changed and absorbed. The various forms of starchy and saccharine matters, unless they have been taken in excessive quantity, soon disappear from the intestine; and the glucose, which is the result of their digestion, may be recognized in the portal blood. As a rule, fatty matters are not found in the lower part of the ileum, having passed into the lacteals, in the form of an emulsion. Neither fibrin, albumen nor caseine, can be detected in the ileum; and the muscular substance, as recognized by its microscopical characters, becomes gradually disintegrated and is lost—except a few isolated fragments deeply colored with bile—some time before the indigestible residue passes into the large intestine.

In the human subject those portions of the food which resist the successive and combined action of the different digestive secretions are derived chiefly from the vegetable kingdom. Hard, vegetable seeds, the cortex of the cereals, spiral vessels, and, indeed, all parts which are composed largely of cellulose, pass through the intestinal canal without much change. These substances form, in the fæces, the greatest part of what can be recognized as the residue of matters taken as food. It is well known that an exclusively animal diet, particularly if the nutritious matters be taken in a concentrated and readily assimilable form, leaves very little undigested matter to pass into the large intestine, and gives to the fæces a character quite different from that which is observed in herbivorous animals or in man when subjected to an exclusively vegetable diet. The characters of the residue of the digestion of albuminoid substances are not very distinct. As a rule, none of the albuminoids are to be recognized in the healthy fæces by the ordinary tests.

Absorption of various articles of food in a liquid form may take place with great activity in the large intestine, although it has not been shown that the secretions in this part of the alimentary canal have any distinct digestive properties; still, as is shown in rectal alimentation, eggs, milk and meat-extracts may be taken up by the mucous membrane, and they enter the circulation in such a form that they contribute to the nutrition of the body.

*Processes of Fermentation in the Intestinal Canal.*—The processes of fermentation in the intestines are not properly digestive and are to a great extent due to the action of micro-organisms, which exist here in great numbers and variety. It is possible, however, that future researches may show that micro-organisms play an important part in actual digestion, as is foreshadowed in a recent article by Pasteur (August, 1887). Pasteur has isolated seventeen different micro-organisms of the mouth. Some of these dissolved albumen, gluten and caseine, and some transformed starch into glucose. The micro-organisms described were not destroyed by the action of the gastric juice. These observations are very suggestive, and they seem to open a new field of inquiry as regards certain of the processes of digestion. Most of the fermentations in the small intestine are either putrefactive or of a nature analogous to fermentation, and the processes are continued with increased activity in the large intestine.

Some of the substances resulting from intestinal fermentations have already been described. Indol, skatol, phenol etc., seem to be produced by



the action of micro-organisms; but the effect of these products is to kill the micro-organisms and thus to limit the putrefactive processes. The production of indol, skatol and phenol is arrested by the action of certain drugs, such as calomel, salicylic acid and other so-called antiseptics. The fermentative changes in the intestines involve the production of certain gases, which will be described at the close of this chapter.

### Contents of the Large Intestine.

When the contents of the small intestine have passed the ileo-cæcal valve, they become changed in their general character, partly from admixture with the secretions of this portion of the canal, and are then known as the fæces. The most notable changes relate to consistence, color and odor. The odor, especially, of normal fæcal matter is characteristic.

Fæcal matter has a much firmer consistence than the contents of the ileum, which is due to a constant absorption of the liquid portions. As a rule, the consistence is great in proportion to the length of time that the fæces remain in the large intestine; and this is variable in different persons, and in the same person, in health, depending somewhat upon the character of the food. The color changes from the yellow, more or less bright, which is observed in the ileum, to the dark yellowish-brown characteristic of the fæces. Although the bile-pigment can not usually be recognized by the ordinary tests, it is this which gives to the contents of the large intestine their peculiar color, which is lost when the bile is not discharged into the duodenum. In a specimen of healthy human fæces, which had been dried, extracted with alcohol, the alcoholic extract precipitated with ether and the precipitate dissolved in distilled water, it was impossible to detect the biliary salts by Pettenkofer's test. In a watery extract of the same fæces, the addition of nitric acid failed to show the reaction of the coloring matter of the bile (Flint, 1862). The color of the fæces, however, varies considerably under different forms of diet. With a mixed diet the color is yellowish-brown; with an exclusively flesh-diet it is much darker; and with a milk-diet it is more yellow (Wehsarg).

