, branchial arches; *c*, allantois canal; *fg*, fore gut; *hg*, hind gut; *k*, kidney; *lg*, lung; *lv*, liver; *m*, mesentery; *p*, pancreas; *pag*, post-anal gut; *s*, stomach; *uv*, umbilical vesicle; *wb*, Wolffian body.

Eventually, by the bending ventrally of the fused outer germ layer and parietal layer of the middle germ layer on each side, the vitelline duct and allantoic stalk become approximated, and there is then formed the umbilical cord, which contains not only the above-mentioned structures, but also the umbilical arteries and vein.

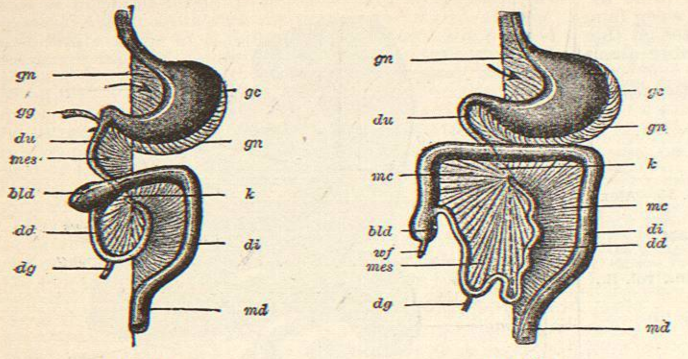

FIG. 72.

FIG. 73.

FIGS. 72 and 73.—Diagrams of the Development of the Human Alimentary Canal and Its Mesentery. Fig. 72, earlier, Fig. 73, later stage. (After Hertwig.) *gn*, Greater omentum, which is developed from the mesogastrium. The arrow indicates the entrance to the omentum (bursa omentalis); *gc*, greater curvature of the stomach; *gg*, ductus choledochus; *du*, duodenum; *mes*, mesenterium; *mc*, mesocolon; *dd*, small intestine; *di*, large intestine (colon); *md*, rectum; *dg*, vitelline duct; *bld*, cæcum; *wf*, appendix vermiformis; *k*, place where the loops of the intestines cross each other. The colon with its mesocolon crosses the duodenum.

In embryos 2 to 3 mm. in length, the alimentary tube is nearly straight, but in embryos of about 4 mm. length there is a remarkable ventral flexure (Fig. 70).

With the wheel-like bending of the body of the embryo, the head and tail approach each other (Fig. 71), and the entire alimentary tract becomes bent together. This bending takes place gradually. The ventral flexure disappears and the embryo becomes straight. With the increase in size of the embryo, the alimentary tube also lengthens, and we can now distinguish anteriorly a pharyngeal portion, while posteriorly to this, and extending as far as the rudiments of the liver and pancreas, is that part of the alimentary tube which gives origin to the œsophagus, stomach, and duodenum. Posteriorly to the rudimentary liver we have that portion of the alimentary tube which gives rise to the jejunum, the ileum, and the different subdivisions of the large intestine. At first this portion shows only a slight anterior convexity near the vitelline duct, but later it gives rise to the very complex arrangement of the small and large intestines. The most posterior portion of all, the hindgut, gives rise to the rectum and ends blindly by means of the transitory post-anal gut in the tail of the embryo.

Fig. 72 shows the digestive tract of a human embryo 4.2 mm. long. The wide communication between the mid gut and yolk sac is shown; so also is the comparatively straight course of the intestine.

In Fig. 73, taken from an embryo, 7 mm. long, the stomach shows a slight indication of the greater and lesser curvatures, and the general conformation of the stomach can be made out. A loop of the intestine projects ventrally, and the now narrow connection with the yolk sac is shown. The rudiments of the liver and pancreas can be seen arising respectively from the dorsal and ventral sides of the duodenum.

