THE FÆCES OF CHILDREN AND ADULTS

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THEIR EXAMINATION AND DIAGNOSTIC SIGNIFICANCE WITH INDICATIONS FOR TREATMENT

BY

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PREFACE.

Messrs. John Wright & Sons having obtained the English rights of Dr. Adolf. F. Hecht's "Die Fæces des Säuglings und des Kindes," asked me to prepare and edit for them a translation. On mature consideration it was decided, however, that a book of wider scope, dealing with the fæces of both adults and children, would be more generally useful.

In preparing the following pages I have made extensive use of Hecht's work, and also drawn on the mine of information contained in Schmidt and Strasburger's "Fæces des Menschen," as must all workers in this field; but much of the matter is original and the result of my own observations during the past fifteen years, during which time I have examined several thousand specimens of fæces.

The practical part of the book follows as far as possible the sequence in which I have found it is most advantageous to make the examinations, but the order must necessarily vary with the end aimed at.

The two last chapters are devoted to a consideration of the clinical inferences to be drawn from the results of the analyses described in the previous pages and the indications for treatment that they suggest. Although brief, I hope that they may be of use, particularly to those who are dependent upon others for the carrying out of the laboratory investigations. In this connection I should like to point out that in applying laboratory results to clinical medicine, here as in other similar investigations, it is essential, for the greatest advantage to accrue to the patient, that the pathologist should be aware of the clinical signs and symptoms, so that he may arrange his investigations accordingly, and that the results of the analyses in any doubtful case should be discussed in consultation with the clinician. If the two functions are combined in one person, so much the better for the patient.

In a subject presenting such a wide field for observation as the fæces, there are necessarily many gaps, and if the following pages help and stimulate others to add to our comparatively scanty information on the subject, I shall feel that they have not been written in vain.

P. J. CAMMIDGE.

32, *Nottingham Place, W.*
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CHAPTER I.

INTRODUCTION.

DISEASES of the gastro-intestinal tract and disturbances of digestion are among the commonest ailments that the medical man is called upon to diagnose and treat; but with rare exceptions advantage is not taken of the help which an examination and analysis of the fæces might give in determining the exact nature of the condition. The reason is no doubt partly an æsthetic one, but it is also due to the lack of precise information on the part of most practitioners as to the composition of the stools in health and the variations caused by disease.

Our knowledge of the processes of digestion and absorption in the normal state is now based upon such sure foundations that the existence of partial or complete failure in any one of the numerous steps can be deduced with considerable certainty from analyses of the stools, while the work of numerous observers on the pathological side during the past ten or twelve years has resulted in the accumulation of a large amount of information as to the changes produced by abnormal states of the gastro-intestinal tract and its contents on the fæces.

Most observers now make use of the diagnostic help to be derived from analyses of the stomach contents after a test meal, but it is much easier to obtain a specimen of the fæces than it is to secure a sample of the gastric contents, and equally useful data for purposes of diagnosis may be obtained by even a superficial examination. It is often objected that an analysis of the fæces necessitates the use of a test meal, and that many patients dislike being deprived of their ordinary food for several days; but if the observer has had much experience of fæcal examinations, he can usually derive sufficient information for ordinary purposes from an investigation of the stools passed on any simple diet, and it is only occasionally necessary to give the patient special meals when greater accuracy is aimed at.

Thanks to the comparatively simple dietary of infants, the relatively rapid passage of the intestinal contents, and the absence of intestinal decomposition under ordinary conditions, the results of the analyses of their stools are much easier to interpret than is the case with adults, in whom we have to contend with a more complicated dietary, and also to take into account a large number of underlying factors, including the effects of former illnesses, etc. Even in adults, however, analyses of the fæces are of considerable assistance in studying conditions of perverted nutrition, diagnosing certain lesions, investigating many epidemiological questions, and establishing rules of hygiene.

When making use of investigations of the fæces for diagnostic purposes, it must always be borne in mind that the results of most laboratory tests are capable of more than one interpretation, and that they must therefore be confirmed if possible by other methods, and always be considered in the light of the clinical signs and symptoms.

COLLECTION OF THE FÆCES.

The method adopted for the collection of the fæces for examination will depend upon the purpose for which the investigation is intended. When search is to be made for amœba coli or other motile protozoa, the stool should be passed into a well-warmed bed-pan or other vessel and be examined as soon as possible, so that it does not become chilled. If a bacteriological examination is intended, a portion of the stool, which has been passed into a sterile or well "scalded" vessel, is placed in a surgically clean wide-mouthed bottle, which should be tightly corked and kept warm while being transferred to the laboratory, where it is at once placed in an incubator at 37° C. until required for examination. Where a physical and chemical examination only is required, two or three ounces of the fresh, well-mixed stool, contained in a small wide-mouthed bottle or ointment pot, will usually afford sufficient material; but in cases where elaborate metabolic experiments are to be carried out, it is necessary to collect and mix the fæces passed during two or three days, and analyze a sample of the mixture. As a rule, it is not advisable to add an antiseptic, but when the specimen has to be sent a long distance, especially in hot weather, it may be preserved by mixing it with a little formaldehyde; the analyst should always be advised when this has been done, as it alters the reaction and interferes with a few of the tests that it may be thought desirable to carry out. I have obtained satisfactory results with specimens preserved in this way that have been sent from India, America, and Australia.

Since the fæces of infants have generally to be scraped off diapers, they are usually contaminated to a greater or less extent with materials derived from the dusting powders or ointments that are generally applied to the neighbouring parts, and this must be taken into account in both the microscopical and chemical examinations.

It is most important that the fæces should be obtained free from urine, as the presence of the latter interferes with the reaction, the ammonia content, and so forth. Adults should be made to micturate before the specimen is collected, while with children the best way to prevent contamination is by care on the part of the nurse, and the use of a large pad of absorbent wool over the orifice of the urethra.

Suspicion of an admixture of urine with the fæces may be aroused by its appearance; but with soft or liquid stools this is no guide. It may be suspected, however, if the specimen is strongly alkaline in reaction, has an ammoniacal odour, and shows numerous knife-rest crystals of ammonium magnesium phosphate microscopically. The best proof that the fæces have been contaminated with urine is the presence of a well-marked reaction for chlorides, since chlorides occur in abundance in the urine, but are only found in small quantities in the fæces. This point may be determined as follows:—

A fairly concentrated water extract of the fæces is made with boiling distilled water. The extract is filtered, acidified with nitric acid, and a 10 per cent watery solution of silver nitrate added drop by drop. If the stool has not been contaminated with urine, only a slight opalescence is seen, whereas a more or less dense white precipitate, depending on the degree of contamination, will form should urine have been mixed with the stool.

For purposes of bacteriological analysis it may be advisable to give a purgative in some cases, but specimens obtained in this way are unsuited for quantitative chemical investigations. A sample for chemical analysis may be secured, if necessary, by the use of a plain water enema, but injections containing soap or oil should on no account be employed, as these substances would interfere with the results. For the same reason, the use of drugs by the mouth, and particularly iron, bismuth, liquid paraffin, olive oil, etc., should be discontinued for several days before a sample of fæces is collected for chemical analysis.

GENERAL COMPOSITION AND CHARACTERS.

The fæces are composed for the most part of the following constituents:—

1. Remnants of the food that have escaped absorption

2. Remnants of the food which are relatively or entirely incapable of digestion.

3. The secretions of the intestinal mucous membrane and of the digestive glands.

4. Cell elements and, under pathological conditions especially, mucus, serum, red blood corpuscles, and leucocytes.

5. The products of the splitting up of the food-stuffs, some due to the effects of ferments, others arising from the action of bacteria.

6. Excretory products of the intestinal mucous membrane, such as salts of calcium, iron, and possibly other metals, etc.

7. The bacterial flora of the intestine.

8. Adventitious additions to the stools, such as intestinal parasites or their eggs, enteroliths, gall-stones, etc.

This applies to the fæces of infants and children, as well as to adults, although the relative proportions of the individual ingredients are necessarily different at different ages and under varying conditions, the most noteworthy contrast existing between the stools during the first few months and in later life.

Both in health and disease the composition of the fæces is largely dependent upon the character and amount of food taken, so that before reliable conclusions can be drawn from the results of analyses, whether these be chemical, bacteriological microscopical, or merely macroscopical, the exact nature of the diet for the previous two or three days should be known. A variety of "test-diets" have been devised by different observers, mostly German, but I find that as a rule they prove very distasteful to English patients, and consequently do not probably give a true picture of their digestive powers. Experiment and everyday experience alike prove what important factors psychical influences and appetite are in the digestive processes, and it is therefore better, in my opinion, to give a patient foods that he is accustomed to and likes rather than some unappetizing mixture that he will probably only swallow from a sense of duty. I have generally found it sufficient to ask the patient to include in his dietary for forty-eight hours or so the following substances: (1) Milk, undiluted or mixed with coffee; (2) Eggs; (3) Protein foods, such as fish, poultry, beef, and veal, boiled or roasted; (4) Starchy foods, including bread, potatoes, and rice; (5) Various green vegetables and roots, according to the season; (5) Butter, bacon, ham, and the fat of meat. The choice of these articles, as well as the amount taken, may be left to the patient's taste, provided that he keeps a list, with the approximate quantity at least, of each consumed.

The following test diet is recommended by Harley and Goodbody :—

8.0 a.m.—10 oz. hot water.
9.0 a.m.—3 oz. whiting, 4 Mackenzie's toast biscuits (or 2 oz. of toast or rusk), ⅓ oz. butter, 10 oz. tea, 2 oz. milk.
Noon.—10 oz. hot water.
1.0 p.m.—3 oz. mutton, 3 oz. cabbage, rice pudding (½ oz. rice, 10 oz. milk), 4 biscuits (or 2 oz. of toast or rusk), ⅓ oz. butter.
4.30 p.m.—10 oz. tea, 2 oz. milk, 2 biscuits (or 1 oz. of toast or rusk).
6.0 p.m.—10 oz. hot water.
7.0 p.m.—3 oz. plaice, 3 oz. chicken, 3 oz. spinach, rice pudding as at lunch, 2 biscuits (or 1 oz. of toast or rusk), ⅓ oz. butter.
10.0 p.m.—10 oz. milk.

This diet contains about 130 grams of protein, 72 grams of fat, and 119 grams of carbohydrate, yielding 1697 calories, a sufficient allowance for an average adult weighing 154 lb. (70 kilos) when at rest.

The disadvantage of such a diet as the preceding is that, in the process of cooking, the food is so much altered that microscopical examination of the residues passed in the fæces does not always give very satisfactory results. To meet this difficulty Schmidt has devised a test diet leaving easily distinguished food residues, which he strongly recommends in the investigation of gastro-intestinal disorders by microscopical and chemical analyses of the fæces. The patient is first thoroughly purged, and then put on the following diet for several days :—

7.30 a.m.—17½ oz. (0·5 litre) milk or, if milk does not agree, cocoa [made from ⅔ oz. (20 grams) cocoa powder, ⅓ oz. (10 grams) sugar, 14 oz. (400 grams) water, and 3 oz. (100 grams) milk], 1¾ oz. (50 grams) of rusk or toast.
9.0 a.m.—17½ oz. (0·5 litre) of gruel [made from 1½ oz. (40 grams) oatmeal, ⅓ oz. (10 grams) butter, 7 oz. (200 grams) milk, 10½ oz. (300 grams) water, one egg, and strained].
1.0 p.m.—4½ oz. (125 grams) (raw weight) minced beef, fried in ¾ oz. (20 grams) butter, so that the interior remains raw, 9 oz. (250 grams) potato purée [made from 7 oz. (190 grams) of mashed potato, 3½ oz. (100 grams) of milk, and ⅓ oz. (10 grams) of butter].
4.30 p.m.—As at 7.30 a.m.
7.30 p.m.—As at 9.0 a.m.

This diet contains about 102 grams of protein, 111 of fat, and 190 of carbohydrate, yielding about 2230 calories. The fæces are collected for examination as soon as they show the characteristic light colour given by the diet.

When using a test diet, it is of course necessary that only analyses of fæces resulting from that diet should be taken into account, and as long an interval as possible should therefore be interposed between it and the previous meal, six or seven hours for example. The commencement of its passage may be marked by administering with the first meal a cachet containing half a gram (7 grains) of powdered carmine or vegetable charcoal, the contents of which, passing through the digestive canal unchanged, give to the fæces an easily recognizable colour. For metabolic experiments, where the total fæces for several days are to be collected, the end of the period must be marked by the administration of a second cachet. In cases where diarrhœa exists, the demarcation of the coloured from the uncoloured part of the fæces is not sharp, but this difficulty can be overcome by prolonging the test over a longer period. With normal evacuations it is generally found that a stool derived from the test diet occurs about the second defæcation after its commencement, but no general rule can be laid down.

The above methods of procedure naturally cannot be applied to young children. With infants a macroscopic and microscopic examination of the fæces is often sufficient to establish a diagnosis. In cases where it is desired to quantitatively balance the ingesta and excreta, the child should be kept on a known diet for five or six days, during three of which the fæces should be collected for analysis.

Amount.—On a mixed diet under normal conditions, the quantity of fæces dejected during twenty-four hours varies between 60 and 250 grams (2–9 oz.), with an average of 100 to 200 grams ($3\frac{1}{2}$-7 oz.). Pathologically it is not unusual to find from 500 to 1200 grams ($17\frac{1}{2}$–42 oz.). No reliable conclusion can be drawn, however, from the examination of a single stool, as even under ordinary conditions the quantity passed varies from day to day, and it is therefore essential that an average should be struck, the longer the period of observation the more accurate being the conclusion. The sensations of the individual, being influenced chiefly by the hardness of the motion, do not furnish a reliable guide as to the quantity of fæces passed.

In estimating the bulk of the motions in children, it is important to bear in mind several possible sources of error. Profuse watery excretions are apt to be very much under-estimated when they take place into diapers, since the fluid, which is for the most part very deficient in colouring matter, sinks into the cloth, and can be recognized only as a stain around each particle that has been less wanting in colour than the rest. If it is particularly desired to estimate the amount and percentage of water in a diarrhœic motion passed by an infant, the stool must be collected in some waterproof material. On the other hand, the stools may appear to contain too high a percentage of water, owing to their being mixed with urine.

The bulk, and also the dry weight of the fæces, is influenced by the age of the individual, the quantity and character of the food, the degree of intestinal irritation, and the frequency of the peristaltic waves. Protracted constipation, or a temporary intestinal obstruction, may be followed by a copious discharge of fæces. In one case of prolonged constipation, Lynch states that no less than 20 kilos (44 lb.) were passed.

During a period of fasting, the excretion of fæces continues, the motions consisting of the remains of the digestive secretions and material excreted by the intestinal walls. Even in such circumstances, however, individual variations are met with. The fasting man, Cetti, during a ten days' abstinence from food, passed 22 grams of fresh fæces daily, containing 3·4 grams of dry substance; whilst Breithaupt, during a six days' fast, passed 9·5 grams, containing 2·0 grams of dry substance (Müller).

As a general rule, it may be stated that there is a tendency for the quantity of fæces to increase with age, but children reared on cow's milk pass a larger quantity than those nourished at the breast. Escherich found that a ten-week-old child, taking one litre of cow's milk a day, passed nearly ten times as much fæces as a breast-fed child of the same age. This is largely due to the quantity of food taken, for even in adults Harley and Goodbody have shown that the quantity of fæces has a tendency to increase with the quantity of milk. The same observers have also proved that when milk is added to a mixed diet there is a tendency for the bulk of fæces to increase in proportion to the quantity of milk given.

The amount of the fæces is increased by a diet rich in vegetables and starchy foods, and is diminished by one consisting of meat, or rich in animal protein. Thus, on a vegetable diet, Rumpf and Schumm found that the fresh fæces weighed 370 grams. On a flesh diet Rübner gives 64 grams as the average weight, and Harley and Goodbody 54·5 grams. With Schmidt's diet the last-named observers found that the weight of the fæces varied from 56 to 135 grams, with an average of 89·9 grams.

The amount of fæces passed by children spontaneously does not vary so much as in later life, although considerable alterations in the amount evacuated daily may occur in seemingly normal children without any apparent cause. It therefore follows that if a reliable opinion is to be formed, an average must be struck, and for this purpose observations should be made for at least three consecutive days. Since there are certain conditions, especially in the case of infants at the breast, in which it is important that the ordinary daily amount of the stools should be known, the observations of different investigators are of interest. Michel gives the following figures for breast-fed infants from five to fifteen days old :—

Weight of Stool per Kilogram of Body Weight per Diem.	Weight of Stool per Hundred Parts of Food by the Mouth.
2·00 grams	1·56 per cent
2·63 ,,	1·40 ,, ,,
4·54 ,,	2·57 ,, ,,
4·02 ,,	2·17 ,, ,,

Camerer investigated the fæces of an infant fed entirely at the breast, and found an average of from 1 to 3 grams per 100 grams of food, except during the first fourteen days, when the excretion in relation to the milk taken was somewhat more. From the third to the twenty-second week 3·7 grams of fæces were passed, which was equivalent to rather less than 1 gram per 100 of milk. In the seventeenth and nineteenth weeks the average amount of fæces in twenty-four hours amounted to 5·7 grams.

There are few standard figures available in the case of infants fed upon artificial foods. At seven months Camerer found that a child being fed upon cow's milk passed daily 53 grams of fæces, all at one stool. When eleven months old, the same child received 1½ litres of milk, a certain amount of meat, bread, and apple up to a weight of 25 grams, and passed 120 grams of fæces daily. On the 273rd, 274th, and 275th days of life, Camerer and Soldner found an average of 59 grams of fæces per 1085 c.c. of milk. A continuous record in the case of two children, a boy and a girl, until they were grown up, was made by Camerer, with the following results :—

Girl. Weight of Stool per Diem.	Boy. Weight of Stool per Diem.
2–4 years, 72 grams	5–6 years, 134 grams
5–7 ,, 67 ,,	7–10 ,, 113 ,,
8–10 ,, 70 ,,	11–14 ,, 98 ,,
11–14 ,, 84 ,,	15–16 ,, 79 ,,
15–18 ,, 71 ,,	17–18 ,, 73 ,,
21–24 ,, 91 ,,	

In these two instances, the excretion in the case of the girl slowly increased, while in the case of the boy it showed a remarkable and progressive diminution. In this connection it is also important to note that the number of evacuations fell after puberty from 1·3 and 1·0 per diem respectively, to 0·5, so that latterly each child had a motion only once in each two days. Camerer states that the excretion of fæces in the child corresponds to that in grown-up people, and also that the degree to which a mixed diet is absorbed and utilized is remarkably good. He concludes from the fact that the absolute figures in the case of the boy, and the figures relative to the body weight in the case of the girl, steadily decreased, that there is evidence of there being an increasing improvement in the extent to which the food is made use of as the age of the child increases.

A careful estimation of the daily average amount of the fæces passed, when compared with the standard figures for successive periods of life and for different dietaries, affords a very useful indication of the way in which the alimentary canal is performing its functions. This is true for the infant before weaning, for older children, and also for adults, if the differences that result from diets consisting of breast milk, cow's milk, and various types of solid food, etc., are borne in mind.

The digestive functions of the stomach influence the bulk of the fæces very little, even complete achylia gastrica causing scarcely any modification. Failure of the digestive secretions of the intestine giving rise to an increased proportion of undigested fat or albumin in the stools is among the commonest causes of an increase in their bulk, the most noticeable alterations being produced by obstruction of the bile flow, and diseases of the pancreas that interfere with the normal production of its digestive ferments. Schmidt and Strasburger state that the average weight of the fæces in three cases of biliary obstruction was 876·3 grams on a diet which with three healthy individuals produced only 249·5 grams. Heubner reports the case of a boy aged three and a half years, who was suffering from an extreme degree of digestive insufficiency, and invariably passed copious stools, 500 grams per diem, with a total dry residue of 64 grams.

The amount may also be increased by admixture with pathological products coming from the intestinal wall or elsewhere, such as mucus, blood, pus, serum, etc. Caro, for instance, met with a case of rectal carcinoma which passed about ¾ litre of clear fluid from the bowel daily.

Conditions favouring abnormal putrefactive or fermentative changes in the intestinal contents may increase the bulk of the fæces by causing proliferation of the bacteria. According to

Strasburger about one-third of a normal stool consists of bacteria, but in some cases of dyspepsia they may constitute from a half to five-sixths. In three cases of slight fermentative dyspepsia Schmidt found the average weight of the fæces increased to 689 grams, while in one severe case 2780 grams of fæces were passed daily. Herter draws particular attention to the large bulk of the stools passed in the condition which he terms "intestinal infantilism," and in which there is a persistence of the intestinal flora of the breast-fed child beyond the suckling period. With habitual constipation the quantity of fæces may be considerably diminished, an average of 125·5 grams being found by Schmidt in two cases. It is noteworthy that in this type of case the bacteria may constitute only a fifth or even a tenth of the dry weight of the stool.

Frequency of the Intestinal Discharge.—The frequency with which the bowels are opened varies considerably. Broadly speaking, the average daily quantity of the fæces and the frequency of their evacuation run parallel. The normal child at the breast is, however, an exception to this general rule, for there are more frequent actions of the bowels than is the case with an artificially-fed infant, although the total quantity of fæces passed by a breast-fed child is much smaller than with one receiving cow's milk. The healthy infant at the breast during the first week passes from four to five stools in the twenty-four hours, later two to four, and toward the period of weaning, when he is already taking some cow's milk, only one or two stools a day. After weaning, only a single stool is usually passed daily. The child brought up entirely upon cow's milk passes generally only one or two stools a day from the beginning, if no disturbance of digestion arises. Occasionally a breast-fed child who is thriving well, will pass more than the usual number of motions daily, and even five or more cannot be considered abnormal. If, on the other hand, the breast-fed infant's stools are passed seldom, and at the same time are small in total quantity, it at once arouses a suspicion that too little food is being taken, and the mother's breasts and the amount of milk yielded by them at each feed should be carefully investigated. Repeated vomiting may, however, be an explanation of the condition, and it is then spoken of as "pseudo-constipation." An examination of the abdomen usually suffices to decide whether infrequency of the stools is due to insufficient nourishment, or whether the fæces are not being evacuated owing to delay in the lower bowel. The existence of a congenital malformation of the colon or rectum, or more rarely stenosis of the œsophagus, may in this way attract attention very soon after extra-uterine life has been entered on, but stenosis of the pylorus is often only manifested after the lapse of a few weeks. The absence of such symptoms does not exclude pyloric stenosis, especially when reliance has to be placed on the statements of the mother or nurse that the bowels are acting freely several times a day, for there may be considerable relative interference with the emptying of the stomach into the intestine, while the secretions from the walls of the bowel may suffice to produce a motion which superficially suggests that a sufficient stool has been passed.

Adults and children taking a solid mixed diet have, as a rule, one or two motions of the bowel daily, but even under physiological conditions the number is subject to wide variations. Individuals obviously enjoying perfect health may pass only one stool every two to four days, and cases are on record where an evacuation occurred but once every seven, eight, or even fourteen days. It is doubtful, however, whether it is permissible to regard the latter as normal. On the other hand, the number of stools may be increased to three, and even four a day, in quite healthy people. It is therefore important that the habitual number of stools for the individual should be determined before coming to any conclusion as to the existence of a pathological frequency.

When too frequent and liquid stools are passed, the condition is spoken of as "diarrhœa," while the reverse is spoken of as "constipation." The term "obstruction" is used to define a state of affairs in which no movement of the bowels occurs. In a general way it may be said that any cause giving rise to increased peristalsis is associated with diarrhœa, while whatever causes diminished peristalsis gives rise to constipation. In the former condition the number of stools may vary from one to forty, fifty, or more in the twenty-four hours, the consistency of the motion deciding whether the condition should be regarded as diarrhœa or not when one stool only is passed.

Under certain circumstances, a single motion daily may be regarded as a symptom of constipation, but this term is usually applied to a condition in which only one stool occurs every two, three, four, or more days. Pathological constipation may result from a variety of diseases. As a rule, maladies beginning abruptly are accompanied by constipation, and although typhoid fever and dysentery are characterized by frequent stools, the diarrhœa is usually preceded by constipation. In amœbic dysentery and in other conditions there may be alternating constipation and diarrhœa. Constipation is a valuable early diagnostic sign of peritonitis and paralysis of the intestine, and may also be a prominent feature in the symptoms of carcinoma of the œsophagus and of malignant disease of the stomach or intestine. In the latter group of cases it is usually the result of starvation. Narrowing of the lumen of the bowel, from whatever cause, induces constipation or obstruction according to the degree to which the calibre of the intestine is interfered with. The character and quantity of the food, as well as the nature of the disease, materially influence the frequency and also the quantity of the intestinal discharge, and constipation therefore, while extremely troublesome and annoying, is not necessarily of serious import.

Diarrhœa always indicates an intestinal catarrh, which may be the result of errors in diet, exposure to cold, or be dependent upon the growth of some infectious agent, such as the B. typhosus, the Amœba coli, the B. dysenteriæ, etc. The stools are thin, more or less watery, and in certain diseases have characteristic features, as for example the pea-soup stools of typhoid fever, and the muco-serous or muco-sero-purulent evacuation of acute dysentery. These may occur every few hours, or even more frequently. The stools of Asiatic cholera are characterized by their rice-water appearance. Some drugs excite frequent movements of the bowels, and at times give rise to an intestinal catarrh. In such cases the evacuations closely resemble those of acute dysentery. The frequency of the evacuations gives some indication as to the seat of catarrhal affections of the alimentary canal. When the small intestine is most affected the stools as a rule are more abundant and are passed at rather longer intervals than when the colon is the chief seat of the trouble, the evacuations then being more frequent but smaller in amount. Thus in dysentery, when there is much tenesmus, the evacuations are exceedingly small in quantity, but follow one another with hardly a quarter of an hour's interval, while with duodenal catarrhs larger motions with longer intervals between, are the rule.

Psychical, general, and reflex nervous influences have an important bearing on the frequency with which the bowels are opened. The diarrhœa of fear and of exophthalmic goitre are examples of psychical and general nervous influences respectively, while it is well known how even slight local lesions of the rectum, such as an ulcer or fissure, may cause frequent stools. Constipation may in a similar way be brought about by affections of the nervous system, such for example as melancholia, tabes, lesions of the cord, etc.

It may be mentioned in passing, that the time spent by the food in the intestines bears no particular relationship to the frequency of the evacuations. If the stools are passed at regular intervals, and yet the duration of their stay in the alimentary tract is unduly long, the condition may be spoken of as "latent constipation." On the other hand, acute diarrhœa is not incompatible with a normal time of passage, as for example in colitis. The fact that the duration of the passage bears no necessary relation to the frequency of the evacuations is well shown in cases of partial intestinal obstruction in which there may be a remarkable prolongation of the time the intestinal contents take to pass through the bowel, and yet there may be frequent evacuations.

Duration of Passage.—The time occupied in the passage of the food from the mouth to the anus is of importance in connection with a quantitative estimation of the fæcal residue after a test diet, and also from a clinical point of view. According to Hertz, a mass containing bismuth salts passes through the œsophagus, stomach, and small intestine in about four and a half hours. Rieder found that the material began to appear in the cæcum in three and a half hours, and the small intestine was emptied at the end of nine and a half hours. At least as much more time is required for the passage along the relatively short distance from the cæcum to the splenic flexure: according to Hertz four and a half hours, according to Rieder about eleven hours. Defæcation nine hours after breakfast, for example at 5 p.m. after an 8 o'clock meal, might therefore rid the body of waste taken in the same day. If the act were performed at 4 o'clock, however, this waste would not be discharged, so that if 4 o'clock were the regular time for the act, the waste from breakfast must be retained for another twenty-four hours. Thus the interval between the taking of a meal and the excretion of its residue in the fæces may vary, when the bowels are opened once a day, between nine and thirty-two hours, the actual period depending on the time of eating and the time of defæcation. Strauss, using a diet of 100 grams of scraped beef, found that it passed through the alimentary canal on an average in ten to twenty hours. Maurell, using a pure milk diet, gives as the normal period thirty-six to forty-eight hours.

The time of passage of the food through the alimentary canal is much less in infants than in adults—usually from one-third to one-quarter. It is probably owing to this rapid passage that certain phenomena, such as reduction and putrefaction, do not occur in infants with the same intensity as in older people. Koziczkowski states that the normal period for children on a milk diet is from fifteen to twenty-five hours.

The clinical importance of an accurate determination of the time spent in the alimentary tract by the food lies in the information it affords as to the particular portion that is concerned in the production of a diarrhœa or constipation. By means of a bismuth meal and the fluorescent screen the actual progress of a test meal can be watched and its course compared with that of the healthy individual. The radiographic method is not, however, always available, and much may then be learnt by the administration of carmine or charcoal capsules. If in a case of diarrhœa it is found that the time of passage is approximately normal, it will suggest that peristalsis in the small intestine is not increased, and that the disturbance is in the lower part of the large intestine. A too rapid appearance of the colouring matter in the stools would, on the other hand, point to the seat of the trouble being in the small intestine or ascending colon. In a patient who has a daily motion, a failure of the distinctive colour to appear in the next day's motion when it has been given at breakfast, points to there being latent constipation. If the bowel is then washed out and coloured fæces are brought away, there is retention in the lower bowel; but if the fæces are uncoloured, there is delay in the cæcum or ascending or transverse colon. The recovery of coloured fæces by lavage of the bowel on the morning following the administration of a cachet in a patient who does not have a daily motion, would show that atony or dilatation of the lower bowel was an important factor in the production of the constipation. The appearance of coloured fæces for several days after the administration of a cachet, points to atony of the bowel and latent constipation.

Form and Consistency.—In health the form and consistency of the fæces is mainly determined by the quantity of water they contain, and is hence largely dependent upon the nature of the ingesta. With a mixed diet they exhibit a characteristic cylindrical form, and are of fairly firm consistency. When the amount of vegetable food is increased they become softer, and are usually of a more pultaceous character. On a purely meat diet they tend to be very firm, and appear as short rolls of varying length, which are generally quite separate from each other. The fæces of an adult on a milk diet are usually not as well formed as those that result from mixed foods, and often consist of cylindrical rolls accompanied by masses of soft pasty material.

The diameter of solid motions is chiefly determined by the size and tone of the anal orifice, so that if the rectum is stenosed, pencil-shaped or ribbon-like motions may be passed. A similar result may also be produced by muscular spasm of the rectum or anal orifice, or by paralysis of the lower part of the large intestine. True stenosis of the lower bowel more commonly gives rise to a pultaceous motion containing short cylindrical masses about the size of the little finger, than to pencil-like fæces alone.

In some pathological conditions, the consistency of the stools is determined by the amount of intestinal secretion, and by the absorptive power and the motility of the bowel. As a rule, the consistency of the stools varies directly with their number. They are usually thin, soft, and even watery, when diarrhœa exists, and firm when there is constipation. In the latter condition the fæces tend to form rounded balls which become harder and more isolated as the condition persists, until in chronic cases they appear as typical scybalous masses. The individual scybala may vary in size from that of a walnut, or larger, to that of a hazel-nut, and frequently show indentations representing the tænia of the colon. Still smaller masses, having a faceted surface, and resembling the dejecta of sheep, are sometimes seen. These were at one time regarded as characteristic of stricture of the colon, but they are also met with in cases of ordinary chronic constipation. The presence of scybala indicates long delay of the fæces in the large intestine, and points to imperfect contractile power of the muscular walls of the large bowel. They may collect in the rectum and form large accumulations, and are frequently seen in the motions preceding the onset of diarrhœa. They are also common after typhoid fever, and are met with in some patients on a milk diet.

Abnormally soft motions occur when there is an excess of fluid, fat, or mucus, and when a large amount of vegetable material is taken. An excess of fluid may be due to abnormal motility preventing absorption, defective absorption from disease of the intestinal walls, etc., or an increase in the intestinal secretions, as in cholera. An abnormal fat content may arise from a diet rich in fats, especially those of a high melting-point, disease of the pancreas, or interference with the absorptive power of the bowel dependent upon lack of bile, deficient alkalinity, disease of the intestinal walls, or obstruction of the lacteals, etc. Softness of the stools due to water may be readily distinguished from an increase of fat by pressing a cover-glass down on to a small portion on a slide; if, on relieving the pressure, the cover-glass springs back and air rushes in from all sides, it may be concluded that it is due to water, while if no inrush of air takes place, it is probable that an excess of fat is present. Softness of the stools dependent upon the presence of mucus indicates a catarrhal inflammation of the bowel wall. An excess of vegetable tissue is most likely to arise after the ingestion of pears, apples, plums, cabbages, and the like, which contain much cellulose and hard sclerenchymatous material.

If a watery stool is allowed to stand in a tall vessel undisturbed for some time, the watery elements will occupy the upper stratum, while the solid constituents will fall as a precipitate to the bottom. Such stools are characteristic of intestinal catarrh, and, although seen whenever the stool is largely composed of water, are best observed in typhoid fever. Fæces contaminated with much urine will behave similarly.

Frothy stools indicate an intense abnormal bacterial decomposition, and are most characteristically seen in sprue. In such cases the fæces often appear acholic, owing to the changes in the fæcal pigments brought about by the action of the bacteria on them.

The infant at the breast has soft soapy stools, of a curdy consistency, which are smeared more or less evenly on the diapers, and contain no definitely recognizable particles. There are, however, many exceptions to this ideal infantile stool. Very often, for instance, in breast-fed infants who are receiving an abundance of nutriment and are thriving well, the stools are a good deal thinner, so that they appear more or less fluid, and are lacking in coherence. The fact that they are mixed with a certain amount of residual fat, together with some mucus, gives them an almost completely homogeneous appearance under the microscope. A stage further, the stools are no longer homogeneous, but in the midst of the darker parts are seen yellowish-white, or lighter coloured, particles of varying size, which, in order to avoid a more definite statement of their nature, may be called " milk particles." These ought not to be present, and they are to some extent pathological, although they may exist for several weeks continuously without the general condition of the child appearing to suffer. When the stools of a breast-fed child begin to be of a firmer consistency, and especially when they show relatively dry brownish-coloured particles and streaks, the condition of the child demands attention. As a rule, when this state of affairs exists, the evacuations are less frequent than normal, and the total amount of fæces passed daily, as well as the total dry residue, is diminished. The infant is then suffering from a more or less pronounced degree of starvation, and it is necessary to thoroughly investigate the case to discover in what way the relative starvation is being brought about. It may be that the child is sick, or it may be that the mother's milk is too small in amount, or contains too little fat.

The stools of an infant that is being fed upon cow's milk are normally of a rather stiffer consistency than those of a breast-fed child. Under-feeding, or imperfect digestion, as in the case of the breast-fed infant, causes the stools to be firmer and less homogeneous. When more acute disturbances of the alimentary tract occur, the consistency may diminish more and more until the stools become quite watery. In the course of acute infections of the digestive tract, it is not uncommonly found that the stools, which have been thin and watery, become of closer consistency than the normal and are not quite homogeneous. The condition of the soaps and fats in stools of this kind is of great significance, and will be discussed subsequently. Motions which are of a soapy consistency, or like unset mortar, and are of a greenish-white or greenish-yellow colour, are sometimes seen. They may look particularly dry, and, while more coherent in themselves than normal, show less tendency to adhere to things with which they come in contact, so that they can very often be peeled off the diapers without leaving any residue. Such motions are generally very foul smelling, are alkaline in reaction, give Ehrlich's aldehyde reaction, contain a high percentage of calcium, and are usually deficient in mucus. A form of stool which has been compared by Selter to a liquefying Limburg cheese, is considered by him to indicate the putrefaction of proteins in the intestines; but Hecht maintains that these, like the soapy stools, are mainly due to the poor absorption of fat, which is consequently passed in relatively large quantities. In these stools there is, however, an excess of mucus, and not a deficiency as in the soapy stools. The consistency of the fæces passed by an infant on a diet of cow's milk may be diminished by increasing the percentage of water, fat, or carbohydrate.

When the diet contains starch or flour, the stools generally become more pultaceous, but at the same time they are greasy, homogeneous, and normally contain mucus particles in small numbers. The addition of sugar to the starch causes the motions to become thinner, while a high proportion of dextrin tends to produce constipation and increase the consistency. The admixture of mucus renders the stools very coherent. The normal homogeneous character of the stools of infants may be interfered with by the presence of relatively large jelly-like particles of mucus among the other constituents, or by the existence of numerous gas bubbles from fermentative changes. It is probable that the irritants which act upon the intestinal mucous membrane to induce the formation of abnormal quantities of mucus are the volatile fatty acids produced by the action of bacteria on sugar. Before the bacteria can produce these irritating products, however, it is necessary that most carbohydrate food-stuffs should have been acted upon by the ferments contained in the secretions of the alimentary canal, and it thus comes about that the formation of gas, and the irritating action of the bacterial products, are much more pronounced with certain foods than with others. These effects are most marked with ordinary sugar, the administration of which often causes the stools to become thin, slimy, and strongly acid, since the bacteria are able to act directly upon it without any preliminary preparation by the digestive juices, as in the case of starch.

Meconium has a high degree of adhesive power and also of cohesion. It is more or less tough, and, as it were, elastic, being capable of being drawn out or elongated without breaking.

Colour.—Normally the colour of the fæces is chiefly due to the presence of hydrobilirubin (stercobilin), which is derived from the bile pigments by a process of reduction during the passage of the intestinal contents along the large bowel. The colour is also influenced somewhat by the nature of the food ingested. On a mixed diet, the fæces are generally brown. If much meat is taken they are darker, and may be almost black, owing to the colouring matter of the meat being changed to hæmatin (the presence of which, it may be noted, deprives the more delicate tests for blood of much of their value when applied to the fæces of persons on a meat diet). A large quantity of vegetable material gives rise to light brown or greenish-brown stools, the lightness of the colour being partly dependent upon the presence of gas bubbles entangled in the cellulose residues, while the greenish tint is due to the presence of chlorophyll, and is more especially evident when large quantities of green vegetables, such as salads, cabbage, and particularly spinach, have been consumed. Certain berries, such as blackberries, give the fæces a greenish-brown tint, while carrots colour them reddish-brown, particularly in young children. An excess of starch tends to give rise to yellow motions, and fat to clay-coloured stools. On a milk diet the fæces are pale orange, yellow, or white. Cocoa and chocolate tend to produce reddish-grey motions, and red wines give the stools a dark brown colour. Caramel also colours the fæces a deep brown.

The colour of the fæces of a healthy breast-fed infant is normally a golden yellow, due to the presence of unaltered bilirubin, although sometimes a brownish or slightly greenish tint may be noticed. On a diet of cow's milk the colour is for the most part lighter, owing partly to peristalsis being less active, and partly to a greater reduction and decomposition of the bile pigments, which in breast-fed children are excreted with relatively less change. For this reason a greenish tint is much less often seen in the stools of healthy children fed on cow's milk than in breast-fed infants, and when it does occur is much more likely to be pathological. The stools of children receiving a carbohydrate diet are brownish-yellow, or even dark brown, and the interior is often lighter than the surface. Motions that contain bile pigments, if exposed to the air in a thin layer, generally become green, especially on the surface, where the oxydizing effect is most marked, while the underlying portions become paler as a consequence of the reducing action and resulting decolorization of the bile pigments by the contained bacteria. Meconium is of a dark green or even black-green colour.

The colour of the fæces is influenced to some extent by the length of time they remain in the intestine, a firm hard stool being generally darker than a soft or thin one. The surface of a firm stool is usually darker than the interior, so that when noting the colour it is advisable that the motion should be thoroughly broken up. A stool that has been exposed to the air is always somewhat darker on the surface than in the interior, from oxidative changes.

The administration of various drugs may alter the colour of the stools. After calomel they sometimes have a green tint. This is due to the presence of biliverdin, and depends chiefly on the inhibitory action that calomel has upon the putrefactive processes which ordinarily reduce the bile pigments. In addition, it is possible that calomel itself also exerts an oxidizing effect on the pigments. Bismuth salts may cause the stools to be almost coal-black in colour. This does not depend upon the formation of bismuth sulphide, as was at one time thought, but arises from a reduction of the salt to the black bismuth sub-oxide. Senna, santonin, gamboge, and rhubarb give the fæces a yellow colour, which turns to red on the addition of an alkali. Iron turns the stools a dark brown, grey, or even black after they have been exposed to the air. The fact that the blackening does not take place until the fæces have been exposed to the air is an important point to bear in mind, as a stool which contains blood may, on the contrary, be black when fresh. Manganese dioxide given by the mouth also imparts a dark brown or black colour to the fæces. Ipecacuanha gives rise to clay-coloured stools. Kino colours the fæces bright red, and phenol-phthalein, which is now much used as a purgative, will also give a similar appearance if the reaction is alkaline. After the ingestion of extracts of logwood or hæmatoxylin the fæces are violet or violet-red. When methylene blue has been taken the stools are normal when first passed, but they quickly take on a bluish-green tint, which rapidly intensifies when they are exposed to the air.

The colour of the fæces varies much in disease, being usually lighter the larger the number of motions, and vice versa. Thus in Asiatic cholera and dysentery they may be colourless, but in severe constipation they are almost black. Some of the most striking effects are produced by alterations in the character or quantity of the pigments, while the presence of various undigested food materials and abnormal constituents may give rise to noteworthy changes.

Special names have been given to some of the more characteristically coloured stools :—

Bilious stools are bright golden yellow in typical cases, but may have a greenish tint, or even be dark green. The presence of unaltered, or but slightly altered, bile pigment in the fæces of adults is always pathological, unless it is due to calomel, and indicates the hurried passage of the intestinal contents through the bowel.

Acholic or colourless stools are most commonly associated with obstructive jaundice, in which the fæces have a typical " pipe-clay " appearance. Although the greyish colour in such cases is partly due to lack of bile, it is not the entire explanation, even when there is complete occlusion of the common bile-duct, for experiments upon animals in which a loop of the intestine has been shut off from the rest of the bowel have shown that the intestinal contents may be coloured when there is no possibility of bile reaching them. Moreover, in cases of biliary obstruction not due to malignant disease of the head of the pancreas, chemical analysis of the fæces generally shows a considerable amount of altered bile pigment to be present. In most instances the lack of colour is largely dependent upon the excess of unabsorbed fat which masks the pigment, for on extracting the fat with ether a brown residue is obtained. Colourless stools may also occur when there is no obstruction of the bile-ducts. They have been observed in a large variety of conditions which have nothing in common, such as leukæmia, carcinoma of the stomach or intestine, infantile enteritis, chronic nephritis, chlorosis, scarlatina, tuberculous enteritis, and are especially common in debilitated consumptives and in cases of chronic tuberculous peritonitis in children. In some of these, such as tuberculosis of the intestine and peritoneum, the lack of colour can be explained by a defective absorption of fat by the diseased intestinal wall or by obstruction of the lymphatics, but in others this explanation does not hold good, for an excess of fat is not always found in the fæces. In such cases it is probable that the acholia is dependent upon the abnormal activity of various intestinal bacteria which reduce the bile pigments beyond the stage of hydrobilirubin to a colourless compound, which has been termed by von Nencki leuko-urobilin. Stools of this type, when exposed to the air, gradually darken from oxidation of the leuko-derivative to ordinary hydrobilirubin. It is interesting to note that the colour of the fæces may vary in this type of case, not only from day to day, but also within the space of twenty-four hours. Thus Simon speaks of a neurasthenic patient under his care who passed acholic stools almost every morning, and normal-coloured fæces in the afternoon, for a space of several weeks.

In 1889, Walker drew attention to the fact that white stools may be associated with disease of the pancreas in which there is no jaundice and the bile-ducts are patent. He consequently suggested that the normal brown colour of the fæces is dependent upon the action of the pancreatic secretion on the bile pigments. The large excess of fat, and particularly of fatty acid crystals, present in the stools in such cases, appears, however, to be the chief explanation of their white glistening appearance, while the reducing action of anaerobic bacteria upon the bile pigments is, as I have shown, a further factor in their production.

The close resemblance to acholic stools of the fæces passed after the administration of ipecacuanha has already been mentioned.

Bloody stools may be scarlet, brownish-red, coffee-coloured, or black. As a rule, the higher in the alimentary tract the source of the blood is situated, the darker is the colour of the fæces. Bright red blood, especially when adherent to the surface of solid fæces, is usually derived from the anus or rectum. Adherent blood, slightly changed in colour, suggests the colon as its source. Black or coffee-coloured stools are seen after gastric or duodenal hæmorrhages, the colour being due to the conversion of the blood pigment into sulphide of iron and hæmatin respectively. When the bleeding is profuse, several ounces for example, the stools appear like tar in consistency and colour; but when there is an associated diarrhœa, as in typhoid fever, etc., the blood may be passed in the fæces little, if at all, changed.

Red Stools.—Cases have been reported by Carter and MacMun in which the fæces became red on exposure to the air. It has been suggested by MacMun that the chromogen concerned is closely related to stercobilin, but Boston thinks it is more probably of bacterial origin, and is due to the presence of B. prodigiosus, etc.

Green stools are particularly common in infants, and are referable to two distinct causes. They may, on the one hand, be dependent upon the presence of biliverdin, or on the other may be due to the presence of a bacillus described by Le Sage, which produces a green pigment when grown on culture media, but is not the

B. pyocyaneus apparently. Brownish-green stools are met with in underfed infants, but when green stools occur frequently, they are generally associated with the symptoms of cholera infantum. In such cases, owing to the concentration of the bile secreted and the abundant watery transudate from the bowel, the fæces have a peculiar dirty-green colour. Green stools have also been noticed in dysentery, and appear then to be due to an infection with the B. pyocyaneus. When alimentary disturbances occur in infants fed on cow's milk, the stools often present a mosaic of greenish, yellow, brown, and white areas. When there are serious putrefactive changes taking place in the intestinal contents, and particularly when, owing to the presence of superficial ulceration, there is exudation of blood from the mucous membrane, the colour of the fæces may be greenish-brown, or even resemble the tint of the fæces of the adult.

Odour.—The smell of the fæces depends partly upon the nature of the food, and partly upon the decomposition changes undergone in the intestine. As a rule skatol, and to a less extent indol, are the substances to which the characteristic odour of the stools is due, but occasionally sulphuretted hydrogen, and more rarely methane or phosphin, may be detected. Since skatol and indol are products of the putrefaction of proteins by bacteria in the large intestine, the intensity of the smell from these will depend upon the quantity of protein in the diet and the number of putrefactive bacteria in the large intestine. On a mixed or meat diet, therefore, diarrhœal motions have generally a very offensive odour. In health, a milk diet usually gives rise to almost odourless motions, owing to the small amount of protein reaching the large intestine, but when there is an intestinal catarrh with rapid peristalsis, they may have a putrid smell or an odour resembling that of decomposing cheese. When fermentative changes occur, the stools on a milk diet often have an acid smell, due to the presence of butyric and acetic acids.

The normal odour of the fæces may be affected by various articles of diet, such as onions, or by drugs, such as asafœtida. The stools of persons suffering from acute or chronic alcoholism have often an extremely foul smell. An admixture of blood or pus with the fæces may produce a rather heavy odour, resembling that of rancid butter. Motions which contain a large amount of mucus have a characteristic aromatic seminal or moist-hay smell. In cases of Asiatic cholera the stools exhibit a similar odour, which is said to be due to the presence of cadaverin. A putrid smell, quite distinct from that of indol and skatol, is often noticed in cases of malignant disease or gangrene of the intestine, particularly when the large bowel is affected. A similar odour is sometimes present in cases of dysentery, although often the fæces themselves have no smell, but each motion of the bowels is accompanied by the discharge of a large amount of fœtid gas. In amœbic dysentery the fæces sometimes have a sweet glue-like smell. The motions passed in cases of tuberculosis of the bowel are frequently very foul. An ammoniacal odour is characteristic of a fistulous communication between the bladder and intestine. Stools deficient in bile have not a foul smell, excepting when an unlimited allowance of food-stuffs of all kinds has been permitted, and led to an abundant secretion in the intestine, and so favoured putrefactive changes. In well-marked cases of pancreatic insufficiency, the fæces have a peculiar rancid smell due to the presence of fatty acids.

The stools of infants on a diet of mother's milk have a characteristic aromatic, sourish smell, depending upon the presence of lactic and fatty acids. Under pathological conditions the sourness increases until the odour is more or less irritating. When constipation is present they may also develop a putrefactive taint. If a breast-fed child is receiving insufficient nourishment, the stools are apt to resemble meconium in their smell, or may have a peculiar heavy odour, or even, unlike meconium, have a putrefactive smell. Another odour that is sometimes observed is like that of fresh paste, while occasionally the stools smell like dilute vinegar.

The fæces of infants that are being fed on cow's milk are apt to have a "fæcal" odour, while sometimes they are distinctly ammoniacal. When they contain an excess of fat a cheesy smell may be perceptible, or they may have an irritating acid smell reminiscent of sour cream. Occasionally, they present the odour of putrefaction. Infants fed with food containing milk from which the fat has been first abstracted pass stools of an ointment-like consistency and a yellowish-brown colour, which are remarkably free from smell. When flour, etc., are added to the diet, the stools may develop a biscuit-like odour so long as the carbohydrate is well borne, but when fermentation occurs they develop a strongly acid smell, like acetic acid. It was pointed out by Selter that the odour of the stools gives a clue as to whether fermentation or putrefaction is the prevailing change in the alimentary tract under pathological conditions. Dyspepsia due to fermentation is often associated with fæces smelling decidedly of butyric acid, while ulcerative lesions of the intestines often lead to fæces having a carrion-like odour. Cases affected by the blue bacillus described by Escherich pass stools which may be leek-green, or on the other hand may be of a yellow-ochre tint without any tendency to green. Their reaction is alkaline, and the smell is insipid and not offensive. Cases of enteritis due to staphylococci have been described by Moro, in which the motions were of a light yellow or greenish colour, acid, serous, very slimy, often containing undigested particles and occasionally small quantities of recognizable pus ; nevertheless they retained their aromatic odour throughout.

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Chapter II.

MACROSCOPIC EXAMINATION.

AN experienced observer can gain useful information as to the functional activity of the various digestive processes and the condition of the alimentary tract by a naked-eye examination of the stools. For the purpose of such an examination, the fæces should be thoroughly mixed, and a small piece, about the size of a walnut, be transferred to a glass mortar. It is then ground up, with gradual additions of water, to the consistency of pea soup, taking care that the solid constituents are separated as much as possible. The inspection of the mixture is best carried out in a shallow glass dish, one half of which is coloured black, using only a very thin layer.

The elements recognizable macroscopically in the fæces may be divided into (*A*) *Those derived from the food*; and (*B*) *Those arising from the digestive apparatus itself.*

(*A*) FOOD RESIDUES.

A certain amount of indigestible material is an important and advantageous constituent of all diets, for its presence promotes peristalsis and tends to prevent the constipation from which those who consume only the carefully prepared products of high-class cookery are liable to suffer. It is important to recognize, however, that while some substances, such as pieces of bone, cartilage, tendons, hairs, scales of animal origin, and vegetable materials like seeds, cellulose, and the lignified or corky elements of fruits, nuts, etc., are essentially indigestible, others are only relatively so. In the latter class fall a large number of food stuffs which are generally classed as "hard to digest," and whose fate in the alimentary tract is largely determined by personal idiosyncrasy, by the activity of the digestive secretions, and by the rapidity of peristalsis. The way in which food-stuffs are prepared for the table, and the extent to which they are masticated, both exert a considerable influence on the readiness with which these and other materials appear more or less unchanged in the fæces. Further, if more than a certain amount of any particular article of diet is consumed, a portion of it is not digested, and reappears in the fæces unaltered. If these causes can be excluded, the presence of masses of undigested food in the motions may be considered as indicative of disease. The condition in which large quantities of recognizable food remains occur in the motions is characteristic of what has been termed " lientery."

1. **Connective Tissue** is only digested in the stomach, and its presence in the fæces can therefore be taken as an indication of probable gastric insufficiency. A few isolated fibres are often found even when the digestion is normal, and it is therefore only when they are present in considerable numbers and in large masses that a disturbance of digestion can be diagnosed. The cooking of meat, and especially boiling, renders the connective tissue softer and more easily digested, so that it is more likely to be present when smoked, raw, or underdone meat, as in Schmidt's test diet, has been taken. Connective-tissue remains are liable to be mistaken for mucus, but they can be distinguished by their whitish-yellow colour, their thread-like appearance, their more solid consistency, and their reaction to certain stains and acetic acid. In doubtful cases a microscopical and chemical examination should be made. They may also be mistaken for intestinal parasites or vegetable fibres.

2. **Elastic Fibres** are of a clear pearl-white shade, and, even when slightly coloured by the fæcal pigments, can be recognized by the fact that they are well outlined, and often branch and show curled ends where they are broken across. Their presence is of no pathological significance.

3. **Muscle Fibres and Masses of Meat.**—Properly prepared and masticated meat of all kinds is readily digested. The process commences in the stomach, where the connective tissue binding the muscle fibres together is dissolved, and is continued and completed by the pancreatic juice in the intestine. The presence, therefore, in the fæces, of large masses of meat, in a condition much as they were swallowed, indicates gastric derangement. When only separate fibres, or small bundles of muscular tissue, are found, it points to absence of the pancreatic secretion arising from blocking of the duct or atrophy of the gland. The same condition may also be produced by absence of the succus entericus, with its contained enterokinase, which normally activates the proteolytic ferment of the pancreatic juice, as in cases of amyloid disease, tuberculosis, etc., of the intestine. The appearance of undigested muscle in the fæces may also arise from too rapid

propulsion of the food through the alimentary tract, as in some cases of diarrhœa. It is evident, therefore, that the presence of undigested muscle in the stools, when an excess of meat has not been taken and the food has not been "bolted," while indicating an abnormal condition of the gastro-intestinal tract, is not pathognomonic of any one pathological state, and must always be considered in connection with other signs and symptoms.

4. **Casein.**—In the stools of infants who are being artificially fed and who are suffering from symptoms of indigestion, and also occasionally in the fæces of adults on a milk diet, yellow or white thread-like particles, flakes or pellets, varying in size from microscopic granules to masses as large as a bean, are met with. These are generally regarded as consisting of undigested casein. Many of them, however, contain really little or no protein material, and consist of conglomerations of calcium soaps, bacteria, intestinal epithelium, fat droplets, and crystals. The larger pellets, which sink in water, are tough, and cannot be readily broken up, are usually undigested casein; but the smaller particles, that are soft and float on water, generally have the composition mentioned. As a rule their true nature is only determined with certainty by a microscopical and chemical examination. Except in cases of biliary obstruction, the exterior of the larger masses is coloured yellow or brown by bile pigments or their derivatives, while the interior is generally white. Nothnagel has described another kind of particle in the stools of infants, about the size of a poppy seed or a small pin's head, yellowish or brownish in colour, and about the consistency of butter. These, too, appear to consist largely of a mixture of fatty acids and calcium salts, and are particularly common in children fed on artificial foods and cow's milk. Selter states that they most commonly appear in the stools when the child is beginning to convalesce from a severe disorder of protein metabolism.

5. **Fats.**—Undigested fat rarely appears in the fæces in a recognizable form. Occasionally in cases of severe disease of the pancreas, and in the "fat diarrhœas" of infants, obviously fatty motions may be passed, but the former are not as common as is generally assumed. When warm, the fat may be liquid, and look like soft butter or oil floating on the surface of the motion, but as a rule, it quickly sets and then appears white or light yellow. In most cases of pancreatic disease and severe biliary obstruction, the excess of fat that is present is very finely divided, or exists as fatty acids and soaps intimately mixed with the stool, so that it can only be recognized macroscopically by the white or grey tint it gives to the fæces, and by their glistening appearance.

6. **Vegetable Tissue.**—The presence of vegetable remains in the fæces in a form that can be recognized by the eye is not uncommon, even in health, and does not therefore indicate anything abnormal. It is important, however, that they should be carefully differentiated from other substances of pathological significance. Small pieces of softened woody fibre may, for instance, be easily mistaken for muscle, and the glassy transparent granules, like sago grains or frog-spawn, that are seen after fruits, imperfectly cooked potato, or large quantities of other vegetables have been taken, may be readily confused with flakes of mucus. In both instances an appeal to the microscope will settle the question, but it may be pointed out that woody fibres are usually somewhat harder and are not so readily crushed as muscle fibres, while the globular shape and denser consistency of vegetable remains cause them to project above the surface of a thin, evenly-spread layer of liquid, whereas mucus spreads out flat. Some fruit and vegetable remains closely resemble certain parasites. They will be considered later.

(*B*) PATHOLOGICAL CONSTITUENTS FROM THE INTESTINAL WALLS, Etc.

1. **Crystals.**—Ammonium magnesium phosphate or triple phosphate crystals are sometimes so large as to be seen with the naked eye. They may result from abnormal putrefactive changes in the contents of the lower part of the intestine, or form in fæces that have been allowed to stand for some time, when they do not indicate any abnormality.

2. **Mucus.**—Mucus in the fæces may be partly derived from the bile, but to a very much larger extent originates from the goblet cells of the intestinal epithelium, and particularly those of the large intestine. Under normal conditions the mucus of the bile and lesser bowel is digested in the small intestine, so that the chyle passes into the colon practically free from mucus. There a certain quantity is normally added, but it is so intimately mixed with the intestinal contents that it cannot be recognized macroscopically.

Under certain conditions, as when there is a catarrh of the walls of the small intestine, more or less mucus may escape digestion and appear in recognizable amounts in the stools. Similarly, a catarrh of the large bowel increases the amount of mucus. It may, therefore, be laid down as a general rule, that the appearance of mucus in the fæces is evidence of an intestinal catarrh. Only the thin coating that is met with on the surface of hard voluminous scybalous masses, and the secretion that follows the use of irritating aperients, can be regarded as compatible with a normal condition of the intestinal mucous membrane. During the suckling period, and especially during the first week of life, mucus not infrequently occurs in the stools, although the child is thriving well and shows no other pathological signs. It is probable that the secretion of mucus in these cases is of a protective character, and results from the unaccustomed irritation of the intestinal mucous membrane, just as hyperæmia and peeling of the skin in the new-born babe arise from a similar cause.

The form and distribution of mucus in the stools afford useful indications as to the seat and nature of the pathological process to which its presence is due. It may occur as large slimy masses, as small more or less translucent shreds or granules, as a semi-transparent folded membrane (*Fig.* 1), and in dense, leathery, tape-like tubes which may be half a metre or more in length. These varieties may be met with alternately, or even together, in the same individual.

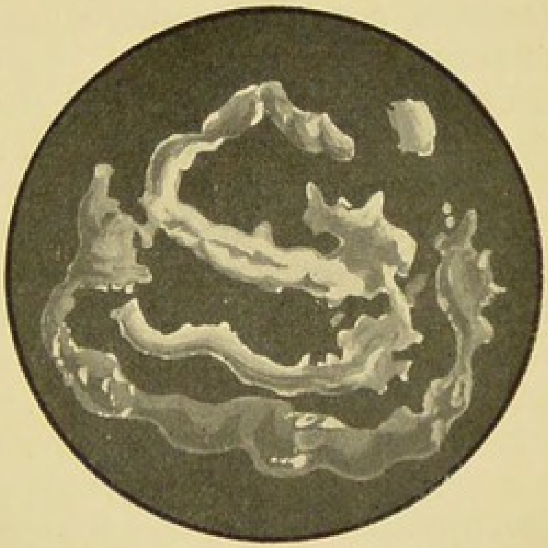

Fig. 1.—Mucus in membrane form.

Pure mucus is clear, transparent, and colourless; but when there is much associated inflammation, it is often more or less opaque, and greyish-white, or yellowish, from the presence of embedded cells. It may also be stained brown by the fæcal pigments, a faint yellowish-green by bile, or a reddish-yellow by bilirubin. In some cases it may have a tint suggestive of blood. Small streaks of actual blood in mucus are regarded by some authors as evidence that it has been adherent to the intestinal wall, but it is more probable that blood-streaks usually indicate a breach of surface in the intestinal mucous membrane. Another evidence of such a breach of surface is the presence of numerous pus corpuscles with very little mucoid material between them. Mucus may be of a gelatinous, or even leathery consistency, and it is not surprising that when it has the latter character it should be frequently confused, especially by the laity, with connective tissue, food particles, and even parasites, such as tape worms.

It is clearly important that mucus should be carefully distinguished from other substances for which it may be mistaken.

For this purpose the suspected particles should be isolated and examined microscopically and chemically. It is possible to distinguish between mucus and connective-tissue particles from the food, or necrotic fragments from the intestinal wall, very quickly, by washing the suspected material with water, then shaking with a 5 per cent solution of corrosive sublimate in alcohol, pouring off the alcohol, and replacing with water to which three drops of a solution, made by adding 1 gram of Grübler's Ehrlich-Biondi powder in 30 c.c. of water, have been added. After three minutes the mixture is allowed to settle, the supernatant liquid is poured off, and the residue well washed with distilled water. Mucin and nuclein are stained green, while basic substances, such as fibrin and nucleo-albumin, are stained dark red. Unfortunately this test does not serve to differentiate mucus from vegetable material. It may be mentioned in passing, that neither by this nor similar staining methods, nor in any other way, has fibrin yet been demonstrated in intestinal exudates.

The nature of the so-called "*frog-spawn*" *granules*, and the "boiled sago" granules, sometimes met with in the fæces, has been a subject of much controversy. These small globular pellets may consist, according to Kitagawa, of mucus ; but Virchow, Nothnagel, and others maintain that they are the remains of vegetable food. The latter appears to be the correct explanation, in most instances at least. Nothnagel has described what he calls "*hyaline mucus islets*" (hyaline Schleiminseln). These are homogeneous, highly refractile particles, about the size of an ascaris egg, with sharp but irregular outlines. According to Schmidt, they are not mucus, but may possibly be dead amœbæ. Nothnagel's "*yellow mucus granules*" are also probably not mucus, but appear to consist of small masses of soaps or protein infiltrated with bile. In Asiatic cholera, particles of mucus resembling grains of rice are seen ; at one time their presence was regarded as characteristic of the disease, but it is now known that they occur in other catarrhal conditions also.

There is a good deal of doubt as to whether any accurate deductions can be drawn as to the locality of an intestinal catarrh from the appearance of the mucus passed per rectum, but there are certain considerations which, when taken in conjunction with other indications, may be useful in making a diagnosis. Mucus derived from the small intestines is ordinarily digested and destroyed, even in catarrhal conditions, by the action of the ferments and putrefactive organisms present, but if the chyme is hurried through with abnormal rapidity, some may escape and appear in the fæces. The stools are then markedly of the small intestinal type; that is to say, are thin and watery, and are often evacuated as though discharged from a syringe. The mucus is intimately mixed with the fæces, and often presents more or less definite shapes, such as knobs, threads, or small cylinders. Microscopically it is found to contain few cells, although both blood corpuscles and pus cells may be found, and even give to it an appearance reminiscent of pneumonic sputum. Mucus coming from the upper part of the intestine is usually stained yellow by bilirubin, and it is frequently said that the finer the state of subdivision and the deeper the staining, the higher is the seat of the catarrhal process; but it must be remembered that Schorlemmer has shown that mucus derived from the colon may also absorb bilirubin. The diagnosis of a duodenal or jejunal catarrh from the character of the mucus in stools alone is therefore a risky procedure. On the other hand, it must be borne in mind that the absence of mucus does not by any means exclude a catarrh of the upper part of the intestine. In some severe affections of the intestine accompanied by the passage of blood and pus in the stools, a secretion of visible mucus may occur only during the first day or two, though both the blood and pus may disappear if the condition becomes chronic, while the secretion of mucus persists. According to Leube, the passage of mucus which separates from the stool is characteristic of inflammation of the rectum, but Nothnagel has shown that the evacuation of pure mucus may also occur when there is an affection of the sigmoid flexure or lower end of the descending colon.

3. **Casts of the Bowel.**—More or less complete casts of the bowel are sometimes passed. These usually consist of mucus, but occasionally are "diphtheritic" membranes. The former may be mere shreds of mucin-like material or cylindrical masses, varying in length from 1 or 2 in. up to 8 or 10 ft., and of different degrees of density. Even in children, casts 18 or 20 in. long are sometimes met with. Such casts usually have a constant diameter throughout their entire length. They are generally grey in colour, but may be translucent or even transparent. On their free surface they are seen to be studded with fine white granules, and when associated with an acute inflammatory process, may be streaked with blood. They are frequently passed with severe tenesmus, without any associated fæcal material. Mucus casts are met with in both acute and chronic inflammations of the mucosa of the large intestine, the intensity of the lesion being indicated by the number of entangled epithelial cells. The long, thin tubular

or tape-like membranes passed in muco-membranous colitis have been ascribed to absorption of water and the astringent action of the fæces on the mucus which accumulates round them when they are retained for several days; but more probably they arise from the action of a special mucus-coagulating ferment secreted by the mucous membrane. Casts which do not present a membranous formation until they have been carefully suspended in water may also be passed with a good deal of tenesmus and the absence of fæcal material in mucous colitis (*Fig.* 2), and are not uncommon in gastroptosis and in enteroptosis.

The reason why mucus is sometimes passed in amorphous masses and at others in the form of membranes, has been experimentally investigated by Roger and others. By boiling the mucous membrane of the small intestine with water, treating the extract repeatedly with acetic acid, then with lime-water, and finally with strong alcohol, Roger obtained a water-soluble mucin in a pure

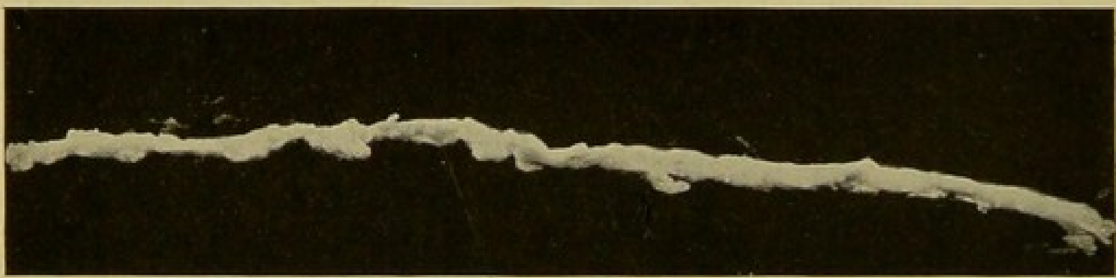

Fig. 2.—Tubular mucus cast of large intestine, from a case of muco-membranous colitis, The cast measured 25½ inches in length. (From *Index to Differential Diagnosis.*)

form. When this was mixed with a small quantity of a glycerin extract of the intestinal mucous membrane, the mucin was completely thrown down in a few hours. To the ferment possessing this coagulating action the name "mucinase" has been given. It was found that the addition of bile to the mixture prevented the precipitation, owing to the presence of a heat-resisting and alcohol-soluble anti-ferment, thus accounting for the fact that pseudo-membranes of mucin are not formed in the small intestine. It also follows that the passage of membranes by patients suffering from entero-colitis is probably due to an excessive formation of mucinase, and inferentially to an insufficient secretion of bile. Riva, and subsequently Trémolières and Riva, succeeded in demonstrating the coagulating ferment in the fæces, and also in the blood of patients suffering from well-marked colitis. It was also found in 40 per cent of all the stools examined, independent of their character and the length of their stay in the intestine. In chronic constipation and in one case of tropical dysentery, the ferment was present in excess, and in chronic colitis the quantity appeared to correspond to the amount of membrane passed. Nepper and Riva have shown that an anti-coagulating ferment similar to that met with in the bile is a constant constituent of the fæces, thus accounting for the fact that extracts of the fæces do not always produce a precipitate with mucin. Since mucinase does not appear to be always present in the fæces, it would seem possible that mucus is only passed in the form of membranes when the mucinase occurs in larger quantities than the anti-coagulating ferment. A mucus-coagulating ferment has been found by Ciaccio in the lymphatic glands, especially those of the mesentery, in the spleen, and in purulent exudates, and he is of opinion that the leucocytes are the source of the ferment. By treating rabbits with thyroid extract, sodium oxalate, or by faradization of the right vagus nerve, Trémolières and Riva produced a secretion of mucus from the intestine, and showed that the fæces contained mucinase. On mixing a solution of mucin with the serum from such animals, and incubating for eighteen hours, a precipitation of the mucin was secured, whereas control experiments with normal animals gave only a very slight sediment in forty-eight hours.

Diphtheritic casts of the bowel are darker in colour than mucus casts, and are, as a rule, but a few inches in length and incomplete in outline. They have been described in cases of diphtheria and in dysentery. When a large number of such casts are voided with a considerable amount of blood, death usually follows in the course of a few hours. Similar, although rather paler casts, may be occasionally passed for long periods of time late in the course of certain chronic diseases, such as diabetes, tuberculosis, etc.

4. **Pus.**—Pus in sufficient quantity can be recognized in a thin layer of the fæces floated on the black portion of the dish, or on the transparent portion on holding it to the light. It does not appear as a macroscopical constituent of the stool, however, unless an abscess has perforated into the bowel, and particularly the lower part, for the pus cells are so rapidly digested and broken down in the intestine, that those which are formed in the ordinary ulcerative processes rarely escape in sufficient numbers to appreciably alter the naked-eye characters of the fæces, and can indeed be recognized with difficulty by the microscope. The abscesses most apt to cause a recognizable escape of pus in the stools are those formed in connection with the appendix, the gall-bladder, in the kidney region, in the psoas muscle, and in the pelvic organs. Perigastric abscesses and other local peritoneal

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collections of pus may also perforate into the bowel and give rise to visible quantities of pus in the fæces. As a rule, the less intimately the pus is mixed with the fæcal material, the nearer is the perforation to the anus.

5. **Blood.**—The recognition of blood in the fæces by the naked eye alone is sometimes an easy matter, but in other cases it is difficult to be certain without a chemical analysis, and occasionally may be impossible. Large quantities of unaltered blood coming from the large intestine or lower part of the ileum have a characteristic appearance and rarely cause any serious difficulty; but when the blood comes from high up in the alimentary tract, as for example from the stomach or duodenum, its colour is so altered through the reduction changes that the blood pigments undergo during their transit through the intestine, that a definite diagnosis is not always easy. The tarry black stools (melæna) passed in such cases may usually be distinguished from the dark-coloured fæces due to pigmentation with iron or bismuth, by their viscid consistency and their more intense black colour. The black stools following the ingestion of charcoal or bilberries can, however, be often only distinguished from melæna by chemical tests. Even when the stomach or duodenum is the site of the hæmorrhage, blood may appear in the stools little, if at all, altered, if a large quantity is being lost and the intestinal contents are being quickly hurried along. Blood coming from the small intestine is, as a rule, intimately mixed with the fæces, while that from the lower colon or rectum often forms an external coating.

The presence of large quantities of changed blood in the fæces usually indicates, as we have seen, gastric or duodenal hæmorrhage. Large quantities of unaltered, or but slightly altered, blood may be due to ulceration of the intestine, chronic interstitial nephritis, rupture of an aneurysm into the stomach or bowel, acute pancreatitis, embolism or thrombosis of one of the mesenteric vessels, Henoch's purpura, or some general hæmorrhagic condition such as leukæmia, purpura hæmorrhagica, or profound anæmia. In infants, considerable quantities of blood may be passed when ulcers of the stomach or intestine are present, or owing to a general purpuric condition associated with septic infection of the umbilical cord. As a rule, large quantities of blood originate from lesions of the small intestine or stomach, while smaller hæmorrhages are commonly associated with lesions of the large intestine. In the latter, the blood is generally mixed with more or less mucus, and is bright red in colour. Such a condition is met with in dysentery, ulcerative colitis, malignant disease of the colon or rectum, and ulcers of the large intestine, and in children in simple colitis. In intussusception, blood-stained mucus, without any fæcal material, is passed. Simple prolapse of the anal mucosa may give rise to slight hæmorrhage. Traces of blood on the surface of the motion are suggestive of piles, but profuse hæmorrhage may also occur if a vessel ruptures. Rectal polypi, papilloma, or villous tumours, anal fistula, arsenical poisoning, infection of the rectal mucous membrane with bilharzia hæmatobia, and, in children, the presence of thread worms, must also be borne in mind as possible causes of the presence of more or less blood in the fæces.

6. **Organized Tissue** from the intestinal walls, such as the sloughs of dysenteric and other ulcers, gangrenous portions of the intestine separated in cases of intussusception, polypi, portions of ulcerated neoplasms, etc., are sometimes met with in the fæces, and must be carefully distinguished from shreds of tough mucus, and from connective tissue and other food remains. Masses of carcinomatous material are generally irregular in outline, friable, and blood-stained. Pedunculated fibro-adenomata are usually rounded and of firm consistency. A microscopical examination of frozen sections is of great assistance in distinguishing these, and other organized tissues, from food remains, etc.

(*C*) CONCRETIONS.

These may be discovered in the fæces by the method of examination already described, but when their presence is suspected it is

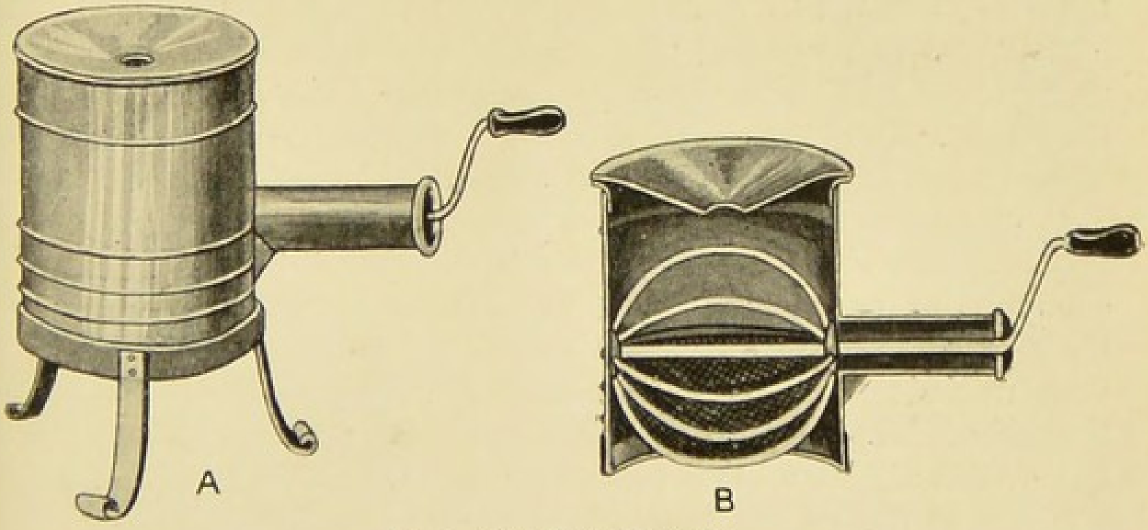

Fig. 3.—Einhorn's stool sieve.

better to thoroughly mix the whole mass of the stool with several changes of water, pass it through a sieve, and examine the residue. Special " stool sieves " have been devised for the purpose by Boas, Einhorn (*Fig.* 3), and others, but a double thickness of cheese-cloth tied over a ring of wood, or on to the edge of a pail, serves the purpose quite well. Kemp has described a method which is simple and easy to carry out. A circular wire is fitted to the water-closet seat, and to this is attached a bag, made of a double thickness of cheese-cloth, which dips into the pan. The patient defæcates into the bag, and water is poured through until only the more solid parts remain. These are then scraped off and examined.

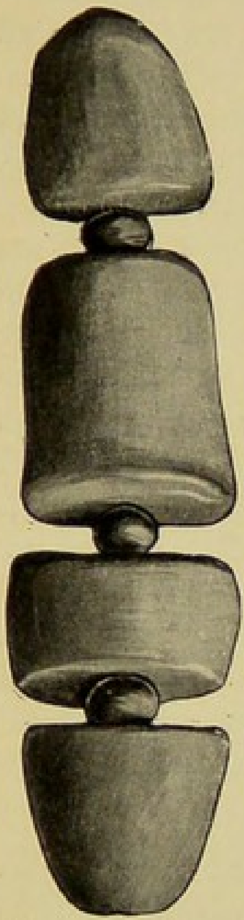

Fig. 4. — Gall-stone producing acute intestinal obstruction passed per anus in four pieces. [*Leeds Museum*.]

The concretions most commonly met with in the fæces are gall-stones, pancreatic calculi, intestinal sand, enteroliths, and coproliths.

1. **Gall-stones** are easily recognized if of fair size, but the small ones need more careful examination. Those found in the fæces usually vary in size between a millet seed and a pigeon's egg; larger stones are rarely passed by the bowel. The presence of large stones points to there being a fistulous opening between the bile-passages and the intestine, usually the colon. Gall-stones are generally shining white, greyish, bluish, or greenish in appearance (cholesterin calculi), and are soft, being easily crushed between the fingers, or more rarely are reddish-brown and hard (bilirubin-calcium stones). The former are of low specific gravity, the latter are heavier than water. If the stones are larger than a pea they have probably come from the gall-bladder; if they are faceted, the existence of a number may be inferred. Their chemical characters will be considered subsequently.

2. **Pseudo-Gall-stones,** consisting of calcified masses of vegetable material, especially the sclerenchyma of pears, are much harder than true gall-stones, and differ both microscopically and chemically. Masses of inspissated olive oil and fatty acids are sometimes passed after a course of the oil has been taken for the "cure" of gall-stones, and may cause confusion unless the possibility of their presence is borne in mind.

Fig. 5.—Gall-stone weighing 228 grains passed after five days' intestinal obstruction.

3. **Pancreatic Calculi** are rare. They are white, have a rough surface, which is occasionally faceted when more than one

exists, and are brittle (*Fig.* 6). They are always small, generally less than a pea, or at the most a small bean. Their appearance should suggest their origin, but a chemical and microscopical examination will settle the point. Since they are nearly always composed mainly of calcium carbonate, they should effervesce on the addition of hydrochloric acid.

4. **Intestinal Sand.**—Small masses of very hard grit, or sand, are sometimes met with in the fæces in considerable quantity, as much as half an ounce being passed at once in some cases. The granules are reddish-brown, greyish, or greenish in colour, and spherical or irregular in shape. In the majority of cases they are what is termed " pseudo-sand," and consist of the hard portions or the seed-cases of pears, figs, and other fruits infiltrated with calcium and magnesium salts, swallowed grains of quartz coated with phosphates, etc. True intestinal sand is met with in patients suffering from mucous colitis, although it has also been described in neurotic individuals who did not suffer from that disease. In this there is no organic nucleus, and the granules consist chiefly of inorganic salts. The two can only be differentiated by means of a microscopical and chemical examination.

Fig. 6.—Pancreatic calculi. [R.C.S. 2834.]

5. **Drug Calculi.**—The habitual use of certain drugs occasionally results in the formation of concretions which are passed in the stools. Calculi of this description have been met with after salol, benzoic acid, carbonate of magnesia, carbonate of lime, subnitrate of bismuth, and sulphur. The use of water containing large quantities of carbonate of lime may also produce small calculi.

6. **Enteroliths and Coproliths** are hard masses of undigested food material mixed with fatty acids and calcium and magnesium salts, formed in the small and large intestine respectively.

Enteroliths (*Fig.* 7), are light brown or grey brown in colour, and are usually of small size. They are generally oval or round, and may be faceted if more than one is present. In districts where oat-bran enters largely into the diet, concretions consisting of concentric layers of the bran round a central foreign body as a nucleus are sometimes met with. They are extremely light, and resemble the hair-balls met with in herbivora.

Fig. 7.—Enteroliths

Coproliths are larger, heavier, and usually of stony hardness. They are generally sausage-shaped, and show concentric rings on section. They may attain considerable size, and may even cause intestinal obstruction.

Fig. 8—Coprolith.

(*D*) FOREIGN BODIES.

Children, insane, or hysterical persons, and sometimes even people who are apparently in possession of their senses, either intentionally or accidentally swallow foreign bodies, such as coins, bones, marbles, needles, pins, buttons, nails, false teeth, and even knives, which pass through the alimentary tract and are found in the fæces. Hair balls, similar to gastric bezoars, may be found in the fæces of young women, and seamstresses sometimes pass masses of cotton. Concretions of shellac have been found in the stools of patients who have drunk furniture polish. It must never be forgotten that in certain cases of hysteria, patients may claim to have passed per rectum most startling objects, such as beetles, snakes, frogs, earth-worms, etc., which have been wilfully added to the stools.

(*E*) PARASITES.

Some of the parasites met with in the fæces are liable to be mistaken for connective-tissue threads, pieces of coagulated mucus, etc., unless their presence is suspected or a close examination is made. All suspicious pieces should therefore be picked out, washed with water, and investigated with a lens or microscope. The characters of the individual parasites will be dealt with in a subsequent section.

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Chapter III.

MICROSCOPICAL EXAMINATION.

A MICROSCOPICAL examination of the fæces may be made to confirm and extend the results of the naked-eye inspection, or for some special purpose, such as a search for amœbæ, parasites and their ova, etc. In any case it is advisable that the material should be as fresh as possible; but when animal parasites are to be looked for, and particularly when it is sought to establish the presence of amœbæ, the fæces must be kept as nearly as possible at the temperature of the body, and the examination be conducted on a warm stage, at or about that temperature, so that the motility of the organisms is maintained.

For ordinary purposes, a portion of a solid stool should be thoroughly mixed with about four or five times its bulk of water, and a series of microscopical preparations be made from this. Fluid stools may be allowed to sediment in a conical glass and the more solid particles be withdrawn by means of a pipette for examination, or they may be centrifugalized. Excepting with very liquid fæces, the latter is not usually necessary. The sediment will generally be found to separate in more or less distinct layers. At the bottom there will be the heavier vegetable tissues, the larger masses of muscle and connective tissue, the larger crystals, etc., while the fats and fatty acid crystals and lighter cellulose structures will collect on the surface. If it is thought desirable, the process of differentiation may subsequently be carried further by successively centrifugalizing with water acidulated with hydrochloric acid to remove the alkaline salts, with absolute alcohol to extract the ethereal oils and chlorophyll, and with ether to get rid of the fats, leaving behind the acid salts and undigested residues.

The determination of the nature of the structures met with under the microscope is much facilitated by the use of various reagents and dyes, such as acetic acid 30 per cent, hydrochloric acid 3 to 5 per cent, osmic acid 5 to 10 per cent, caustic soda or potash 10 to 15 per cent, Lugol's solution (iodine 1 gram, potassium iodide

2 grams, water 100 c.c.), glycerin, alcohol, ether, chloroform, an alcoholic solution of Sudan III. or Saathoff's reagent (90 c.c. glacial acetic acid and 10 c.c. of 96 per cent of alcohol, into which is stirred a knife-point of Sudan III.), Millon's reagent (mercury dissolved in an equal weight of nitric acid and diluted with an equal quantity of water; the solution must be used fresh, but old solutions can be re-activated by adding a few drops of potassium nitrite solution), aqueous solutions of eosin, methylene blue, and Ehrlich-Biondi triacid stain, etc.

When no special object is being looked for, three preparations, one of the plain diluted fæces, one mixed with acetic acid, and one treated with iodine solution, will usually be sufficient. The first gives a general picture. In the second, the striation of any muscle fibres is rendered more distinct, connective tissue is swollen up in contrast to elastic tissue which is unchanged, mucus is coagulated and rendered more distinct, cells are cleared and their nuclei appear sharper, albuminous granules are dissolved, and some crystals, such as triple phosphate, disappear, while others, such as oxalates, are unaffected. In the third preparation, undigested starch granules are coloured deep blue, and partially digested ones brown or red. By a careful study of a series of preparations made in this way valuable information for purposes of diagnosis can often be obtained. If a preparation of the fæces is to be kept for some time, it is best made with glycerin, either alone or with the addition of gelatin or gum, and a trace of formalin.

The microscopical appearances and micro-chemical and staining reactions of the various substances met with in the fæces will now be described in the same order as in the macroscopical examination.

(*A*) FOOD RESIDUES.

1. Connective Tissue.—Filaments and masses of fibrous tissue are seen under the microscope to consist of colourless or bilirubin-stained threads, following a somewhat wavy course, with rather faint ill-defined outlines (*Fig.* 9). They are striated longitudinally, and may be resolved into delicate unbranched fibrils. The fibrillation is, however, often difficult to make out. On being treated with 30 per cent acetic acid, the fibres swell up and become clear, gelatinous, and homogeneous. They are soluble in caustic soda or potash, and on adding a little dilute copper sulphate to the solution, a beautiful biuret reaction is often obtained. Vegetable fibres can be distinguished by their structure and by the negative results of the biuret and xanthoproteic reactions. The latter, which gives a yellow colour with connective tissue, is carried out by warming a preparation to which a little concentrated nitric acid has been added. Elastic tissue is often mixed with connective tissue, but can be differentiated by its appearance and reaction with acetic acid, which also serves to differentiate mucus. Connective tissue on being stained for several hours with diluted Ehrlich - Biondi triacid stain, is coloured red, and on being subsequently treated with acetic acid is rendered transparent. Dilute eosin solution stains connective tissue red, and iodine solution stains it yellow. Connective tissue is normally found in the fæces of persons on a mixed diet in small quantities, and in larger amounts when much undercooked or smoked meat has been taken. It is only pathological when present in large amounts, and then points to some disturbance in the digestive functions of the stomach. Schmidt states that 100 grams of cooked scraped meat should normally leave no connective-tissue residue, and that when found after such a meal it is pathognomonic of derangement of the gastric functions.

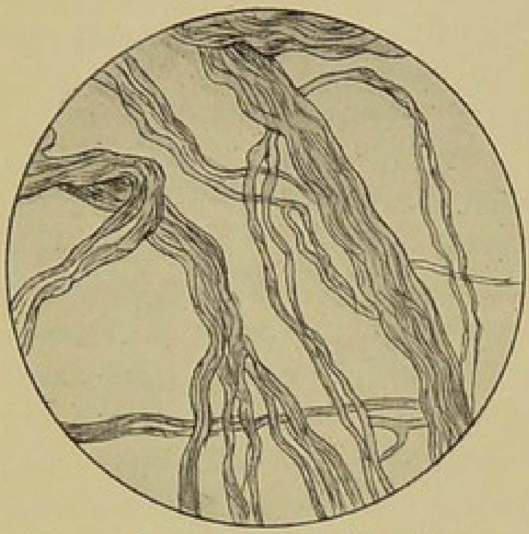


Fig. 9.—Connective (white fibrous) tissue.