The odor of the fæces, which is characteristic and quite different from that of the contents of the ileum, is variable and is due in part to the peculiar decomposition of the residue of the food, in part to the decomposition of the bile and in part to matters secreted by the mucous membrane of the colon and of the glands near the anus.

The entire quantity of fæces in the twenty-four hours, according to Wehsarg, is about 4·6 ounces (128 grammes). This was the mean of seventeen observations; the largest quantity being 10·8 ounces (306 grammes), and the smallest, 2·4 ounces (68 grammes).

The reaction of the fæces is variable, depending chiefly upon the character of the food. Marcet found the human excrements always alkaline. Wehsarg, on the other hand, found the reaction generally acid, but very frequently it was alkaline or neutral.

The proportions of water and solid matter in the fæces are variable. Ber-

zelius found in the healthy human fæces, 73·3 parts of water and 26·7 parts of solid residue. The average of seventeen observations by Wehsarg was precisely the same. In the observations of Wehsarg, the mean quantity of solid matter discharged in the fæces in the twenty-four hours was 463 grains (30 grammes), the extremes being 882·8 grains (57·2 grammes), and 251·6 grains (16·28 grammes). The proportion of undigested matters in the solid residue was very small, averaging but little more than ten per cent., the mean quantity in the twenty-four hours in ten observations being but 52·5 grains (3·4 grammes). This was found, however, to be very variable; the largest quantity being 126·5 grains (8·2 grammes), and the smallest, 12·5 grains (0·81 gramme).

Microscopical examination of the fæces reveals various vegetable and animal structures which have escaped the action of the digestive fluids. Wehsarg also found a "finely divided fæcal matter" of indefinite structure, but containing partly disintegrated intestinal epithelium. Crystals of cholesterine were never observed. Whenever the matter is neutral or alkaline, crystals of ammonio-magnesian phosphate are found. Mucus is also found in variable quantity in the fæces, with desquamated epithelium and a few leucocytes. In addition, recent microscopical researches have shown the presence of spores of yeast and a great variety of bacteria, which latter exist in the fæces in great abundance. These organisms probably excite many of the so-called putrefactive changes in the intestinal contents, which result in the formation of indol, phenol, skatol, cresol etc. According to Senator, these putrefactive products do not occur in the meconium. The quantity of inorganic salts in the fæces is not great. In addition to the ammonio-magnesian phosphate, magnesium phosphate, calcium phosphate and a small quantity of iron have been found. The chlorides are either absent or are present only in small quantity.

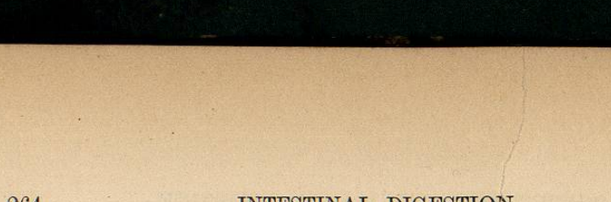


FIG. 80.—*Micro-organisms of the large intestine* (Landois).
1, bacterium coli commune; 2, bacterium lactis aërogenes; 3, 4, the large bacilli of Bienstock, with partial endogenous spore-formation; 5, the various stages of the development of the bacillus which causes the fermentation of albumen.

Marcet has pretty generally found in the human fæces a substance possessing the characters of margaric acid, and volatile fatty acids; the latter free, however, from butyric acid. He also found a coloring matter, which is probably a modification of bile-pigment. Cystine is mentioned as an occasional constituent of the fæces.

In addition to the matters just enumerated, the following substances have been extracted from the normal fæces:

*Excretine and Excretoleic Acid.*—Excretine was obtained from the normal fæces, by Marcet, in 1854. This substance crystalizes from an ethereal solution in two or three days, in the form of long, silky crystals. Examined



with the microscope, these are found to consist of acicular, four-sided prisms of variable size. Excretine is insoluble in water, slightly soluble in cold alcohol, but very soluble in ether and in hot alcohol. Its alcoholic solutions are faintly though distinctly alkaline. Its fusing-point is between 203° and 205° Fahr. (95° and 96° C.). It may be boiled with potassium hydrate for hours without undergoing saponification. The quantity of excretine contained in the fæces is not large. Only 12·6 grains (0·816 gramme) were obtained by Marcet from nine evacuations.

There exists very little definite information concerning the production of excretine. Marcet examined on one occasion the contents of the small intestine of a man who had died of disease of the heart, without finding any excretine. It is probable that this substance is formed in the large intestine, although farther observations are wanting on this point.