At a somewhat later stage of development (Fig. 74.) the form of the stomach is more clearly shown. The duodenum caudad to the pylorus passes backward until it comes close to the dorsal body wall; it then bends around sharply ventrally and forms a long loop, the convexity of which is directed forward. This loop consists of two nearly parallel arms running near each other. One is directed ventrally and somewhat backward, while the other, which is situated caudad to it, runs dorsally and is again bent near the vertebral column. From this latter bend it passes caudad toward the anus. The convex end of the long loop thus formed extends beyond the body into the umbilical cord, within which there is an excavation for its reception. The vitelline duct, which is now undergoing degenerative changes, is connected with the intestine at the ventral end of the long loop just described. A short distance from the vitelline duct, on the caudal end of the loop, a second evagination can be seen. This latter develops into the cæcum, and therefore indicates the boundary between the large and the small intestine. “In consequence of these first foldings, four regions of the intestine can be distinguished even now. These are more sharply separated later. The short portion running from the stomach to the backbone and provided with a small mesentery becomes the duodenum (Fig. 74, *Du*); the anterior descending arm (*D*), together with the bend in the loop, furnishes the small intestine. The posterior ascending arm is developed into the colon (*C*), and the terminal part, embracing the last bend, into the sigmoid flexure and rectum (*R*). In embryos of the third and following months there occur, in connection with a further increase in length, important changes in the position of the stomach and the intestinal loops. The stomach undergoes a double twisting about two different axes, and thereby early acquires a form and position (Figs. 72 and 73), which correspond approximately to the permanent condition. First, its longitudinal axis, which unites cardia and pylorus and is, in the beginning, parallel with the vertebral column, takes an oblique and finally an almost transverse position in consequence of a rotation around the dorsal ventral axis. By reason of this rotation the cardia moves to the left half of the body and downward, but the pylorus more to the right side and somewhat higher. Then at the same time the stomach experiences a torsion around its longitudinal axis by which the original left side becomes the front and the right the back. Consequently the greater curvature comes to lie below, the lesser above. The terminal part of the œsophagus is also affected by the torsion. It undergoes a spinal twisting by which this left side becomes the front. . . .

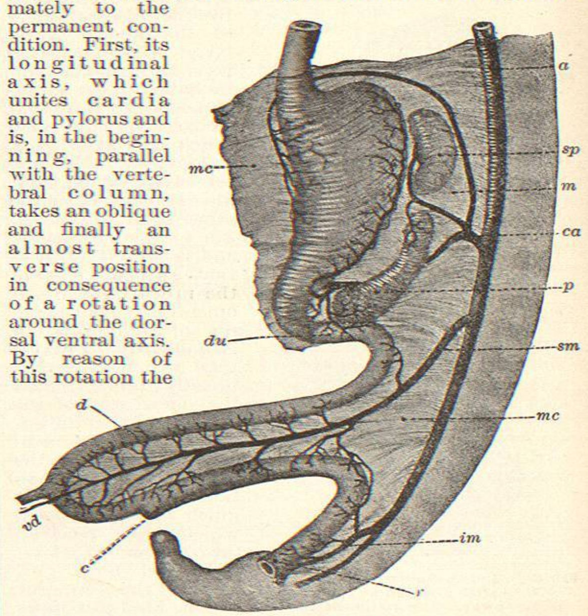

FIG. 74.—Alimentary Canal of a Six-Weeks Human Embryo. (From Kollmann, after Toldt.) *a*, Aorta; *c*, cæcum, on the ascending arm of the intestinal loop; *ca*, cœliaca; *d*, descending arm of the intestinal loop which becomes the small intestine; *du*, duodenum; *im*, mesenterica inferior; *m*, mesogastrium; *mc*, mesogastrium commune; *p*, pancreas; *r*, rectum; *sm*, mesenterica superior; *sp*, spleen; *vd*, vitelline duct.

“The intestinal loop with its mesentery passes through a no less fundamental twisting around its place of attachment in the lumbar region than the stomach does. The descending and the ascending arms at first lie side by side, then the latter (which becomes the colon) lays itself obliquely over the former and across the beginning of the small intestine transversely (Fig. 72, *k*).

“Both parts, but especially the small intestine, continue from the end of the second month to increase rapidly in length and to take on a folded condition. Meanwhile the initial part of the colon, called the cæcum, which exhibits even in the third month a curved sickle-shaped vermiform appendage, comes to lie wholly on the right side of the body up under the liver (Fig. 72, *bld*). From here it runs in a transverse direction across the duodenum under the stomach to the region of the spleen; then it bends sharply about and descends to the left pelvic region, where it is continued into the sigmoid flexure and rectum. Therefore there are distinguishable in the colon, even in the third month, the cæcum, the transverse and the descending colon. An ascending colon is still wanting. It is formed in the succeeding months (Fig. 75, *b*) by the gradual sinking down of the cæcum, which was at first under the liver, until in the seventh month it is below the right kidney, and from the eighth month onward descends past the crest of the ilium.

“Meanwhile the cæcum has increased in length, and toward the end of gestation is a rather large appendage at the place of transition from the small to the large intestine. It early exposes the want of uniformity in development (Figs. 72 and 73, *bld*). The terminal part, which often embraces more than half its length, does not keep pace in its growth with the more rapidly enlarging proximal portion. The former is designated as the appendix vermiformis; the latter as the cæcum. At the time of birth the vermiform appendage is still not so sharply differentiated from the cæcum as it is a few years later, when it has been converted into an appendage the size of a goose quill and 6–8 cm. long.

“Within the region embraced by the bends of the large intestine the small intestine, which is derived from the descending arm of the loop, is disposed in more and more numerous folds, owing to its extensive growth in length (Fig. 73).” (Mark.)