2. **Elastic Tissue.**—Elastic fibres are usually larger than connective - tissue fibres. They are more definite in outline. They branch and anastomose, and their free ends are generally curled (*Fig.* 10). Treated with acetic acid they do not swell up, but stand out rather more sharply. They are not dissolved by even strong solutions of caustic soda or potash. As elastic tissue is extremely indigestible, it is constantly met with in the stools of those taking a mixed or meat diet, and is of no diagnostic significance. Its chief importance lies in the possibility of its being confused with connective tissue.

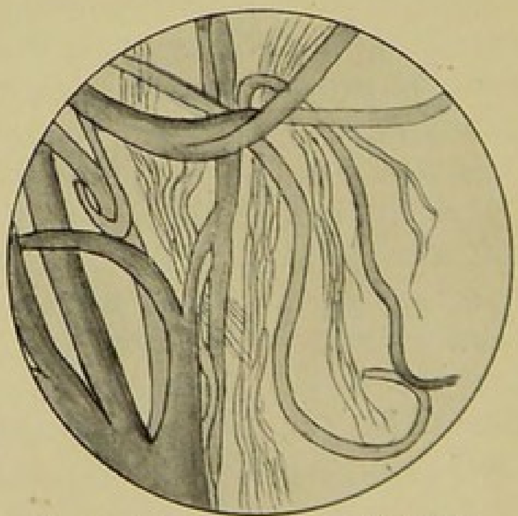


Fig. 10.—Elastic fibres mixed with white fibrous tissue.

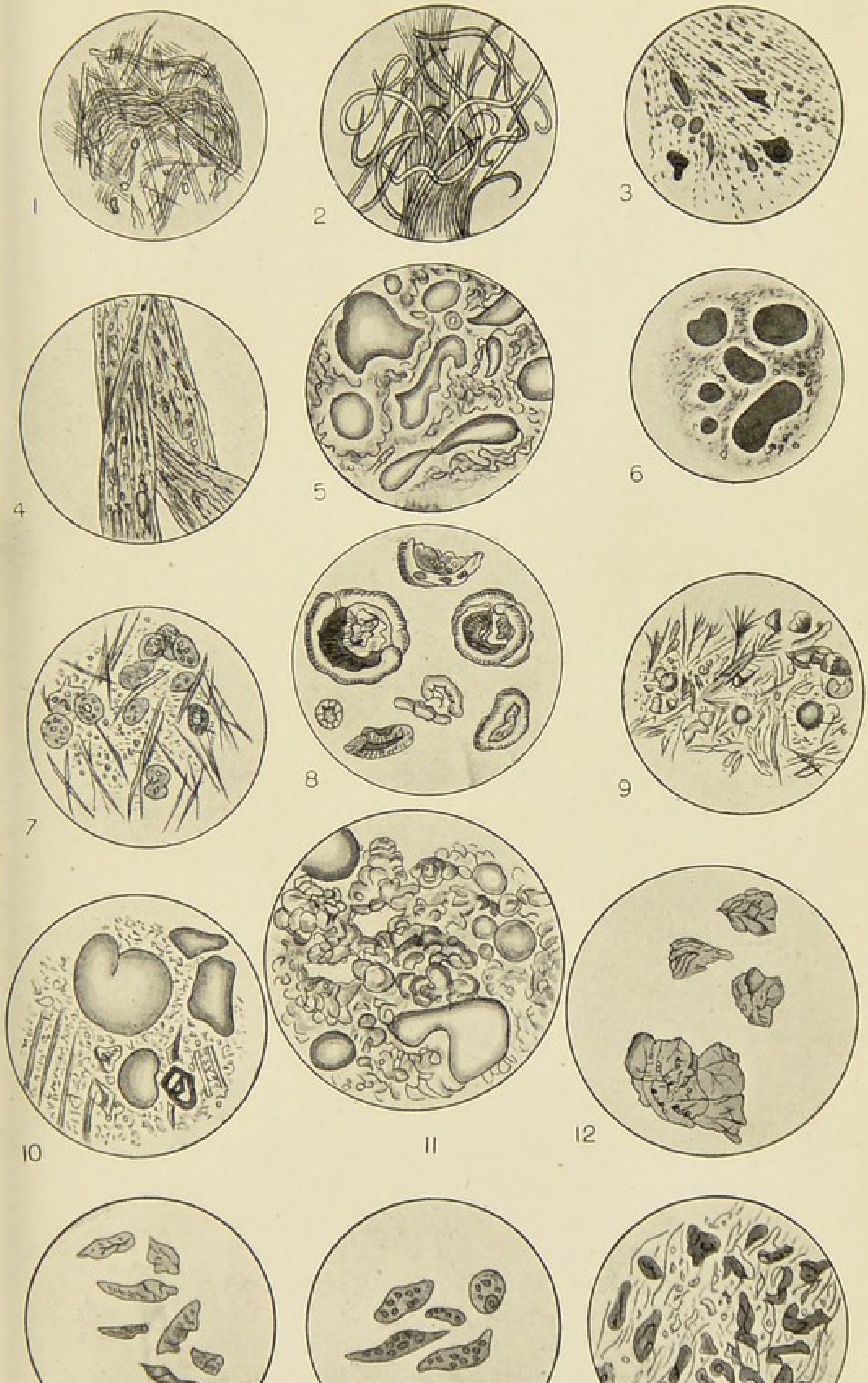
3. **Muscle.**—The appearance of muscle fibres under the microscope varies considerably. Fibres may be met with which retain their shape and characteristic striation in an almost unaltered condition; others are partly or entirely split up into discs; while more common than either are more or less rounded, yellow, apparently homogeneous fragments, which at first sight do not resemble muscle at all (*Plate II*, 1–3). On careful examination, however, the true nature of the latter becomes apparent; two of the sides, in some places at least, are more or less parallel, and, with an oil-immersion lens, some traces of cross-striation can usually be discovered. Even if morphologically unrecognizable, they answer to the various protein tests, such as Millon's, the biuret, and xanthoproteic. It should be noted, however, that bile pigments also give the biuret test, so that before making use of this reaction in testing for muscle, etc., hydrobilirubin must be removed with alcohol and bilirubin with chloroform, since it is to the presence of these pigments that the yellow colour of the muscle seen in the fæces is due. Acetic acid causes muscle fibres to swell up, and caustic soda or potash dissolves them. Undigested fibres can be readily recognized, especially after the addition of acetic acid, but to demonstrate the smaller fragments it is best to add a weak watery solution of eosin, which makes them stand out very distinctly, since the muscle takes up the dye more quickly and more intensely than the rest of the fæcal material. On careful search, fragments of muscle fibre can usually be found microscopically in the fæces of most persons on a mixed diet, but normally they are not numerous and are not well preserved, unless a large quantity of meat has been consumed. Tough meat, smoked meat, and meat containing much connective tissue, and also imperfectly cooked meat, increase the number. The smaller, the more rounded, and the more homogeneous are the fragments, the more advanced is their digestion. The presence of distinct striation is evidence that intestinal digestion is not being normally carried out, and theoretically, at least, unchanged nuclei should also be found in cases of pancreatic insufficiency.

According to Schmidt, cell nuclei, in contrast to connective tissue, are only digested by the pancreatic secretion and are not attacked by the gastric juice. If, therefore, undigested tissue nuclei appear in the fæces, it may be concluded that the digestive functions of the pancreas are at fault in the same way as the appearance of connective tissue argues in favour of insufficient gastric digestion. In order to test this point more decisively, Schmidt prepares fresh

EXPLANATION OF PLATE I.

1. White fibrous (connective) tissue.
2. Elastic tissue.
3. Mucus.
4. Mucus treated with acetic acid.
5. Neutral fat globules.
6. Neutral fat globules treated with osmic acid.
7. Fatty acid crystals embedded in mucus.
8. Soap crystals, ring formation.
9. Fatty acid and soap crystals.
10. Nothnagel's "mucus islets."
11. Fat globules and casein flocculi.
12. Desquamated epithelial cells.
13. Verschollte Zellen : isolated, natural condition.
14. The same, after warming with acetic acid.
15. The same, mixed with mucus.

PLATE I.



Examination of Fæces P. J. Cammidge

marbled beef by cutting it into cubes about ½ to ¾ cm. thick.. After hardening the cubes in alcohol, they are placed in very small gauze bags, which are preserved in alcohol until required. The bags are then well washed in water for several hours, placed in a wafer, and given with a test diet for several days, at noon. The fæces that result are collected, the bags separated, well rinsed with water, and the muscle examined either fresh with acetic acid or methylene blue, or after a preparatory hardening and staining, for nuclei. The drawbacks to this method are that only the preservation of all or nearly all the nuclei can be taken as evidence of disease of the pancreas, for in diarrhœal conditions not associated with pancreatic disease, a considerable number often remain intact, while on the other hand the nuclei may be destroyed as the result of putrefactive changes, especially if the fæces remain in the intestine more than thirty hours, even when there is obvious disease of the pancreas. The technique of Schmidt's test has recently been simplified by Fronzig, who gives the dried nucleated red blood corpucles of frogs or birds mixed with barium sulphate in place of prepared muscle. Several tablespoonfuls of this mixture are incorporated with the food, and the fæces are examined subsequently for nuclei.

A correct estimation of the value to be attached to the presence of a number of more or less imperfectly digested muscle fibres in the fæces demands experience and a consideration of numerous factors. Such a condition is most commonly due to disease of the pancreas, but motor, secretory, and absorptive disturbances arising from other causes, such as the nature of the diet, fevers, diarrhœa, amyloid disease, tuberculosis, etc., may also bring about a similar result.

4. Casein.—Much attention has been devoted by pediatrists to the investigation of the "casein" granules and flocculi met with in the stools of infants, and for this purpose considerable use has been made of the microscope. The smaller particles, termed by Schmidt and Strasburger "milk granules," are either yellow globules the size of a pin's head, or white flakes suggesting milk coagula. Their chief constituents are soaps, however, which on microscopical examination are found to be present in the form of yellow, or nearly colourless, lumps or crystals (*Plate I*, 11). In addition, a varying quantity of fat droplets and fatty-acid crystals, and large numbers of bacteria are seen. If the cover-glass is pressed down, the change in shape and distribution produced is maintained when the pressure is removed. Milk granules are only soluble with difficulty in 5 per cent soda solution, and on adding acetic acid to this solution only a slight cloudy opalescence results. The larger particles, termed by Schmidt and Strasburger "coagulated casein," are seen on microscopical examination to consist of a network in which are entangled droplets of fat, with relatively few bacteria and hardly any calcium soaps or bile pigments. On pressing down the cover-glass and then releasing the pressure, it is found that the pellets are so elastic that they quickly resume, in whole or in part, the shape they formerly had. Like casein they are easily soluble in 5 per cent soda solution, and on adding acetic acid the solution gives a heavy flocculent precipitate. Talbot endeavoured, by producing similar particles artificially from samples of milk containing various percentages of fat, to prove that the ground substance consists of casein, or a derivative of it, which has undergone coagulation and entangled in its meshes fat droplets, the number of which depends on the percentage of fat in the milk. Talbot, unlike other observers, believes that the appearance of these particles in the fæces is due to a deficiency of hydrochloric acid in the stomach and not upon an excessive secretion. The soft yellowish particles described by Nothnagel are readily pressed out between the cover-glass and the slide. Even with the highest powers of the microscope no particular structure can be made out. Treatment with caustic soda, alcohol, ether, acetic or hydrochloric acids, produces no change in them, but upon the addition of sulphuric acid, their colour alters to a brownish-red and crystals appear. Strasburger and Schorlemmer showed that they consist fundamentally of protein, and are coloured with bilirubin (*Plate II*, 8). The latter fact indicates that the normal reduction of bile is not being carried on in the intestine, and, since they are often found embedded in mucus and do not occur in normal motions, they are significant of some inflammatory affection of the small intestine accompanied by mucus formation. Various colour tests for casein have been described. The most convenient is probably Leiner's test.

A small amount of the suspected material is spread on a slide and dried in the air. It is then fixed by being passed through a Bunsen flame three or four times, and stained with a mixture of equal parts of 0·75 per cent solutions of acid fuchsin and methyl-green in 50 per cent alcohol diluted ten times with water. After standing for fifteen minutes the preparation is placed in distilled water and left for an hour, or longer. Casein and para-casein are stained light blue or violet, while the pseudo-nucleinic bodies are practically all coloured light green, or more rarely yellowish-green.

The presence of casein in the stools of children, and more particularly of adults who are on a milk diet, is not necessarily a sign of organic disease, and may be merely a symptom of a functional disability to cope with the amount or kind of casein ingested. It is therefore chiefly valuable as an indication that the quality or quantity of the milk should be altered.

5. **Fats.**—Fats are met with in the fæces in three forms: (*a*) Neutral fats, (*b*) Fatty acids, (*c*) Soaps. The fatty acids result from the splitting of the neutral fats into their constituents, fatty acids and glycerin, by the action of the steapsin of the pancreatic juice, while the soaps are formed by the union of the fatty acids with the sodium, potassium, calcium, and magnesium of the salts of these bases present in the intestinal contents. These various forms of fat have certain microscopical and micro-chemical characters by which they can be differentiated.

The *neutral fats* may appear in the fæces either as droplets or as irregular flakes, the difference depending upon the melting-point of the fat, those with a low melting-point forming droplets, while those with a higher melting-point appear as flakes. The drops are generally colourless, but the flakes are usually more or less deeply stained with bile pigments. On being heated, the neutral fats melt, and on cooling again, form drops which are readily soluble in ether or chloroform, but are insoluble in water and sodium hydrate solution, and are only slightly soluble in cold alcohol. They are, however, readily soluble in hot alcohol. Osmic acid stains the olein fats a dense black, and other forms a rusty red to black after treatment with alcohol. A concentrated alcoholic solution of Sudan III, which has been filtered just before use, stains all neutral fats an orange to a blood-red colour. Saathoff's reagent gives similar results (*Plates I*, 5, 6; *II*, 4, 5).

Some of the *fatty acids* present in the fæces, such as butyric acid, are volatile and rapidly evaporate, so that they cannot be recognized by the microscope. Others are non-volatile and are seen partly as flakes, similar to those composed of neutral fats, and partly as thin curved colourless needle-like crystals, which are generally aggregated into thick masses, so that it is difficult to distinguish the individual crystals. Fatty acids, like the neutral fats, are soluble in ether, and are also soluble in cold alcohol and sodium hydrate solution. The crystals do not stain with osmic acid or Sudan III., but the flakes take on an irregular black appearance on being treated with osmic acid, and stain red with Sudan III. On being warmed, fatty-acid crystals form drops, which separate out on cooling again in the form of flakes and tufts (*Plate I*, 7, 9).

The *soaps* appear in the fæces partly as amorphous flakes and partly as crystals. The flakes may be colourless, or be stained with bile pigments. They are of firmer consistency, and are less shining, than the similar masses of neutral fat or fatty acids, and have usually sharper angles. The crystals are generally in the form of long colourless needles, often arranged in sheaves; but they may also be met with as short blunt crystals, or as globular aggregations with a darker granular central part and a lighter striated margin, thus resembling somewhat the eggs of tænia. They are, however, frequently broken, and are of a light yellow colour, or may be quite colourless. The calcium soaps, which form the bulk of those met with in the stools, can be distinguished from the potassium and sodium compounds by the fact that they are insoluble in hot water, alcohol, and ether. They do not stain with osmic acid or Sudan III., and on being warmed in the presence of sulphuric acid they are decomposed and yield fine lancet-shaped and long rhomboidal crystals of calcium sulphate on cooling. The soaps of sodium and potassium are readily soluble in hot water and in alcohol. Simple warming does not affect either form of soap, but on being heated with 30 per cent acetic acid, the fatty acids set free are deposited in the form of drops, which crystallize out on cooling (*Plates I*, 8, 9; *II*, 7).

Briefly then, the neutral fats are characterized by their appearance and staining reactions with Sudan III. The fatty acids are distinguished from the soaps by the fact that they melt when heated, while the soaps are unchanged. In addition, fatty acids, like neutral fats, dissolve readily in ether, whereas the soaps must first be decomposed by an acid. It has been claimed by Jakobsohn that the three forms of fat can be differentiated by their staining reactions with dilute carbol-fuchsin (4 to 5 drops of carbol-fuchsin in a test-tubeful of water). The soaps are coloured pink, the fatty acids stain a bright red, and the neutral fats are unaffected. Jakobsohn states that by this test it can be shown that some of the droplets that stain with osmic acid and are soluble in ether are really free fatty acids, and not neutral fats as is generally assumed; but Hecht considers that the test is not sufficiently reliable for such a conclusion to be drawn.

The stools of all persons taking a mixed diet contain some fat, but it usually occurs as small amorphous masses of soap intimately mixed with the fæces. More rarely soap crystals can be distinguished. Fat droplets are not found normally unless large quantities of an oil with a low melting-point, such as olive oil or castor oil, have been taken. Their occurrence in the stools of an adult can therefore be regarded as evidence of a pathological condition, and usually points to serious interference with the functions of the pancreas. Under the influence of organisms of the colon group, fat-splitting may go on energetically in the lower part of the small and upper portions of the large intestine, so that even when the entrance of the pancreatic ferments into the intestine is interfered with or prevented, a considerable amount of the fat may appear in the fæces as fatty acids and soaps. An absence of fat globules in the fæces does not consequently exclude disease of the pancreas. In cases of biliary obstruction, where the functions of the pancreas are not interfered with, fat-splitting takes place in the normal way, but the fatty acids and soaps formed are not absorbed owing to the absence of bile, and the fæces consequently contain little or no neutral fat but much soap and fatty acid. Failure of absorption of the soaps and fatty acids may also be due to atrophy of the mucosa, as in sprue, amyloid disease, extensive caseation of the retroperitoneal lymph-glands (tabes mesenterica), peritonitis, and even as a result of simple catarrhs of the intestinal walls. In all of these a microscopical examination of the stools shows numerous flakes and crystals of soap and fatty acids. In infants, owing to the incomplete development of the fat-splitting functions, much larger quantities of fat, in the form of neutral fat, fatty-acid crystals, and soaps, are met with than in adults, even under perfectly normal conditions. In some pathological states (e.g., "fat diarrhœa") fats may be the preponderating element in the fæces, and they then form an important symptom.

6. Vegetable Tissue.—Very little is known definitely of the changes that vegetable tissues undergo in the gastro-intestinal tract in health, so that a microscopical examination of the fæces for plant remains does not yield much information of a practically useful character. An acquaintance with the appearance and chemical reactions of the vegetable detritus likely to be encountered in the stools is, however, essential if mistakes in diagnosis are to be avoided, for some vegetable tissue may be easily mistaken on casual inspection for animal remains, parasites, etc., and occasionally the discovery of some plant constituents may suggest a diagnosis, or help to confirm one arrived at in other ways (*Plate IV*).

Plant cells differ from those of animal origin in the possession of a distinct cell-wall composed of cellulose, or some modification of it. Cellulose is not as indigestible as it is generally supposed to be, and it is not uncommon to find that young vegetable cells enclosed by it have been broken down in the intestine so as to be unrecognizable, especially if the material has been well cooked and masticated. Moeller has pointed out that although only thin cellulose walls are readily broken down in this way in the digestive tract, the pectin-like material which forms the middle lamellæ of plant-cells is almost invariably attacked, so that the individual cells fall apart and are thus exposed to further digestion. The results of micro-chemical tests show that the cellulose met with in the fæces is not quite the same as in the undigested state, for, instead of the pure light-blue colour usually given with iodine and sulphuric acid, a faint purple is more commonly obtained. The cellulose residues in the fæces are also very frequently much more soluble in copper oxy-ammonia solution than is the fresh material. The nature of the processes by which cellulose is digested in the intestine is not understood, but it is probably a hydrolysis brought about by the combined action of the intestinal bacteria, the alkalies of the contents of the bowel, and the intestinal ferments. It is well known that the ferments produced by certain moulds have the power of breaking down cellulose, and even lignified vegetable material such as wood, and that the intestinal bacteria of the herbivora behave in a similar way. The enzymes of germinating seeds also cause the cellulose envelopes of the cells to swell up and convert them into a soluble carbohydrate which contributes to the nutrition of the young plant. In the laboratory it can be shown that by the action of weak alkalies on cellulose it is partly converted into meta-arabic acid, which is soluble in water. By some such series of changes it is not unlikely that partial digestion of the cellulose ingested with the food may take place, and that the comparative absence of recognizable cellulose in the fæces may be thus explained. The digestion of cellulose appears to be favoured by mild constipation, probably owing to the greater opportunity afforded to the action of bacteria. In diarrhœal conditions, on the other hand, and particularly those associated with rapid peristalsis in the small intestine, the plant cells in the fæces are collected together in large masses and show comparatively little change when tested with iodine and concentrated sulphuric acid.

The modifications of cellulose, such as the cutinized peripheral walls of stems and leaves, and the suberized or corky cells met with in other situations, are digested with more difficulty than the unaltered material; they are consequently more often encountered in the fæces. The flat epithelial cells, with the intervening stomata, of leaves, and plant hairs, present very characteristic pictures which are readily recognized. The plant detritus most commonly met with, however, is the lignified cells forming the spiral, pitted, and scalariform vessels, and the bast fibres of the fibrovascular bundles. In young green vegetables, only delicate spiral vessels are met with, pitted and reticulated ducts appearing chiefly in old and over-ripe plants. The woody tissue, fruit envelopes, etc., of vegetables and fruits pass through the alimentary tract in an unchanged condition and appear in the fæces (*Plate III*, 6–13).

7. **Starch,** in the form of single well-preserved granules, with concentric or excentric markings, is seldom seen in the fæces of an adult, unless large quantities of raw or partly cooked starch have been included in the diet. They are, however, not uncommon in the stools of infants who have been fed on prepared foods. The partly digested granules of starch that occur in the stools are as a rule unrecognizable as such by the microscope, and can only be detected by their chemical reactions. Undigested starch gives a characteristic blue colour with iodine (Gram's or Lugol's solution), the semi-digested " erythrodextrin " stains a red to mahogany brown, while in the final stages of digestion the starch gives no colour reaction with iodine (*Plate III* 1-4). The spores of fungi, which also stain blue with iodine, must be carefully distinguished from starch granules. Yeast cells are coloured yellow, and so should not give rise to any difficulty (*Plate XIII*, 2. *e*, *f*). It is interesting to note that, unlike muscle débris, etc., starch is never stained with bile pigments. When examining the fæces for starch, care should be taken not to break up any contained vegetable tissue more than necessary, as undigested starch granules may thereby be set free and lead to an erroneous conclusion. The presence of such vegetable masses containing undigested starch is of no diagnostic importance, for they indicate only that some unripe, old, or imperfectly prepared or masticated vegetable food has been taken. They are particularly common after peas and beans, and more especially the dried forms, have been consumed. If isolated unaltered starch granules are found in the fæces in any number, they point to a disturbance of digestion of a severe type affecting the small intestine. It might be thought that failure of the pancreatic secretion would invariably result in the appearance of a large quantity of undigested starch in the stools, but this is not the case, and it is very rare to find even a few granules. This is probably owing to the activity of the intestinal bacteria, which digest the starch, and it is only when there is increased peristalsis associated with a failure of the digestive secretions, that the starch passes through the intestine unchanged or merely swollen. The amount of starch present in the stools is in no way affected by a lack of bile.

In oily seeds, such as almonds, there are found, in place of starch, or associated with it, granular structures of a rounded or angular form known as *aleurone* grains (*Plate III*, 5). These although not dissimilar from starch in appearance, are of an albuminoid nature, and do not give a blue colour with iodine. Being very soluble in water, aleurone grains are usually dissolved out of the cells in which they occur in the intestine; but as they do not appear to be soluble in serum, they are met with, in only a slightly altered form, in the motions passed in dysentery and serous diarrhœas.

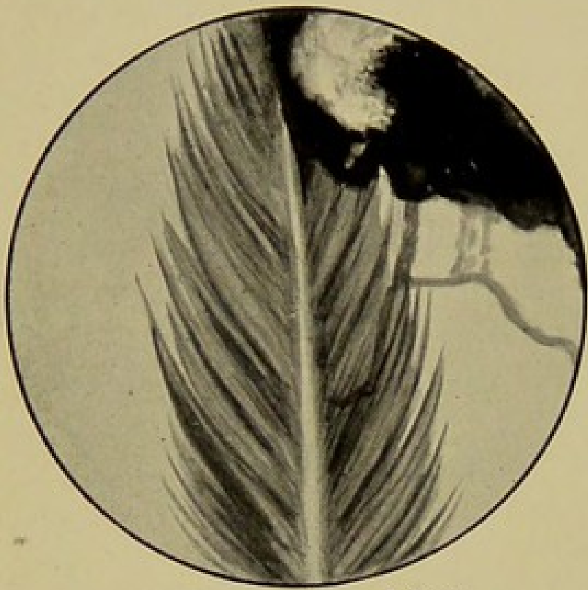


Fig. 11.—Down of Goose.

8. Chlorophyll is usually completely destroyed in the intestine, but when large quantities of such vegetables as spinach are eaten, numerous unaltered chlorophyll granules may be met with in the fæces. As the result of catarrhal conditions of the upper part of the intestine, especially in children, unaltered green chlorophyll may be met with in the cells passed after only a comparatively small quantity of green vegetable has been taken.

9. Indigestible Residues.—In addition to those already mentioned, there may be found in the fæces, fish bones and scales, pieces of bone, tendons, membrane, and skin from meat and particularly pork, feathers, down, shot from birds and game, and portions of the inner membrane of eggs, with occasionally, pieces of egg-shell, etc. (*Figs.* 11, 12).

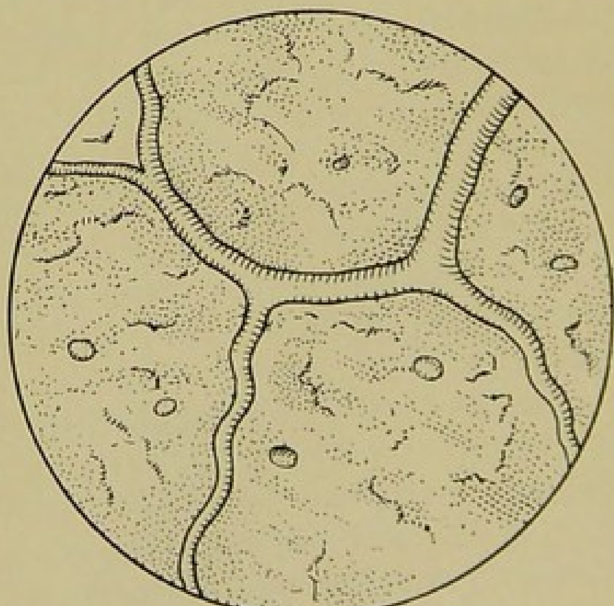


Fig. 12.—Membrane of Calf's brain.

(*B*) CONSTITUENTS DERIVED FROM THE INTESTINAL WALLS, Etc.

1. Crystals.—A variety of crystalline salts occur in the fæces. Some are derived from the food, while others arise as the result of chemical changes that go on in the intestinal contents.

The commonest are crystals of *ammonium magnesium phosphate, or triple phosphate*. These usually occur in the typical " knife-rest " or " coffin-lid " form, but may be more or less irregular in outline (*Plate V*, 5). Occasionally they are so large that they can be detected by the naked eye. The crystals are easily soluble in dilute acetic or mineral acid, and on adding ammonia to the solution, the crystals separate out again. They can be distinguished from neutral magnesium phosphate crystals, which they resemble somewhat microscopically, by the fact that they are insoluble in ammonium carbonate solution.

Di-calcium Phosphate, or Neutral Phosphate of Lime Crystals are not uncommon in the fæces. They usually appear as coarse sheaves, which, unlike the triple phosphate crystals, are occasionally stained with bile pigments (*Plate V*, 1). They are soluble in acetic acid, in mineral acids, and in ammonia. Both triple phosphate and di-calcium phosphate crystals may be met with in normal stools, and are particularly apt to form when alkaline fæces have been allowed to stand for some time. They are often present in large numbers in the alkaline stools passed in catarrhal conditions of the lower part of the intestine.

Calcium Oxalate Crystals are nearly always found if vegetables, such as rhubarb, tomatoes, spinach, etc., that contain them in abundance, are being taken, and even on a mixed diet they are often met with. On a meat or milk diet they are usually absent. When, therefore, large quantities of vegetables have been taken, they are of no pathological significance; but if only a small quantity has been consumed, their presence points to an intestinal catarrh, for it shows that cellulose disintegration has been retarded, so that the crystals could not escape from the plant-cells in which they were imprisoned. In hyperchlorhydria, on the other hand, even an abundance of vegetables containing oxalates may not give rise to the appearance of calcium oxalate crystals in the fæces, since they are dissolved in the acid gastric juice and appear as oxalates in the urine. Oxalate crystals are seen in the fæces as the typical rosettes or envelopes, but rhomboid and acicular varieties (rhaphides) are also met with (*Plate V*, 3). Oxalate crystals are insoluble in acetic acid and alkalies, but are soluble in mineral (e.g., hydrochloric) acids.

Lactate of Calcium is not uncommonly met with in the stools of children on a milk diet. It occurs in the form of sheaves composed of radiating needles.

Calcium Carbonate occasionally occurs as amorphous granules or dumb-bell shaped crystals (*Plate V*, 2).

EXPLANATION OF PLATE II.

1. Undigested muscle fibres.
2. Partly digested muscle fibres.
3. Muscle remains.
4. Neutral fat globules stained with bilirubin.
5. Neutral fat globules stained with Sudan III.
6. Fat tissue stained with Sudan III.
7. Yellow calcium salts of fatty acids.
8. Bile-stained albumin.
9. Bilirubin crystals and globules in a patch of mucus.
10. Hæmatoidin crystals.
11. Meconium, showing epithelial cells, fat globules, cholesterin crystals, and meconium corpuscles.

PLATE II.

Calcium Sulphate Crystals are rare naturally, but may be produced artificially by the addition of sulphuric acid to the fæces, when beautiful needles and plates of the salt form (*Plate V*, 4).

Calcium Salts of Unknown Acids are sometimes seen as irregular oval or circular bile-stained masses, that are often fissured, and show concentric markings.

Charcot-Leyden Crystals are found in the fæces in a great variety of diseases, but are most commonly seen, embedded in mucus, in cases of mucous colitis and in helminthiasis. They were at one time supposed to be characteristic of the latter condition, and their presence in large numbers is certainly suggestive. Intestinal worms may, however, be met with in the absence of Charcot-Leyden crystals, and vice versa. The crystals are apparently identical with those found in the sputum, and are seen as colourless octahedra with sharp margins and generally broken angles (*Plate V*, 7). Their relation to the conditions in which they are found is not understood.

Cholesterin Crystals can sometimes be recognized in the fæces by means of the microscope as flat superimposed plates, often with re-entrant angles, but they rarely have the typical form, and have generally to be tested for chemically (*Plate V*, 8). Cholesterin is insoluble in cold alcohol, but easily soluble in hot, reprecipitating on cooling; and is soluble in chloroform. If the crystals are brought into contact with a mixture of sulphuric acid four parts and water one part, a play of colours ranging from blood-red to violet-red is seen. Cholesterin is said to be present in the stools whenever there is any great increase in the excretion of mucus, and is particularly common in the stools of infants.

Crystalline derivatives of the blood pigments are sometimes seen in the fæces. Hæmin crystals probably do not occur, but *hæmatoidin*, as reddish-brown needles, rhombs, or amorphous masses, is occasionally met with after hæmorrhages into the stomach or intestine (*Plate II*, 10). Similar in appearance but of a lighter colour, are the *bilirubin* crystals met with in the diarrhœal stools of adults in some cases (*Plate II*, 9).

After the use of *bismuth* salts, crystals of bismuth sub-oxide are seen in the fæces as small, black, irregular rhombs or granules (*Plate V*, 10). *Iron*, *manganese*, and *charcoal* are passed as black amorphous granules (*Plate V*, 9, 11).

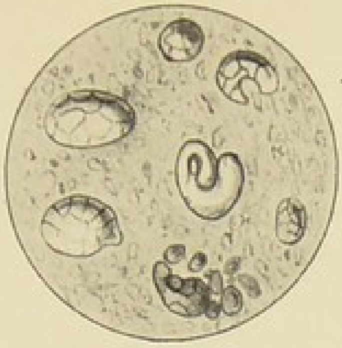
2. **Mucus.**—Microscopically, mucus appears as a more or less homogeneous transparent substance with faintly marked outlines. On being treated with 30 per cent acetic acid it is precipitated and

EXPLANATION OF PLATE III.

1. Undigested raw starch.
2. Partly digested starch.
3. Undigested starch treated with iodine solution.
4. Rice starch enclosed in cellulose envelopes.
5. Aleurone and starch granules.
6. Portion of the epidermis of a leaf, showing stomata.
7. Portion of the epidermis of a plant stem.
8. Portion of the cuticle of a seed.
9. Palisade parenchyma of peas and beans.
10. Columnar cells of pea.
11. Woody cells of pear.
12. Spiral and pitted vessels from plant stems, etc.
13. Scalariform vessels from woody tissue.

PLATE III.

1



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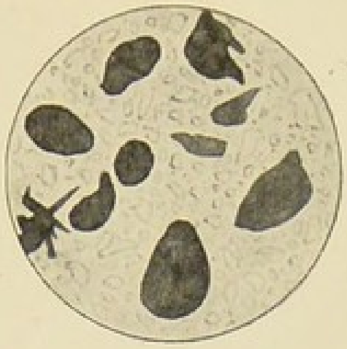

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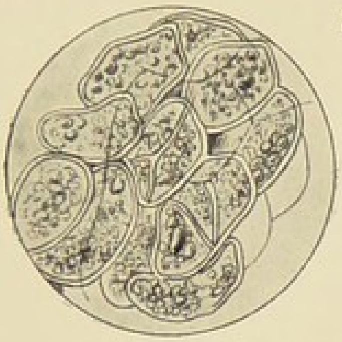

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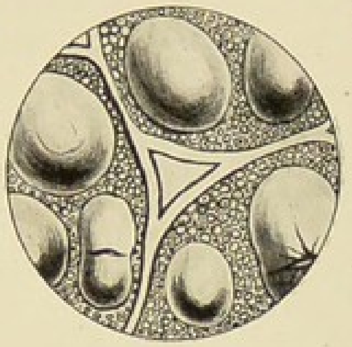

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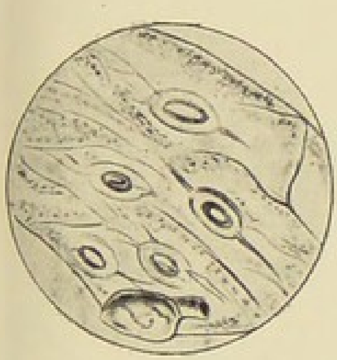

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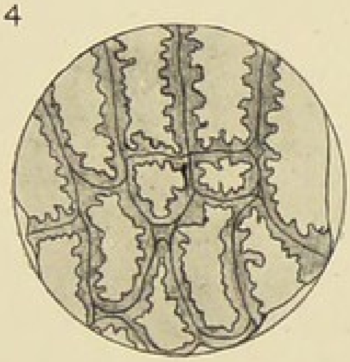

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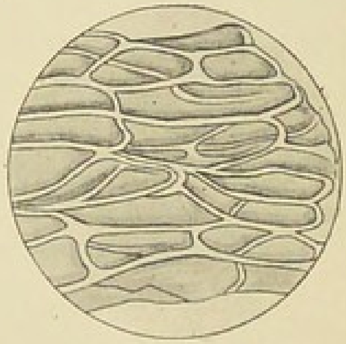

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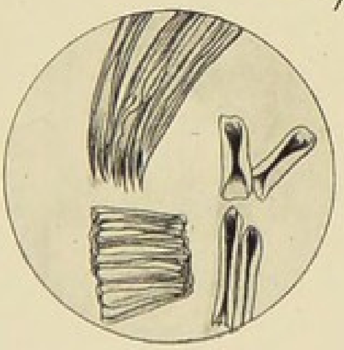

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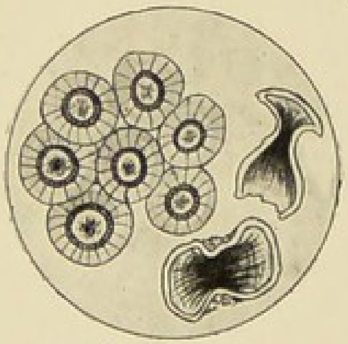
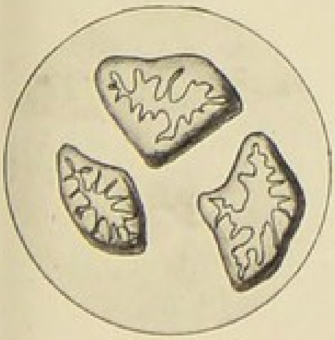
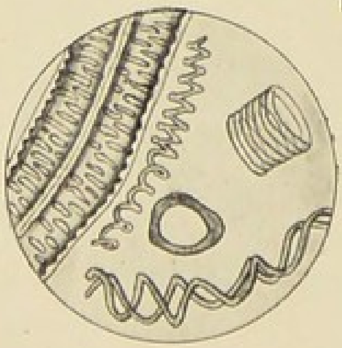


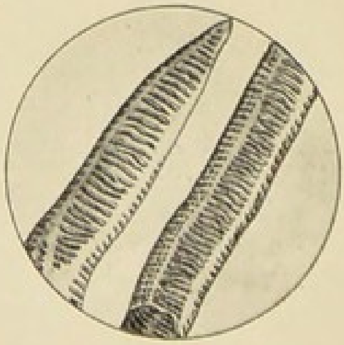
10



11



12



13

becomes cloudy, irregular linear markings appearing at the same time (*Plate I*, 3, 4). It is thus distinguished from connective tissue. Another point of difference is the ease with which connective tissue is digested by a pepsin-hydrochloric-acid mixture, disappearing in a few hours, whereas mucus is not attacked.

Various micro-chemical tests for mucus have been proposed. Hecht adds a drop of a mixture of equal parts of 2 per cent brilliant green and 1 per cent neutral red; the mucus stains red and the rest of the stool green, except the nuclei and cell membranes, which are also red or red-violet. Strongly alkaline fæces do not give the differential staining distinctly, however. Adler advises a 1 per cent solution of alizarin sulphate of soda, which he states stains mucus red to yellow according to its source. Bright red flakes are said to have come from the lower part of the large intestine, yellow particles from the small bowel, while intermediate colours indicate a source between these two points, the paler the colour the nearer being the situation of the catarrh to the duodenum. Thionin stains mucus particles violet, connective tissue, fibrin, etc., blue.

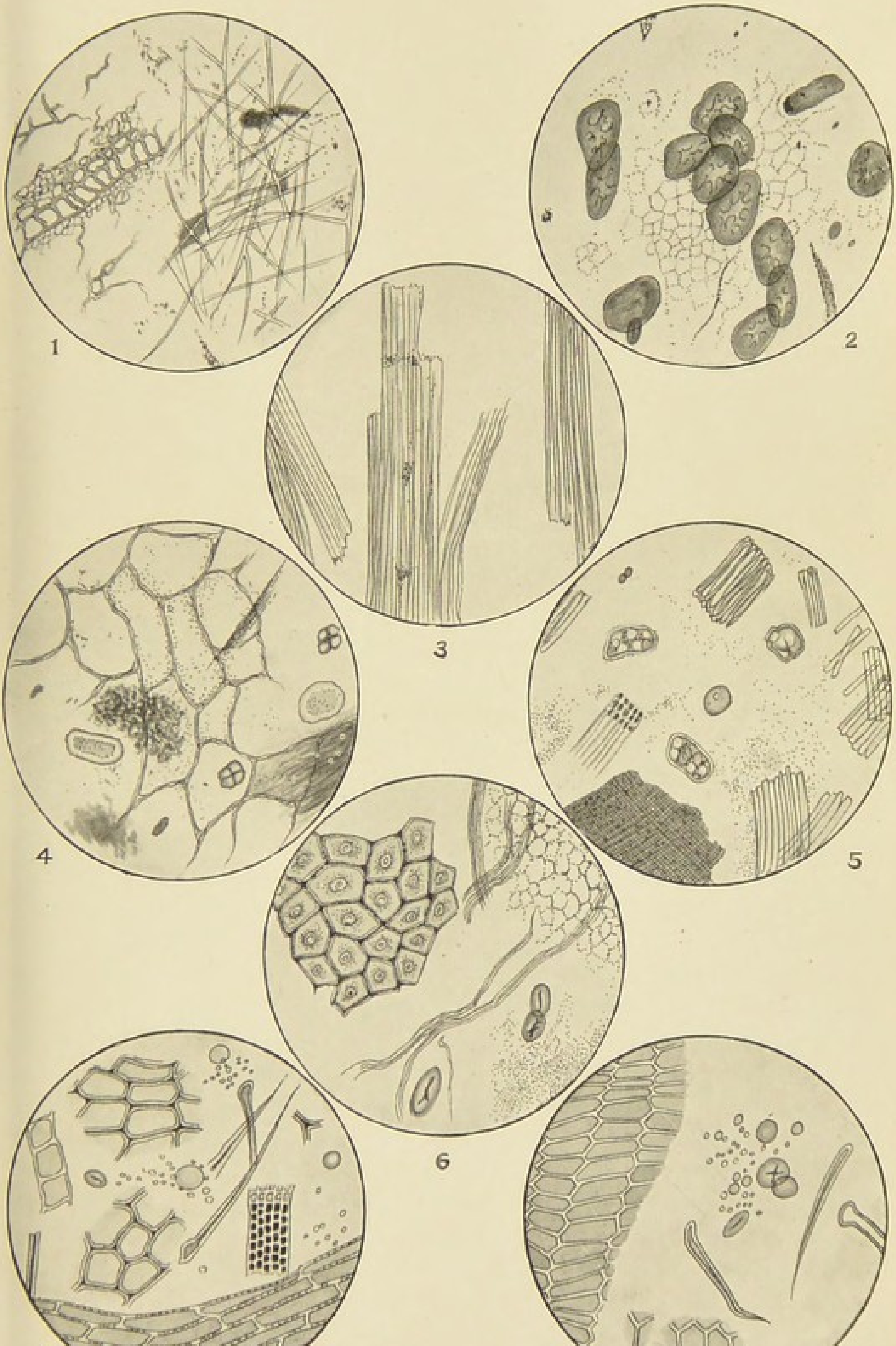
Particles of hyaline vegetable material should be carefully distinguished from mucus. The more solid and elastic form of the former is a distinguishing feature, as was mentioned in describing the naked-eye characters of the fæces; but it should also be remembered that mucus, unlike vegetable tissue, never gives a blue colour with iodine, or iodine and sulphuric acid, and that an examination even with high powers shows an entire absence of any definite structure. It has already been pointed out that Nothnagel's "yellow mucus granules" are not mucus, but are of an albuminous or fatty nature. They occur as minute granules, the largest being the size of a pin-head, and vary in number, sometimes forming almost the entire fæcal mass. They are yellow to brown in colour, and are of soft consistency. When pressed under a cover-glass they spread out to form a homogeneous mass, free from cells or other structures. The fact that these bodies are generally embedded in small shreds of mucus and are coloured with bilirubin, lends to them the same diagnostic significance as was originally claimed by Nothnagel, namely an ileitis (*Plate I*, 10).

Mucus may occur in the stools in a pure form or be mingled with leucocytes, epithelial cells, blood, or food residues, and is sometimes slightly stained with bile. Small hyaline particles of mucus, visible only with the microscope, are not uncommonly met with in pathological conditions, and are of some diagnostic significance. When bile-stained, their presence suggests a catarrhal condition of the upper part of the intestine, while unstained particles point to the

EXPLANATION OF PLATE IV.

1. Débris from melon.
2. Débris from pear.
3. Débris from asparagus.
4. Débris from spinach.
5. Débris from peas.
6. Débris from beans.
7. Débris from white bread.
8. Débris from rye bread.

PLATE IV.



Examination of Fæces — *P. J. Cammidge*

existence of a similar condition in the upper part of the large intestine or lower part of the small bowel. The presence of bilirubin granules and crystals in a cellular arrangement, as if the cells had been digested, indicates a catarrh of the small intestine with much more certainty than a mere discoloration with bilirubin. If mucus is densely infiltrated with bacteria, detritus, and food remains, it has probably originated high up in the bowel. The presence of semi-digested cells, or their nuclei, also points in the same direction. Mucus containing hyaline cells has probably come from the colon, and indicates a catarrhal condition. Numerous leucocytes point to an inflammatory affection. Pure mucus, unmingled with epithelial or pus cells, indicates a low degree of inflammation, for the experiments of Kaalk and Rosenheim on dogs have shown that mucus is probably only formed as a result of irritation.

The cellular contents of fæcal mucus depends chiefly upon the mechanism by which it is loosened, as Nothnagel suggested. The contention of Boas that a considerable quantity of epithelium proves the presence of a desquamative catarrh, and the assumption of A. Schmidt that a poverty in cells tends to prove a neurosis, have been refuted by Schutz. He explains the comparative absence of cells in some cases of mucous colitis by the action of the digestive juices, and points to the existence of a pale, slightly refractile, finely punctate cell in the small flakes sometimes met with in that condition, as a proof of his view. Schutz considers a purely nervous formation of mucus to be a very rare occurrence, and states that it cannot be diagnosed by macroscopical or microscopical examination. The presence of perspiration round the anus is, in his opinion, much stronger evidence of a nervous condition with which an excessive formation of mucus may be associated.

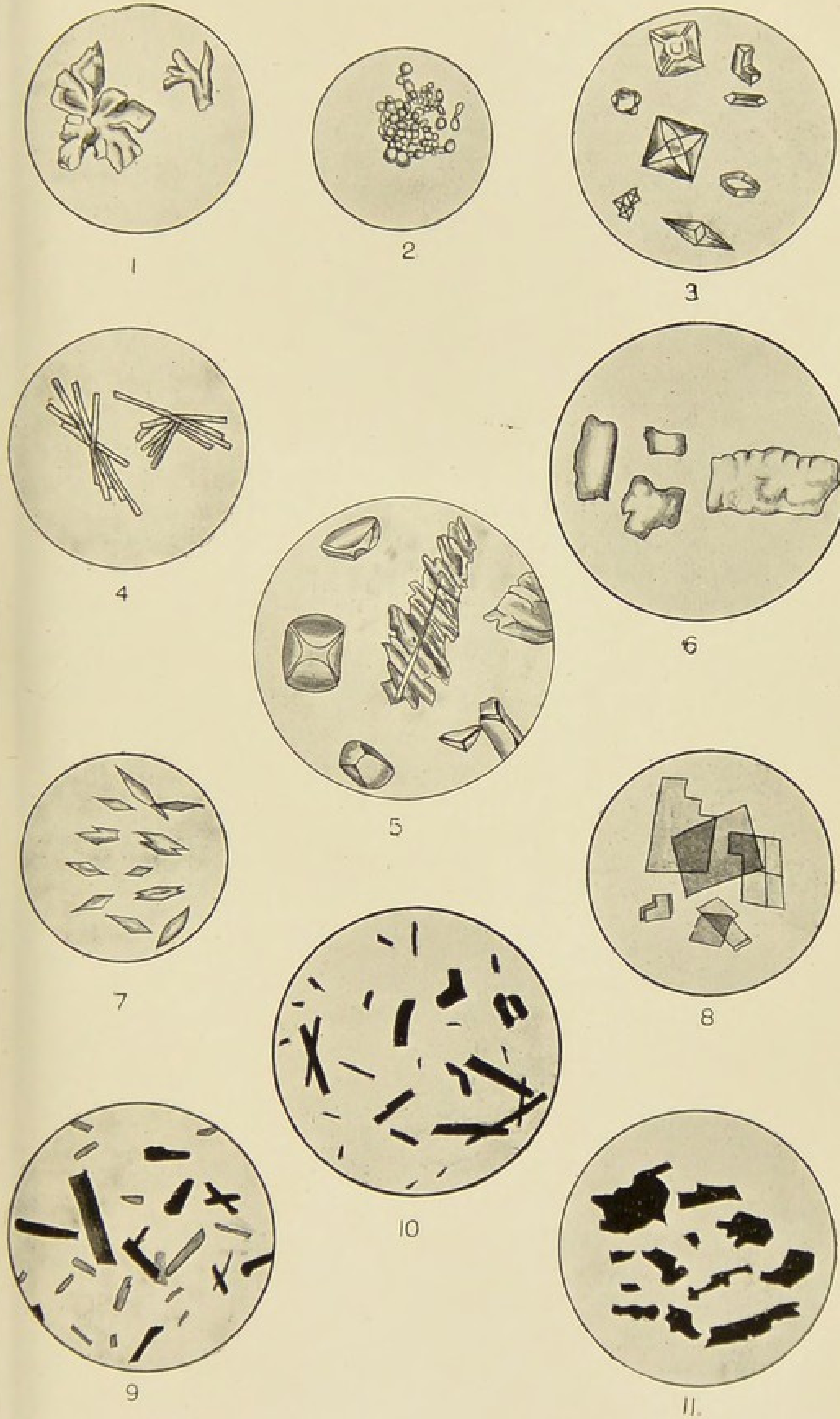
3. **Casts.**—Under the microscope, mucus casts are found to consist principally of a faintly opalescent, hazy, homogeneous material, in which are entangled a variable number of leucocytes, epithelial cells, Charcot-Leyden crystals, and, may be, red blood corpuscles. Their pathological significance depends upon the number of epithelial cells they contain, since the presence of these serves as a direct index of the degree of destruction that is taking place in the bowel wall from which they are derived. When the catarrhal process has gone on to the stage of necrosis of the epithelial cells lining the intestine, a diphtheritic membrane is formed. This contains necrotic material and is much thicker than a mucus cast.

4. **Epithelial Cells.**—Under normal conditions, but few epithelial cells are to be found in the fæces, and they are usually so altered by digestive changes, and so intimately mixed with the other

EXPLANATION OF PLATE V.

1. Neutral calcium phosphate crystals.
2. Calcium carbonate crystals.
3. Calcium oxalate crystals.
4. Calcium sulphate crystals.
5. Triple phosphate crystals.
6. Neutral magnesium phosphate crystals.
7. Charcot-Leyden crystals.
8. Cholesterin crystals.
9. Iron salt crystals.
10. Bismuth oxide crystals.
11. Charcoal granules.

PLATE V.



constituents of the stool, that they cannot be readily identified. When present in large numbers, they always indicate an inflammatory condition of some part of the intestinal tract. The type of cell met with varies according to the particular area from which it is derived; thus those from the anus are of the stratified squamous type, while those from the intestine are cylindrical. It is rare, however, to meet with typical epithelial cells in the fæces. They are usually seen as more or less distorted forms, owing to the action of the digestive juices or to the abstraction or imbibition of water (*Plate I*, 12). The cells when cast may also have been in a degenerate condition. Consequently they may be small and shrunken, swollen to three or four times their normal size, or have ragged outlines, clouded protoplasm, and often only the remains of a nucleus is seen. A peculiar type of cell, described by German writers as "hyaline or vanishing cells or epithelial cell ghosts" (Verschollte Zellen) are frequently met with, especially in association with mucus. They are small, homogeneous, appear to possess no nucleus, and show increased refractile power, like amyloid. They were at one time considered to represent a special type of degeneration, but it has now been shown that their peculiar characters are due to an infiltration with soaps, which probably occurs as a post-mortem change. On adding acetic acid and warming, droplets of fat extrude from the cells, which then clear so that a nucleus can be seen (*Plate I*, 13-15). They appear to originate from the large intestine. More or less modified cylindrical cells are found in abundance in all inflammatory affections of the intestinal mucous membrane, frequently embedded in mucus. When large masses of mucus are passed without epithelial cells, it is generally assumed that the condition is neurotic and not inflammatory. When the stools are watery, owing to increased peristalsis, etc., the epithelial cells appear rolled together, giving the liquid an appearance as though particles of cracked rice were floating in it. Bile-stained epithelial cells are supposed to indicate lesions of the small intestine. The degree of digestion is also taken as an indication of their source, the more complete it is, the higher being their origin in the intestinal tract. Well-digested epithelial cells enclosed in small masses of mucus almost certainly come from the upper part of the small intestine.

5. **Leucocytes.**—A few leucocytes may be found normally in almost every stool, but as they undergo the same physical and chemical changes as the epithelial cells, they are equally difficult to recognize with certainty. When present in abundance they

point to some ulcerative lesion. In catarrhal conditions, they are usually not much increased and do not form so prominent a feature of the microscopic picture as the epithelial cells. Masses of pus cells point to the rupture of an abscess into the intestine, and the better preserved the histological characters of the cells are, the lower down is the abscess probably situated. Intestinal decomposition and digestion may destroy pus cells within a very short period, so that it is impossible to recognize them. The nuclei of the polymorphonuclear cells may resist the change for some time, but as they readily break into fragments and differ in no way from the nuclei of the food that may have escaped digestion, they do not afford much assistance in diagnosis. Even the pus coming from a perforating peri-typhlitic abscess is often so changed in the abscess itself and in the colon, that it cannot be demonstrated in the stools. The shreds of undigested casein and soaps passed in the diarrhœal stools of patients on a milk diet can be differentiated from pus by the microscope, the numerous fat globules in the former indicating their true nature. Preparations of the fæces stained with methylene blue and eosin, or some similar blood stain, show in some instances, and notably in helminthiasis and muco-membranous colitis, a number of eosinophile leucocytes. The reason for their presence in these conditions is not understood, but it is probably related to the eosinophilia of the blood and sputum met with in parasitic conditions and asthma respectively.

6. **Erythrocytes.**—Unaltered red blood corpuscles are but rarely met with in the fæces, even when the stool is coloured an intense red, unless there is an ulcerative process affecting the rectum or colon, when, as also in the more severe forms of dysentery, a large number may be present. If the hæmorrhage has occurred high up in the intestine, the blood-cells are usually distorted beyond recognition when passed in the stools, but when there is an associated diarrhœa, the cells may be fairly well preserved. Occasionally "shadow corpuscles," which retain the form but not the colour, may be found. Large or small masses of a brownish-red colour consisting of hæmatoidin may be seen mixed with the fæces. They are usually amorphous, but occasionally may appear as characteristic rhombic crystals. Streaks of blood containing well-preserved corpuscles on the surface of the stool, usually point to the presence of bleeding hæmorrhoids.

7. **Tumours.**—Fragments of tumours when passed in the fæces are difficult to recognize as such, for, although their colour, consistency, and form may suggest their nature, and the arrangement of the nuclei in sections may assist in the diagnosis, the finer details

are usually lost and a reliable opinion can rarely be given. Occasionally pieces of hæmorrhoids come away, and sloughs of the intestine may also be passed. These should be examined by microscopic sections or scrapings, but the result is usually not very satisfactory. Polypi are sometimes found in the fæces complete, and sections may show a fairly characteristic picture.

8. Parasites.—The microscopical characters of the parasites and their eggs, as well as the pseudo-parasites met with in the fæces, will be considered in the next chapter.

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Chapter IV.

ANIMAL PARASITES.

THE alimentary tract of man, in common with that of other animals, is liable to be the haunt of various animal parasites, which, with their eggs, appear in the fæces. Owing largely to the fact that his food is submitted to a process of sterilization by cooking, the number met with in man is, however, small as compared with other vertebrates, and this is particularly the case in districts and countries, such as Great Britain, where uncooked salads and vegetables are but sparingly used. Since the incidence of entozoal infections, as well as of pathogenic bacteria, is also dependent upon the climate and general hygiene of the country, parasitic infections are more common in tropical and sub-tropical regions than in northern climates, and in countries with primitive sanitary arrangements and water supplies than in more civilized communities.

The animal parasites met with in the alimentary canal are both protozoal, or unicellular, and metazoal, or multicellular, but the latter are the more numerous and important. The Protozoa are divided into two groups, the Gymnomyxa, corresponding to the old group Rhizopoda, and the Corticata, which comprises the Infusoria and Gregarinidea. The former group includes those forms which, like amœba, have, during the dominant phase of their life-history, no limiting membrane, while in the latter the cortical layer of protoplasm is differentiated into a limiting membrane which gives a definite shape to the organism. The Corticata are sub-divided chiefly in accordance with the number and arrangement of the flagella they possess. Those with one to eight are known as Flagellata, and are represented in the intestinal parasites by the Cercomonas, etc.; those with a perioral ring, or that are more or less completely covered with flagella, are termed Ciliata, nad arere presented by Balantidium coli, etc.; while those i nwhich these organs of locomotion are absent belong to the sub-division Sporozoa, including the true gregarines and coccidiidea. Most of the metazoal parasites belong to two main groups of the animal kingdom, the Platyhelminthes and the Nematodes. The former are subdivided into the Cestoda, or solitary worms, and the Trematoda, or flukes, while the Nematodes include the thread and round worms. In addition, various members of the group Arthropoda and their larvæ have been met with in the fæces.

A naked-eye examination of the fæces will often reveal the presence of the larger metazoal parasites. By this means segments of tape-worms, round-worms, thread-worms, and hook-worms may be discovered, especially after the administration of anthelminthics, and even in some instances after the patient has taken a liberal dose of calomel. During the first stage of trichinosis, when there is an associated diarrhœa, the adult worm may be found in the stools. In most instances a microscopical examination is necessary, and it should always be employed to confirm the results of a macroscopical investigation. The presence of intestinal parasites may be suggested by the condition of the blood, since eosinophilia is often associated with such infections. The fæces should be examined as fresh as possible. If it is necessary to preserve them for a time, they should be kept in a well-stoppered bottle to protect them from drying, and infection by flies. Care should be taken to prevent soiling of the hands, etc., during the examination, and the apparatus used must be subsequently sterilized. To separate the material required for a macroscopical and microscopical examination of most parasites and their ova, an ounce or two of of the stool are thoroughly mixed with one or two quarts of water or 10 per cent formalin, and allowed to stand in a tall vessel for sedimentation to take place. The supernatant water, and material floating in it, is then poured off from the sediment, which is again washed, and the washing repeated until no more material floats off from the deposit. The washed sediment is finally placed in a conical glass and allowed to stand for several hours, when it is examined for parasites and their ova. The former may often be separated by straining the sediment through gauze. When only a few ova are likely to be present, or a search of the sediment prepared in the above way proves negative, Yaoita advises that a sample of the fæces should be mixed with a strongly alkaline solution of sodium hypochlorite to which has been added an equal amount of ether. This mixture rapidly disintegrates food particles, but does not appreciably affect the ova, which can be readily found in the deposit at the tip of a centrifuge tube.

All suspicious objects should be carefully examined, since plant cells and fibres, which closely resemble the ova and embryos of some intestinal worms, always occur in the fæces. The discovery of the ova of animal parasites in the stools does not necessarily mean that the adult organism is present in the alimentary canal, for the eggs of the liver-fluke, the paragonimus which invades the lungs, and the distoma hæmatobium which find a resting-place in the venous system of the bladder or abdominal viscera, may be passed per rectum. Permanent preparations of the ova may be made by smearing the sediment from the fæces, made liquid with 10 per cent formalin, on slides, fixing with 1 per cent osmic acid vapour, and mounting in glycerin jelly. To preserve nematodes and small trematodes, they should be fixed in 2 per cent formaldehyde solution for from two to twelve hours, according to the size. They are then placed in Braun and Lühe's lactophenol (lactic acid 1, phenol crystals 1, glycerin 2, water 1 part), diluted with an equal quantity of water, and subsequently transferred to full strength lactophenol. The anatomical structure is well brought out, and there is only slight shrinkage.

When protozoa are to be sought for, the fæces should not be washed, but be examined while they are still fresh and warm. Amœbæ are most readily found by picking out any particles of mucus that may be present, especially those that are blood-stained, mixing them with a little normal saline, and examining with a $\frac{1}{6}$ or $\frac{1}{8}$ in. objective, preferably on a warm stage at about 36° C., or, as Emerson suggests, with the microscope standing on the top of a steam radiator. The cover-glass should be supported at the sides by a large hair to avoid compressing the material, and evaporation should be prevented by ringing the preparation with vaseline. The addition of a drop of a 1 per cent watery solution of methylene blue stains pus and epithelial cells blue at once, but the amœbæ resist the stain and retain their activity for some time. If no amœbæ can be discovered in this way, the liquid part of the stool should then be examined. Better results are often obtained with the mucus secured by a rectal tube with several lateral openings introduced for a distance of 3 to 6 in. or more. If the fæces are not perfectly fresh and have been allowed to cool, only the encysted forms are likely to be met with.

(*A*). PROTOZOA.

I. GYMNOMYXA.

1. Lobosa.—Nuda.

Amœba.—According to Quincke and Roos, three kinds of amœbæ are parasitic in man: *Amœba intestini vulgaris*, *Amœba coli mitis*, and *Amœba coli* (Lösch). Some authors consider that the first two are really one organism, and there is much to be said for this view, for while they closely resemble each other, and differ only slightly as regards their power of producing disease, they are quite distinct from the Amœba coli, which is alone credited with real pathological significance.

Amœba coli is from 15 to 25 microns in diameter, being usually much larger than the largest leucocyte or epithelial cell, and is highly motile. It consists of a clear hyaline ectosarc, best seen in the pseudopodia, and a more or less finely granular endosarc, which, in addition to bacteria and ingesta, usually contains red blood corpuscles (*Fig.* 13), an important point of difference from Amœba vulgaris and A. mitis, in which they are never found. The nucleus is spherical and about 6 microns in diameter. In most cases it is obscured in the living parasite by the granules contained in the endosarc, and can only be satisfactorily made out when the amœba has been killed with acetic acid or corrosive sublimate. In addition, the endosarc contains one or more non-pulsatile vacuoles, which constitute its most striking feature. The most distinctive character of these organisms, which differentiates them from other cells in the fæces with which they may be confused, is their power of movement by the extrusion of pseudopodia, consisting of the clear ectosarc, followed by a flow of the granular endosarc. It is most important that definite amœboid movement, and not a mere change of shape of the cell, should be made out before concluding that it is an amœba, since the latter may be produced in other cells by variations in the physical conditions. Resting forms of a round or ovoid shape, that cannot be readily differentiated in the fæces from degenerate epithelial cells, and cells from the food, also occur. It is said that in this state the nucleus repeatedly divides, and that is the form which infects another host. In the encysted stage Amœba coli has a simple contour, while the encysted forms of the other two varieties have a double outline. Amœba coli is now generally regarded as the cause of the so-called amœbic dysentery. In well-marked cases of this disease, the stools contain blood-stained mucus in which large numbers of these parasites occur, and even during remissions they may also be found in the hard constipated fæces. Experiment has shown that Amœba coli is pathogenic for both man and cats. Amœba mitis, which is somewhat larger,

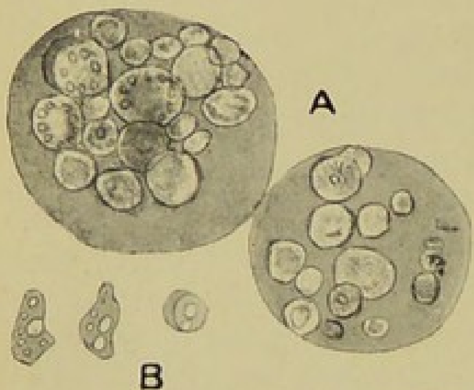


Fig. 13.—A, Amœba dysenteriæ containing red blood corpuscles, from a case of dysentery (×400). B, Amœba from normal stool. (×400).

varying from 25 to 35 microns in diameter, is only slightly pathogenic for man, giving rise to slight enteritis, and has no effect on cats. Amœba vulgaris is not pathogenic for either man or animals. The two last-named varieties may be met with in the fæces in various forms of diarrhœa, in the stools of typhoid cases, in acute and chronic enteritis, in colitis, and even occur in normal stools.

It is stated by Simon that in cases of chronic malarial intoxication with dysenteric symptoms, *Plasmodium malariæ* may be found in the red blood corpuscles passed in the stools, indicating the probable nature of the colitis.

II. CORTICATA.

1. **Flagellata.**—Lissoflagellata.—An examination of the fæces by the same method as for amœbæ may reveal the presence of actively motile, flagellate organisms. Some of these are plants, and must be regarded as pseudo-parasites, but others belong to the animal kingdom, and are true parasites. If one were to be guided only by the names given to these organisms, it would appear that a very large variety may occur in the stools; but a careful study of their characters shows that they all belong to two families, and three chief types, which have been variously named by different authors.

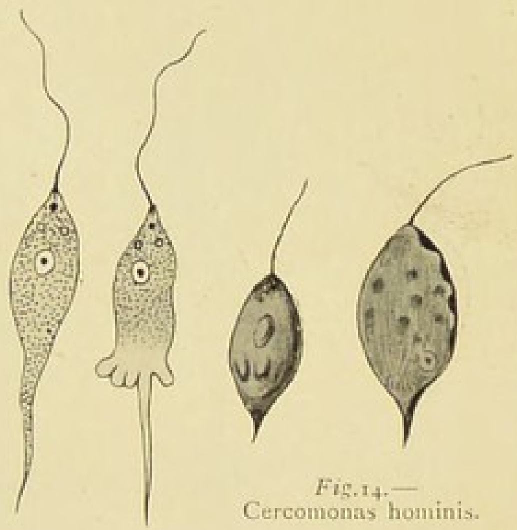


Fig. 14.—Cercomonas hominis.

(*a*). *Protomonadina.*—The parasites of this family are provided with one, or two equal, or one principal and one or two smaller, flagella. They are small, and either oval or slightly elongated in outline. Their relation to the gymnomyxa is shown by the fact that the posterior end of the body is very apt to throw out pseudopodia, and that the young forms often exhibit amœboid movements. Only one type is met with in the human fæces.

Cercomonas hominis (Monas, Monas lens, Monas monomitina).—The adult organism is round or oval in form, and varies in length from 8 to 16 microns. It is provided with a single long flagellum at its anterior extremity, which may be twice the body length, and with which it moves very rapidly. The younger forms are pear- or S-shaped, and are sometimes irregular in outline; the flagellum is either absent or rudimentary. Although organisms of this type have been frequently described in the fæces, and also in the sputum and various parts of the body, their pathogenicity is doubtful.

(*b*). *Polymastigina*.—These are small, somewhat oval animals, having three equal, or from four to eight unequal, flagella inserted at different points. They may also have an undulating membrane, which may be readily mistaken for a row of cilia. Two representatives are met with in the fæces.

Trichomonas (Trichomonas hominis, Trichomonas vaginalis, Monocercomonas hominis, Cimænomonas hominis, Protorycomyces coprinarius, Cercomonas coli hominis, Trichomonas intestinalis, Cercomonas s. bodo urinarius).—The names given to this parasite by different observers refer in some instances to the situation in which it was found, while others indicate its peculiar biological characters; there can be little doubt, however, that they are all really identical. The trichomonas (*Fig.* 15) is an oval or pear-shaped organism, which measures from 15 to 25 microns in length, and from 7 to 12 in breadth. From its anterior pole are given off three flagella of equal length, which are almost as long as the organism itself. Sometimes they seem united at the base. From this point arises an undulating membrane that extends laterally to the posterior pole, which may be rounded off, or taper to a tail-like appendage.

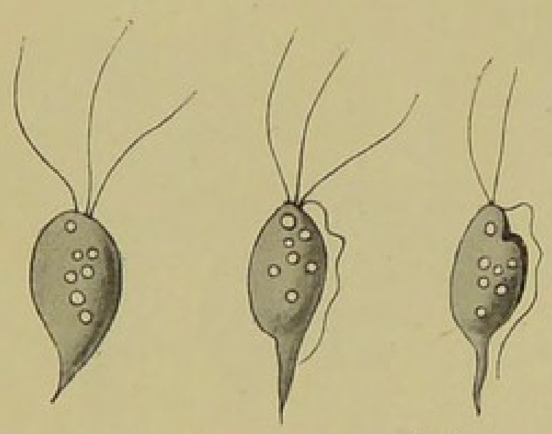


Fig. 15.—Trichomonas intestinalis.

A fourth flagellum is sometimes described, but this is probably the edge of the undulating membrane. The membrane is best seen when the movements of the flagella have ceased, or in specimens fixed in perchloride of mercury solution (1–5,000). The nucleus is situated at the base of the flagella, but is usual y only seen in stained specimens. Behind are one or more non-pulsatile vacuoles. The pathogenicity of these parasites has been much discussed, but it is now generally conceded that they can give rise to severe diarrhœa.

Lamblia intestinalis (Megastoma entericum, Cercomonas intestinalis, Megastoma intestinale, Dimorphus muris, Cercomonas coli, Trichomonas intestinalis).—The parasite is pear-shaped, and is from 10 to 21 microns long, and 5 to 12 broad (*Fig.* 16). In its anterior portion is a more or less well-marked depression, which constitutes the peristome, or mouth opening, of the organism. It is provided with eight flagella grouped in pairs. The first pair are situated on the sides of the peristome and are directed backward. The second and third pairs arise at the projection at the inferior end of the peristome, and likewise project backward. The fourth pair issue from the tapering tail-end of the body. In fresh specimens the third and fourth pairs are frequently agglutinated and cannot be separately made out. In specimens killed with perchloride of mercury they can usually be differentiated. All the flagella are of about equal length, and measure from 9 to 14 microns. The

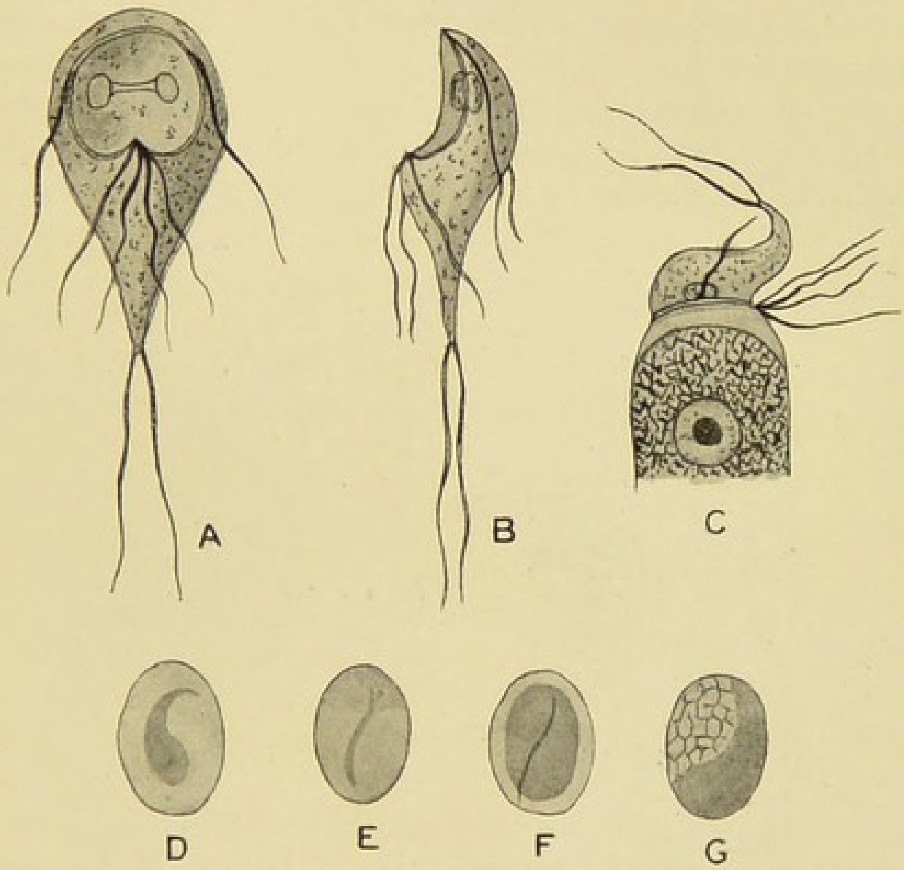


Fig. 16.—Lamblia intestinalis: A, Ventral surface (× 1500). B, Lateral surface (× 1500). C, Attached to epithelium (× 1500). D-G, Encysted forms.

protoplasm is hyaline and finely granular. The organism is surrounded by a fine cell membrane, which can be readily seen in fixed specimens. The nucleus is dumb-bell-shaped and lies at the base of the peristome. Vacuoles and solid inclusions are absent, nutrition taking place by osmosis. The parasites live in the duodenum and jejunum, adhering to the epithelial cells with its peristome. When they reach the large intestine they become encysted (*Fig.* 16, D–G), and are then seen as round or oval bodies, measuring 10 to 14 by 8 to 10 microns, surrounded by a very distinct membrane, within which lies the folded organism. This is the form usually found in the fæces, and unless there is severe diarrhœa or the patient is well purged with salines, the motile parasite does not appear. Fresh specimens examined on a warm stage exhibit rapid but irregular movements. In some instances an enormous number have been passed. They are found chiefly in children, and it is supposed that the infection is carried by water from the original host, chiefly the mouse, rat, rabbit, dog, cat, and sheep. They certainly thrive best when there is intestinal trouble, and it is probable that they accentuate the disease, but it is doubtful whether they can initiate it.

2. **Ciliata** (Infusoria)—Heterotricha.—The body of organisms of this group is uniformly covered with cilia, and a circlet or spiral of longer cilia is developed in relation to the mouth. A nucleus is always present, and is accompanied by a paranucleus. One or more contractile vacuoles occur in the protoplasm.

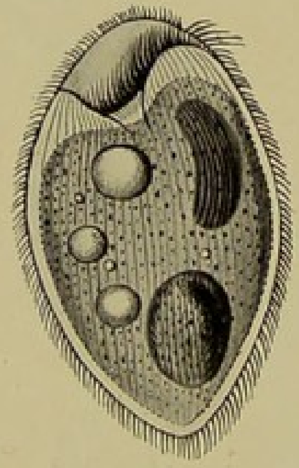


Fig. 17.—Balantidium coli.

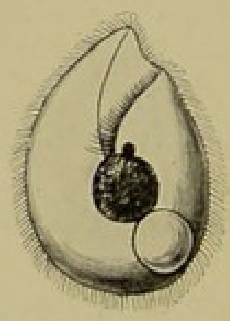


Fig. 18.—Balantidium minutum.

Balantidium coli (Paramœcium coli) is the chief representative of the group met with in the fæces (*Fig.* 17). It is an oval organism of from 60 to 100 microns long, and 50 to 70 broad. At the anterior end is the mouth, a funnel- or cleft-shaped cavity which extends for about a quarter of the body length, and at the posterior blunter extremity is a small anal orifice. The ectosarc and the endosarc are clearly differentiated. The latter is finely granular, and contains numerous fat and starch granules, besides, in some cases, bacteria, red blood corpuscles, and leucocytes. The nucleus is kidney-shaped and is accompanied by one or more paranuclei. There are usually two feebly contractile vacuoles. The organism is entirely covered with fine cilia, which are longer and more densely grouped about the mouth, while the anus is surrounded by only a few. The surface is traversed by parallel longitudinal lines, more distinct at the anterior end, which connect the two poles. The parasite is most common in Sweden, but has also been observed in Germany, Russia, Italy, Cochin-China, and the United States. Infection occurs through the dejecta of swine. The parasite occurs especially in the colon, but in severe cases may be found in the jejunum. It may be passed in the stools in enormous numbers, associated with blood-stained mucus and epithelial cells. Its pathogenicity has been questioned, but there can be no doubt that it may give rise to a most severe catarrh, which may be even fatal. Hunt classifies it as one of the causes of dysentery. Patients infected with this parasite are said to be liable to develop a profound anæmia resembling that present in the later stages of gastric carcinoma.

Balantidium minutum (Colpoda cucullus.)—This organism was described by Jakoby and Schaudinn as being present in dysenteric stools. It resembles Balantidium coli, but is smaller, measuring 20 to 30 by 15 to 20 microns (*Fig.* 18). The peristome is longer, and extends at least half way down the body. The nucleus is median and spherical, and there is only one contractile vesicle.

Nyctotherus faba is about the same size as the preceding (*Fig.* 19). It is shaped somewhat like a haricot bean, the peristome occupying

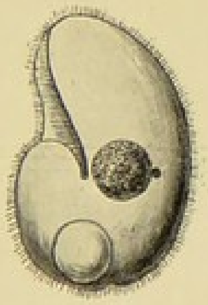


Fig. 19.—Nyctotherus faba.

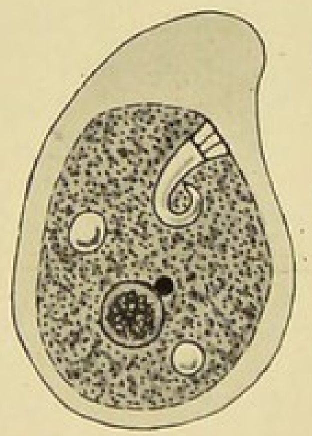


Fig. 20.—Chilodon dentatus.

the concavity. There is a spherical nucleus about the centre of the body, and a single large contractile vacuole at the lower extremity of the animal. This parasite was described by the same authors as the preceding, and has only been met with a few times in man.

Chilodon dentatus (*Fig.* 20), was found by Guiart in the stools of a dysenteric patient. It is of an oval shape, 35 to 55 microns long by 25 to 35 broad. The ventral face is flat, and the dorsal surface highly convex. The latter is free from cilia, but the former possesses large numbers arranged in longitudinal lines. The highly granular endoplasm occupies the whole of the posterior part of the parasite, the clear ectoplasm forming only a narrow peripheral band round the body, but constituting the greater part of the anterior extremity, where it is prolonged into a highly contractile membrane. The mouth is situated on the inferior surface just anterior to the limit of the endoplasm, and a little to the left of the middle line. It is connected with a pharyngeal cavity directed backward into the endoplasm, where it recurves on itself, forming almost a complete circle. This is a very characteristic feature. A large spherical nucleus, with a small paranucleus, is situated about the centre of the body. Two contractile vacuoles exist, one to the left of the nucleus, and the other to the right of the mouth.

3. Sporozoa—Coccidiidea.—All the sporozoa are parasitic, but the only members of the group that have been met with in human fæces belong to the sub-class Coccidiidea (*Fig.* 21). These are the Coccidium cuniculi, which occurs in the liver or epithelial cells of the intestine, and the Coccidium bigeminum, which lives in the intestinal villi.

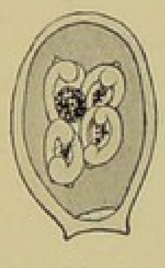


Fig. 21. Coccidium hominis.

Coccidium cuniculi.—The form most frequently met with in the fæces is the oocyst, which appears as a small ovoid body about 25 to 50 microns long by 15 to 30 broad. The protoplasm is contracted to the centre, forming a pale spherical mass, which has been described as a nucleus. No cilia, or other organs of locomotion, are present, nourishment being obtained by endosmosis. Coccidia are most commonly met with in the rabbit, giving rise to the condition of psorospermiasis. An analogous disease of the liver has been described in man, and it is assumed that when these organisms appear in the fæces they have reached the intestine by the bile. The coccidia occurring in the intestine are considered by some authorities to be a different species, distinguished by their slightly smaller size, and are spoken of as *Coccidium hominis*.

Coccidium bigeminum (*Fig.* 22).—Railliet and Lucet, and later Guiart, met with a form of coccidium in the fæces which they consider distinct from the former. It is extremely small, measuring only 12 by 8 microns. The name bigeminum was given to the organism because in some instances the oocyst was found to contain two cell membranes, enclosing separate protoplasmic masses, or four sporoblasts.

(*B*). METAZOA.

I. PLATYHELMINTHES.

The platyhelminthes as a class are characterized by the absence of a distinct vascular system, the fact that the alimentary canal when present has no anus, and a reduction of the cœlom to mere slits and irregular cavities between the mesoderm cells. The nervous system consists of a plexus of nerves, mostly on the ventral side of the animal, which in the higher members of the series is concentrated into a central nerve ganglion giving off two longitudinal cords that may be connected by transverse commissures. An excretory system, consisting of fine branches, which, at the inner end terminate in flame cells, and, at the outer end, open to the exterior, is a very characteristic feature of the group. They are all hermaphrodite, but reproduction may be asexual at times, and then an alternation of generations takes place. Two groups

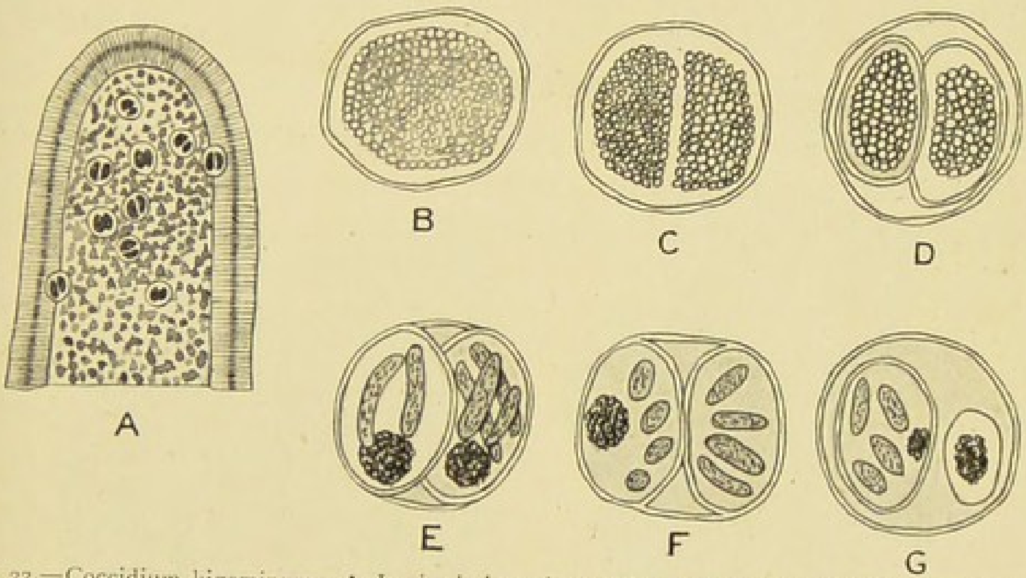


Fig. 22.—Coccidium bigeminum. A, In situ in intestinal villi. B–G, Stages in development of egg

affect man. The *Cestoda*, or tape-worms, are all endoparasites, and are provided with organs of adhesion in the shape of hooks or suckers, by which they attach themselves to the walls of the small intestine of their host. They are devoid of any mouth, alimentary canal, or anus. The nervous system is composed of a cerebral ganglion and two lateral nerve cords. The excretory system opens to the exterior by one or more pores, which are sometimes furnished with pulsating vacuoles. The generative organs are usually repeated many times. The *Trematoda*, or flukes, are platyhelminthes with a cylindrical or flat leaf-like body, devoid of segmentation. They are provided with adhesive organs in the shape of suckers. Hooks are rarely present. They are parasitic and hermaphrodite, both reciprocal and self-fertilization taking place. The embryo may develop directly, or it may pass through a series of changes, in some of which asexual reproduction occurs. Both the cestoda and trematoda have no doubt undergone considerable modification as a result of the parasitic life they lead. They have lost their organs of locomotion and are dependent upon cilia, or on the boring hooks of their larvæ, for a change of host, but in compensation are provided with suckers or hooks, by which they adhere to the intestinal wall of their victim. They have also acquired the power of producing enormous numbers of eggs, and thus obtained a better chance of meeting the necessary host for their development. In many cases their power of propagation is still further increased by asexual budding of the embryo. In the cestoda, the group in which the parasitic habit has left its deepest mark, the whole alimentary system has disappeared and the food is absorbed through the skin. In both groups sense organs, for which there can be little use, are developed slightly, or not at all.