The substance called excretoleic acid is very indefinite in its composition and properties. It is described as an olive-colored, fatty acid, insoluble in water, non-saponifiable, and very soluble in ether and in hot alcohol. It fuses between 77° and 79° Fahr. (25° and 26·11° C.).

*Stercorine.*—This substance, discovered in the fæces in 1862 (Flint), was described by Boudet in 1833, as existing in minute quantity in the serum of the blood, and was called seroline. As it is one of the most abundant and characteristic constituents of the stercoraceous matter, it may properly be called stercorine, particularly as observations have led to the opinion that it really does not exist in the serum, but is formed from cholesterine by the processes employed for its extraction from the blood (Flint).

Stercorine may be extracted in the following way: The fæces are first evaporated to dryness, pulverized and treated with ether. The ether-extract is then passed through animal charcoal, fresh ether being added until the original quantity of the ether-extract has passed through. It is impossible to entirely decolorize the solution by this process; but it should pass through perfectly clear and of a pale-amber color. The ether is then evaporated and the residue is extracted with boiling alcohol. This alcoholic solution is evaporated, and the residue is treated with a solution of potassium hydrate for one or two hours at a temperature a little below the boiling-point, by which all the saponifiable fats are dissolved. The mixture is then largely diluted with water, thrown upon a filter, and washed until the fluid which passes through is neutral and perfectly clear. The filter is then dried and the residue is washed out with ether. The ether-solution is then evaporated, extracted with boiling alcohol, and the alcoholic solution is evaporated. The residue of this last evaporation is pure stercorine.

When first obtained, stercorine is a clear, slightly amber, oily substance, of about the consistence of Canada balsam used in microscopical preparations. In four or five days it begins to show the characteristic crystals. These are few in number at first, but soon the entire mass assumes a crystalline form. In one analysis, from seven and a half ounces (202·5 grammes) of normal human fæces (the entire quantity for the twenty-four hours), 10·417 grains (0·675 gramme) of stercorine were obtained, the extract consisting entirely

of crystals. This was all the stercorine to be extracted from the regular, daily evacuation of a healthy male twenty-six years of age and weighing about one hundred and sixty pounds (72·58 kilos.). In the absence of other investigations, the daily quantity of this substance excreted may be assumed to be not far from ten grains (0·648 gramme).

In many regards stercorine bears a close resemblance to cholesterine. It is neutral, inodorous, and insoluble in water and in a solution of potassium hydrate. It is soluble in ether and in hot alcohol, but is almost insoluble in cold alcohol. A red color is produced when it is treated with strong sulphuric acid. It may be easily distinguished from cholesterine, however, by the form of its crystals. It fuses at a low temperature, 96·8° Fahr. (36° C.), while cholesterine fuses at 293° Fahr. (145° C.).

Stercorine crystallizes in the form of thin, delicate needles, frequently mixed with clear, rounded globules, which are probably composed of the same substance in a non-crystalline form. When the crystals are of considerable size, the borders near their extremities are split longitudinally for a short distance. The crystals are frequently arranged in bundles. They are not to be confounded with excretine, which crystallizes in the form of regular, four-sided prisms, or with the thin, rhomboidal or rectangular tablets of cholesterine. They are identical with the crystals of seroline, figured by Robin and Verdiel.

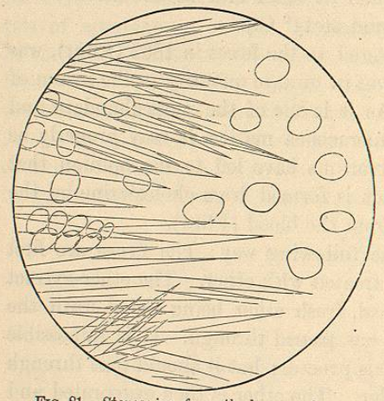

Fig. 81.—*Stercorine from the human fæces.*

There can be no doubt with regard to the origin of the stercorine which exists in the fæces. Whenever the bile is not discharged into the duodenum, as is probably the case for a time in icterus accompanied with clay-colored evacuations, stercorine is not to be discovered in the dejections. In one case of this kind, in which the fæces were subjected to examination, the matters extracted with hot alcohol were entirely dissolved by boiling for fifteen minutes with a solution of potassium hydrate, showing the absence of cholesterine and stercorine. In another examination of the fæces from this patient, made nineteen days after, when the icterus had almost entirely disappeared and the evacuations had become normal, stercorine was discovered. These facts show that the cholesterine of the bile, in its passage through the intestine, is changed into stercorine. Both of these substances are crystallizable, non-saponifiable, are extracted by the same chemical manipulations, and behave in the same way when treated with sulphuric acid. Stercorine must be regarded as a modification of cholesterine, which is the excrementitious constituent of the bile.