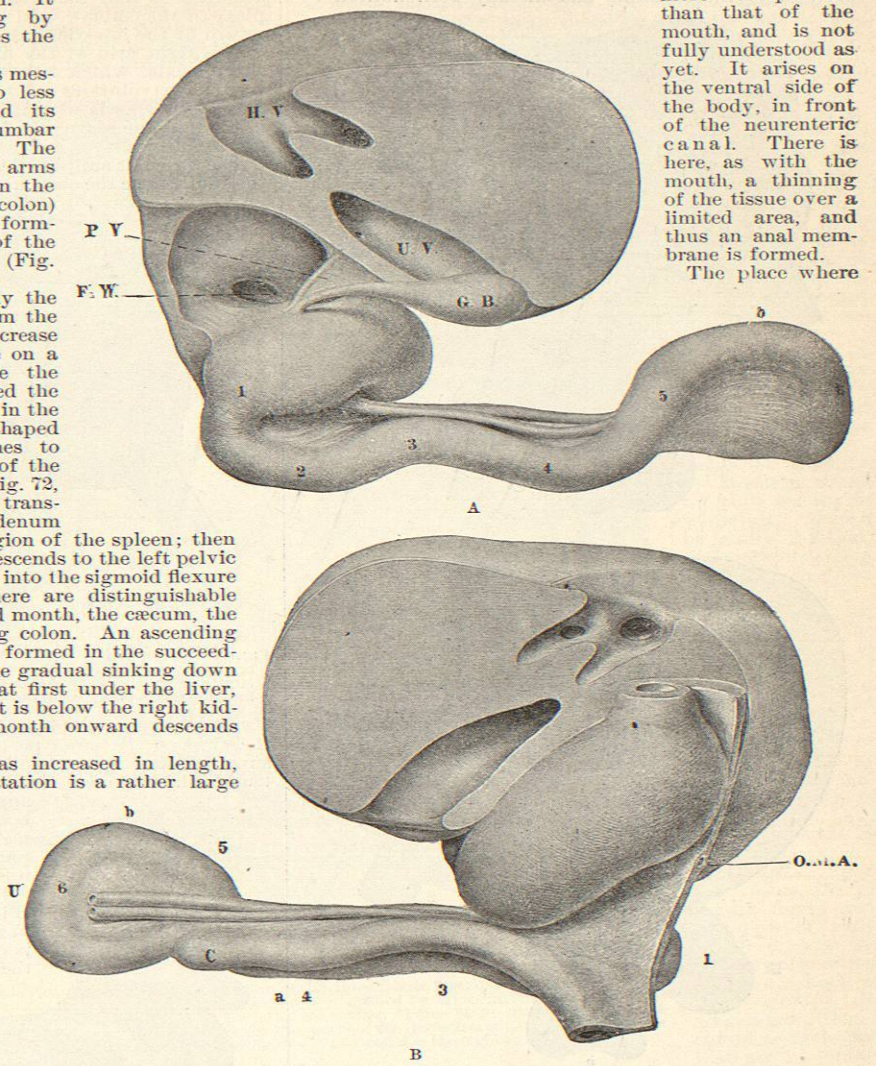

FIG. 75.—Reconstruction of the Liver and Intestine of a Human Embryo of About Five Weeks. A, From the right side; B, from the left side. (After Mall.) × 20. *C*, Cæcum; *F.W*, foramen of Winslow; *G.B*, gall bladder; *H.V*, hepatic veins; *O.M.A*, omphalo-mesenteric artery; *P.V*, portal vein; *U*, place where the omphalo-mesenteric artery and vein cross the intestinal loop; *U.V*, umbilical vein. The numbers 1—6 indicate the commencing intestinal coils. The letters *a* and *b* designate constant points which serve as landmarks in comparing the following series of figures.

The permanent mouth is developed as a pit (stomodæum) on the under surface of the rudimentary head (Fig. 69). This pit extends until it meets the blind end of the fore gut, being separated from it at first by a thin sheet of tissue composed of outer and inner germ layers, and known as the pharyngeal membrane. By the rupture of this membrane, communication is established with the exterior. The formation of the anus is much more complicated than that of the mouth, and is not fully understood as yet. It arises on the ventral side of the body, in front of the neurenteric canal. There is here, as with the mouth, a thinning of the tissue over a limited area, and thus an anal membrane is formed.

The place where this thinning of the tissue takes place gives rise externally to a pit (proctodeum), which later becomes connected with the hind gut by the rupture of the above-described anal membrane. The process is therefore similar to that by which the mouth is established.

Until within a few years the growth and arrangement of the coils of the small intestine were but little understood. The first attempt to find a typical arrangement of the coils was made by Henke, followed by Sernoff, Weinberg, and Mall. In the ensuing de-