I. Cestoda.

Tænia saginata (T. mediocanellata, T. dentata, T. incruris) is one of the commonest tape-worms found in man, and is met with in all parts of the civilized world (*Figs.* 23, 24, 27). It may attain a length

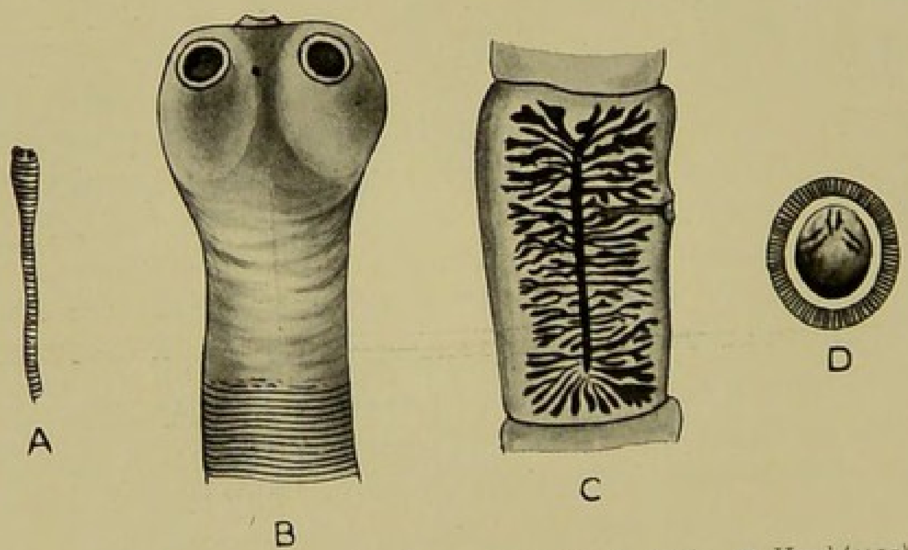


Fig. 23.—Tænia saginata. A, Head and upper segments (nat. size). B, Head (×15). C, Ripe segment (×2). D, Egg (×400).

of six or even twelve yards, and may be composed of many hundred segments, termed proglottides, which increase in size as they recede from the point of attachment of the parasite to the intestinal wall. It is usually described as consisting of a head, a neck, and a segmented trunk, but recent observations on the nervous system suggest that the "head" is in reality the posterior extremity of the worm. The "head," which is best studied under a low-power objective (e.g., two-thirds), is cuboid in shape and is from 1·5 to 2·0 mm. in diameter. It bears on its sides four well-developed pigmented suckers, each about 0·8 mm. in diameter, but is devoid of hooks. The head is mobile and can move its point of attachment with ease. The neck is slender and tapering, increasing in size as it gradually merges into the body. The first trace of segmentation is the appearance of shallow grooves which separate the proglottides from each other. As they grow backward the proglottides increase in size, and those situated a foot or more behind the head are sexually mature. The ripe segments are from 16 to 20 mm. long, and from 5 to 7 mm. wide. The over-ripe segments are longer and rather more slender. The excretory system consists of an annular vessel in the head, from which four ducts, corresponding in position to the four suckers, pass backward. Two of them soon disappear, while the other two are continued, one on each side of the proglottides. The longitudinal ducts are put into communication, at the posterior end of each

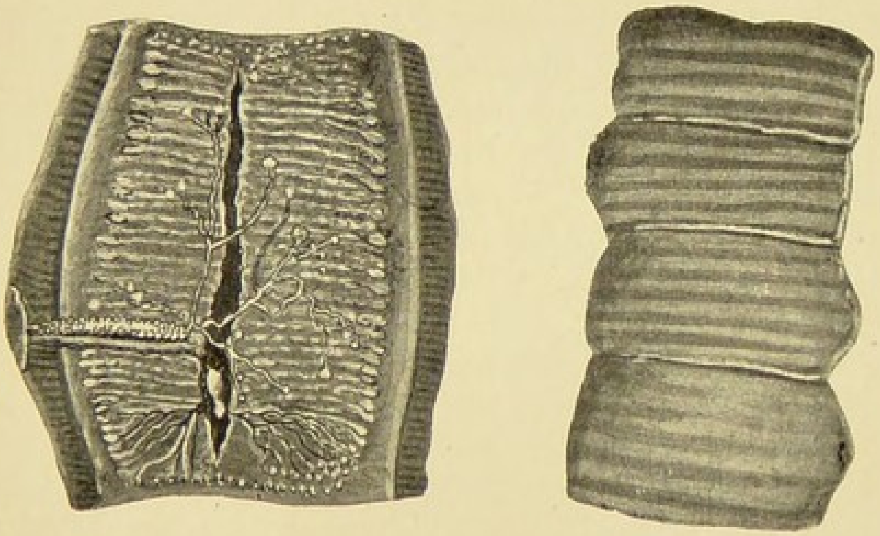

A B

Fig. 24.—Tænia saginata A, Ripe segment (×3). B, Four unripe segments (×3).

segment, by a transverse vessel, which in the last opens to the exterior by a pore. Both male and female reproductive organs are repeated in each proglottis. The testis is composed of numerous vesicles dispersed all over the segment. They contain spermatozoa, and each is attached to one of the branches of the ramifying vas deferens. From these branches arises a common duct, which is slightly coiled, and runs from the centre of the segment to the common genital pore, situated in the middle of one side. The section of the vas deferens lying next the orifice has very muscular walls, and can be extruded, acting as a penis. The vagina opens into the genital pore a little behind the penis. It then passes backward to a small cavity, the receptaculum seminis, in which the spermatozoa are stored until the ova are ripe for fertilization. The ovaries are two in number and are composed of a large number of tubules opening into a branched duct. The two oviducts unite and receive a small duct, termed the fertilizing duct, from the receptaculum seminis. The oviduct then unites with a duct from the yolk gland, which lies between and behind the ovaries, and, passing through a small spherical shell gland, enter the uterus. In the unripe segments the uterus is an inconspicuous simple sac, but as it fills with eggs it increases in size and becomes branched, eventually occupying almost the whole of the interior of the segment; meanwhile the reproductive organs of both sexes atrophy. A ripe proglottis, which is ready for separation, therefore only consists of a sac with a central canal, from each side of which a large number, usually about 15 to 20 on each side, of dichotomously dividing branches are given off. By a series of contractions of its muscular walls the ripe segments break off from the rest of the tape-worm and pass out from the alimentary tract of the host at any time, or with the fæces. Outside the body the walls of the proglottis and uterus rupture, and the contained eggs escape. Eggs may also escape within the bowel and be passed in the stools. The eggs, which are spherical, and brown in colour, have a thin inner shell surrounded by an outer thick, oval, concentrically striated embryonic covering that is transparent. They measure from 30 to 40 microns long, and are 20 to 30 broad. The eggs enter the stomach and intestine of the ox, which is the intermediate host, with food or water, and there the eggshell is dissolved, and a small embryo, the proscolex, emerges. By means of three pairs of hooks, with which it is provided, the proscolex burrows through the walls of the alimentary canal and enters the blood-vessels or body-cavity. It then settles down in various tissues and undergoes development, forming a vesicle full of fluid, which, when found between the muscle fibres, gives rise to the condition known as "measly" beef. Later a head, provided with a rudimentary ring of hooks, arises on one side of the vesicle. The head and short neck, termed the scolex, with the containing bladder, or vesicle, are known as the Cysticercus bovis. So long as it remains in the body of the ox the cysticercus undergoes no further development, but when it is swallowed by man the vesicle is digested, and the head attaches itself to the intestinal wall, when it commences to develop proglottides.

Tænia solium (*Figs.* 25, 27, 28).—Infection with this parasite comes from the ingestion of the Cysticercus cellulosæ of "measly" pork. It is fairly common in the Old World, but is uncommon in America.

At one time it was the tape-worm most frequently met with in Germany, but is now only comparatively rarely seen, owing probably to the fact that uncooked pork is less frequently consumed, and to more careful inspection of the food supplies of the large towns. The adult worm is usually much shorter than T. saginata, averaging about three to three and a half yards in length. Its most characteristic feature is the globular head, which varies from 0·6 to 1 mm. in diameter, and is provided with four pigmented suckers, about 0·4 to 0·5 mm. in diameter, and also a rostellum furnished with from 22 to 32 hooklets, from 0·11 to 0·18 mm. long, arranged in a double row. The suckers are best seen with a two-third-inch objective, but the hooklets need a quarter-inch for their satisfactory demonstration. The neck is about 3 cm. long and is unsegmented. The mature proglottides measure from 9 to 10 mm. long by 4 to 5 mm. broad, and contain a uterus with but 7 to 10 coarse, main,

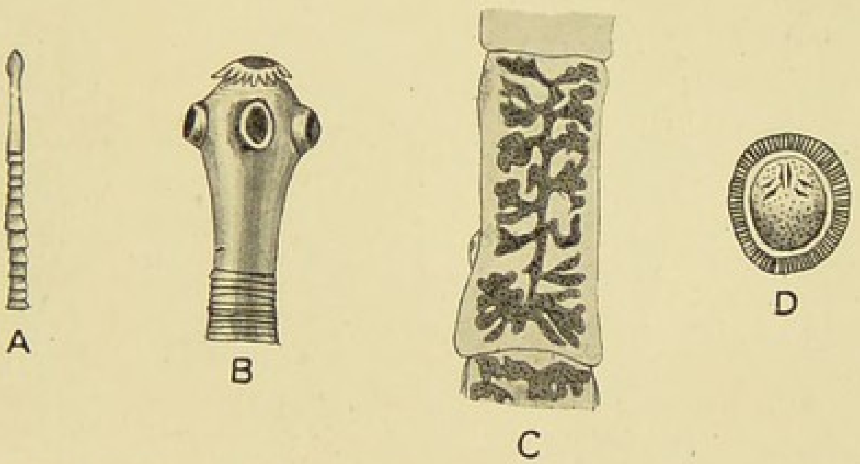


Fig. 25.—Tænia solium. A, Head and first few segments (nat. size). B, Head (×15). C, Ripe segment (×2). D, Egg (×400).

lateral branches, thus differing greatly from T. saginata. The genital openings of the segments are at the margin, and, like those of T. saginata, are arranged in a fairly regular alternating manner. The ova of T. solium are secreted constantly, and appear in large numbers in the fæces. They are round or oval, and, when fully developed, are surrounded by a thin shell covered with a thick striated embryonic membrane, which is often yellow in colour. In the interior, the hooklets of the embryo can often be made out. The eggs are about 35 microns in diameter. Rarely an auto-infection with Tænia solium has been observed in man, the embryos set free in the stomach migrating to various parts of the body, where they become encysted, constituting the cysticercus stage in the development of the parasite.

Bothriocephalus latus (Dibothrium latum, T. lata) is the largest cestode that inhabits the human intestine (*Figs.* 26, 27, 28). It often attains a length of 8 or 9 yards, and in some cases has reached even 50 feet. The cysticercus stage occurs in fish, particularly the pike, and the parasite is therefore most commonly met with in maritime countries and marshy districts. It appears to be most frequently encountered in the countries bordering on the Baltic Sea, in Holland Switzerland, and Northern Italy. Outside Europe it is most common in Japan. Multiple infection may occur. The head is 2 or 3 mm. long by about 1 mm. broad. It is ovoid in contour, and is almond- or spoon-shaped. In striking contrast to *T. saginata* and *T. solium*, it possesses neither hooklets nor suckers. The hooklets, which were present in the early stages of development, are lost before the animal is mature. On either side of the flat surface of the head are two deep grooves which probably act as suckers. There is no

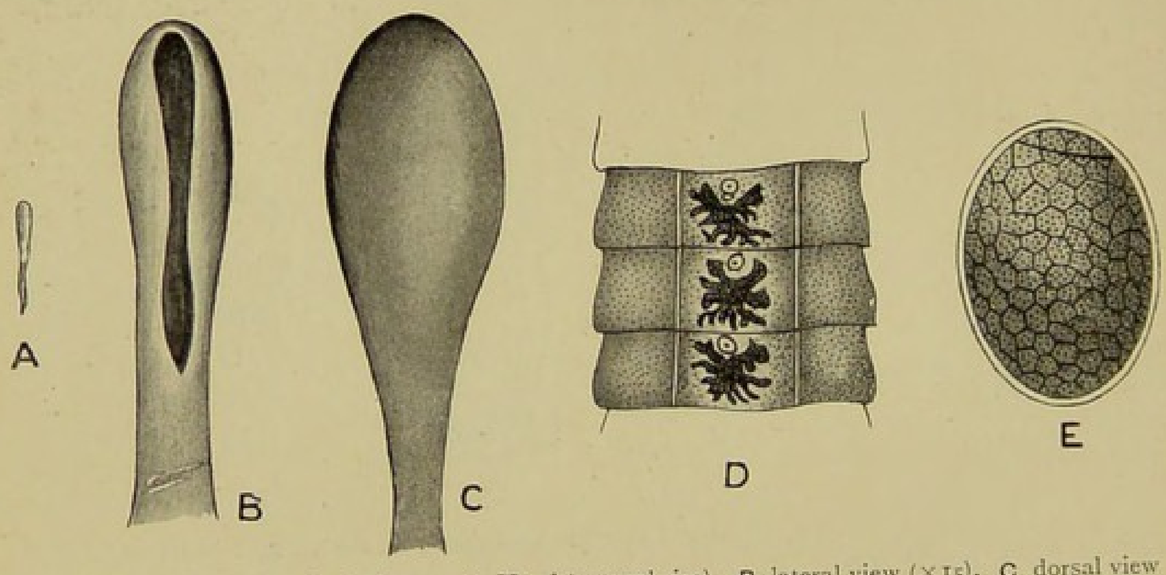


Fig. 26.—Bothriocephalus latus. A, Head (natural size). B lateral view (×15). C, dorsal view ×15). D, Ripe proglottides (×2). E, Egg (×400).

distinct neck between the head and the small first segments. The mature proglottides, which begin about 50 cm. from the head, increase in size until about 10 to 15 mm. broad and 3 to 5 mm. long. The genital pores are not on the side, but on one surface of each segment in the middle line. The male orifice is distinct, and in front of the female opening, and the uterus has an aperture for the exit of the ova behind the female orifice through which the spermatozoa are introduced. The uterus presents four to six convolutions on each side, which become especially distinct when the segments are placed in water or exposed to the air. A rosette-like appearance is then seen, which is quite characteristic. The eggs have a very distinctive appearance. They are oval, about 70 microns long by 45 microns broad. They are enclosed in a thin, brown envelope, at one end of which a small lid may be made out, except in very young eggs. The contents consist of coarsely granular protoplasmic spherules forming a mulberry-like mass. In certain cases the presence of the parasite is associated with a condition of the blood which cannot be distinguished hæmatologically from primary pernicious anæmia. It is probably due to a toxin affecting the blood, and possibly the bone-marrow. It rapidly disappears after the worm has been got rid of.

The chief distinguishing characters of the segments and heads of the three cestodes already described are shown in the following tables (and *Figs.* 27, 28) :—

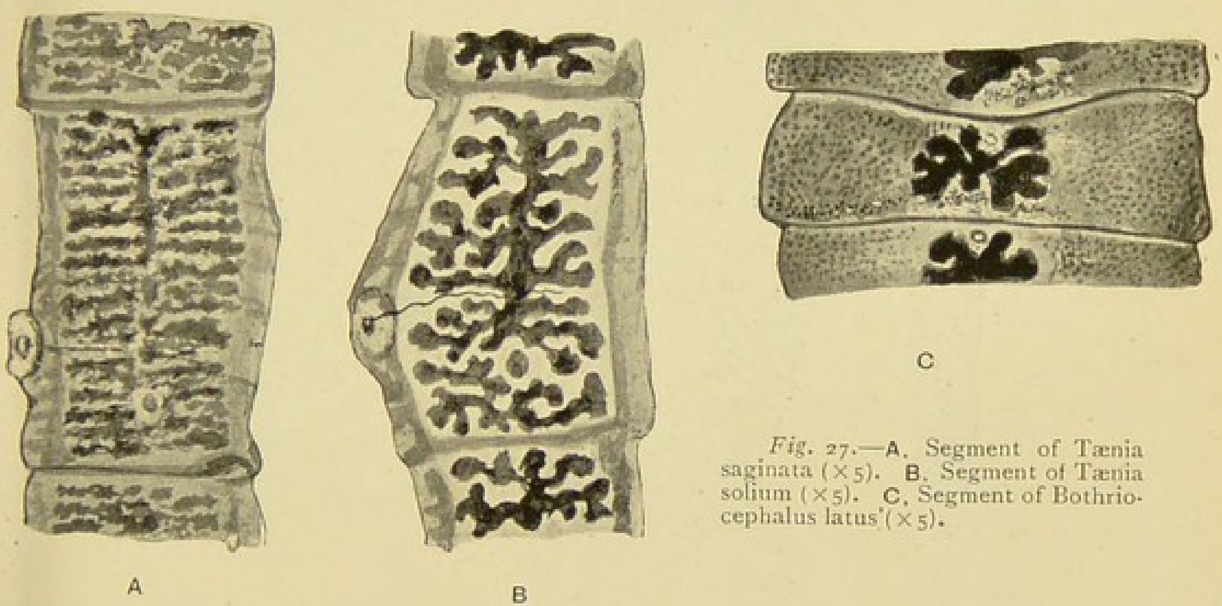


Fig. 27.—A. Segment of Tænia saginata (×5). B. Segment of Tænia solium (×5). C. Segment of Bothriocephalus latus (×5).

Ripe Proglottides.

T. saginata.	*T. solium.*	*Bothriocephalus latus.*
Segments detached separately and escape at any time	Segments expelled in short chains with the fæces	Segments expelled in long chains
Segments longer than broad (18 ×6 mm)	Segments longer than broad (10 × 5 mm.)	Segments broader than long (5 ×15 mm.)
Genital papilla lateral	Genital papilla lateral	Genital papilla medio-ventral
Uterus 20 to 30 lateral branches	Uterus 7 to 10 lateral branches	Uterus in rosettes

HEAD.

T. saginata.	*T. solium.*	*Bothriocephalus latus.*
Cuboid (1·5–2 mm.)	Globular (0·6–1 mm.)	Ovoid (2–3 × 1 mm.)
Suckers, four round pigmented	Suckers, four round pigmented	Two lateral slits
No rostellum	Rostellum present	No rostellum
No hooklets	A double row of hooklets (22–32)	No hooklets

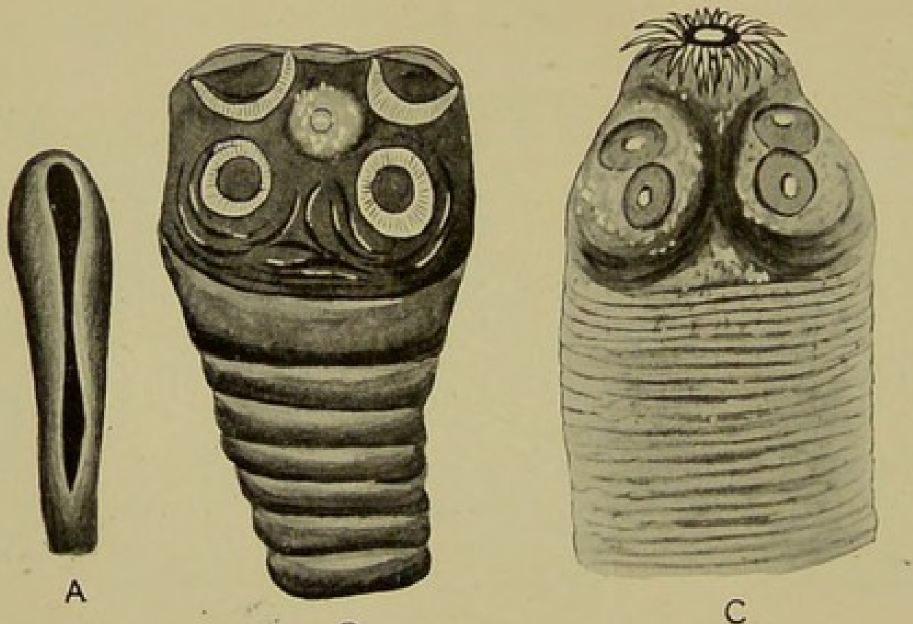


Fig. 28.—A, Head of Bothriocephalus latus (×15). B, Head of Tænia mediocanellatus (×30). C, Head of Tænia solium (×30).

In 1896 H. Ward described what he considered a new species of tape-worm, the "T. confusca." This resembles T. saginata very closely, and is probably but an abnormally elongated variety of that parasite. In 1900 von Linstow described, under the name "T. africana," a tape-worm occurring in subjects residing in the vicinity of Lake Nyasa, which was probably an extremely contracted form of T. saginata. Certain authors claim to have met with the Tænia serrata and Tænia marginata of the dog in man, but their descriptions are too brief to be convincing, and might equally well apply to T. solium.

Bothriocephalus cordatus (Dibothriocephalus cordatus).—This is a parasite of Greenland, met with principally in the dog, dolphin, and walrus (*Fig.* 29). It measures at least over a yard long, and contains about 600 segments. It is only distinguished from B. latus by the head, which is heart- or arrow-shaped.

Diplogonoporus grandis (Krabbea grandis).—This parasite is only known from an incomplete example met with in Japan. It measured 10 metres long, and is therefore one of the largest parasites of man. The head is unknown. The diplogonoporus differs from the bothriocephalus in the existence of two longitudinal furrows, into the bottom of which the sexual orifices open, on the ventral face of each segment. The sexual organs are double.

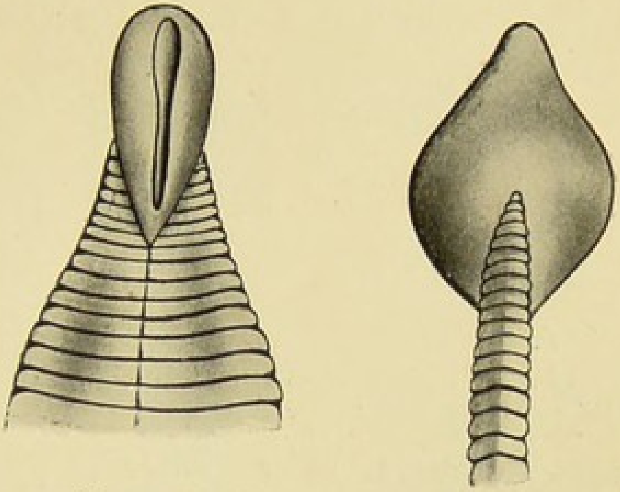


Fig. 29.—Bothriocephalus cordatus (× 15).

Tænia cucumerina (T. canina, T. elliptica, Dipylidium caninum).—This parasite is met with almost exclusively in children, the infection occurring through cats and dogs (*Fig.* 30). It is from 15 to 35 cm. long, and from 1·5 to 3 mm. broad. The small club-shaped head is provided with four suckers and about sixty hooklets, arranged in three or four irregular

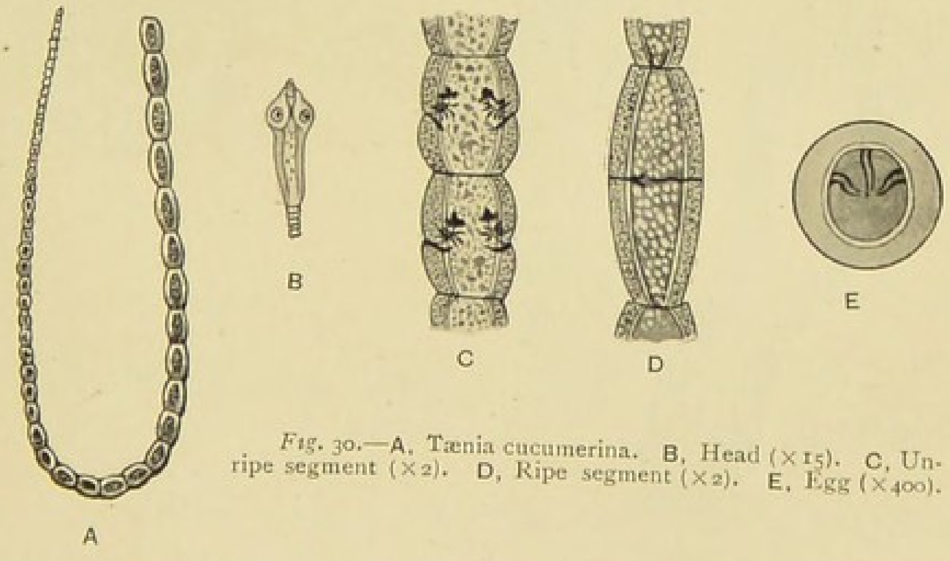


Fig. 30.—A, Tænia cucumerina. B, Head (×15). C, Unripe segment (×2). D, Ripe segment (×2). E, Egg (×400).

rows round a rostellum, which can be withdrawn into the head. The ripe segments have a reddish colour, and are elongated and elliptical, giving to the body a moniliform appearance. Each segment has two genital pores, one on the left and the other on the right side, corresponding to the double sexual organs of each segment. In the ripe segments the uterus breaks up into round capsules each containing eight or ten eggs. The eggs are round, measure from 43 to 50 microns in diameter, and have a thin shell. The embryo, already armed with six hooklets, may be seen in the interior. Never more than a few

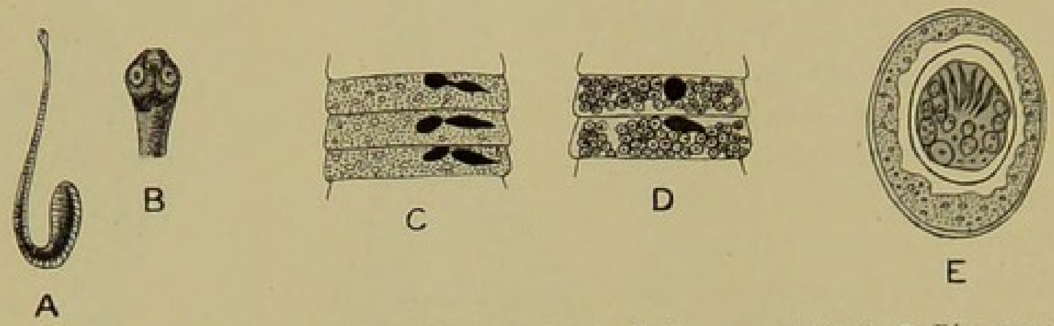


Fig. 31.—A, Tænia nana (×2). B, Head (×15). C, Unripe segment (×20) D, Ripe segment (×20). E, Egg (×400).

eggs are found in the fæces, and these may be readily overlooked owing to their small size. Even careful search frequently fails to reveal their presence, in contrast with the comparative ease with which the ova of T. saginata, T. solium, etc., are generally found. The cysticercus form develops in fleas and lice.

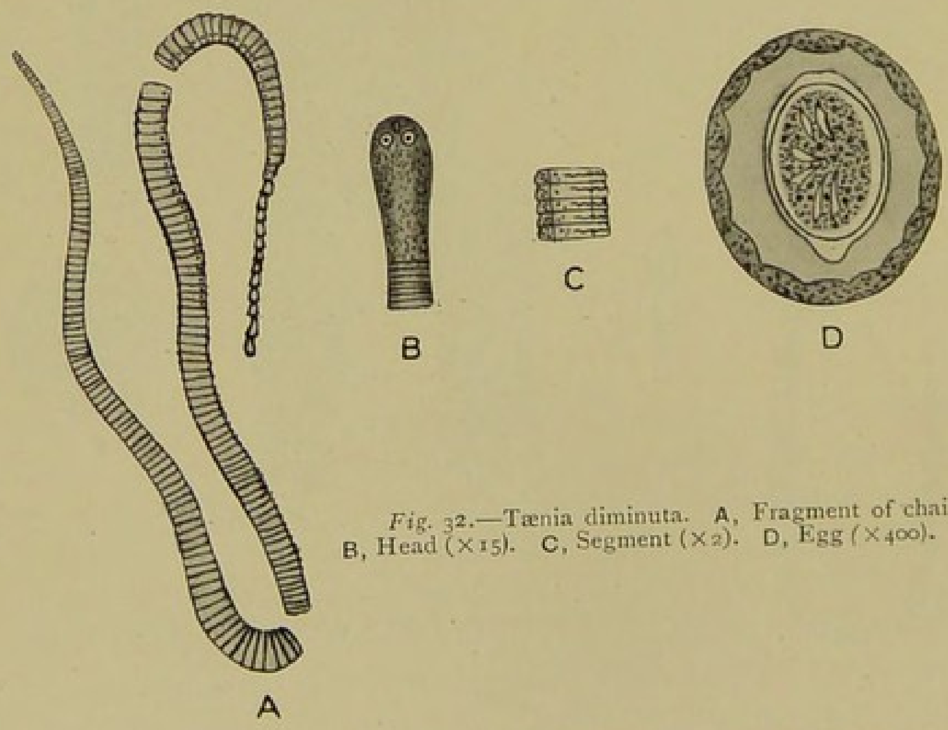


Fig. 32.—Tænia diminuta. A, Fragment of chain. B, Head (×15). C, Segment (×2). D, Egg (×400).

Tænia nana (Hymenolepis murina), or the dwarf tape-worm, is common in the intestines of the lower animals (*Fig.* 31). In man it is most frequently met with in Italy, Egypt, and along the Mediterranean. It usually affects young individuals, often, it is said, causing severe nervous symptoms. It is from 10 to 25 mm. long, and from

0·5 to 0·7 mm. broad. Its outline, except for the head, and the fact that the single sexual pores are all situated on the same side of the body, is practically the same as that of the larger tape-worms. The head is spherical, and is provided with four suckers and a rostellum bearing along its anterior edge a single row of twenty-four to thirty very small hooklets, each about 14 to 18 microns long. The segments, about 150 in number, are of a yellowish colour, and about four times as broad as long (0·4 to 0·9 mm. by 14 to 30 microns). The uterus is oblong, and contains numerous ova. These are slightly opalescent, spherical or oval bodies, 30 to 37, up to 48 microns in diameter, and have two distinct thick membranes, each pole of the inner showing a more or less conspicuous process with filamentous appendages. In the interior of the egg the embryonic worm, with five or six hooklets, may be distinguished. The parasite inhabits the ileum, where an astonishing number—5,000 or more—have been seen. The cysticercus stage is believed to occur in certain snails which are frequently eaten raw in Italy and Egypt.

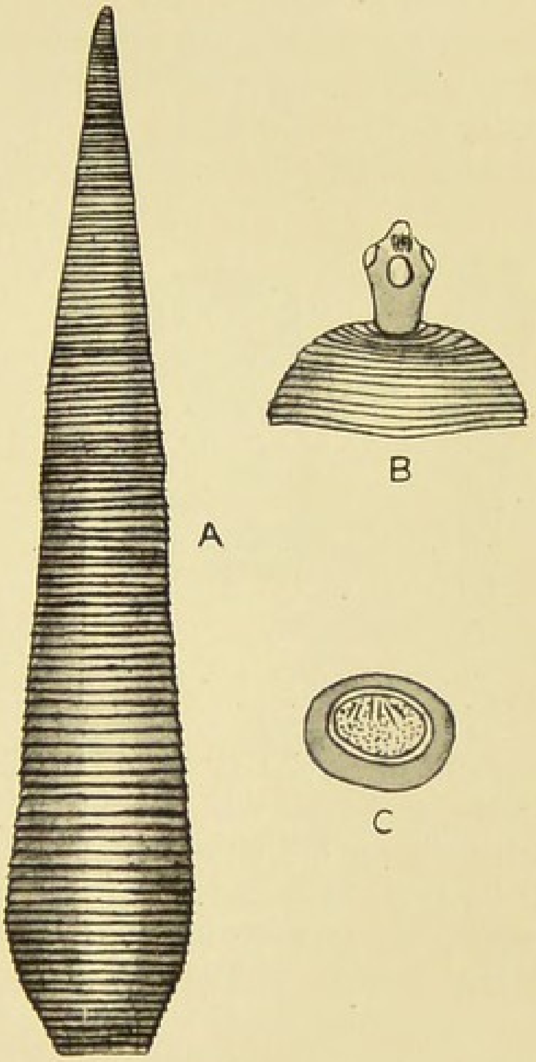


Fig. 33.—A, Tænia lanceolata (nat. size). B, Head (×100). C, Egg (×400).

Tænia diminuta (T. flava-punctata, T. minima, T. varerina, T. leptocephala, Hymenolepis diminuta).—This is a rare intestinal parasite in man (*Fig.* 32). It was first described by Leidy as occurring in human fæces, and was subsequently studied by Grassi, Parona, and Packard. In length it varies from 20 to 60 cm., and is formed of 800 to 1,000 segments, with single sexual pores on the same side of the body. The head is provided with two suckers, but is without a rostellum or hooklets. The ova resemble those of T. solium. The cysticercus form develops in certain caterpillars and cocoons.

Tænia lanceolata (Hymenolepis lanceolata) (*Fig.* 33).—This cestode is lanceolate in shape. It is from 3 to 13 cm. long, and varies from 5 to 18 mm. broad. The head is very small, and shows a rostellum armed with a row of 8 long hooklets (31 to 35 microns). The genital pores are marginal and unilateral. It is a common parasite of the goose and duck, and has as intermediate host various small crustaceans living in water.

Tænia madagascariensis (Davainea madagascariensis) is a form of tape-worm found to infest man residing on the east coast of Africa. It varies in length from 15 to 30 cm., and consists of 300 to 600 segments, which are broader than long. A double row of hooklets surrounds the four sucking-cups and voluminous rostellum. The latter can be withdrawn into the head, and then resembles a fifth sucker. The hooklets are readily shed, so that the head of the worm is often free from them when found. The sexual pores are unilateral. When ripe the uterus breaks up, and the eggs are shed in conglomerate masses covered by a capsule, similar to that of T. cucumerina, but much larger. The cysticercus form and intermediate host are unknown. It is interesting to note that it is the only representative in man of a group of cestodes peculiar to birds.

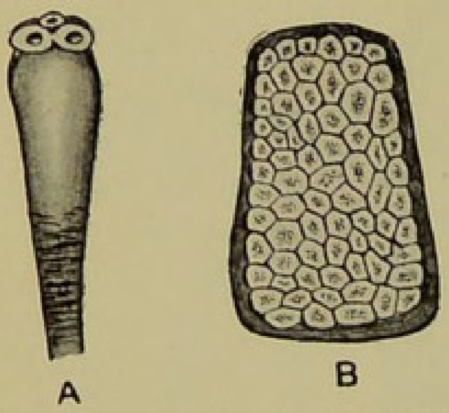


Fig. 34.—Tænia Madagascariensis. A, Head. B, Ripe segments.

Tænia asiatica (Davainea asiatica).—Only one example of this worm, and that without a head and not quite ripe, has been met with, in an individual living in the neighbourhood of Aschabad. It measured 3 metres in length, and had about 750 segments. The genital pores were all situated on one side of the body, and the uterus was divided into 60 or 70 large pouches.

DIFFERENTIAL TABLE OF THE HEADS OF THE CESTODES KNOWN TO AFFECT MAN.

1	Hooklets	2
	No hooklets..	5
2	One ring of hooklets	3
	Two rings of hooklets	4
	Three or four rings of hooklets (50–60), from 6 to 15 microns long	*T. cucumerina*
3	Eight hooklets, 31–35 microns long ..	*T. lanceolatus*
	About 26 hooklets, 15 microns long ..	*T. nana*

4	About 90 hooklets, 18 microns long ..	*T. madagascariensis*
	Twenty-two to 32 hooklets, from 120 to 170 microns long	*T. solium*
5	Four suckers	6
	Two lateral slits	7
6	Small rostellum, small suckers, large neck	*T. diminuta*
	No rostellum, large suckers often pigmented, black neck slender	*T. saginata*
7	Head oval	*B. latus*
	Head cordate	*B. cordatus*

DIFFERENTIATION OF THE CESTODES AFFECTING MAN EXPELLED WITHOUT THE HEAD.

1	Genital pore marginal	2
	Genital pore ventral	8
2	Tænidæ — Genital pore single ..	3
	Tænidæ — Genital pore bilateral, eggs in capsules	*T. cucumerina*
3	Genital pore unilateral	4
	Genital pores alternating	7
4	Uterus occupying all the segment ..	5
	Uterus formed into egg capsules ..	6
5	Body from 10 to 15 mm. long	*T. nana*
	Body from 3 to 13 cm. long	*T. lanceolata*
	Body 30 cm. long	*T. diminuta*
6	Body 30 cm. long	*T. madagascariensis*
	Body 3 m. long	*T. asiatica*
7	Uterus few branches (7–10)	*T. solium*
	Uterus many branches (20–30) ..	*T. saginata*
8	Pseudophyllidæ (Bothriocephalidæ)—	
	Genital pore single	9
	Genital pore double	*Diplogonoporus grandis*
9	Body about 1 metre long	*B. cordatus*
	Body several metres long	*B. latus*

To Remove Tape-worms from the alimentary canal it is necessary that the parasites should be detached from their hold on the intestinal mucous membrane. As the head is buried in the valvulæ conniventes, and mucus collects about its point of attachment, it is unlikely that any vermicide that may be given will come in contact with it unless the bowel is empty of food and the mucus cleared away. As a preparatory measure, therefore, a gentle saline laxative should be given each morning, fasting, for two or three days, and be followed by a soap and water enema at night. Meanwhile the food should be mostly fluid and in a concentrated form, so that as little residue as possible is left. The bowels having been completely evacuated on the evening of the second or third day, no further food should be taken, and in the morning the vermicide selected should be given in a sufficient dose. If after the lapse of three or four hours no aperient action has followed, a tablespoonful of castor oil, repeated in half an hour if necessary, or another saline purge should be administered. When the worm begins to escape from the anus the patient should be placed over a commode partly filled with warm water, and be directed to remain there until the whole parasite has been passed. When within 10 or 12 inches of the head, the worm appears as a pale slightly flattened thread with no distinct segments. So long as any part of the parasite is protruding from the anus it is probable that the head has not escaped. When it has all been passed, the contents of the commode are stirred up with a glass rod, and, when the worm has sunk to the bottom, the greater part of the water is poured off and replaced by fresh. The washing is repeated until the parasite is quite clean. The larger segments are then drawn over the edge of the vessel by means of a rod until the thread-like neck and slightly enlarged head are reached. These are then detached and mounted on a slide, with a slight concavity, in Farrant's medium, glycerin, or glycerin jelly. As the worm often breaks at a distance of about 1½ in. from the head, the latter may need to be sought for separately, a process which is facilitated by filtering the wash waters and sediment through muslin, or better, black crêpe, which shows up the white filament terminating in the head more distinctly. The ripe segments may be mounted for microscopical examination in the same media, or be allowed to dry on a slide, when the characteristic features will become evident. If the head cannot be found, it is probable that a sufficiently large dose of the vermicide has not been given, or the preliminary treatment has not been effectual. In any case it is best to wait three months to see whether any fresh segments are expelled before repeating the treatment, as the worm will require eight to ten weeks to arrive at maturity.

Characters of the Eggs of the Cestodes Affecting Man.—It sometimes happens that a microscopical examination of the fæces will reveal the eggs of animal parasites when the host is quite unaware of their presence. It will therefore be advisable briefly to summarize the characters of the eggs of the cestoda that affect man.

The egg of *Bothriocephalus latus* is the most characteristic, and is usually the only one that can be recognized with certainty. It has already been pointed out that this parasite possesses a special aperture for laying its eggs, and that they are consequently found in large numbers in the fæces. The egg measures about 70 by 45 microns, is surrounded by a relatively thin shell of a light brown colour, and contains granular masses of protoplasm arranged in a mulberry-like form (*Fig.* 35). On careful examination, a lid, similar to that found in the eggs of the trematodes, is seen at one extremity. It becomes more evident on treatment with a few drops of a dilute solution of potash or soda.

The egg of *Tænia solium* is round in shape and about 30 microns in diameter (*Fig.* 35). It is surrounded by a thick membrane, showing fine concentric striations. In the interior of the granular contents six small hooklets, arranged in pairs, can be distinguished. The embryo and its hooklets can be made more evident by treatment with a few drops of a dilute solution of soda or potash.

The eggs of *Tænia saginata* (*Fig.* 35), can only be distinguished from the preceding by the fact that they are usually oval.

The eggs of *Tænia cucumerina* are globular, and measure 45 microns in diameter. Their transparent covering permits of the six-hooked embryo being readily seen.

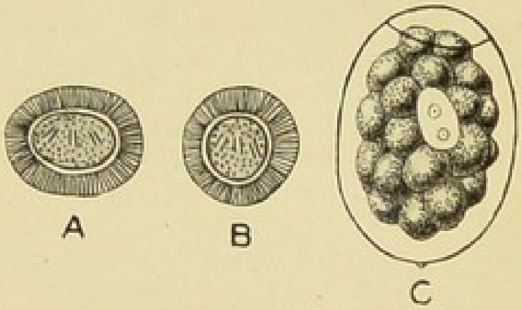


Fig. 35.—A, Tænia saginata—Egg (×400). B, Tænia solium—Egg (×400). C, Bothriocephalus latus—Egg (×400).

The eggs of *Tænia nana* are oval, and are from 30 to 50 microns long. They are covered by three transparent membranes, one within the other. The external and the internal membranes are hard. The middle membrane is soft and wrinkled. The internal membrane is lemon-shaped, but the embryo is usually spherical.

The egg of *Tænia diminuta* is slightly larger, measuring 60 to 90 microns in length. Its external membrane is yellowish, hard, and delicately striated. The embryo is elliptical.

The eggs of *Tænia madagascariensis* are about 40 microns long. They are covered by two transparent membranes, the external showing a pointed prolongation at each pole. The eggs adhere to each other by these prolongations and form opaque masses, similar to those seen in the egg-capsules of the interior of the ripe segments.

Anomalies of the Cestodes.—The cestodes frequently exhibit anomalies of structure and form (*Fig.* 36). *Tænia saginata* is particularly remarkable in this respect.

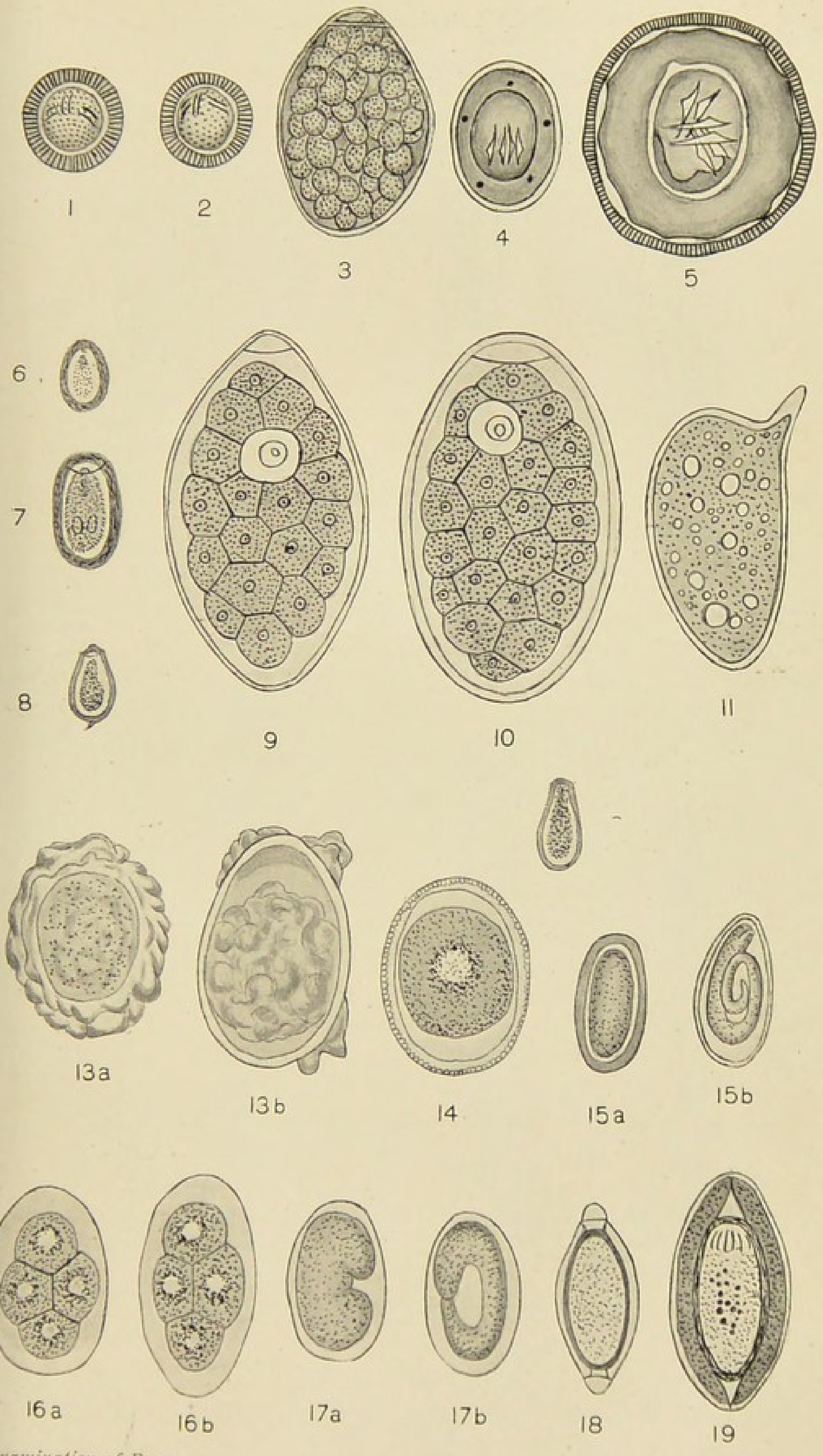
Through the ingestion of certain drugs, and particularly salts of iron, bismuth, and mercury, a *black or slate coloration* of certain cestodes may be produced (*Tænia nigra*). Similar changes in colour may also be brought about by bile pigments and hæmoglobin.

EXPLANATION OF PLATE VI.

Eggs of the commoner intestinal parasites under the same magnification (ca. 400).

1. Tænia saginata.
2. Tænia solium.
3. Bothriocephalus latus.
4. Tænia nana.
5. Tænia diminuta.
6. Distomum heterophyes.
7. Distomum lanceolatum.
8. Distomum sinense.
9. Distomum crassum.
10. Distomum hepaticum.
11. Distomum hæmatobium.
12. Distomum sibericum.
13. Ascaris lumbricoides: (*a*) with envelope, (*b*) envelope partly lost.
14. Ascaris mystax.
15. Oxyuris vermicularis: (*a*) undeveloped, (*b*) developing.
16. (*a*) Ankylostomum duodenale.
    (*b*) Uncinaria americana.
17. Strongyloides intestinalis (*a*), (*b*), different stages of development.
18. Trichocephalus dispar.
19. Giganthorhynchus gigas.

PLATE VI.



Examination of Fæces

P. J. Cammidge

shows the line of fusion by a ridge or crest, so that there are three free borders, and in section a V- or Y-shaped appearance is produced. *Tænia moniliforme* arises from the contraction of the muscles of the segments, which are almost entirely separated, and only connected by a median band consisting of the layers of cuticle. When segmentation partially fails to take place, it gives rise to the form known as *Tænia fusa*. If the anomaly only affects two or three segments, it gives the appearance of multiple genital pores in one large segment. Various intermediate stages are met with between complete fusion and separation of the segments. A partial segment interposed between two perfect ones is not an uncommon anomaly, and is apparently due to a transitory affection of the genital apparatus of the animal. A bifurcation of the chain arises from an analogous but more persistent trouble. *Tænia fenestra* is a tape-worm showing perforations of the segments at intervals. These openings may arise in two ways; the most common, where the space occupies the centre of the segment and reduces it to a mere sac, appears to be due to premature rupture of the uterus; in the rarer form the space is at the side, and is due to lateral rupture of the segment and an escape of its contents in that way.

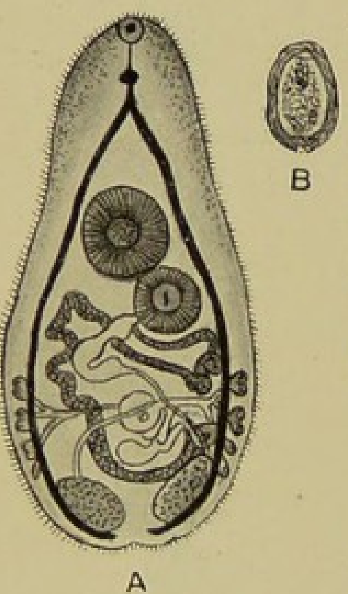


Fig. 37.—A, Distomum heterophyes (×40). B, Egg (×400).

2. Trematoda.

The trematodes living in the intestine are four in number: the Distomum heterophyes, the Distomum crassum, the Cladorchis watsonii, and the Amphistomum hominis.

Distomum heterophyes (Heterophyes heterophyes, Cotylagonymus heterophyes, Mesogonimus heterophyes) (*Fig.* 37). Although this organism has never been discovered in the fæces, it is not a rare intestinal parasite in some countries; Looss, of Alexandria, for instance, found it twice in nine autopsies. It is met with in large numbers in the small intestine, of which, however, it appears to be an inoffensive inhabitant. It is of a reddish colour and small size, measuring 3 mm. by 1·5 mm. The anterior part of the body is covered with small scales directed backward. The posterior sucker, which is considerably larger than the anterior, is situated toward the middle of the body. The position of the genital pore near the ventral sucker, and the presence of another sucker round it, are characteristics of the order and species. The eggs are reddish-brown in colour, and are enclosed in a hard shell provided with a lid at one end. They are about 26 microns long by 15 microns broad.

Distomum crassum (D. rhatonisii, D. buski, Fasciolopsis buski).—This is a parasite of much larger size, measuring 4 to 7 cm. long by 3 cm. wide (*Fig.* 38). The suckers are 3 mm. apart, the posterior being the larger. The integument is smooth. The folds of the uterus occupy the anterior part of the body, and the testicles and their ramifications the posterior. This fluke lives in the small intestine, and has been met with in India, China, and Borneo. It is found in colourless diarrhœic stools containing blood, but is not associated with a true dysentery. The eggs, provided with an operculum, are about 125 microns long by 75 microns broad. Infection probably occurs through certain fishes and oysters.

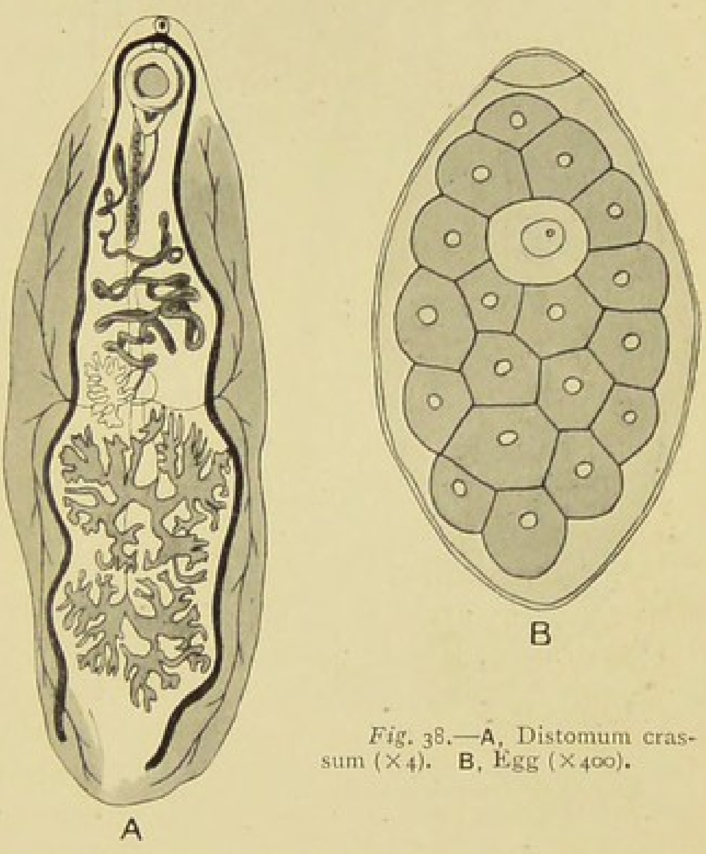


Fig. 38.—A, Distomum crassum (×4). B, Egg (×400).

Cladorchis watsonii (*Fig.* 39) is translucent and gelatinous, of a yellowish-red colour in the fresh state, and is from 8 to 10 mm. long and 4 to 5 mm. broad. The concave ventral surface is transversely folded. At the anterior extremity the mouth, which is not provided with a distinct sucker, opens into a well-marked pharyngeal bulb with two lateral pouches. The genital pore is situated just behind the pharyngeal bulb. The ventral sucker is large and quite at the posterior extremity. This parasite was found in the intestine of an African negro who died with a violent diarrhœa. The stools were watery and bilious, but contained no blood or mucus. Numerous flukes were present.

Amphistomum hominis (Gastrodiscus hominis).—This is a reddish parasite, about 8 mm. long by 4 mm. broad (*Fig.* 40). Posteriorly there is a large ventral sucker, which much exceeds in diameter the width of the body. On its posterior border there is a small accessory sucker. The anterior, narrower part of the body terminates in a buccal sucker and carries the genital pore, which opens on the middle of its ventral aspect. Up to the present it has only been found in the choleraic stools of persons in India and Assam. It is probably a normal parasite of the horse, etc., accidentally acclimatized in the digestive canal of man. The oval eggs possess a lid, and are about 150 microns long by 72 microns broad.

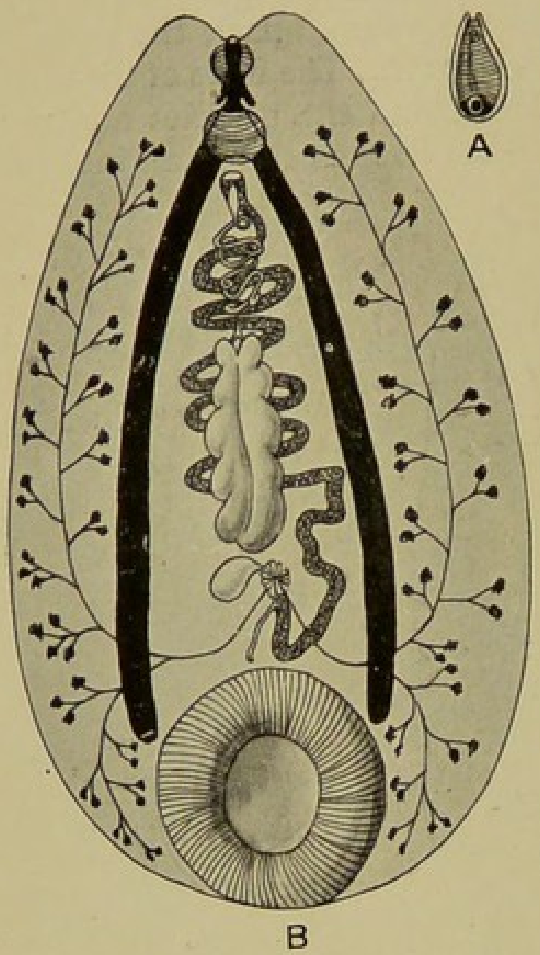


Fig. 39.—Cladorchis watsonii. A, Natural size. B, Magnified 8 times.

In addition to the flukes occurring in the alimentary tract, there are a certain number which live in the bile-passages. Published observations on these are not common, but it is probable that if greater attention were paid to the microscopical examination of the fæces in affections of the liver, the eggs of hepatic flukes that have entered the intestine by way of the bile-ducts would be found more frequently than has hitherto been the case. The administration of calomel would probably cause the expulsion of the worms, and assist in their recognition in the stools.

Distomum hepaticum (Fasciola hepatica), or the large fluke, is leaf-shaped, and 2 to 3 cm. long by 1 to 1·5 cm. broad (*Fig.* 41). The ventral surface of the body is covered by many small backwardly-directed spines. The two suckers are close together at the anterior end of the body, and between them opens the genital pore. This species is characterized by the extreme ramification of all its organs, and particularly of the digestive tube. The egg is brownish-yellow, and is readily recognized owing to its large size, 130 to 145 microns long by 70 to 90 microns broad. The yolk is generally segmented. At one extremity is an operculum, which is difficult to make out

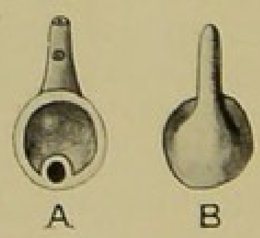


Fig. 40.—Amphistomum hominis (×2). A, Ventral aspect. B, Dorsal aspect.

until after the specimen has been treated with caustic soda. Distomum hepaticum is the parasite which gives rise to the condition in sheep known as "liver rot." In human beings it is a rare infection, taking place through a small snail, the Linnæus

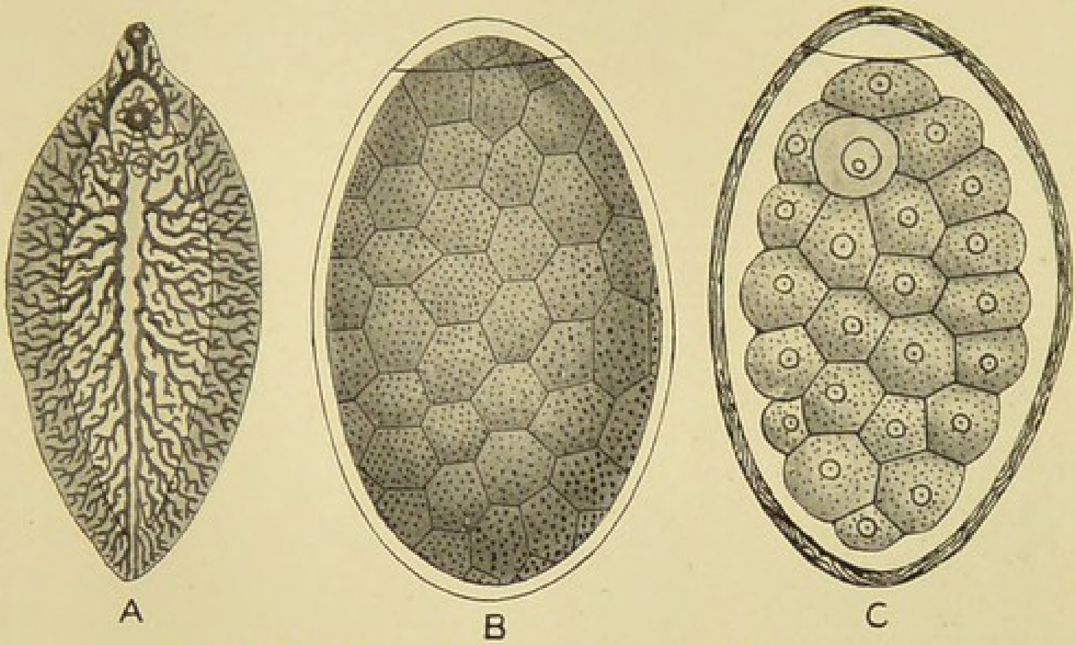


Fig. 41.—A, Distomum hepaticum (× 2). B, C, Eggs (× 400).

minutus, which is found on water-cress. The life history of the organism is complicated, and is summarized as follows by Shipley :—

Sexual adult (sheep)
|
Ciliated embryo (water and snail)
|
Sporocyst (snail)

Sporocyst (by division)	Redia (snail)
Redia (by gemmation)	Cercaria (encysted on grass, etc.)
	Sexual adult (sheep).

Distomum lanceolatum (Dicrocœlium lanceolatum), or the small fluke, is a lancet-shaped worm (*Fig.* 42), much smaller than the preceding. It measures at the most 4 to 9 mm. long by 1·5 to 2·5 mm. broad. In common with the flukes to be subsequently referred to, D. lanceolatum is semi-transparent, and has a bifurcated digestive tube which does not further branch ; the testicles occur as two small opaque white structures occupying corresponding positions on opposite sides of the body, and the uterus is seen as a large dark tube, owing to the eggs it contains. In this particular parasite the testicles form two elongated rounded streaks immediately posterior to the ventral sucker, and the uterus occupies the whole of the posterior part of the body. The eggs are ovoid, and are enclosed in a hard shell of a brownish tint. They are from 38 to 45 microns long and 22 to 30 microns broad. The operculum is generally larger, and more easily seen, than in the D. hepaticum. It can always be brought into evidence by treatment with caustic soda. The life history of the parasite is similar to that of the preceding, but its intermediate host is another aquatic snail, the Planorbis marginatus. The organism is common in ruminants, and has been found in man in a few cases.

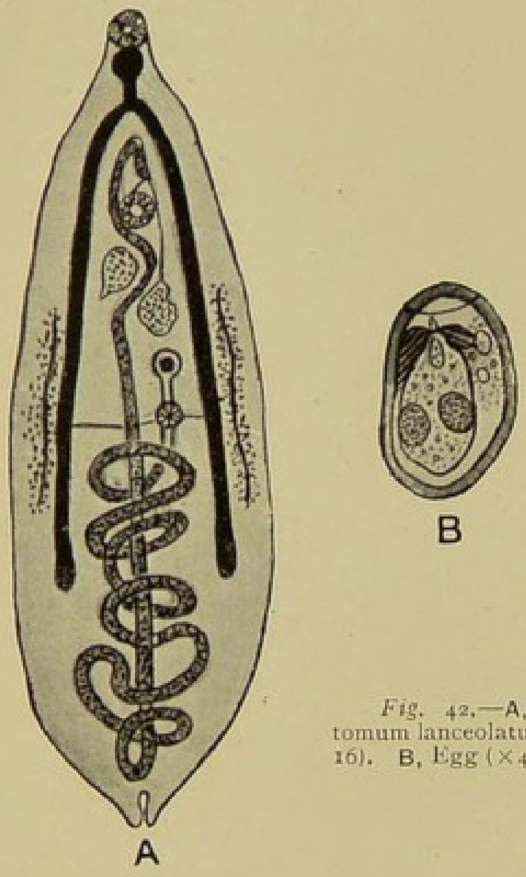


Fig. 42.—A, Distomum lanceolatum (× 16). B, Egg (× 400).

Distomum sibericum (D. felineum, Opisthorchis felineus). (*Fig.* 43).—This is a lanceolate worm, transparent, and reddish in colour. It is 7 to 18 mm. long and 2 to 2·5 mm. broad. The ventral sucker is only slightly larger than the anterior. The uterus is situated in the anterior end of the body, and the two lobulated testicles in the posterior end. It is a common parasite in the biliary apparatus of the cat. In 1891 Vinogradov found it in 7 per cent of the inhabitants of Tomsk. The egg is ovoid, 25 to 30 microns long by 10 to 15 microns broad. The situation of the lid is clearly indicated by a circular projection of the shell.

Opisthorchis noverca was discovered by Lewis and Cunningham in the liver of a dog, and in the liver of man by MacConnel. It is a small lancet-shaped fluke, 10 to 12 mm. long by 2·5 broad, and is covered with spines (*Fig.* 44). The buccal sucker is much larger than the ventral. The testicles are behind the uterus. The vitelline glands occupy the median lateral portions of the body. This species is often described under the name *Opisthorchis conjunctum*, a form discovered by Cobbold in an American fox in the London

Zoological Gardens; a comparison of the two forms shows, however, that they are quite distinct. The egg is provided with an operculum, and is 35 microns long by 20 microns broad.

Distomum sinense (D. spatulatum, D. endemicum, D. japonicum, Opisthorchis sinensis) (*Fig.* 45).—The normal habitat of this organism is the intestine of the cat, but it has also been met with in man, especially in India, Tonkin, China, and above all in Japan, where it is a veritable plague, over 20 per cent of the inhabitants of some districts being affected. It gives rise to very serious symptoms, the true cause of which can be recognized by the discovery of the eggs of the parasite in the fæces. It is a reddish transparent worm, 10 to 20 mm. long and 2 to 3 mm. broad. The buccal sucker is much larger than the ventral. The uterus always occupies the anterior end of the body and the testicles the posterior. The latter consist of branching tubules. The eggs are ovoid and are almost black. They are 28 to 39 microns long by 16 to 17 broad. Like those of D. sibericum they show a circular collar surmounted by a lid, but they also possess, at the opposite pole, a small pointed spine. In the interior an embryo, covered with cilia, can generally be seen.

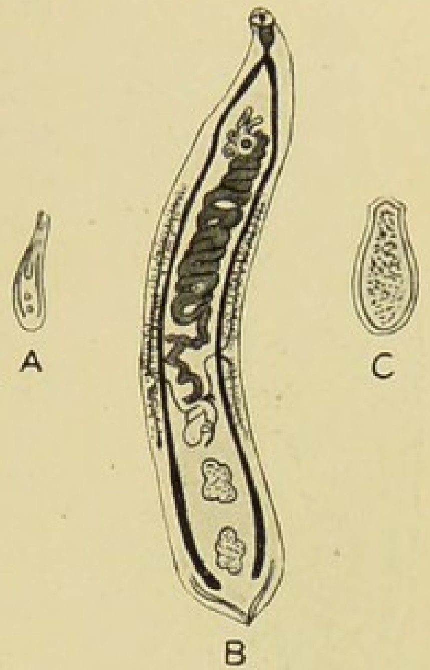


Fig. 43.—Distomum Sibericum. A, Natural size; B, × 8. C, Egg (× 400).

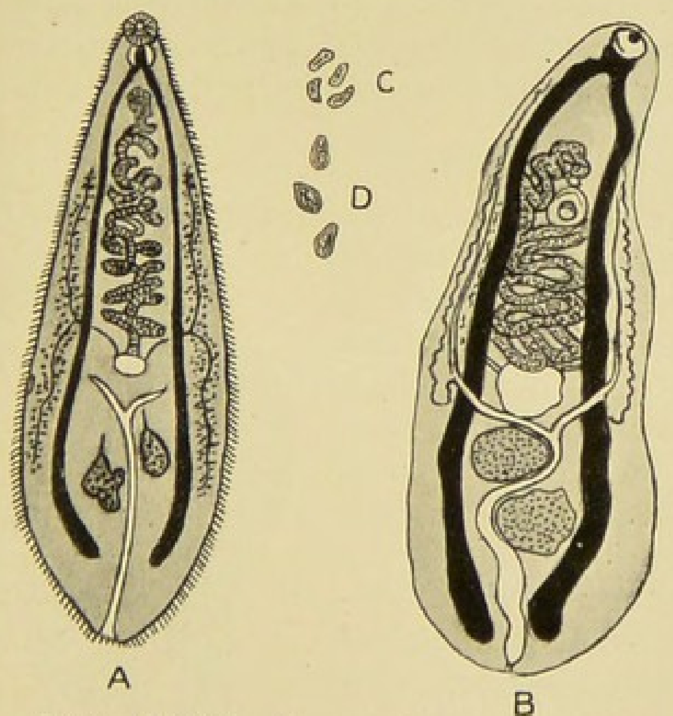


Fig. 44.—A, Opisthorchis noverca (× 6). B, O. conjunctum (× 12). C, O. conjunctum (nat. size). D, O. conjunctum—eggs.

Distomum hæmatobium (Bilharzia hæmatobia, Schistosomum hæmatobium, D. capense, Gynæcophorus, Thecosma) (*Fig.* 46). The eggs of this parasite live in the blood, but may pass through the walls of the vessels and intestine to be eliminated in the fæces. In this case villous polypi, often seen just within the anus, and simulating hæmorrhoids, may be produced. At the same time dysenteric symptoms, including colicky pains and the passage of blood mixed with the stools, which are often diarrhœic, occur. An examination of the fæces with the microscope will show a larger or smaller number of the characteristic eggs. These are oval in form, and unlike other trematode eggs, have no operculum. They are about 130 to 210 microns long by 45 to 60 microns broad. Their characteristic feature is the presence at one pole of a pointed spine, measuring at least 20 microns in length, by which the tissues are pierced, thus accounting for the presence of blood in the stools, etc. It must not be forgotten, however, that the spine is occasionally lateral, and that, according to some authors, this is always the case with the form eliminated by the intestine. The worm is particularly common in Africa, especially Egypt and the Transvaal, but is only rarely met with in Europe and America, and then only in imported cases.

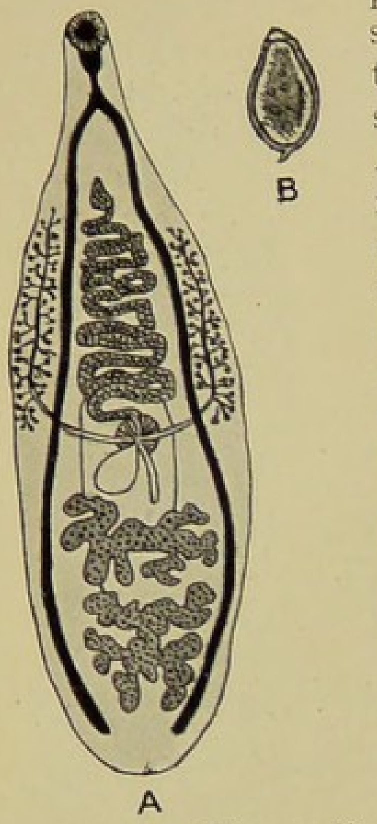


Fig. 45.—A, Distomum Sinense (× 5). B, Egg (× 400).

II. NEMATODA.

The nematoda are animals with an elongated, unsegmented body tapering at each end. A well-developed cuticle is secreted by the epidermis. A digestive system is present, and the excretory system exists in the form of lateral ducts, which open anteriorly by a median ventral pore. Many are endoparasites, and among these an alternation of hermaphrodite and bisexual generations may occur.

Ascaris lumbricoides.—The ordinary "round-worm" is one of the commonest intestinal parasites, especially in children (*Fig.* 47). It is said to occur in about 0·4 per cent of all cases. Its normal habitat is the small intestine. It is a light yellow or white worm, cylindrical in shape, and pointed at each extremity. The sexes are separate. The female is from 20 to 30 cm.

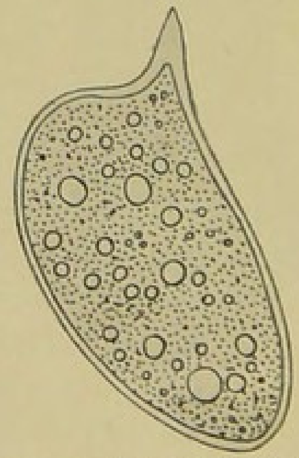


Fig. 46.—Egg of Distomum hæmatobium (× 400).

long and 5 mm. broad (*Fig.* 47, D). The male is about half that length (A), and 3 mm. thick. The male, which is less common than

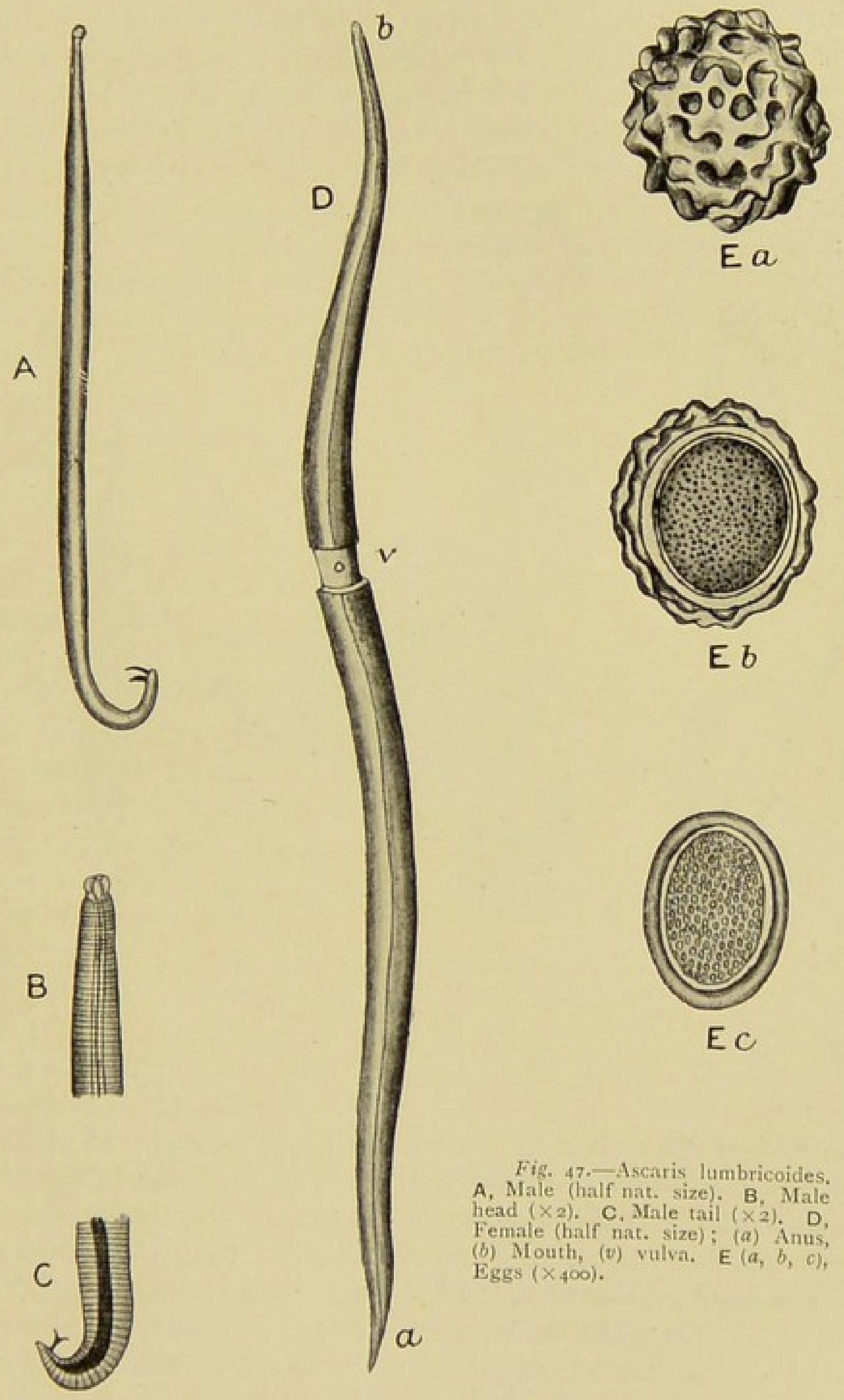


Fig. 47.—Ascaris lumbricoides. A, Male (half nat. size). B, Male head (×2). C, Male tail (×2). D, Female (half nat. size); (*a*) Anus, (*b*) Mouth, (*v*) vulva. E (*a*, *b*, *c*), Eggs (×400).

the female, can be distinguished by its curved hinder end and the presence of two bristles in the neighbourhood of the anus. The tail of the female is straight and conical. The head consists of three projections or lips, provided with suckers and fine teeth. The eggs are laid in enormous numbers, and are yellowish-brown in in colour, elliptical in shape, and 50 to 75 microns long by 40 to 60 microns broad (*Fig.* 47, E). The unsegmented protoplasmic contents are surrounded by a thick transparent shell, which in its turn is covered by a thick gelatinous uneven envelope that is usually bile-stained. The outer envelope is sometimes lost, and in that case the smooth-shelled egg may be mistaken for that of uncinaria. The embryos develop in water or damp earth, and are probably introduced into the human host by drinking contaminated water. Ascaris lumbricoides is found in all countries, and infests the pig and ox as well as human beings. Its presence in the alimentary tract is most readily diagnosed by the discovery of the characteristic eggs on microscopical examination of the fæces. As a rule the worms are expelled singly by the anus. Sometimes, however, they exist in large numbers, even giving rise to intestinal obstruction, and may then be passed rolled in a ball. When their presence is suspected, the administration of santonin is useful for both diagnostic and therapeutic purposes.

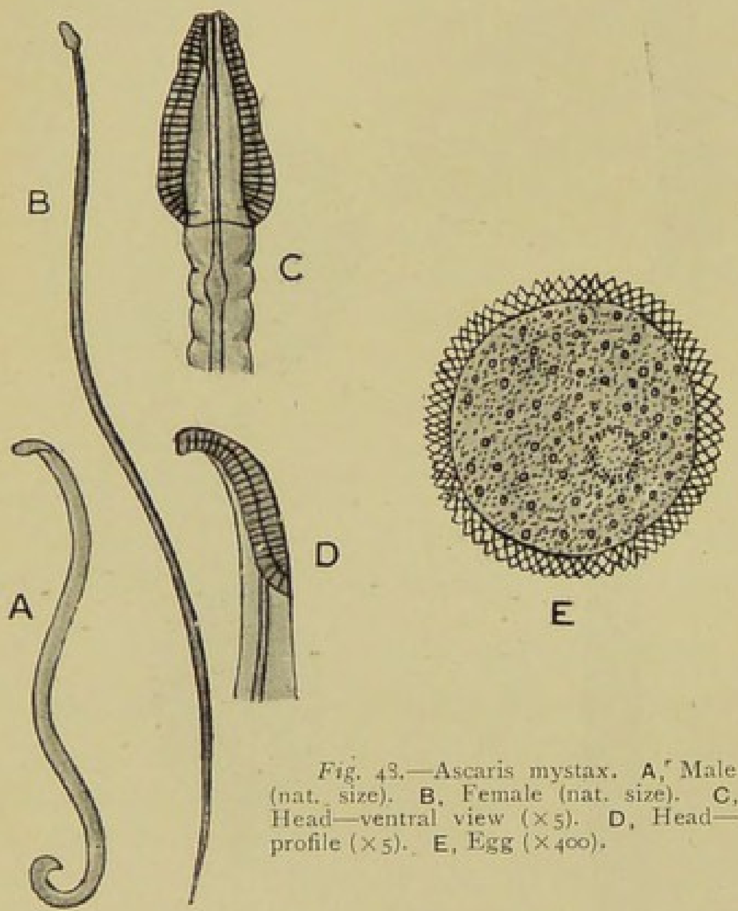


Fig. 48.—Ascaris mystax. A, Male (nat. size). B, Female (nat. size). C, Head—ventral view (×5). D, Head—profile (×5). E, Egg (×400).

Ascaris mystax (A. canis, A. marginata, A. alata).—This parasite is much shorter and thinner than A. lumbricoides, but is otherwise similar (*Fig.* 48). The male is 4 to 6 cm. long and about 1 mm. thick, the female about 2 mm. thick and about from 6 to 12 cm. long, although it may reach 18 to 20 cm. Besides the difference in size, A. mystax is distinguished from A. lumbricoides by the presence of a wing-like projection of the cuticle, about 2 to 4 mm. long, on either side of the pointed head, which give it a heart-shaped appearance (*Fig*. 48, C, D). The eggs are more or less spherical, and somewhat larger than those of A. lumbricoides, being 68 to 72 microns in diameter. The external albuminous envelope is covered with projections forming a network and giving to the egg the appearance of a poppy seed (E). Like that of A. lumbricoides, the outer coat of the egg is rapidly destroyed in water, so that a smooth-shelled egg is sometimes seen. The worm is very common in dogs and cats, but is rare in man.

Oxyuris vermicularis (Ascaris vermicularis, A. græcorum).—The "seat- or pin-worm" (*Fig*. 49), in contrast to the preceding, is very small. The male (B) never measures more than 3 to 5 mm. long, and the female (C) 9 to 12 mm. The cephalic extremity is provided with

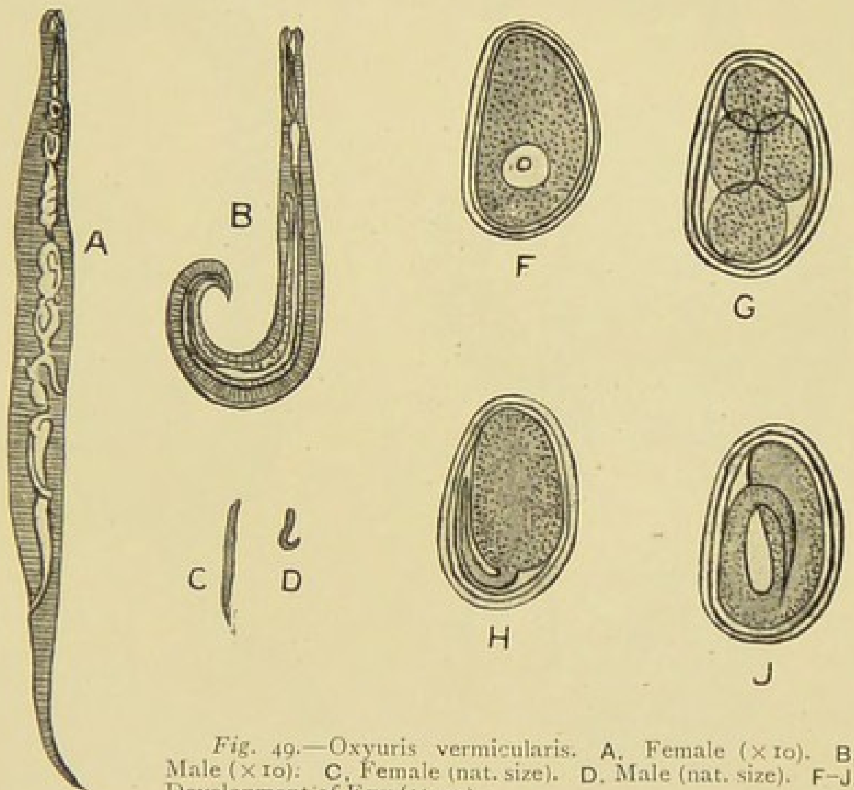


Fig. 49.—Oxyuris vermicularis. A, Female (× 10). B, Male (× 10). C, Female (nat. size). D, Male (nat. size). F–J, Development of Egg (× 400).

three lip-like projections, with lateral cuticular thickenings. The tail of the male is rolled on itself, while in the female it is straight, long, and pointed. The eggs (F–J) measure 50 to 55 microns by 20 to 25 microns, and exhibit a characteristic asymmetry. In profile the ventral surface is flattened and the dorsal markedly curved. When deposited they already contain a well-developed embryo; hence the parasite spreads with great rapidity. On being swallowed, the egg-shell is dissolved in the stomach, setting free the embryo, which passes into the intestine. It is rare to find the eggs in the stools, except in the mucus that surrounds the harder masses of fæces. They can, however, often be secured by scraping the surface epithelium from the margin of the anus, where the adult worms may also be found. Oxyuris is a common cause of pruritus ani, especially in children. It is generally stated that the worm lives in the large intestine, but its true habitat is the small bowel. The male dies shortly after copulation, and is expelled with the fæces, so that it is not often seen. The female, engorged with eggs, descends through the length of the large intestine to become attached to the folds of mucous membrane in the neighbourhood of the anus, where she lays her eggs.

Ankylostomum duodenale (Uncinaria duodenalis, Strongylus quadridentatus, Dochmius ankylostomum, Sclerastoma duodenale,

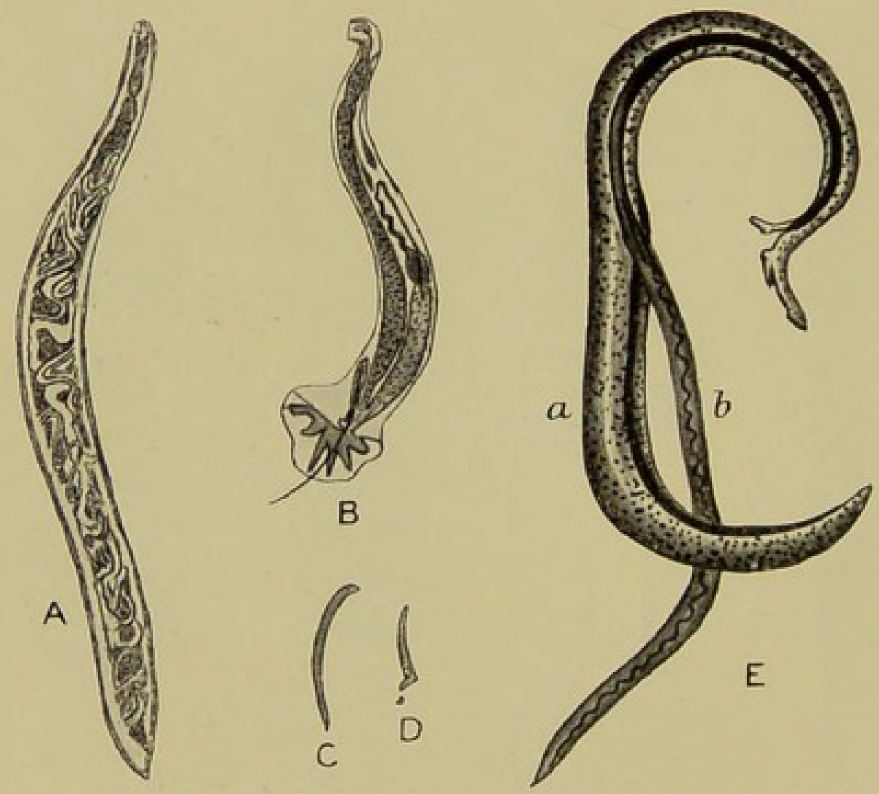


Fig. 50.—Ankylostomum duodenale. A, Female (×5). B, Male (×5). C, Female (nat. size). D, Male (nat. size). E, Copulating—(*a*) Male, (*b*) Female.