The change of cholesterine into stercorine is directly connected with the process of intestinal digestion. If an animal be kept for some days without food, cholesterine will be found in the fæces, although, for a few days, stercorine is also present. It is a fact generally recognized by those who have analyzed the fæces, that cholesterine does not exist in the normal evacuations; but whenever digestion is arrested, the bile being constantly discharged into the duodenum, cholesterine is found in large quantity. For example, in hibernating animals, cholesterine is always present in the fæces. The same is true of the contents of the intestines during fœtal life; the meconium always containing a large quantity of cholesterine, which disappears from the evacuations when the digestive function becomes established. Stercorine has not been subjected to ultimate analysis. Its physiological relations will be considered in connection with the excretory office of the liver.



*Indol*, *Skatol*, *Phenol etc.*—The so-called putrefactive processes, which begin in the small intestine, are more marked in the large intestine and give rise to certain products which have the characteristic fæcal odor. Certain of these substances may be produced by the prolonged action, out of the body, of the pancreatic juice upon albuminoids. The pancreatic juice, in an alkaline medium, changes the trypsine-peptones into leucine, tyrosine, hypoxanthine and asparaginic acid. By still farther prolonging this action, indol ($C_8H_7N$), skatol ($C_9H_9N$) and phenol ($C_6H_6O$), with some other analogous substances and volatile fatty acids, are formed, and there is an evolution of certain gases. It is probable that these products are formed in abnormal quantities in the small intestine in certain cases of intestinal dyspepsia. The relations of the substances just mentioned to the general process of nutrition are not understood.

*Movements of the Large Intestine.*—Movements of the general character noted in the small intestine occur in the large intestine, although the peculiarities in the arrangement of the muscular fibres and the more solid consistence of the contents render these movements in the large intestine somewhat distinctive. In all instances where the movements have been observed in the human subject or in the lower animals, they have been found to be less vigorous and rapid than the contractions of the small intestine. Indeed, when the abdominal organs are exposed, either in a living animal or immediately after death, movements of the large intestine are generally not observed, except on the application of mechanical or electric stimulation; and they are then more circumscribed and much less marked than in any other part of the alimentary canal. That the fæces remain for a considerable time in some of the sacculated pouches of the colon, is evident from the appearance which they sometimes present of having been moulded to the shape of the canal. This appearance is frequently observed in the dejections, which are then said to be "figured."

In the cæcum, the pressure of matters received from the ileum forces the mass onward into the ascending colon, and the contractions of its muscular fibres are probably slight and inefficient. Once in the colon, it is easy to see how the contractions of the muscular structure—the longitudinal bands shortening the canal, and the transverse fibres contracting below and relaxing above—are capable of passing the fæcal mass slowly onward. Although

the transverse fibres are thin and apparently of little power, their contraction is undoubtedly sufficient to empty the sacculi, when assisted by the movements of the longitudinal fibres, especially as the canal is never completely filled and the fæces are frequently in the form of small, moulded lumps. By these slow and gradual movements, the contents of the large intestine are passed toward the sigmoid flexure of the colon, where they are arrested until the period arrives for their final discharge. The time occupied in the passage of the fæces through the ascending, transverse and descending colon is undoubtedly variable in different persons, as great variations are observed in the intervals between the acts of defæcation. During their passage along the colon, the contents of the canal assume more and more of the normal fæcal consistence and odor and become slightly coated with the mucous secretion of the parts.

The accumulation of fæces generally takes place in the sigmoid flexure of the colon; and under normal conditions, the rectum is found empty and contracted. This part of the colon is much more movable than other portions of the large intestine. At certain tolerably regular intervals, the fæcal matter is passed into the rectum and is then almost immediately discharged from the body.

*Defæcation.*—In health, expulsion of fæcal matters takes place with regularity generally once in the twenty-four hours. This rule, however, is by no means invariable, and dejections may habitually occur twice in the day or every second or third day, within the limits of health. At the time when defæcation ordinarily takes place, a peculiar sensation is experienced calling for an evacuation of the bowels; and if this be disregarded, the desire may pass away, after a little time the act becoming impossible. It is probable that the fæces are then passed out of the rectum by antiperistaltic action.