Strongylus duodenalis, Dochmius duodenalis) (*Figs.* 50, 51).—This organism belongs to the family strongyloides, and is one of the most dangerous parasites infesting man. It has been found in Italy, Germany, Switzerland, Belgium, Egypt, the West Indies, and elsewhere. It had not been met with in England until recent years, when a number of cases were found in miners working deep Cornish mines. Its presence gives rise to a severe, and often fatal, anæmia, which is particularly liable to affect miners, tunnel-makers, brick-makers, and others working in damp earth, since a certain degree of moisture and warmth is necessary for its development. It was first pointed out by Griesinger that the so-called Egyptian chlorosis is produced by this parasite. The female, about 7 to 18 mm. long (*Fig.* 50, A, C), has a cylindrical body, somewhat attenuated anteriorly, and ending in a pointed extremity posteriorly. To the naked eye it closely resembles the female of oxyuris. The male, on the contrary, can

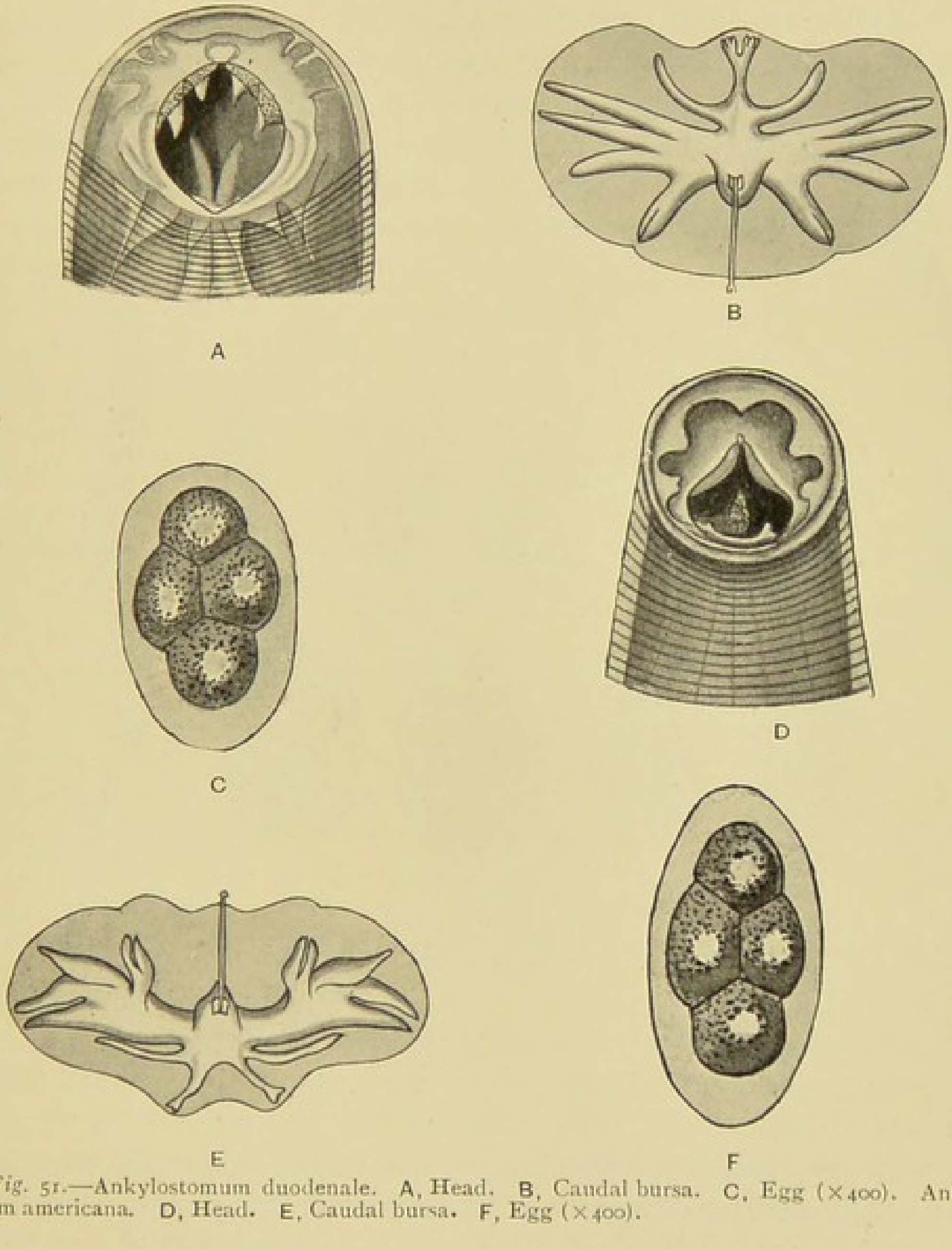


Fig. 51.—Ankylostomum duodenale. A, Head. B, Caudal bursa. C, Egg (×400). Ankylostomum americana. D, Head. E, Caudal bursa. F, Egg (×400).

be easily distinguished by the presence of a copulatory bursa (B, D), in which the microscope shows a characteristic distribution of the muscular bundles at the posterior end. The male is from 6 to 11 mm. in length, about half the size of the female. Examination of the head of the parasite with a $\frac{2}{3}$-in. objective shows that the chitinous buccal cavity is armed with two pairs of ventral teeth curved like a hook, and one pair of dorsal teeth directed forward (*Fig.* 51, A). The caudal bursa of the male is divided into a dorso-median lobe and prominent lateral lobes, joined by a ventral lobe. The walls of the bursa are traversed by eleven ribs or rays, the arrangement of which varies in different species of the worm. In the Old World variety, the dorsal or posterior ray is single and bifurcated at its extremity, each branch dividing into three digitations. The other rays are symmetrical. From each side of the dorsal ray arises the first lateral ray, which passes into the posterior part of the corresponding lateral lobe. The remaining portions of the lateral lobes are traversed by three lateral rays arising from a common trunk. Finally, a fifth lateral ray arises from the base of this same common

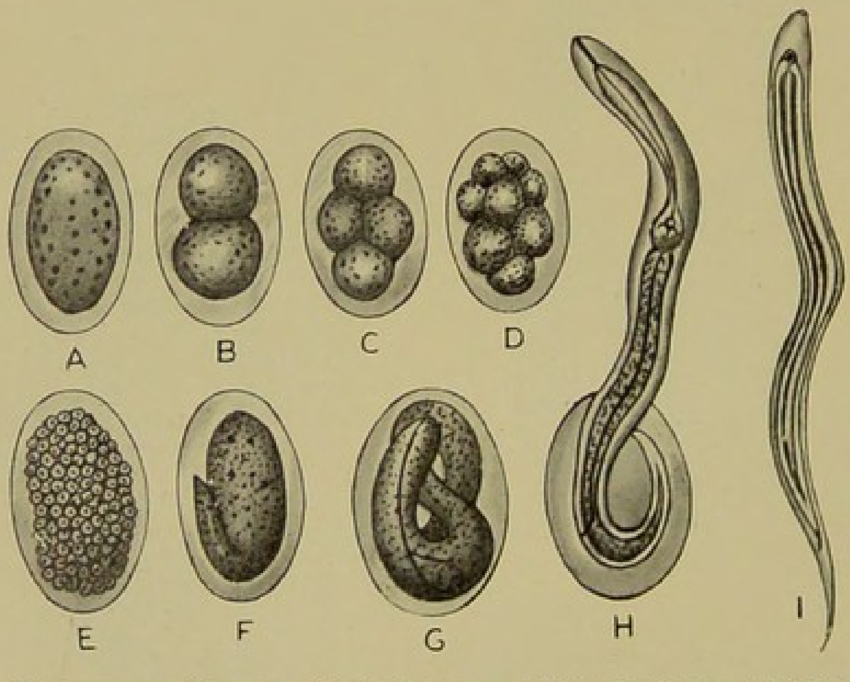


Fig. 52.—Development of the egg of ankylostoma. A-D, In the fæces. E-G, In culture. H, Rhabditiform larva leaving the egg. I, Strongyloid larva.

trunk, and terminates at the border of the slope that separates the lateral from the ventral lobe. The rays are prolongations of the longitudinal muscular bundles, and enable the animal to contract or enlarge the bursa for the purpose of copulation. By means of its bursa the male attaches itself to the female in the neighbourhood of the vulva, which is at, or near, the posterior third of the body. The two individuals then form a species of Y, of which one of the branches and the leg are represented by the female, and the other branch by the male. A union of this character usually lasts for several days. The eggs of the ankylostoma are ellipsoid (*Fig.* 52). At the moment of being laid the yolk is just beginning to segment, but in the fæces, as a rule, segmentation has proceeded to the formation of two, four, or eight cells. The egg is surrounded by a very thin shell, and measures from 50 to 60 microns long by 30 to 40 microns broad. After being evacuated in the fæces, the ova continue to develop, either there or in damp earth with which they come into contact. No intermediate host is needed, and the eggs or embryos are taken directly into the digestive tube of man.

Uncinaria americana (Necator americanus), the American hook-worm (*Fig.* 53), differs from the preceding in that its buccal capsule shows a dorsal pair of prominent semilunar plates or lips, and a ventral pair of slightly developed lips of a similar nature, but no hook-like teeth. The copulatory bursa of the male is also different. There is a short dorso-median lobe, which often appears as if divided into two, and prominent lateral lobes united by an indistinct ventral lobe. The common base of the dorsal and dorso-lateral rays is very short, and the dorsal ray is divided to its base, the two branches being markedly divergent and their tips bipartite. In the female, the vulva is in the anterior half of the body, but nearer to the equator than to the head. The eggs are like those of the preceding type, but slightly longer, measuring 64 to 72 microns by 36 to 40 microns. This species of worm has been met with in the United States, in Brazil, Porto-Rico, and Cuba, and also in the African chimpanzee, from which it possibly originated.

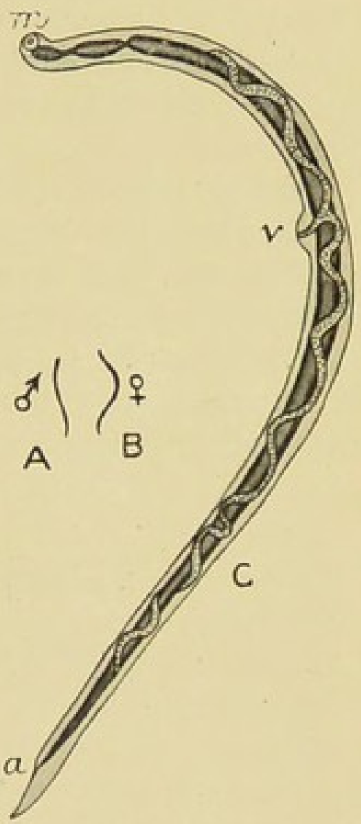


Fig. 53.—Uncinaria americana. A, Male (nat. size). B, Female (nat. size). C, Enlarged—(*a*) Anus, (*b*) Mouth, (*v*) Vulva. (*Stiles*).

The eggs of these worms may be sought for by simply mixing the fæces with a little water and examining on a slide under the microscope. It is better, however, to stir the suspected stool with a considerable excess of water and centrifugalize the mixture, or allow it to sediment, when the eggs, and possibly also the adult worm, will be found at the bottom. The ova may often be obtained from the mucus secured by introducing a catheter into the rectum. Hook-worms may be present in the intestine for a considerable time without any being found in the fæces. It is, therefore, often necessary to give some drug which will expel the parasite.

The most efficient is thymol, but as this has frequently a depressing effect on the heart, its action should be watched, and if signs of cardiac weakness appear, stimulants, such as strychnine or alcohol, must be administered. Before giving the vermifuge, the bowels should be thoroughly emptied, and no food should be taken, as described in connection with the removal of tape-worms. The thymol should be given in two doses of 30 grains each, one at 8 a.m. and the other at 10 a.m. Two hours later the patient should take a liberal dose of castor oil, or some saline purge. All the fæces passed subsequently must be preserved and examined by washing, sedimenting, and straining through gauze. The worms may be mounted in Farrant's or some similar medium, or be dehydrated, cleared, and mounted in Canada balsam. They are usually found in the stools eight to twelve hours after the administration of the thymol.

These parasites are frequently red in colour from the blood with which they are engorged. A simple test for the presence of ankylostoma has been suggested by Stiles, which depends upon the naked-eye recognition of the blood. A small quantity of the stool is wrapped up in white blotting-paper and allowed to stand for several hours; the occurrence of a reddish-brown stain on the white paper points to the presence of the parasite.

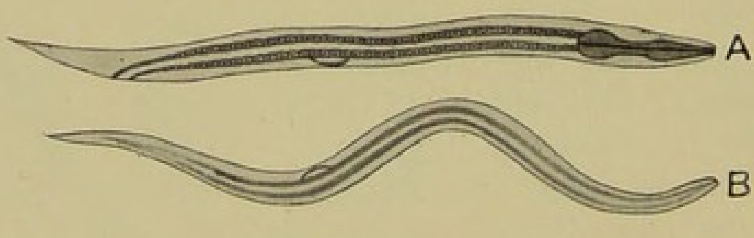


Fig. 54.—Strongyloides intestinalis. A, Rhabdite larva (×120). B, Filaric form (×120).

Strongyloides intestinalis (Anguillula stercoralis, A. intestinalis, Leptodera stercoralis, L. intestinalis, Rhabditis stercoralis, Rhabdomena strongyloides, etc.). This parasite has been described by different authors under various synonyms, a few of which are given. The adult female, first found by Normand in the intestine of a patient who died with severe diarrhœa in Cochin China, and described by Bavay under the name Anguillula intestinalis, resembles a filaria. It is about 2 mm. long by 34 microns broad. The body increases in size slightly and gradually, from the rounded head to the posterior quarter, where it terminates rather suddenly in a short tail with a rounded extremity. The uterus always contains a number of oval eggs arranged in a row and isolated from each other, so that it has a characteristic moniliform appearance. According to Askanazy, the impregnated female penetrates under the mucous membrane of the intestine, where she lays her eggs, but sometimes they appear to be laid in the intestinal contents. At any rate the resulting embryos gain the lumen of the gut, where they are found in large numbers. The eggs, which can only rarely be discovered in the fæces, closely resemble those of Ankylostoma duodenale, but are slightly larger, measuring 50 to 60 microns by 30 to 35 microns. The yolk is always much segmented, and usually contains a more or less developed embryo. These are described as rhabditiform, since the œsophagus shows two swellings united by a narrower portion, as in the genus rhabdita. If the fæces are kept at the ordinary temperature, the embryos undergo no further development, but become encysted; if, however, they are kept in the incubator at body temperature, the sexually mature larvæ, which have been described under the name Anguillula stercoralis, develop. These are actively motile. The posterior extremity tapers to a fine point, the œsophagus is rhabditiform, and the anus is at the base of the tail. The male is about 0·7 mm. long and 35 microns broad. Its tail is recurved and shows two spicules at its base. The female is about 3 mm. long and 50 microns broad. Its tail is straight and filiform. The eggs, enclosed in the uterus, occupy the greater part of the body. Each female gives rise to thirty or forty rhabditiform embryos analogous to those of the first generation. When, however, they attain a length of about 0·55 mm. they moult, and then resemble young strongyloides, being generally known as strongyloid larva. This second form is again characterized by the shape of the œsophagus, which is cylindrical, and occupies the greater part of the length of the body. On reaching the intestine of man, the larvæ continue their development and give rise to the Anguillula intestinalis. It is to be noted that this parasite is often associated with the ankylostoma, and probably intensifies the pathological changes induced by the latter. The worm is abundant in the duodenum and less common in the jejunum. Adult forms rarely occur in the stools, which usually contain the active rhabditiform larva, and rarely the eggs.

Trichina spiralis (Trichinella spiralis).—A diagnosis of trichinosis can sometimes be made from an examination of the fæces, the adult worms and embryos living for a certain length of time in the intestinal tract. When pork affected with trichinæ is ingested, the cysts are destroyed by the gastric juice and the embryo is set free in the stomach. It then passes into the intestine, where, in a couple of days, it reaches the adult stage. The adult trichina is a very minute worm, the male measuring 1·5 mm. long and the female 3 mm. (*Fig.* 55). The intestine of the parasite presents the peculiarity of being enclosed in a mass of cells, which probably function as a digestive gland. The female is viviparous. It possesses only one ovary and a single uterus. The vulva is situated in the anterior fifth of the body. The voluminous uterus usually contains a considerable number of embryos. The male possesses no spicules, but during copulation the cloaca is evaginated and plays the role of a copulatory organ. In addition there are two conical projections at the free extremity, which are turned toward the ventral surface, and assist in holding the female. Copulation takes place in the intestine. Subsequently the male dies, and is passed in the fæces, where it may be found. The female begins to liberate the embryos about the sixth day, and during the succeeding month it has been estimated that ten to fifteen thousand may be produced by one worm. During this period the embryos may frequently be found in the fæces. They are very small, measuring 90 to 100 microns long by about 6 microns broad. The anterior end is blunt, the posterior pointed. The expulsion of the adults and their embryos continues for six or eight weeks. The latter may often be seen as a moving mass in the middle of intestinal mucus passed with the stools. If all the worms and their embryos are got rid of in the stools, trichinosis is not a serious malady, but as a rule some of the active embryos penetrate the intestinal mucous membrane and, reaching the lymphatics and veins, are carried to the intermuscular connective tissue, where they become encysted. The presence of a trichina infection may give rise to intestinal and other symptoms which closely resemble those of enteric fever, so that the discovery of the parasite in the fæces is of great importance.

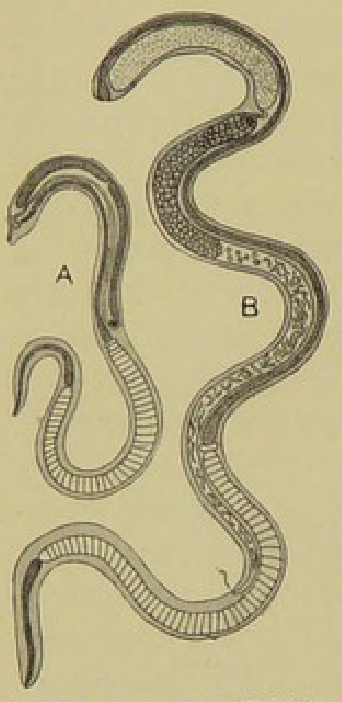


Fig. 55.—Adult Trichina
A, Male. B, Female.

Trichocephalus dispar (T. hominis, T. trichuris, T. mastigodes).—The whip-worm, as its name implies, is characterized by the head end being very thin and hair-like, while the posterior third is relatively thick (*Fig.* 56). In the male, which measures 3·5 to 4·5 cm., the tail is rolled on itself. The terminal cloaca is surrounded by a funnel-shape membrane, enclosing a single spicule. The female, which measures 3·5 to 5 cm., is differentiated by the posterior extremity being simple and pointed. The anterior thin portion is occupied by a mass of glandular cells which surround the intestine. The eggs (D) are highly characteristic. They are lemon-shaped, and measure 50 by 25 microns. The shell is very thick and hard, and of a yellowish-brown or brown colour. At each pole it shows a bright clear plug or ridge, which is of a lighter colour or quite colourless. The egg is laid without having undergone any segmentation, and is found in this condition in the fæces. The parasite usually inhabits the cæcum, but may also be found in the colon, and occasionally in the small intestine. The living worm is rarely met with in the fæces, since it is firmly fixed to the wall of the intestine by its filiform extremity, which extends more or less

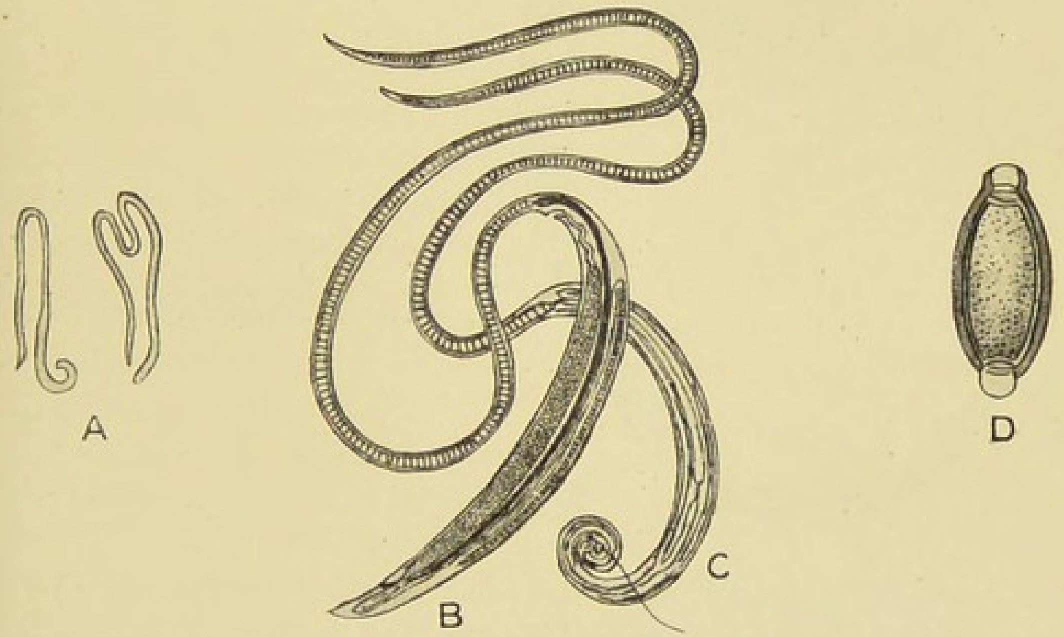


Fig. 56.—Tricocephalus dispar. A, Natural size. B, Female (×4). C, Male (×4). D, Egg (×400)

deeply under the mucosa. It is said to be the most widely distributed of all intestinal parasites, occurring in Europe, America, Asia, Africa, and Australia. Recent investigations have shown that Trichocephalus dispar is often the cause of more serious pathological changes than had previously been supposed, and that it may cause enteritis, diarrhœa, anæmia, etc.

III. ACANTHOCEPHALA.

The acanthocephala are vermiform internal parasites related to the nematoda, but distinguished by the presence of a large anterior proboscis, which is armed with recurved hooks and is retractile. They are without mouth or alimentary canal. The sexes are distinct, and the female is generally much larger than the male. They are met with in the intestines of fishes, birds, and some mammals, but are rare in the human species. Their eggs are, however, occasionally found in the fæces.

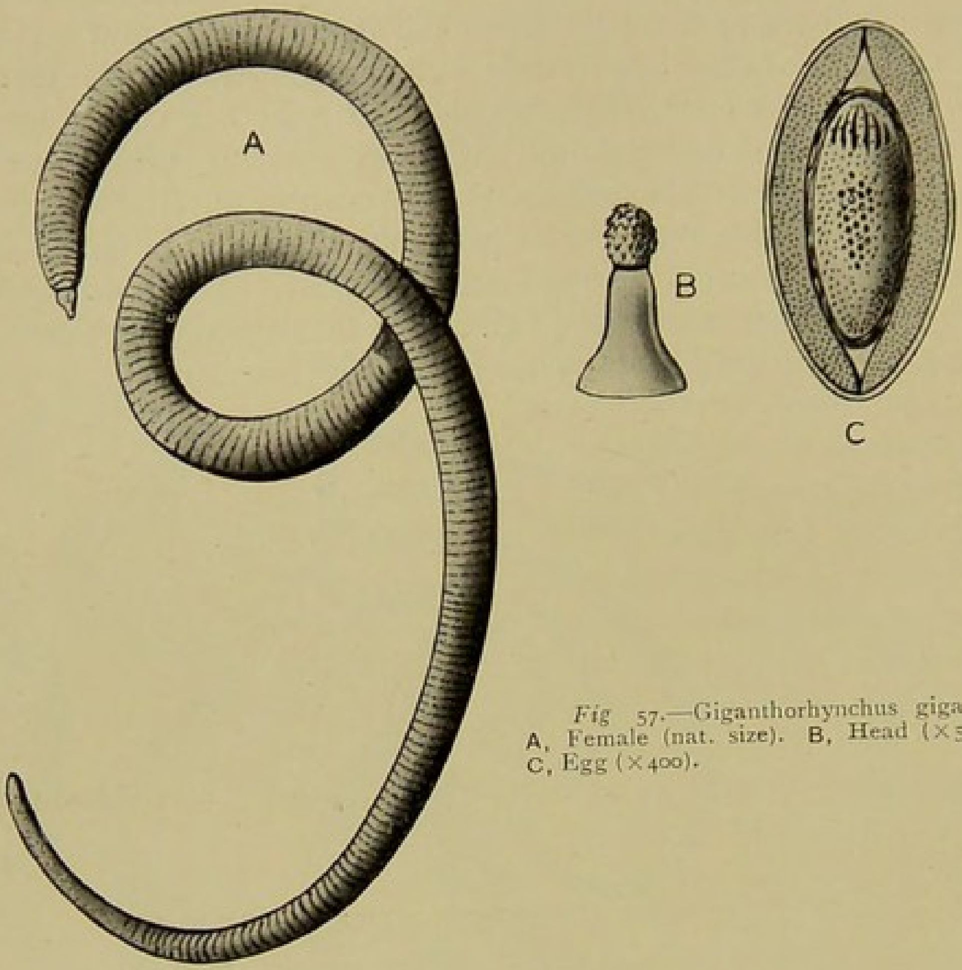


Fig 57.—Giganthorhynchus gigas. A, Female (nat. size). B, Head (×5). C, Egg (×400).

Giganthorhynchus gigas.—This is a common parasite in the pig and wild boar, and has been met with in man in the neighbourhood of the Volga (*Fig.* 57). The male is 6 to 10 cm. long by 3 to 5 mm. broad. The female is about twice the size, 20 to 35 cm. long. The proboscis is globular and is furnished with five or six rows of recurved teeth. The eggs (*Fig.* 57, C) are oblong and 87 to 100 microns in length. They possess three envelopes, of which the middle is the thickest. The embryo shows four hooklets and a number of small spines.

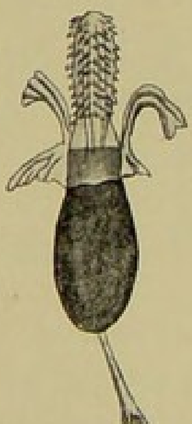


Fig. 58.—Head of Giganthorhynchus moniliformis (×20).

Giganthorhynchus moniliformis is smaller than the preceding, the male being 4 to 4·5 cm. long and the female 7 to 8 cm. The proboscis is at least twice as long as broad, and possesses about fifteen rows of hooks (*Fig.* 58). The egg is ellipsoidal, about 85 by 45 microns. The external envelope is thin and yellow, the middle thick, homogeneous, and colourless, and the external somewhat thinner. The embryo is covered with spines, which increase in size as the head is reached, where they are replaced by hooks.

IV. GORDIACEA.

The Gordians are hair-like worms which live in the interior of various insects. They may be accidentally introduced with drinking-water into the stomach of man, whence, after a more or less lengthy stay, they may pass into the intestine and be evacuated with the fæces. They are ordinarily of a brownish or slatey colour, and may sometimes (e.g. Gordius aquaticus) attain a length of two or three feet when fully mature (*Fig.* 59). Some half-dozen cases are on record in which this animal has been passed in the stools, after giving rise to colic and other intestinal disturbances.

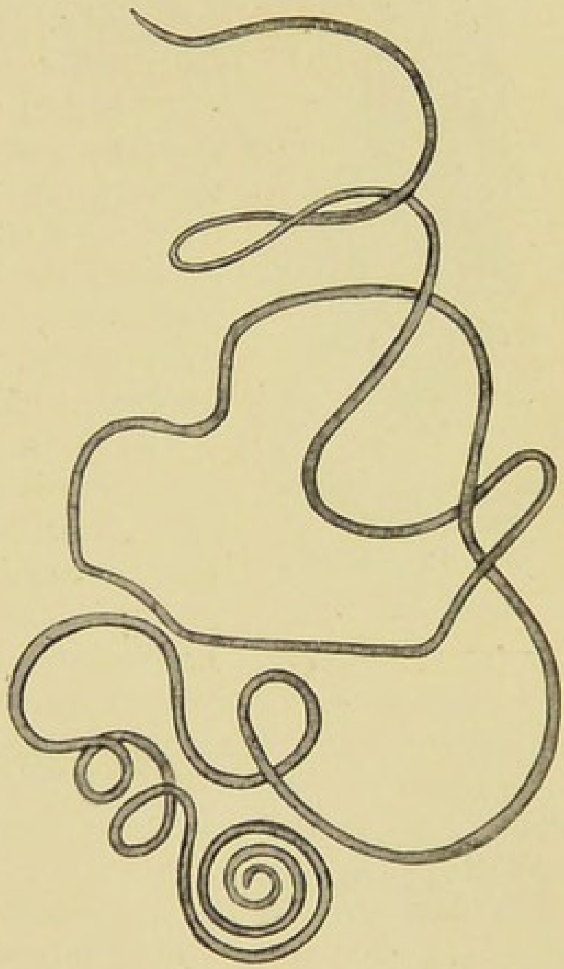


Fig. 59.—Gordius aquaticus—female (natural size).

V. ARTHROPODA.

Representatives of several families of this group of animals, which includes the Myriapoda (centipedes and millipedes), the Hexapoda or Insecta, and the Arachnida (spiders, scorpions, mites, and ticks), are occasionally met with in the fæces.

1. **Myriapoda.**—Millipedes, and similar animals, sometimes gain entrance to the stomach with fruit and vegetables, and, as their chitinous covering protects them from the action of the gastric juice, they can live there for some time. They are most commonly got rid of by vomiting, but may occasionally pass into the intestine and be voided with the fæces. Their presence usually gives rise to colicky pains, which cease abruptly when they have passed.

2. **Hexapoda** (*Insecta*)—*Diptera.*—It was at one time taught that the larvæ of various flies that occur in the fæces are always derived from the vessel into which the stool has been passed, or

originate from subsequent inoculation, but it is now certain that this is not by any means always the case, and that they are capable of traversing the alimentary tract unaffected by the digestive juices and appearing in a living condition in the fæces. The larvæ of the diptera vary in form according to the species. They are usually elongated and cylindrical, and are made up of a series of segments, carrying one or more bristles, which are directed backward, and by which the creature progresses. The mouth is armed with two to four, more or less powerful, buccal hooks. They live in cracks in the earth, in water and meat, etc., and may consequently be attached to vegetable or animal tissues, with which they are introduced into the digestive system. A complete list of the larvæ that have been met with in the fæces would be more lengthy than useful, and only a few of the more important will be mentioned.

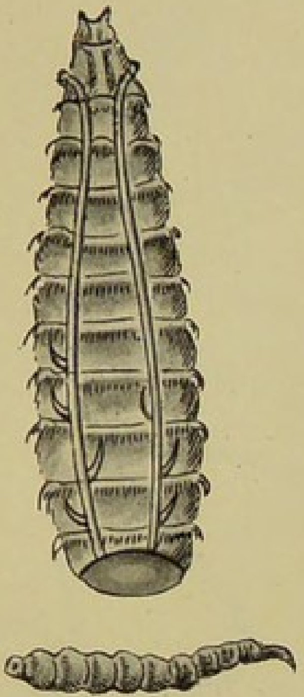


Fig. 60.—Larva of Musca vomitoria (blue-bottle fly) as found in fæces.

The larva of *Musca domestica*, the common house-fly, is rarely seen, as it lives in dung, and so is not readily introduced into the human body. More common are the larvæ of *Calliphora vomitoria*, the blow-fly (*Fig.* 60), *Lucilia cæsar*, the dory fly, and *Sarcophaga carnaria*, a small grey-black fly, which all live in meat and are sometimes accidentally consumed in consequence. The most common are the larvæ of the Anthomyia, Teichomyza fusca, and Piophila casei. The *Anthomyia* larvæ (*Fig.* 61) are distinguished from those of other flies by their size and flatness, and by the presence of long lateral barbed spines, which increase in length toward the posterior end of the body. The most frequently met with are the larvæ of *Anthomyia canicularis*, *A. scalaris*, and *A. incisurata*. They are generally taken into the body with radishes and salads, and occasionally give rise to a species of dysentery. The *Teichomyza fusca* is a small elongated black fly frequently seen in the neighbourhood of urinals and privies (*Fig.* 62). The larvæ, which live in fæces and urine, are small, elongated, and transparent, and have a bifurcated posterior extremity. Their presence in the intestine gives rise to

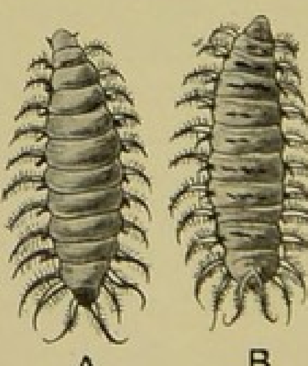


Fig. 61.—Larva of Anthomyia (×3). A, Ventral view. B, Dorsal view.

violent colic, and is often attended by dysenteric symptoms. Enormous quantities are occasionally passed at one time. Infection with this parasite is especially frequent in the summer months. The larva of *Piophyla casei*, or the cheese maggot (*Fig.* 63), possesses the power of projecting itself for a considerable distance by curving and straightening its body, so that it can easily leave its birthplace and attach itself to the skin by the two large and sharp mandibular hooks with which it is provided. The punctures produced in this way are said, in some cases, to have given rise to abscesses, and even to tetanus. Its entrance into the intestine may also give rise

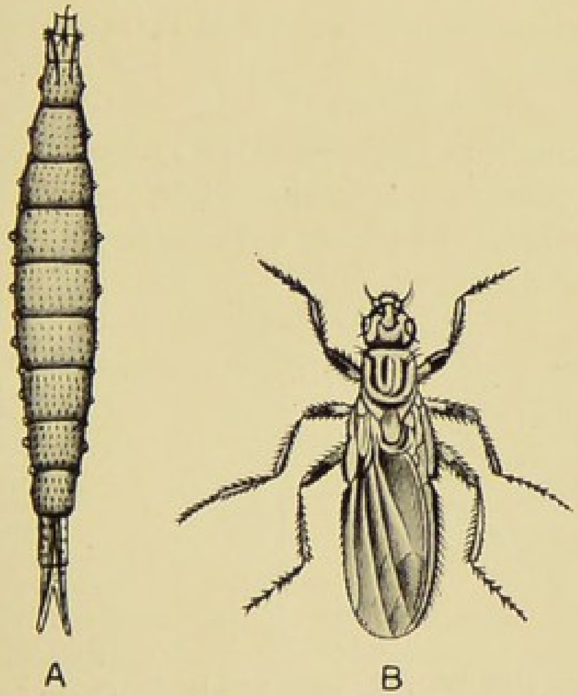


Fig. 62.—A, Larva of Teichomyza fusca (×5). B, Teichomyza fusca (×5).

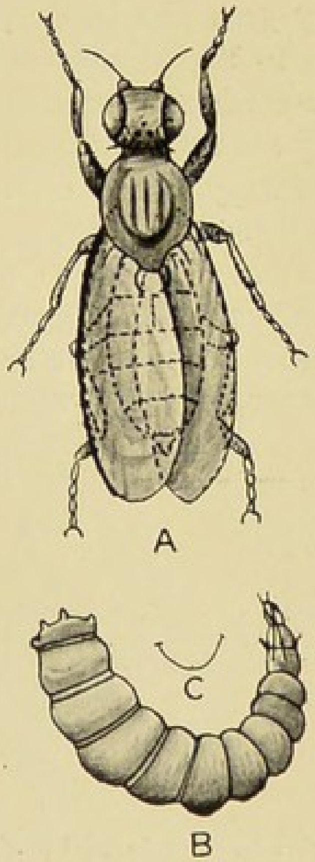


Fig. 63.—Piophyla casei. —A, Adult fly (×10). B, Larva Larva (magnified). C, (nat. size).

to grave troubles, resembling in some instances the symptoms of typhoid fever. It would seem that these effects are due to the abrasions of the mucous membrane produced by the mandibular hooks of the larva, the wound being either infected by bacteria carried by the parasite, or inoculated from the organisms present in the intestinal contents ; in either case a pyretic condition results, and, as this may be associated with a discharge of blood from the punctures, the resemblance to typhoid fever is often very close.

3. **Arachnida—Acarina.**—The acarina, or mites, are sometimes introduced accidentally into the intestine, and may be found in the fæces. The most frequently met with are *Tyroglyphus siro* and *Aleurobius farinæ.* The cheese mites which frequent particularly Parmesan, Chester, Gruyère, and Dutch cheeses, are found in enormous numbers, particularly under the crust, where they form innumerable tunnels filled with the mites, their eggs, and fæcal material. Similar mites are found under the envelopes of sausages. Other forms of acarus, such as the *Carpoglyphus passularum*, are met with in badly-corked sweet wines, dried figs, prunes, and other preserved fruits. In the stomach these parasites may give rise to dyspeptic symptoms, which are, however, largely due to the ammoniacal and other products of fermentation in the nidus where they have grown. On arriving in the intestine they may set up a catarrh, and cause what is sometimes termed "acarus dysentery." In such cases the mites may be found in the stools.

PSEUDO-PARASITES.

It has already been pointed out that some patients, and especially those who are hysterical, may introduce into the stools, for various reasons, a large variety of substances which outwardly resemble

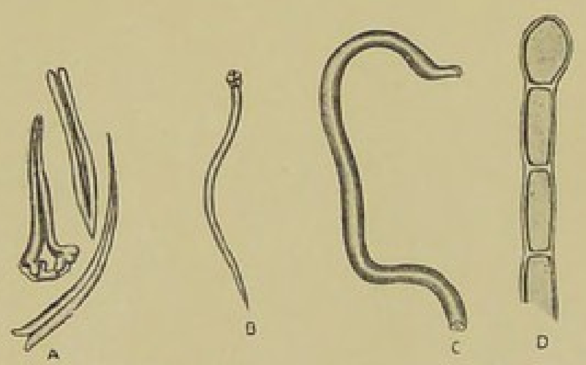


Fig. 64.—Pseudo-parasites. A, Epidermal plant hairs. B, Down from raspberry. C, Down from quince. D, Leaf hair.

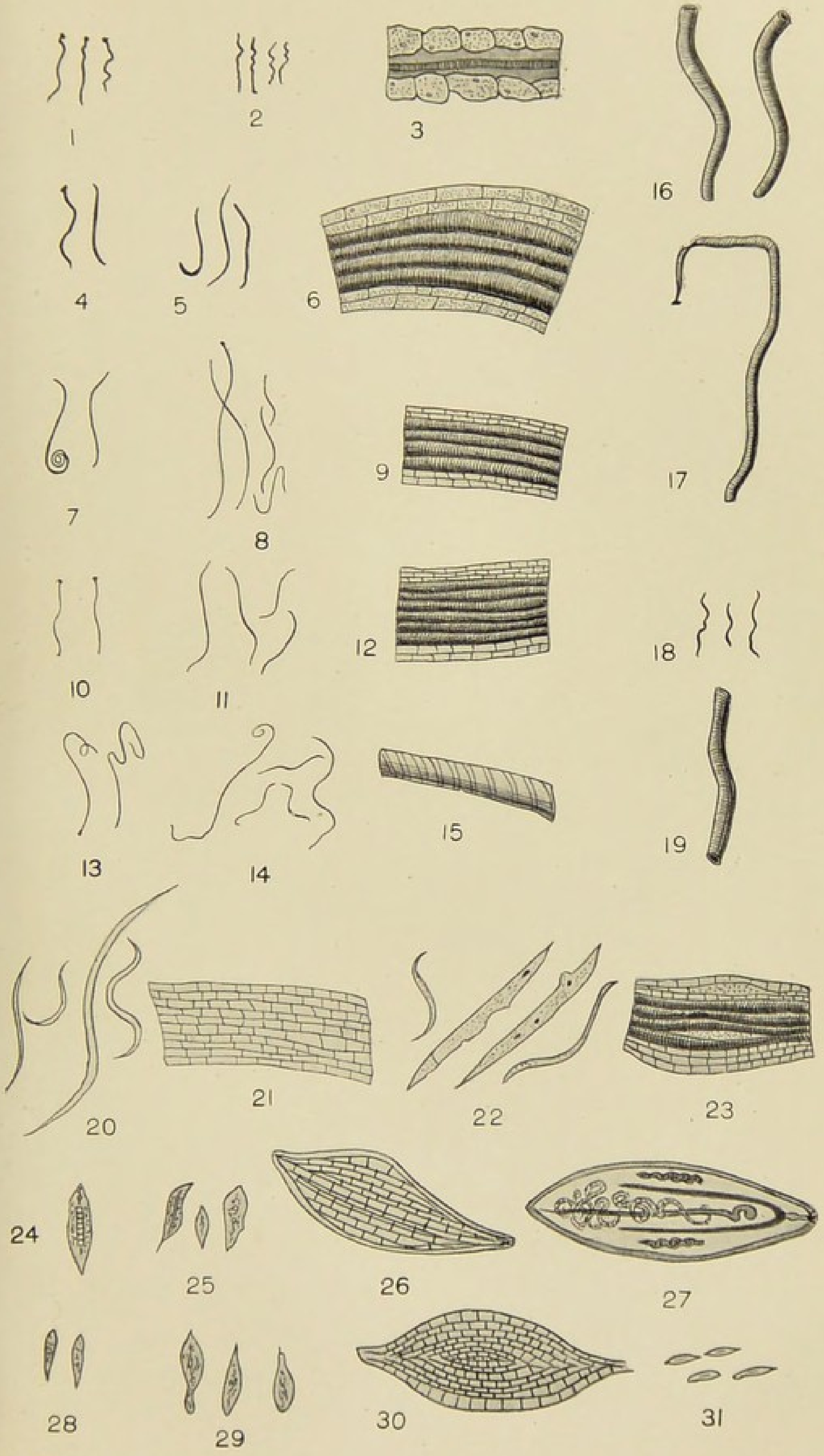
parasites and may be of a very bizarre character. Mere naked-eye inspection will in many cases reveal the true nature of these; in others a microscopical examination may be necessary.

There are, however, other substances, usually derived from the food, met with in the fæces, which are very deceptive at first sight, and which often need a microscopical examination to prove their true nature. Even experienced physicians have been deceived in some instances, and described them as new intestinal parasites. Thus Stibel described and figured a piece of the wood from a bunch of grapes under the name *Diacanthos polycephalus*. The larynx of a swallow found in the fæces by Bastiani, was considered by him to be an intestinal worm and was called *Sagitula hominis*. Scopoli thought that the trachea of a bird was a new entozoon, and baptized it *Physis intestinalis*. Bavay has shown that the radula of gasteropoda may be passed intact in the fæces and simulate small myriapoda. The pseudo-parasite most frequently encountered in the fæces is probably the pulp of the *orange*, which appears as large oblong vesicles, with pointed extremities, overlapping each other and forming a sort of parenchyma. When present in the stools they bear some resemblance to certain trematodes, for which they have not infrequently been mistaken. A similar difficulty may arise with *lemons*. An examination with a $\frac{1}{6}$-in. objective will reveal their true structure, however, and show that unlike Opisthorcis noverca, Distomum hepaticum, Distomum sinensis, and similar worms, they are devoid of mouth, oral suckers, and intestine, and have a double cell wall with the cell structures inside. The fibres of *bananas* have been mistaken for small tape-worms, and particularly Tænia nana and T. diminuta. Microscopically, the fibres are seen to be composed of bands, or rows, of oblong cells, with a well-defined outline and granular contents, in which are occasional spaces due to retraction of the protoplasm; between are the fibro-vascular bundles, etc. Even when magnified, the oblong cells bear some resemblance in shape and arrangement to the segments of a tape-worm. The long fibro-vascular bundles of *celery* may be passed in the fæces as yellowish-white threads which bear a great resemblance to Ascaris mystax, Oxyuris vermicularis, Ankylostomum duodenale, Trichocephalus trichiurus, and Diphylidium caninum macroscopically. Single fibres under the microscope may resemble somewhat Tænia nana, T. diminuta, or segments of other tape-worms. Careful examination under a higher power of the microscope will show the presence of the characteristic spiral and scalariform vessels, etc., and prove their vegetable origin. The stalk of *rhubarb* is similar to that of celery, and the passage of fibro-vascular bundles from this source may give rise to the same difficulties of diagnosis. Pieces of *onion*, consisting of whitish fibres slightly stained by fæcal pigments, passed in the stools, may be mistaken for undeveloped Ascaris lumbricoides if large, or if small, for Ankylostomum duodenale or Ascaris mystax. The discovery of parallel fibro-vascular bundles with the microscope will lead, however, to a correct conclusion. The fibres and vessels of other vegetables of similar structure may in the same way cause passing difficulties. The thick white covering of the seeds of *dates* may undergo only

EXPLANATION OF PLATE VII.

Comparison of the commoner pseudo-parasites and the parasites for which they may be mistaken.

1. Tænia nana.
2. Débris from banana
3. Ditto magnified.
4. Oxyuris vermicularis.
5. Débris from rhubarb.
6. Ditto magnified.
7. Ascaris mystax.
8. Débris from celery.
9. Ditto magnified.
10. Ankylostomum duodenale.
11. Débris from pineapple.
12. Ditto magnified.
13. Trichocephalus dispar.
14. Cotton thread.
15. Ditto magnified.
16. Banana débris magnified.
17. Tænia nana magnified.
18. Débris from date.
19. Ditto magnified.
20. Débris from onion.
21. Ditto magnified.
22. Débris from cabbage.
23. Ditto magnified.
24. Distomum sinense.
25. Débris from orange.
26. Ditto magnified.
27. Tænia lanceolatum.
28. Distomum conjugatum.
29. Débris from lemon.
30. Ditto magnified.
31. Débris from oatmeal.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partial digestion in the intestine, and, being passed with the fæces, suggest segments of tape-worms; but the presence of fibro-vascular bundles microscopically will again give the correct diagnosis. The consumption of large quantities of *oatmeal* is sometimes followed by the presence in the fæces of small white particles, of a soft consistency, which closely resemble the segments of a tape-worm. They really consist of the shell of the oat, and their vegetable nature may be proved by the arrangement of the cells and the fact that they give the chemical reactions for cellulose. The *down* and *hairs* from fruit and vegetables may at first sight suggest small entozoa, but careful microscopical examination will speedily reveal their true nature.

Women and tailors often swallow portions of *thread*, and pass them in the fæces. These may be mistaken for small round-worms, such as Oxyuris vermicularis, Ascaris mystax, Dipylidum caninum, Trichocephalus, Trichiuris, or Ankylostomum duodenale.

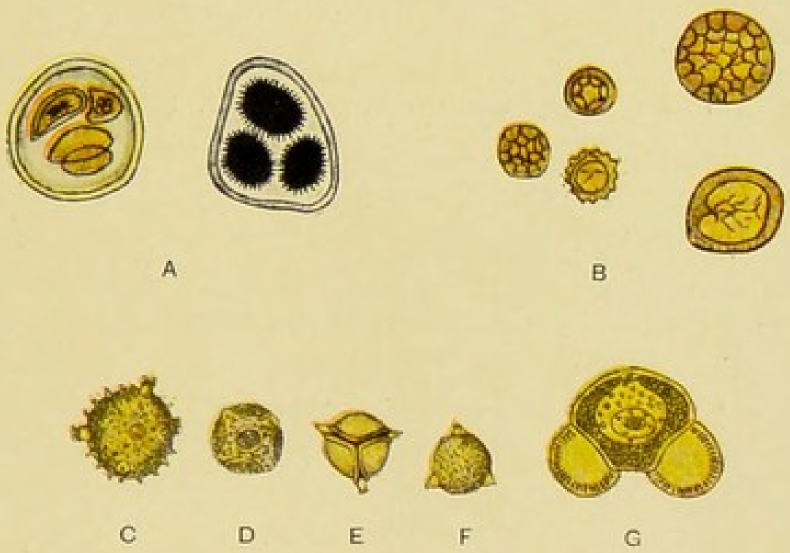

Fig. 65.—Vegetable cells resembling eggs of intestinal parasites. A, Spores of truffle. B, Spores of mushroom. C–F, Pollen grains of flowers. G, Pollen grain of conifer.

Various vegetable cells bear a superficial resemblance to the eggs of some intestinal parasites. They can be readily distinguished, however, by a careful examination with a sufficiently high power of the microscope. The spores of *truffles*, which occasionally appear in the fæces in considerable numbers, may be mistaken for the ova of Ascaris owing to their size—66 by 42 microns—and rough surface. *Mushroom* spores have also a somewhat similar appearance. The *pollen grains* of plants have given rise to difficulties in some instances in spite of their very characteristic appearance microscopically. In this connection it should be remembered that the pollen of conifers is not infrequently met with in the stools of persons living in the neighbourhood of plantations of pine trees, etc.

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Chapter V.

BACTERIOLOGICAL EXAMINATION.

THE bacteriology of the intestinal contents is a subject that has attracted the attention of numerous observers; but, although a large amount of work has been done, exact knowledge is as yet very scanty, and a bacteriological examination of the fæces is not at present as useful clinically as might be expected. This is chiefly due to the enormous number and large variety of the micro-organisms which appear in the stools. Even in health it has been calculated that some one hundred and twenty-six billion bacteria are passed daily in the excreta of an average man, and various methods of examination show that these consist of many different species and varieties. From a bacteriological point of view the alimentary canal may be regarded as a most perfect incubator, in which the range of reaction and diversity of foodstuffs is so great that practically all micro-organisms capable of developing at the body temperature can find some situation suitable for their growth, so that their number and variety is not surprising. Since it is impossible to avoid the entrance of bacteria into the intestinal tract, we might expect even a greater variety than is normally found, but this appears to be prevented by the activities of the obligate bacteria, such as B. coli, B. lactis aerogenes, B. bifidus, etc., which, having adapted themselves to the conditions existing in this part of the body, are ordinarily able to hold their own against "wild" varieties, and thus discourage the growth of many harmless and harmful species which cannot be readily excluded from the digestive tract. What happens when wild varieties come in contact with the obligate parasitic forms of the intestine is not exactly known, but the available evidence suggests that there is a well-defined biological antagonism between them. It would appear, therefore, that the bacteriology of the fæces is likely to develop, and can be more usefully studied, along the lines of a consideration of the general biological character of its flora, than by a separate investigation of the ordinary morphological and cultural peculiarities of the contained bacteria, excepting in special cases where a particular form of infection is believed to exist.

METHODS OF INVESTIGATION.

Fæces that are to be submitted to a bacteriological examination must be carefully preserved from contamination. They should be investigated at once after they have been passed, as the bacterial flora is much altered on standing; but if this is impossible they may be preserved on ice. The soft fæces of infants are most conveniently obtained by the method suggested by Escherich. The anus is thoroughly cleaned with some mild disinfectant, a sterilized rod is then introduced into the rectum to irritate it, and the resulting motion is received in a sterilized dish. Cohnheim devised a metal instrument of small calibre, carrying an eye at one end, which is passed into the rectum and carries away a small sample of the fæces in the eye. With the hard fæces of adults this procedure is not usually applicable, and it is better to collect the fæces in a sterilized vessel, and, after breaking open the fæcal cylinder with a sterile spatula, remove the material for examination from the interior.

The number and variety of the methods that have been devised for investigating the bacterial flora of the fæces are in inverse proportion to the value of the results obtained. It will be impossible to consider them all in detail, and only the outlines of the more important will be given.

1. **Quantity of Bacteria in the Fæces.**—(*a*). The bacterial content of the fæces may be determined in a similar way to that employed for water, known dilutions of the stool being sown on plates of suitable media; but as some 90 per cent or more of the bacteria are already dead when they are passed, a very low estimate of the richness of the intestinal contents in bacteria is thus obtained. Moreover, not every organism passed in a living condition in the stools will grow upon ordinary culture media. The composition of the latter, its reaction, the temperature of the incubator, and the extent to which oxygen is admitted or excluded, all exert a powerful influence on the result. As a rule, the most exuberant growth takes place on bile-salt-agar, incubated at 40° C. under anaerobic conditions; but even here a serious source of error is necessarily introduced by the extreme dilution that is necessary, for if the number of colonies that result are to be counted, not more than $\frac{1}{1000}$ of a milligram of the solid fæces can be used for inoculating each plate.

(*b*). Microscopical methods of enumerating the bacteria in the fæces, so that about 0·002 gram of the material is spread over about 100 microscope fields, have been devised by Eberle, Hellstrom, and Klein. The chief sources of error are the dilution of the fluid from which the films are made—about 1 in 500—the fact that detritus and precipitates from the pigments used for staining may be mistaken for bacteria, or, vice versa, that some organisms may escape enumeration owing to their being covered by other particles, and that some large bacteria may break up and so be counted more than once.

(*c*). An altogether different method was devised by Strasburger, who attempted to separate the bacteria from the rest of the fæces by mechanical means and then weigh them.

The evacuation is placed upon ice directly after it has been passed, and kept there until the examination is commenced. The total dry residue is first determined in a 2 c.c. sample. A second sample of exactly the same size is then used for the estimation of the bacteria. For this purpose it is very thoroughly mixed with about 30 c.c. of 0·5 per cent solution of hydrochloric acid, to dissolve out the soluble salts, and then centrifugalized for about one minute at about 2,000 revolutions per minute. The supernatant fluid, which contains hardly anything but bacteria, is drawn off with a pipette, or Sato's suction apparatus, and put on one side. The precipitate is then mixed with a further portion of dilute hydrochloric acid and centrifugalized. The supernatant fluid is pipetted off and added to the first. This procedure is repeated until microscopical examination of the precipitate shows that it contains only a very small number of bacteria, and the supernatant fluid is only slightly cloudy. As a rule, four successive centrifugalizations suffice, but it is to be noted that the better the mixing with the hydrochloric acid is carried out, the more quickly is the end point reached. The whole of the mixed supernatant liquids are now placed in the centrifuge and given about thirty rapid turns to remove any heavy particles that may have been carried over. They are then mixed with an excess of 96 per cent alcohol. This mixture is placed on a water bath at 40° C. for twenty-four hours to reduce the bulk of the liquid to manageable proportions. Fresh alcohol is now added to the residue, and the mixture is centrifugalized. The precipitate is again washed by centrifugalizing with alcohol, and the fat removed by centrifugalizing with ether. After the ether has been pipetted off, the precipitate is washed into a weighed crucible with absolute alcohol, dried, and the dish again weighed, when the difference between the two weighings will give the weight of the bacteria present in the known weight of dry fæces used.

If the specimen contains an abundance of fat, equal parts of alcohol and ether are added to the first fæcal emulsion and the mixture centrifugalized. Three layers then separate out: the uppermost consists of alcohol and ether containing the fat, the middle holds the bacteria, and there is finally the precipitate at the bottom. After the middle layer has been pipetted off, the remainder is mixed with more alcohol and ether, centrifugalized, and the whole of the supernatant solution of fat in alcohol-ether removed. The precipitate is then treated as above, and the fluid obtained from it added to the middle layer previously removed.

This method has given somewhat different results in the hands of different observers, and it has been shown that the duration and speed of the centrifugalization exert a considerable influence. Schmidt found that if he centrifugalized for two minutes, the bacteria amounted to 25·3 per cent of the total dry residue of the stool, while if he centrifugalized for ten minutes the corresponding percentage of bacteria was only 14·75. In order to obtain comparable results it is advisable to use healthy fæces as a control, and submit both specimens to exactly the same procedure. The percentage relation of bacteria to the total dry residue of the fæces found by different observers may be summarized as follows :—

Strasburger	24·3 per cent
Schittenhelm and Tollens ..	42·0 ,,
Lissauer	8·7 ,,
Tobaya	11·2 ,,
Sato	24·4 ,,
Berger and Tsuchiya ..	12·6 ,,
Harris	9·2 ,,

(*d*). Instead of weighing the bacteria recovered by successive centrifugalizations, some observers have estimated the nitrogen, and maintain that it gives a more valuable index of the bacterial content of the fæces. Schittenhelm and Tollens state that normally the bacteria contribute about half to the total nitrogen of the stools. According to Mattill and Hawk, three serial centrifugalizations of a 2-gram sample of the fresh fæces, brought into suspension in a 0·2 per cent dilution of hydrochloric acid, are carried out. The bacterial suspension thus obtained is concentrated, extracted with alcohol, and the nitrogen determined in the precipitated material. On an absolutely uniform diet of simple and easily digested food during a period of three or four weeks, these observers found that in two subjects the average amount of bacterial nitrogen was 53·9 per cent of the total fæcal nitrogen, and that calculated on this basis, the average daily amount of dry bacteria was 8·27 grams.

In healthy breast-fed infants, Leschziner states that the bacterial nitrogen amounted to from 6·5 to 29·4 per cent of the total nitrogen, and that the bacteria represented from 2 to 28·4 per cent of the dry weight of the stools. Using his own method, Strasburger found that in the normal breast-fed child of two months, the percentage relation of bacteria to total dry weight is about 25·8, and for children taking cow's milk it varies from 11·5 to 42·3. In a breast-fed child whose digestion was imperfect, the bacteria were shown to constitute 61·4 per cent of the total dry weight of the fæces. Bahrdt investigated the effect of different diets on the bacterial content of the fæces, and found that they were lowest with breast milk, higher with butter-milk, and still higher with cow's milk diluted with an equal quantity of water, varying from 15 to 30 per cent of the dry residue. According to this observer, stools that contain most water also contain most bacteria, and he also states that the more fat and soap there are present, the poorer is the stool in water and bacteria. In adults it would seem that the nature of the diet exerts little if any influence upon the total quantity of bacteria excreted, for Tobaya found that on an average European diet the stools contained from 16 to 30 per cent of bacteria; on a diet consisting mainly of rice and milk, with hardly any fish or meat, the results varied from 12 to 36 per cent; while with an average Japanese diet, which contains a considerable quantity of vegetables, there was a minimum of about 7 per cent and a maximum of about 20 per cent of bacteria in the fæces. Allowing that fresh bacteria contain about 85 per cent of water, they would constitute about one-third of the weight of the moist fæces, with an average daily excretion of about 56 grams of micro-organisms, weighed moist.

The influence of intestinal antiseptics on the quantity of bacteria in the stools has been investigated by Adolf Schmidt and others. Schmidt holds that anything which stimulates the intestine and leads to the secretion of intestinal juices capable of putrefaction, brings about an increased growth of bacteria. This he states is particularly the case with calomel, the administration of which, instead of diminishing the number of bacteria in the fæces, may actually cause an increase. Berger and Tsuchiya were not able to confirm this conclusion with regard to calomel, however, and consider that a diminution may follow its use. They found that the most marked results were brought about by the use of hypogen (MgO_2) and oxygar, both of which exerted a favourable antiseptic action. Oxygar is a pure agar-agar containing 12 per cent of hydrogen peroxide, and is given three times a day in dessertspoonful doses. It is believed to liberate hydrogen peroxide gradually in the intestinal contents, and so to exert an antiseptic action. During the use of this substance it was found that the daily excretion of dry bacteria fell from 4·42 grams to 0·8 gram.

In spite of the statement by some writers that the bacterial content of the fæces, and especially the nitrogen value, is a valuable index of the condition of the intestine, the processes involved in their determination are too laborious and time-consuming to be used frequently in clinical diagnosis, so that other methods fo investigation are much more commonly employed.

2. **Microscopical Examination.**—A microscopical examination of cover-glass preparations made from the fæces is the most easily carried out of all methods, and should never be omitted, for to the experienced observer it yields much valuable information, especially when the smear has been treated with Gram's stain, or some modification of it. Simple hanging-drop preparations of the well-diluted fæces may be helpful sometimes. In making cover-glass preparations, the suspension used must not be too concentrated, as the picture may be confused by the excessive amount of material. It is also advisable that the same procedure should be constantly employed, so that one specimen may be compared with another. As a rule a suspension of one part by weight of fæcal material to ten parts of normal saline gives the best dilution. The bacteria may be separated from the other solid constituents of the stool by centrifugalizing a suspension with water, then diluting the supernatant fluid with two volumes of 95 per cent alcohol, and centrifugalizing again. The sediment obtained in this way will consist almost exclusively of bacteria.

(*a*). *Iodine.*—Preparations of the fæces made by mounting a smear in Lugol's solution (iodine 1, pot. iod. 2, water 200) not only reveal the presence of undigested starch, but according to Rodella also furnish an important index to the condition of the intestine, a strongly iodine-positive flora being found when the digestion and absorption of starches are interfered with. He states that it is especially well marked in cases of pancreatic disease, and this is also my experience.

(*b*). *Simple stains*, such as Löffler's methylene blue, carbol thionin, or a 10 per cent solution of carbol-fuchsin may be used to stain cover-glass preparations and give some idea as to the number and general characters of the intestinal flora.

(*c*). *Gram's Stain.*—This is by far the most useful method of studying the flora of the intestine microscopically, for, although there are some instances in which Gram-stained microscopical fields appear normal, and yet other methods show a pathological condition of the intestinal flora, as a rule results are obtained that are very suggestive, and often give a distinct clue to the type of disease that is present. In order that full advantage may be taken of the results that this method is capable of yielding, it is essential that the observer should be familiar with the appearances seen in the normal fæces and the modifications brought about by different types of food, etc. A uniform method of applying the stain should be followed; otherwise varying and confusing results are likely to be obtained.

The simplest method of applying the stain is to treat the dry preparation of the fæces for five minutes with methyl alcohol, to dissolve out the fat, and fix it. It is then stained with aniline-gentian-violet, or carbol-gentian-violet, for three minutes. The excess of stain is run off, but the preparation is not washed. Pour on Lugol's solution and leave for two minutes, rinse with water, and decolorize with absolute alcohol for half a minute. The smear may then be counterstained with dilute carbol-fuchsin for a minute or so, washed, dried, and mounted. A useful modification, which I employ in my work, is that introduced by Weigert-Escherich. The following materials are required: (i) Dissolve 2 grams of gentian-violet in 200 c.c. of distilled water by boiling for half an-hour, and filter; (ii) Mix 11 c.c. of absolute alcohol with 3 c.c. of aniline oil; (iii) Lugol's solution (1 gram iodine, 2 grams pot. iod., 60 c.c. water); (iv) Equal parts of aniline oil and xylol; (v) Pure xylol. To carry out the staining, mix $8\frac{1}{2}$ parts of (i) with $1\frac{1}{2}$ parts of (ii), pour on to the smear, and leave half a minute and then dry with blotting-paper (the mixture of these two ingredients will not keep for more than two or three weeks, and is best prepared as required). The preparation is next treated with Lugol's solution until black (usually about half a minute). It is then decolorized with successive portions of the aniline-xylol mixture (iv) until no more blue colour comes away, and finally washed with pure xylol. After being blotted, the smear is counter-stained with dilute carbol-fuchsin (one minute), washed with distilled water, dried, and mounted.

By a study of Gram-stained preparations an idea may be formed as to the number of organisms morphologically resembling B. coli that are present, and their state of preservation may also be noted. The presence or absence of the long, slender Gram-negative organisms of the B. liquefaciens ilei type may also be determined. The relative number of Gram-positive diplococci and other coccal forms can be seen, and an opinion may be arrived at as to the presence of Gram-positive B. bifidus, especially in its unbranched form. Finally, the experienced observer can estimate whether free spores, spore-containing organisms, and vegetative anaerobic forms are present in excessive numbers or not. It is not safe to give an absolute opinion as to the identity of the dominant bacteria on the microscopical appearances alone, but it may aid in forming conclusions which are valuable on account of their high degree of probability. In order that a reliable opinion may be formed, it is important that the appearances met with in Gram-stained smears from normal fæces, and the modifications brought about by different types of food, should be thoroughly understood. Allowance must also be made for the variations that occur at different ages, owing to the nature of the diet, mode of life, etc.

Experiment has shown that when only protein food is taken, and the protein flora become dominant in the fæces, Gram-stained smears prepared from the fresh stools show a fairly equal distribution of Gram-negative and -positive organisms (*Plate VIII*, 6). Among the latter are many large and medium-sized rods with rounded ends, which cultural examination shows consist largely of subtiloid organisms with some B. aerogenes capsulatus. In addition, a moderate number of diplococci and coccoid forms are seen. Most of the Gram-negative organisms are bacilli which resemble B. coli morphologically. There are frequently also a fair number of thin Gram-negative rods (B. liquefaciens). When the diet is of a carbohydrate character, the field is strongly Gram-positive and has a more homogeneous appearance (*Plate VIII*, 5). It consists chiefly of long, slender Gram-positive rods, some of which are seen to be slightly curved. These organisms belong to the B. acidophilus and B. bifidus groups.

On comparing the fæcal flora of nurslings and adults it is found that the former is relatively simple and more homogeneous than the latter, which contains a much larger variety of types (*Plate VIII*, 3). The fæces of the breast-fed child are strongly Gram-positive, while the smears from adult stools contain as a rule approximately equal numbers of Gram-positive and -negative organisms. This is no doubt to be explained by the difference in the diet, for whereas the food of the nursling is of a monotonous character and carbohydrates are a prominent feature, the food of the adult is varied and contains much more protein. In the soft yellow fæces of the nursling, bacteria are very abundant, much more so than in the adult. Gram-stained smears show that the majority are bacilli of similar morphological characters, so that the field appears to consist of a nearly pure culture of an organism resembling B. coli except that it is Gram-positive and some are slightly curved. This can be shown to be chiefly B. bifidus, and is the characteristic organism of the human nursling's digestive tract. Some, however, are B. acidophilus. A few thick Gram-positive bacilli with rounded ends, resembling B. subtilis and B. aerogenes capsulatus, may also be seen. Another Gram-positive organism that is regularly present in small numbers, is a diplococcus that frequently grows in chains. This coccus is commonly associated with a similar organism that is Gram-negative. The other Gram-negative bacteria are small coccal or coccoid forms, and short or medium-sized bacilli which have the biological characters of B. lactis aerogenes and B. coli. It will thus be seen that in the normal nursling's stools, acid-forming organisms of the B. bifidus and B. acidophilus types largely predominate.

The number of bacteria present in the fæces of the bottle-fed child is considerably greater than is the case with the breast-fed infant, and this is true even when the child has been brought up on sterilized or pasteurized milk. Many of the bacterial forms described in the fæces of the nursling are also present in the stools of the bottle-fed infant, but the appearance of the field is very different, for the majority of the organisms are Gram-negative instead of Gram-positive (*Plate VIII*, 4). This is due to there being a preponderance of coliform organisms, and a relative scarcity of B. bifidus and B. acidophilus. The latter are fairly well represented, but they are by no means as numerous as in the fæces of the nursling. In addition to these leading types, there are a certain number of Gram-positive and -negative diplococci, some of which form chains; also an organism described by Kruse as Streptococcus lacticus. Among other forms that are often present are Staphylococcus pyogenes albus and B. cloacæ, while sarcinæ and yeasts may be seen.

With the alterations in the diet and increasing opportunity for the entrance of new types of bacteria into the alimentary tract, the fæces of older children and adults show a still more varied flora. So long as the use of milk is continued as a main article of food, the micro-organisms of the bottle-feeding period are still to be found in the fæces; but as a more mixed diet is taken, bacteria of the B. bifidus type diminish, while other organisms increase in number. This is particularly true of the proteolytic forms, such as B. coli, B. putrificus, B. aerogenes capsulatus, and subtiloid organisms. During childhood and adolescence they are few, however, as compared with the adult, and putrefactive processes in the intestine are consequently less active. Although there are some people of fifty years or more of age, the bacterial flora of whose fæces do not materially differ from those of the normal adolescent, the number of putrefactive anaerobes is considerably increased as a rule in adult life. Bacilli of the colon group are well represented, and B. putrificus is usually present in moderate numbers. Bacilli of the subtiloid and aerogenes groups are also found more abundantly. The Gram-stained field, therefore, corresponds fairly closely to that obtained experimentally with a protein diet. It is probable,

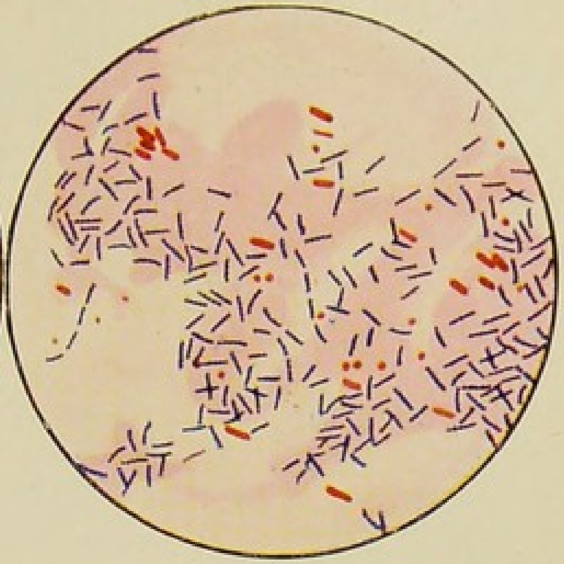
EXPLANATION OF PLATE VIII.

Cover-glass preparations stained with the Weigert-Escherich modification of Gram's stain (× ca. 1000).

1. Meconium.
2. The blue bacillus of Escherich.
3. Fæces of a breast-fed infant.
4. Fæces of a bottle-fed infant.
5. Fæces of an adult on a carbohydrate diet.
6. Fæces of an adult on a meat diet.

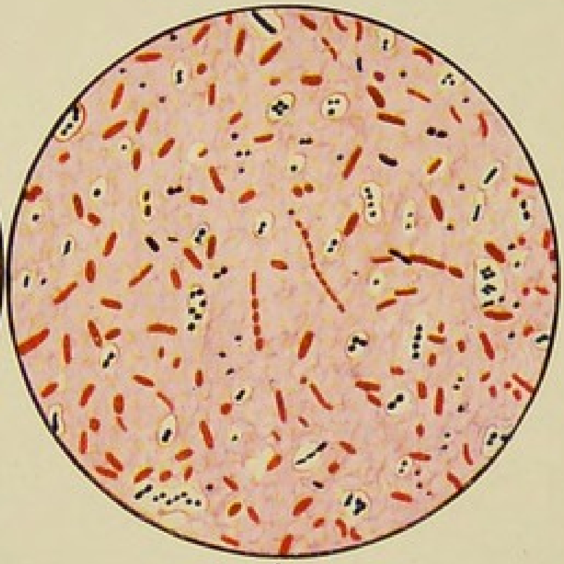
PLATE VIII.

1



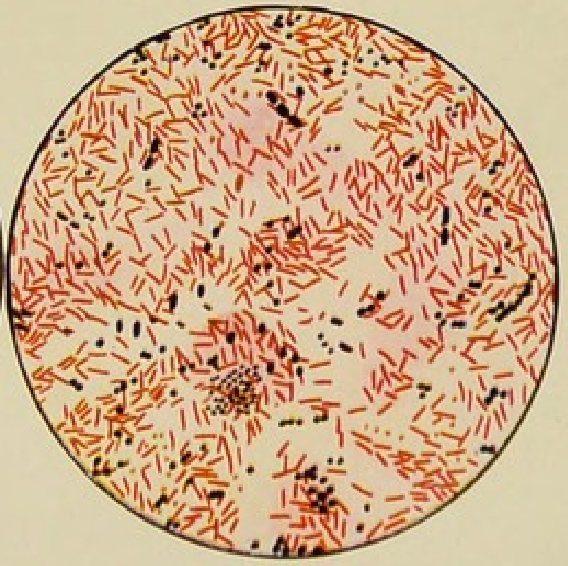
2

3



4

5



6

Examination of Fæces

P. J. Cammidge

however, that the tendency to an increase in the putrefactive organisms is not entirely the direct result of a more or less highly protein diet, but is also connected with the repeated, but not necessarily severe, derangements of intestinal function that are experienced from time to time by most individuals. Great differences exist in the habits of different persons at this time of life, and these differences are reflected in the character of the bacterial contents of the intestine, so that it is not an easy matter to say what is normal and what is pathological. It is only when a marked variation from the average is seen in the Gram-stained smears that it can be stated with any degree of certainty that the flora of the intestine is abnormal.

(*d*). *Special Methods.*—For some bacteria met with in the fæces under pathological conditions, notably tuberculosis, special differential stains can be employed. These will be referred to under the particular micro-organism.

3. **Biological Characters.**—The cultural characters and morphological features of individual microbes are of great interest to the scientist, but, since the physician is concerned with the host rather than with the parasite, it is more important for his purpose to determine what bacteria do than what they are. In some instances it may be necessary to isolate a particular organism, which is probably the specific cause of a disease, but in many pathological conditions of the intestine this is practically impossible, and would serve no useful purpose. In such cases it is sufficient to determine the type of bacteria that predominates, so that measures may be taken to control its activities by suitable rearrangement of the diet, etc. For such a purpose, samples of the stool are inoculated into a certain number of selected media, and from the results that ensue an opinion is formed as to the dominant type of organism that is present. The most suitable media are : (*a*) Sugar-free gelatin ; (*b*) Acid dextrose broth (0·5–1·0 per cent acetic acid in 2 per cent dextrose broth) ; (*c*) Dextrose broth (2 per cent) ; (*d*) Lactose broth (2 per cent) ; (*e*) Saccharose broth (2 per cent) ; (*f*) Litmus milk ; (*g*) Agar-agar dilution cultures. These media can be divided into groups according to the types of bacteria that grow in them :—

(i). Gelatin is particularly adapted to the growth of proteolytic forms.

(ii). Acid dextrose broth is specific for certain fermentative organisms, chiefly those of the B. acidophilus and B. bifidus types.

(iii). Sugar-fermentation media and milk, in which practically all the chief bacteria represented in the fæces grow well, form a field in which the various types struggle for supremacy, so that the results of the tests furnish valuable indications as to the dominant type of bacterial activity in the intestinal tract.

(iv). Progressive dilutions of the fæces grown in solidified agar-agar supply information as to the relative numbers of aerobic, facultative, and strictly anaerobic bacteria. The first-named develop in the upper 2 cm. or so of the medium, the strict anaerobes grow in the depths of the tube, and the facultative anaerobes occupy a middle position. As a rule, the aerobic and facultative anaerobic bacteria appear earlier (twenty-four to forty-eight hours) than the strict anaerobes, thus furnishing another means of distinguishing them. The inoculation is made with the liquefied medium at a temperature of about 40° C., and, after the contents of the tube have been thoroughly mixed, the agar is quickly solidified by being plunged into cold water.

The sugar media and milk are contained in U-shaped tubes with one closed arm, in order that the extent to which fermentation takes place can be estimated by measuring the gas that collects. In the case of the milk, the degree of clotting and the extent to which peptonization of the casein occurs should also be noted. The quantity of gas produced in conditions of health by the mixed flora in the sugar tubes is somewhat variable, but may be roughly stated to range between 15 and 30 per cent of the height of the anaerobic limb. In normal children on a milk diet the gas production is often somewhat less than in adults, and may not be more than 10 to 15 per cent. As a rule, the quantity of gas formed in conditions of disease is considerably less than the average in health for both adults and children. This appears to be due to an elimination, or inhibition, of the coli groups of the fæces by fermentative organisms of the acidophilus and bifidus or other types. The acidophilus organisms appear to inhibit the growth of those belonging to the colon group by producing acid so rapidly and intensely from the sugars that the coli cannot develop and bring about the usual formation of gas. A very abundant production of gas in the sugar media suggests the presence of yeasts, which can thrive in a more acid medium, but may occasionally depend on the abnormal activity of subtiloid bacilli or B. aerogenes capsulatus. In some cases it may be advisable to investigate the gas formula of the fermentation tubes, that is to say, determine the relation between the carbon dioxide and hydrogen by adding caustic soda to absorb the former.

An examination of the sediments of the fermentation tubes is a most useful aid in diagnosis, and gives very important help in forming an opinion as to the dominant type of organism. In tubes inoculated from the fæces of healthy adults, Gram-negative organisms correspond ng in size and form to B. coli grow abundantly in all the media, and, as a rule, constitute the dominant flora of the sediment. Mixed with them there are generally a moderate number of Gram-positive and Gram-negative diplococci, with often a fair number of organisms morphologically resembling B. aerogenes capsulatus. The latter are, however, often entirely absent. In the lactose broth, and to a less extent in the dextrose broth, tubes, large numbers of the plain or branched form of B. bifidus may occur. Under pathological conditions, different bacterial elements may be met with in the sediments. In cases where the fæces contain considerable numbers of Gram-positive streptococci or diplococci these forms will be seen in abundance, but they may be also met with in large numbers, even when the microscopical examination of the fæces themselves reveals no striking increase. Sometimes the field may consist wholly of streptococci and bacteria resembling B. aerogenes capsulatus, and this, according to Herter, is particularly common in cases of advanced saccharobutyric putrefaction with an extreme degree of anæmia. A greenish colour in the open aerobic arm of the tube, with the formation of a greenish pellicle on the surface, is occasionally observed in cases where the patient presents signs of digestive disturbance, and is due to B. pyocyaneus. A gradual reappearance of the colon bacillus in the sedimentary fields, with a corresponding disappearance of coccal, streptococcal, and anaerobic forms, can be taken as a sign that the bacterial flora of the intestine is assuming a more normal type, and will be found to be associated with an improvement in the clinical condition. Observations on the quantity of indol, ammonia, sulphuretted hydrogen, etc., formed on inoculating portions of the fæces into fermentation media contained in tubes or flasks, have been made by Herter and others, but as yet the results are not sufficiently definite to be of clinical value.

Rapid peptonization and gas formation in the milk tube is often due to organisms of the B. cloacæ type, which are not rarely found in the human intestine. Kendall has shown that it may be also brought about by the symbiotic activity of organisms of the subtiloid group and B. coli or B. proteus. The former act on the milk and peptonize the casein, but do not attack the lactose. In some way that is not understood, the solution of the casein appears to make the lactose more accessible to the action of the colon bacillus, which then splits it up. At the same time the alkali produced by the subtiloid bacillus tends to neutralize to a certain extent the acid formed through the fermentation of the lactose by the colon bacillus, so that the process can proceed further than it would do if the colon bacillus were present alone, while on the other hand the acid produced by the colon bacillus neutralizes the alkali formed by the subtiloid organism, and thus prevents an alkaline reaction of the medium sufficient to inhibit its activities. In dextrose and lactose fermentation media an unusual gas formation may arise in a similar way from the growth of these organisms symbiotically. B. aerogenes capsulatus, when grown in milk, quickly makes it acid, sets up stormy fermentation, due to the rapid formation of gas from the lactose, and peptonizes the casein, so that the coagulated milk is partly digested and broken into small masses.

One advantage of the fermentation method of investigating the fæces is that it provides conditions under which both aerobic and anaerobic organisms can develop, the former growing in the open, and the latter in the closed limb of the tube. Most anaerobes only grow satisfactorily in sugar broths when pieces of sterile tissue, such as guinea-pig or rabbit liver, are present, but as a rule sufficient organic material appears to be introduced with the fæces to allow of their satisfactory development. Comparatively little has been definitely established as yet with regard to the etiological relationship of anaerobic intestinal infections and specific diseases. The problems confronting investigators in this field are unusually difficult, but it appears probable that they are responsible for some primary anæmias, and may also give rise to the so-called "enteric catarrh" of infancy.

The influence of diet must not be overlooked when considering the question of gas-formation by the mixed fæcal flora. Much useful work in this connection has been carried out by Kendall and Herter. Since the products of digestion of protein in the alimentary canal are far more numerous and varied than those of carbohydrates, it might be expected that the protein flora would be more heterogeneous than that developed on a carbohydrate regimen, and this has been proved experimentally to be the case. When the food is sharply restricted to these two classes of food-stuffs, it has been found that marked alterations in the types of bacteria occur, and also that certain organisms change their metabolism to accommodate themselves to their environment. Inoculated into gelatin, the mixed fæcal flora of a protein diet causes a decided liquefaction, which commences as a rule within eighteen hours, and continues until practically the whole of the medium is peptonized. In sugar broths, a marked gas-formation occurs within eighteen hours, and may sometimes reach 100 per cent of the closed arm. The Gram-stained sediment from the fermentation tubes contains short Gram-negative bacilli resembling B. coli and B. proteus, and also larger, longer, and thicker Gram-positive rods morphologically similar to B. aerogenes capsulatus, but which can be proved on sub-culture to belong to the subtilis group. In acid dextrose broth there is very little growth and no gas-formation. Milk is vigorously attacked, the casein being peptonized to a very considerable degree, and usually from 50 to 80 per cent of gas is formed within eighteen hours. On a protein diet, therefore, the dominant organisms are of two principal types: (*a*) Liquefying, of which subtiloid organisms appear to be the most prominent; and (*b*) Gas-forming bacilli, of which B. coli and B. proteus are the most common. Anaerobic organisms do not appear to play an essential part in any of the processes.

On a carbohydrate diet the fæcal flora is of an entirely different character. In gelatin there is very little growth, and those organisms that do develop appear to be remnants of the protein flora. The gas production in sugar broth is usually under 10 per cent, and the turbidity in the closed arms of the fermentation tubes is less marked than with a protein diet. The sediment shows both long, thin Gram-positive organisms (B. acidophilus) and similar slender organisms with bifid ends (B. bifidus). Although milk is firmly clotted, no gas formation or peptonization takes place. With acid dextrose broth a marked turbidity is seen, and microscopical examination shows that it consists of long, thin organisms of the B. acidophilus type in almost pure culture.

The explanation of these results appears to be that when the fæces containing organisms of the acidophilus and bifidus types are inoculated into sugar-containing media, acid is produced so quickly that even the rapidly-growing colon and subtiloid bacilli cannot develop. In sugar-free gelatin, and also in plain sugar-free broth, on the contrary, the fermentative organisms of the acidophilus and bifidus type cannot grow; hence the typical proteolytic flora, consisting chiefly of B. coli and subtiloid organisms, develop unhindered. We may therefore conclude that on a protein diet the absence of carbohydrate prevents the development of acid-forming bacteria, and favours the overgrowth of the proteolytic and gas-forming bacteria, while on a purely carbohydrate regimen, the excessive formation of acid, through fermentation of the sugars by acidophilus bacteria, inhibits the growth of the proteolytic and aerogenic forms.

The fæces of the breast-fed child give very different results according to the medium employed and the conditions under which growth takes place. On gelatin or in simple broth, in the presence of air, the growth consists almost entirely of B. coli, with some diplococci and B. lactis aerogenes. If, however, the mixed fæcal flora is inoculated into acid dextrose broth, the growth of members of the colon group is inhibited, and an examination of the sediment shows that it consists almost entirely of B. bifidus and acidophilus. In sugar broths, although there is some gas-formation, it is not large, and generally does not exceed 10 per cent of the closed arm. Milk is clotted, but there is little or no peptonization or gas-formation. It will be noticed that the results correspond very closely to those obtained experimentally on a carbohydrate diet.

The mixed fæcal flora of the bottle-fed child generally causes some liquefaction of gelatin, and in simple broth gives rise to little or no gas. The medium which was originally neutral remains so, or becomes alkaline, from the formation of ammonia, and a moderate quantity of indol is usually present. With sugar broths there is always a considerable formation of gas: most in the tube containing lactose, less in that containing dextrose, and least in the saccharose medium. Treated with a strong solution of caustic soda, it is found that from one- to two-thirds of the gas formed consists of carbon dioxide, the remainder being chiefly hydrogen and partly methane. The sugar media are all strongly acid in reaction. Examination of the sediment shows large numbers of coliform bacilli, with some staphylococci and Gram-positive diplococci. Should only a small quantity of gas have been formed, it will often be found that there has been an abundant growth of streptococci. The fæces of the bottle-fed child, therefore, contain more proteolytic and gas-forming bacilli than those of the breast-fed infant, but their activity is comparatively limited.

In the adult, proteolytic and gas-forming organisms are much more in evidence; there is consequently greater liquefaction of gelatin, more marked indol formation in simple broth, and a larger volume of gas with sugar media. Milk may or may not be partially peptonized, according to the conditions. Briefly, the fæcal flora of the adult approximates more nearly to the type resulting experimentally from a protein diet.

In the study of the flora of the intestinal tract and fæces, the employment of pasteurization at 80° C. for fifteen to twenty minutes previous to making aerobic and anaerobic cultures is of much value. Most vegetative forms of bacteria are killed by this means, and only bacteria survive which have formed spores. This procedure is important, both in the study of physiological conditions, and for the detection of pathological peculiarities of the intestinal flora. Even in the fæces of nurslings it can be shown that several spore-forming bacteria are present. The more common of these are B. bifidus, B. putrificus, B. aerogenes capsulatus, and B. subtilis. Occasionally the bacillus of malignant œdema has been found (Passini). The number of spore-bearing forms in the fæces of the bottle-fed child is ordinarily small as compared with what is met with in disease. The most common are the motile butyric acid bacillus, B. putrificus, B. aerogenes capsulatus, B. subtilis, and the bacillus of malignant œdema. In the fæces of adults, spore-bearing organisms of the subtiloid, aerogenes, and putrificus types are usually more abundant, and other ill-defined forms also make their appearance.

CLASSIFICATION.

A large proportion of the numerous varieties of bacteria met with in the fæces have not been isolated and identified as yet, and the description of many of those that have been studied by various observers is so indefinite that it is often difficult to re-identify them. The morphological and biological characters of many of the more important normal and pathological intestinal bacteria have, however, been carefully investigated. Some of the former have been incidentally referred to in the preceding pages, but it will now be convenient to consider them individually in more detail, and also refer to the pathological varieties, giving in some cases the special methods adopted for their separation and recognition. An exhaustive account of even the well-recognized species would be, however, beyond the scope of this work. For further details, and also for a description of the micro-organisms that are not dealt with, the reader is referred to the accepted text-books of bacteriology.

Bacteria may be roughly classified according to the degree of parasitism they exhibit. Thus the plague bacillus in man and the anthrax bacillus in the guinea-pig, are highly parasitic, for they find in their hosts conditions suitable for their rapid multiplication and invasion, although the original infection may have been established by very few bacteria. Directly opposed to such organisms are the saprophytic bacteria, which have the utmost difficulty in establishing themselves in the tissues of their host, even when introduced in considerable numbers, but may prove injurious if inoculated in large quantities. To this class belong many of the micro-organisms of the intestinal tract. Midway between these two groups stand the hemiparasites, organisms which only successfully invade the tissues of the host when inoculated in considerable numbers, and which are only pathogenic when the defensive mechanisms of the organism are defective. The typhoid bacillus, the spirillum of Asiatic cholera, and the dysentery bacillus fall into this group. Although such a classification is convenient, it must be understood that no hard-and-fast boundaries separate the hemiparasites from the parasites on the one hand, or from the saprophytes on the other, and that, given suitable conditions, an organism which is usually saprophytic may become parasitic.

It is now well established that pathogenic bacteria may be present in the intestinal tract in moderate or even considerable numbers without giving rise to clinical symptoms. The most striking and important example of this condition is met with in the so-called " carrier cases " of typhoid, in whom the fæces can be shown to contain typhoid bacilli although the patients themselves are apparently quite healthy. In 1902 von Drigalski and Conradi found typhoid bacilli in the stools of four persons who had had no symptoms of typhoid fever, but had been in contact with patients suffering from the disease. Soon it was shown that a number of typhoid convalescents continued to pass typhoid bacilli for long periods, and examinations of persons who have had typhoid fever years before, revealed the remarkable fact that some one or two per cent of them still had typhoid bacilli in their fæces, sometimes in very large numbers. Subsequent investigations by other observers showed that chronic typhoid carriers are even more common than these figures would suggest, and that from 3 per cent (Kayser) to 4 per cent (Lentz) of typhoid patients continue to pass bacilli after they are quite convalescent. The period of infectivity is not confined to a few months, but may extend to years (*Fig.* 66), cases having been reported in which typhoid bacilli were found in the stools, and the " carrier " had proved a source of disease, ten, fifteen, twenty, and even forty-two years, according to Lentz, subsequent to the original attack. It appears probable that the retention of typhoid

Fig. 66.—Typhoid bacilli isolated from the fæces ten years after an attack of typhoid fever (v. Ermengem's flagella stain).

bacilli in such cases is dependent upon faulty metabolism and concurrent chronic disease. Lentz has pointed out that women, and especially those who have borne children, preponderate over men carriers in the proportion of about three to one. As is well known, this proportion represents also the relative incidence of gall-stone disease in the two sexes, and it has been shown that many of these female carriers actually suffer from gall-stones. Moreover, it is a well-recognized fact that only some 10 per cent of cases of cholelithiasis present symptoms of gall-stones during life, and it is interesting to note that symptoms have also been present in about 10 per cent of typhoid carrier cases. From a consideration of such facts, and also from the results of bacteriological and post-mortem examination of a number of carrier cases, it is evident that in many, the gall-bladder is the situation in which the bacilli continue to multiply, and from which they pass into the intestinal contents. It is possible, as Lentz suggests, that in some instances the appendix and the deeper folds of the intestine may also provide a nidus. The presence of typhoid bacilli in the fæces is not confined, however, to persons who have suffered at some time or other from typhoid fever, for Klinger examined the fæces of 1700 healthy persons, who had never knowingly had typhoid fever, and found bacilli in eleven. The stools of persons living in the vicinity of, or in close contact with, typhoid cases, not infrequently contain typhoid bacilli in small numbers for a short time. It may, of course, be argued that these " temporary or acute carriers " are really suffering from a mild ambulant form of the disease, and as a rule, bacteriological examination of the fæces subsequently shows that they are free from typhoid bacilli. Intermittency in the excretion of typhoid bacilli is also seen, however, in chronic carrier cases, some being "effective" at one time and not at others. Finally, there can be no doubt that typhoid bacilli can be ingested without harm by certain individuals and be passed in the excreta. Individual susceptibility, virulence of the strain, and the magnitude of the dose, are all factors that must be reckoned with; that is to say, an organism that is usually parasitic may be saprophytic under certain conditions, while given another set of circumstances it causes the usual pathological changes.

Although the evidence is neither so extensive nor so strong, it seems likely that other organisms which are usually regarded as parasitic may lead a saprophytic existence in the intestinal tract, and be found in the fæces of apparently healthy persons. Duval has shown, for instance, that dysentery bacilli are occasionally present in the stools of normal individuals, and his observations have been confirmed by others. According to Ledingham and Arkwright, about half the persons who recover from an attack of true cholera retain the vibrios for from ten to fourteen days, but only 5 or 6 per cent remain infected over twenty-five days. Of the latter, 1 to 2 per cent excrete the organism intermittently for two or three months. Herter states that B. pyocyaneus may be found in the intestinal contents of persons in apparently good health. It also seems probable that usually saprophytic types such as B. coli, B. putrificus, streptococci, etc., may multiply abnormally, and take on pathogenic properties, under the influence of alterations in the intestinal secretions or in the presence of unusually large quantities of partly digested food.

The Colon-Typhoid-Dysentery Group.—More work has been done on this group of organisms than any other found in the intestinal contents. Our knowledge of the biological characters of the bacteria comprising it is not complete even yet, but there is abundant evidence to show that they form an intimately linked series. They all possess certain common characters; but while typical members of each class have properties which serve to distinguish them one from the other, there are various intermediate types which bridge the gaps and suggest that they may have been descended from a common ancestor through successive slow modifications. It has been claimed by some observers that such a transition can be brought about in the laboratory by suitable means, and that a natural transformation of one type into the other is the explanation of some outbreaks of disease. In 1896 Roux, for instance, maintained that under certain mysterious influences the colon bacillus was changed into the B. typhosus, a normally inoffensive organism being thus transformed into a virulent bacillus capable of setting up a general infection. Roux and those who support his views state that the colon bacilli isolated from the intestines of cases of typhoid fever are much more virulent than the supposed specific organism obtained by puncture of the spleen, and that the organism found in the pleurisies and pneumonias that occur as complications of typhoid is the colon bacillus and not the bacillus of Eberth. Tarchetti has also claimed to have transformed B. coli into B. typhosus by introducing a culture of the former into the peritoneal cavity of a rabbit. However enticing such a theory may be, and in spite of the zeal with which its supporters have maintained their view, it is not now generally accepted, for none of the proofs advanced are conclusive, and moreover, modern sero-diagnostic methods have shown that, although various members of the series have affinities with each other, they are separate and distinct organisms.

The organisms comprising the group are all cylindrical, Gram-negative bacilli, varying from short ovals to long rods or filaments. Many of them are provided with flagella which surround the whole body of the bacillus, and vary in number from a few to fifteen or twenty; they are consequently more or less actively motile. Endospores are not known to be formed. They are aerobic and facultative anaerobic. No pigment is formed on either agar or gelatin, and the latter medium is not liquefied.

Bacillus coli is a short bacillus, measuring 0·5 by about 1 to 2 microns. It has four to six flagella, and is Gram-negative (*Plate IX*, 1, 2). It forms acid and gas in glucose broth. It coagulates milk, although sometimes slowly, forming indol but not phenol, and does not peptonize the casein. Litmus milk is reduced and rendered acid, and the culture has usually a fæcal odour. Lactose broth gives much gas, but with saccharose broth there is usually no gas production, and the reaction of the medium is not altered. Neutral-red broth becomes fluorescent. On potato there is a yellowish to yellowish-brown growth.

B. coli is found in comparatively small numbers in the fæces of infants, but is pre-eminently the intestinal saprophyte of adults. In the healthy individual, it is met with chiefly from the lower part of the ileum downward, and appears in large numbers in the stools. It is normally a harmless, and possibly a beneficial, saprophyte. In favour of the latter view there is evidence which points to the colon bacillus playing an important part in controlling the activities and growth of other less harmful organisms.

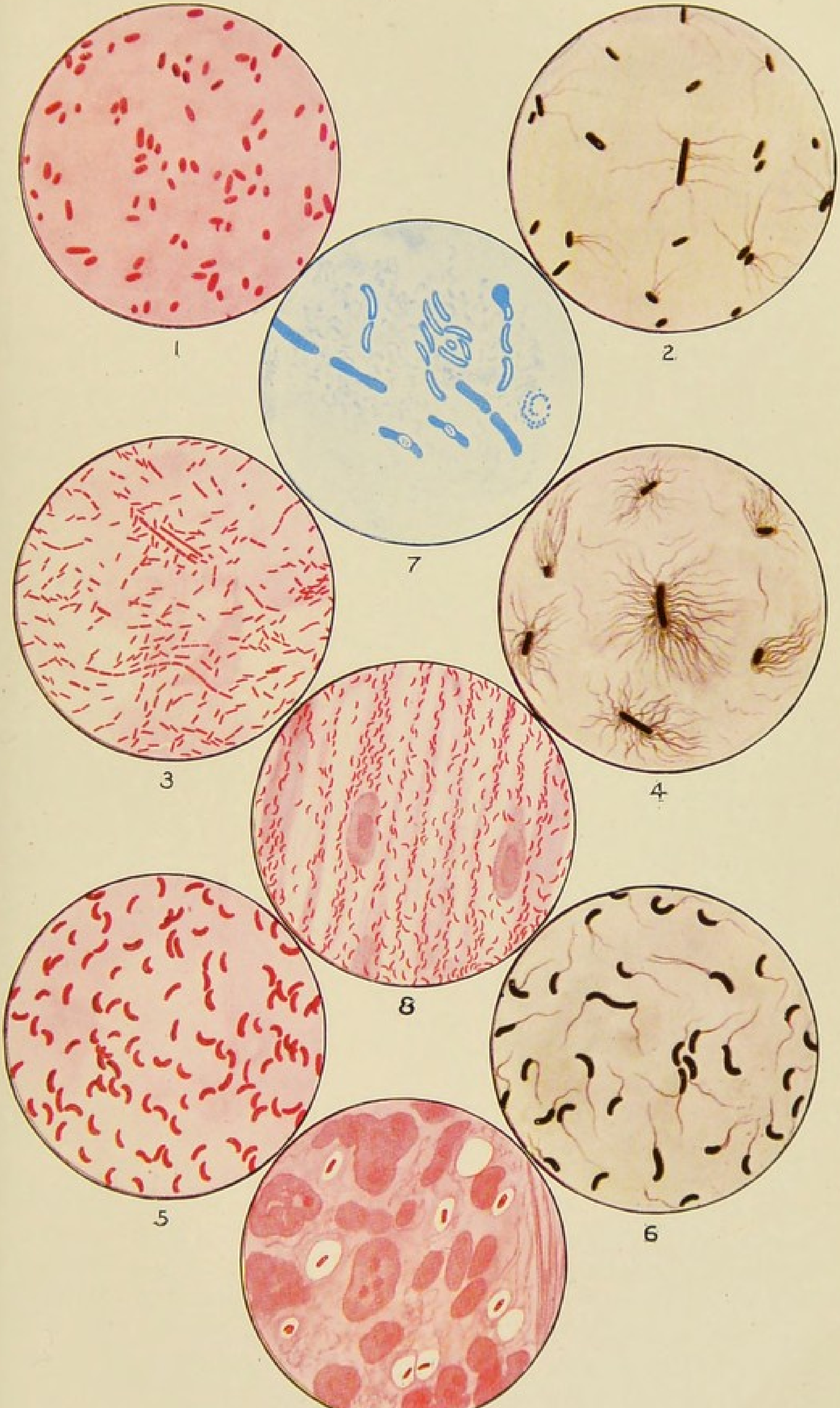
A disappearance of normal colon bacilli from the fæces has been observed in a variety of pathological conditions, such as excessive saccharo-butyric putrefaction, in some cases of mucous colitis, in various cases of dysentery due to the Shiga bacillus, and it probably also occurs in cholera and typhoid fever. A complete or partial suppression of B. coli is suggested when sugar-broth tubes inoculated with the mixed fæcal flora form little or no gas, and this suspicion can be confirmed by plate cultures on suitable media, such as litmus gelatin, Conradi and Drigalski, etc. It is now a well-established fact that B. coli can give rise to pathological changes in various tissues and organs, for it can be obtained in pure culture from the effusion in peritonitis, angiocholitis, pyelonephritis, cystitis, etc., but there has been much controversy as to whether it can give rise to abnormal conditions of the intestinal tract.

Many of the supposed examples of colon-bacillus diarrhœa at one time described were probably due to the dysentery bacillus; but as the result of modern fermentative and agglutinative tests,

EXPLANATION OF PLATE IX.

1. Bacillus coli (× ca. 1000), stained carbol-fuchsin.
2. Bacillus coli (× ca. 1000), Van Ermengem's flagella stain.
3. Bacillus typhosus (× ca. 800), stained carbol-fuchsin.
4. Bacillus typhosus (× ca. 1000), Van Ermengem's flagella stain.
5. Microspira comma (Vibrio choleræ) (× ca. 1000), stained carbol-fuchsin.
6. Microspira comma (× ca. 1000), Van Ermengem's flagella stain.
7. Microspira protea (Finkler & Prior Spirillum), after Cornil and Babes.
8. Smear from a fleck of mucus in a cholera stool, showing the characteristic arrangement of the micro-organisms (× ca. 500).
9. Smear from a particle of pus showing dysentery bacilli (× ca. 1000).

PLATE IX.



it seems to be established that some acute diarrhœal conditions may be dependent upon the activity of colon bacilli endowed with a high degree of virulence. It is not clear whether in such cases a variety normally present in small numbers, or introduced from without, has gained an ascendancy, or it is merely the usually non-virulent type that has developed irritating characters as the result of abnormal conditions in the food or environment. Almost any healthy child who has eaten an excessive quantity of ripe fruit, rich in sugar, will develop loose motions in which colon bacilli are present in large numbers, but in this type of case it is probable that the intestinal derangement is dependent upon the irritation produced by the acid and gas formed as a result of fermentative changes in the sugar brought about by the action of B. coli, and possibly other organisms, such as B. lactis aerogenes, and that the excess of colon bacilli found is merely a physiological overgrowth expelled by the diarrhœa. It is difficult to establish an etiological relation between chronic disorders of the intestinal tract and an obligate saprophyte such as B. coli, but it is probable that it actively participates in excessive putrefactive changes initiated by other organisms. B. coli by itself has practically no power to dissolve and peptonize native proteins, such as casein, etc., but it can energetically cleave peptones prepared by other micro-organisms. If there is good absorption of proteins above the level where the colon bacillus becomes predominant, very little putrefactive decomposition can occur, no matter what the nature of the inhabitants of the colon may be ; but if an excess of protein food is taken, so that native proteins find their way into the large intestine and putrefactive anaerobes are present to initiate peptonization, the colon bacillus will take an active part in breaking down the hydrolysation products that are then formed. It seems not unlikely that some such association of B. coli with peptonizing bacteria may explain the nervous and other symptoms of some cases of so-called neurasthenia that give evidences in the urine of abnormal intestinal putrefaction, and show an abnormal intestinal flora on examining the fæces. In support of this I may state that I have for some years employed autogenous vaccines prepared from the fæces in such cases with beneficial, and often very striking, results. It sometimes happens that B. coli becomes the dominant organism at a much higher level than its normal limit of the lower part of the ileum, extending up to, and even invading, the bile channels and pancreatic duct. In such cases, the conditions necessary for the exercise of its putrefactive powers are always at hand without the intermediary of peptonizing bacteria, and we consequently find that, although an examination of the fæces does not necessarily show any striking departure from the normal, the urine gives evidences of excessive putrefaction. In many instances, however, smears from the stools are strongly Gram-negative, and fermentation experiments point to an excess of coliform bacilli. If the experiments of Woolley and Newburgh, which suggest that indol, tyrosin, and other lower derivatives of protein decomposition in the intestine, when introduced into the circulation, cause hyper-activity of the suprarenals, are confirmed, it would suggest that hypertension and arteriosclerosis may be dependent upon abnormal activity of B. coli and similar organisms in the alimentary canal.

Bacillus typhosus was first clearly differentiated from B. coli by Eberth and Gaffky, independently, in the year 1884. Like B. coli, it is a short, plump, Gram-negative bacillus, but is more actively motile, possessing ten to fourteen long, undulate, peritrichic flagella (*Plate IX*, 3, 4). It is less hardy in its growth on ordinary culture media, and needs much more special conditions to thrive than the colon bacillus. It grows abundantly in dextrose and lactose broth, giving an acid reaction, but producing no gas. Milk is not coagulated, and is rendered only slightly acid. No indol is formed in cultures in peptone-broth or milk, and they do not have a fæcal odour. Neutral-red broth shows no change of colour. On potato it forms a delicate, moist, pure white, glistening growth, which is often almost invisible. To obtain a typical result the potato should have an acid reaction.

Many methods for isolating typhoid bacilli from the fæces have been introduced by various observers. Most of them depend upon the addition to the culture media of substances which are known to have a differentiating influence upon the growth of B. typhosus and other fæcal bacteria, especially B. coli. In this way a degree of selection is introduced, or a distinctive appearance of the colonies is brought about, which permits of their separation and further study. A small specimen of the fæces to be examined may be taken, and spread with a right-angled glass rod over a series of four to six plates of the selective medium without recharging, or the bacteria contained in the fæces may be separated more or less completely from the solid material of the stool with normal saline, and a few drops of this suspension be used for the inoculation. To carry out the later procedure about 4 or 5 grams of the fæces are well mixed with 15 to 20 c.c. of sterile normal saline, or broth, in a conical glass, and allowed to stand at the room temperature, or better, at 37° C., for half to one hour, in order that the heavier particles may settle. One or two drops of the supernatant fluid are then spread on a series of plates. The more commonly employed plating media are :—

Endo's medium, which is an alkaline lactose agar, containing fuchsin rendered colourless by sodium sulphite. Colonies of typhoid (and paratyphoid) are transparent, colourless, dewdrop-like, and usually measure from one to two millimetres in diameter. Owing to the acid produced by B. coli its colonies are deep red, and sometimes show on the surface a sheen from the precipitation of the fuchsin. They are from 3 to 4 mm. in diameter.

Drigalski and Conradi's medium is an alkaline agar medium containing nutrose, lactose, neutral litmus, and crystal violet. After fourteen to twenty-four hours' growth at 37° C., typhoid bacilli develop as small, glassy, dewdrop-like colonies, with a single contour. They have a bluish colour with a tinge of violet. Rarely, however, the larger colonies have a clouded appearance. The colonies of B. coli are larger, and are usually brilliant red and non-transparent. Some colonies, although bright red, are not so cloudy, and other varieties produce large colonies with a waxy appearance, and are surrounded by a red-stained area. It must be pointed out that other organisms than B. typhosus and B. coli also grow on this medium, and, like the former, do not change the colour. These colonies can, however, be usually distinguished by their size, distinctly double contour, and dull dry surface. Among these are B. fæcalis alkaligenes, and bacteria of the subtilis, proteus, and fluorescent groups. Numerous colonies of streptococci also often develop, and exactly resemble in colour those of the typhoid bacillus. They are, however, of much smaller size. The medium must be absolutely dry when used, and should be placed in the incubator for some time after the plates have been prepared, and before they are inoculated.

Conradi's new medium consists of an acid agar (+ 30) containing a mixture of 1–150,000 brilliant green and 1–15,000 picric acid. This combination was found, as the result of a very large number of experiments, to be the least hurtful to typhoid bacilli and most inhibitory to other organisms. Typhoid colonies are smooth-edged, round, and almost flat. Conradi states that colonies of some saprophytes may resemble those of B. typhosus, but that on treatment with ox-bile the saprophytes are agglutinated while typhoid are unaffected.

Löffler's malachite-green medium is of a similar character, and has been extensively used by some bacteriologists. Conradi claims, however, that typhoid bacilli grown on his brilliant-green medium do not lose their agglutinability, as is the case when they develop on one containing malachite green.

If colonies resembling those of B. typhosus are obtained on one of the above media, they are sub-cultured on to agar, and their morphological and biological characters determined. The most important test, and one which should never be omitted if a reliable diagnosis is to be made, is the reaction of the bacilli with an active typhoid serum of known strength. If a particle of the growth is mixed with a drop of typhoid immune serum, and examined as a hanging-drop with the microscope, agglutination should be seen to occur within about twenty minutes or half an hour if the organism is B. typhosus.

Typhoid bacilli have been found in the stools of patients suffering from enteric fever from the second or third week onward, and usually become more numerous as the disease progresses. They cannot be demonstrated in every case, and even with the improved technique now employed, Eberth's bacillus has only been met with in some 20 to 30 per cent of cases. Klinger examined the fæces of 428 cases, and found typhoid bacilli in 138 (31·8 per cent), but other observers have obtained much lower figures. Since the introduction of the Grüber-Widal agglutination test, and the discovery that typhoid bacilli can be isolated from the blood during the first week of the disease in about 90 per cent of cases, cultural methods for demonstrating their presence in the stools have become of little diagnostic value. Examinations of the fæces are, however, of very distinct hygienic value, for as Brückner has pointed out, all the data collected by the Commission appointed by the German Government to combat typhoid fever render it certain that the sick or healthy "carrier" is the exclusive source of the disease. From a public health point of view, therefore, it is most important that patients suffering from enteric fever should be kept under observation until repeated examinations of their excreta, including both fæces and urine, have shown them to be free from typhoid bacilli; also that when an outbreak of the disease occurs, it should be traced to its source, and the "carrier" be prevented from further spreading the infection.

Intermediate between the typical colon bacillus on the one hand and the typical typhoid bacillus on the other, there is an important group of organisms which, while more or less nearly allied to one or the other, can yet be differentiated by a careful study of their biological characters, agglutinative reactions, and pathological properties. This includes the bacilli that give rise to hog-cholera, spermophile disease, mouse-typhoid, guinea-pig disease, calves' diarrhœa, certain forms of pseudo-tuberculosis, parrot plague or psittacosis, and also the paracolon and paratyphoid bacilli, B. enteriditis, B. icterogenes, B. fæcalis alkaligenes, B. flavosepticum, and others. Many of the bacteria mentioned cause disease in animals, and have their normal habitat in the intestinal tract. Only a comparatively small number are, however, met with in human fæces.

Bacillus paratyphosus, like the typhoid bacillus, is motile, Gram-negative, does not coagulate milk, and does not produce indol, but, unlike B. typhosus, ferments certain sugars and often reduces neutral-red. Two types of paratyphoid bacilli can be distinguished by their agglutinative characters and growth on agar, gelatin, potato, and litmus-whey. *Type A* (Brion and Kayser) grows upon these culture media like the typhoid bacillus. *Type B* (Conradi-Drigalski) produces at first in litmus-whey a small amount of acid, and later alkali. Upon the other culture media it grows more luxuriantly than the typhoid bacillus. B. paratyphosus is separated from the fæces by the same means as are employed for the detection of typhoid bacilli, from which it is distinguished by its biological characters and by the agglutination test. Paratyphoid fever runs a clinical course like that of typhoid fever, only milder, especially when due to the (*B*) type. The organism is probably widely distributed, and it has been stated by Kutscher and Meinicke that it is identical with the bacillus of mouse typhoid, but while B. paratyphosus (*B*) is pathogenic for mice, it has never been proved that the bacillus of mouse-typhoid can produce typhoidal symptoms in man. Its relation to, and possible identity with, the B. enteritidis of Gaertner is of more practical importance, for bacilli of the paratyphoid (*B*) type have been shown by Levy and Fornet and others to cause outbreaks of meat-poisoning similar to those produced by B. enteritidis.

Bacillus fæcalis alkaligenes.—This organism, first described by Petrusky, is a motile bacillus with numerous flagella, which is indistinguishable from B. typhosus, excepting that it usually, but not invariably, gives an alkaline reaction with litmus-whey, and its growth on potato is brown. It can also be differentiated by the serum reaction. It is said to give rise to a febrile state clinically indistinguishable from mild forms of typhoid fever.

Psittacosis is a septicæmia affecting parrots, which is transmissible to man. At the onset, the disease resembles typhoid fever; but later, the pulmonary symptoms overshadow the intestinal affection. It is said to be due to a bacillus, discovered by Nocard in 1893, which closely resembles B. typhosus morphologically and culturally.

In broth it forms, however, a thin pellicle on the surface, its growth on gelatin is more abundant than that of Eberth's bacillus, and corresponds more to that of B. coli, while on potato it also forms a growth resembling that of the colon bacillus. It neither ferments sugars nor coagulates milk. It is only very feebly agglutinated by typhoid-immune serum.

Bacillus flavosepticum may be mentioned here, for, although it is readily differentiated from B. typhosus and B. coli by the fact that it liquefies gelatin and forms yellow colonies, it was separated by Brion and Kayser from the stools of a patient who suffered from a fever clinically resembling mild typhoid.

Morgan's No. 1 Bacillus.—This organism was isolated by Morgan from the stools of twenty-eight out of fifty-eight cases of infantile diarrhœa in 1906, and was also obtained from the fæces of a nurse in charge of the cases. It is a motile bacillus slightly smaller than B. typhosus, and like the latter has numerous flagella. In litmus milk it forms no acid, but after about a fortnight gives an alkaline reaction. Dextrose is fermented, with the formation of acid and gas, but lactose and saccharose are not attacked. Cultures in peptone solution give a well-marked indol reaction.

Bacillus enteritidis (Gaertner) is a short, thick, Gram-negative bacillus, which may or may not be surrounded by a capsule. It does not liquefy gelatin, and the surface colonies are round, grey, translucent, and granular. In lactose broth it gives an acid reaction and forms gas. The growth on potato is greyish-white to greyish-yellow, and glistening. It has been found in association with a number of outbreaks of food poisoning, particularly those due to veal and pork.

Bacillus icterogenes is morphologically and culturally like B. coli, but grows less vigorously. It forms little or no gas in lactose broth, and never any gas in saccharose broth. Milk is rendered slightly acid. It has been separated by Pasquale from typhoid stools, and was obtained by Guarniere from the liver and blood in acute yellow atrophy of the liver.

Bacillus pestis.—Plague bacilli have been found in a few instances in the fæces of plague patients. Their detection is accomplished by rubbing the fæces into the shaved abdomen of a guinea-pig and examining its tissues after death. B. pestis is a short bacillus, which does not retain Gram's stain, and with many dyes shows marked polar staining (*Plate X*, 1). Gelatin is not liquefied, and milk is not coagulated. On potato there is a scanty whitish-grey growth. The most characteristic appearance is seen when a large bulk of broth is inoculated and left completely at rest in the incubator. Under these circumstances a film, adherent to the walls of the flask, forms on the surface, and stalactite-like growths project into the body of the medium from its under-surface.

Bacillus dysenteriæ.—Tropical dysentery is an amœbic disease, due to the amœba coli, which has been considered with the animal parasites. Epidemic non-tropical dysentery has been shown by Shiga, Kruse, and Flexner to be dependent upon the activities of bacilli which are of the colon type. These bacilli are found in the mucoid and purulent portions of the stools, sometimes almost in pure culture. (*Plate IX*, 9). Although agreeing in most points, the organism described by Flexner differs in some respects from that described by Shiga and Kruse. They are both plump bacilli, which do not retain Gram's stain, and are usually said to be non-motile, although some authors state that motility can be detected in young cultures. They do not liquefy gelatin or coagulate milk. In some of its biological characters Flexner's bacillus is more closely allied to B. coli than the Shiga-Kruse organism, retaining more fully the capacity to ferment sugars, such as lactose, maltose, and mannite, and also forming indol in peptone solutions. The Flexner bacillus gives a denser yellowish, more coli-like growth on potato than the Shiga bacillus, cultures of which on this medium are white and almost invisible, like B. typhosus. The two types are further distinguished by their agglutination reactions, and to some extent by their action with immune sera.

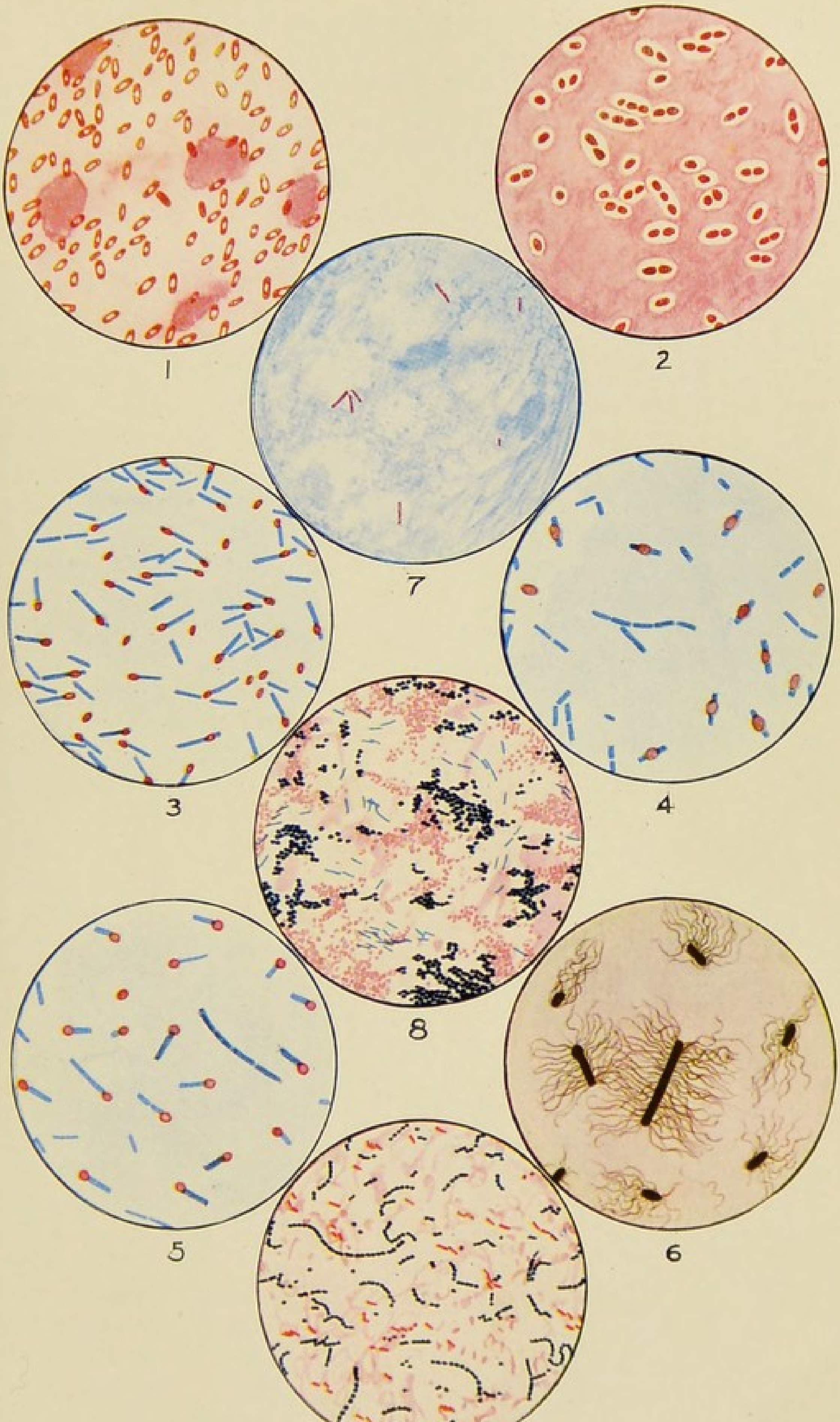
Subsequent observation has shown that, in addition to the two main types of dysentery bacillus mentioned, there are other forms. Shiga now recognizes five intermediate groups, differing in their fermentative characters. Some writers classify these and Flexner's organism as " para-dysentery " bacilli, reserving the term dysentery bacillus for the form described by Shiga and Kruse, but as the lesions caused by them are apparently identical with those produced by the Shiga bacillus, such a terminology is only likely to lead to confusion.

Dysentery bacilli can be most readily differentiated from B. typhosus by their plumpness, their lack of motility, and by the absence of flagella. The clinical symptoms associated with the two organisms are so different, however, that there is little danger of the diseases being confused, and if typhoid-like bacilli can be demonstrated in the stools of a patient exhibiting the symptom-complex of dysentery, it can be concluded with a considerable degree of certainty that it is a case of bacillary dysentery.

EXPLANATION OF PLATE X.

1. Bacillus pestis (× ca. 1000), stained carbol-fuchsin.
2. Pneumococci (× ca. 1000), stained carbol-fuchsin to show capsules.
3. Bacillus aerogenes capsulatus (B. perfringens), showing spores (× ca. 1000), carbol-fuchsin and methylene blue.
4. Bacillus œdematis (B. œdematis-maligni), showing spores (× ca. 1000), carbol-fuchsin and methylene blue.
5. Bacillus tetani, showing spores (× ca. 1000), carbol-fuchsin and methylene blue.
6. Bacillus tetani (× ca. 1000), Van Ermengem's flagella stain.
7. Tubercle bacilli (× ca. 1000), Ziehl-Neelsen.
8. Staphylococci enteritis (× ca. 1000), Weigert-Escherich.
9. Streptococci enteritis (× ca. 1000), Weigert-Escherich.

PLATE X.



Examination of Fæces — *P. J. Cammidge*

Flexner's bacillus and the intermediate forms are more commonly the cause of acute attacks of dysenteric diarrhœa in this country than Shiga's organism, and are also frequently met with in cholera infantum and asylum dysentery.

A survey of the various members of the group which have been considered will show that while B. coli possesses to a marked degree certain biological characters, such as the power to coagulate milk, reduce neutral-red, form indol in peptone solutions, and ferment sugars with the liberation of acids and gas, these properties have been lost by B. typhosus, with the exception of the capacity to form acid from some sugars. Coincident with this alteration in biological features there has been developed a much increased pathogenicity for man, a property no doubt dependent upon the formation of other, as yet unknown, chemical products. The intermediate organisms possess increased, or diminished, pathogenic powers as their biological characters correspond more closely to one or other of these extreme types.

The chief points in which the more important members of the group differ from each other, and by which they may be distinguished, are shown in table form on the following page.

Fermentative Organisms growing in Acid Media.—When considering the growth of the mixed fæcal flora on various media, we saw that certain organisms of the B. acidophilus type had the power of growing in dextrose broth containing a percentage of acid which inhibits the development of most other bacteria. Bacilli of this type are characteristic of the nursling's stool, and are also found in relative abundance when a purely carbohydrate diet is taken. Whether they can assume pathological characters is not certain, but Herter states that organisms indistinguishable microscopically from B. bifidus are found to be almost exclusively the inhabitants of the lower digestive tract in some children suffering from chronic intestinal indigestion with abdominal distention and retarded growth. He also points out that a bacterial form which is entirely physiological when dominant during infancy, may not be equally physiological when it constitutes the dominant type in later years, for it may carry with it a relatively feeble power of defence against some harmful bacteria. A determination of the presence and relative abundance of fermentative organisms may therefore give a clue to a pathological condition which would otherwise be inexplicable.

Bacillus bifidus.—This organism (*Fig.* 67), was originally included by Escherich with the colon bacillus, but was separated by Tissier, who recognized its distinctive characters. It is a small bacillus of

	B. coli	B. typhosus	B. paratyphosus A. (Schottmüller)	B. paratyphosus B. (Schottmüller)	B. alkaligenes	B. enteritidis (Gaertner)	B. dysenteriæ Flexner	B. dysenteriæ Shiga-Kruse
Motility	Slight	+	+	+	+	+	O	O
Flagella	4–10	10–15	8–12	8–12	8–12	—	—	—
Gram stain	O	O	O	O	O	O	O	O
Gelatin, liquefaction	O	O	O	O	O	O	O	O
Peptone solution-indol	+	O	O	Tr.	O	O	+	O
Milk, coagulation	+	O	O	O	O	O	O	O
Litmus-whey	Acid	tr. Acid	Persistent tr. acid	Tr. acid, then alk.	Alk.	Tr. acid, then alk.	Acid, later alk.	Tr. acid later alk.
Neutral-red	Fluorescent	O	Slowly fluorescent	Fluorescent	O	Fluorescent	O	O
Potato	Thick, light brown	Faint white, glistening	Faint white, glistening	White, glistening	Light brown	Thick yellow, brown	Yellowish	Faint white
Fermentation: Dextrose	Acid and gas	Acid	Acid and gas	Acid and gas	Acid	Acid and gas	Acid	Acid
Lactose	Acid and gas	O	O	O	O	O	O	O
Saccharose	O	O	O	O	O	O	O	O
Maltose	Acid and gas	Acid	Acid and gas	Acid and gas	—	—	Acid	O
Mannite	Acid and gas	Acid	Acid and gas	Acid and gas	—	Acid and gas	Acid	O
Raffinose	O	O	O	O	—	O	Acid	O
Dulcite	Acid and gas	O	Acid and gas	Acid and gas	—	Acid and gas	—	O
Sorbite	—	Acid	—	—	—	—	O	O
Glycerin	Acid	Acid	Slowly	Slowly	—	Slowly	—	—
Salicin	O	O	+ or O	O	—	O	O	O

moderate thickness, varying between 3 and 5 microns long and 0·2 to 0·4 micron broad. It is usually straight, but may be slightly bent. The ends are rounded or may be pointed, and occasionally, owing to attenuation of one end and development of the other, it may assume a comma form. Although distinctly Gram-positive, B. bifidus varies very much in the degree to which it retains the stain, both in material from the same individual at different times, and in different persons. Occasionally some portions stain with much greater intensity than others, giving what Escherich described as " punctate " bacilli. Sometimes in smears from the fæces, and more commonly in culture, one end of the organism is seen to be bifid, and it is from this peculiarity that it takes its name. A cephalated, knobbed, or headlet (Knöpfchen) variety, in which one or both ends are enlarged, can occasionally be found. In preparations which have been fixed with heat and stained with Lugol's solution, granules, generally limited to the peripheral ends, can be made out. In hanging-drop preparations made from fresh material, many of the bacilli show sluggish movements, which are, however, soon lost. The fact that the organism is strictly anaerobic accounts for its presence being overlooked for so long in the fæces, B. coli, and other organisms which grow well in the presence of air, interfering with its development on ordinary media. Even in anaerobic cultures, organisms of the coli group and some diplococci, which are facultative anaerobes, are apt to restrict the growth of the less hardy B. bifidus, so that pure cultures are not easy to obtain. On sugar-agar, small, white, lens-shaped, smooth-edged colonies appear in the depths of the medium in about three days, and on microscopical examination show marked polymorphism, all the three varieties mentioned being represented. Cultures made from material which has been heated at 80° C. for a quarter of an hour show spore-bearing bacilli, which appear to be identical with the headlet form of B. bifidus. This bacillus is the predominant organism of the nursling's stool and, although much less abundant,

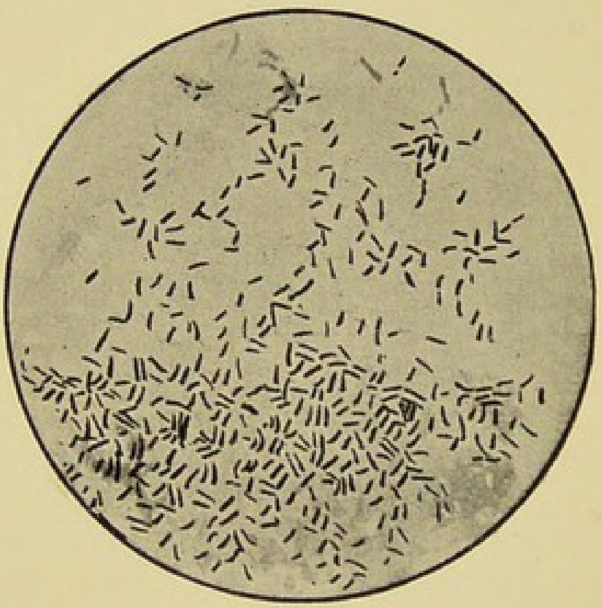


Fig. 67.—Bacillus Bifidus.

it is still present in the fæces of infants brought up on cow's milk. It is usually only scantily represented in the fæces of the adult, but may occasionally be found in considerable numbers even in elderly persons.

Bacillus acidophilus (Fig. 68) was described by Moro, and shares with B. bifidus the power of growing in a more strongly acid medium ($\frac{1}{2}$ to 1 per cent acetic acid) than most organisms met with in the alimentary tract. It is usually somewhat shorter, but stouter, than B. bifidus, measuring 1·5 microns long by 0·6 to 0·9 micron broad. It is non-motile and is Gram-positive. It grows only with difficulty on gelatin, and not at all on potato. In sugar-agar it forms small white colonies with dentate margins, in the depths of the medium. The most luxuriant growth is obtained in acid glucose broth, or beer-wort, in which it produces a large quantity of acid and but little gas. Unlike B. bifidus, this organism is aerobic.

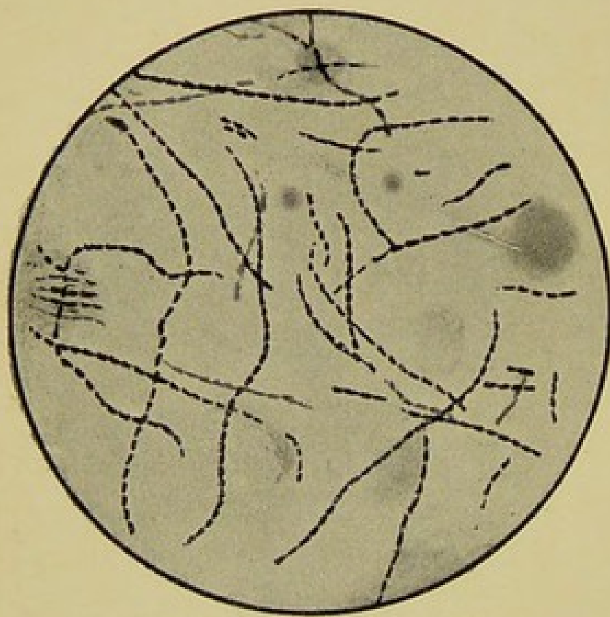


Fig. 68.—Bacillus Acidophilus.

Blue Bacillus of Escherich.—In 1898 Escherich investigated a very severe outbreak of diarrhœa occurring in young children, and found that their stools showed, instead of the usual excess of Gram-negative organisms, a large number of blue-stained bacilli (*Plate VIII*, 2). Some of these resembled B. coli morphologically, and others were more like the organisms met with in breast-fed children. On culture, some were found not to grow at room temperature, and to resemble in many respects the pseudo-diphtheria bacillus, while others belonged to the streptothrix group and formed radiating colonies on agar. It was not determined to which of these species the pathological organisms belonged. Subsequently Finkelstein and Salge investigated other cases in which the "blue bacillus" of Escherich was found. It is said that this organism can be distinguished from the Gram-positive bacilli of normal infants' stools by the irregular way in which they stain with Gram and by thei less uniform shape. They are also stated to be more resistant to acids, and to form colonies on sugar-agar which are more opaque.

Facultative Anaerobes, Liquefying Gelatin.—Organisms of this type are met with in the fæces both in health and disease. Owing to the power which they possess of liquefying gelatin and attacking native proteins, they have been regarded as important causes of putrefactive changes in the intestinal contents, but it is probable that they are much less active in this respect than many of the obligate anaerobes to be considered presently.

Bacillus vulgaris, or *Proteus vulgaris*, is the most important member of the group. It is a Gram-negative bacillus, measuring 1·2 to 4 microns long by about 0·6 broad, and is provided with numerous flagella. It commences to liquefy gelatin in about six to eight hours, a small depression forming in the medium in that time. On agar it gives a translucent, moist, slimy growth. Milk is coagulated and becomes acid, but no marked peptonization occurs. On potato it gives a yellowish-white, raised growth, with a putrefactive odour and alkaline reaction. In lactose broth it forms no gas, but in dextrose and saccharose broth there is well-marked gas-formation, with a gas index of $\frac{H}{CO_2} = \frac{2}{1}$. B. vulgaris is sometimes found in the fæces of healthy individuals in moderate numbers, and was at one time regarded as the organism mainly responsible for putrefactive changes in the intestinal contents. Under certain circumstances it can no doubt give rise to acute disease of the gastro-intestinal tract, a number of outbreaks of poisoning following the ingestion of meat, sausages, and cheese having been shown to be due to its presence.

Bacillus entericus.—Another Gram-negative facultative anaerobe which rapidly liquefies gelatin is B. entericus. It was described by Ford, and subsequently met with by Herter in the stools from cases of pernicious anæmia. Like B. vulgaris, it is actively motile, does not form spores, and ferments dextrose and saccharose, giving an acid reaction and much gas. It is, however, able to ferment lactose also. On potato it gives a dirty-brown growth that spreads very rapidly. In litmus milk an acid reaction is first produced, but later it becomes alkaline. No peptonization of the casein takes place.

Bacillus cloacæ is a small Gram-negative bacillus which gives a white porcelain-like growth on agar, rapidly liquefies gelatin, and forms a yellowish growth on potato. Milk is rendered acid and is coagulated. It ferments dextrose, lactose, and saccharose broth, forming gas with an index of $\frac{H}{CO_2} = \frac{1}{3}$.

Bacillus bookeri is a small, actively motile bacillus, measuring 0·5 to 1·5 by 2 microns, isolated by Booker from the alvine discharges of children suffering from cholera infantum. Gelatin is slowly but completely liquefied. The growth on potato is yellowish-white and luxuriant. In litmus milk there is an intense alkali production, without any preliminary acidity. The casein is not coagulated, but is slowly liquefied. Blood serum is also slowly peptonized. Dextrose, lactose, and saccharose broth give an abundant growth, but there is no gas-formation and the reaction is alkaline. Growth in peptone solutions does not give any indol.

Bacillus anthracis.—Anthrax-like organisms are not uncommonly seen in cover-glass preparations made from the fæces, but cultural experiments show that these are usually of the B. subtilis and B. aerogenes capsulatus types. Intestinal anthrax is very rare in man, although it is common in cattle and less common in the horse. It is said to be occasionally produced by the ingestion of infected meat. In cases of pulmonary anthrax (woolsorter's disease), anthrax bacilli and spores may be passed in the stools.

Bacillus anthracis is most readily isolated from the fæces in cases where the frequent blood-stained motions point to an intestinal infection. Cultures are prepared on gelatin and agar plates, the characteristic hair-like colonies are removed, grown in pure culture, and their identification completed by injections into white mice. B. anthracis is an aerobic, and facultative anaerobic, spore-forming bacillus. It retains Gram's stain. Milk is coagulated, peptonized, and rendered slightly alkaline. Gelatin is slowly liquefied. In gelatin stabs a very characteristic arborescent growth appears. On potato it gives a greyish-white dense elevated growth.

Other Gram-negative liquefying anaerobes are sometimes found in the intestinal contents. Among these may be mentioned B. subentericus (Ford), which is closely allied to B. entericus, and only differs in the fact that it does not ferment saccharose; B. plebius and B. infrequens, which resemble B. vulgaris; B. recti, B. pylori, and B. cæci, which resemble B. bookeri. For further details respecting these the reader is referred to Ford's papers, in which they are fully described.

Organisms Liquefying Gelatin and Giving a Coloured Growth.—Occasionally, cases of diarrhœa are met with, particularly in children, in which the stools are of a bright-green colour. In some of these the coloration is due to the presence of unreduced bile pigment, which can be recognized by its characteristic chemical reactions; but in others the appearance of the stools is dependent upon the presence of pigments elaborated by micro-organisms.

Bacillus lesagei or *viridis* was first described by Hayem and Lesage, who considered that it was a pigment-forming variety of B. coli. This, however, is not the case, for, although it is a short bacillus which forms filaments, it slowly liquefies gelatin and retains Gram's stain. In gelatin stabs it grows only on the surface, forming a thin spreading film which has a green fluorescence and an irregular margin. On potato it gives a dark green, or rarely reddish, growth, with an odour of stale urine. Both by feeding experiments and by intravenous inoculation it has been found to produce " green diarrhœa " in rabbits.

Bacillus pyocyaneus is stated to have been found in the stools in some cases of green diarrhœa, and is also said, by Herter, to be occasionally present in the digestive tract of persons apparently in the best of health. It is a small, Gram-negative, actively motile bacillus, which grows readily on all ordinary culture media at room temperature. On gelatin it forms yellowish-green colonies that liquefy the medium. Milk is coagulated and peptonized within forty-eight hours. In sugar fermentation tubes it forms acid but no gas, and a greenish pellicle forms on the surface of the broth in the open limb.

Bacillus prodigiosus.—In 1905, Parkes reported an outbreak of diarrhœa apparently due to the ingestion of food contaminated with *B. prodigiosus*, although the organism does not appear to have been isolated from the intestinal discharges. The diagnosis was based upon the presence of the typical pink bacillus in the food, and the fact that the diarrhœa ceased when the use of the larder where it had been stored was discontinued.

Microspira (Spirilla).—In 1883, Koch discovered in the intestinal discharges, and also post mortem in the intestinal contents, of patients suffering from cholera, an organism which is now generally known as the " Comma bacillus " or " Cholera spirillum." Since that date other observers have confirmed his results, and also described a number of similar organisms found in the stools of patients with acute diarrhœa and other intestinal affections. Some of these closely resemble the comma bacillus, but others differ so widely in their cultural and other characters that they must be classified as different species. To avoid confusion with the true spirilla, which possess a bundle of polar flagella, the name microspira has been given to this group. The microspira (Migula) are small, slightly curved comma-shaped bacilli, which are provided with one, or rarely two or three, polar flagella (*Plate IX*, 5, 6). They do not form spores, and although aerobic, are able to adapt themselves to an atmosphere in which there remains only a minimal trace of oxygen, provided it is withdrawn slowly (Williamsky). Gelatin is liquefied by many members of the group, by some more rapidly than by others. They do not retain Gram's stain.

Microspira comma (Comma bacillus, Spirillum choleræ-asiaticæ, Vibrio choleræ) is by far the most important. Its presence in the fæces may often be suspected from a microscopical examination of a smear, prepared if possible from a mucus fleck taken out of the watery stool. Stained with dilute carbol-fuchsin, large numbers of comma bacilli, arranged in characteristic "shoals," and sometimes in pure culture, may be seen (*Plate IX*, 8). Hanging-drop cultures of mucus flecks in alkaline peptone water, incubated at 37° C. for half an hour, will at times assist in the diagnosis by revealing large numbers of motile comma bacilli, especially at the margins. As a rule it is not possible to distinguish the cholera bacillus among the numerous other organisms in the stool, and in any case the diagnosis must be confirmed by cultural examination and serum tests. Where only a few organisms are probably present, their development may be favoured by mixing about 1 c.c. of the fæces with 50 c.c. of alkaline peptone solution, incubating at 37° C. for six to twelve hours, then withdrawing a little of the fluid from the surface without disturbing the rest, and preparing cultures on gelatin and agar from this. Gelatin and agar plates may also be prepared directly from the fæces. As the organism grows best in an alkaline medium, 3 c.c. of a 10 per cent solution of sodium hydrate should be added to each 100 c.c. of the medium, previously neutral to litmus, before use. On alkaline gelatin, after eighteen to twenty-four hours at 22° C., cholera colonies appear as very small bright points, which, when examined with a low power of the microscope, are seen as small, round, yellowish, coarsely granular, glistening discs, with wavy outlines. In twenty-four to thirty-six hours it will be found that the gelatin surrounding the colonies is liquefied. On alkaline agar, after twenty-four hours at 37° C., they are seen as small transparent colonies, which, when held against the light, have a bluish iridescence. Their transparency distinguishes them from most other fæcal bacteria. Subculture into broth, alkaline peptone water, milk, and gelatin gives confirmatory evidence. In broth the comma bacillus grows luxuriantly, clouding it evenly, and forming a film on the surface. Alkaline peptone water is a selective medium to some extent for all microspira, which grow more rapidly in it, especially near the surface, than other bacteria. A twenty-four hours' culture gives the nitroso-indol ("cholera-red") reaction, which, although suggestive, is not conclusive evidence of the presence of cholera bacilli, as was at one time supposed. Milk is not coagulated at first, but after two days at 37° C. it is found to be acid and a coagulum forms. In litmus milk a blue pellicle appears on the surface, but below the medium is red. Stab cultures in gelatin are characterized by the fact that on the surface the gelatin is liquefied very rapidly to form a funnel-shaped depression, while in the depths the liquefaction takes place only in the immediate neighbourhood of the needle track. No gas is formed in dextrose, lactose, or saccharose broth, but in dextrose broth left-handed lactic acid is produced. On acid potato there is no growth, but on alkaline potato it gives a dirty yellowish-white growth, which later becomes brownish-red. Serum diagnosis affords the most reliable means for differentiating the comma bacillus from other microspira which may be met with in the fæces, and which cannot often be readily distinguished by their morphological and cultural characters. Only such organisms as are agglutinated by high dilutions of a serum obtained from animals immunized with comma bacilli, and are dissolved by the bacteriolytic elements of such a serum (Pfeiffer's test), can be regarded as true cholera organisms. Such thorough and complete proof is particularly necessary in the examination of the stools of isolated cases presenting choleraic symptoms, which may be the commencement of an epidemic, and also in the detection of " contact " and " carrier " cases. In the course of an epidemic, and in the examination of the stools of convalescents, cultural examinations and a simple agglutination test in a hanging-drop preparation will usually suffice.

The *Vibrio invanoff*, cultivated by Ivanoff from the stools of typhoid patients, reacts to Pfeiffer's test like a cholera organism, and is probably only a morphological variety. The *Vibrio romanus* was obtained by Celli and Santori from the fæces of twelve out of forty-four cases presenting symptoms of mild diarrhœa. They looked upon it as a transitory variety of the comma bacillus. A somewhat similar organism, *Vibrio lisboni*, was cultivated by Pestana and Bettencourt from a number of cases during an epidemic in Lisbon of gastro-enteritis, with choleraic symptoms in a few instances. Neither organism is pathogenic to animals, and the latter reacts negatively to Pfeiffer's test. *Spirillum massauah* was obtained by Pasquale during an outbreak resembling cholera at Massauah. It possesses four flagella, and differs slightly from the comma bacillus in its cultural characters; moreover, it gives a negative Pfeiffer's reaction. *Spirillum gottschlich* was obtained from the stools in an outbreak of cholera nostras, and differs from the organism of Asiatic cholera in developing much sulphuretted hydrogen in all cultures, and not giving the nitroso-indol reaction. An organism that attracted much attention at one time was the vibrio of cholera nostras described by Finkler and Prior, also known as the *Vibrio proteus* or *Microspira protea* (*Plate IX*, 7). It was obtained from the stools of cases of cholera nostras after they had been allowed to stand for some days, and has since been isolated from many other sources. Although it is rather thicker in the centre and more pointed at the ends than the comma bacillus, it is chiefly by its cultural characters that it is differentiated. It liquefies gelatin much more rapidly, a stab-culture showing commencing liquefaction in twenty-four hours, and a well-marked funnel in forty-eight hours. A slimy, greyish-yellow growth forms on potato at room temperature in twenty-four hours. Grown in peptone solution, no cholera-red reaction is given within twenty-four hours, although later a faint reaction may be obtained. On experimented animals its action is similar to that of the comma bacillus, but milder. *Spirillum helcogenes* is a similar organism that has been isolated from the stools in diarrhœa.

Cocci.—Streptococci, diplococci, and staphylococci are normal inhabitants of the intestinal tract, and are consequently met with in the fæces. Houston examined a number of normal stools, and found streptococci in numbers varying from a thousand to ten millions per gram. Diplococci are also numerous, but staphylococci are usually present in comparatively small numbers. The normal Gram-positive diplococci of the intestine form chains in broth culture, and are not pathogenic for guinea-pigs. At times the *pneumococcus* may be found in the fæces in large numbers (*Plate X*, 2). According to Rutz they are very constantly present in acute lobar pneumonia, and are the cause of the tympanites that occurs in this disease. Sahli states that Fraenkel's pneumococcus is a frequent cause of intestinal infection, which may be shown merely by a febrile reaction or by pronounced symptoms of enteritis. The digestive tract is much less resistant to the attacks of streptococci during infancy than in later life, and some of the severest forms of infantile ileo-colitis are associated with streptococcal infections (*Plate X*, 9). At times dysenteric and coli-like forms may be met with at the same time, and it is then difficult to say how far the disease is due to these. In many instances it is probable that the streptococcal infection is secondary, although ultimately it may be chiefly responsible for the symptoms. Streptococcal infections may also give rise to diarrhœal disorders in adults, but they are more commonly associated with chronic catarrhs and auto-intoxications. It has been claimed by Gordon that streptococci can be divided into types according to the power they possess of fermenting different carbohydrates, etc. The activities of the commonest forms in this respect are tabulated by Andrewes and Horder as follows :—

	Saccharose	Lactose	Raffinose	Inulin	Salicin	Coniferin	Mannite	Milk	Neutral red
Strept. longus	+	+	o	o	+	o	o	o	o
Strept. brevis..	+	+	+ / o	o	o	o	o	+	+ / o
Strept. fæcalis	+	+	o	o	+	+	+	+	+
Pneumococcus	+	+	+	+ / o	o	o	o	+ / o	o

The specificity of these tests has been questioned recently by Walker and others, who state that on re-testing various strains after cultivation on various media, and after passage through animals, the original reactions are materially changed. It remains to be seen whether the modification of Gordon's method, introduced by Winslow, of estimating quantitatively the amount of acid formed, will give more helpful results. For the present it may be concluded that, while there are variations in streptococci brought about by alterations in their surroundings, we have no reliable evidence that more than one species exists, so that, although the fermentation tests may be of use in sanitary work for determining the probable source of a streptococcal infection of milk or water, they do not furnish a means of differentiating pathogenic from non-pathogenic varieties in fæcal and similar examinations.

Staphylococci and streptococci are sometimes met with in the intestinal contents in large numbers as the result of an abscess breaking into the bowel, but apart from this, cultures may occasionally show that staphylococci are among the dominant organisms of the fæces (*Plate X*, 8). In such cases there are often symptoms of excessive intestinal putrefaction, probably dependent upon the power which staphylococci have of peptonizing and liquefying proteins. Comparatively little is known as yet, however, with regard to the coccal forms met with in the fæces in health and disease.

Anaerobic Bacteria.—Until recently the strict anaerobes of the intestine have received very little attention. The greatest amount of work has been devoted to the butyric-acid-forming group, of which the gas bacillus (B. aerogenes capsulatus) is a typical example. As with organisms of the colon group, it has been found that the different members, while fairly sharply differentiated from each other, pass, by a series of intervening forms, from one extreme type to another, so that precise classification is difficult. Since they show the phenomenon of group-agglutination it is obvious that they are closely akin. The pathological significance of the anaerobic intestinal flora is as yet almost an unexplored field. Numerous experiments have led to the belief that the bacteria, including the anaerobes, of the intestinal tract are beneficial, in the main, and it is apparently only when certain forms become unduly prominent, or alterations in the diet, etc., afford opportunities for the abnormal activity of some particular organism, that direct harm results. The problem of establishing a definite etiological relation between a specific disease and a normal bacterial inhabitant of the intestine, and especially with a strict anaerobe, is very great. In a few instances such an association appears to have been made out. Thus Herter has found that primary anæmias of the pernicious type are commonly associated with a predominance of B. aerogenes capsulatus in the fæces, and Campbell claims that the enteric catarrh of infancy, which usually follows on an excessive sugar diet, is due to the formation of toxins by the same organism from the sugar reaching the lower ileum and colon.

Bacillus putrificus.—This organism, described by Bienstock, is a slender bacillus which forms spores, and is strictly anaerobic. On gelatin it appears as a mother-of-pearl growth which becomes yellowish. It is capable of attacking and hydrolysing native proteins, and gives rise to characteristic products of putrefaction, such as butyric acid, hydrogen, hydrogen sulphide, and mercaptan, but not usually indol. Bienstock has recently brought forward evidence to show that two distinct bacteria are included under the name B. putrificus; one, the true form, attacks native proteins, such as fibrin, and the other, although morphologically indistinguishable, does not attack them, but decomposes sugars. The latter is termed by Bienstock B. para-putrificus, and is, he states, the organism met with normally in the contents of the lower bowel. As B. putrificus is very widespread, being present in most samples of dust, and is commonly associated with other organisms in intestinal conditions where there are abnormal putrefactive changes going on, it is not easy to determine its rôle in the production of disease, but, according to Herter, it is probable that it plays a part in certain putrefactive disorders.

Bacillus liquefaciens ilei is a long, slender, Gram-negative bacillus, described by Nencki. It is usually abundant in the lower ileum, ascending colon, and cæcum, and may be met with in the fæces. According to Herter, it is probably a vegetative form of *B. putrificus*.

Bacillus subtilis.—Organisms of the subtilis type are found in fæces with great constancy. They are large stout bacilli, with rounded ends, which retain Gram's stain. On agar they give a grey-white, glistening, mealy growth, resembling that of anthrax. Gelatin is rapidly liquefied, and a white pellicle forms on the surface. A similar pellicle, adherent to the walls of the tube, forms on the surface of broth, and the medium becomes turbid. Milk is coagulated and peptonized, and becomes slightly alkaline. The growth on potato is whitish-grey, thick, and mealy. These organisms are aerobes and facultative anaerobes. They form spores, which are situated equatorially, but the shape of the bacillus is not altered by their presence.

Bacillus mesentericus, and the allied organism, *B. mesentericus vulgatus*, closely resemble B. subtilis, but are usually slightly shorter. They both liquefy gelatin and form a surface membrane. In broth there is a turbidity, and a firm pellicle forms on the surface. Milk is slowly coagulated, becomes faintly alkaline, and in the case of B. vulgatus is peptonized. On potato, a thin white crumpled growth is formed. Agar slants in the case of B. vulgatus give a grey-white glistening growth, and in the case of B. mesentericus a yellowish-brown glistening raised growth. They are Gram-positive. Both organisms have been found in the intestinal contents, and especially in the stools of infants and children suffering from diarrhœa.

Bacillus aerogenes capsulatus (B. perfringens, B. enteritidis sporogenes, B. welchii, Granulo-bacillus immobilis liquefaciens, the Gas bacillus, or the Gas-phlegmon bacillus). Although described under a large variety of names in different countries and by different observers, it seems probable that these organisms are all varieties of one form, differing slightly only in their pathogenicity and minor characters. B. aerogenes capsulatus is a strictly anaerobic, spore-forming, non-motile bacillus, that retains Gram's stain. It is found in small numbers relative to other bacteria, in the intestinal contents of most adults, and in still smaller numbers in healthy children. As seen in the fæces it is a large, plump, straight bacillus, with slightly rounded ends, and can often be shown to be surrounded by a capsule (*Plate X*, 3). The latter can, however, be more readily made out in organisms that have developed in a living or dead rabbit. It occurs sometimes singly, often in pairs, end to end, occasionally as threads which may be nearly straight or be bent sharply on themselves. Spore-formation only takes place under special conditions, such as on a medium containing blood-serum, or within the body of an animal. Sugar-broths are rapidly fermented, twice as much, or more, gas being formed in twenty-four hours as is usually produced by coliform organisms. The gas consists of hydrogen and carbon dioxide in the proportion of two to one or three to two (Theobald Smith). Grown in milk, B. aerogenes capsulatus induces rapid gas-formation, with disruption of the curds into small masses, and peptonization of the casein. In nearly sugar-free media the bacillus produces butyric acid, and at the same time ammonia, which serves to partly neutralize the acid. Some strains do not form indol when grown in blood bouillon, but others do. Herter has shown that five-days-old cultures in this medium contain hæmolytic substances, and Kamen states that soluble poisons, capable of producing a state of nervous excitement, followed by general convulsions and paralysis of respiration in animals, are formed. In rabbits that have been inoculated with the organism, then killed, and incubated, rapid liquefaction of the muscles, liver, etc., occurs. At the same time a marked gas-formation, associated with a characteristic sweetish sickening odour, takes place. The gas obtained from the peritoneal cavity and connective tissue burns with a blue flame, and gives the characteristic " bark " of hydrogen when the light is applied. Opinions differ widely as to the pathogenic powers of B. aerogenes capsulatus for man, but this appears to be due largely to the fact that organisms isolated from different sources vary very much in their virulence. It is certain that some acute diarrhœas are associated with the presence of large numbers of the bacillus. Such have been described by Tissier in nursling children, and by Klein and Andrewes. Howard has reported instances where superficial necrosis of the mucous membrane of the intestine and stomach was associated with the presence of large numbers of B. aerogenes capsulatus. Herter considers that the diarrhœas common in persons with severe primary anæmia may be due to the combined action of this organism and streptococci.

Bacillus œdematis (B. œdematis-maligni, Vibrio septique).—This, which is a Gram-negative organism, but otherwise closely resembles B. aerogenes capsulatus, is sometimes found in the human intestine and fæces (*Plate X*, 4). Whether it ever occurs in large numbers, or is of pathological significance, is not at present known. It is distinguished from B. aerogenes by its biochemical characters, and by the fact that it is motile. It also forms spores more readily. On sugar media it forms less gas than B. aerogenes, and litmus milk is only slowly coagulated, or not at all. When injected into a living rabbit, which is subsequently killed and incubated, little or no gas-formation is found in the liver and other tissues.

Bacillus botulinus has a varied morphology, but is usually seen as an anthrax-like bacillus, about 4 to 9 microns long by 0·9 to 1·2 broad. It is motile, possessing four to eight flagella, and is Gram-positive. The oval spores are terminal, thus resembling the tetanus bacillus. Gelatin is slowly liquefied. Sugar broths become turbid and have a butyric acid odour, but little or no gas is formed. In milk there is only slight growth, and the medium is not coagulated. On potato there is no growth, even under anaerobic conditions. In glucose-gelatin stab cultures a radiating growth appears in the depths, the medium is slowly liquefied, and a yellowish-white sediment forms at the bottom. The organism is an obligate anaerobe, and the optimum temperature for its growth is 20° to 30° C. At 38·5° C. growth ceases. Subjected to the biological test of inoculation and incubation in a rabbit, putrefaction of the liver results, but no trace of gas-formation occurs. B. botulinus was isolated in 1896 by van Ermengen from a sample of ham which had caused poisoning in those who had partaken of it in a raw state, and in some instances had produced fatal results. Similar outbreaks have also followed the ingestion of sausages and even vegetable foods, such as canned beans, which had probably been infected by manure.

Bacillus butyricus (Botkin) is an obligate anaerobe which is slightly motile, forms equatorially situated spores, and rapidly liquefies gelatin. Milk is coagulated and much gas formed. Lactose is fermented, with the formation of acid and gas. It has been isolated from milk, water, and earth, and was separated from the stools in acute infantile diarrhœa by Klein in 1895.

Bacilli tetani.—The fæces of the horse, ass, and other domestic animals not infrequently contain tetanus bacilli even in health, but, although it has been suggested that "spontaneous" tetanus occurring without an obvious skin lesion in man may be due to intestinal infection, the specific organism does not appear to have been isolated from the stools. Tetanus bacilli have characteristic morphological and biological characters by which they can be readily recognized in pure cultures, but their separation and differentiation from such a mixture of bacteria as is met with in the fæces is an exceedingly difficult process (*Plate X*, 5, 6).

Tubercle Bacilli.—Tubercle bacilli may be sought for in the fæces either by selecting the flecks of pus and mucus masses, especially those that are blood-stained, preparing smears, and treating them as is done in the case of sputum, or the organisms may be looked for in preparations made from the solid stool that has been emulsified and digested, or centrifugalized. Page advises mixing a piece of the stool about half the size of a pea with 1·5 c.c. of distilled water, adding 54 c.c. of a mixture of equal parts of alcohol and ether, and centrifugalizing for ten minutes; a smear made from the sediment is fixed to a slide with egg-albumen, and stained in the ordinary way. Strasburger mixes the fæces with water and sediments, or centrifugalizes the mixture. The cloudy supernatant liquid is then poured off, diluted with one-third of its bulk of 96 per cent alcohol, and centrifugalized. Smears are made from the sediment. Some observers have reported better results with the antiformin method. About a cubic inch of the fæces is thoroughly emulsified with 20 c.c. of antiformin (15 per cent), and another 20 c.c. then added to the emulsion. The conical vessel containing the mixture is covered and allowed to stand at rest for two hours. At the end of this time a creamy sediment will have collected at the bottom of the vessel. Some of this layer is removed with a pipette, films are prepared, dried, fixed with perchloride of mercury, and stained. Cecconi adds a few cubic centimetres of ligroin to the antiformin mixture, and examines the layer that forms on standing just below the ligroin. Ziehl-Neelsen's method of staining may be employed, using 60 per cent alcohol, as well as 25 per cent sulphuric acid, to decolorize; or the preparation, which had been previously stained in the cold for fifteen to thirty minutes with carbol-fuchsin, may be treated with Pappenheim's stain until the colour is deep blue, when it is thoroughly washed in water, dried, and mounted in balsam. It is important that thin films should be used, or the red bacilli cannot be well made out (*Plate X*, 7). In forming an opinion from the results of a microscopical examination of the fæces, it should be borne in mind that all acid-fast bacilli are not tubercle bacilli, and that other acid-fast bacilli have been repeatedly found in the fæces. Moreover, tubercle bacilli may gain entrance to the intestine in sputum which has been swallowed. This is particularly the case with children, and is more common in adults than is generally supposed, even in patients who try to be careful in this respect. Klose claims to have found tubercle bacilli in the fæces of every patient he examined who had them in the sputum. Philip and Porter obtained very similar results, and in addition found tubercle bacilli in the fæces of twenty-nine out of forty-two tuberculous patients whose sputum was negative, and seventeen without sputum.

Inman found tubercle bacilli in the sputum of eighteen out of twenty-six adults, and in sixteen of these they were also present in the fæces. Of eight patients whose sputum was negative, one showed tubercle bacilli in the stools.

Mycoses.

Actinomycosis.—In certain cases of chronic diarrhœa, the characteristic yellowish or brownish granules of actinomycosis may be discovered in the fæces, and the fact that they consist of tangled masses of Gram-positive filaments may be demonstrated in cover-glass preparations. The diagnosis of intestinal actinomycosis is, however, always a difficult matter, and is more frequently made by the presence of a tumour in the region of the appendix and cæcum, which ultimately forms an abscess discharging the characteristic granules through an external fistula.

Oidium albicans.—The organism of thrush, although most commonly met with in the mouth, can also develop in the intestinal tract, and by augmenting the activity of the colon bacilli, may give rise to serious forms of gastro-intestinal disturbance in infants. An examination of the fresh stools will show in such cases a number of ovoid cells, which may be isolated, or united to form chains or filaments. Some of them may also be seen to be budding. The organism stains by Gram's method, liquefies gelatin, produces an alkaline reaction from the formation of ammonium carbonate, and does not ferment lactose.

Yeast cells, which may also show budding and form chains, are often present in normal stools. They may be increased in cases where there is abnormal fermentation, and then form much gas in all sugar media. An examination of the sediment shows them to be the dominant organism in such cases (*Plate XIII*, 2, *f*).

Sarcinæ are often found in the fæces in cases of dilated stomach, and may suggest the presence of that condition, although they may also occur under other circumstances. When present in large numbers, they may give rise to diarrhœa as a result of the fermentative changes they induce.

Moulds are comparatively rare in the stools, and are usually a contamination from the air or vessels into which the stool has been passed (*Plate XIII*, 2, *e*).

Lactic Acid Bacilli.—As a result of the work of Metchnikoff, Herter, and others, on the flora of the intestinal tract in health and disease, the idea has been steadily gaining ground that certain normal intestinal bacteria have a beneficial action, while others have a detrimental effect on the organism, so that the vigour and health of the individual is largely dependent upon the relative preponderance of the various types. Potentially harmful bacteria are believed to be present in the intestinal contents of all persons, but their activities are held in check by the benign forms which give rise to conditions unfavourable to their growth. Arguing on these lines, and also from the vigorous health and longevity of various races of people into whose dietary substances containing lactic acid enter, it has lately been fashionable to prescribe, somewhat indiscriminately, however, cultures and preparations containing lactic acid bacilli in intestinal disorders and conditions believed to be due to intestinal auto-intoxication. In some instances very satisfactory results have been obtained, but in others no benefit has followed, and indeed, occasionally the patient's symptoms have been aggravated. It is probable that this varying effect has been due to the fact that the treatment has been based on the clinical symptoms alone, and the condition of the intestinal flora has not been taken into account. If the results of a bacteriological examination of the fæces were made the basis of the treatment, it is likely that much more uniform benefit would follow its use in suitable cases. It has been my experience that the best results are obtained in cases where it is found that the fæces show evidence of a predominance of putrefactive organisms, and that when acid-forming and gas-forming bacteria are present in excess the treatment is worse than useless. In prescribing any lactic acid bacillus preparation, it is essential that its administration should be controlled by an examination of the fæces, for since most of the putrefactive changes take place in the lower parts of the intestine, no marked benefit can be expected until it can be shown that the lactic acid bacilli have reached the large bowel and form the predominant organism of the stools (*Fig.* 69). The chief lactic acid organisms that curdle milk are :—

Bacillus bulgaricus (B. caucasicum, Mossel's bacillus, Bouchard's bacillus) is usually a stout and rather long bacillus, about 5 or 6 microns long by about 1 broad (*Fig.* 70). It is sometimes straight and sometimes curved, and has square ends. The bacillus stains well with all ordinary aniline dyes, and retains Gram's stain. In stained preparations, granules with unstained portions resembling vacuoles are often seen. Old specimens often stain irregularly with Gram, part of the bacillus appearing blue or violet, and part being coloured with the counter-stain. It grows both aerobically and anaerobically, at 37° C., but the optimum temperature appears to be 42° to 44° C. Sugars are not fermented, and on potato there is no growth. On glucose gelatin some strains develop very slowly and sparingly. Litmus milk is strongly acidified, up to 3 per cent of lactic acid, decolorized, and slowly coagulated. The casein is very slowly peptonized. There are apparently several strains of the Bulgarian bacillus, which vary somewhat morphologically, but have the same cultural characters. When investigating the fæces to determine when the organism given by the mouth has passed through, the fæcal smear should be compared with one made from the milk preparation which has been washed with xylol, to remove the fat, and been stained by Gram's method.

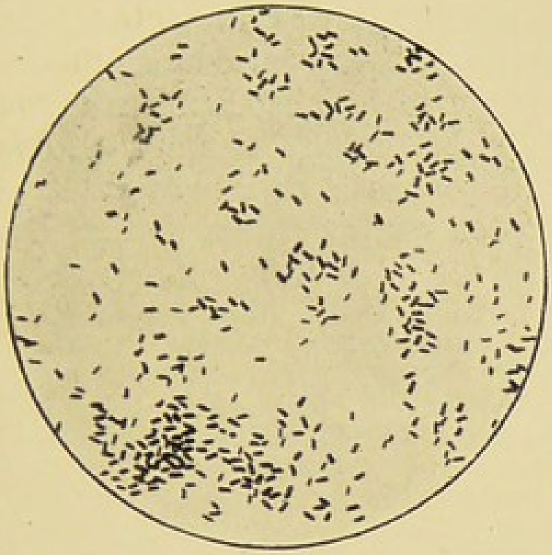


Fig. 69.—Lactic acid bacilli from spontaneously curdled milk (× ca. 1000).

Bacillus para-lactici (Günther's bacillus) is a much shorter bacillus, 1 micron long by about 0·5 to 0·6 broad (*Fig.* 71). It is usually found in pairs or short chains, and the ends are pointed. It does not retain Gram's stain. Milk is strongly coagulated, with the formation of much acid. In dextrose and lactose broth, it forms acid but no gas. Günther's bacillus is found in abundance in spontaneously coagulated milk, but is apparently a less hardy organism than B. bulgaricus, as it dies out when the two are inoculated together, and after the more slowly developing Bulgarian bacillus has well established itself.

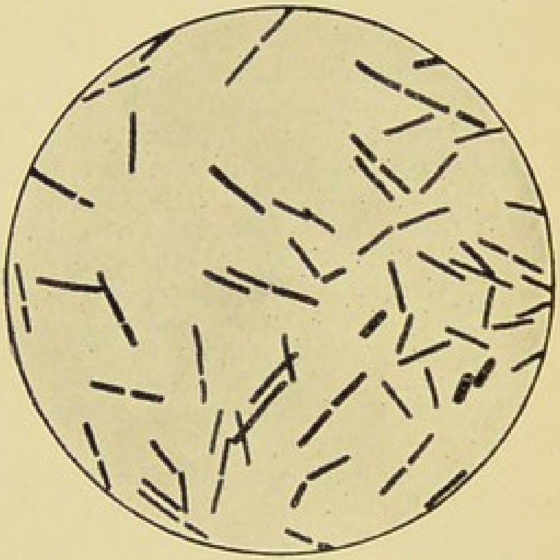


Fig. 70.—Pure culture of Bouchard's Bacillus bulgaricus (× ca. 1000).

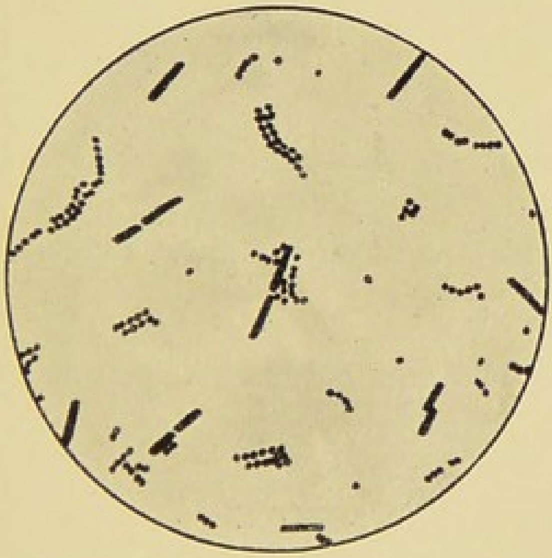


Fig. 71.—Bouchard's Bacillus bulgaricus and strepto-bacilli from curdled milk (× ca. 1000).

Bacillus acidi lactici (Hüppe's bacillus) is a short oval bacillus, 0·6 to 2 microns long by 0·4 to 0·6 broad. It is usually found in pairs, and more rarely in chains. It is generally said to stain well by Gram's method, but some authors state that it is Gram-negative, and others that it varies. Unlike the two organisms previously described, it ferments both dextrose and lactose, with the formation of much gas, at the same time producing lactic and acetic acids. It grows well on all ordinary culture media, but after long cultivation on agar or gelatin, loses its power of forming lactic acid and coagulating milk. It is found in most samples of milk, and is present in milk that has soured spontaneously. Besides coagulating milk, it breaks up the fats and peptonizes the casein, so that the milk has a bitter taste.

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Chapter VI.

CHEMICAL ANALYSIS OF THE FRESH FÆCES.

It is generally assumed that the fæces are composed chiefly of food residues, but analysis shows that this is usually not the case, a large part of the stool of a healthy individual bearing no direct relation to the food consumed. In the normal state some 85 to 95 per cent of an average mixed diet is completely absorbed, so that only about 5 to 15 per cent, and this mainly indigestible residues, is passed in the motions. The greater part of the fæces is in reality derived from the intestine, the secretory and excretory powers of which are as a rule not fully appreciated. On an average, some two-thirds of a normal stool consists of secretions and débris derived from the intestinal mucous membrane and digestive glands, while of the remaining third about half is composed of bacteria. Only a comparatively small proportion, usually about a sixth, is therefore contributed by the food. When, however, the digestive and absorptive functions of the gastro-intestinal tract are being imperfectly or improperly carried out, undigested and partly digested food materials form a much larger proportion of the motions, while the appearance of various pathological constituents may add to their bulk and alter their characters. By means of a naked-eye and microscopical examination of the fæces much useful information can be obtained as to the fate of the various food materials, and the existence of abnormal constituents, so that important conclusions can be drawn as to the probable nature and seat of many pathological conditions; but in others neither the macroscopical nor microscopical appearances of the stools reveal any striking abnormality, and it is only from the results of a chemical analysis that the existence and probable cause of certain pathological conditions can be established. Chemical analyses are also useful as a means of confirming many of the results obtained by inspection or examination under the microscope. In some instances a qualitative analysis will afford the necessary information, but in others quantitative estimation will be desirable, and may be essential if a reliable opinion is to be formed.

Chemical analyses of the stools are carried out with the fresh material for some purposes, while for others, and more particularly those in which quantitative results are required, the dried fæces are used. In this chapter we shall deal with the former class of investigations, and consider those requiring preliminary drying of the stool in another section.

REACTION.

The reaction of the fæces may be tested in various ways, the result depending a great deal upon the indicator employed. For clinical purposes it is usual to employ litmus.

The simplest method is to moisten pieces of absorbent red and blue litmus paper with distilled water, place them on a glass slide, rub a fragment of the fæces on to the paper, and then observe the change of colour from the other side.

A more delicate method is to introduce a few cubic centimetres of a watery solution of litmus tincture (1–10) into a couple of test tubes of equal diameter, and add a few drops of a watery emulsion of the fæces to one of them. The reaction is determined by a comparison of the colour. The cloudiness due to the presence of the fæces may be overcome by centrifugalizing and examining the supernatant liquid.

Under normal conditions the reaction of the fæces does not deviate markedly from the neutral, although slight variations, chiefly due to the nature of the diet, are met with even in health. Fasting stools, which may be regarded as the normal product of the alimentary tract unaffected by food residues, are faintly acid, owing to the presence of fatty acids, which are important excretory products of the intestinal wall. On a meat diet the reaction is alkaline, sometimes markedly so. A faintly acid reaction always results when the diet is exclusively vegetable in character. On a mixed diet the fæces are usually faintly alkaline in reaction, but if an excess of meat is being taken they may become decidedly alkaline, and a diet rich in starchy foods tends to cause them to be acid, while an excess of fats also leads to an acid reaction. The normal fæces yielded by a milk diet in an adult are neutral or faintly alkaline. It must be borne in mind that the outer part of the fæces may have a reaction different from the deeper parts. Blood, mucus, and pus change the reaction, and when the consistency is uneven it is necessary to test different portions before drawing a general conclusion as to the reaction. As putrefactive and fermentative changes go on in the stools after they have been passed, increasing the alkalinity in the one case and the acidity in the other, it is obviously important that the examination should be made as soon as possible after they have been collected.

Under pathological conditions the reaction of the stools may vary markedly from the normal. It may be laid down as a general rule, that any condition that favours increased putrefaction and the consequent formation of ammonia and other alkaline products of protein decomposition, gives rise to alkaline stools, while intestinal fermentation, associated with imperfect digestion of carbohydrates and the formation of the lower fatty acids, such as acetic, lactic, and butyric, causes the stools to become acid. An excess of fat in the fæces also gives rise to an acid reaction, owing to the presence of the higher fatty acids formed through their fission by bacteria in the lower part of the intestine. The nature of the diet is therefore of as much, or more, importance in determining the reaction in disease as it is in health. Fixed alkalies and mineral acids, even although they are present in considerable quantities, rarely affect the reaction, as they are usually bound by bases and organic acids respectively. Diseases of the stomach, if not associated with intestinal disorders, do not affect the reaction of the stools. With catarrhal affections of the upper part of the bowel, the fæces are usually strongly acid if peristalsis is increased, but in most cases of chronic enteritis, tuberculosis of the intestine, typhoid, etc., the reaction is alkaline, and the stools often have an ammoniacal odour. In chronic colitis the reaction is nearly always strongly alkaline. Absence, or marked diminution, of the pancreatic secretion gives rise to acid stools, owing to the presence of fatty acids formed as the result of abnormal fat-splitting and the decomposition of carbohydrate; but if much protein is taken they may be alkaline, the acidity being masked by the ammonia formed by the increased putrefaction of the protein. Obstruction of the bile flow, if it is associated with pancreatic disease, also gives acid stools, but if it is uncomplicated by disease of the pancreas and is due to gall-stones, malignant disease of the common bile-duct, etc., the reaction of the fæces is usually alkaline. In " catarrhal " jaundice the reaction of the fæces is almost always strongly alkaline. In all cases of jaundice and pancreatic disease, the nature of the diet exerts an important influence on the reaction. (*See Tables*, *pp.* 174, 175).

The reaction of the fæces in infants varies according to the diet. With breast-fed children it is faintly acid. With those brought up on the bottle it is neutral or faintly alkaline. According to Schlossmann, the reaction does not depend so much on whether the diet consists of cow's milk or breast milk, as upon the balance between the protein and fat consumed. If for every one part of protein there are three or more parts of fat, the reaction is acid, but if for every one part of protein there is only one part of fat, the stools are alkaline. He states that by varying the proportions of protein and fat it is possible to regulate the reaction of the fæces at will. If, for instance, centrifugalized cow's milk, from which some of the fat has been removed, is given, the reaction becomes alkaline; but if, on the other hand, cream is added to ordinary milk so that the proportion of fat to protein is raised to about three to one, the reaction becomes acid. This observation may sometimes be of considerable clinical importance, and be of assistance in diagnosis as well as in treatment. Should an infant that is being fed entirely on the breast, for example, pass persistently alkaline stools, it is probable that the mother's milk is deficient in fat or else the child is getting too little nourishment, and this may be the case even when the breasts appear to be over-filled. That the fat content of the stools is the determining factor of their reaction in children is also shown by the well-known alkalinity of buttermilk stools. If on a diet of buttermilk the stools become acid, it ought not to be persevered with. Müller confirms Schlossmann's contention that an alkaline reaction of the stools of breast-fed children points to the milk being poor in fat. He examined the fæces with various indicators, and found that the acidity during breast-feeding diminishes with the age of the child but is subject to considerable variation. In one breast-fed infant that he observed for a period of two months, he found that it throve only when the reaction remained alkaline, and that three times it showed a loss of weight when the reaction became acid. According to Blauberg, feeding with undiluted milk makes the stools acid, but Selter maintains that on the contrary they are alkaline. He regards only a strongly acid or alkaline reaction as pathological, and allows considerable variation within the extreme limits as normal. He also found that the surface of the fæces always gave a more markedly alkaline reaction than the inner part of the mass, and considers the intrinsic secretion of the intestine as responsible for this.

The addition of sugar to the diet produces different results in different cases, sometimes increasing the alkalinity by stimulating the flow of the intestinal secretions, at other times leading to an acid reaction from the production of fatty acids. Gaultier is of opinion that the acid reaction of the stools, when a carbohydrate diet is being taken, partly depends upon the fact that the carbohydrates do not bind the hydrochloric acid of the gastric juice, for he found that, in adults, there is a direct relationship between the acidity of the fæces and the total acidity and hydrochloric acid

REACTION, ETC., OF THE FÆCES IN 592 CASES.

			Reaction			Hydrobilirubin			Blood		Ash			
		No. of Cases	Acid	Am-phot.	Alk.	Present	Traces	Nil	Present	Nil	Average per cent	Excess	Normal	Sub-normal
1	Appendicitis	3	0	0	3	3	0	0	0	3	16·8	3	0	0
2	Arteriosclerosis—pancreatitis ..	8	2	4	2	8	0	0	1	7	17·9	4	3	1
3	Cancer—ampulla of Vater	1	1	—	—	—	1	—	—	1	12·4	—	1	—
4	,, —common bile-duct	5	3	1	1	2	2	1	3	2	10·6	0	4	1
5	,, — ,, ,, —2nd pancreas	2	0	2	0	0	2	0	1	1	10·9	0	2	0
6	,, —gall-bladder	2	0	0	2	2	0	0	0	2	13·7	0	2	0
7	,, — ,, —2nd pancreas ..	4	1	1	2	2	2	0	2	2	7·4	0	0	4
8	,, —intestine	19	0	15	14	19	0	0	17	2	19·0	18	1	0
9	,, — ,, —2nd pancreas ..	6	0	1	5	6	0	0	5	1	16·5	4	2	0
10	,, —pancreas	38	30	0	8	3	13	22	25	13	9·0	1	11	26
11	,, —stomach	15	0	10	5	15	0	0	12	3	14·5	8	5	2
12	,, — ,, —2nd pancreas ..	8	1	2	5	8	0	0	6	2	19·0	5	3	0
13	,, —other organs	10	0	4	6	10	0	0	0	10	13·1	0	8	2
14	,, — ,, ,, —2nd pancreas	4	0	1	3	4	0	0	0	4	14·3	0	3	1
15	Catarrhal pancreatitis	47	13	6	28	47	0	0	4	43	15·9	24	20	0
16	Cirrhosis of pancreas	28	19	8	1	28	0	0	1	27	12·1	1	17	10
17	Cyst of pancreas	1	1	—	—	1	—	—	—	1	12·6	—	1	—
18	Cirrhosis of liver	5	0	2	3	5	0	0	0	5	14·8	3	2	0
19	Chronic colitis	30	0	0	30	30	0	0	5	25	25·3	30	0	0
20	Congenital family steatorrhœa ..	1	—	—	1	1	—	—	0	1	13·0	—	1	—
21	Dilated stomach	4	0	0	4	4	0	0	0	4	24·1	3	1	0
22	Enteritis, chronic	18	0	2	16	18	0	0	0	18	20·3	18	0	0

REACTION, ETC., OF THE FÆCES—*continued*.

23	Enteritis, chronic—pancreatitis ..	83	8	18	57	83	0	0	83	0	16·3	49	29	5
24	,, tuberculous ..	3	0	1	2	3	0	0	3	0	20·4	3	0	0
25	,, ,, —pancreatitis ..	1	—	1	—	1	—	—	—	1	12·0	—	1	—
26	Gall-stones in common bile-duct—no jaundice—no pancreatitis ..	9	0	3	6	9	0	0	0	9	18·2	7	2	0
27	Gall-stones in common bile-duct—jaundice—no pancreatitis ..	16	4	1	11	14	2	0	0	16	12·2	3	10	3
28	Gall-stones in common bile-duct—no jaundice—pancreatitis	25	14	2	9	25	0	0	0	25	14·5	11	12	2
29	Gall-stones in common bile-duct—jaundice—pancreatitis	51	29	2	20	43	8	0	2	49	12·6	9	28	14
30	Gall-stones in gall-bladder	23	1	6	16	23	0	0	0	23	15·5	9	11	3
31	,, ,, ,, —pancreatitis	11	3	1	7	11	0	0	0	11	18·5	9	2	0
32	Jaundice—catarrhal	2	0	0	2	2	0	0	0	2	32·6	2	0	0
33	,, ,, —pancreatitis ..	24	14	6	4	24	0	0	0	24	12·1	8	10	6
34	Heart disease	4	1	0	3	4	0	0	1	3	16·4	3	1	0
35	Pancreatic infantilism	2	2	0	0	2	0	0	0	2	13·3	0	2	0
36	Pernicious anæmia	1	—	1	—	1	—	—	—	1	13·4	—	1	—
37	,, ,, —pancreatitis ..	2	0	0	2	2	0	0	0	2	26·2	2	0	0
38	Sprue	5	5	0	0	5	0	0	0	5	13·3	1	4	0
39	,, —pancreatitis	8	6	1	1	8	0	0	0	8	13·3	2	5	1
40	Simple stricture of common bile-duct	1	—	1	—	—	1	—	—	1	13·6	—	1	—
41	Ulcer—duodenum	6	0	0	6	6	0	0	2	4	19·0	5	1	0
42	,, ,, —pancreatitis ..	15	4	2	9	15	0	0	3	12	15·4	6	6	1
43	,, —stomach	13	0	0	13	13	0	0	4	9	16·1	8	4	1
44	,, ,, —pancreatitis ..	3	0	1	2	3	0	0	1	2	15·9	2	1	0
45	Normal	25	2	20	3	25	0	0	0	25	12·5	0	25	0

value of the stomach contents when acid diarrhœa occurs. It seems unlikely, however, as Hecht points out, that the small amount of hydrochloric acid secreted in the stomach of infants can have much effect in this way, and for clinical purposes it may be taken that strongly acid stools in infants point to the existence of abnormal fermentative changes. Hedenius carried out a number of researches upon the fate of carbohydrates in the intestines of infants, and found that the reaction of the fæces affords a useful indication of the degree to which they are absorbed. Older children, who make better use of the carbohydrates they take than younger ones, have less acid stools, but when the carbohydrate diet is persisted with, the latter seem to become more accustomed to it, and the acidity of their fæces diminishes. He also showed that biscuit and malt are less completely utilized than simple flour, and are more apt to cause a strongly acid reaction in the fæces.