The condition which immediately precedes the desire for defæcation is probably the descent of the contents of the sigmoid flexure of the colon into the rectum. It was formerly thought that the fæces constantly accumulated in the dilated portion of the rectum, where they remained until an evacuation took place; but the arguments of O'Beirne against such a view are conclusive. He demonstrated, by explorations in the human subject, that under ordinary conditions, the rectum is contracted and contains neither fæces nor gas. It is, indeed, a fact familiar to every surgeon, that the rectum usually contains nothing which can be reached by the finger in physical examinations, and that paralysis or section of the muscles which close the anus by no means involves, necessarily, a constant passage of fæcal matter. O'Beirne not only found the rectum empty and presenting a certain degree of resistance to the passage of injected fluids, but on passing a stomach-tube into the bowel, after penetrating six to eight inches (15 to 20 centimetres), it passed into a space in which its extremity could be moved with great freedom, and there was instantly a rush of flatus, of fluid fæces, or of both, through the tube. In some instances in which nothing escaped through the tube, the instrument conveyed to the hand an impression of having entered a solid mass; and on being withdrawn it contained solid fæces in its



upper portion. The sensation which leads to an effort to discharge the fæces is due to the accumulation of matters in the sigmoid flexure, which finally present at the contracted, upper portion of the rectum. This constriction, situated at the most superior portion of the rectum, is sometimes called the sphincter of O'Beirne.

The above is the mechanism of the descent of fæcal matter into the rectum in defæcation, as the act is usually performed; but under certain conditions, fæces must accumulate in the dilated portion of the rectum. Ordinarily, the discharge of fæces takes place only after the efforts have been continued for a certain time, and when the evacuation is "figured," the whole length discharged frequently exceeds so much the length of the rectum, that it is evident that a portion of it must have come from the colon; but in cases in which the fæces are very fluid, or when the call for an evacuation has not been regarded and has become imperative, the immediate discharge of matters when the sphincter is relaxed shows that the rectum has been more or less distended.

In the process of defæcation, the first act is the passage, by peristaltic contractions, of the contents of the sigmoid flexure of the colon through the slightly constricted opening of the rectum into its dilated portion below. The fæcal matter, however, is not allowed to remain in this situation, but it passes into the lower portion of the rectum, in obedience to the contractions of its muscular coat, assisted by the action of the abdominal muscles and the diaphragm. The circular fibres of the rectum undergo the ordinary peristaltic contraction; and the action of the longitudinal fibres is to render the rectum shorter and more nearly straight. The internal and the external sphincters present a certain resistance to the discharge of the fæces, particularly the external sphincter, which is a striated muscle of considerable power. There is always, however, a voluntary relaxation of this muscle, or rather a cessation of its semi-voluntary contraction, which immediately precedes the expulsive act. The dilatation of the anus is also facilitated by the action of the levator ani, which arises from the posterior surface of the body and ramus of the pubis, the inner surface of the spine of the ischium, and a line of fascia between these two points, passes downward, and is inserted into the median raphe of the perineum and the sides of the rectum, the fibres uniting with those of the sphincter. While this muscle forms a support for the pelvic organs during the act of straining, it steadies the end of the rectum, and by its contractions, favors the relaxation of the sphincter and draws the anus forward.

The diaphragm and the abdominal muscles merely compress the abdominal organs, and consequently those contained in the pelvis, and assist in the expulsion of the contents of the rectum. The diaphragm is the most important of the voluntary muscles concerned in this process; and during the act of straining, the lungs are moderately filled and respiration is interrupted. The vigor of these efforts depends greatly upon the consistence of the fæcal mass, very violent contractions being frequently required for the expulsion of hardened fæces after long constipation. Although more or less

straining generally takes place, the contractions of the muscular coats of the rectum frequently are competent of themselves to expel the fæces, especially when they are soft.

By a combination of the movements above described, the floor of the perineum is pressed outward, the anus is dilated, the sharp bend in the lower part of the rectum is brought more into line with the rest of the canal, and a portion of the contents of the rectum is expelled. Very soon, however, the passage of fæces is interrupted by a contraction of the levator ani and the sphincter, by which the anus is suddenly and rather forcibly retracted. This muscular action may be effected voluntarily; but after the sphincter has been dilated for a time, the evacuation is interrupted in this way, notwithstanding all efforts to oppose it. After a time, another portion of fæces is discharged, until the matters have ceased to pass out of the sigmoid flexure and the rectum has been emptied.