Quantitative estimations of the acidity of the fæces have been chiefly made in connection with the investigation of the stools of children.

Rübner extracts the fæces with hot water and then titrates the extract with a solution of barium hydrate, but the method suggested by Blauberg is more satisfactory.

The fresh fæces are thoroughly mixed, and 20 to 30 grams weighed out. This is then diluted with ten times its volume of boiled distilled water, and titrated with decinormal caustic soda or hydrochloric acid, according to the reaction, using phenolphthalin or neutral litmus paper as the indicator. From the quantity of decinormal solution used and the known weight of the fæces employed, the acidity or alkalinity of the 100 grams of the fæces can be calculated.

Using this method of estimation, Blauberg found that 100 grams of the fæces from a healthy breast-fed child require 25 c.c. of decinormal alkali to neutralize them, while 100 grams of the stools from a healthy child upon a diet of cow's milk require 11·33 c.c. In both cases the fæces were submitted to steam distillation, and the distillate and residue in the flask titrated. A hundred grams of the distillate from the stool of the breast-fed infant were neutralized by 1·875 c.c., and from the child on cow's milk by ·9163 c.c., while the residue from the former required 23·35 c.c., and from the latter 8·66 c.c., showing that the acidity in both instances was due for the most part to non-volatile substances. Hellstrom, also Langstein, obtained much lower figures for the stools of breast-fed children, only about a tenth of those quoted by Blauberg, and the readings obtained by the latter were also lower for the fæces of some children fed on cow's milk, although for others they were higher. Langstein points out that the result is ot some extent dependent upon the indicator employed, and that it is higher with phenolphthalin than with litmus. Hedenius has carried out a number of researches upon the fate of carbohydrates in the intestines of infants, and has shown that the acidity of the fæces as determined by Blauberg's method affords a useful indication of the degree to which carbohydrates are being absorbed. He found, for instance, that when a twenty-four-week-old infant was being fed with biscuit, 34·2 c.c. of decinormal soda were required to neutralize 100 grams of the stool, and that when a milk diet was resumed, the quantity of alkali required fell to 12·5 c.c. In another case, of a nine-and-a-half-week-old child, the alkali required during the first period was 140·4 c.c., while three weeks later on a milk diet it had fallen to 50 c.c. Even the latter is about ten times the normal for a child on a diet of cow's milk, which Hedenius gives as 5 c.c.

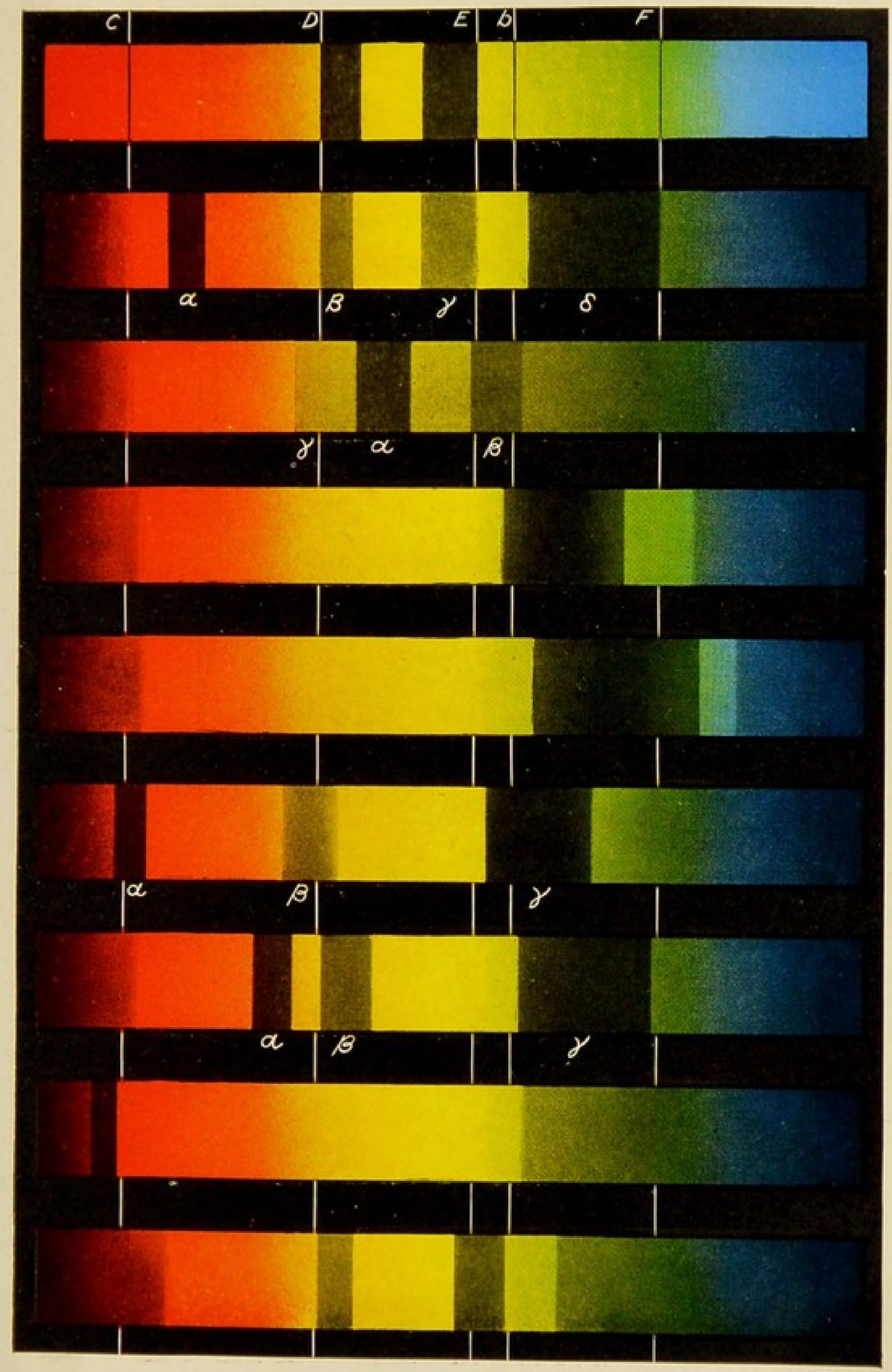
BILE CONSTITUENTS AND THEIR DERIVATIVES.

The normal pigment of the fæces, *hydrobilirubin* or *stercobilin*, is, as we have seen, formed from the bilirubin of the bile by a process of reduction in the cæcum and upper part of the large intestine. According to Talbot, bile pigments and bile salts first appear in the intestine during the third month of fœtal life. This material, with the secretion of the intestinal canal and the desquamated epithelium, gradually accumulates to form the meconium. The conversion of bilirubin into hydrobilirubin does not take place to any considerable extent until putrefactive types of bacteria are well established in the intestine, which commences when the child begins to take cow's milk. It is usually said that the hydrobilirubin of the fæces and the urobilin of the urine are identical, but recent researches suggest that this is not the case, for hydrobilirubin, according to Maly, contains 9·45 per cent of nitrogen, whereas, according to Garrod and Hopkins, urobilin contains only 4·11 per cent. Recently, Fromholdt has isolated a hydrobilirubin-like pigment with a nitrogen content of 5·93 per cent, and he suggests that it is more correct to speak of a hydrobilin group of pigments as occurring in the fæces than of a single substance. At any rate it would seem that a distinction between the chief normal pigment of the fæces and the urobilin of the urine is justifiable, and that it is wiser not to use the latter term for both, as some writers have done in the past.

The simplest method of detecting hydrobilirubin is the sublimate test of Schmidt :—

EXPLANATION OF PLATE XI.

1. Spectrum of oxyhæmoglobin.
2. Spectrum of hæmatin in acid solution.
3. Spectrum of hæmochromogen.
4. Spectrum of hydrobilirubin in alkaline solution.
5. Spectrum of hydrobilirubin in acid solution.
6. Spectrum of cholecyanin in alkaline solution.
7. Spectrum of cholecyanin in acid solution.
8. Spectrum of chlorophyll.
9. Spectrum of Pettenkofer's reaction.



Examination of Fæces

P. J. Cammidge

1. A piece of the fresh fæces, the size of a hazel-nut or walnut, is thoroughly rubbed up in a mortar with a small quantity of a concentrated watery solution of corrosive sublimate (mercuric chloride 25 grams, sodium chloride 2·5 grams, distilled water 500 c.c.), and allowed to stand for twenty-four hours in a covered Petri dish. If hydrobilirubin is present, a deep-red colour develops, sometimes within the space of a few minutes, owing to the formation of a compound of hydrobilirubin with the mercuric chloride. With only traces, a distinct reaction may not be seen for twenty-four hours. The red solution, when separated and examined with the spectroscope, shows an absorption band between *F* and *b* (*Plate XI*, 4, 5). A typical reaction is only obtained with quite fresh fæces, specimens that have stood for some time giving only a red-brown or dirty-brown colour. Stools containing much fat should be extracted with ether before applying the test.

A more delicate test is carried out in the same way as for urobilin in urine (Schlesinger) :—

2. A sample of the fæces is shaken with ether to remove the fat. The residue is then extracted with acid alcohol (hydrochloric acid 5 c.c., alcohol 100 c.c.), and the yellow or brown liquid that results is neutralized with a little ammonia, or sodium hydrate solution. It is then mixed with an equal quantity of a 10 per cent solution of zinc acetate in alcohol. Any precipitate that forms is removed by filtering through a dry filter-paper. The clear filtrate is examined against a black background for the green fluorescence that indicates the presence of hydrobilirubin. On examining the red fluorescent solution with the spectroscope, it shows an absorption band between *F* and *b*, which moves nearer to *F* when the liquid is acidified (*Plate XI*, 4, 5). The absorption bands cannot be well seen if the fæces contain blood pigments. The dried fæces give this test as readily as fresh specimens, and the residue left after fat extraction may be conveniently used for the purpose.

3. The presence of hydrobilirubin in the fæces may also be proved by rubbing up 3 to 4 grams with 30 cm. of amyl alcohol, and examining the filtrate for the characteristic spectrum of hydrobilirubin (Tsuchiya). This test can also be applied to the dried fæces.

The tests for hydrobilirubin are chiefly important in connection with the examination of light-coloured and acholic stools. With the latter it should never be omitted, as the results are of great diagnostic importance. A negative result with the zinc acetate test shows that no bile is reaching the intestine, and, when associated with deep painless jaundice and progressive loss of weight and strength, is strongly suggestive of malignant disease of the head of the pancreas. With jaundice due to obstruction of the common bile-duct by primary malignant disease, traces of hydrobilirubin are usually found, for growths in this situation, and also those originating in the gall-bladder, consist of a soft mass of columnar cells which allows some bile to percolate through, in contrast to the hard scirrhous growths of the head of the pancreas which compress the duct from without and cause complete obstruction. Gall-stones in the common bile-duct, even when associated with intense jaundice, rarely cause complete obstruction, so that, with these, traces at least of hydrobilirubin are found in the stools. Repeated examinations will, as a rule, show that the reaction varies in intensity from day to day as the stones move and the inflammation consequent on their presence increases or diminishes. The fæces in catarrhal jaundice nearly always give a well-marked reaction for hydrobilirubin, but in this too, it may vary as the pressure of the inflamed head of the pancreas changes.

The quantitative estimation of hydrobilirubin in the fæces is a troublesome procedure, and does not give exact results, as hydrobilirubin is a substance that readily undergoes chemical change. For the details of the various methods that have been suggested, the reader is referred to Abderhalden's "Handbuch der Biochemischen Arbeitsmethoden," 1911, Bd. v., p. 390, or some other standard work on biological chemistry.

Under normal conditions, the fæces of the adult contain no unaltered bile pigment; but bilirubin, alone or mixed with biliverdin, is met with in meconium and the stools of infants during the first fortnight or so of life.

The presence of *bilirubin* can be demonstrated easily when it occurs alone, but when mixed with other pigments its recognition is more difficult.

1. *Schmidt's Sublimate Test* is carried out in the manner already described for the detection of hydrobilirubin. The bilirubin is oxidized to biliverdin, which can be recognized by its green colour. The test may also be employed as a micro-chemical reaction for the detection of small quantities.

2. *Gmelin's Test.*—On adding a few drops of nitric acid containing nitrous acid to a smear of the fæces on a white tile, a play of colours, green, blue, violet, red, and yellow, results if bilirubin is present. The green is alone characteristic, and must be definitely seen before it can be concluded that unaltered bile pigment is present. If the fæces are already green from the chlorophyll or bacterial pigments, they should be extracted with water, and the watery extract be tested with nitric acid.

3. *Nakayama's Test.*—The fæces are ground up with water to form a thin liquid, a trace of sodium sulphate added, and mixed with an equal volume of a 10 per cent solution of barium chloride. The mixture is then centrifugalized and the supernatant liquid poured off. The precipitate that is left is mixed with 2 c.c. of a mixture consisting of 99 parts of 95 per cent alcohol, 1 part of fuming hydrochloric acid, 4 grams of perchloride of iron per litre, and heated to boiling. In the presence of bilirubin the fluid turns green or bluish-green.

Quantitative Estimation.—A known weight of the fresh fæces is rubbed down in a mortar with Müller's baryta mixture (1 vol. saturated barium chloride solution, 2 vols. saturated barium hydrate solution) and filtered. The residue on the filter is made feebly acid with acetic acid and extracted with chloroform. The chloroform extract is well shaken with several portions of water to remove the acetate salts, mixed with alcohol, and filtered. The alcohol is now removed by shaking with water, the chloroform evaporated, and the residue dried and weighed.

If the stools contain *biliverdin*, its presence can usually be recognized by the green colour, which must, however, be distinguished from that due to chlorophyll and the bacilli of green diarrhœa. On making an alcoholic extract of the fæces and examining with the spectroscope, biliverdin shows no absorption bands, but gives Gmelin's test with nitric acid, whereas chlorophyll shows a band to the left of *C* (*Plate XI*, 8), and does not give Gmelin's test.

Unaltered bile pigments are most commonly met with in the stools as the result of increased peristalsis, and are hence found in diarrhœa, especially the so-called jejunal diarrhœa of Nothnagel. Their presence is also contributed to by conditions which interfere with absorption and the usual chemical changes that go on in the large intestine.

The *bile acids*, glycocholic and taurocholic acids, are normally reabsorbed almost completely from the intestine, so that only small quantities pass into the lower part of the bowel. There, under the influence of putrefactive organisms, they are split up into glycocoll, taurin, and cholalic acid. The cholalic acid combines to form cholate of soda, which in the healthy state is the only representative of the bile acids in the stools. If, however, the intestinal contents pass so rapidly through the large intestine that the usual fission processes have not time to take place, unaltered bile acids may be met with.

To detect the presence of biliary acids, a small quantity of the fæces is extracted with alcohol and filtered. The filtrate is distilled to drive off the alcohol, and the residue taken up with water rendered faintly alkaline with caustic soda. The watery solution is treated with a trace of cane sugar, or a few drops of a very dilute solution of furfurol, and concentrated sulphuric acid added. In the presence of bile acids a bright crimson colour develops (Pettenkofer's test). The sulphuric acid must be added a drop at a time, shaking after each addition, and care must be taken that the temperature does not rise above 70° C., the test-tube being cooled in water from time to time if necessary.

BLOOD.

When blood occurs in the fæces in considerable quantities in an unaltered condition, it can be recognized easily by the naked eye, and its presence can be confirmed by the microscopical detection of red blood corpuscles, or by examining an extract with the spectroscope for oxyhæmoglobin and its derivatives. As, however, the spectrum is apt to be obscured by the normal pigments of the fæces, even when the blood has come from the lower part of the bowel and has not been changed by a long stay in the intestines, and much of the blood pigment often occurs as hæmatin, which is only imperfectly soluble in water, the spectroscopic examination is best carried out according to the method recommended by Sahli.

A small quantity of the stool to be examined is mixed with water, and acidulated with dilute sulphuric acid until a well-marked Congo-red reaction is obtained. The mixture is then filtered, and the filtrate extracted with ether. If the ether does not separate well, a few drops of alcohol may be added. When blood is present, the ether takes on a reddish-brown colour, and shows the characteristic bands of acid hæmatin with the spectroscope (*Plate XI*, **2**).

When, however, the blood is in an altered condition, or only present in small quantities, macroscopical and microscopical examination are alike unreliable, and indeed may be most misleading. In such cases, blood can only be detected by chemical or spectroscopic means. Since 1903, when Boas directed attention to the significance of small, or "occult" hæmorrhages, from the gastro-intestinal tract, it has been recognized that the presence of minute traces of blood in the fæces is a matter of great diagnostic significance, and may afford most important evidence of the presence of serious disease of the stomach or intestine. Many refinements in the laboratory methods of detecting blood have consequently been devised, and it is now possible to demonstrate extremely minute traces. The tests employed all depend upon the presence of a single chemical constituent of the blood, hæmoglobin, or one of its near substitution products.

Teichmann's hæmin test, and the turpentine-guaiac test of Schönbein and Almén, are now rarely used, as they are not very delicate and are frequently indecisive. Both on account of its delicacy and the ease with which it is carried out, the *benzidin test* of O. and R. Adler is now most commonly employed. The modification devised for clinical work by Schleisinger and Holst and Goodman is performed as follows :—

1. A small portion of the fæces is ground up with water to form a thin emulsion, poured into a test-tube, and boiled. While this is cooling, a concentrated solution of benzidin (Merck) is made by dissolving a knife-point of the substance in 1 or 2 c.c. of glacial acetic acid. From 3 to 10 drops of the boiled solution of fæces, further diluted with an equal volume of water, are added, and the two well

mixed by shaking. Hydrogen peroxide (3 per cent) is now cautiously introduced, shaking after each addition, until a blue or green colour develops, or some 2 c.c. of the reagent have been used. Some observers employ filter-paper, saturated with the benzidin solution, on which the fæces are smeared, but the delicacy of the test is not so great, and in my opinion it is much better to use a freshly prepared solution of the reagent. Only Merck's benzidin puriss. should be employed, as Schumm and Westphal found that it is ten times as active as the benzidin puriss. of other firms. As the success of the reaction depends upon the relative amount of the reagents employed, and an excess of hydrogen peroxide may cause the green colour to disappear, the quantities and strengths advised should be carefully adhered to. The following substances have been found by various authors to give a positive reaction: oxydizing ferments of animal and vegetable origin (these are, however, readily destroyed by boiling), iron salts, potassium iodide, pure animal charcoal, metallic iron, platinum and copper in all forms (test-tubes that have been used for sugar reactions must not therefore be used). Pus, saliva, nasal secretions, bowel detritus, and mucus are said by some writers to give a doubtful reaction.

According to Walther, the benzidin test gives a distinct reaction with one part of blood in 250,000. A negative result may therefore be taken as conclusive evidence that no appreciable quantity of blood is present, provided that the test has been properly carried out. If, on the other hand, a positive reaction is obtained, it is advisable to confirm it by the aloin or guaiac test.

2. *The Aloin Test of Rossel.*—A small quantity of the fæces is ground up with water into a thin paste and mixed with an equal quantity of pure ether, well shaken, and allowed to stand for a quarter of an hour. The ether is then poured off and the residue well mixed with one-third of its volume of glacial acetic acid and 10 c.c. of pure ether. After standing for fifteen minutes the ethereal extract is separated. Meanwhile an alcoholic solution of Barbados aloin is prepared by dissolving a knife-point (0·3 gram) of the substance in 10 c.c. of 70 per cent alcohol. About 2 or 3 c.c. of the clear yellow aloin solution are then mixed with an equal quantity of the acid ether extract of the fæces, and 2 or 3 c.c. of old ozonized turpentine.* The mixture is gently shaken and allowed to stand. In the presence of blood a beautiful cherry-red colour develops in the lower layer of aloin, either at once or within fifteen minutes. When the fæces are free from blood the solution is yellow, but a red tint may gradually appear on standing. It does not develop, however, for one or two hours. The aloin solution must be freshly prepared, as old solutions turn red. Fat must be removed as completely as possible, since it reduces the turpentine and interferes with the reaction. It is advisable to treat stools that contain much

* Ozonized turpentine can be prepared by exposing pure turpentine to the air, in large open vessels, in a semi-dark cellar for several weeks. It must not stand in direct sunlight, as it is then liable to give the characteristic colour alone. Before use, its reliability should always be tested by a blank experiment and with a blood mixture.

fat or chlorophyll, with alcohol before extracting with ether, as this prevents the formation of an emulsion that is difficult to clear, and removes other pigments than blood. The ether extraction should also be repeated several times, using small quantities of ether. The reaction may be carried out as a ring-test, by pouring the aloin solution on to the mixed turpentine and acid ethereal extract.

3. *Guaiac Test* (*Weber*).—An acid ether extract of the fæces is prepared as in the preceding test. Two or three cubic centimetres of this are mixed with 10 drops of a freshly prepared tincture of guaiac, and 20 to 30 drops of ozonized turpentine. In the presence of blood, the mixture turns blue-violet, whereas a reddish-brown colour, often with a tinge of green, is seen if blood is absent. The blue colour may be made more distinct by adding water and then extracting with chloroform. The blue of a slight reaction is liable to be masked by the fæcal pigments, giving a green, purple-red, or even a brown-red.

Steele and Butt perform the test by mixing equal parts of a freshly-prepared solution of guaiac in ether, acid ether extract of the fæces, and hydrogen peroxide (3 per cent), and gently shaking. On standing, the peroxide sinks to the bottom, and the ether quickly takes on a blue colour if blood is present. With this method, too, a trace of blood may only be shown by a purple-red colour.

For diagnostic purposes it is wise to disregard all doubtful results, and only consider a distinct blue coloration as indicative of blood. According to Jager, the blue colour is more distinct and the reaction more specific, if a few drops of a solution of sodium hydroxide or ammonia are added to the ether extract before continuing the test. Boas advises that the test should be carried out with an alcoholic solution of acetic acid (glacial acetic acid 25, absolute alcohol 75) instead of with ether, and claims that the colour develops more quickly and is more pronounced. The chief disturbing agent with the guaiac test is iron, and its use should, therefore, be discontinued for several days before the test is applied to the fæces.

The aloin and guaiac tests appear to be of about equal sensitiveness, both reacting with a dilution of one part of blood in 25,000.

4. *A phenolphthalein test* for blood in the fæces has been advocated by Boas :—

The reagent employed is an alkaline solution of phenolphthalein which has been reduced to phenolphthalin by the action of zinc. It is prepared in the following manner : 1 gram of phenolphthalein and 25 grams of fused potassium hydrate are dissolved in 100 c.c. of water, and 10 grams of powdered zinc added. The red liquid that results is stirred and shaken over a small flame until it is completely decolorized, and is then filtered. A little powdered zinc is added to the filtrate to prevent its being oxidized and turned red by the acids in the air. To carry out the test, the fæces are rubbed up with water, a little glacial acetic acid is added, and the mixture extracted with ether. The acid ether extract is poured off into a clean test-tube, 20 drops of the reagent are added, and the mixture is gently shaken. Three or four drops of hydrogen peroxide are then introduced. In the presence of blood-pigment the phenolphthalin is oxidized to phenolphthalein, and appears as a more or less marked pink to red coloration, according to the quantity of blood present. With much blood the red colour persists for some time, but quickly fades if only traces are present. The addition of hydrogen peroxide is not essential if the specimen contains much blood, but to demonstrate small quantities it is necessary. This affords a rough measure of the amount. It is essential that the ether extract should not be too acid, and it is advisable to nearly neutralize it by adding a few drops of 10 per cent sodium hydrate if more than a small quantity of acetic acid has been used.

The delicacy of the phenolphthalein test is said to lie between that of the benzidin and Weber's guaiac test, and it has been claimed that its results are not influenced by meat in the diet. Recent observations by Ruttan and Hardisty suggest, however, that it is the most delicate of all tests for blood, showing one part in 10,000,000 or more; in fact, they state that it is so sensitive that a pinkish colour is obtained with ordinary laboratory distilled water, owing to the presence of infinitesimal traces of iron and copper salts, so that water redistilled in glass had to be used.

Ruttan and Hardisty recommend *tolidin* or *orthotolidin*, a crystalline body of the aromatic series, as a reagent for blood, and claim that it is greatly superior to the reagents in ordinary use. It is said to show one part in 7,000,000 of blood, and, unlike benzidin, which loses 50 per cent of its delicacy when the solution is more than twenty-four hours old, it remains unchanged for three or four weeks. Another point in favour of tolidin is that when the blood is present in only small quantities, the reaction increases gradually in intensity and persists longer than with other reagents, thus being more easily read. The reagent, which is very slightly soluble in water, is easily soluble in alcohol and ether. With blood it gives a green to a blue-black colour, depending on the dilution. The colour does not develop quite as rapidly as the benzidin test, but gradually increases and persists for several hours.

One of the chief difficulties in deciding whether small quantities of blood in the fæces are of pathological significance, is the danger of confusing exogenous with endogenous blood. Many patients object to being kept for several days on a diet free from meat, and it is not always easy to be certain that a patient has carried out instructions to this effect. Boas has therefore suggested that the difficulty may be overcome in the following way. The patient is told to take a suitable purgative, Carlsbad salts, rhubarb, magnesia, or some aperient water, for example, to clear the intestines, and is then only allowed meat prepared by decolorizing it with hydrogen peroxide. From 100 to 125 grams of minced or scraped meat—veal or chicken for choice—are thoroughly mixed with 100 c.c. of a 3 per cent solution of hydrogen peroxide in a porcelain dish, until all the colour has been discharged and a snowy-white mass remains. A plentiful froth must be produced. The meat is then transferred to a sieve and well washed under the tap to remove the peroxide, and made into croquettes. If the patient is allowed no other than this decolorized meat for two or three days, any blood found in the fæces at the end of that time will certainly be of endogenous origin.

The significance of quantities of blood recognizable by the naked eye has already been dealt with; and for such, a chemical examination is merely confirmatory. It now remains to consider what is the diagnostic significance of blood that can only be detected by chemical means. Many of the methods described are so delicate that a characteristic reaction is obtained with very minute quantities. This has the advantage that a negative result may be taken as conclusive evidence of absence of bleeding in the course of the gastro-intestinal tract, but it has the disadvantage that a positive reaction may be due to accidental sources of blood, such as slight hæmorrhages from the nose, gums, etc., even when a diet free from meat or Boas' special preparation exclude an exogenous origin. If, therefore, it is found that, say, the benzidin test, which I apply as a matter of routine to all specimens of fæces, gives a positive reaction, and this is confirmed by the aloin or guaiac test, the patient should be put on a diet of milk, bread, eggs, fruits, and starchy foods, or Boas' decolorized meat, and should not be allowed to brush his teeth or take any drug likely to confuse the issue, for several days before a further test is made. It is also advisable to restrict the fats and limit the quantity of chlorophyl-containing vegetables. Should the stools still contain blood, it may be concluded that there is a bleeding ulcerated surface in the course of the gastro-intestinal tract, if hæmorrhage from the nose, pharynx, and the occasional bleeding from portal or cardiac obstruction, and from polypi or hæmorrhoids, can be excluded. A differential diagnosis may be often thus made between organic disease on the one hand, and cholelithiasis, hyperchlorhydria, simple gastritis, benign obstructions of the pylorus or intestine, etc., on the other. If it is found that a series of four or five examinations on consecutive days all give a positive result, it is very probable that there is a malignant growth in the stomach, intestine, pancreas, or bile-ducts, while the intermittent presence of occult blood is in favour of the ulcer being a simple one.

Boas has reported a remarkable case of ulcerative colitis, in an individual twenty-eight years of age, who passed blood, pus, and Charcot-Leyden crystals in his stools. The large intestine was shut off by a cæcal fistula, and seven months afterwards the fæces were free from pus but still contained blood and crystals. Twelve months later the patient had completely recovered.

As a rule, there is little inclination to hæmorrhage in infantile diseases. During the suckling period blood may be met with in the fæces in cases of melæna vera and spuria, hæmorrhagic enteritis (dysentery), from fissures, polypi, rectal papilloma, trauma, the hæmorrhagic diathesis, invagination, and typhoid ulceration. Tuberculous intestinal ulcers bleed only very rarely, but parenchymatous intestinal hæmorrhage may occur, and lead to fatal results, the lesion being frequently not discovered post mortem. Sochaczewski has reported five cases of intestinal hæmorrhage during the suckling period. In one of these the source of the blood was not known, in another no visible lesion was found after death, in a third a fresh hæmorrhage was found in the ileum at autopsy, and a fourth died from miliary tuberculosis, and ulcers of the intestine were found post mortem. Henry F. Helmolz considers that duodenal ulcers are very common in children, and that in cases of marked anæmia, a loss of blood from this cause must always be considered. He found a duodenal ulcer in eight out of sixteen cases that he examined post mortem. In six of these the patient was under three months old, and in three of them there had been bloody stools. Torday, on the other hand, considers that duodenal ulcer at the suckling age rarely or never gives rise to bloody stools.

PROTEIN SUBSTANCES AND THEIR DERIVATIVES.

Apart from the fibrous tissue and muscle remains found in the fæces of adults on a mixed diet, coagulated albumin is not met with normally. Soluble albumin and albumoses are also only present in pathological conditions. A watery extract of every specimen of fæces will, however, give in the cold a precipitate consisting of nucleo-protein, derived from the nuclei of the cells of the intestinal mucous membrane and the food. Before testing the fæces for albumin and albumoses, it is therefore necessary that this should be removed.

The Detection of Albumin and Albumoses (Schloessmann).—The fæces are gradually ground up with water and then diluted to a thin fluid consistency (about 500 c.c. for the total day's fæces). After standing for about an hour they are filtered through a double filter. The turbid filtrate is then well mixed with a little pure kieselguhr and again filtered. The clear fluid that should result is cautiously acidified with 30 per cent acetic acid, avoiding an excess. The precipitated nucleo-protein is now removed by filtering once or more through a double filter If the filtrate comes through quite clear, it is tested for the presence of nucleo-protein by adding a few drops of 3 to 5 per cent acetic acid, but if it is turbid or gives a nucleo-protein reaction, it must be again treated with a little kieselguhr and the process of filtration be repeated. The clear nucleo-protein-free fluid is then tested for albumin with cold nitric acid, by boiling with acetic acid after adding a little sodium chloride, or by the ferrocyanide test. Great care must be exercised in adding the strong acetic acid, as nucleo-proteins are soluble in an excess. As kieselguhr, like other porous substances, takes up albumin, as little as possible should be used. Simon avoids this difficulty by shaking with fine pebbles. Albu and Calvo use small quantities of animal charcoal to clear and decolorize the filtrate, although they allow that part of the albumin is lost in the process. If care is taken in carrying out the test, it can be shown that normal stools contain no albumin.

The presence of albumoses is most readily demonstrated in the solution by the acetic acid and brine test. The fluid is made strongly acid with acetic acid, and mixed with one-sixth of its volume of a concentrated solution of sodium chloride. If much protein is present, a white precipitate appears, even in the cold. If, on warming, the precipitate disappears, albumoses alone are present. If the solution contains both albumin and albumoses, the precipitate that first appears will disappear as the solution is further heated, and again show a turbidity as the boiling-point is neared. On filtering the hot fluid, the albumoses will form a white cloud in the filtrate as it cools, and the albumin will be left behind on the filter.

Some observers have made use of the biuret reaction in testing for dissolved albumin in the fæces. The most practical method of applying this test to the fæces is that devised by Tsuchya :—

A portion of the well-mixed stool is worked up with water until it has the consistency of a thin syrup. It is then tested with litmus paper, and to each 10 c.c. a quantity of 10 per cent acetic acid and alcohol, varying with the reaction, is added—if the stool is strongly acid, add 0·5 c.c. ; if faintly acid or neutral, 1 c.c. ; if slightly alkaline, 1·5 c.c. ; if strongly alkaline, 2·0 to 2·5 c.c.—and well mixed. Five c.c. of chloroform are now added and thoroughly rubbed up with the mixture. This is now placed in a test-tube and allowed to stand until the chloroform and grosser particles have sunk to the bottom. The upper yellow and faintly tinted layer is decanted into another test-tube and a disc of copper-sulphate agar introduced. After about an hour the disc is taken out, washed with water, and examined. If the fæces contain a large amount of albumin, the disc retains its original bright blue colour ; but if no albumin, or only traces are present, it will be brownish-blue. On pouring over it a little dilute sodium or potassium hydrate solution, the colour will change to blue-violet if albumin is present.

The copper-sulphate agar is made by boiling 2 grams of agar-agar in 100 c.c. of distilled water until it is completely dissolved, and then adding 10 c.c. of a 10 per cent solution of copper sulphate. The hot mixture is poured into a glass tube 0·8 to 1·0 cm. in diameter and 20 to 30 cm. long, closed at one end by a plunger. When the tube has been filled, the other end is covered with a metal or rubber cap. When a test is to be made, the cap is removed, the plunger is pushed in until a piece about 1 cm. is expressed, and this is then cut off level with the end of the tube with a sharp knife.

Relying on the biuret reaction, some observers have stated that albumin and albumoses are almost constantly present in the fæces, but Salkowski, and later Stockvis, found that hydrobilirubin also gives the reaction ; and Ury drew attention to the fact that other pigments, and also the remains of paranuclein and casein, may give rise to misleading results. To obviate these difficulties, Ury advises that the test should be carried out as follows :—

The total fæces passed in twenty-four hours are triturated with 2 per cent acetic acid, made up to a litre, and filtered. The filtrate is concentrated to between 300 and 400 c.c., and mixed with an equal volume of 96 per cent alcohol, or as much more as is necessary to cause complete precipitation. The precipitate is filtered off and the filtrate again concentrated. It is then mixed with eight times its bulk of absolute alcohol, the precipitate separated by filtration, and washed with alcohol until the washings come through colourless. It is then washed and stirred with ether. The residue is now extracted with a warm solution of caustic potash in water, using about 15 c.c., and the product filtered. The deep brown filtrate is boiled with hydrogen peroxide until it becomes yellow, when it is again filtered. On adding a few drops of a very dilute solution of copper sulphate, it will give a violet-purple coloration if albumoses are present. Fæces that contain much mucus must be diluted with water, acidified with a little acetic acid, filtered, and then treated with alcohol. If the patient is taking milk or cheese, and it is thought that casein may be a source of error, it is advisable to omit these articles from the dietary. Simon states that it is better not to evaporate the acetic alcohol filtrate, but to neutralize it and then precipitate with ten times its bulk of alcohol. The precipitate is dissolved in water, giving a light brown solution. The pigments are removed by adding alcohol up to 70 per cent of the volume, mixing with animal charcoal, and filtering. Boiling with peroxide of hydrogen for a short time then serves to remove them completely. Simon's, like Ury's method, depends upon the fact that albumoses are not precipitated in an acetic acid solution by 50 per cent alcohol, but has the advantages that a lighter-coloured solution results, that less prolonged heating with peroxide of hydrogen is necessary, and that the separation of albumoses which have been rendered insoluble is avoided. By employing one or other of these methods it has been shown that normal fæces do not give the biuret reaction.

Schmidt's Fermentation Test (*p.* 215) gives information as to the presence of dissolved albumin in the fæces, although it is more particularly useful in connection with the detection of unutilized carbohydrates. A distinct alteration in the reaction on the alkaline side, an intense putrefactive odour, a dark coloration of the fæces, and gas-formation after twenty-four hours in the incubator at 37° C., show that putrefaction of proteins has been going on. Such putrefactive changes occur only in the albumin contained in the intestinal exudates, and not in that derived from the food, so that their presence points to the existence in the fæces of albumin from that source.

Dissolved albumin is only found in the excreta of adults under pathological conditions, and when there is an inflammatory condition of the alimentary tract. As the large intestine can absorb considerable quantities of protein, albumin is only met with in the fæces when the inflammation is extensive and serious. Albu and Calvo examined the stools of eleven cases of typhoid fever and found traces of albumin in three, but never any albumose or peptone; but of fifteen cases of intestinal catarrh, small quantities of albumin were detected in six, and in three of these there were also traces of some substance that was precipitated by acetic acid. A considerable quantity of albumin may be present in the fæces in diarrhœa, cholera, dysentery, and colitis; and in chronic mucoid conditions of the bowel there is generally a slight albumin reaction. When blood, pus, or mucus occur in the fæces, a positive reaction may be due to these substances. Ury states that the albumin met with in pathological stools is never derived from the food, but comes from the intestinal transudates. It is not unlikely, however, that in some cases of simple diarrhœa and jaundice, a positive reaction may depend to a certain extent upon the presence of unabsorbed food residues. According to Simon, albumoses are only very rarely met with in the fæces of adults, and then always in association with albumin.

Albu and Calvo investigated the stools of six healthy children varying in age from one to six years, and in four of these found no protein of any kind. In two, however, they met with traces of a substance precipitated by acetic acid, and also with traces of albumin, but never any albumose or peptone. In the fæces of seven infants suffering from gastro-intestinal affections (four with vomiting and diarrhœa, three with enteritis), and seven older children (four with subacute enteritis, one with acute enteritis, one with subacute dysentery, and one with recent dysentery), it was found that in all the acetic acid reaction was positive in the cold and generally gave an abundant precipitate, especially in the younger children. The presence of albumin was demonstrated in most of the cases, and was particularly common in the infants, but albumoses were never found. They therefore came to the conclusion that albumin is present in the stools of children far more constantly than in adults under corresponding conditions. They point out that the acetic acid reaction observed is very possibly due to mucus in solution, especially in those cases where undissolved mucus can be recognized by the naked eye and under the microscope. Whether the protein reaction indicates defective absorption or, as is perhaps more likely, is dependent upon albumin arising from an excretion by the intestinal wall itself, was not decided. Oshima states that breast-fed children pass at the most traces of protein in their stools if they are healthy, or even if they are suffering from slight indigestion, but that when affections of the stomach or bowels exist, the fæces may contain considerable quantities. He found that the protein reaction is almost always positive with children fed on cow's milk, and is more marked in those suffering from dyspepsia or gastro-intestinal symptoms than in those apparently healthy. When the diet consists of skimmed milk or buttermilk he found traces of protein in healthy children, and distinctly larger quantities when there were digestive difficulties. The fæces of children who received more than the average amount of cow's milk gave a decided precipitate with phosphotungstic acid, but other reactions for protein were only slight. Where there was constipation, and the child was taking cow's milk, the potassium ferrocyanide reaction was distinct, but other reactions were negative or only very faint. When Liebig's extract was given in the form of soup, there were traces of albumin even in normal children, and with dyspeptic infants a decided reaction was obtained. He confirms the well-known observation that the stools passed by starving persons to whom tea has been administered, give a positive reaction with Millon's reagent and a slight reaction with other protein tests. When, however, food containing a little protein was taken, or the diet consisted exclusively of carbohydrates, he was unable to demonstrate any protein in the stools, or at most there was slight clouding on adding acetic acid, even when there was severe intestinal catarrh. Adler carried out a number of detailed investigations upon the nitrogenous content of the fæces of infants, and found that, whether they were brought up on cow's milk or were breast-fed, a precipitate was always given with acetic acid, and that a similar result was obtained with the stools passed during starvation. He came to the conclusion that the substance giving rise to this reaction is a normal constituent of the stools, and is a nucleo-protein derived from the gastro-intestinal juices or the bile. He found only traces of albumoses in the fæces of infants fed on breast milk or cow's milk, and only in one case of intestinal catarrh was there any increase. Adler states that normally, whatever the diet may be, most of the nitrogen is present in the fæces in a coagulable form, and that a very considerable part of it can be attributed to the intestinal bacteria. The soluble nitrogen is for the most part precipitated by phosphotungstic acid, and consists of ammonium salts and decomposition products of albumin. The biuret reaction is usually negative, and only in exceptional cases is peptone to be found. When the precipitate given by phosphotungstic acid is filtered off, the filtrate contains hardly any nitrogen, and usually none at all.

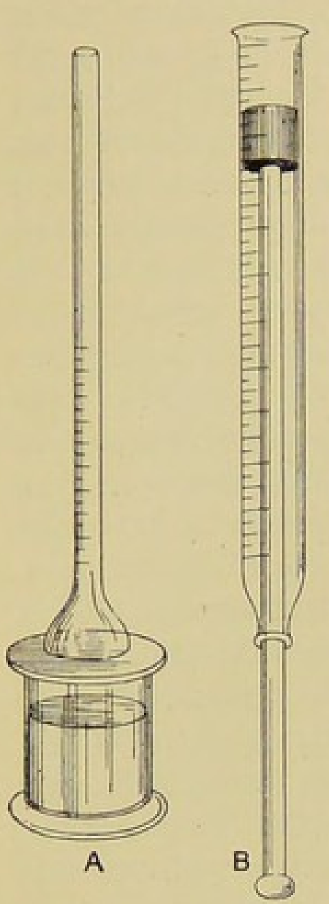


Fig. 72.—Strasburger's Apparatus for measuring fæces. A, For large masses. B, for small masses.

For the detection and estimation of the undigested albuminous material derived from the food, Schmidt recommends the following method :—

By means of Strasburger's or Sato's apparatus (*Fig.* 72), a quantity of the well-mixed stool equivalent to 0·25 gram of the dry substance, corresponding to 1 c.c. when the fæces are of average consistency, about 0·8 c.c. when they are hard, and 3 c.c. when they are fluid, is taken and very thoroughly rubbed up with a few cubic centimetres of water in a glass mortar. The emulsion is then washed into a centrifuge tube with water and filled up to 9 or 10 c.c. It is now centrifugalized for about half a minute. The supernatant liquid is poured off from the sediment, which is mixed with water and then centrifugalized again. The residue at the bottom of the tube is now washed successively with 0·4 per cent hydrochloric acid, alcohol, ether, and water, by being centrifugalized with each for half a minute. After the water has been poured off, the residue is mixed with 8 c.c. of a digestive mixture, consisting of hydrochloric acid 10 c.c., water 1000 c.c., pepsin 30 c.c., and placed in a special stoppered centrifuge tube. This is about 8 or 9 cm. long, and the upper 6 cm. are about 1·5 cm. broad; but the lower 2 cm. are narrowed to 0·5 cm. and are graduated in millimetres (*Fig* 73). After being submitted to centrifugalization in this, the height of the solid deposit is read off on the scale. The tube is now closed with the stopper, well shaken, and placed in the incubator for twenty-four hours. It is then centrifugalized again, and the height of the deposit read off on the scale. The difference between this and the reading given before the digestion is taken to

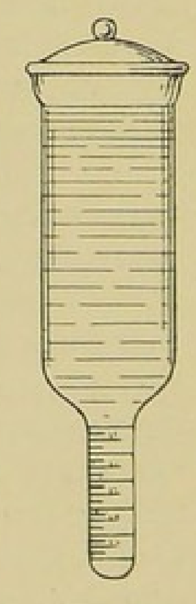


Fig. 73. Schmidt's tube for albumin residues.

represent the volume of the undigested albuminous residues in the fæces.

The quantity of "rest" albumin in the fæces is determined by Koziekowsky in the following manner :—

A certain weight of the stool is rubbed up with alcohol, filtered through a nitrogen-free filter, and washed off with 3 per cent hydrochloric acid. It is then divided into two equal portions. Both are placed in closed flasks, and to one is added 50 c.c. of a digestive fluid (hydrochloric acid 10, distilled water 1,000, and pepsin 30), while the other is mixed with 50 c.c. of the same fluid which has been boiled for three-quarters of an hour to destroy the pepsin. The acidity is tested with Meth's test, and both flasks are placed in an incubator for twenty-four hours. At the end of that time the fluids are filtered, and the free and attached acid is determined by titration with decinormal soda solution, using dimethyl-amido-azobenzol and phenolphthalein as the indicators.

The Biological Differentiation of Proteins.—It has lately been suggested by Schloessmann that the proteins in the fæces coming from the food may be differentiated from those originating within the organism by the precipitin reaction, using about 0·1 c.c. of immune serum and 2 c.c. of an acetic acid extract of the fæces, freed from nucleo-protein. He found that human anti-serum always gave a positive reaction. According to Hecht, the test is, however, of little practical value, and Hamburger has shown that egg-albumen loses its characteristic properties after digestion in the stomach.

CASEIN.—Several methods of testing chemically for casein in the stools have been devised, but none of them are satisfactory.

Albu and Calvo make an emulsion of the fæces, remove the hydrobilirubin with animal charcoal, and acidify with acetic acid until the maximum clouding is obtained. The precipitate is then collected on a clean filter, thoroughly washed four times with water, and dissolved in 20 c.c. of weak caustic soda solution. The solution is carefully neutralized with acetic acid. On adding a little more acetic acid, a dense precipitate, insoluble in excess of the acid, appears. Heller's cold nitric acid test, the potassium ferrocyanide test, the xanthoproteic reaction, the boiling and the biuret tests, all give a positive reaction. After incubating with hydrochloric acid, no reducing substance should be produced, and the percentage of phosphorus, as estimated by Salkowski's method, should be considerable. Simon points out, however, that beside casein, any nucleo-protein, such for example as the nucleo-albumin of the bile, may give these reactions.

Biedert extracts the fresh fæces successively with distilled water, a dilute solution of sodium chloride, and very dilute hydrochloric acid. The residue is then mixed with sodium hydrate solution and filtered. On adding acetic acid, a precipitate, insoluble in excess, appears, if casein paranuclein is present. The same objection applies to this as to the preceding method.

Nucleo-proteins and Nucleins.—The nucleo-proteins are combinations of nucleic acid with a protein substance. They are very widely distributed in the organism, and occur to such an extent in cell-nuclei that their presence in the fæces can be readily accounted for. For the most part, however, nucleo-proteins are broken up in the intestine into albuminous products, which are readily absorbed, and nucleins, which are nucleo-proteins of a very acid character containing a high percentage of phosphorus, and, although more or less resistant to the action of pepsin and hydrochloric acid, are digested by trypsin. The nucleins may be changed still further, and it is characteristic of them that they yield various purin bases, including guanin, adenin, xanthin, hypoxanthin, and uric acid. The stages of nucleo-protein catabolism are conveniently summarized in the following table :—

- Nucleo-protein
  - Nucleo-proteins poorer in protein but richer in phosphorus
    - Nuclein
      - Nucleic acid not giving the biuret reaction
        - Phosphoric acid in organic combination
        - Purin bases, one or more,
        - pyrimidon bases, hexoses, pentoses
      - protein
    - protein
  - protein

The nuclein bodies appear to be broken down by the action of certain ferments. One of these, nuclease, transforms nucleic acids from the gelatinous to the non-gelatinous form, and then splits them up into phosphoric acid, purin bases, and pyrimidon. This ferment, which is found in the pancreas and in the mucous membrane of the intestine, is quickly destroyed by trypsin. The purin bases are also acted on by other ferments, termed guanase and adenase, which change guanin into xanthin and adenin into hypoxanthin respectively. Beside these there is a ferment known as xanthin-oxydase, which changes hypoxanthin into xanthin.

The nature of the individual bases met with in the fæces has been investigated by Krüger and Schittenhelm, who found mostly guanin and adenin, less hypoxanthin, and still less xanthin. A comparison of their results with those obtained by Schindler is of interest. He allowed nucleic acid to decompose in an infusion of pancreas, and found that guanin changes into xanthin, and adenin into hypoxanthin. Since hypoxanthin is only soluble with difficulty, and is therefore likely to be slowly absorbed, it would seem that this affords another instance of the fact that experiments in vitro often yield results very different from those which occur in the alimentary canal.

The possible sources of nucleins in the fæces are: the remains of the nuclei of the food which are only soluble in pancreatic juice; the secretions of the intestinal mucous membrane; the juices poured into the alimentary tract by the glands opening into it; and the bacteria of the intestinal canal.

The fact that adenin and guanin constitute the greater part of the nuclein bases of the fæces, though from the composition of the food we should expect hypoxanthin to preponderate, suggests that the nuclein bases of the stools are not derived from the food. Nor can they come from the bile, which contains no nuclein bases; and moreover these bodies are still present in the stools when bile is excluded from the intestine. There remain, therefore, only the bacteria of the alimentary tract, and the derivatives of the intestinal mucous membrane and the pancreas. The epithelial cells that are constantly being shed from the alimentary tract are probably an important source, but an explanation is still needed of the fact that in jaundice the amount of nuclein bases in the fæces is less than under normal conditions. It has been suggested that when no bile enters the bowel, the intestines contain so much unabsorbed fat that they act like an ointment to the mucous membrane and minimize the desquamation of epithelium.

Weintraud has made the interesting observation that uric acid, as well as purin bases, is always present in the fæces of even young infants, meconium yielding between 0·3 and 0·1 gram of pure uric acid for every 100 grams of the dry weight. In adults, however, uric acid is nearly always absent when calomel has been administered. Weintraud therefore concludes that when putrefaction and processes of reduction, which generally go together, predominate in the alimentary canal, the formation of uric acid is not possible; but when, as in the case of meconium, processes of oxidation are going on, not only is the conversion of bilirubin to biliverdin possible, but there is also a development of uric acid from nuclein bases. Since meconium is sterile and consists mainly of the products of excretion from the body, these discoveries with regard to the presence of nuclein bases in meconium support the view that they are partly of intestinal origin. Nuclein bases are also to be found in the fæces of starving individuals, but in this case they may be derived from bacteria; and the same explanation holds good for their presence on a diet of cow's milk, although the milk may be free from nuclein bases. Another observation lending support to this view, is the discovery by Weintraud that there is no increase in the nuclein-base nitrogen after the administration of foods containing an abundance of nuclein, but that there is a decided increase in leukæmia. The origin of nucleins from the juices poured into the intestine by the digestive glands is suggested by the fact that Hammersten and others have found nucleo-proteins in the pancreas containing as much as 4·48 per cent of phosphorus.

Schittenhelm added nuclein substances to fæces and found that they disappeared under the influence of the putrefactive changes that take place. It is not certain, however, whether this results only in consequence of the action of bacteria, or whether ferments also play a part. It is possible that the addition of nuclein substances to the fæces in this way does not reproduce exactly the conditions present in the alimentary tract where the bases may not be free, but combined as nucleo-proteins, possibly within the bodies of bacteria, and only become free on the dissolution of the latter. Tollens and Schittenhelm have shown that some 25 per cent of the nuclein bases of the fæces are actually contained in the bacteria.

The nucleins and their degradation products, the purin bases (xanthin, hypoxanthin, guanin, adenin, and uric acid), are sought for in the fæces by the following method, devised by Krüger and Schittenhelm :—

The total day's output of fresh fæces is mixed with 1 to 2 litres of water acidified with 15 to 20 c.c. of concentrated sulphuric acid, and heated for about three hours over the free flame in a flask provided with a reflux condenser. The mixture is then made alkaline with sodium hydrate, acidified by the addition of 10 to 20 c.c. of acetic acid, and heated for a short time on a water bath. While still hot, 10 grams of oxalic acid are added, and an excess of chalk is introduced. The mixture is now cooled, made up to 1,500 to 3,000 c.c. with water, and filtered through a dry filter paper. If there is a large residue on the filter, it is washed off with hot water, mixed with an acid solution of sodium acetate, warmed, filtered, and the filtrate added to that previously obtained. A part of the filtrate (500 c.c.) is placed in a flask, made alkaline with sodium hydrate, mixed with 10 c.c. of a solution of sodium bisulphite for each 100 c.c., and heated to boiling. An equal quantity of 10 per cent copper sulphate solution is now added, and the mixture is heated to boiling for a few minutes. The resulting flocculent precipitate of the copper compound of the purin bases and uric acid is filtered off, washed, and placed, with the filter, in a flask. About 200 c.c. of water are added and shaken up with the precipitate. The mixture is now heated to boiling, and a solution of sodium sulphide that has been previously treated with 1 per cent sodium hydrate to free it from sulphuretted hydrogen, is added, until lead-acetate paper no longer gives a brown colour. The contents of the flask are again boiled for a few minutes, acidified with 10 c.c. acetic acid, and heated until the copper sulphide is aggregated. If this does not take place, the fluid is treated with 5 to 10 c.c. of a saturated solution of aluminium acetate and again heated. The precipitate is separated by filtration, mixed with water, boiled, again filtered, and the filtrate added to that first obtained. This procedure is repeated several times. To the mixed filtrates are now added 10 c.c. of a 10 per cent solution of hydrochloric acid, and the solution is evaporated down to dryness. The residue is then treated with 5 c.c. of hydrochloric acid and a little warm water and gently heated, cooled, and filtered. The flocculent brown deposit is washed several times with water, and the purin bases are then sought for in the combined filtrates by (1) the copper, or (2) the silver method.

1. The filtrate is made feebly alkaline with ammonia, after being brought to the boil; 10 c.c. of sodium bisulphite solution and 10 c.c. of copper sulphate solution are then added, and the mixture is boiled for three minutes. It is now filtered through Swedish filter-paper, the precipitate washed with hot water, and the nitrogen estimated with Kjeldahl's method.

2. The filtrate is made faintly alkaline with ammonia, and mixed with 10 c.c. of ammoniacal silver solution and 20 c.c. of 10 per cent ammonia. To this are now added 10 c.c. of a 6 per cent solution of di-sodium phosphate solution and 5 c.c. of magnesia mixture. After standing for two hours, the precipitate that has formed is filtered off, washed free from ammonia, and transferred to a round-bottomed flask with hot water. The ammonia is then neutralized by mixing the solution with magnesia usta, and boiling. The nitrogen in the remaining silver compound is then estimated by the Kjeldahl process.

The brown residue that remains on the filter from the original solution contains the uric acid present in the fæces. This can be tested for in the ordinary way, and may be estimated by direct weighing or from an estimation of the contained nitrogen.

Nicko's modification of Kossel's method of demonstrating the nuclein bodies in the dried fæces is described in the next chapter.

It may be pointed out here that the nucleo-proteins must not be confused with the nucleo-albumins, phospho-proteids, or para-nucleo-proteins, which resemble them in yielding phosphorus, and also to some extent in their solubilities and digestibility. They are essentially different, however, in that they do not yield nucleic acid or purin bases on cleavage.

MUCUS.

It is important to bear in mind that not all mucus-like substances contain mucin. This, in its typical form, is a compound proteid consisting of a protein radicle and a nitrogen-containing carbohydrate, glucosamin. Hence, when boiled with acids, mucin yields a substance reducing alkaline solutions of copper, etc., like a sugar. Mucin is acid in reaction, probably owing to the presence of chondroitin-sulphuric acid, at least in some varieties, and therefore stains with basic aniline dyes. Certain of the more characteristic staining reactions of mucin have already been mentioned. Mucin readily dissolves in very weak alkaline solutions, and is precipitated by acetic acid. On adding 1 per cent acetic acid to mucus under the microscope, it usually becomes cloudy and soon develops lines in its substance, either in the form of streaks or a net-work. Sometimes, however, it first appears clearer, and it must then be assumed that the ground substance does not consist of mucin but of protein. According to Akerlund, a 2 per cent solution of hydrochloric acid dissolves mucus, and when the solution is warmed it develops a brown colour, but according to Schmidt a 10 per cent solution is necessary for solution to take place.

The term mucin probably embraces a number of related but distinct substances; some are alkaline in reaction and are not precipitated by acetic acid (pseudo-mucins), others yield a reducing substance without previous decomposition with acids (para-mucin), while even the "true" mucins differ in their solubility. It has been established that the mucus of the intestinal epithelium and of the stomach is a "true" mucin, and that formed in catarrhal inflammations is merely an excess of a normal secretion. According to Paijkull, the mucus of the bile is a nucleo-albumin which only gives a reducing substance with 7·5 per cent hydrochloric acid when the boiling is continued for half an hour.

Gross masses of mucus may be picked out of the fæces with forceps, or water may be added to the stool, and they may be separated by a special sieve, such as that of Boas, in which a stream of water is allowed to play on the stool, washing away much of it, and leaving behind the particles of mucus, connective tissue, foreign bodies, intestinal parasites, and larger fragments of undigested food. Strauss has modified this sieve so that the water plays on the fæces from below instead of from above, thus avoiding breaking up the particles by the mere weight of the water falling upon them. Strauss' apparatus also has the advantage that the masses of mucus do not so readily block up the apertures in the sieve. Schütz devised another sieve, which, although slower in its action, is sometimes useful. It consists of three strainers, one within the other, and each having a finer mesh than the preceding. The water comes in from below. The coarser particles are retained on the first sieve, those of an intermediate size on the middle, and the finest on the last sieve. Gulzner advises breaking up the stool with a stream of alcohol, about half a litre being used, and an apparatus resembling an egg-whisk. As the mucus particles quickly shrink in the alcohol, this method is not to be recommended. The mucus obtained in any of these ways is dissolved in weak sodium hydrate solution and tested with acetic acid. If a precipitate insoluble in excess forms, the fact that it is due to mucus must be proved by demonstrating the absence of phosphorus, and testing its reducing power after boiling with a hydrochloric acid, thus showing that it is not due to nucleo-proteins, etc.

To Test for Phosphorus.—The precipitate is well washed, dried, and mixed with about thirty times its volume of a mixture of three parts of potassium nitrate and one part of sodium carbonate. The mixture is then placed in a platinum dish and fused. The fused mass is dissolved in water strongly acidified with nitric acid, and heated until the evolution of nitrous acid fumes has ceased. The solution is then evaporated to a small bulk on the water bath, ammonium nitrate and ammonium molybdate solution are added, and the mixture is left to stand at the room temperature until the next day. It is then decanted through a small filter, and the dish and filter washed with a solution containing 150 grams of ammonium nitrate and 10 c.c. of nitric acid to the litre. The yellow residue in the dish, if any, is dissolved in dilute ammonia (1–3) by warming, and filtered through the same filter. Hydrochloric acid is now added to the solution until a yellow precipitate begins to form, and about one-fourth of the volume of ammonia and a tenth of magnesium chloride mixture are then introduced. Next day the precipitate of ammonium magnesium phosphate that will have separated if any phosphorus is present, is filtered off and washed with dilute ammonia until the filtrate no longer gives a turbidity with silver nitrate. It is then strongly ignited, and the magnesium pyro-phosphate (111·36 parts of which correspond to 31 parts of phosphorus) may be weighed.

To Determine the Reducing Power.—The washed precipitate is mixed with 7·5 per cent hydrochloric acid, and heated to boiling-point in a water bath for about ten minutes. The fluid is then filtered, made strongly alkaline with sodium hydrate, a little copper sulphate solution added, and heated.

The entire quantity of the fæces may be examined for mucus by Hoppe-Seyler's method :—

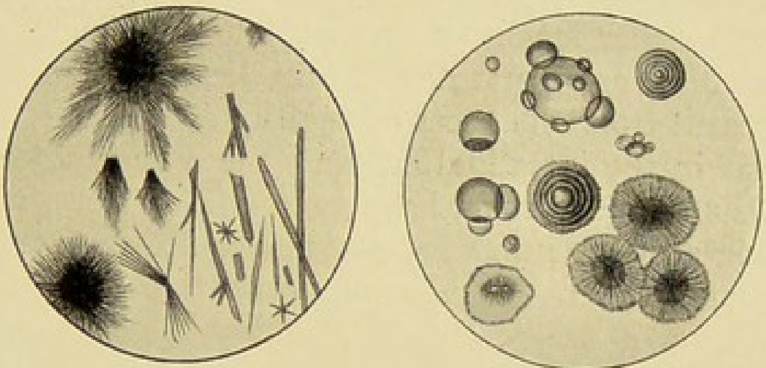
The stool is thoroughly mixed with water, and an equal quantity of lime-water added. The mixture is allowed to stand for a few hours, filtered, and the filtrate tested with acetic acid. If mucus is present, a precipitate, insoluble in excess of the acid, is thrown down. As in the preceding method, the precipitate can only be regarded as due to mucus if it contains no phosphorus, and if, after boiling for a short time with 7·5 per cent hydrochloric acid, it strongly reduces an alkaline solution of copper sulphate.

For clinical purposes the macroscopical and microscopical discovery of mucus is much easier and more reliable than its chemical demonstration, for the latter, unless thoroughly carried out, is apt to give most misleading results. Moreover, the mucus formed in the upper part of the intestine is usually so altered during its passage through the bowel, that its chemical characters are lost, while that coming from the lower part of the colon is so dense and permeated with fat and cells that it is almost insoluble, excepting in strong alkalies, and does not then give the usual precipitate with acetic acid. Nothnagel obtained a cloudiness on adding acetic acid to a solution of membranous mucus in hot potash, but it was soluble in excess. He found that globulin, as well as mucus, is present, and attributes this to the cells embedded in the mucus. Although micro-organisms do not grow well in mucus, it has no marked bactericidal powers. Most bacteria that liquefy gelatin also liquefy mucus. Bacillus coli dissolves it slowly, and B. typhosus more slowly still. Incubation experiments show that when putrefactive processes are going on, mucus quickly becomes unrecognizable. This is possibly the explanation of the fact that the soapy stools met with in infants are free from mucus, the alkaline reaction of such stools favouring the growth of putrefactive organisms and so leading to the destruction and disappearance of any mucus that may be present. It may be contended, however, that in the absence of an abundant secretion of mucus, saponification takes place more rapidly than usual, and that conversely, an excessive secretion of mucus envelops and protects the fats from chemical change. Finkelstein, v. Reusz, and Sperk have recently maintained that the presence of sugar has an important influence on the production of mucus, and they hold that in those cases in which soapy stools are due to a deficiency or absence of carbohydrate in the food, this factor is also responsible for the absence of mucus in the fæces.

AMINO-ACIDS AND THEIR DERIVATIVES.

In the digestion and putrefaction of protein substances a number of simple and aromatic amino-acids are split off. The best known of the former is leucin (amino-isobutyl acetic acid), and of the latter tyrosin (oxyphenyl-amino-propionic acid) and tryptophan (indol-amino-propionic acid). Under normal conditions these undergo further changes and give rise to phenol, paracresol, indol, skatol, and other related substances, which appear partly in the urine in combination with sulphuric and glucuronic acids, and partly in the fæces in an unchanged condition. When, however, there is defective absorption from too rapid passage of the intestinal contents, or interference with the digestive processes from lack of the pancreatic secretion, etc., amino-acids, and particularly leucin and tyrosin, may be found in the fæces.

Leucin and Tyrosin may be separated from the fæces by extracting with ether, and then with alcohol, filtering the alcoholic extract, evaporating down, and dissolving the residue in hot water. On standing, the amino-acids crystallize out. Or they may be obtained separately by treating the watery solution of the alcoholic extract with lead acetate, removing the excess of lead with sulphuretted hydrogen, and evaporating the filtrate to dryness. The leucin is then dissolved out with hot alcohol, and the tyrosin extracted with hot water.



A B

Fig. 74.—A, Tyrosin. B, Leucin.

Leucin crystallizes out in the well-known balls and knobs, which melt at about 297° C. On adding a boiling solution of copper acetate to a boiling watery solution of leucin, it forms blue rhombic tables that are only feebly soluble in water, and are insoluble in methyl alcohol.

Tyrosin separates in characteristic sheaves of colourless needles, which, on being warmed with Millon's reagent, give a red colour. A little dry tyrosin, on being heated in a water-bath for half an hour with a small quantity of concentrated sulphuric acid, diluting with water, neutralizing with barium carbonate, filtering and evaporating, yields tyrosin sulphate, which, on being treated with a few drops of neutral perchloride of iron solution, shows a violet colour.

Uffelmann has employed the method of Fischer and Bergell of testing for amino-acids in the fæces :—

Eight or ten stools are mixed together, triturated with water, boiled with acetic acid, and filtered. The filtrate is concentrated on the water bath, cooled, and shaken with ether for eight hours to remove the fat. The remainder is neutralized with potash, and is then treated with 20 per cent sulphuric acid and 20 per cent phosphotungstic acid.

The precipitate that forms is filtered off, and the filtrate neutralized with barium hydrate, which removes the sulphuric and phosphotungstic acids. The filtrate is now concentrated on the water bath, and for every 500 c.c. of the original fluid 2 c.c. of a 10 per cent solution of naphthalene-sulpho-chloride are added. It is then made slightly alkaline and shaken for twelve hours. Every three hours 1 c.c. of the reagent and a little potash are added. At the end of the twelve hours the product is flooded with ether, the supernatant fluid is made acid with hydrochloric acid, and allowed to stand for twenty-four hours. At the end of this time a crystalline precipitate, consisting of naphthalene-sulpho-tyrosin, separates out. It is soluble in water with difficulty, and is readily crystallizable from alcohol, melting at 129° C. A watery solution, even when extremely dilute, gives a beautiful Millon's reaction.

Meconium is always free from leucin and tyrosin. Uffelmann found leucin frequently in the fæces of young children, and tyrosin occasionally. With the method just described, the crystalline precipitate amounted to 0·11 gram with breast-fed children, and to about 0·24 gram when the food consisted of cow's milk. Wegscheider failed to find either leucin or tyrosin, but Adler agrees that very small quantities are present even in health. Amino-acids are not only absent from the fæces of healthy adults, but they are not even present in the intestinal contents when they enter the colon. Traces of leucin and tyrosin have been chiefly met with in conditions associated with hurried peristalsis and defective absorption, such as Asiatic cholera (Gamgee and others).

Phenol, Indol, Skatol, and the aromatic oxy-acids appearing in the fæces as the result of putrefactive changes in the intestinal contents, are demonstrated by the following procedure (Schmidt and Strasburger).

The fæces are well rubbed up with water to a thin fluid and distilled, about a third of the volume of the liquid being driven over. This distillate (1), which contains the indol, skatol, phenol, and volatile fatty acids, is neutralized with sodium carbonate and again distilled. The fatty acids which have combined with the sodium to form soaps remain behind, and the phenol, indol, skatol, and phenol pass over into the distillate (2). In order to separate the phenol from the indol and skatol, the distillate is made strongly alkaline with potassium hydrate and re-distilled. The new distillate (3) contains the indol and skatol. In order to obtain the phenol which is present in the residue in the flask, the latter is made acid with sulphuric acid and again distilled (4).

The presence of *aromatic oxy-acids* may be demonstrated by making the residue from the first distillate (1) acid with sulphuric acid, extracting with several portions of ether, evaporating off the ether from the mixed extracts, dissolving the residue in a little water, and testing it with Millon's reagent. A red colour on warming should result.

The presence of *phenol* in distillate (4) is shown by a red coloration or red precipitate on heating with Millon's reagent, an amethyst-blue colour on adding a few drops of a dilute neutral solution of perchloride of iron, and the formation of a turbidity, and then a precipitate of yellowish-white needles or cheesy flocculi of tribromphenol with bromine water.

Indol is looked for in distillate (3) by treating it with a few drops of nitric acid containing nitrous acid, or pure nitric acid and sodium nitrite, when a red colour, and eventually a precipitate due to the formation of the nitrate of nitroso-indol, appears; on adding a few drops of a fresh solution of sodium nitroprusside, and making the solution alkaline with sodium hydrate, the mixture takes on a violet colour which, on the addition of glacial acetic acid, turns pure blue; a pine-wood splinter moistened with strong hydrochloric acid is coloured cherry-red by an alcoholic solution of indol.

The *skatol* in distillate (3) gives the following reaction: with nitric and nitrous acid only a milky cloudiness results; on adding sodium nitroprusside, an intense yellow colour develops, which, on boiling and adding one-half of its bulk of glacial acetic acid, turns violet; skatol dissolves in concentrated hydrochloric acid with a violet colour.

The demonstration of cresol in the presence of phenol, with which it is obtained in distillate (4), is not easy when only small quantities are present. They may be separated from each other by converting them into the sulpho-acids, and taking advantage of the fact that the barium salt of para-sulpho-phenol is practically insoluble in barium hydrate solution.

The following methods have been suggested for the quantitative estimation of indol and skatol in the stools:—

Schmidt and Baumstark have shown that a 5 per cent alcoholic solution of Ehrlich's reagent (dimethylamidobenzaldehyde), on the addition of concentrated hydrochloric acid, gives, with a solution of indol, a red, and with skatol, a blue, colour, of extraordinary intensity. The spectra of these solutions are characteristic, that of indol showing a band between D and E, beginning at D, and skatol two bands, one identical with the indol band, and a second between C and D.

By making use of a test solution consisting of 1 c.c. of such an indol preparation, containing 0·005 gram in 1000 c.c. of absolute alcohol, diluted with 3 c.c. of absolute alcohol, Baumstark has devised a method for estimating indol in the fæces.

According to the consistency of the stool, 2·5 to 3 grams, or with fluid fæces 10 grams, are weighed out and ground down with 40 c.c. of absolute alcohol until no gross particles can be seen. After standing for a short time, the mixture is filtered through a moist filter. The residue on the filter should now give no reaction for indol, showing that it has been completely extracted. To 10 c.c. of the filtrate is added 1 c.c. of Ehrlich's reagent and 1 c.c. of concentrated hydrochloric acid, drop by drop. The mixture is then well shaken for ten minutes. One cubic centimetre of the solution is now compared with the standard, and diluted if necessary with absolute alcohol until the absorption bands correspond. If x is then taken to represent the indol content of the 10 c.c. of the fæcal filtrate, and y the dilution necessary to bring 1 c.c. of it to the same strength as the test solution, then $x = 0{\cdot}000015 \times y$, and from this the total quantity of indol in the fæces can be reckoned. As the hydrobilirubin of the fæces passes over in the alcohol extract and gives a similar spectrum to indol, it must be removed by extracting with petroleum ether or treating the solution with chloride of zinc or tincture of iodine.

Moraczewski advises the following method: 30 to 40 grams of the stool, or more if it is fluid, are mixed with 700 c.c. of water in a 1500 c.c. flask, and carefully distilled, regulating the flame to prevent excessive frothing. When 500 c.c. have passed over, 150 c.c. are taken, mixed with 10 drops of concentrated sulphuric acid and 1 gram of kieselguhr, well shaken, and filtered. To the clear filtrate are now added 2 to 8 drops of 0·2 per cent sodium nitrite solution. After standing for two to three hours, the solution is placed in a colorimeter and compared with a standard solution. This consists of 1 c.c. of a 1 per cent solution of indol diluted with 500 c.c. of water, of which 5 c.c. are mixed with 10 drops of sulphuric acid and 2 to 5 drops of sodium nitrite solution, and then diluted to 100 c.c. Each cubic centimetre of the standard solution contains 0·000002 of indol.

Herter and Foster's method of separating indol and skatol from the fæces gives very satisfactory results: 25 grams of the fæces are mixed with 20 c.c. of water and 1 to 2 c.c. of 10 per cent sodium hydroxide, and submitted to steam distillation until the distillate no longer gives a reaction with Ehrlich's reagent. The mixed distillate is then made faintly alkaline with sodium or potassium hydroxide, and an excess of beta-naphthaquinone-sodium-monosulphonate in 2 per cent solution is added. In the course of fifteen to thirty minutes, the latter substance reacts almost completely with the indol, but not with the skatol, forming a closely-felted bluish precipitate of acicular crystals, which is filtered off. The filtrate, which should have a slight yellow tinge, showing that sufficient of the naphthaquinone compound has been used, is acidified and steam-distilled. The skatol passes over in the distillate, whereas any indol is held back in the form of the indol-naphthaquinone compound, excepting a negligible quantity which passes over with the skatol. The distillate is boiled with a 5 per cent solution of dimethyl-amidobenzaldehyde in 10 per cent sulphuric acid, and sufficient dilute hydrochloric acid added to produce the maximum intensity of colour. An excess must be carefully guarded against, as it causes the colour to fade again. The cooled mixture is now extracted with chloroform, and the blue colour matched against a freshly-made standard solution of skatol in water that has been treated the same way. The residue left in the flask from which the distillate has been obtained is extracted with chloroform, the extract separated, the crystals of indol-naphthaquinone previously removed are added, and the indol present is estimated by comparing the colour of the solution with a standard in a colorimeter, or the chloroform may be evaporated and the residue weighed.

Since the indol, phenol, and skatol contained in the fæces result from degradation processes in the proteins present in the alimentary tract, the quantity of these substances is largely dependent, in the healthy state, upon the amount of albuminous food taken. With a diet rich in carbohydrate and poor in protein, small quantities only are formed, but with a purely meat diet there is a considerable increase. As, however, the number and activity of the putrefactive bacteria in the intestine also influence the formation of these substances, and stagnation of the food residues in the intestine favours their action, the constipation that usually results from a meat diet, as well as the quantity of protein, must also be taken into account. A milk diet, in spite of the quantity of protein that it contains, causes comparatively little indol or skatol formation, owing to the nature of the protein and its being quickly absorbed (Laquer and Escherich). Even in the stools of fasting individuals, however, some of these aromatic degradation products are found, arising no doubt from the protein contained in the residue of the digestive secretions, etc., that form the stools. When for any reason the food passes more rapidly than usual through the alimentary tract, the indol and skatol content of the fæces is diminished. Thus, a lessened excretion is found in diarrhœas and after the use of purgatives. The most marked reduction is said to be produced by calomel, which not only causes increased peristalsis, but also has possibly a bactericidal action. According to Senator, meconium, in which putrefactive changes do not occur, is free from indol, phenol, and skatol. Although Winternitz and Blauberg could find none of these substances in the fresh stools of young infants, they developed on standing, in both those that had been fed on mother's and cow's milk. They attribute the absence of putrefactive products in the fresh fæces to the rapid passage of the food through the intestine, and the fact that milk proteins are not readily affected by bacteria. Blauberg found oxy-acids in the fæces of infants fed on mother's milk on the seventh to the ninth day in some instances, and in others on the fourth or fifth day. On being mixed with water and left in the incubator for eight days, a very considerable increase occurred. The fæces of infants fed on mother's milk showed indol, but no skatol, phenol, or tryptophan; while cow's-milk stools yielded indol, but no phenol or skatol. Behrend has shown that even in new-born infants intestinal putrefaction may take place, the passage of the meconium being then succeeded by putrid stools containing mucus. This is associated with sickness on the first day of life, then slight fever, and is followed by recovery or death within a fortnight.

Evidences of intestinal putrefaction are more readily and easily obtained by an examination of the urine than from an analysis of the fæces, so that in clinical medicine this is the method most usually relied upon. The indol and skatol may be directly tested for and estimated, but while the tests for these substances are easily carried out, it must be remembered, as Eisenstadt has pointed out, that a failure of the indican reaction does not exclude intestinal putrefaction. A quantitative determination is not such an easy matter, and cannot be relied upon as an absolute indication of the quantity of putrefactive products being formed in the intestine. According to Combe, 0·012 to 0·015 gram of phenol, 0·005 to 0·015 gram of indol, and 0·005 to 0·010 gram of skatol are excreted daily under normal conditions.

Poisonous substances, formed within the body or introduced from without, are usually rendered innocuous in one or more of four ways: (1) By being rapidly eliminated; (2) By being deposited and fixed in various organs and tissues, notably the liver; (3) By being chemically altered through oxidation, reduction, hydrolysis, or neutralization; (4) By being combined with substances formed or contained in the tissues so that compounds of a harmless or less toxic character than the original poison result. The chemical defences employed against inorganic poisons are mainly the simple processes of oxidation, reduction, etc., but with the more complex organic poisons, protective combinations are very frequently formed in addition. The chief protective substances employed for this purpose are alkalies, protein, hydrogen sulphide, glycocoll, urea, bile salts, acetic acid, sulphuric acid, and glucuronic (glycuronic) acid. The aromatic substances formed in the intestine as the result of putrefactive processes are chiefly excreted in combination with the two last named, constituting the ethereal sulphates and combined glucuronates of the urine. A determination of one or both of these therefore furnishes an index of the amount of intestinal putrefaction. In practice it is usual to estimate the ratio existing between the ethereal or aromatic sulphates and the preformed sulphates, that is to say, those present in the form of simple alkaline salts, and to consider that any marked variation from the normal relation of about 1 to 10, or 1 to 16, is indicative of excessive intestinal putrefaction. Other methods have been advocated by Amann and Combe. Amann determines the relation which the ethereal sulphates bear to the total nitrogen of the urine, and considers that any variation of the normal ratio of the former to the latter of 1·4 or 1·5 per cent, points to autointoxication. Combe's coefficient is obtained by dividing the total nitrogen of the urine expressed in grams by the total number of milligrams of aromatic substances. For clinical work, a sufficiently accurate result for both Amann's and Combe's coefficient is obtained by estimating the total urea nitrogen by Liebig's mercuric method rather than the actual total nitrogen by the Kjeldahl's process, and roughly determining the aromatic substances with a colorimeter.

An absolute or relative determination of the ethereal sulphates is after all only a rough index of the extent to which aromatic putrefactive products are being absorbed from the intestine, for a portion is probably always excreted in combination with glucuronic acid. Many observers hold that sulphuric acid is the first line of defence, and that it is only when there is not sufficient of this to combine with all the absorbed toxin, that the excess is excreted in combination with glucuronic acid. Salkowski has pointed out, however, that the latter may begin to be formed before the sulphuric acid is exhausted, and Tollens has conclusively proved that the lower derivatives of protein decomposition do not unite indifferently with sulphuric and glucuronic acids, but that indol given by the mouth is excreted mainly in combination with sulphuric, and phenol with glucuronic acid. Under normal conditions the excretion of compound glucuronates is about double that of ethereal sulphates, viz., about 0·35 gram of the former to about 0·18 gram of the latter, the glucuronic acid being chiefly in combination with phenol and the sulphuric acid with indoxyl and skatoxyl. When, however, excessive protein decomposition is going on in the intestine, this relation is disturbed and no definite rule can be laid down. It has also to be remembered that, as Adrian has shown, there may be a decrease in the aromatic substances in the urine without any diminution in intestinal putrefaction owing to defective absorption, while the experiments of Strauss and Philippson suggest that some of the absorbed toxins, and particularly phenol, may be destroyed within the organisms and never find their way into the urine. Salkowski's discovery that saccharin yields aromatic products, phenol, etc., that may be excreted in the urine and lead to a mistaken diagnosis of intestinal putrefaction, is important, especially in infants.

Experiments have been carried out by Siemnitzki on the influence of carbohydrates upon intestinal putrefaction, with the following results: (1) The decomposition of sugar and albumin begins simultaneously, but does not proceed in the same proportion; (2) The presence of sugar hinders the decomposition of albumin by bacteria, and the quantity of protein decomposed is in inverse ratio to the amount of sugar or carbohydrate present; (3) Milk sugar diminishes putrefaction more than dextrose, and the latter more than galactose.

Gans has reported on the influence of various bacteria upon intestinal putrefaction. He found that cultures of B. coli about two to four days old increase the ethereal sulphates but not the indican in the urine, whereas four- to seven-day cultures of Proteus vulgaris increase the excretion of indican enormously without necessarily raising the ethereal sulphates. Yeasts do not seem to influence the excretion of sulphates, but raise the output of indican. A mixture of B. coli and B. acidi lactici, on the other hand, increase the excretion of sulphuric acid, but not the indican.

The influence of diet upon intestinal putrefaction in infancy has been carefully investigated by Max Soldin. He found that a breast-fed infant excretes about 4 milligrams of ethereal sulphates a day, and an artificially-fed child about three times as much, which is a large amount in proportion to the body weight, for an ordinary adult only excretes about 0·1 to 0·2 gram a day, as a rule. When an infant suffers from dyspepsia, the excretion may be increased fourfold, even when it is breast-fed. The ratio of ethereal to preformed sulphates was highest on a diet of malt soup (1 : 5), lower with cow's milk, lower still with Dutch milk (1 : 8), and with human milk varied between 1 : 6 and 1 : 7. If the milk was mixed with flour, the ethereal sulphates increased. Indicanuria is hardly ever met with in healthy infants, and Mayer states that it does not occur even when there is atrophy and intestinal disease. Longo studied the relation between intestinal putrefaction and diet in older children, and showed that when tapioca and phosphatine were taken, only slight putrefactive changes took place, but that they increased on a milk diet and Mellin's food. He also states that the toxicity of the fæces and the urine move on parallel lines, being greater on a milk diet, less on Mellin's food, and almost nil with tapioca and phosphatine.

Intestinal putrefaction varies so much both in adults and children in the normal condition that it is difficult to draw useful clinical conclusions. There is no doubt that it can be enormously reduced by a diet containing an abundance of carbohydrates or by a pure milk diet. The presence of hydrochloric acid in the stomach has an important bearing on the extent to which putrefactive changes take place, for they can be increased by diminishing the secretion with alkalies or atropine, and giving a diet rich in albumin. The influence of bile upon putrefactive changes in the intestine has been investigated by a number of observers. Blumenthal found that in catarrhal jaundice there is an increase in the excretion of indol, phenol, etc., especially during convalescence, when the bile is again re-entering the intestine. Rohmann and F. Müller state that the absence of bile does not increase intestinal putrefaction, but Strauss found that the products of putrefaction in the urine diminished when an obstruction to the bile flow is removed. It must be borne in mind that in such observations the influence of the pancreatic secretion has to be taken into account, and that the presence or absence of this may account, in part at least, for the seemingly conflicting results obtained by different observers.

Since a reduced secretion of pancreatic juice results in an impaired digestion of proteins, and these are likely to be attacked and broken down by bacteria in the intestine, it might be expected that the fæces and urine would show signs of excessive intestinal putrefaction. According to Herter, this does in fact occur, the proportion of ethereal to preformed sulphates in the urine rising to 1 : 6, 1 : 4, or even 1 : 1, and an excess of indican being also present. Edsall, on the other hand, considers that a diminution in the ethereal sulphates in the urine is an indication of pancreatic disease, for he points out that, although the products of proteolytic digestion are readily decomposed by bacteria, native albumin is not. If, therefore, there is little or no proteolytic digestion going on in the intestine, as is the case in severe diseases of the pancreas, the products of bacterial activity will be diminished and the quantity of ethereal sulphates and indican in the urine decreased.

Pisenti has estimated the amount of indican in the urine of dogs before and after tying the pancreatic ducts. In one instance he found 11·7 to 19·9 mgrams, and in another 15 to 21 mgrams per day before the operation, as compared with 4·3 to 4·2 and 6 to 9 mgrams per day respectively, after, thus showing a marked diminution. The administration of pancreas-peptone to animals in which the ducts had been tied increased the quantity of indican excreted. In 1886, Gerhardi reported a case of pancreatic disease which he had diagnosed during life from the absence of indicanuria, although the clinical symptoms suggested obstruction of the upper part of the intestine. Absence of indicanuria has also been observed by Stefanani in a case of purulent pancreatitis, and by Biondi in a case of adenoma of the pancreas. Katz found that when depancreatized dogs were fed with easily digested and rapidly absorbed food, the excretion of ethereal sulphates was low, but that when a diet of pure meat was substituted, the daily excretion was unusually high, although low readings were occasionally met with even under these conditions. He failed to discover any diminution in the excretion of indican after lesions of the pancreas; in fact, in many instances they were associated with marked indicanuria. Similar results have also been reported by Renzi. Schlagenhaufer has recorded an increase of indican in a case of syphilitic pancreatitis, and Hennige considers that the indicanuria met with in cholera and lead-colic are to be referred to alterations in the secretion of the pancreas.

I have found an excess of indican in 49 per cent of the cases of chronic pancreatitis and in 54 per cent of the cases of cancer of the pancreas that I have investigated, but there does not appear to be any relation between the intensity of the lesion and the degree of indicanuria. It seems probable that, although absence or a diminished secretion of pancreatic juice provides conditions under which there may be an abnormal formation of putrefactive products in the intestine, these do not make their appearance in the urine unless there is at the same time some affection of the intestinal wall which facilitates absorption, and that an excess of indican and ethereal sulphates in the urine is, therefore, rather an indication of an associated enteritis than of pancreatic disease.

Nothnagel found that in affections of the large intestine there was no marked indicanuria, even when diarrhœa was present, so long as the patient was well nourished, and that it was only when the small intestine and peritoneum were affected that there was a distinct increase in the indican in the urine. According to Jaffe's experiments, ligature of the small intestine causes an increase in the excretion of indican in the urine, while tying the large intestine is followed by an increase in the skatol. My own observations also suggest that clinically indicanuria points to an affection involving the upper part of the intestine, but that an excess of skatol alone is indicative of a disturbance of the large bowel.

CADAVERIN (PENTAMETHYLENEDIAMINE) AND PUTRESCIN (TETRAMETHYLENEDIAMINE).

These substances were first found in the fæces in 1888 by Udranszky and Baumann. The patient, who was a cystinuric, passed about ½ gram a day in his stools. The same diamines were also isolated from the urine; but whereas the major part of the urinary diamines was cadaverin (about 60 per cent), in the fæces putrescin was more abundantly present (85·9 per cent). A number of cases of cystinuria have been investigated by other observers, and, although cadaverin and putrescin have been found in some, they have not been by any means uniformly present, even in the urine. In no other case than that originally described by Udranszky and Baumann have they been found so continuously or in such large quantities, and in their case the amounts and relative proportions varied considerably. Roos isolated cadaverin from the fæces of a patient with malaria and dysenteric stools, and putrescin from dejecta of a case of cholera nostras. Diamines do not appear to have been met with in any other disease, nor have they been discovered in normal fæces. Putrescin was found in traces by Glaessner in the intestinal contents of normal dogs, and in larger amounts where there was intestinal obstruction.

To separate the diamines from the fæces, the whole of the stool is digested with alcohol acidified with sulphuric acid. It is then filtered, the filtrate evaporated down to dryness on a water-bath, dissolved in water, and again filtered. This filtrate is mixed with 10 per cent soda solution and benzoylchloride (200 c.c. of soda and 20 to 25 c.c. of benzoylchloride to each 1500 c.c.), and shaken until the smell of the benzoylchloride has disappeared. The precipitate that forms is filtered off, dissolved in alcohol, and the solution evaporated to a small volume. It is then poured into a large excess of cold water. After standing for about forty-eight hours, the needle-like crystals of benzoyldiamine that have formed are filtered off, dissolved in alcohol, and again re-crystallized by pouring the solution into an excess of distilled water. The separated crystals are then treated with ether, in which the benzoyl compound of cadaverin is soluble, while the putrescin compound is not. Dibenzoyl-putrescin forms shining plates or colourless needles that are insoluble in water, quite insoluble in ether, feebly soluble in cold, and readily soluble in warm alcohol. They melt at 175° to 176° C. The benzoyl compound of cadaverin forms long needles and plates, that are insoluble in water, but are soluble in alcohol and ether. They melt at 130° C.

Both cadaverin and putrescin are formed in the putrefaction of proteins, and are closely related to the diamino-acids lysin and ornithin. Lysin is converted into cadaverin by the elimination of carbon dioxide, and in a similar way ornithin, which enters into the composition of the important protein fraction arginin, yields putrescin. It was therefore natural to assume that the presence of cadaverin and putrescin in the fæces and urine in cystinuria and other conditions, is dependent upon protein decomposition in the intestine. Cultures from the fæces of cystinurics have failed, however, to reveal the presence of any abnormal organisms having the power of forming diamines from proteins, and the administration of intestinal antiseptics in several cases was found to have no influence upon the excretion of diamines or cystin. This theory of their origin has now been abandoned, and it is believed that, in cystinurics at any rate, they are derived from the lysin and arginin of proteins broken down within the organism owing to an inborn error of metabolism. This hypothesis has received support from the observations of Loewy and Neuberg, who found that a patient suffering from cystinuria, whose urine was normally free from diamines, excreted cadaverin in large quantities when lysin was given by the mouth, and putrescin when arginin was similarly administered. Unfortunately, it does not appear to have been determined whether diamines were at the same time excreted in the fæces. It does not necessarily follow that the diamines found in the stools of cases with grave intestinal infections, such as Roos examined, have the same origin as those in cystinuria, for it is possible that they may be formed in the intestine through the action of bacteria. In cases of cystinuria where there is no intestinal disorder, the diamines are almost certainly formed within the body, and it is probable that those met with in the fæces have the same origin as those found in the urine.

In this connection it is worthy of note that in a case of cystinuria which I examined with Garrod, cadaverin was found in the urine on two days out of forty-one, and putrescin only once in six examinations. On this occasion no diamine could be found in the urine. In our experiments with this patient, diet did not appear to affect the excretion of diamines in any way.

BETA-IMIDO-AZOLETHYLAMINE.

In 1910, Barger and Dale isolated from intestinal extracts this base, which Ackermann had previously obtained from histidine by putrefaction, and suggested that its presence was due to resorption from the intestinal contents, where it had been formed by the action of an enzyme or bacteria on proteins. Subsequently Bertrand and Bertholet cultivated from the fæces of cases of auto-intoxication with intestinal disorders, an organism related to Friedländer's bacillus, which they called B. amino-philus intestinalis, that produced beta-imido-azolethylamine from histidine, but failed to find it in normal stools.

AMMONIA.

The presence of ammonia in the stools can sometimes be detected by the smell; but before it is concluded that ammonia is present, admixture with urine must be excluded. In other cases, ammonia can only be proved to be present after a water solution of the fæces has been warmed. It can then be detected by the smell, by the ammonium chloride fumes formed when a rod dipped in hydrochloric acid is held near, or by its action on a piece of moistened litmus or turmeric paper. If the presence of bound ammonia is to be demonstrated, the fæcal solution must be made alkaline with caustic soda or potash before it is warmed.

Quantitative Estimation (Schittenhelm).—The apparatus shown in *Fig.* 75 is set up. A is a litre distillation flask containing the fæcal mixture, B a flask containing the standard acid, C a Wolff's bottle to catch any acid that may be aspirated from B, D is a sulphuric acid wash-bottle through which the air is passed, E is a stopcock to regulate the flow of air, F is a funnel through which additions are made to the contents of A, G is a safety bulb, H is a tube connecting the apparatus to an aspirating apparatus and manometer. The estimation is carried out as follows: The fæces are rubbed up with 25 to 50 c.c. of 0·5 per cent hydrochloric acid, made up to a definite volume, and placed in the flask A. There are then introduced about 10 grams of sodium chloride and sufficient sodium carbonate to make the mixture faintly alkaline,

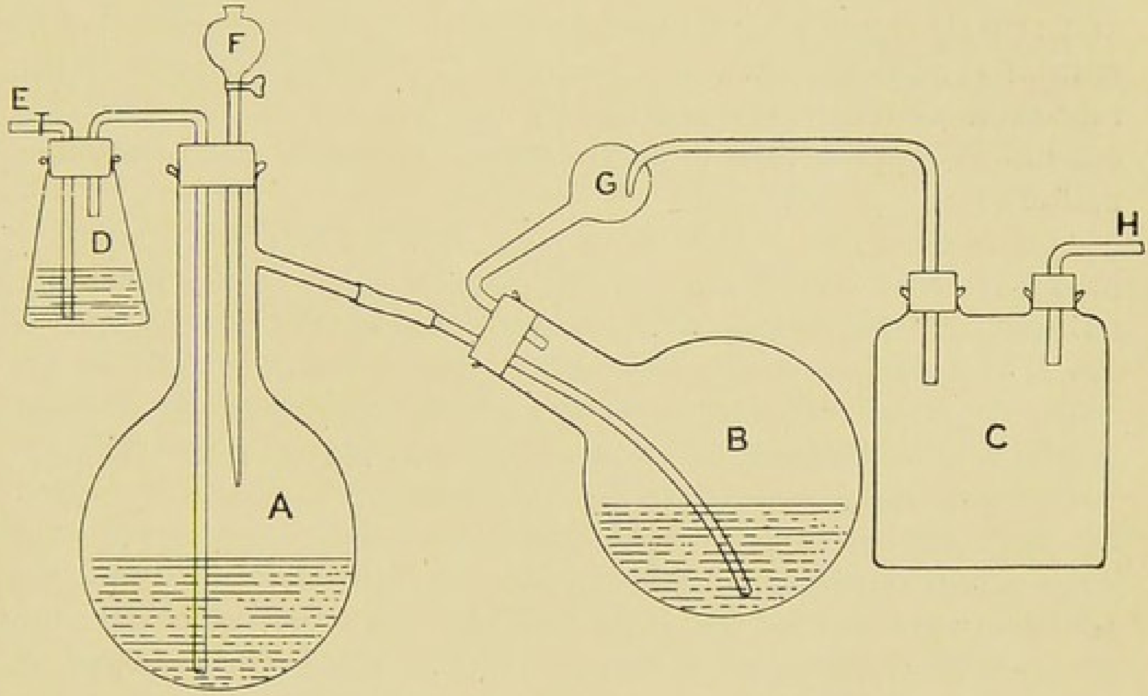


Fig. 75.—Steyrer's Apparatus for Ammonia Determination.

at most a gram. The stopper is then put in place, and the outlet tube connected with the flask B, in which 10 to 30 c.c. of decinormal hydrochloric acid, containing a few drops of a 1 per cent alcoholic solution of rosalic acid to serve as an indicator, have been previously placed. Suction is now commenced through the tube H, and a vacuum of 18 to 25 mm. of mercury set up in the apparatus. When this point has been reached, 20 c.c. of alcohol are introduced into the distillation flask through F, and the flask is heated in a water bath at a temperature of 43 to 44° C. In about ten minutes another 10 c.c. of alcohol are admitted, and if the contents of the flask have been much reduced in volume, 10 to 15 c.c. of water may be added, with a further 10 c.c. of alcohol. After thirty to forty minutes the apparatus is disconnected, and the contents of the flask B are titrated with decinormal soda. Each cubic centimetre of hydrochloric acid used corresponds to 1·7 mgram of ammonia, and this multiplied by 1·4 gives the ammonia nitrogen in milligrams.

The fresh fæces of a healthy individual contain only a very small quantity of ammonia—0·151 per cent, according to Brauneck. In some diseases, typhoid and cholera nostras for instance, it may be increased to 0·682 or 0·766 per cent. Baginski found free ammonia in the fresh fæces in cases of cholera infantum, also indol, but no phenol or skatol.

CARBOHYDRATES AND THEIR DERIVATIVES.

Sugar.—Owing to the readiness with which sugars are absorbed from the intestine, they do not ordinarily appear in the fæces of adults, but according to the experiments of Blauberg, Langstein, and others, traces may be met with in the stools of infants under normal conditions. When absorption is interfered with, and the intestinal contents pass rapidly through the bowel, as in catarrhal conditions, appreciable quantities may be found both in children and adults.

The absence of sugar from the fæces does not, however, prove that it has been absorbed, for it may be destroyed by fermentative processes, and this is probably the explanation of the failure of Lange and Behrend to detect a reducing substance in the dry stools of badly thriving infants, and Blauberg's observation that the pathological stools of infants fed on cow's milk do not contain more sugar than the healthy excreta of infants nursed by their mothers. The characters of an infant's stools are to a large extent dependent upon the sugar content of its food and the products that are formed from it. The bright yellow colour, the acid reaction, and the pleasant aromatic smell of the fæces of infants brought up on the breast, are no doubt due to the presence of sugar derivatives, whereas a similar acid reaction and presence of sugar derivatives is only found under pathological conditions in children fed on cow's milk, when the stools become soft, pasty, and darker in colour, and occasionally have a yellowish-green appearance.

To detect sugar in the stools, the fresh (or dried) fæces are extracted with water, filtrated, and the filtrate tested, either directly or after evaporation, to a small bulk on the water bath, with Fehling's solution, Trommer's test, Nylander's test, or with phenylhydrazin. Owing to the presence of albumoses and peptones, the reduction tests are not reliable, and Uffelmann advises, therefore, that the fæces should be extracted with alcohol, filtered, and the alcohol be evaporated off from the filtrate. The residue is then dissolved in water and tested for sugar. Blauberg suggests the following method: About 3 grams of the dried fæces (*see p.* 240) are extracted with ether to remove most of the fat; they are then treated with thymol water on the water bath for several hours, filtered, and washed with thymol water. The proteins are now precipitated with lead acetate and basic lead acetate, and filtered off. The excess of lead in the filtrate is removed with carbon dioxide gas, and the filtrate evaporated to a small volume. It is then tested for sugar. Milk sugar, which is a characteristically animal product, and can only be found in the fæces when the patient is on a milk diet, is distinguished from the other reducing sugars by the fact that reduction is not as prompt, and does not take place until the mixture has been boiled, by the negative result of the fermentation test within the first twenty-four hours, and most certainly by the characters of the osazone that it forms with phenylhydrazin. This appears as balls or tangled masses of fine crystals that are relatively soluble in water, and that do not therefore separate as easily as dextrosazone. Its melting-point lies between 210° and 212° C. when pure, but it usually melts at about 200° C. It is soluble in alcohol, but is precipitated out again on the addition of ligroin, and an alcohol-ligroin preparation is therefore optically inactive. On boiling a solution of lactose with 5 per cent sulphuric acid for a short time, neutralizing the excess of acid, and then testing the solution with phenylhydrazin, crystals of dextrosazone, and with proper precautions galactosazone, can be found.

More important than the mere discovery of a reducing substance in the fæces is the determination of the question as to whether the normal process of fission has taken place; that is to say, whether the di-saccharides, which alone are introduced with the food, have been broken down into mono-saccharides by the inverting ferments or not. In this way Orban proved the absence of lactose in the acute stages of several intestinal affections in children, and Pfaundler found that the inversion of milk sugar does not take place in marasmic infants, thus accounting for the lactosuria that has been reported in such cases.

Starch.—For practical purposes, the presence of starch in the fæces is most readily determined by the microscope, using the micro-chemical tests already described. The purely chemical methods which may be employed are as follows:—

The fæces are boiled with water and filtered. The filtrate is then evaporated down and tested with iodo-potassium lodide (Lugol's) solution.

A more satisfactory method is to boil the dry powdered fæces with 2 per cent hydrochloric acid for half an hour, using a reflux condenser, to invert it to sugar. The mixture is then neutralized, filtered, and the filtrate tested with one or other of the reduction tests, or with phenylhydrazin. If 10 per cent hydrochloric acid is employed, the use of a reflux condenser is not necessary, and the boiling need not be contiuued more than a few minutes. As the reduction tests are not very satisfactory when only small quantities of starch are present, the modification of the phenylhydrazin test advised by Strasburger is advisable: 5 drops of pure phenylhydrazin are mixed in a test-tube with 0·5 cm. of glacial acetic acid, or 1 c.c. of 50 per cent acetic acid, and 4 cm. of the filtrate, and boiled for one minute over a small flame. There are then added 4 or 5 drops of a solution of caustic soda (sp. gr. 1·16), taking care that the solution remains faintly acid. The mixture is boiled again and set aside to cool. Crystals of phenyl-glucosazone should appear within half an hour if starch was present, and often can be found in a few minutes.

Schmidt's fermentation test has the merit of simplicity, and renders possible the detection and approximate estimation of the carbo-hydrates that are easily acted upon by the digestive juices. It

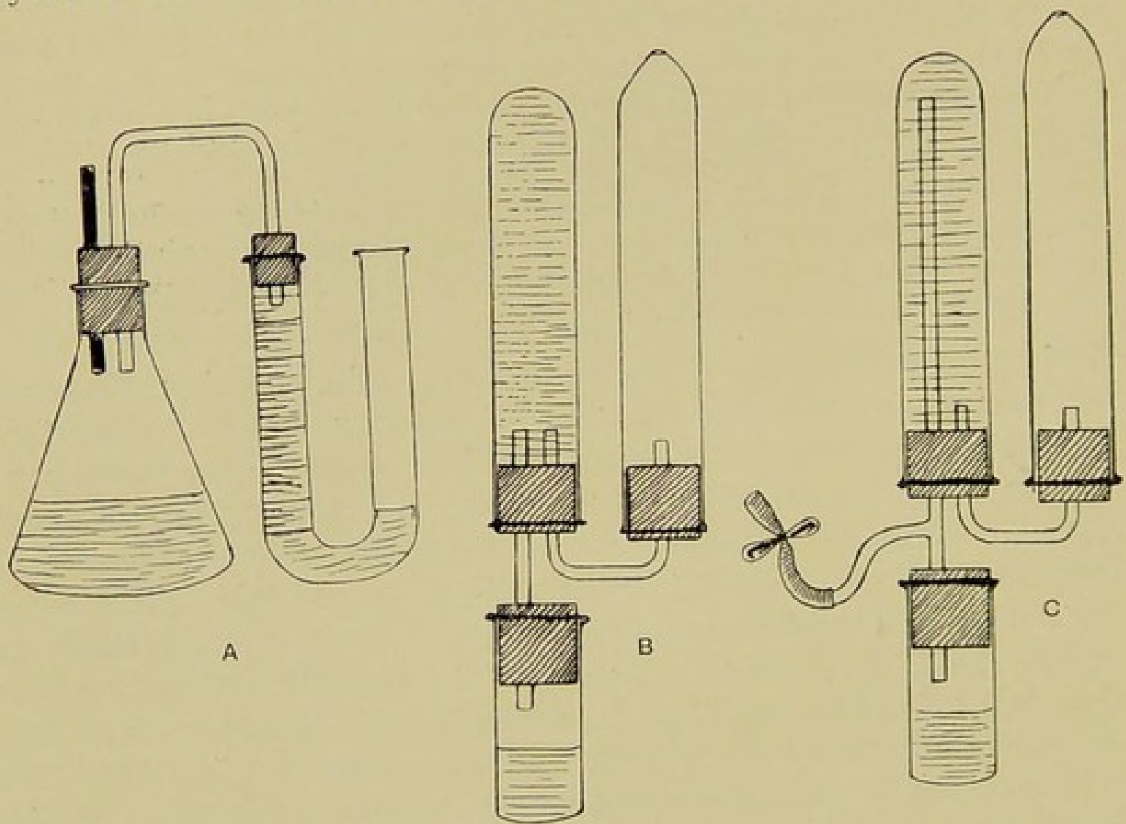


Fig. 76.—Fermentation Apparatus. A, Amann. B, Schmidt. C, Münzer.

can therefore be used to determine the efficiency of the digestive apparatus. The test depends upon the fact that the dissolved carbohydrates, as well as those starches which lie free and are easily acted upon, are inverted by the diastase which is always present in the fæces, and are then fermented by the intestinal bacteria, with the formation of gas. It is carried out as follows :—

About 5 grams of the stool, or more if it is fluid, are well mixed with water and placed in the receptacle of a Schmidt's fermentation apparatus, which is then closed with a rubber stopper, taking care to exclude air bubbles (*Fig.* 76 B). The outlet tube of the receptacle is connected with a close graduated tube filled with water, in which any gas that is formed may collect, and this in its turn is joined to a tube where the displaced water passes. When filled and set up, the apparatus is placed in an incubator at 37° C. for twenty-four hours. If at the end of this time gas has collected in the tube, it is cooled to the temperature of the room and measured, and at the same time the reaction of the fæcal mixture to litmus is taken. An acid reaction and the formation of gas indicates the presence of fermentable carbohydrates, and the quantity formed is taken as a measure of these. For diagnostic purposes, only a positive result is of value, as under pathological conditions the test may be negative even when sugar and starch are present. Similar tests have been devised by Münzer and Amann.

Schmidt advises that the patient should take his test diet (*p.* 5) for several days before a specimen of the fæces is submitted to examination, and states that under these conditions, if sufficient gas to fill the tube one-fourth full is formed in twenty-four hours, intestinal dyspepsia can be diagnosed. Experiment has shown that 0·1 gram of starch gives rise to half a tube of gas (50 per cent); starch too finely divided to be recognized microscopically can therefore be detected by the fermentation test. The diet must not contain rice, since this may be unabsorbed even by healthy individuals, and give rise to misleading conclusions. Cellulose ferments too slowly to affect the results seriously, but if there is much starch it may ferment more quickly and assist in the production of gas. The presence of fat interferes with the fermentation, and according to Rübner the test is unreliable if the fæces contain a large quantity.

The gases formed in the early stages (twenty-four hours) are carbon dioxide, methane, and hydrogen, in the proportions of 17 : 4 : 1. After forty-eight hours a late fermentation takes place, and the proportion of gases is then different, viz., CO_2 2·1 : CH_4 4·3 : H_2 1. In the early stages only small quantities of sulphuretted hydrogen, indol, and skatol appear, but in the later stages, when putrefaction occurs, they are more abundant. Strasburger recommends that in all cases the presence of sulphuretted hydrogen should be tested for with lead acetate paper, and the acidity of the liquid be titrated. The test may be negative although fermentable carbohydrates are present, owing to (1) absence of the diastatic ferment, (2) insufficient material for the growth of bacteria, (3) lack of the necessary bacteria, (4) too great acidity.

Experiment has shown that the amount of gas formed and the quantity of starch in the stools are not proportional. Thus 5 grams of fæces to which were added 10 cm. of a 1 per cent starch solution gave much gas, but the same quantity of fæces mixed with 30 cm. of starch solution gave no gas, but only inactive lactic and formic acids at first, and subsequently valeric and caproic acids, still without gas-formation. It is therefore always necessary to estimate the acid produced, as fermentation may have been stopped by excessive acidity. The fermentation test does not distinguish between disorders of secretion, absorption, and motility. A positive result only points to trouble in the upper part of the small intestine, and excludes a purely gastric or colon disorder. Callomon states that the fermentation test is very often positive with normal breast-fed children, and comes to the conclusion that there is no test diet with which a negative result can be confidently relied upon.

The presence of starch in the fæces is partly dependent upon the quality and quantity of the food, and partly upon the condition of the intestinal tract and its flora. The influence of different varieties of food is shown by the following results obtained by Nicloux :—

Diet	Carbohydrate		Per cent
	In the Food	In the Fæces	
White bread . .	670	5	0·8
Rice	493	4	0·9
Macaroni . .	462	6	1·2
Potatoes . .	718	55	7·6
Brown bread . .	659	72	10·9
Cabbage . .	247	38	15·4
Carrots . .	282	50	18·2

The following table given by Strasburger shows the influence of variations in the quantity of ingested carbohydrate upon the amount passed unutilized in the fæces :—

Diet	Carbohydrate		Per cent
	In the Food	In the Fæces	
White bread . .	391	6·0	1·7
,, ,, . .	670	15·0	2·2
Peas . .	357	14·4	4·0
,, . .	357	12·9	3·6
,, . .	587	41·0	7·0

The digestibility of starch is also largely dependent upon the way in which it is prepared and cooked. Thus raw wheat-meal is much more readily assimilated than raw potato starch, but when the potato has been thoroughly cooked, the difference is not nearly so marked.

With regard to pathological conditions, it has been shown by Schmidt and Strasburger, Gaultier, Hebel, and others, that absence of bile from the intestine has no influence on the digestion and utilization of starches. Contrary to what might be expected, diseases interfering with the flow of pancreatic juice into the intestine do not cause undigested starch to appear in the stools, owing apparently to its being destroyed by the action of bacteria. In functional diseases of the intestines, and particularly those affecting the upper part and associated with rapid peristalsis, starches, like sugar, may be found in large quantities in the stools.

In infants and young children the digestibility of starchy foods is of much greater importance, both in health and disease, than in adults. If the diet of a child is to be satisfactorily arranged, it is necessary that we should know at what period starchy foods can be digested and assimilated, and what is the best form in which to administer them in. Over-feeding with carbohydrates has been proved to be the cause of many illnesses in infants; but, on the other hand, it is now well known that farinaceous foods are therapeutically useful in certain disorders of the alimentary tract.

The question as to when an infant should first be given starch has been much discussed. Zweifel and Korowin state that in the newly-born child the parotid secretes a diastatic ferment, but that the amylase of the pancreatic secretion does not make its appearance until the second month. Carstens and Deubner consider that even young infants can utilize starch to a certain extent, and they state that wheat-flour in small quantities is nearly all absorbed, and can be given without harm. Biedert pointed out, however, that the failure of carbohydrates to appear in the fæces does not show that they have been absorbed, and Schloessmann has proved that starch, even when not dextrinized, may be decomposed by some intestinal bacteria. B. coli cannot form sugar from starch, but B. lactis aerogenes will attack starch, especially when oxygen is excluded, and in about seventy-two hours will decompose 90 per cent of a ½ per cent solution, giving rise to acetic acid, aceto-acetic acid, propionic acid, butyric acid, acetone, and succinic acid. Schloessmann found both acetone and butyric acid in the urine of children on a diet containing an excess of flour. Heubner considers that the experiments just referred to must be accepted with caution, and that the addition of flour to the diet may be useful in the treatment of infants even in the first few months of life.

As Gilet found that an active pancreatic secretion may be formed in infants as young as two days, and Moro showed that from birth the pancreas contains a diastatic ferment which can also be demonstrated in the fæces, Hesenius re-investigated the question. He came to the conclusion that over 90 per cent of the starch given by the mouth always disappears, and not more than 10 per cent is recoverable from the fæces. He found that simple starches are best assimilated, and that on continuing the diet for some time, the infant becomes adapted to it. These conclusions have been confirmed by Kerley and Campbell, who found that barley-water, which had been boiled for an hour and a half, given in quantities of 24 grams to an infant four weeks old, and 100 grams to a child six months old, was well assimilated, although considerable individual variations were noticed. According to Czerny and Keller, the stools of infants who have received starch too early, and in too large a quantity, are loose, yellow or brown, very acid in reaction, and without much smell, as a rule, although when there is much fermentation they may smell of fatty acids, particularly of acetic acid. There may also be a large quantity of mucus, and in such cases the stools may have a putrid odour. When dextrinized starches, such as those contained in various proprietary infant foods, are used to excess, the stools are of firmer consistency, and may have a greenish-grey colour (Finkelstein).

Hemi-cellulose.—The name hemi-cellulose was given by Schulze to a group of substances having affinities to starch on the one hand and cellulose on the other, that occur in the cell walls of plants, especially the endosperm of nuts and the seeds of the leguminosæ. On being heated with dilute hydrochloric or sulphuric acid, they give rise to the sugars galactose, arabinose, and xylose. They may therefore be detected in the fæces by carrying out the phloroglucin or orcin test for pentoses with the filtrate from a sample of the stool that has been boiled with 2 per cent hydrochloric acid. Their importance lies in the fact that, when present in considerable quantity, as when peas, etc., have been taken, they may give rise to incorrect conclusions as to the digestion and absorption of starch when this is tested for chemically.

In this connection the characters and properties of *agar-agar* may be referred to. Agar, often called Japanese isinglass, is a colloid substance prepared from marine algæ. It consists of a carbohydrate, galactan, which on being boiled with dilute hydrochloric acid, is converted into the sugar galactose. At the same time a small proportion of pentoses appear. It is sold in transparent strips, or shorter yellowish-white pieces, and is odourless and tasteless. It is soluble in hot water but not in cold, although the dry product, when soaked in cold water, swells, and takes up about sixteen times its own weight. As it passes through the alimentary tract without undergoing digestion, it increases the bulk of the fæces, rendering them soft, slippery, and mucilaginous, thus mechanically stimulating intestinal contractility and assisting in the passage of the stools. It is consequently used in the treatment of constipation. Commercially it is utilized for thickening cheap ice-cream and "hokey-pokey," and as a substitute for gelatin owing to its higher melting-point.

Cellulose.—As we have already seen, cellulose, which chemically is an anhydride of dextrose, is excreted for the most part unchanged. The intestinal secretions contain no ferments capable of digesting it, but it may be decomposed by bacteria and thus be brought into an assimilable form. This is most likely to occur when there is stagnation of the contents of the large intestine, which in part accounts for the small cellulose residue and the hard dry characters of the fæces in many cases of chronic constipation, as Schmidt was the first to point out. Young cellulose is more readily attacked than old, tough varieties, but the digestibility of the latter is, to a certain extent, dependent upon the method of preparation. Thus, finely-chopped green vegetables are more easily attacked than coarser forms, and the same is true of cellulose that has been well cooked and partly pectinized. The digestibitity of cellulose is also dependent upon individual peculiarities, not only physiological but pathological. In constipation, for instance, microscopically recognizable cellulose is often present in only small amounts, but in fermentative dyspepsia large quantities occur in an unchanged condition. Thick cellulose cell walls are very indigestible, and the same is true of cutinized, woody, and corky cell membranes, which often appear in the fæces in macroscopical form. The spores of fungi are unchanged during their passage through the alimentary tract, and must be carefully distinguished from the eggs of intestinal parasites, with which they are liable to be confused.

Like starch, cellulose is most readily recognized in the fæces by its appearance under the microscope and by its micro-chemical characters.

Acid Derivatives of Carbohydrates.—As a result of the fermentation of carbohydrates in the intestine, formic, acetic, lactic, butyric, propionic, and other fatty acids appear in the fæces. In the normal healthy adult, butyric and acetic are the dominant acids. According to Rübner, the usual proportion is

79·2 per cent of butyric acid and 20·8 per cent of acetic acid, but the exact ratio depends upon the extent to which the carbohydrates are utilized, and in consequence upon the general nutrition and state of the digestive functions. In infants, lactic acid practically always occurs in the stools, contrary to what is the case in adults, where its presence is exceptional.

The fatty acids may be recovered from the fæces by the method of Hoppe-Seyler. The stool is extracted with alcohol, filtered, and the filtrate neutralized with sodium carbonate. It is then evaporated to dryness, dissolved in water, made faintly acid with dilute sulphuric acid, and distilled.

Hecht's method is simpler, and gives satisfactory results. About 50 grams of the fresh fæces are mixed with 3 litres of water, placed in a large round-bottomed flask, and 20 cm. of concentrated orthophosphoric acid solution (sp. gr. 1·275) added. The mixture is then submitted to steam distillation. The first litre of the distillate and the succeeding 8 litres are collected separately. They may then be titrated with decinormal caustic soda solution, using phenolphthalein as the indicator, or the individual fatty acids may be sought for by the following chemical and micro-chemical reactions. A portion of the first distillate is completely neutralized with caustic soda, made faintly acid, and then evaporated down. When it is reduced to about 1 c.c. it is cooled and filtered, and the filtrate mixed with cerium nitrate. On examining a drop under the microscope, especially after it has been gently warmed, characteristic radiating masses with negative Brewster's polarization crosses are seen if *formic acid* is present. Formic acid in neutral solution also gives with neutral ferric chloride a dark red solution which, on being heated, yields a yellow precipitate, and on being heated with an ammoniacal solution of silver nitrate forms a mirror on the walls of the test-tube from the deposited silver.

The remainder of the distillate is mixed with milk of lime, feebly acidified, and evaporated down. From the concentrated cooled solution the calcium salts are filtered off and tested by the following methods. A few drops are mixed with uranium nitrate, sodium formate, and a little formic acid. There then separate out, particularly after gently heating and rapidly cooling, non-polarizable tetrahedra and octahedra of uranium acetate if *acetic acid* is present. Acetic acid gives with neutral ferric chloride the same reaction as formic acid. On heating a solution of acetic acid with a mixture of equal parts of concentrated sulphuric acid and alcohol, the characteristic smell of ethyl acetate is noticed. Another portion is mixed with barium acetate, when, if *propionic acid* is present, pseudo-octahedral crystals that act on polarized light are seen. The remainder of the solution is mixed with nitrate of copper, which gives very characteristic crystals of *propionic, butyric,* and *valerianic acids*, particularly valerianic acid.

To separate *lactic acid* from the fæces, the residue from the preceding distillation is, according to Strasburger, treated in the following manner: It is first diluted with water, then mixed with baryta, filtered, and the residue on the filter well washed. The filtrate is now freed from excess of barium by passing through it a stream of carbon dioxide. The filtrate from this is evaporated down at a temperature not exceeding 70° C., and the residue extracted thrice with ten times its volume of absolute alcohol. After evaporating off the alcohol, the residue is mixed with an equal volume of phosphoric acid, and shaken out with ten times its volume of ether about five times. The small quantity of phosphoric acid that passes over is removed by decanting and diluting the ether. The ether is then evaporated off and the residue dissolved in water. This solution may be titrated or tested for the presence of lactic acid. For the latter purpose the ether solution may, however, be used. To about 5 c.c. of the solution, 2 drops of a 10 per cent solution of ferric chloride are added, when, if lactic acid is present, a yellowish-green to an intense green coloration results. The solution may also be tested with Uffelmann's reagent (3 drops of ferric chloride, 30 c.c. of a 1 per cent solution of carbolic acid). The amethyst blue of the solution is changed to a yellow or yellowish-green by a solution of lactic acid.

Although a considerable amount of work has been done by Bokai, Czerny and Keller, Hecht, and others, on the fatty acids occurring in the stools, particularly of infants, a determination of the varieties present and their relative proportions has not yielded any information of importance from the point of view of diagnosis, and it can only be stated that an excess of such acids indicates abnormal fermentation in the intestine.

FATS.

The fats of human fæces consist for the great part of the insoluble higher fatty acids (oleic, palmitic, and stearic), and their salts (soaps), and glycerin esters (neutral fats). To a much smaller extent there are also present lower fatty acids and fat-like bodies, the lipoids, cholesterin and lecithin. It has generally been assumed that all the neutral fat, fatty acids, and soaps met with in the fæces are derived directly from the food, but latterly it has been suggested that, just as the kidneys excrete the waste products of protein metabolism and the lungs the oxidation products of carbohydrates, so the intestine may be an excretory organ for the waste products of fat metabolism, and notably the saturated fatty acids. It is now well recognized that the heavy metals are excreted largely by the intestine, and that calcium and magnesium are eliminated from the body by this channel ; if, therefore, it is allowed that saturated fatty acids are also got rid of in the same way, it would explain the excess of fat, and particularly of calcium soaps, met with in some disorders of metabolism and diseases of the intestine that are not associated with an obvious defect in the fat-splitting powers of the pancreas. Williams has sought to account for the formation of intestinal concretions, intestinal sand, appendix concretions, and gall-stones, by supposing that they are formed, not as the result of a local disease at the site of their formation, as is usually taught, but as the outcome of a general metabolic disorder which throws on the intestine, or its appendages, the onus of excreting the saturated fatty acids, calcium salts, etc., which are a burden on the economy. In support of his contention he has brought forward evidence of the constant presence of fatty acid compound in these bodies. Whether further observation and experiment lend support to the view just outlined as to the source of a portion of the fat met with in the fæces, particularly under pathological conditions, or not, we can safely conclude that the bulk of the fat, as a rule, is derived from the food, so that the manner of its digestion and absorption is a matter of great practical interest in accounting for the forms in which it may occur in the stools, and thus explaining the probable cause of any abnormality that may be met with.

There has been much discussion as to the way in which the fats taken in the food are digested and absorbed. It was for long taught that a small fraction is split into fatty acids and glycerin in the intestine by the action of the pancreatic secretion, and that the acids so formed, aided by those already present when the fat leaves the stomach, convert the remainder into a fine emulsion which is then taken up as such by the intestinal villi; but this hypothesis has now given way to the theory of absorption in solution. There can be no doubt that normally there is sufficient fat-splitting enzyme in the intestinal contents to convert completely all the neutral fats usually taken into fatty acids and glycerin, and the main question is exactly how these are absorbed. According to one view, the fatty acids combine with the sodium, potassium, calcium, and magnesium of the intestinal contents to form alkaline soaps which, along with the glycerin, diffuse into the epithelial cells and are there synthesized back again to neutral fats. It is contended by others that the diffusible fatty acids and glycerin are separated from the fats as they are formed, and absorbed as such into the intestinal walls. A condition of unstable equilibrium is thus brought about in the intestine, with the result that the fat-splitting process continues until practically all the fat has been decomposed and its products absorbed. When the mixture of fatty acids and glycerin first enters the epithelial cells of the intestinal villi there is a state of unstable equilibrium, for no fat is absorbed as such. In consequence of this, the reversible action which enzymes are known to have comes into play, and the lipase, which Kastle and Loevenhart have shown to be present in these cells, causes a combination of the glycerin and fatty acids to again form neutral fat. As a result there exists in the cells a mixture of fat, fatty acids, and glycerin which only attains equilibrium when no further additions of fatty acids and glycerin take place. According to this view, the passage of the fat into the tissue fluids and cells is brought about in a similar way through the reversible action of a fat-splitting ferment, and an attempt to establish equilibrium between those that are poor and those that are rich in fat. On the theoretical, and also on the experimental side, there is something to be said for both theories, and it appears probable that fat in man is absorbed both as dissolved soaps and as dissolved fatty acids and glycerin, although it appears possible for fine emulsions of fats with a low melting-point to be absorbed to a certain extent without their undergoing preliminary cleavage or conversion into soaps.

Since the pancreatic juice is the only digestive secretion that contains an enzyme which has a chemical action of any importance on neutral fats, fat digestion and absorption in its absence must be more or less seriously interfered with. Abelmann found that when the pancreas was entirely removed in dogs, non-emulsified fats were not absorbed at all, and emulsified fats only to a slight extent (18·5 per cent). Animals from which the pancreas had been partly removed showed better absorptive powers, but their capacity in this direction was limited, for whereas small amounts of emulsified fats were about half absorbed, larger quantities, 70 to 150 grams, were less efficiently dealt with. A neutral emulsion of fat, in the form of milk, was much better dealt with in both instances, 30 per cent of large amounts and 53 per cent of smaller quantities being absorbed when the pancreas was completely extirpated, and up to 80 per cent when a portion of the gland had been left. The administration of pig's pancreas with the food was found to facilitate the absorption of fats, thus showing that the absence of the pancreatic secretion was the main cause of their defective assimilation. After extirpating the pancreas in a dog, Cavazzani found that unused fat was present in the fæces, and while the animal ate soap with great eagerness, it rejected fat. Baldi observed a large amount of fat in the fæces of depancreatized dogs fed on meat from which the fat had been removed, but was unable to produce so high a degree of steatorrhœa by tying the bile-ducts.

These experiments show that in animals, extirpation of the pancreas is attended by a defective absorption of fat, except that of milk, and that while similar but less marked results can be produced by excluding bile from the intestine, the increased proportion of fat in the stools is to be mainly attributed to absence of the pancreatic secretion. The digestion of fats may therefore be regarded as peculiarly a function of the pancreatic juice. Neutral fats are entirely unaffected by the secretion of the salivary glands, and in the stomach they are only slowly changed, yielding but 1·0 to 2·7 per cent of fatty acids after some hours. Fine emulsions of fat, such as occur in the yolk of eggs, and in milk, may be more completely digested, for Volhard found that the former, after one to four hours' stay in the stomach, may contain as much as 78 per cent of free fatty acid, a fact probably of some importance in young infants before the lipolytic action of the pancreatic secretion is fully developed, and in adult patients whose pancreas is disorganized by disease. The fat-splitting power of the stomach is stated by some to be due to a gastric lipase, but others attribute it to the action of bacteria. No fat-splitting enzyme has been obtained from the intestinal mucous membrane or from the chyle.

The digestive power of the pancreatic juice for fats is considerably increased by the presence of bile, and still more by the presence of bile and hydrochloric acid. Bile of itself has little or no digestive power, but a mixture of bile and pancreatic juice can digest more than three times as much fat as the pancreatic juice alone. According to the experiments of Wohlgemuth, the lipase of the pancreatic secretion exists partly in an inactive form, and he states that this is activated by the accession of bile. Bile, besides activating and intensifying the digestive power of the pancreatic secretion for fats, also performs another important function in fat digestion and absorption. The free fatty acids formed by the action of the pancreatic lipase on neutral fats are insoluble in water but are soluble in bile, so that its presence in the intestinal contents aids in their absorption by the epithelium. Alkaline soaps are also rendered more soluble in the presence of bile. Its solvent action is greatly augmented by the presence of lecithin, but is mainly dependent upon the bile salts it contains.

Chemically the presence of fat in the fæces can be readily demonstrated by extracting a portion of the stool with ether, allowing the solid portion to settle, and drawing off a sample of the ether extract with a pipette. A few drops of this are allowed to evaporate on a piece of filter paper, and give a transparent spot which cannot be washed out with water. The fact that the fæces can be shown to contain fat by this method is of no diagnostic significance, for it is normally present in quantities that give a positive result. A quantitative estimation, carried out with the dried fæces, is the only way in which results of value can be obtained.

LIPOIDS.

Cholesterin.—Traces of cholesterin are constantly present in the fæces of man and animals. It is found most abundantly in meconium and in the stools of newly-born infants during the first two or three days of life, thus proving that it is not entirely derived from the food, but comes partly from the secretions of the alimentary tract, principally from the bile. An excess in the crystalline form is nearly always met with in pathological conditions, and even functional derangements, of the digestive canal in infants. On a mixed diet, and especially one containing much meat, a great part is found in the form of coprosterin (dihydro-cholesterin), but this reduction product of cholesterin is absent from meconium, and only occurs in very small quantities on a milk diet.

Cholesterin may be recovered from the fæces in the following manner: The volatile fatty acids and phenol are distilled off; the residue is then treated with sulphuric acid, alcohol, and finally with ether. The ether extract is filtered, and the ether distilled off from the filtrate. The residue is then digested with a watery solution of sodium carbonate, to remove any traces of volatile fatty acids that have come over in the ether, evaporated to a small bulk, and extracted with hot alcohol. The alcoholic extract is filtered, saturated with carbonate of soda, the alcohol distilled off, and the residue dissolved in water. This is extracted with ether, the ethereal solution is separated, and the ether evaporated. The residue is now treated with alcoholic potash, the alcohol is removed by evaporation on a water-bath, and the residue dissolved in water. This solution is treated with ether, in which the cholesterin dissolves, while the soaps of the fatty acids remain in solution in the water. The presence of cholesterin in the ethereal solution may be shown by: (1) Placing a drop on a microscope slide and, after the ether has evaporated, looking for the characteristic crystals. These are soluble in alcohol, ether, acids, and strong alkalies. Treated with dilute sulphuric acid and iodine, they turn successively blue-violet, green, and red; (2) A solution of the crystals in chloroform, treated with sulphuric acid and shaken, turns rapidly blood-red and then purple-red, while the sulphuric acid shows a green fluorescence.

Cholesterin is estimated quantitatively in the ether extract of the dried fæces (*p.* 257).

Lecithin occurs in traces in normal fæces. It is possibly derived to a slight extent from the food, but as it is also met with in meconium, the greater part comes, no doubt, from the intestinal secretions, and particularly the bile. The lecithins are ethereal compounds formed by the union of cholin with glycerophosphoric acid, in which the two glycerin hydroxyl groups have been replaced by fatty acid radicles. Like the fats, they are digested by the steapsin of the pancreatic juice, and are decomposed into their components. The glycerophosphoric acid is absorbed, the fatty acids are also absorbed, and the cholin is decomposed by the intestinal bacteria, with the formation of carbon dioxide, methane, and ammonia. In pathological conditions, and, according to Deucher, especially in diseases of the pancreas interfering with the flow of the pancreatic secretion, the amount of unchanged lecithin in the fæces may be much increased. No satisfactory qualitative tests for lecithin in the fæces are available, and it is usually determined by estimating the phosphoric acid contained in the ether extract of the stools (*p.* 258).

Lecithin occurs in cow's milk to the extent of 1 gram per litre, and is even more abundant in human milk; yet neither Vegscheider nor Blauberg could find it in the stools of infants on a milk diet, as it is apparently broken down into its constituents and absorbed.

FERMENTS.

The various enzymes concerned in the digestive processes that go on in the alimentary tract are excreted for the most part in the fæces, and can be detected there by appropriate measures. By such means it is possible to determine with a considerable degree of probability the functional activity of the digestive organs, and assist in the diagnosis of the true cause of otherwise obscure symptoms, thus furnishing a basis for their rational treatment.

The ferments may be extracted from the fæces by mixing them well with thymol water, dilute soda solution, or glycerin, and then filtering until a clear filtrate is obtained: or Leo's method of separating the ferments with blood fibrin may be followed. To this end, 2 to 5 grams of fibrin, washed free from blood pigment, are enclosed in a small gauze sac and left in contact with a mixture of the fæces with thymol water for twenty-four hours. The fibrin is then washed with water, and the presence of the adherent ferments proved by suitable artificial digestion tests.

Amylase (Diastase.)—The presence of diastase is shown by the digestive action that it has upon starch, using a solution of iodine as the indicator.

The following is Robert and Strasburger's method, as modified by Goiffon and Tallarico: A 1 per cent solution of starch is mixed with an equal part of a 10 per cent solution of the fæces in thymol water, neutralized, and filtered. The filtrate is placed in the incubator at 37° C., and at regular intervals a drop is brought in contact with a drop of iodine solution. When it ceases to give a blue colour, the digestion of the starch is considered to be complete. The stool should be fresh, and there should not be the slightest admixture of urine. It is often enough merely to mix the stool and the starch solution in a test-tube, heat in a water bath, and apply the iodine test. If an abundance of amylase is present, the starch will be digested in about five minutes.

Wohlgemuth has adopted the following quantitative method for determining the diastase in the stools. The fresh fæces are well mixed, and 5 grams are thoroughly ground in a mortar with 20 c.c. of 1 per cent solution of sodium chloride, added a small quantity at a time. The emulsion is then left for half an hour at the room temperature, stirring it frequently meanwhile. It is now divided into two equal portions of 10 c.c. each, and is transferred to graduated centrifuge tubes, which are centrifugalized until all the solid material is collected at the bottom and stands at the same height in both tubes. The quantities of sediment and supernatant fluid are noted. Nine test-tubes are now taken. Into the first three, 1·0 c.c., 0·5 c.c., 0·25 c.c. of the undiluted extract; into the next three, 1·0 c.c., 0·5 c.c., 0·25 c.c. of an eightfold dilution of the original extract, made with 1 per cent sodium chloride; and in the last three, 1·0 c.c., 0·5 c.c., 0·25 c.c. of a sixty-four-fold dilution are placed, so that each tube contains half the fæcal extract of the preceding :—

1st tube 1·0	4th tube 0·125	7th tube 0·0156
2nd tube 0·5	5th tube 0·0625	8th tube 0·0078
3rd tube 0·25	6th tube 0·0312	9th tube 0·0039

To each tube 5 c.c. of a 1 per cent solution of starch are then added. The tubes are now plugged with wool, or closed with corks, and placed in the incubator at 38° C. for twenty-four hours. At the end of that time they are filled to within a fingerbreadth of the brim with cold distilled water, one drop of a decinormal iodine solution is added to each, and the lowest dilution giving a blue reaction looked for. It is then assumed that the tube next lowest in order contains sufficient diastase to convert all the added starch, and from this the quantity of 1 per cent starch solution fermented by 1 c.c. of the fæcal extract can be calculated. Knowing the proportion of solid residue to liquid extract in the 5 grams of fæces, the quantity of ferment corresponding to 1 c.c. of this residue can be determined, and from this the diastatic power of the total daily mass of fæces can be determined. According to Wohlgemuth and Wynhausen, the average diastatic value of the fæces lies between 470 and 500. To obtain satisfactory results, the fæces must be homogeneous and alkaline in reaction, as diastase does not act in an acid medium. It is advisable to place the patient on a simple mixed diet, calculated to stimulate the functions of the pancreas to normal activity, for a couple of days before the fæces are collected for examination.

Amylase was first demonstrated in the fæces of infants by Wegscheider. Later v. Jaksch, Maro, Allaira, and others showed that the fæces of children constantly contain it. It is found during the first week of life in abundance, and Pottevin proved that it is constantly present in meconium. The quantity appears to diminish somewhat in later life, but, according to Strasburger, it never entirely disappears. It has been suggested that the diastatic action of fæcal extracts on starch might be due to the contained bacteria, but the experiments of Kerley, Mason, and Craig have proved that an extract freed from bacteria by filtration through a

Berkefeld filter has an unchanged action on starch. The amount present in the stools appears to vary within very wide limits normally, perhaps as a result of changes in the diet. Diarrhœa increases the quantity, and constipation generally diminishes it. In diseases of the pancreas interfering with the flow of pancreatic juice into the intestine, the digestive action of an extract of the fæces for starch is diminished, or may be altogether abolished; thus in many cases of cancer of the head of the pancreas I have obtained an unchanged blue reaction with iodine after twelve or even twenty-four hours' incubation; but with growths of the gall-bladder and common duct that did not obstruct the pancreatic duct, starch digestion has not been interfered with.

Lactase was originally demonstrated by Orbán in the intestinal mucous membrane, and was subsequently found in the fæces of infants. It is never present in the fæces of adults. It is a ferment which has the power of converting milk-sugar into dextrose and galactose, and although principally found during the period that the child is being fed on milk, can also be demonstrated after suckling is ended.

To demonstrate the presence of lactase in the fæces, a thymol- or chloroform-water extract of the stool is mixed with a solution of milk-sugar, well shaken with chloroform, and placed in the incubator at 37° C. for twenty-four hours. The albumin is then precipitated out of the solution with 15 per cent soda solution and neutral acetate of lead. The filtrate from this is feebly acidified with acetic acid, and the excess of lead removed with sodium sulphate in 10 per cent solution. The presence of dextrose and galactose is shown in the filtrate by means of the phenylhydrazin test, taking advantage of the fact that while the osazones of these sugars are insoluble in hot water, the osazone of milk-sugar is readily soluble.

According to some observers, lactase is formed only by the epithelial cells of the intestinal walls, but Martinelli states that it is also present in the pancreas. Most investigators have failed to find the ferment in meconium. In severe disturbances of the alimentary tract in infants, the lactase in the stools is diminished in amount or may be entirely absent, thus accounting for the alimentary lactosuria noticed by some observers in such cases.

Invertase, the ferment which converts cane-sugar into dextrose and levulose, has been shown by Ibraham to be present in the pancreas and parotid gland at birth. V. Jaksch states that it is constantly present in the fæces of both children and adults.

The fæces are tested for invertase in a similar way to that described for lactase, replacing the milk-sugar solution by one of cane-sugar. Pure cane-sugar gives no osazone with phenylhydrazin, but the commercial variety usually contains some dextrose, so that if it is employed in carrying out the test, a small yield of dextrosazone crystals may be disregarded.

Maltase can be extracted from the mucous membrane of the small intestine ; it also occurs in the parotid gland, and frequently in the pancreas extract at birth.

In testing for maltase, the same procedure as for lactase and invertase is followed, using a solution of maltose. Maltosazone is distinguished from the osazone which the dextrose produced by the action of maltase on maltose forms, by the fact that the latter is insoluble in hot water, while the former is readily soluble and reprecipitates on cooling.

Trypsin.—The fact that the fæces normally contain traces of a proteolytic ferment was shown by Leo, Baginsky, Schmidt, and others, while Hemmeter proved that it was trypsin, and not pepsin, since it digests fibrin in an alkaline, or neutral, but not in an acid medium. The experiments of Frank and Schittenhelm with fæcal extracts passed through a porcelain filter have shown that the proteolytic action of the fæces is not dependent upon the presence of bacteria. The earlier experiments were carried out with fibrin, or Mett's tubes filled with white of egg or blood serum, and it was not until Müller showed that drops of the fluid fæces obtained by the administration of a purgative, such as calomel or purgen, or an emulsion of a formed stool with glycerin, placed on a serum plate containing dextrose broth (Löffler), and incubated at 50° to 60° C., gave, under normal conditions, pits due to the digestion of the solid serum, that the examination of the stools for trypsin as a diagnostic measure began to attract much attention. If the pancreas is functioning normally, evidence of digestive changes in the serum plate should be obvious in about half an hour. If no change has taken place in twenty-four hours, it may be concluded that there is pancreatic insufficiency. This method has, however, inherent difficulties which militate against its general use, and the test devised by Gross, or one of its modifications, is now more frequently employed. In principle Gross' test depends upon the fact that casein in alkaline solution, in contrast with its digestion products, is easily precipitated by dilute acetic acid, so that if an alkaline solution of casein is digested with trypsin, the addition of acetic acid gives no precipitate, whereas if digestion has not taken place or is incomplete, a more or less marked deposit follows the addition of the acid to the mixture.

Gross' test is carried out as follows : A solution of casein, made by heating 0·5 gram of pure casein (Grübler) with a litre of 0·1 per cent caustic soda solution and preserved with a few drops of chloroform, is prepared. The specimen of fæces to be tested is thoroughly rubbed up in a mortar with three times its volume of 0·1 per cent soda solution, left to stand for about an hour, and repeatedly filtered until a clear filtrate is obtained. If a quite clear filtrate cannot be secured, the fluid is allowed to settle for some time, and the supernatant clear fluid is pipetted off. Ten c.c. of this are mixed with 100 c.c. of the casein solution and a few drops of chloroform in a small flask, and placed in the incubator at 37° to 40° C. From time to time a small portion is removed and tested with 1 per cent acetic acid until a precipitate no longer forms, showing that the casein has been completely digested. Under normal conditions complete digestion takes place in from eight to fifteen hours, usually twelve to fourteen. A more or less marked precipitate of casein after that length of time points to absence or interference with the digestive functions of the pancreas.

Wynhausen has suggested the following method for carrying out Gross' test quantitatively: Twelve test-tubes are taken. Into the first two are placed 0·25 c.c. and 0·1 c.c. of the undiluted fæcal extract; into the next five, 0·6 c.c., 0·4 c.c., 0·25 c.c., 0·16 c.c., and 0·1 c.c. of a ten-times dilution; into the next three 0·05 c.c., 0·25 c.c., and 0·1 c.c. of a hundred-times dilution; and into the last two, 0·5 c.c. and 0·25 c.c. of a thousand-times dilution. To each is now added 5 c.c. of 0·1 per cent casein solution. The tubes are closed with corks or wool and incubated for twenty-four hours. At the end of this time they are tested with 1 per cent acetic acid. The digestion of 1 c.c. of 0·1 per cent casein solution by 1 c.c. of the filtrate is taken as the tryptic unit. Normally, the value exceeds 200.

The diastatic value of the fæces may be determined in a similar way, using 5 c.c. of 1 per cent starch solution in place of the casein, and testing for the undigested starch with iodine.

Heiberg has devised a modification of Gross' test, which does away with the need for frequent examination of the solution, and like Wynhausen's method, gives quantitative results: Five test-tubes are taken, and into each is placed 5 c.c. of a 0·1 per cent soda solution. To the first is added 0·25 c.c. of the fæcal extract; to the second, 0·5 c.c.; to the third, 1 c.c.; to the fourth, 2 c.c.; and to the fifth, 4 c.c. The contents of each tube are then made up to 10 c.c. with a 0·1 per cent solution of sodium carbonate. The tubes are placed in the incubator at 38° to 40° C., and left undisturbed for ten hours. One c.c. of 1 per cent acetic acid is then added to each. Normally the fifth, fourth, third, and frequently the second, tubes yield no precipitate; a distinct positive reaction with these is taken to indicate a more or less marked pancreatic insufficiency. By this method a rough quantitative result is obtained, for, according to Heiberg, every normal stool contains trypsin, and 1 c.c. of the extract should digest 10 c.c. of a 0·5 per cent solution of casein in one hour at 37° C.

While some observers have failed to find trypsin in meconium by these methods, others state that it is usually present. There can be no doubt, however, that it quickly makes its appearance, and may usually be detected within a short time of birth. In normal persons the tryptic activity of the fæces is uninfluenced by the diet, or a diminution of the acidity of the gastric juice by the administration of large doses of bicarbonate of soda (Schlecht).

It is increased in diarrhœa and conditions which stimulate peristalsis, thus hindering the absorption and destruction of the ferment. Constipation, on the other hand, diminishes the quantity of trypsin in the stools. Schlecht states that he only obtained a feeble reaction in several cases of carcinoma of the stomach in which there was no mechanical obstruction of the pancreatic ducts, and explains this result by suggesting that a diminished activity of the pancreas was produced by the gastric disease or by the associated cachexia. In a case of poisoning by corrosive sublimate with markedly bloody stools, no proteolytic action could be obtained with the fæces owing to the anti-ferment present in the blood serum. In my experience, and that of most other observers, a negative result is most constantly obtained in cases of cancer of the head of the pancreas, and it is therefore an exceedingly useful test in the diagnosis of that disease. Cirrhosis of the pancreas and obstruction of the duct by gall-stones, etc., interfere more or less with the digestion of proteins by extracts of the fæces, but rarely give rise to such very striking results as are seen in cases of growth in the head of the pancreas.

Mention may be made here of Müller and Schlecht's adaptation of Sahli's glutoid capsule test to the detection of the tryptic ferment in the fæces.

A gelatin capsule hardened in an alcoholic solution of formalin is filled with powdered wood charcoal, and floated on 10 or 15 c.c. of a liquid stool, which must not have been filtered, in a wide test-tube, so that it does not touch the walls, and incubated at 37° C. If the fæces contain a normal proportion of trypsin, the capsule should dissolve in about half an hour, and its contents will stain the fluid in the tube black. If no trypsin is present, the capsule will remain unaltered for a day or so before it finally dissolves.

This test has the same drawbacks as Sahli's, and particularly the difficulty of properly adjusting the hardness of the gelatin and preventing accidental opening of the capsule. It has now been replaced by the more satisfactory casein tests.

Erepsin.—This enzyme was discovered by O. Cohnheim in the succus entericus of the dog, and was subsequently separated from the intestinal mucous membrane. It has the property of splitting proteoses and peptone into simpler products, but has no action on native proteins. According to Kutscher it is, however, a comparatively feeble and unimportant ferment.

To detect its presence in the fæces the method of Langstein and Soldin may be followed: 10 c.c. of a solution of Grübler's peptone, made to contain 58·64 mgrams of nitrogen, is mixed with an extract of the stool, saturated with thymol, and placed in the incubator at 37° C. for seventy-two hours. It is then filtered and tested by the biuret reaction, which should no longer be obtained if erepsin is present.

Abderhalden advises the following procedure: A sample of the stool is well mixed with water in the proportions of one to two, or one to four. It is then carefully filtered and the filtrate freed from bacteria by passing it through a porcelain candle. After being made alkaline with sodium bicarbonate, and saturated with chloroform or thymol, 1 c.c. is mixed with 0·5 gram of Grübler's peptone that has been sterilized by heat. The mixture is placed in an incubator at 37° C. for one to three days. Any sediment that may have formed is then examined with the microscope, and should show crystals of tyrosin in the form of colourless sheaves if much erepsin is present. If no sediment appears, the mixture is placed in an ice-chest for twenty-four hours and then re-examined. Should the solution still be perfectly clear, it can be concluded that the erepsin is absent.

Enterokinase.—The proteolytic ferment formed by the pancreas is in an inactive form known as trypsinogen, and it is not until it comes in contact with the enterokinase secreted by the intestinal mucous membrane that it is converted into active trypsin. The absence of this ferment may therefore give rise to an apparent pancreatic insufficiency in cases where the pancreas is functioning normally, although, according to Hekma, bacteria have also some power in activating trypsinogen. This "ferment of a ferment" was discovered in meconium by Ibrahim, and later by Schonberner, by the following method:—

A fresh pig's pancreas is freed from fat and connective tissue, finely chopped, and rubbed to a pulp in a mortar, with 2 per cent sodium fluoride solution and quartz sand. From this the juice is expressed. The meconium is well mixed with water, 1 part to 10, and saturated with toluol. To 5 c.c. of this solution are added 5 c.c. of a 5 per cent solution of sodium fluoride, and a second similar preparation, which is, however, boiled, is also prepared as a control. To each are now added 12 drops of the pancreatic extract, drop by drop. A second control, consisting of 12 drops of the pancreatic extract in a 2 per cent solution, is also prepared. Mett's tubes are placed in each preparation, and they are then left in the incubator for twenty-four hours. If the two controls show no digestion of the albumin contained in the Mett's tubes, while in the third preparation the albumin is more or less completely digested, enterokinase is considered to be present. A negative result points to absence, or a defective production of the ferment.

Lipase.—In 1875, Pfeiffer showed that the fæces contain a fat-splitting ferment. It is not derived from the pancreas, but appears to come from the intestinal mucous membrane, although a bacterial origin cannot be altogether excluded. Hecht has proved that the stools of infants contain a ferment which has the power of splitting the fats contained in the yolk of eggs by the Voldard-Stade method :—

The yolks of three eggs are emulsified with 100 c.c. of water. Ten c.c. of this are mixed with the specimen to be tested, and the mixture is placed in the incubator for two to three hours. It is then well shaken with 75 c.c. of ether and left to stand, the separation of the ether being promoted by the addition of a few cubic centimetres of neutral alcohol. With a pipette, 50 c.c. of the ether are removed and mixed with 75 c.c. of neutral alcohol and titrated with decinormal soda. The mixture is then placed in a flask, 10 c.c. of normal soda solution are added, the flask is well corked, and left at the room temperature for twenty-four hours. Ten c.c. of normal hydrochloric acid are now added, and the mixture is again titrated with decinormal soda. In both titrations phenolphthalein is used as the indicator. The result of the first titration gives the fatty acids, and the second the soaps that have been formed. From these the amount of fat that has undergone saponification can be reckoned.

Another method is to incubate a mixture of the fluid to be tested with ethyl butyrate for a few hours. If the mixture has been previously rendered neutral, the presence of butyric acid can be recognized by its action on neutral litmus, or it may be titrated with decinormal soda and phenolphthalein.

According to Hemmeter, the fat-splitting ferment contained in an extract of fæces does not act upon olive oil. Hecht could not find any parallelism between the quantity of lipase in the stools and the amount of neutral fat, fatty acids, and soaps in the fæces.

THE "BEAD" TEST.

It has been suggested that information as to the particular kinds of food-stuffs that are not digested in diseases of the gastro-intestinal tract may be gained by attaching pieces of raw catgut, meat, potato, and mutton fat each to a different coloured bead, and enclosing them, with a dose of carmine or charcoal, in a capsule. This is taken by the patient at the end of a meal, and washed down with a glass of water. The motions are watched until the characteristic colour of the pigment is seen, when they are collected, mixed with water, passed through a sieve, and the beads recovered. These are then examined, and the extent to which the materials attached to them have been digested is ascertained. From these results, inferences as to the activity of the gastric and various pancreatic ferments are drawn. The time that elapses between the taking of the capsule and the colouring of the fæces by the pigment it contains, shows the rate of passage of the food through the alimentary tract. The test has not proved satisfactory in practice, for, apart from the large size of the capsule needed to contain the beads and test materials, one can never be quite sure that the food-stuffs have not been mechanically detached during their journey through the stomach and intestine. This is more especially liable to happen with the mutton fat and potato.

SPECIFIC GRAVITY.

The specific gravity of the fæces is best estimated with the pycnometer, but in the case of firm motions it is first necessary to rub them up with a known quantity of water until they are quite homogeneous. It is also important to exclude gross food residues such as fibrin and vegetable fragments, and also gas bubbles. When the fæces are semi-fluid and can be obtained in a sufficient quantity, the specific gravity may be estimated by means of the urinometer.

Strausz has devised a simple method of estimating the specific gravity of fæces by which, after taking precautions to exclude bubbles of air, a quantity of the motion is received in a suitable clean vessel up to a marked point, and carefully weighed. The weight of the vessel is known, and so also is the weight of the amount of distilled water which will fill it up to the same mark as that to which the fæces came ; in this way the ratio of weight to volume is obtained and the specific gravity thus determined.

Schmidt finds the average specific gravity of the fæces in healthy persons upon a definite dietary to be from 1045 to 1067 ; in patients suffering from fermentation in the stomach and from disorders of food absorption, the figure was often much lower, for instance 1026. When fat absorption is taking place badly, so that relatively large quantities of fat are being passed in the stools, the specific gravity of the latter, even when all precautions are taken to exclude air bubbles, may be less than that of water ; in one case, for example, when the dry fæces contained 48·8 per cent of fat, the specific gravity of the stool was 938·2. Apart from excess of fat, the more watery the stool the lower the specific gravity, as has been demonstrated by Schmidt in the case of cholera asiatica in adults, and by Monti for the allied malady in infants. Monti found the specific gravity even so low as 1001 in cases of infantile diarrhœa. If, on the other hand, the stools can be shown to contain no particular excess of water, a marked diminution in the specific gravity is an important indication of there being an excess of fat, and, broadly speaking, a 30 per cent increase of fat in the dry stool corresponds to 100 points of diminution in the specific gravity. Most motions float upon water, but this is due not to their specific gravity being less than that of water, but to their containing large numbers of bubbles of gas.

Just as the presence of much fat diminishes the specific gravity of the fæces, so an excess of carbohydrates increases it, as Strausz has shown. The specific gravity is consequently high in cases of dyspepsia due to the fermentation of carbohydrates in the intestines.

Janert carried out investigations on the specific gravity of the fæces in fifty-three cases, and concluded that the formed stools of healthy persons have an average specific gravity of from 1050 to 1070; fairly thick but unformed stools have a specific gravity of 1030, or less when they contain a high percentage of fat, or when the patient is suffering from achylia gastrica, tuberculosis of the bowel, carcinoma of the stomach, or from the phenomena of intestinal putrefaction, whilst when affected by acid intestinal fermentative dyspepsia the total dry residue might be from 20 to 27 per cent, and the specific gravity from 1070 to 1102. When the stools were thin and fluid, with a dry residue of under 20 per cent, the specific gravity might nevertheless be 1040 and over.

The highest specific gravity recorded seems to be 1452, and this was in the case of a stool passed after the administration of bismuth; one of the lowest records was 937, in a case of Janert's, in which, as the result of biliary obstruction, fat resorption was very imperfect.

The above figures apply almost entirely to adults, and there appear to be no records upon the subject in the case of infants and young children.

Janert's work seems to show that the length of time the motion takes in passage, as determined by the carmine method, is of considerable influence upon the specific gravity. Long duration of passage, up to forty-eight hours and more, raises the specific gravity to 1051 or 1083, whilst marked diminution in the time of passage, down to, for instance, twelve to twenty-four hours, lowers the specific gravity to 1012 or 1016; intestinal fermentation dyspepsia constituting, however, an important exception to the latter rule.

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Chapter VII.

CHEMICAL EXAMINATION OF THE DRIED FÆCES.

THE chemical investigations described in the last chapter may all be carried out with the fresh fæces as they are passed, but there are a certain number of others which can only be satisfactorily conducted with material from which the water has been driven off and the resulting product has been reduced to a fine powder. As a rule it is not necessary to dry the whole bulk of the stool, and for most purposes it suffices to take 10 to 50 grams of the well-mixed moist fæces, according to the nature and extent of the analyses to be made. If the total daily output of any particular constituent is to be determined, it is of course necessary that the ratio which the portion taken for drying bears to the whole weight of the mixed stools should be determined.

THE DRYING AND POWDERING OF THE FÆCES.

These are carried out as follows. The required quantity of the stool is placed in a shallow porcelain dish, of known weight, and carefully weighed. The dish and its contents are then transferred to a water-bath at a temperature of 50° to 60° C. When most of the water has been driven off, the residue is broken down as much as possible with a glass rod or spatula, being careful to avoid loss. The dish is then returned to the water-bath and heated for another half-hour or so. At the end of this time the fæces are removed from the dish, without loss, and transferred to a porcelain or glass mortar, where they are ground down to a fine powder, again taking care that no loss occurs. The powder is now returned to the dish and again heated on the water-bath. After an interval of half an hour or so, it is cooled in a desiccator and weighed. The dish and its contents are again heated on the water-bath for about half an hour, cooled, and weighed, the process being repeated until two consecutive weighings give the same reading. This is taken to be the weight of the dry material contained in the quantity of moist fæces originally used.

If the stool contains much fat it is difficult to dry it thoroughly in the manner described, as the fat forms a film on the surface which interferes with evaporation, and the solid greasy mass that results on cooling prevents the material being finely powdered. To meet the first difficulty, Poda advises that the boiling-point of the fluid should be lowered by adding alcohol from time to time.

The fæces are placed in a porcelain capsule and heated on the water-bath for three or four hours in the ordinary way. They are then thoroughly mixed with 50 c.c. of absolute alcohol by means of a glass rod, and again heated on the water-bath. In about an hour another 25 c.c. of alcohol are well stirred in, and the mixture is evaporated as before. A third portion of alcohol is similarly added, and evaporated off, at the end of another hour. In this way all but some 2 to 5 per cent of the water can be removed, even from a very fatty stool. To get rid of this, the dish is rapidly heated on the water-bath to 100° C., and the heating repeated until a constant weight is arrived at.

The drying of fatty stools at a low temperature may also be assisted, and the formation of lumps be avoided, by mixing the stool with a known weight (about 10 volumes) of silver sand which has been successively washed with hydrochloric acid, water, and alcohol, and dried. When a rapid drying of the stool for the purpose of fat estimation only is necessary, the same procedure may be adopted, and the drying carried out at a temperature of 100° C.

In the process of drying, the fæces not only lose water, but also other substances, such as volatile fatty acids, ammonia, and various aromatic bodies, especially if too high a temperature is employed. To prevent the loss of ammonia, and consequently too low a reading of total nitrogen when the dry fæces are to be used for this estimation, they may be mixed with a small quantity of dilute sulphuric acid or a couple of small oxalic acid crystals; or a small portion of the stool may be dried in a desiccator under a vacuum, and the nitrogen and water, etc., in the air be estimated.

ESTIMATION OF THE WATER CONTENT.

A gravimetric estimation of the water contained in the fæces is a matter of considerable importance clinically, as it is the only certain means of deciding whether true diarrhœa and constipation exist. A mere naked-eye inspection of the stools is liable to prove most misleading as to the quantity of water present, for fluid or semi-fluid motions may arise from the presence of an excess of mucus, or of fats with a low melting-point, and apparently hard motions may prove on quantitative examination to contain a normal, or nearly normal, amount of water.

If the method of drying the fæces previously described is carefully and thoroughly carried out, the result will give a sufficiently accurate determination of the water content of the fæces for all practical purposes; but, as the powder is not quite water-free, the figures so obtained are not strictly correct. To arrive at an accurate estimation of the water content of the stool a much higher temperature must be employed.

A small quantity of the well-mixed powdered fæces are placed in a clean, dry weighing-glass, or between two watch-glasses, the tare of which is known, and weighed. The glass and its contents are placed in a drying cupboard at a temperature of 100° to 105° C. for two or three hours, cooled in a desiccator, and weighed. It is then returned to the drying cupboard for half an hour, again cooled, and weighed. If there has been a loss of weight, the drying must be continued until the figures obtained on two successive weighings are identical. From the loss of weight in the preliminary drying and in this second more complete desiccation, the total water content of the fæces can be accurately estimated.

The percentage of water contained in the fæces varies considerably even in healthy people, the nature of the diet exerting a most important influence. When an ordinary mixed diet is taken, the water content of the stools usually lies between 70 and 80 per cent, with an average of about 76 per cent. If meat only is taken, there is a tendency to excrete less water by way of the fæces, the average quantity being about 70 per cent. On an exclusively vegetable diet the reverse condition occurs, and the water content of the stools rises to an average of about 87 per cent. The diminished water excretion on a meat diet is explained by the small amount of residue it leaves to stimulate the peristaltic functions of the intestine, with the result that there is stagnation of the intestinal contents and an excessive absorption of water, while the increased amount of water on a vegetable diet is to be ascribed to the acid condition of the intestinal contents, which tends to stimulate peristalsis and inhibit its absorption, and the presence of an excessive quantity of cellulose, which acts in a similar way and helps to keep the fæces moist. The amount of water in the fæces of an adult on an exclusively milk diet varies, according to Rübner, from 89·8 to 92·3 per cent, with an average of 91 per cent, but it is apparently dependent to some extent upon the quantity consumed, increasing as larger quantities are taken, for Harley and Goodbody found that with 4 pints of milk a day the water in the fæces averaged about 77 per cent, and with 5 pints a day about 79 per cent. This variation is probably to be partly accounted for by the larger quantity of fluid taken, but is no doubt principally dependent upon the increased amount of fat, for Rübner and others have shown that increasing the fat in the food raises the percentage of water in the fæces. In a similar way the addition of milk to a mixed diet tends to increase the amount of water in the stools.

In consequence of the differences which variations in the diet bring about in the water content of the stools, even in health, it is obviously essential that some fixed diet should be employed in estimating the alterations that occur in disease, and for this purpose Schmidt's has been most frequently employed. It is very easily assimilated and absorbed, and therefore leaves very little residue to stimulate the bowel and increase peristalsis, while at the same time it is not so rich in fat as a milk diet. Using this test, nearly all observers have found practically the same percentage of water in the fæces of normal individuals, namely about 76 per cent.

Pathologically, the quantity of water contained in the fæces is influenced by an increase or decrease in the movements of the intestine, abnormalities in the absorptive power of the intestinal wall, increased elimination of fluid by this channel, and modifications in the digestive juices. Since the absorption of water is chiefly a function of the large intestine, it is in connection with diseases of this part of the bowel that alterations in the percentage of water in the stools are mostly met with. In constipation, the fæces may contain as little as 60 per cent of water, owing to the long sojourn of the intestinal contents in the large intestine promoting an excessive absorption of water. In conditions associated with excessive peristalsis, on the other hand, the water content of the stools is increased, and may approximate more or less nearly to that of the intestinal contents on their entry into the colon. Thus in diarrhœa the stools may contain 93 to 94 per cent of water, and in conditions such as cholera, where there is also an increased exudation from the intestinal walls, the water may rise to 98 to 99 per cent. An increase in the water of the fæces may also be due to diminished absorption apart from too rapid peristalsis, as in cases of atrophy or amyloid disease of the mucous membrane. An increased exudation or transudation of fluid from the intestinal walls, mixed in various proportions with mucus, blood, pus, and other solid constituents, raises the water content in many catarrhal and inflammatory conditions. The effect of the digestive secretions is mainly exerted through their indirect, or direct, influence on peristalsis. Thus, absence of bile from the intestine tends to cause stagnation of their contents, with the result that the water in the fæces may be reduced to 67 or 68 per cent. When, however, both the bile and pancreatic secretion fail to enter the intestine, there is a tendency to undue frequency of the motions, and the water in the fæces may be increased to 87 or 88 per cent.

The quantity of water contained in meconium varies considerably according to the results of different observers. Zweifel, for instance, found 80 per cent, Davy 72·7 per cent, and Knopfelmacher 71·6 and 62·86 in two cases, so that it is evident the percentage may be sometimes remarkably low. During the first fourteen days of life, Michel found 78·5 to 72·2 per cent of water in the stools, and in a healthy breast-fed infant of two and a half months 87·3 per cent. A series of observations by Uffelmann during the first thirty-two and thirty-eight weeks of life gave an average of 85 per cent of water in the stools. Wegscheider and Camerer obtained very similar results; but the latter observed that after weaning, when cow's milk was substituted for breast milk, the water fell to 71·7 per cent. The difference in dry residue between children taking mother's milk and those having cow's milk has been very thoroughly investigated. Biedert, for example, found that in the case of a breast-fed child, from 1 to 1·3 per cent of the total solid in the food appeared in the dry residue of the fæces, while the corresponding figures for artificially-fed children were 2 to 3·1 per cent. When no excess of food was allowed, but when more than the average amount of milk was given, the figure rose to between 5·9 and 7·5 per cent. Escherich studied the digestion of milk in an infant ten weeks old, during a period of eight days, and found that the total dry residue in the fæces upon a cow's-milk dietary was 15·95 per cent, whereas with breast-feeding it lay between 14 and 15 per cent. On a natural diet only 3 per cent of the dry residue of the food appeared in the fæces, whilst with a diet of cow's milk it amounted to 6·96 per cent. Rübner and Heubner made an interesting comparison of the degree to which the dry residue of the food was made use of on different dietaries and under different conditions, and came to the following conclusions :—

1. A five-months-old breast-fed child, receiving the ordinary amount of food, passed unutilized 5·42 per cent of the dry residue.

2. A child aged seven and a half months, weighing 7570 grams, in good health, and receiving a dietary of milk diluted to half and with added lactose, lost 6·13 per cent of the dry residue.

3. A marasmic child of three and a half months, weighing barely 3000 grams, that had been for four days upon a diet of cow's milk, was losing 8·19 per cent.

4. During three days on a diet of barley-water, 14·71 per cent of the dry residue of the food was lost.

Thus showing that in marasmus, the absorptive power of the intestine suffers to such a degree that a considerable proportion of the dry residue of the food is passed in the stools.

The metabolic researches of Lange and Berend on infants who were digesting badly, showed that from 3·5 to 1·9 grams of dry fæces were passed for each 100 grams of cow's milk, while for a breast-fed infant the corresponding figure was 0·67 grams. Lange gives about 5 grams as the average daily amount of dry residue in the fæces of fourteen apparently healthy children who were artificially fed, and for nine children with symptoms of indigestion the average quantity was 9·5 grams.

In children of ten to twelve years old, a strictly milk diet for a few days was found by Camerer to result in the passage of fæces containing 23 per cent of water. When a more varied diet was taken he obtained the following readings :—

Dry Residue in the Fæces.

Girls			Boys		
Age	Total	Per cent of Food	Age	Total	Per cent of Food
2–4 years	16 grams	5	—	—	—
5–7 ,,	15 ,,	6	5–6 years	28 grams	8
8–10 ,,	15 ,,	5	7–10 ,,	23 ,,	6
11–14 ,,	18 ,,	4	11–14 ,,	23 ,,	5
15–18 ,,	15 ,,	4	15–16 ,,	21 ,,	4
21–24 ,,	18 ,,	4	17–18 ,,	20 ,,	4

These figures seem to indicate a progressive improvement in the extent to which foodstuffs are made use of, and this is more marked in males than in females, chiefly owing to the fact that boys absorb less efficiently than girls in early life.

Bendix has investigated the dry residue in the fæces of children taking sterilized and unsterilized food, and showed that there is practically no difference.

It has been proved by Heubner that, during convalescence from acute disorders of the alimentary tract, infants not only excrete larger quantities of fresh fæces, but the dry residue in their stools is also increased, quite three times the normal being found in one case.

According to Koziczkowski, the average dry residues in the various types of stools passed by infants are : (*a*) Formed motions, 30 per cent ; (*b*) Thick but unformed motions, with good fat absorption, 25 to 27 per cent ; (*c*) Thick but unformed motions with poor fat absorption, 20 to 24 per cent ; (*d*) Loose motions, 16 per cent.

TOTAL NITROGEN.

The total nitrogen in the fæces is estimated by Kjeldahl's method. This depends upon a conversion of the ammonia nitrogen and nitrogen of the proteins and their derivatives into ammonium sulphate by heating the fæces with sulphuric acid, then setting free the ammonia with a caustic alkali, distilling, and titrating it with standard acid in the distillate. To aid in the destruction of the organic matter, mercury, or the oxide of one of the heavy metals, is added to the sulphuric acid mixture. The nitrates are not included in the estimation, but as they only occur in very small quantities in the fæces this does not introduce any appreciable error. The estimation is usually conducted with the dry powdered fæces, in which the escape of ammonia has been prevented by the addition of dilute sulphuric acid, but about double the weight of the fresh stool may also be used.

About 2 grams of the dry fæces are carefully weighed out and introduced into the bottom of a hard glass Kjeldahl flask (*Fig.* 77 A). This

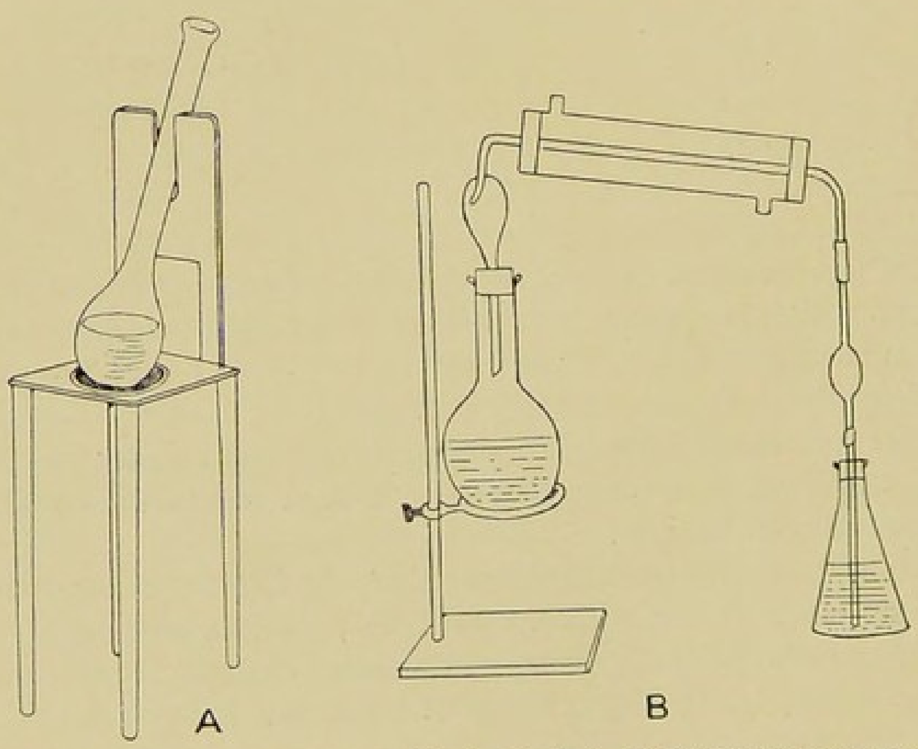

Fig. 77.—Kjeldahl Apparatus. A, Combustion flask. B, Distillation apparatus.

can be most readily effected by the use of a long-stemmed funnel which will reach nearly to the bottom of the flask, or the specimen may be folded up in pure tinfoil. Twenty c.c. of a sulphuric acid mixture, composed of 3 parts of the pure concentrate and 1 part of the fuming acid, or 800 c.c. of the pure, 200 c.c. of the fuming sulphuric acid, and 100 grams of anhydrous phosphoric acid free from nitrogen, are then poured in. A few drops of mercury (about 0·1 c.c.) are added from a capillary pipette. It is best to now place the flask aside for twelve or twenty-four hours, after shaking it, since if it is heated at once the mixture is liable to froth in a way that is difficult to control. At the end of that time the flask is supported in an inclined position on a sand-bath, or asbestos board, and heated, at first with a small, and later with a full, flame, until the fluid is perfectly clear and transparent. This generally takes three or four hours. Care must be taken that any particles which have been carried to the upper part of the flask are shaken down into the fluid and thoroughly destroyed. The flask is now cooled, and its contents are washed out into a half-litre distillation flask with 50 c.c. of water. Any residue is also transferred to the flask by adding two or three further portions of distilled water, the total contents by this means being raised to not more than 200 c.c. The distillation flask is now cooled in a stream of water, and 50 c.c. caustic soda solution (500 grams to 500 c.c.), 40 c.c. of potassium sulphate solution (4 grams in 100 c.c.), and a spoonful of talc or a few zinc filings are added. Finally, a further 50 c.c. of the sodium hydrate solution are introduced, and the flask is quickly connected with the condenser to avoid any loss of ammonia. The delivery end of the condenser dips to the bottom of a small flask into which have been placed 50 c.c. of fifth-normal sulphuric acid (*Fig.* 77 B). The flask is then heated and the distillation carried out. After twenty minutes, the apparatus is disconnected and the flame removed. The delivery tube from the condenser is washed out with a little distilled water into the receiver flask, to the contents of which a small quantity of tincture of cochineal or methyl-orange solution is added. The acid in the flask is now titrated with fifth-normal sodium hydrate. The number of milligrams of nitrogen contained in the weight of dry fæces used is calculated by multiplying the number of cubic centimetres of fifth-normal sulphuric acid bound by the ammonia distilled over by 2·8. The bound acid is of course the difference between the quantity of acid placed in the flask and the quantity of soda solution consumed in the titration. It is always advisable to control the results of the estimation by a second experiment.

Salkowski recommends a modification of the ordinary Kjeldahl process. A weighed quantity of the fæces is heated with 10 c.c. of sulphuric acid (sp. gr. 1·84), and 5 to 6 c.c. of a cold 10 per cent solution of acetate of mercury are added. If the solution that results is not quite colourless, a small crystal of permanganate of potash is then introduced. Previous to distilling off the ammonia he adds 10 c.c. of a 20 per cent solution of sodium thio-sulphate and 40 c.c. of caustic soda solution (sp. gr. 1·34).

The nitrogen contained in the fæces may be derived from (*a*) the proteins of the food, (*b*) the secretions, etc., of the alimentary tract, and (*c*) the bacteria of the intestinal contents. It was at one time supposed that the greater part at least of the fæcal nitrogen came from the food, but careful investigation has shown that the quantity and quality of the diet do not influence the output in the way that might at first sight be expected, and moreover, that even in starvation the fæces still contain nitrogen. The well-known researches of Müller on the professional starving men, Cetti and Breithaupt, showed that they excreted 0·316 gram and 0·116 gram of nitrogen a day respectively, and on the average it has been found that "starvation fæces" contain about 0·254 gram of nitrogen. These figures are naturally the minima, but it is evident that part at least of the nitrogen contained in the fæces is not derived from the food. Experimenting with dogs and patients on a nitrogen-free diet, Rieder found that about 0·73 gram of nitrogen was excreted daily in the stools, thus showing that the ingestion of food influences the amount of nitrogen contributed by the body to the fæces. As a progressive increase in the quantity of non-nitrogenous food has been shown to be associated with a corresponding rise in the nitrogen excreted in the fæces, it is evident that the latter, and also the difference between the results obtained during fasting and when food is being taken, must depend upon the nitrogen contributed by the digestive secretions, and possibly also the increased facilities provided for the growth of micro-organisms. When a purely nitrogenous diet is substituted for a non-nitrogenous one, there is an increase in the output of nitrogen in the fæces, but this is not so marked as might be expected. Thus Rübner found that when meat only was taken, 1·12 to 1·2 grams of nitrogen were excreted daily. The smaller quantity resulted, however, from the ingestion of 1435 grams of meat, and the larger was found when only 884 grams were taken. It would therefore seem that the greater the quantity of nitrogen in the diet, the less the proportion appearing in the fæces, and that an increased amount of nitrogenous food in the diet aids digestion. This is, however, not really the case, for properly prepared meat leaves but little protein residue, so that an increase in the amount ingested yields a relatively smaller quantity of nitrogen in the fæces, while the nitrogen derived from the alimentary tract itself remains the same and is relatively diminished. In a similar way, eggs, milk, and certain vegetable foods, such as macaroni, white bread, rice, and maize, which leave little residue, do not markedly raise the nitrogenous output in the fæces, but a diet rich in materials leaving a considerable residue, such as brown bread, peas, and vegetables rich in cellulose, increases the nitrogen content of the fæces very considerably. It is important to note, however, that the percentage of nitrogen does not necessarily rise with the total quantity; in fact the reverse is usually the case. This apparent contradiction is explained by the fact that while these articles of diet contribute a considerable amount of undigested protein to the fæces, thus increasing the total nitrogen, they add far more proportionally to the other constituents of the stool, so that the percentage of nitrogen sinks. This is well shown in the following table given by Schmidt and Strasburger :—

Diet	Grams	Total Nitrogen	Percentage of Nitrogen
Macaroni ..	6·95	1·86	6·88
White bread ..	6·89	1·95	8·30
Rice	6·38	2·13	7·87
Maize	7·50	2·27	4·60
Potatoes ..	3·07	3·69	3·93
Brown bread ..	13·60	4·26	3·68
Peas	6·00	3·57	7·35
Carrots	51·33	2·52	3·01

It is therefore evident that under normal conditions the nitrogen content of the fæces cannot be taken as a direct indication of the extent to which nitrogenous food is being utilized by the organism. In fact, Prausnitz and his school have assumed that the greater part of the fæcal nitrogen comes from the intestine itself, and go so far as to say that it would be better to speak of the secretion of more or less fæcal nitrogen than of the more or less complete absorption of the nitrogen of the food. Ury's work tends, however, to disprove this extreme view. A not inconsiderable proportion of the nitrogen found in the fæces is contributed by the contained bacteria. Schmidt and Strasburger consider that, on a diet yielding only a small amount of residue, the bacteria furnish no less than a quarter, or even a half, of the total nitrogen of the stools. Bacterial activity in the intestinal tract also influences the nitrogen content of the fæces indirectly, for by their action on the proteins of the food and intestinal secretions, they give rise to nitrogenous residues which pass unchanged in the excreta instead of being absorbed and utilized by the organism.