Very little need be said concerning the influence of the nervous system on the movements concerned in defæcation. The non-striated muscular fibres which form the muscular coat of the rectum are supplied with nerves from the sympathetic system; and to the external sphincter are distributed filaments from the last sacral pair of spinal nerves. These nerves bring the sphincter in a certain degree under the control of the will, and impart likewise the property of tonic contraction, by which the anus is kept constantly closed. The nerve-centre for defæcation in the dog, or the ano-spinal centre, is in the spinal cord, at the site of the fifth lumbar vertebra (Budge).

## Gases found in the Alimentary Canal.

The gases in the stomach appear to have no definite office. They generally exist in very small quantity and they are sometimes absent. The oxygen and nitrogen are derived from the little bubbles of air which are incorporated with the alimentary bolus during mastication and insalivation. The other gases are probably evolved from the food during digestion; at least, there is no satisfactory evidence that they are produced in any other way. Magendie and Chevreul collected and analyzed a small quantity of gas from the stomach of an executed criminal a short time after death and ascertained that it had the following composition:

GASES CONTAINED IN THE STOMACH.

| | |
|---|---|
| Oxygen | 11·00 |
| Carbon dioxide | 14·00 |
| Pure hydrogen | 3·55 |
| Nitrogen | 71·45 |
| | 100·00 |

Magendie and Chevreul found three different gases in the small intestine. Their examinations were made upon three criminals soon after execution. The first was twenty-four years of age, and two hours before execution, he had eaten bread and Gruyère cheese and had drunk red wine and water. The second, who was executed at the same time, was twenty-three



years of age, and the conditions as regards digestion were the same. The third was twenty-eight years of age, and four hours before death, he ate bread, beef and lentils, and drank red wine and water. The following was the result of the analyses:

GASES CONTAINED IN THE SMALL INTESTINE.

| | First criminal. | Second criminal. | Third criminal. |
|---|---|---|---|
| Carbon dioxide | 24·39 | 40·00 | 25·00 |
| Pure hydrogen | 55·53 | 51·15 | 8·40 |
| Nitrogen | 20·08 | 8·85 | 66·60 |
| | 100·00 | 100·00 | 100·00 |

No oxygen was found in either of the examinations, and the quantities of the other gases were so variable as to lead to the supposition that their proportion is not at all definite. Reference has already been made to the mechanical office of these gases in intestinal digestion.

In the large intestine, the constitution of the gases presented the same variability as in the small intestine. Carburetted hydrogen was found in all of the analyses. In the large intestine of the first criminal and in the rectum of the third, were found traces of hydrogen monosulphide. The following is the result of the analyses in the cases just cited. In the third, the gaseous contents of the cæcum and the rectum were analyzed separately:

GASES CONTAINED IN THE LARGE INTESTINE.

| | First criminal. | Second criminal. | Third criminal. Cæcum. | Third criminal. Rectum. |
|---|---|---|---|---|
| Carbon dioxide | 43·50 | 70·00 | 12·50 | 42·86 |
| Carburetted hydrogen and traces of hydrogen monosulphide | 5·47 | ..... | ..... | ..... |
| Pure hydrogen and carburetted hydrogen | ..... | 11·60 | ..... | 11·18 |
| Pure hydrogen | ..... | ..... | 7·50 | ..... |
| Carburetted hydrogen | ..... | ..... | 12·50 | ..... |
| Nitrogen | 51·03 | 18·40 | 67·50 | 45·96 |
| | 100·00 | 100·00 | 100·00 | 100·00 |

*Origin of the Intestinal Gases.*—The most reasonable view to take of the origin of the gases normally found in the intestines is that they are given off from the articles of food in their various stages of digestion and decomposition. That this is the principal source of the intestinal gases, there can be no doubt; and it is well known that certain articles of food, particularly vegetables, generate much more gas than others. The principal gases found in the intestinal canal may all be obtained from the food. Some of them, as hydrogen and carburetted hydrogen, do not exist in the blood; and it is difficult to conceive how they can be generated in the intestine except by decomposition of certain of the articles of food. Gases do not exist in the alimentary canal of the fœtus.