Another factor which, as v. Noorden points out, must always be considered in interpreting the results of analyses of the fæces for nitrogen, is the existence of individual variations. Such variations are found not only between different persons taking the same diet, but also occur in the same individual at different times and under various circumstances. It is therefore impossible to lay down any hard and fast rule as to the total quantity or percentage of nitrogen in the fæces that may be considered normal for any particular diet. It has been calculated, however, that on the average, a diet poor in solid residue normally yields fæces containing 8 to 9 per cent of nitrogen, with a total daily output of 1·14 grams, while with a diet rich in indigestible constituents, the nitrogen lies between 5 per cent and 6 per cent, with a total daily excretion of about 2·53 grams. As a rule, the more food taken the higher is the amount of nitrogen passed in the fæces.

According to Schmidt and Strasburger, the fæces of adults on a milk diet contain on the average about 1·11 grams of nitrogen, but Harley and Goodbody obtained considerably lower readings in the cases they investigated. When 5 pints of milk were taken, they found an average of 1·06 grams of nitrogen in the fæces, with 4½ pints 0·76 gram, and with 4 pints 0·84 gram. The figures quoted by these observers for a mixed diet are also lower than those usually given, namely, a maximum of 1·55 grams and a minimum of 0·30 gram, with an average of 0·97 gram. On a meat diet their analyses gave a maximum of 0·79 gram, a minimum of 0·26 gram, and a mean of 0·52 gram, results which, it will be noticed, are again considerably lower than those previously quoted from Rübner's experiments. Their observations on the fæces of patients on Schmidt's diet gave a maximum of 1·9 grams, a minimum of 0·43 gram, and an average excretion of 0·88 gram of nitrogen a day.

The wide normal variations in the percentage and total quantity of nitrogen in the fæces that result from the causes already considered, deprive such estimations of much of the diagnostic value in pathological conditions that it was at one time hoped they would have. Numerous investigations have been carried out by various observers on the nitrogen content of the stools in diseased conditions of the gastro-intestinal tract and its appendages, but although a considerable increase or decrease has been noted in some, the variations are as a rule neither so extensive nor so constant as to make analyses of the fæces for nitrogen, of great clinical importance. It has been found, as might be expected, that all conditions which interfere with the proper digestion of the food increase the total nitrogen in the fæces, but, for the reasons already mentioned, the percentage is diminished. Gastric diseases have, however, very little influence in this direction, as the digestive functions of the stomach can be carried out by the intestinal secretions. Experiments upon animals and clinical observations have proved that interference with the digestive functions of the pancreas brings about the most marked increase in the excretion of nitrogen in the fæces, although here, too, the percentage may not be abnormally high. According to Weintraud, the loss of nitrogen is far greater than of fats, a fact of some importance in differentiating such a condition from one in which absorption only is interfered with, as in amyloid disease of the intestine, or in tabes mesenterica. A mere absence of bile from the intestine does not appreciably raise the nitrogen in the stools, but since most causes of biliary obstruction also interfere with the entrance of the pancreatic secretion into the intestine, the output of nitrogen, but not the percentage, is often increased in cases of jaundice. In some instances a certain parallelism between the total nitrogen and the fat in the fæces has been noticed. Inanition from any cause usually diminishes the output of nitrogen in the fæces, owing to a deficiency of the intestinal secretions. It has been suggested that the increase found in such conditions as nephritis, leukæmia, and gout is, on the other hand, dependent upon an increased secretion of nitrogenous material by the intestinal walls. In diseases of the intestinal tract where blood or pus is excreted in the fæces, an increase in both the total and percentage nitrogen is naturally found.

An excess of nitrogen in the stools has been observed in other intestinal disorders, but it is impossible in most instances to determine whether it is dependent upon an abnormal amount of protein food residues being carried through by excessive peristalsis, or arises from deficient absorptive power on the part of the intestine from other causes, or whether an increase in the bacterial content of the fæces or an excessive production of secretion is the true cause of the increase. Probably, in many instances several of these factors are involved.

The excretion of nitrogen in the fæces of infants has been very thoroughly investigated by Tschernoff, who has pointed out that the percentage of nitrogen in the infantile stool is not solely an expression of nitrogenous metabolism, but is influenced by the degree of fat absorption. The dried fæces of healthy breast-fed children contain from 4·5 to 5·4 per cent of nitrogen, while the stools of those fed on cow's milk, mare's milk and Nestlé's food contain about 6·4 per cent. When digestive difficulties exist, a fall to 3 per cent may be observed, while the disappearance of the symptoms is followed by a rise to the former level. The drop in the percentage of nitrogen in the abnormal condition is no doubt to be explained by the excess of fat present in the stool. When a change of diet is made, the nitrogen at first rises, from which it may be concluded that the alteration causes an increase in the intestinal secretions. Michel found an average of 6·4 parts of nitrogen in the fæces for every hundred parts of nitrogen in the food of seven breast-fed children between four and fourteen days old, the extremes being 3·38 and 9·42 per cent. Lange obtained an average of 2 to 3 per cent of nitrogen in the dry residue of the fæces of fourteen healthy infants fed upon cow's milk, while the figure was only 2 per cent, or about one-third less, in nine with gastro-intestinal symptoms. Expressed in percentages of the nitrogen of the food, Lange's results worked out from 3·4 to 6·8 per cent. Keller, in an infant fed upon half strength cow's milk, found a nitrogen loss in the fæces of 6·8 per cent, but when the diet consisted of undiluted milk the loss was only 4·8 per cent. In an infant of two months, fed upon half strength cow's milk, the absorption values obtained by Meyer were 79·91 and 77·35 per cent. On changing to breast milk, which was poorer in nitrogen, the absorption fell to 51·97 per cent, but rose again later, until after six days it had returned to its former value. It would therefore seem that the casein of cow's milk does not appear in the stools any more readily than that contained in human milk, for notwithstanding the relatively larger quantity of nitrogen taken by children fed on cow's milk, there is often not more, but actually less, nitrogen in the fæces than when the child is having mother's milk. If the amount of food given, and thus the quantity of food nitrogen, is increased, the fæcal nitrogen rises also, but throughout the rise runs parallel for both natural and artificial feeding. Orgler found practically no difference between the nitrogen figures before and after weaning. According to Keller, the starving infant excretes from 0·074 to 0·097 gram of nitrogen a day. When protein is given, it has comparatively little effect upon the nitrogen content of the fæces, but the administration of foods containing flour increases the fæcal nitrogen. This is not due to any increase in the food protein in the fæces from defective absorption, but, as in adults, depends upon an increased stimulation of the digestive secretions. It is therefore not surprising to find that, according to Orgler's observations, artificially-fed infants generally store up more nitrogen than those taking only mother's milk, no matter whether they are healthy or sick; in fact it not infrequently happens that ailing children can, by careful regulation of the diet, be got to store up more nitrogen than can the average healthy breast-fed child.

On the other hand, Selter insists upon the occurrence of disturbances in the nitrogen economy of infants. He describes a clinical condition in which the children are very tired and apathetic; they have a low temperature in the morning and a strikingly low pulse-rate of only 60 to 70 early in the day, rising in the evening to 120 or 140. The stools are crumbly, possibly with a greenish tinge and a peculiar offensive aromatic smell, and microscopically they are found to contain many crystals. He has also been struck by the prevalence of iodophilic bacteria. The nitrogen amounts to 7·5 per cent of the dry residue, and from 70 to 100 per cent of the food nitrogen appears in the fæces. Taking the nitrogen in the fæces and in the urine together, the total quantity may come to two or three times the amount of nitrogen taken by the mouth. Occasionally as much as a fourth part of the fæcal nitrogen is present in a volatile form. Intestinal putrefaction is so exaggerated that the total sulphates and the combined sulphates in one case came to nine times the normal. The treatment of the condition consists in restricting the dietary to cream, wheat-flour, and breast milk. The proof of there being a disorder of proteid metabolism seems, however, to be still lacking.

NUCLEIN BODIES.

Krüger and Schittenhelm's method of determining the nucleins and their fission products, the purin bases, in the fresh stools was considered in the last chapter (*p.* 195). Nicko's modification of Kossel's method for demonstrating the nuclein bodies, which is carried out with the dried fæces, will now be described.

Ten grams of the finely-powdered dry fæces are allowed to stand for twenty hours in 200 c.c. of 95 per cent alcohol containing 2·5 per cent of HCl; the mixture is then filtered and the residue washed, first with the same strength acid alcohol as before, and then with ordinary alcohol, until the filtrate comes through colourless. The object of this treatment is to remove all the pigments. The alcohol is then removed by washing with 2·5 per cent hydrochloric acid, the filter being filled with the latter and allowed to drip through as fast as possible. The lower end of the funnel is then closed with a cork, and the filter paper filled up once more with 2·5 per cent hydrochloric acid, which is left for twelve hours before it is allowed to run through. The precipitate is washed once more with 200 c.c. of 2·5 per cent watery hydrochloric acid, and then with distilled water, until it is free from chlorine. The residue is brought, still moist, into a Kjeldahl's flask, 140 c.c. of water and 20 c.c. of 10 per cent sulphuric acid are added, and the mixture is kept simmering on the water-bath for sixteen to eighteen hours. It is then diluted to twice its bulk with water, filtered, and the residue carefully washed. The filtrate, which should now amount to about ½ litre, is precipitated on a water-bath with 30 to 35 c.c. of lead acetate solution, allowed to stand for twelve hours, and then filtered through a double filter. The lead is precipitated from the filtrate with sulphuretted hydrogen, and, to take advantage of the decolorizing action of the lead sulphide, is allowed to stand for several hours before it is filtered. The filtrate is evaporated down to 40 c.c., during which process a slight precipitate and a brownish-yellow colour develop. The fluid is now cooled, filtered, and silver nitrate dissolved in an excess of ammonia is added to the filtrate. A precipitate forms at once. This is filtered off after twelve hours and washed on the filter with water containing ammonia. It is then redissolved in boiling hot nitric acid of specific gravity 1·1, to which it is recommended that a little urea should be added. The solution is treated first with silver nitrate and then with ammonia in excess. The slightly yellowish precipitate which comes down during the succeeding twelve hours is collected on a filter, and repeatedly washed with ammoniacal water until no nitric acid can be demonstrated in the filtrate by the diphenylamine reaction. The ammonia is now removed by washing with alcohol, and the nitrogen can then be determined by Kjeldahl's method.

It has been found that when the diet contains meat, the percentage of xanthin nitrogen in the dry residue of the fæces is 0·143, and the ratio of total nitrogen to xanthin nitrogen is 50 to 1. When meat is replaced by plasmon, the corresponding figures are ·055 and 103 to 1, and in both varieties of fæces Nicko has shown that the phosphorus is present for the most part in the form of true nuclein. He also tried to precipitate the nucleins directly, and from the amount of the precipitate to form some kind of estimate of their amount.

He extracted 10 grams of dried fæces in a Soxhlet apparatus for ten hours with ether, and treated the residue in the way that has been described above with alcoholic and aqueous hydrochloric acid. The residue in its moist state was washed into a graduated flask of 250 c.c. capacity, mixed with 100 c.c. of a 1 per cent solution of sodium carbonate, and then made up to the mark with water. The whole was allowed to stand for eight hours, being shaken frequently the while, and was then filtered. The following reagents were added to the filtrate: acetic acid and ferrocyanide of potassium; perchloride of mercury and hydrochloric acid; iodine in solution of potassium iodide and acetic acid. After a little while, definite precipitates occurred, which corresponded with the true nucleins in that they yielded xanthin bases in the process of being broken up.

To estimate the nuclein-phosphorus in the stools, Hecht adopts the following modification of Kossel's method:—

Two to 5 grams of the finely-powdered dry fæces are mixed in a porcelain basin with 100 c.c. of alcohol and warmed on the water-bath. The alcohol is then filtered off and a further 100 c.c. added, the process being repeated three or four times. The residue is now extracted in a Soxhlet apparatus with the ether, and dried. The dry residue is thoroughly rubbed up with 10 to 20 c.c. of 20 per cent hydrochloric acid, and made up to 80 c.c. with the same strength of acid. After standing for twelve to twenty hours, the mixture is treated with 15 c.c. of 10 per cent tannin solution, and filtered through an ash-free filter. The residue on the filter is now washed with dilute hydrochloric acid and a solution of tannin until the filtrate no longer gives a reaction for phosphorus. The filter is then dried, washed with alcohol and ether, dried again, and the phosphorus estimated by Neumann's method. For this purpose the material is treated with 20 c.c. of the Kjeldahl sulphuric acid mixture containing 15 to 20 grams of ammonium nitrate, and precipitated with ammonium molybdate and magnesia mixture. The phosphorus is then estimated from the magnesium pyrophosphate formed on heating the precipitate.

According to Ury, the nuclein-phosphoric acid may be estimated by extracting the fæces with sodium hydrate. For this purpose the whole of the fresh stool is well mixed with 0·5 per cent sodium hydrate, the volume made up to 1000 c.c., and filtered. A hundred c.c. of the filtrate are then evaporated to a syrupy consistency, mixed with 20 grams of fusion mixture, and fused. The fused mass is dissolved in water, and the phosphorus estimated in the usual way. By this method, however, small quantities of inorganic phosphates are included in the estimation.

Schmidt, using the indirect method of determining the phosphorus combined organically, found strikingly high figures in cases of fermentation dyspepsia and in achylia gastrica; but he himself remarks that one must not conclude from this that there has been poor utilization of the nucleins in the food, but rather that there is in this condition an increased excretion from the intestinal wall, and also, no doubt, a great multiplication of the bacteria present.

FATS.

A quantitative estimation of the fats in the fæces can only be satisfactorily carried out with the dried material. If the stool is rich in fat, the drying can be most satisfactorily carried out by adding absolute alcohol and evaporating on the water-bath with frequent stirring, and subsequently leaving the material in a desiccator containing strong sulphuric acid, until a constant weight is attained. Sulphuric acid must not be added to the material if the combined fatty acids are to be separately estimated. The procedure for determining the fats varies according to the results that are desired, and may be divided into the more exact methods which are adopted when accurate determinations are necessary for research purposes, and more rapid methods, which give approximate results that are, however, sufficient for clinical purposes. We shall first consider the principal methods that have been suggested for determining the total fat.

1. **Determination of the "Total Fat" as Total Ether Extract.**—We have already seen that the neutral fats and free fatty acids are soluble in ether, but that the combined fatty acids, or soaps, are not. If, therefore, the latter are to be included in the estimation, they must first be broken down and the fatty acids be set free by heating the material with a dilute mineral acid.

For this purpose a weighed quantity of the dry powdered fæces is well mixed in a porcelain basin with a 1 per cent solution of hydrochloric acid in alcohol, and heated on the water-bath to dryness. The dry material is again powdered, and a definite proportion weighed out.

This is placed in the extraction thimble of a Soxhlet apparatus and extracted for two or three days with water-free ether on a water-bath. At the end of that time the ether in the receiving flask of the apparatus is evaporated off, the residue dissolved in ether, and filtered into a small weighed beaker, the fat absorbed by the filter being washed into the beaker with ether. The ether is then evaporated off, the ether vapour in the beaker is removed by a current of air, and the beaker and its contents dried in a desiccator over sulphuric acid, and weighed. To obtain accurate results, one or two control experiments should be carried out.

Rosenfeld has suggested that the extraction may be shortened by warming the dried fæces, previously treated with acid alcohol in an extraction thimble for half an hour on a water-bath, in a beaker containing alcohol. The thimble and its contents are then dried and extracted for six hours in a Soxhlet apparatus with chloroform. The alcohol and chloroform extracts are mixed, evaporated to dryness, and dissolved in ether. The ether solution is then filtered and dealt with as in the previous method.

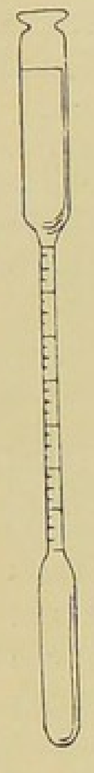

Fig. 78.—Schmidt-Stokes tube.

In 1905 I described a method for estimating fat in the fæces which, while much more rapid than the usual Soxhlet process, gives results that are sufficiently accurate for clinical purposes. I have since examined over two thousand specimens by means of it, and have controlled the results in a number of instances by the classical methods, but even with very fatty stools I have not found a difference of more than about 1 per cent, which is negligible in diagnostic work. The method is an adaptation of the Schmidt-Stokes process for the estimation of fat in milk, and is carried out as follows:—

An accurately weighed quantity—about 0·5 gram—of the dry and finely powdered fæces is introduced into the lower bulb of a Schmidt-Werner milk tube (*Fig.* 78), with the help of a funnel. Ten c.c. of diluted watery hydrochloric acid (30 per cent) are then carefully measured out and poured into the tube in such a way that any particles of the fæcal material that may have stuck to the sides are carried into the lower bulb. The tube is now heated in a boiling water-bath for a quarter of an hour, and rotated occasionally, so as to well mix the contents. After being cooled, the tube is filled up to the 50 c.c. mark with ether, securely corked, and inverted forty or fifty times, the whole of the solid material being allowed to run through the ether each time. It is then rotated between the hands to disengage air bubbles, fixed in an upright position, and left for half an hour or more, so that the whole of the solid material may sink into the lower bulb. Occasional rotation between the hands will hasten this part of the process if the stool is very fatty. When a perfectly clear supernatant layer of ether has been obtained, exactly 20 c.c. are withdrawn by a pipette which is kept for the purpose, and delivered into a small weighed beaker or CO_2-flask.

The ether is then evaporated off, the residue dried by heating on a water-bath, and the vessel cooled and again weighed. The difference between the weights will give the ether extract contained in the 20 c.c. of ether. When the 20 c.c. of ether have been withdrawn from the tube, the height of the remaining liquid should be read off on the graduated scale. The percentage of fat in the fæces can then be calculated :—

If w = the weight of the fæces taken,
x = the weight of fat found in 20 c.c. of ether,
y = the number of c.c. of liquid left in the tube,

then $(y - 10)$ will be the amount of ether left in the tube, for 10 c.c. were dilute hydrochloric acid, and $20 + (y - 10) = (y + 10)$ will be the total bulk of the ether in which the fat from w grams of fæces was dissolved.

$$\therefore \frac{x\,(y + 10) \times 100}{20 \times w} = \text{the percentage of fat in the stool.}$$

Beside the total fat, the ether extract of the fæces obtained by the above methods contains the lower fatty acids, cholesterin, lecithin, cholalic acid, pigments, etc. The quantities of these usually present are, however, comparatively small, so that they may be neglected for ordinary purposes. If necessary, they can be separated from the ether extract by the following methods :—

Separation of the Lower Fatty Acids.—The dry ether extract is washed with hot water, and the watery extract filtered through a small smooth filter paper. The paper, with the fat globules that have remained on it, and the remainder of the ether extract, are then dried. The fat on the paper is dissolved in ether and the solution added to the residue of the ether extract. The ether is then evaporated off, and the beaker, with its content of purified ether extract, weighed. The difference between its present and its former weight gives the weight of the fatty acids removed by the hot water. These can then be investigated in the watery solution by the methods previously described (*p.* 222).

Separation of Cholesterin.—This depends upon the fact that cholesterin is not saponified on treating the ether extract with a caustic alkali, and hence remains soluble in ether after such treatment. The dry extract is mixed with a normal alcoholic solution of caustic potash (about 20 grams of the solution for each gram of the extract), and heated on the water-bath for about half an hour. It is then evaporated to dryness and extracted with ether. The cholesterin is contained in the ether extract, and may be estimated by evaporating off the ether, drying, and weighing, but as a small quantity of soap also passes over, the result is slightly too high. To remove any traces of soap, the residue is treated with a small quantity of alcohol, and one or two drops of hydrochloric acid, when the soaps will dissolve and leave the cholesterin, from which they can be separated by filtration. Traces of coprosterin may still be present, however. The fatty acids remaining in the residue from which the cholesterin has been separated can be recovered by treating it with a large excess of hot water acidified with sulphuric acid and extracting this with ether.

Kossel recommends the following alternative method: The ether extract of the fæces is dissolved in alcohol, and a few cubic centimetres of sodium alcoholate are added (0·15 gram of sodium dissolved in the smallest possible quantity of 99 per cent alcohol by gentle warming). The mixture is well shaken, and left for three hours at the room temperature. The soaps are then separated from the cholesterin by filtration, and entirely freed from the latter by washing with ether.

Coprosterin, like cholesterin, is soluble in ether, and is not saponified by treatment with caustic alkalies. It therefore passes over with the cholesterin in the methods described above. To separate the two, advantage is taken of the fact that coprosterin is soluble in both hot and cold alcohol, and crystallizes out of the alcoholic solution in long fine needles. A chloroform solution of this substance treated with sulphuric acid is at first yellow, and only turns an orange-purple-red on prolonged standing, whereas a similar solution of cholesterin turns blood-red at once, and later becomes purple-red.

Cholalic acid.—The cholalic acid contained in the fæces may be recovered from the residue of the ether extract remaining after the removal of the cholesterin, by warming it with baryta water and shaking. The combination of the fatty acids with baryta are then filtered off and washed with water. The baryta compound of cholalic acid passes through in the filtrate and wash-water, from which it can be recovered by evaporation.

Lecithin.—The lecithin contained in the ether extract of the fæces is split up when this is saponified with alcoholic potash. Its fatty-acid constituents form soaps, and behave as the other soaps formed in the process. The glycerophosphoric acid portion can be separated, with the cholalic acid, by warming with baryta water and filtering. The lecithin content of the fæces is most satisfactorily estimated by determining the phosphorus of the total ether extract after saponification and freeing from cholesterin (Hoppe-Seyler). The soaps are dissolved in water and mixed with an excess of potassium nitrate, evaporated to dryness in a platinum dish, and the residue heated until it is carbonized, but not longer. On cooling, this material is dissolved in hot water, made strongly acid with nitric acid, and, after standing for some time to allow the nitrous acid fumes to pass off, is heated on a water-bath. It is then treated with a solution of ammonium molybdate in nitric acid and left to stand for twelve hours. The precipitate that has formed is then filtered off and dissolved in dilute ammonia. The solution is mixed with ammoniacal magnésia solution and left for twelve hours in the cold. The precipitate is collected on a small filter, washed with dilute ammonia, dried, heated in a platinum crucible until all traces of carbon have disappeared, cooled in an exsiccator, and weighed. From the weight of pyrophosphate of magnesium that results, the weight of lecithin in the weight of fæces from which the ether extract was derived can be calculated by multiplying by 7·27.

The "total fat" of the fæces as estimated from the ether extract, like the total nitrogen, comes in part from the fat residues of the food, and is derived in part from the secretions and débris of the alimentary tract. It is also certain that the bacteria of the stools contribute a not inconsiderable portion. That a certain amount of the ether extract is derived from the intestinal secretions, etc., is shown by analyses of the stools of fasting individuals. Thus Müller found in the fæces of Cetti and Breithaupt, during their fasts, 1·21 grams and 0·57 gram, or 35·46 per cent and 28·42 per cent of the dry weight of the stools, respectively. On the average it has been found that when no food is taken about 0·79 gram of ether-soluble material is passed in the fæces. The greater part of this appears to come from the lesser bowel and its digestive secretions, the bile and pancreatic juice, for Kobert and Koch, who experimented with a patient who had an artificial anus at the commencement of the ascending colon, washed out daily from the large intestine an average of 0·97 gram of dry substance containing from 6·8 to 9·3 per cent of fat, which would correspond to a yield of about 0·09 gram of fat daily from the large intestine itself, and leave 0·7 gram to be derived from the small intestine in a fasting person. The amount of fatty material contributed to the stools by the intestine is increased by the ingestion of food, apart from the fat-content of the latter, as might be expected. Thus Rübner found from 3·1 to 6·5 per cent of ether extract in the fæces when a fat-free diet, consisting of bread and dumpling, was taken.

The ether extract contributed by the fat of the food is dependent upon several factors, and of these the most important are (*a*) the quantity ingested, (*b*) its digestibility, (*c*) its melting-point. We have just seen that with a fat-free diet the fæces may contain as much as 6·5 per cent of ether extract, and it is therefore not surprising to find that when the food contains only a small quantity of fat, more may be found in the fæces than has been taken by the mouth. Thus Malfatti, from the ether extract of the fæces of an individual on a diet of pulse containing 4·06 grams of fat, recovered 4·51 grams of ether extract, and Hosslin obtained 1·71 grams from the stools when the food only contained 1·2 grams of fat. The fat contained in the fæces is no doubt derived in such cases largely from the intestinal secretions and débris, etc. As the fat in the diet is increased, a relatively smaller proportion appears in the stools. Von Noorden found, for example, that when a diet containing 4·2 grams of fat was taken, 57·1 per cent of it could be recovered from the fæces; with an increase of the fat in the food to 42·2 grams, 10·9 per cent was passed unutilized; and when the fat taken by the mouth was still further increased to 80·2 grams, only 6·36 per cent reappeared in the stools. According to Rübner, the assimilation limit for fat reaches its maximum when 350 grams of fat, in the shape of butter, are taken daily; beyond that, the proportion excreted in the fæces steadily increases with the amount ingested. While it is obvious from these results, that estimations of the total ether extract of the fæces cannot be relied upon as an indication of the extent to which the fat in the food is being utilized when the diet is poor in this substance, owing to the masking effect of the ether extractives contributed by the intestine and its secretions, it is generally assumed that when a diet containing an average quantity of fat is taken, the amount of ether extract contributed by the body itself is fairly constant, and that the fat content of the fæces then shown by analysis is an index of the extent to which the fat of the food has been absorbed.

The digestibility of the fat of the food depends upon the form in which it is taken and also upon its melting-point. Large masses of imperfectly cooked and masticated fatty material enclosed in fibrous or cellulose envelopes cannot, obviously, be as readily dealt with and absorbed by the alimentary tract as finely divided or emulsified fats, so that they are more likely to pass through the intestine, and appearing in the fæces add to the amount of ether extract. Thus Gaultier states that when 96 grams of fat in the form of meat and bacon were taken, 17·2 grams (17·4 per cent) appeared in the fæces, but with 95·1 grams of fat in the form of milk only 3·0 grams (3·3 per cent) could be recovered from the stools. The ease with which different fats are absorbed is roughly in inverse ratio to their melting-points, those with a melting-point approximating to the temperature of the body being most readily absorbed. Thus stearin, with a melting-point of about 60° C., is only utilized with difficulty, from 86 to 91 per cent re-appearing in the stools, whereas olive oil, which is fluid at the temperature of the body, when taken in moderate quantities, is all absorbed except about 2 to 3 per cent. When a mixture of fats is taken, those of low melting-point are more completely absorbed than those which melt at a higher temperature; hence the latter appear in the fæces in larger proportion, thus explaining the higher average melting-point (50 to 51·5° C.) of the fat in the stools as compared with the fat of the food. According to F. Müller the difference is usually about 8·5° C. If, however, fat absorption is interfered with, the lower melting-point fats appear in the stools and the melting-point of the fæcal fat is lowered, approaching that of the food fat. According to v. Jaksch, the fat of acholic stools melts at 46° to 48° C., and it is usually considered that a melting-point under 50° C. is pathological. Knöpfelmacher states that the fat in the fæces of children under one year of age with good absorption melts at 46° to 48° C. normally, both in breast-fed and artificially reared infants; but according to Hecht, cow's milk fæces have generally a higher melting-point than breast-fed stools, the difference between the fæcal and food fat varying between 4° and 8° C. The fæcal fat of a healthy child eleven years of age with good fat absorption was found by Knöpfelmacher to be 48·5° C. Under pathological conditions with defective fat absorption the melting-point of the fæcal fat is lowered in children as in adults.

Individual variations exist in the amount of fatty material contributed to the fæces by the intestinal secretions, etc., and also in the extent to which the same fat is made use of. The former is exemplified in the fat content of the fæces found in Cetti and Breithaupt. The latter has been shown by the experiments of Hultgren and Landergren, who found that different persons taking the same amount of margarine passed from 4·5 to 7·7 per cent in their stools, while with butter, differences as wide as 2·7 per cent and 6·3 per cent were met with.

Analyses of meconium show a higher percentage of fat than the fæces of starving individuals, although there is apparently considerable variation. Thus Voit found 8·24 per cent and Zweifel 3·86 per cent. This is probably to be explained by difference in the quantity of vernix caseosa swallowed by the child. The stools of healthy breast-fed infants contain from 10 to 20 per cent of fat calculated on the dry weight of the fæces, while the percentage of fat in the motions of children fed on cow's milk varies from 14 to 23·8 per cent of the dry weight. During the first week or so of life, much higher percentages—40 per cent for breast milk and 50 per cent for cow's milk—may, according to Blauberg, be found. Not only is the percentage higher in artificially-fed children than in those who receive their natural food, but the absolute quantity of fat lost in the stools of the former is further increased by more bulky motions being passed. Uffelmann has calculated that 0·8 to 0·9 gram of fat is excreted daily on a diet of cow's milk, while only 0·44 gram is lost when breast milk is taken. On the average it may be taken that healthy infants over one year of age absorb from 93 to 94·1 per cent of the fat of a milk diet.

With adults on an entirely milk diet, from 93 to 97 per cent of the fat is absorbed, the average, according to Schmidt and Strasburger, being 93·93 per cent. These observers found from 1·5 to 7·5 grams of fat in the fæces daily, the exact amount depending on the amount of milk taken. As the quantity of milk is increased, there is a tendency for the amount of fat in the fæces to increase also. Harley and Goodbody, for example, found an average of 2·18 grams of fat in the stools when 4 pints of milk were consumed, 2·95 grams when 4½ pints were taken, and 5·13 grams when 5 pints of milk a day were given. According to these observers, the absorption of fat on Schmidt's test diet closely resembles that found with a milk diet, an average of 4·26 grams of fat a day being recovered from the fæces, with a minimum of 2·12 grams and a maximum of 6·47 grams, thus showing an average absorption of 96·15 per cent, with a minimum of 94·63 per cent and a maximum of 97·55 per cent. The fat content of the fæces of healthy adults on a mixed diet is dependent upon so many circumstances that no definite rules can be laid down. On the average it would seem that about 95 per cent of the ingested fat is absorbed, and that from 1 to 6 grams of fat, with an average of about 3 grams, appear in the stools. As a rule, from 10 to 20 per cent of the dry weight of the fæces consists of ether-extractable material, and anything over 25 per cent can certainly be regarded as pathological, unless large quantities of fat, and particularly fats of a high melting-point, have been taken. It must be remembered that the administration of liquid paraffin increases the ether extract of the stools to a very large extent, and its use should therefore be discontinued for at least three or four days before a sample is collected for analysis.

An excess of total fat in the fæces may arise from disease of the stomach interfering with the proper digestion of the fibrous-tissue septa holding the fat cells together in animal tissues; from absence or a diminished flow of pancreatic juice, so that the fat is not digested and prepared for absorption in the usual way; from lack of bile, with consequent imperfect absorption; and from disease of the intestinal mucous membrane or obstruction of the lymphatics, which prevents absorption and distribution by the usual channels. According to some authors, a purely functional disturbance of fat digestion may occur and give rise to an excess of fat in the fæces. Garrod has recently described what appears to be a case of congenital family steatorrhœa. In some instances the fatty condition of the stools is obvious to the naked eye, for they are seen to consist largely of masses of liquid fat, which are either passed independently, or separate out on standing to form a crust on the surface. In others the fat is more solid in consistency, and being intimately mixed with fæces gives to them a white appearance, and although not distinguishable by the naked eye, fat globules and fatty-acid crystals are seen in abundance on microscopical examination. An excess of fat may, however, be present without there being any decided alteration in either the macroscopical or microscopical characters of the fæces, and it is only by making a quantitative chemical analysis that its existence can be proved.

The highest percentage of total fat is met with in cases where there is complete obstruction of the bile and pancreatic ducts, and is most commonly due to cancer of the head of the pancreas (*see Tables, p.* 275). In cases of this description, the fat may form over 90 per cent of the dry weight of the stools, and rarely falls below 40 per cent, except in the early stages before deep jaundice has developed. The average amount of total fat in the fæces of the cases of cancer of the head of the pancreas that I have examined, has been 70 per cent. Chronic pancreatitis associated with obstruction of the common bile-duct, whether dependent upon impacted gall-stones or pressure of the swollen head of the pancreas on the duct, appears in severe cases to interfere with fat digestion and absorption almost as much as malignant disease, for 70 to 80 per cent of fat may be found in the fæces, although such high readings are not common, and on the average I have found about 56 per cent of fat in chronic pancreatitis with jaundice. That the high proportion of fat met with in some of these cases is not entirely due to the absence of bile, is shown by the fact that as great an excess may be met with in others in which no obstruction to the free flow of bile into the intestine exists. I have met with as much as 76 per cent of fat in the fæces in cases of advanced cirrhosis of the pancreas where there was no discoloration of the skin and no bile pigment was present in the urine. In the early stages of pancreatitis, on the other hand, an abnormally low percentage of total fat—4 to 5 per cent in some of my cases—is not uncommonly met with, especially when the condition is associated with hyperchlorhydria. This is probably to be explained by an excessive flow of pancreatic juice analogous to the salivation seen in parotitis. The fat content of the stools in other diseases of the pancreas, such as cysts, calculi, cancer of the body or tail, and in the various stages of chronic inflammation and cirrhosis, varies according to the extent of the lesion and degree to which the functions of the gland are interfered with, ranging from the subnormal percentage of early inflammatory affections to the high proportions met with in cases where the parenchyma of the organ has been completely destroyed or the entrance of its secretion into the intestine is entirely prevented. Such variations no doubt account for the widely divergent results published by many observers who have only had the opportunity of examining the stools in a limited number of cases.

We do not yet know sufficient about the effect of purely functional disturbances of the pancreas upon the fat content of the fæces to draw any conclusions of value. I have examined the stools from two cases of pancreatic infantilism, and in one found 23·3 per cent of total fat, and in the other 32 per cent.

Garrod's case of congenital family steatorrhœa, which, however, showed no signs of infantilism or evidence of organic disease of the pancreas, passed 83 per cent of total fat according to an analysis by my method which I was kindly permitted to make, and from about 89 to 76, with an average of about 80 per cent, according to Hurtley's analyses. The utilization of fats in pancreatic disease varies as widely as the percentage of fat in the stools. A loss of 50 per cent of the ingested fat is not uncommon in serious cases, and when there is an associated obstruction of the bile-duct, 80 or 90 per cent of the fat taken may be passed in the stools. Gross has recently published an interesting case of pancreatic disease in which it was found that with a diet containing 750 grams of fat a day, 55·4 per cent was passed in the stool, and that when the intake was reduced to 168 grams a day 52·4 per cent was still excreted unutilized.

In the majority of cases where the free flow of bile into the intestine is interfered with, there is also some pancreatic disease, so that the excess of fat met with is due to a combination of the two causes. In some 30 to 35 per cent of cases of gall-stones, however, there appears to be no involvement of the pancreas, probably because in about that proportion of instances the common bile-duct passes behind and free from the gland, and in such the total fat of the fæces rarely exceeds about 55 per cent, although I have occasionally met with as much as 80 per cent; the exact amount depends upon the quantity of bile that is still reaching the intestine. Cancer of the gall-bladder involving the common bile-duct, and growths of the supra-pancreatic portions of the duct itself, giving rise to jaundice, are usually associated with a high proportion of fat in the stools, quite as great an excess being often met with as in cancer of the head of the pancreas. When these growths invade the pancreas, there is sometimes, but not always, more fat than in simple cases. According to Müller, from 55·2 to 78·5 per cent of the fat in the food is not utilized in jaundice when the patient is on a diet consisting largely of milk, while Schmidt found only 25·9 per cent of the fat contained in his test diet was passed in the fæces by jaundiced patients. According to Brugsch, obstruction of the bile-ducts alone may entail a loss of 45 per cent of the ingested fat, but he considers that when this figure is exceeded implication of the pancreas is probable.

The excess of fat in the fæces due to defective absorptive power from disease of the intestine, such as atrophy, amyloid disease, or tuberculosis of the mucous membrane, and especially the occlusion of many lymph-channels, such as results from caseation of the lymphatic glands in tabes mesenterica and chronic tuberculous peritonitis, varies considerably in amount, according to the extent of the disease. Thus, in one case of intestinal tuberculosis I found 33·1 per cent of the dry weight of the fæces consisted of fat, but in another 61·3 per cent was present, and in neither was there any evidence of pancreatic disease. In a case with secondary deposits in the pancreas, I found 80·5 per cent of fat. The steatorrhœa met with in sprue is no doubt in part due to defective absorption by the diseased intestinal mucous membrane. In uncomplicated cases I have found from 34·3 to 57·7 per cent of total fat in the fæces, but in others the fat has constituted from 70 to 80 per cent of the dry weight; but it is probable that in most of the latter there was also some cirrhosis of the pancreas. Schmidt and Strasburger, in two cases of defective absorption from intestinal disease, found 30·48 and 34·15 per cent of fat in the fæces, representing 13·15 per cent and 21·11 per cent respectively of the fat contained in the food. F. Müller has reported a case of lardaceous disease of the intestine in which the fæces contained 28·6 per cent of fat, corresponding to 32·9 per cent of the total intake.

Intestinal disorders associated with excessive peristalsis and diarrhœa increase the total fat in the stools, although not necessarily the percentage, while in chronic constipation the total fat is diminished, but the percentage often works out at about the normal average or even a little higher. An excess of fat in the fæces dependent upon disease of the stomach is usually associated with achlorhydria, the absence of hydrochloric acid preventing the digestion of the connective tissue enclosing the fat. It is therefore accompanied by the presence of undigested white fibrous tissue in the fæces. Cases of this description have been recorded by Brink.

The fat content of the fæces of infants is normally higher than in adults, and very slight disturbances of health are liable to be associated with the appearance of an excess of fat in the stools, even when there are no distinctly digestive symptoms. Thus, during dentition 37 to 40 per cent of fat may, according to Uffelmann, be met with in the fæces. When disturbances of digestion occur, the fæces may often contain from 30 to 40 or even 50 per cent of fat (Racynski, Tschernoff, Forster, etc.), giving rise to what Biedert has described as "fatty diarrhœa." In some of these it is probable that the high percentage of fat is dependent upon defective action of the pancreas. Walliczek has investigated the fæces in icterus neonatorum, and found in 12 cases an average of 37·8 per cent of fat, as compared with 20·7 per cent in three normal infants of the same age.

Although estimations of the total ether extract of the stools give useful information as to the extent to which the fat of the food is being utilized, and may sometimes be of assistance in diagnosis when taken in conjunction with other signs and symptoms, they do not enable us to distinguish between a number of pathological conditions which clinically have much in common. A high percentage of fat, or even an excessive total excretion, may arise from so many causes, that considered by themselves such determinations are only of secondary importance. The relations existing between the different forms of fat throw far more light on the nature and extent of any disturbances of fat digestion and absorption that may exist, and their determination is therefore of greater diagnostic value.

2. **Determination of the Neutral Fat, Free Fatty Acids, and Soaps.**—The separation and estimation of these forms of fat in the fæces depends in principle upon the solubility of the neutral fats and free fatty acids in ether, and the insolubility of the combined fatty acids or soaps until the latter have been split into their constituents by the action of an acid.

A weighed quantity of the fæces, which have been dried to a constant weight, if necessary with the addition of alcohol but without any added sulphuric acid, is extracted with ether in a Soxhlet apparatus continuously for forty-eight hours. After the completion of the extraction the ether is evaporated off, the flask containing the ether extract is heated in a steam oven for an hour, cooled, and weighed. This extract (*A*) gives the weight of the neutral fats and free fatty acids contained in the weight of fæces taken. If the extraction thimble is allowed to stand in the air until the smell of ether has disappeared, and is then dried and weighed, this weight, plus the weight of the extract and less the weight of the thimble, will give the weight of the quantity of dry fæces used for the extraction, and may therefore be used as a check on this, or may replace the original weighing process if desired. The residue from the thimble is now transferred to a porcelain dish and thoroughly ground up with a dilute watery or alcoholic solution of hydrochloric acid. The mixture is tested to see that it is strongly acid, and then evaporated to dryness on a boiling water-bath. The perfectly dry residue is now transferred to the thimble from which it came, and extracted in a Soxhlet apparatus with ether continuously for twenty-four hours. The ether is then distilled off, the flask is heated in a steam oven, cooled, and weighed as before. This ether extract (*B*) contains the fatty acids present as soaps. The volatile fatty acids in the first extract (*A*) may now be estimated by washing with hot water, filtering, washing the residue on the filter, first with hot water and then with ether, adding the ether to the residue in the flask, drying, and weighing the latter after the ether has been evaporated off. The non-volatile fatty acids are then determined by dissolving the residue in the flask in a considerable excess of absolute alcohol, or a mixture of alcohol and ether, and titrating with a decinormal solution of alcoholic potash, using phenolphthalein as the indicator. Since 1 c.c. of decinormal potash corresponds to ·0284 gram of stearic acid, the weight of the fatty acids present can be calculated in terms of stearic acid by multiplying the number of cubic centimetres of decinormal soda used by ·0284. The difference between this result and the weight of the ether extract previously determined, will give the weight of the neutral fat and any lipoids that may be present. The amount of the latter is so small, that for practical purposes it may be neglected and the value obtained taken as being that of the neutral fat. If it is considered necessary to estimate the cholesterin separately, the solution with which the titration was carried out is evaporated to dryness and warmed with alcoholic potash. The amount of lecithin is then estimated from the phosphoric acid content of the ash, in the manner previously described (*p.* 258). The weight of the saponified fatty acid in the second extract (*B*) can be checked by dissolving the dried residue in alcohol and titrating with decinormal alcoholic potash, and then expressing the result in terms of stearic acid in the way employed for the estimation of the non-volatile fatty acids in the extract (*A*). As a rule, it will be found that the figures obtained by weighing and titration agree fairly closely, but those given by the latter method are to be preferred.

The neutral fats and fatty acids in the ether extract (*A*) may also be estimated by Hoppe-Seyler's method. The extract is dissolved in ether, and shaken with an excess of dilute sodium carbonate solution. The mixture is then placed in a separating funnel and left to stand for a few hours. The watery solution is separated and well shaken with ether, which is again separated. The two ether extracts are now combined, evaporated to dryness, cooled, and weighed. The result gives the weight of the neutral fat (and lipoids), while the difference between this and the original weight of the dry ether extract (*A*) gives the weight of the free fatty acids.

These methods, like the similar processes for estimating the total ether extract of the stools, necessarily occupy much more time than can usually be given to clinical investigations, so that, although they are essential for the accurate results necessary for research work, I usually employ the following much more rapid process for routine investigations.

About 0·5 gram of the dried fæces is weighed out and introduced into the lower bulb of a Schmidt-Werner milk tube as described for the rapid estimation of the total fat. Ten c.c. of distilled water are then added, and the tube is heated for a quarter of an hour in a boiling water-bath, occasionally rotating it to well mix its contents. After being cooled, the tube is filled up to the 50 c.c. mark with ether, and the consequent steps of the process carried out as for the estimation of the total fat; in fact the two experiments are usually carried out side by side, the tubes being labelled *A* and *B* respectively. The ether extract of the *A* tube, the contents of which have been heated with dilute hydrochloric acid, gives the total fat; the ether extract of the *B* tube, in which water only was used, gives the sum of the neutral fats and free fatty acids, and for convenience of reference I generally speak of the latter as the "unsaponified," or better, "unsoaped," fats, while the difference between the two gives the combined fatty acids or soaps. To determine the relation between the neutral fats and free fatty acids, the ether extract from the *B* tube is dissolved in an excess of ether (about 20 c.c.), a few drops of an alcoholic solution of phenolphthalein are added, and it is then titrated with decinormal alcoholic soda. The number of cubic centimetres used to neutralize the solution multiplied by 0·0284 grams, gives the weight of free fatty acids contained in the quantity of dry fæces originally used, and the difference between this and the weight of the ether extract gives the quantity of neutral fat (and lipoids).

The whole process can be carried out in the space of an hour or so after the fæces have been dried down, and if only sufficient of the mixed moist stool to yield a couple of grams of dry material are employed, the whole of the estimations may be made from beginning to end in six or eight hours, most of the time being occupied by drying of the fæces to a constant weight and waiting for the ether extracts to clear.

The solid residue from the *B* tube may be used for the detection of hydrobilirubin or blood, after it has been separated from the ether and water by filtration.

To detect *hydrobilirubin*, the solid on the filter-paper is extracted with acid alcohol (hydrochloric 2 c.c., alcohol 89 c.c.), the acid in the filtrate neutralized with dilute ammonia, and an equal volume of a saturated solution of zinc acetate in alcohol, added. The precipitate that forms is removed by filtration, and the clear filtrate examined against a black background for the green fluorescence that indicates the presence of hydrobilirubin. The intensity of the colour varies with the amount of pigment present, so that, by always using approximately the same quantities of fæces and of the reagents, any marked variation from the normal can be readily seen.

To detect *blood*, the residue on the filter-paper is mixed with 10 c.c. of pure ether and 3 or 4 c.c. of glacial acetic acid, well shaken, and allowed to stand for a quarter of an hour. The ether extract is then poured off and tested by Rossel's aloin test, Weber's guaiac test or the benzidin test. I usually carry out the benzidin test with the fresh, boiled, fæces, as described on *p.* 182, and then confirm this with the aloin test, employing the acid ether extract prepared as above.

Considerable variations occur in the percentage of the fatty constituents of the fæces, even in health, but on the average a normal adult, taking an ordinary mixed diet gives figures which lie between the following extremes :—

Total fat	..	15–25 per cent of the dry weight.
"Unsoaped" fat	..	10–15 ,, ,, ,,
Neutral fat	..	1–2 ,, ,, ,,
Free fatty acids	..	9–13 ,, ,, ,,
Combined fatty acids		10–15 ,, ,, ,,

Far more important than the actual percentages are the ratios existing between the different forms. In health it is usually found that the " unsoaped " fats and combined fatty acids are approximately equal, while the neutral fats bear a relation to the free fatty acids of about 1 to 10. Any marked deviation from these proportions is an indication of the existence of some abnormality of fat digestion or absorption.

The process of saponification is not as completely carried out by infants as by adults. Thus Blauberg, in the fæces of children six to seven days old, found 26 to 37 per cent of ether extract (i.e., neutral fats and fatty acids) and 4·8 to 5·86 per cent of soap when they had been fed on mother's milk, and 32·65 to 43·3 per cent of ether extract and 1·37 to 1·05 per cent of soap when fed on cow's milk. From this it will be seen that during the first weeks of life the fæces are rich in unsoaped fat, and only contain small quantities of combined fatty acids. It will also be noticed that the fæces of the children fed on cow's milk contained less of the latter than those brought up on the breast. With increasing age, the proportion of unsoaped fats diminishes, and there is a corresponding rise in the combined fatty acids until the adult proportion is reached.

Since the pancreatic lipase plays such an important part in the digestion of fats, we should expect to find that when the functions of the pancreas are interfered with, the process of saponification will be more or less seriously impaired, and that an excess of neutral fats will make its appearance in the stools. Analyses by Abelmann of the fæces of dogs in which the pancreas had been extirpated did not confirm this expectation, for they showed that 30 to 85 per cent of the non-emulsified fats of the food, had undergone cleavage into fatty acids and soaps. Katz, who carried out similar experiments, found, however, that there was " a surprising diminution " in the cleavage of fats, 51·53 per cent of neutral fat, 46·94 per cent of fatty acids, and only 2·33 per cent of soap, being present in the fæces of an animal in which the pancreas had been partly extirpated and the main excretory duct tied. Tying and resection of the pancreatic duct, or conducting the secretion of the duct to the surface of the body through a fistula, was found by Gaultier to result in a reduction of the saponified fats to between 11·1 and 23·8 per cent; and of this 7·4 to 15·3 per cent consisted of free fatty acids, and 3·7 to 8·5 per cent of combined fatty acids or soaps, with an increase in the neutral fats to between 77·6 and 87·2 per cent.

The diagnostic value of a determination of the proportion of fat in the fæces which has undergone cleavage was first insisted on by F. Müller in 1887. He investigated three cases of obstruction of the duct of Wirsung, associated with degeneration of the pancreas, and found that although the total quantity of fat absorbed was not far from the normal, the cleavage of fat in the intestine was very considerably diminished, for only 39·8 per cent of the fat in the stools was found to have been split into fatty acids and soaps, instead of the normal of about 84 per cent. Similar results were obtained by Katz, who analyzed the fæces from a series of cases of pancreatic disease. He came to the conclusion that disease of the pancreas is to be suspected when less than 70 per cent of the fat in the stools is present in the form of fatty acids and soaps, provided that the patient is not an infant and is not suffering from profuse diarrhœa. Katz also states that sudden occlusion of the pancreatic duct inhibits the splitting of fats more effectually than a more gradual cutting off of the pancreatic secretion. Other observers, including Weintraud and Pribram, have published investigations bearing out these conclusions. Deucher, on the other hand, found no excess of neutral fat, but a very high proportion of free fatty acids, in the fæces of two cases of carcinoma of the head of the pancreas in which an excess of total ether extract, amounting in one instance to 80 per cent of the ingested fat, was present. Brugsch also found an excess of free fatty acids and a low proportion of neutral fats and soaps, in cases of cancer of the pancreas. Vaughan, Harley, and Gross have reported similar observations in cases of pancreatic steatorrhœa. Zoja attaches most importance to a scantiness of combined fatty acids in the fæces as evidence of disease of the pancreas. That a mere excess of neutral fat does not by itself justify a diagnosis of pancreatic disease is shown by a case described by Whipple. After death, the pancreas was found to be quite normal, but during life fæces containing 80 per cent of the dry weight as fat, and 62·5 per cent as neutral fat, were passed.

According to Müller and most other observers, occlusion of the bile-ducts, provided that the functions of the pancreas are not interfered with, does not bring about any change in the fat-splitting processes in the intestine, although there is defective absorption and a consequent increase in the total fat of the stools. In fact, Müller attributes the steatorrhœa seen in cases of cancer of the head of the pancreas and similar conditions, where the bile-flow is interfered with, entirely to the absence of bile. Gaultier found, however, that suppression of the bile gave rise to the appearance of about 63 per cent of neutral fat, 21 per cent of fatty acids, and 12 per cent of soap in the fæces, the neutral fats varying from 60 to 65 per cent. According to Schmidt and Strasburger, an average of 66·84 per cent of the fat in the fæces in cases of jaundice is in the saponified condition, the extremes being 46·45 per cent and 85 per cent. Hecht found 47·9 per cent of fat in the stools in congenital icterus, and of this 50·8 per cent was unsaponified.

The relation of the unsplit to the split fats, and of the free to the combined fatty acids, in the fæces of cases where both the pancreatic secretion and the flow of bile are interfered with, depends largely upon the extent and relative completeness of the two conditions. But other factors have also to be taken into account in this as well as in other disorders where the fat relations of the stools are abnormal. The distribution and activity of the intestinal flora no doubt influence the proportion of saponified and unsaponified fat in the fæces. Owing to the defensive mechanism of the stomach juices, and the rapid passage of the chyme through the upper part of the intestine in a healthy person, comparatively few bacteria are met with until within a foot or two of the colon. In this region and in the large intestine, the number and variety of the bacteria present rapidly increase, so that owing to the activity of bacteria of the colon group a certain amount of fat-splitting normally goes on. Delay of the intestinal contents in this part of the bowel may therefore result in an excessive saponification and absorption of fats, such as is seen in some cases of constipation. If, on the other hand, the intestinal contents are hurried through both the small and large intestine, resulting in profuse diarrhœa, the fats may not only escape complete pancreatic digestion in the small intestine, but may also not undergo the cleavage usually brought about by bacteria in the colon, and the stools may therefore contain an excess of unsaponified fat. In less acute and chronic intestinal catarrhs, etc., the altered state of the secretions allows an ascent of micro-organisms above the level of their normal habitat when, owing to their increased number and greater opportunity for bringing about chemical changes, and probably also to an alteration in their chemical activities, the saponification of fats is carried out more energetically than usual.

We should then expect to find a high proportion of free and combined fatty acids relative to neutral fats, the relation between the free acids and soaps depending upon the amount of alkaline bases furnished by the intestinal secretions for the acids to combine with. Meyer has shown that in acute intestinal disturbances in children, about half the total fat of the stools is in the form of free fatty acids, with only very small quantities of soaps, whereas Keller has found that in the more chronic conditions, free fatty acids occur in insignificant quantities, and that the bulk of the saponified fat is in the form of soaps.

The results of my own observations with regard to the fat content of the fæces in 700 cases in which it has been possible to check the analyses, are summarized in the tables on *pp.* 273–276. The cases are divided into two groups, an earlier series (*A*) in which the total ether extract and the percentages of unsoaped fat and combined fatty acids only were estimated, and a later smaller series (*B*) in which the proportions of neutral fat and free fatty acids were also determined. In each series the cases are classified in groups, so that the effects of disease of the pancreas, jaundice, and a conjunction of these two conditions, may be seen. Since much of the divergence of opinion among different authors as to the diagnostic value of variations in the percentages of neutral fat, fatty acids, and soaps in pancreatic diseases, etc., is, I believe, due to insufficient attention being devoted to the associated pathological conditions, I have arranged the cases in each group so that the primary cause of the pancreatic disturbance, jaundice, etc., can be seen. Although in some instances the number of examples quoted is too small for any reliable conclusions to be drawn, in others it is probable that the average results represent what may be usually expected under like conditions.

Considering first the relation of the " unsoaped " fat (neutral fat and free fatty acids) to combined fatty acids, it will be seen that the effect of interference with the functions of the pancreas has been as a rule to increase the proportion of unsoaped fats, while obstruction of the bile flow and intestinal catarrhs have tended to raise the percentage of combined fatty acids. The influence of disease of the pancreas in this direction is well seen in both series of cirrhosis of the gland, for in the eight cases comprised in the first series and in 90 per cent of those in the second series, the unsoaped fats were in excess. Again, in the case where a pancreatic cyst was present, it will be seen that, although the total fat was not high (20·5 per cent), nearly three-quarters of this (15 per cent) was in the unsoaped condition, and only about a quarter (5·5 per cent) in the form of combined fatty acids. On the other hand, in a case of simple stricture of the common bile-duct, I found 52·1 per cent of the dry weight of the fæces consisted of soaps, and only 27·8 per cent of neutral fats and free fatty acids. Sixteen cases of simple obstruction of the common bile-duct by gall-stones with no associated pancreatitis, showed an average of 21·7 per cent of unsoaped fat to 33·1 per cent of combined fatty acids. The latter were in excess of the former in all but four, and in these the jaundice was not marked and the difference was slight.

Simple uncomplicated cases of pancreatic disease or jaundice are, *Series A*, GROUP I. PANCREATIC DISEASE—NO JAUNDICE.

	No. of cases	Total Fat per cent	"Unsoaped" Fat per cent	Combined Fatty Acids (Soap) per cent	"Unsoaped" Fat More than Soaps	"Unsoaped" Fat Less than Soaps
1 Stones in common bile-duct	25	36·5 (71·3–16·0)	19·5 (51·0–4·5)	17·0 (37·9–0·3)	56%	44%
2 Stones in gall-bladder	11	27·1 (44·0–16·2)	14·7 (22·4–4·3)	12·4 (21·2–2·6)	54%	46%
3 Intestinal catarrh	83	28·8 (79·9–6·5)	12·5 (45·7–1·0)	16·3 (38·2–1·3)	30%	70%
4 Ulcer, duodenum . .	15	30·5 (48·0–7·2)	14·7 (26·4–1·0)	15·8 (28·2–6·2)	46%	54%
5 Ulcer, stomach . .	3	27·6 (47·2–7·5)	16·6 (20·2–5·4)	11·0 (27·2–4·1)	33%	67%
6 Sprue	8	57·0 (76·1–39·8)	31·0 (42·4–7·4)	26·0 (34·0–16·6)	50%	50%
7 Pernicious anæmia	2	48·1 (50·4–45·8)	19·0 (9·4–8·6)	39·1 (41·8–36·5)	—	100%
8 Tuberculous enteritis	1	60·5	40·2	20·3	100%	—
9 Cirrhosis of liver and pancreas	9	39·0 (68·0–12·6)	22·9 (36·2–3·4)	16·1 (34·0–4·5)	89%	11%
10 Cirrhosis of pancreas	8	36·2 (61·2–15·3)	22·6 (44·1–11·7)	13·6 (27·0–3·5)	100%	—
11 Arteriosclerosis . .	8	27·1 (53·8–15·1)	14·9 (50·8–0·5)	12·2 (34·1–3·0)	50%	50%
12 Heart disease .	4	19·1 (25·7–11·7)	10·7 (16·7–6·1)	8·4 (15·7–4·1)	75%	25%
13 Chronic pancreatitis	47	28·3 (72·2–18·0)	16·3 (52·0–2·2)	12 (29·3–0·5)	49%	51%
14 Cyst of pancreas . .	1	20·5	15·0	5·5	100%	—
15 Pancreatic infantilism	1	57·4	48·5	8·9	100%	—

Series A, Group II. Jaundice—No Pancreatic Disease.

	No. of Cases	Total Fat per cent	"Unsoaped" Fat per cent	Combined Fatty Acids (Soap) per cent	"Unsoaped" Fat More than Soaps	"Unsoaped" Fat Less than Soaps
1 Stones in common bile-duct	16	54·8 (81·3–25·7)	21·7 (46·3–10·0)	33·1 (54·1–8·2)	25%	75%
2 Growth of bile-duct	5	74·6 (90·4–65·0)	30·7 (37·1–30·0)	44·0 (57·5–32·0)	—	100%
3 Simple stricture of common bile-duct	1	79·9	27·8	52·1	—	100%
4 Catarrhal jaundice	2	31·9 (32·9–31·0)	11·3 (11·6–11·0)	20·6 (21·3–20·0)	—	100%
5 Growth of gall-bladder	2	25·6 (27·3–23·9)	12·4 (13·5–11·3)	13·2 (14·8–12·6)	—	100%

Series A, Group III. Pancreatic Disease with Jaundice.

	No. of Cases	Total Fat per cent	"Unsoaped" Fat per cent	Combined Fatty Acids (Soap) per cent	"Unsoaped" Fat More than Soaps	"Unsoaped" Fat Less than Soaps
1 Stones in common bile-duct	51	56·6 (87·2–15·8)	30·2 (59·8–5·5)	26·4 (55·8–2·3)	57%	43%
2 Growth of common bile-duct	2	49·5 (72·7–26·2)	29·6 (33·2–25·9)	19·9 (39·5–0·3)	50%	50%
3 Growth of ampulla of Vater	1	65·7	35·1	30·6	100%	—
4 "Catarrhal jaundice"	24	45·0 (62·9–9·2)	27·0 (69·7–3·7)	18·0 (42·7–1·8)	58%	42%
5 Growth of pancreas secondary to gall-bladder	4	55·4 (66·3–39·6)	38·2 (52·7–30·1)	17·2 (30·0–7·8)	100%	—
6 Growth of pancreas secondary to stomach	8	34·0 (63·7–19·2)	12·3 (31·6–5·6)	21·7 (41·1–4·3)	37%	63%
7 Growth of pancreas secondary to intestine	6	26·2 (39·8–12·7)	10·5 (13·3–6·6)	15·7 (27·6–6·1)	33%	67%
8 Secondary growth of pancreas, primary elsewhere	4	33·3 (39·6–12·7)	20·7 (23·1–14·9)	12·6 (18·1–7·0)	75%	25%
9 Cancer of pancreas	38	71·3 (93·3–22·3)	41·0 (69·0–7·0)	30·3 (63·8–3·6)	57%	43%

Series A, Group IV. No Pancreatic Disease—No Jaundice.

	No. of Cases	Total Fat per cent	"Unsoaped" Fat per cent	Combined Fatty Acids (Soap) per cent	"Unsoaped" Fat More than Soaps	"Unsoaped" Fat Less than Soaps
1 Stones in common bile-duct	9	33·2 (62·3–21·2)	15·3 (34·0–3·5)	17·9 (38·8–3·8)	44%	56%
2 Stones, gall-bladder or cystic duct	23	32·1 (79·9–11·6)	15·4 (27·8–4·4)	16·7 (52·1–0·5)	47%	53%
3 Intestinal catarrh	18	25·3 (39·5–13·8)	8·1 (13·3–2·0)	17·2 (34·2–9·8)	5%	95%
4 Ulcer, duodenum	6	26·4 (36·8–14·0)	7·8 (11·3–2·9)	18·6 (27·2–8·8)	—	100%
5 Ulcer, stomach ..	13	20·6 (27·9–16·8)	8·1 (12·2–4·2)	12·5 (15·7–8·9)	—	100%
6 Sprue	5	48·8 (57·7–34·3)	25·5 (26·7–11·7)	23·3 (32·0–19·0)	40%	60%
7 Pernicious anæmia	1	23·1	12·7	10·4	100%	—
8 Appendicitis ..	3	20·5 (22·1–18·6)	6·5 (7·0–5·6)	14·0 (15·3–11·0)	—	100%
9 Chronic colitis ..	30	20·9 (42·1–8·6)	5·6 (12·7–0·5)	15·3 (33·4–6·2)	—	100%
10 Tuberculous enteritis	3	39·8 (61·3–25·1)	14·9 (23·5–4·6)	24·9 (30·7–22·1)	—	100%
11 Dilated stomach ..	4	26·4 (28·5–20·4)	4·5 (6·4–2·1)	21·9 (23·6–12·4)	—	100%
12 Growth of stomach	15	25·1 (30·4–11·1)	10·0 (14·5–6·1)	15·1 (18·3–2·7)	33%	67%
13 Growth of intestine	19	30·4 (39·8–22·1)	11·5 (17·1–8·0)	18·9 (27·6–7·5)	5%	95%
14 Growth of other organs	10	25·4 (31·4–22·7)	10·8 (15·9–6·3)	14·6 (18·7–4·8)	40%	60%
15 Cirrhosis of liver ..	5	20·2 (26·6–10·5)	10·6 (13·4–5·3)	9·6 (13·2–5·2)	80%	10%
16 Infantile acholia ..	1	39·2	14·1	25·2	—	100%
17 Congenital family steatorrhœa	1	83·1	37·2	45·9	—	100%
18 Normal ..	25	20·6 (25·0–9·1)	10·2 (15·6–6·1)	10·4 (16·2–4·3)	48%	52%

Series B.

	No. of cases	Total Fat per cent	"Unsoaped" Fat per cent	Neutral Fat per cent	Free Fatty Acids per cent	Combined Fatty Acids per cent	"Unsoaped" Fat: More than Soaps	"Unsoaped" Fat: Less than Soaps	Average "Unsoaped" to Soaped Fat	Average Neutral Fat to Free Fatty Acid
Group I. Pancreatic Disease—No Jaundice.										
1 Cirrhosis of pancreas ..	20	26·5 (76·0–10·0)	16·3 (51·4–4·0)	5·1 (22·0–1·9)	11·2 (21·8–1·7)	10·2 (26·0–2·0)	90%	10%	1·6 : 1·0	1 : 2·0
2 Catarrhal pancreatitis ..	25	23·5 (54·5–7·9)	9·5 (31·3–3·0)	2·1 (5·0–1·2)	7·4 (28·4–0·9)	14·0 (23·1–9·7)	72%	28%	1·0 : 1·5	1 : 3·5
3 Pancreatic infantilism ..	1	23·3	6·0	1·1	4·9	17·3	—	100%	1·0 : 2·9	1 : 4·4
Group II. Pancreatic Disease—Jaundice.										
1 Stones in common bile-duct	36	57·1 (78·0–42·4)	26·0 (44·4–20·0)	4·3 (7·2–2·4)	22·0 (42·0–12·4)	31·0 (45·0–22·4)	25%	75%	1·0 : 1·2	1 : 5·1
2 Cancer of pancreas ..	16	64·6 (89·6–45·4)	25·1 (41·2–13·0)	3·1 (7·7–1·1)	22·0 (40·1–11·0)	39·5 (50·7–11·8)	13%	87%	1·0 : 1·5	1 : 7·1
Group III. Intestinal Diseases—No Jaundice.										
1 Chronic intestinal catarrh ..	34	29·0 (40·8–11·1)	9·8 (14·0–2·1)	0·9 (1·2–0·2)	8·9 (12·8–1·9)	19·2 (27·9–9·0)	—	100%	1·0 : 2·0	1 : 9·9
2 Acute intestinal catarrh ..	1	12·8	5·0	2·8	2·2	7·8	—	100%	1·0 : 1·5	1 : 1·3
3 Chronic colitis	18	19·6 (45·0–5·3)	6·2 (14·0–1·6)	0·5 (2·0–0·2)	5·7 (15·6–1·4)	13·4 (41·0–3·7)	—	100%	1·0 : 2·3	1 : 8·0
Group IV.										
Normal	10	21·0 (25·2–8·5)	10·0 (15·0–5·2)	1·0 (2·0–0·8)	9·0 (13·0–8·0)	11·0 (16·0–4·8)	50%	60%	1·0 : 1·0	1 : 9·0

however, comparatively rare. We have most frequently to consider the effects of the two together, or to take into account a co-existent intestinal condition with one or the other. In cancer of the pancreas, where as a rule there is complete blocking of the common bile-duct and serious interference with the functions of the pancreas, since the growth is most commonly situated in the head of the gland, the proportions of soaps and unsoaped fats vary very considerably. In my first series of 38 cases there was an excess of unsoaped fat in 57 per cent, but in the second series of 16 cases such an excess was only found in 13 per cent. This difference is, I think, to be explained by the fact that a small quantity of bile was finding its way into the intestine in a larger number of the cases of the second group than of the first, and in many of them there was evidence of abnormal putrefactive changes in the intestinal contents, so that more of the fat was being split through the agency of bacteria and a larger proportion was being turned into soap. That more efficient fat absorption was as a rule taking place in these cases is suggested by the lower average percentage of total fat. Chronic pancreatitis associated with the presence of gall-stones in the common bile-duct, and jaundice, gave an excess of unsoaped fat in 57 per cent of the cases in the first series and 45 per cent in the second. In both, very wide variations were met with, depending apparently upon the extent to which the bile-flow was interfered with and the amount of damage to the pancreas.

I have examined the fæces from seven cases of growth of the common bile-duct. In five there was no evidence of involvement of the pancreas, and in these the combined fatty acids were considerably in excess of the unsoaped fats. Of the two in which the pancreas was involved in the growth, one showed an excess of combined fatty acids and the other of unsoaped fats, but as the patient with the low percentage of unsoaped fat (·3 per cent) was on an exclusively milk diet, the results are not strictly comparable with those given by the other cases who were taking a mixed diet.

The influence of intestinal affections on the relation between the soaps and unsoaped fats of the stools is well illustrated by the cases diagnosed as "intestinal catarrh" or "enteritis," in which there was neither jaundice nor pancreatitis to complicate the issue, for in 95 per cent of these in the first series, and 100 per cent of these in the second, the combined fatty acids were present in excess. Similar results were also obtained with the fæces of patients suffering from duodenal ulcer, gastric ulcer, and appendicitis. As all these conditions are associated with a pathological state of the intestinal mucous membrane and an abnormal intestinal flora, which may

Series B.

	No. of cases	Total Fat per cent	"Unsoaped" Fat per cent	Neutral Fat per cent	Free Fatty Acids per cent	Combined Fatty Acids per cent	"Unsoaped" Fat: More than Soaps	"Unsoaped" Fat: Less than Soaps	Average "Unsoaped" to Soaped Fat	Average Neutral Fat to Free Fatty Acid
Group I. Pancreatic Disease—No Jaundice.										
1 Cirrhosis of pancreas ..	20	26·5 (76·0–10·0)	16·3 (51·4–4·0)	5·1 (22·0–1·9)	11·2 (21·8–1·7)	10·2 (26·0–2·0)	90%	10%	1·6 : 1·0	1 : 2·0
2 Catarrhal pancreatitis ..	25	23·5 (54·5–7·9)	9·5 (31·3–3·0)	2·1 (5·0–1·2)	7·4 (28·4–0·9)	14·0 (23·1–9·7)	72%	28%	1·0 : 1·5	1 : 3·5
3 Pancreatic infantilism ..	1	23·3	6·0	1·1	4·9	17·3	—	100%	1·0 : 2·9	1 : 4·4
Group II. Pancreatic Disease—Jaundice.										
1 Stones in common bile-duct	36	57·1 (78·0–42·4)	26·0 (44·4–20·0)	4·3 (7·2–2·4)	22·0 (42·0–12·4)	31·0 (45·0–22·4)	25%	75%	1·0 : 1·2	1 : 5·1
2 Cancer of pancreas ..	16	64·6 (89·6–45·4)	25·1 (41·2–13·0)	3·1 (7·7–1·1)	22·0 (40·1–11·0)	39·5 (50·7–11·8)	13%	87%	1·0 : 1·5	1 : 7·1
Group III. Intestinal Diseases—No Jaundice.										
1 Chronic intestinal catarrh ..	34	29·0 (40·8–11·1)	9·8 (14·0–2·1)	0·9 (1·2–0·2)	8·9 (12·8–1·9)	19·2 (27·9–9·0)	—	100%	1·0 : 2·0	1 : 9·9
2 Acute intestinal catarrh ..	1	12·8	5·0	2·8	2·2	7·8	—	100%	1·0 : 1·5	1 : 1·3
3 Chronic colitis	18	19·6 (45·0–5·3)	6·2 (14·0–1·6)	0·5 (2·0–0·2)	5·7 (15·6–1·4)	13·4 (41·0–3·7)	—	100%	1·0 : 2·3	1 : 8·0
Group IV.										
Normal	10	21·0 (25·2–8·5)	10·0 (15·0–5·2)	1·0 (2·0–0·8)	9·0 (13·0–8·0)	11·0 (16·0–4·8)	50%	60%	1·0 : 1·0	1 : 9·0

however, comparatively rare. We have most frequently to consider the effects of the two together, or to take into account a co-existent intestinal condition with one or the other. In cancer of the pancreas, where as a rule there is complete blocking of the common bile-duct and serious interference with the functions of the pancreas, since the growth is most commonly situated in the head of the gland, the proportions of soaps and unsoaped fats vary very considerably. In my first series of 38 cases there was an excess of unsoaped fat in 57 per cent, but in the second series of 16 cases such an excess was only found in 13 per cent. This difference is, I think, to be explained by the fact that a small quantity of bile was finding its way into the intestine in a larger number of the cases of the second group than of the first, and in many of them there was evidence of abnormal putrefactive changes in the intestinal contents, so that more of the fat was being split through the agency of bacteria and a larger proportion was being turned into soap. That more efficient fat absorption was as a rule taking place in these cases is suggested by the lower average percentage of total fat. Chronic pancreatitis associated with the presence of gall-stones in the common bile-duct, and jaundice, gave an excess of unsoaped fat in 57 per cent of the cases in the first series and 45 per cent in the second. In both, very wide variations were met with, depending apparently upon the extent to which the bile-flow was interfered with and the amount of damage to the pancreas.

I have examined the fæces from seven cases of growth of the common bile-duct. In five there was no evidence of involvement of the pancreas, and in these the combined fatty acids were considerably in excess of the unsoaped fats. Of the two in which the pancreas was involved in the growth, one showed an excess of combined fatty acids and the other of unsoaped fats, but as the patient with the low percentage of unsoaped fat (·3 per cent) was on an exclusively milk diet, the results are not strictly comparable with those given by the other cases who were taking a mixed diet.

The influence of intestinal affections on the relation between the soaps and unsoaped fats of the stools is well illustrated by the cases diagnosed as " intestinal catarrh " or " enteritis," in which there was neither jaundice nor pancreatitis to complicate the issue, for in 95 per cent of these in the first series, and 100 per cent of these in the second, the combined fatty acids were present in excess. Similar results were also obtained with the fæces of patients suffering from duodenal ulcer, gastric ulcer, and appendicitis. As all these conditions are associated with a pathological state of the intestinal mucous membrane and an abnormal intestinal flora, which may affect the pancreas either directly through the ducts or indirectly by way of the lymphatics, one sometimes meets with cases in which there is an excess of unsoaped fats. This is most common in connection with ulcers of the duodenum. There was evidence of such a secondary pancreatitis in fifteen out of the twenty-one cases that I have included in the tables, and in about half of these there was a relative excess of unsoaped fats. A similar complication was found in three out of the sixteen cases of gastric ulcer, but only one of these showed an excess of neutral fats and free fatty acids relative to combined fatty acids. Even when well-marked pancreatic insufficiency is present, and there are other indications that the digestive functions of the gland are interfered with, the excess of unsoaped fat that might be expected is often replaced by an abnormally high percentage of soaps, owing to the fat-splitting action of the intestinal bacteria. Thus, out of 83 cases of pancreatitis associated with an intestinal catarrh, the soaps were in excess in 70 per cent, and in only 30 per cent were the unsoaped fats and combined fatty acids equal, or the former in excess.

It is obvious that when there is interference with the functions of the pancreas from cirrhosis consequent on inflammatory changes, and also an abnormal activity of the fat-splitting bacteria of the intestine, the relation between the soaps and the unsoaped fats will vary with the relative intensity of the two, and no hard and fast rule can be laid down; each case must be judged on its merits and the indications to be obtained by other methods of examination. Of these, the presence of indicanuria, an excess of inorganic ash in the fæces, and the results of the pancreatic insufficiency tests are the most important. The varying relations found in my cases of duodenal ulcer and gastric ulcer are examples of this, and the same explanation probably holds good for the cases of sprue and pernicious anæmia that I have examined. Stones in the common bile-duct and gall-bladder have frequently been found not to be associated with a disturbance in the relations between the unsoaped fats and combined fatty acids that might theoretically be expected, especially when there has been no obstruction to the bile-flow, and I am inclined to think that this may be due to the abnormal activity of fat-splitting bacteria, for in such cases there is generally evidence of cholangitis, and this, as well as the gall-stone formation, is probably consequent upon invasion of the biliary tract by intestinal organisms which have ascended beyond their normal habitat to the level of the common bile-duct.

In connection with the variations of the total ether extract of the fæces, it was pointed out that in the early stages of catarrhal pancreatitis there is probably an increased flow of pancreatic juice which may bring about an abnormally low reading. In such cases it is the rule to find that the combined fatty acids are in excess of the unsoaped fats, often very markedly so, even when there is no evidence of abnormal bacterial activity in the intestine. This is probably due to the excess of pancreatic juice causing a higher proportion than normal of the fats to undergo saponification, and, although much of this is absorbed, leading to a low reading of total fat, a still higher proportion than usual of soaps appears in the fæces.

Turning now to the relations between the neutral fats, and free and combined fatty acids, shown by the analyses in Series *B*, we find that in pancreatic disease where there were cirrhotic changes in the gland but no jaundice, the ratio of unsoaped fats to combined fatty acids averaged about 1·6 : 1·0, and of neutral fats to free fatty acids 1 : 2, thus showing that in this condition the excess of unsoaped fats is often largely due to an abnormal proportion of neutral fat. In the cases of catarrhal pancreatitis not associated with obstruction to the flow of bile, although the soaps as a rule were present in higher percentage than the unsoaped fats, separation of the latter into their constituent neutral fats and free fatty acids showed that there was an abnormally high proportion of the former, 1·0 : 3·5 as compared with the normal of about 1 : 9 or 10. The only case of pancreatic infantilism in which these more complete investigations have been made gave an excess of unsoaped fats to combined fatty acids of 1·0 : 2·9, but the fat-splitting process was evidently being imperfectly carried out, for the neutral fats and fatty acids were found to bear a ratio of 1·0 : 4·4. These results were in conformity with what was obtained with the pancreatic insufficiency tests, which showed that casein and starch digestion was also incomplete.

The association of disease of the pancreas with jaundice was found to raise the proportion of combined fatty acids to unsoaped fats, as in the similar cases in the series previously considered. The ratio of neutral fats to free fatty acids was usually abnormally high, but the variation from the normal was found to be less marked the more complete was the obstruction to the bile-flow. In nearly all cases of impacted gall-stones, some bile finds its way into the intestine, and a chemical analysis of the stools usually shows that a considerable quantity is present, even when the stools are white to the eye. With most cases of cancer of the head of the pancreas, on the other hand, the obstruction is absolute, and at most, only traces of hydrobilirubin are present at the stage when they usually come under examination. In accordance with this we find that while the average proportion of neutral fat to free fatty acids in simple pancreatitis with jaundice, and associated with the presence of gall-stones in the common bile-duct, was 1·0 : 5·1, with cancer of the head of the pancreas the ratio was lower, 1·0 : 7·1.

Catarrhal affections of the intestinal tract do not, as a rule, seriously affect the relations existing between the neutral fats and free fatty acids unless there is a profuse diarrhœa, and the average in my chronic cases has worked out at about normal, 1·0 : 9·9. In the case of acute catarrh with diarrhœa, the neutral fats were in excess of the combined fatty acids, although the total fats were less. It will be noticed that in chronic colitis, where there has usually been a more marked excess of combined fatty acids over unsoaped fats than with catarrhal affections of the large intestine, the tendency has been for the proportion of neutral fats to be slightly higher than in the cases of chronic enteritis. This is probably to be explained by the greater amount of fat derived from the intestinal wall itself.

From what has been said, it will have been gathered that, while an estimation of the fats and the relative proportions in which the various forms occur in the stools may often be of considerable service in diagnosis, the problems presented cannot always be solved on first principles, and that before interpreting the results it is always necessary that all the evidence that can be obtained by a thorough analysis of both the fæces and urine should be carefully considered in conjunction with the clinical signs and symptoms. An excess of unsoaped fat relative to combined fatty acids, especially when the proportion of neutral fat is abnormally high, is suggestive of disease of the pancreas ; but the modifications brought about by a co-existent intestinal catarrh or obstruction of the bile-flow must always be borne in mind. An excess of combined fatty acids and a normal proportion of neutral fat, on the other hand, points to a catarrh of the intestinal walls if there is no jaundice or diarrhœa, but the modifying influence of a secondary pancreatic affection may counterbalance the effect of the intestinal condition. It is only by constantly comparing the analytical data with the conditions found post mortem and at operation that the experience can be gained that is necessary for full use to be made of the information to be derived from estimations of the fat in the fæces. Even then, one meets at times with fresh combinations which call for a revision of previously formed opinions. It is obvious that at present we do not fully understand all the factors that are involved in the splitting of fats in the intestine, and there is much to be said for the view advocated by Falta, that the internal, as well as the external, secretion of the pancreas, regulates in some unexplained way the absorption and utilization of fats. It would only seem possible to explain on some such lines the excretion of an excess of fat in the fæces in exophthalmic goitre, congenital steatorrhœa, some cases of pancreatic infantilism, etc., in which there is no evidence of any interference with the external secretion of the gland. The theory advanced by Owen Williams, that the intestine is an excretory organ for the waste products of fat metabolism, as the kidneys are for proteins and the lungs for carbohydrates, is well worthy of consideration and further investigation.

There are certain chemical methods of examining and differentiating fats in common use, of which mention may be made, but as yet only a few of these have been applied practically to fæcal analysis.

1. **The Acid Value,** that is the number of milligrams of potassium hydrate necessary to neutralize a gram of the fat, is a measure of the degree to which the fat has been hydrolyzed.

A weighed amount of the fat is dissolved in neutral alcohol or alcohol-ether; a few drops of 1 per cent alcoholic phenolphthalein, or if the fat is dark in colour, a 2 per cent solution of Meister Lucius & Brüning's "alkali blue 6b" are added, and the titration effected with tenth or half-normal aqueous potash.

2. **The Saponification Value** (Köttsdorfer) is obtained by determining the number of milligrams of potassium hydrate necessary to neutralize the fatty acids split off from one gram of fat on saponification.

A weighed quantity of the fat is boiled with alcoholic potash on a water-bath for half an hour. The alkali in the flask is then titrated with half-normal hydrochloric acid, phenolphthalein being used as the indicator, and the result compared with that given by a control experiment in which the alcoholic potash only was used. The difference gives the amount of alkali neutralized by the fatty acids liberated from the amount of fat taken, and from this the saponification value can be calculated. As the soaps formed are hydrolyzed by water, and therefore react alkaline, it is necessary that neutral alcohol should be added from time to time in sufficient amount to keep it at over 40 per cent, since, according to Kanitz, hydrolysis of soaps does not occur in this strength of alcohol.

The saponification value is a measure of the mean molecular weight of the fatty acids entering into the composition of the fats, so that by means of it the nature of the fat present is suggested. Fats such as tallow or lard give a saponification value of about 195, butter 220 to 233, cocoa-nut oil about 250, cod-liver oil 171 to 189.

3. **The Ester Value** is the difference between the saponification and acid values of the fat, and is therefore the number of milligrams of caustic potash necessary to neutralize the fatty acids present in the form of neutral esters.

4. **The Iodine Value** of a fat is the amount of halogen, reckoned as iodine, that the unsaturated fatty acids it contains will absorb, expressed as a percentage of the weight of the fat. The iodine value of a fat, or a mixture of fats, is therefore an index of the proportion of unsaturated and saturated acids present, for the latter do not absorb iodine. In the fæces, oleic acid, with an iodine value of 90·1, is the most important unsaturated fatty acid. According to Hecht, the fæces of children fed on cow's milk have a lower iodine value, and a higher melting-point, than those of children brought up on mother's milk, and the first stools passed by the latter after the meconium has been voided are particularly rich in this substance. He states that they have an iodine value of 48 per cent and a melting-point of 40° C. At the end of the first week the proportion of oleic acid sinks, and the melting-point and iodine value then approach those of older children, namely 47° to 48° C. for the former and 20 per cent for the latter. In cases of dyspepsia the iodine value rises, while the melting-point sinks. Thus the stools of breast-fed children with fatty dyspepsia have an iodine value of 31 to 41 per cent and a melting-point of 39° to 40° C., while with children fed on cow's milk, Hecht found an iodine value of 24 to 20 per cent and a melting-point of 46·5° to 49·0° C. According to the melting-point and iodine value of the fat in the fæces, Hecht distinguishes two types of fatty dyspepsia: an "olein dyspepsia" due to defective absorption of oleic acid, and a "margarine dyspepsia" where the melting-point is higher and the iodine value less.

Most of the iodine values given in text-books have been obtained by Huber's method, but the shorter process devised by Wijs is to be preferred. In this, a titrated solution of iodine monochloride, obtained by mixing solutions of iodine trichloride and iodine in glacial acetic acid, is added to a solution of the fat in carbon tetrachloride. This, after standing in the dark for one or two hours, is mixed with a 10 per cent solution of potassium iodide, and is then titrated with a standard solution of sodium thiosulphate. From the amount of iodine absorbed by the known weight of fat taken, the iodine value can then be calculated (Leathes).

5. **Hehner's Value** is the percentage of fatty acids insoluble in water given on saponification of the fat. For triolein the Hehner value works out at 95·7, for lard and most fats or oils about 95, for butter between 86 and 88, and for cocoa-nut oil, used in the manufacture of margarine, lower still.

A weighed quantity of the fat is saponified with alcoholic potash, the alcohol evaporated off, the soap dissolved in hot water, and the solution made acid with hydrochloric acid. After being heated on a water-bath till the aqueous layer is clear, the mixture is filtered, the fatty acid washed with boiling water so long as any acid reaction can be detected, and then dried and weighed.

6. **The Reichert-Meissel Value** is the number of cubic centimetres of decinormal potassium hydrate necessary to neutralize the volatile fatty acids produced by the saponification of 5 grams of the fat, and is a measure of the amount of lower fatty acids which volatilize in a current of steam that enter into the composition of a fat. To obtain comparable values, the experiment must be carried out under certain prescribed conditions, which vary somewhat in different countries. In England, the Wollny modification has been adopted by the Society of Public Analysts and is used in the Government Laboratories (Leathes).

7. **The Acetyl Value** gives the number of milligrams of potassium hydrate necessary to neutralize the acetic acid liberated when one gram of acetylated fat or fatty acid, formed by heating the fat with twice its weight of acetic anhydride, is saponified. Animal fats do not as a rule give an acetyl value unless they are mixed with cholesterol or some other alcohol insoluble in water, but certain vegetable oils have high acetyl values ; thus, for castor oil it usually lies between 153 and 156. Owing to partial hydrolysis of an animal fat, an acetyl value may be obtained which is not due to hydroxy-acids, and the presence of soluble fatty acids may also interfere with the result. It is therefore necessary to distinguish between the " true acetyl value " and the " apparent acetyl value."

CARBOHYDRATES.

The total carbohydrates contained in the fæces are sometimes estimated indirectly by determining the values of the proteins, fats, and ash contained in a given weight of the dried fæces, and assuming that the difference between the sum of these and the weight of the sample represents the carbohydrates. It is evident, however, that this method can give only very inexact results, since the residue contains other substances, such as vegetable acids, pigments, etc., which are not included in the estimations. Determinations of the total carbohydrate, moreover, do not furnish a basis on which to form a judgment as to the extent to which starches are being digested, and after all, this is the most important point to settle. It is usual to determine the starch by converting it into dextrose, and calculate from this the amount of starch that is present.

Direct Estimation of Starch. (*a*) *Liebermann-Allihn Process.*—The fæces are dried down at 105° C., any obvious mucus having previously been removed with forceps, and finely powdered, so that the cellulose envelopes are broken open. From 2 to 3 grams are then carefully weighed out, mixed in a flask with 100 c.c. of 2 per cent hydrochloric acid, and boiled on a sand-bath for an hour and a half, with a reflux-condenser. The fluid is neutralized with sodium hydrate, filtered through an asbestos filter by means of an exhaust-pump, and the residue washed with hot water until the filtrate is made up to 200 or 500 c.c. Thirty c.c. of a solution of copper sulphate (Fehling's solution No. 1), 30 c.c. of an alkaline solution of Rochelle salt (Fehling's solution No. 2), and 60 c.c. of water, are then placed in a beaker and heated to the boiling-point. To the boiling liquid, 25 c.c. of the diluted filtrate are now added, and the mixture is boiled for three minutes. The precipitated copper oxide is collected on an asbestos plug supported on glass-wool in an asbestos filter-tube of known weight, using an exhaust-pump. It is first washed with water, then with alcohol and ether, and is finally dried in an oven at 100° C. for fifteen minutes. A stream of pure dry hydrogen is now passed through the tube, which is slightly heated. As soon as the copper oxide has all been reduced to metallic copper, as is shown by the change of colour, the heating is discontinued and it is allowed to cool in an atmosphere of hydrogen. The tube is then weighed. Each gram of copper will correspond to 0·5634 gram of dextrose. From this the starch is found by multiplying by the factor 0·94 (Soxhlet and Linter). The results obtained by this method are always too high, as some of the dissolved material from the fæcal extract is weighed in with the copper.

(*b*). *Strasburger's Process.*—The weighed and powdered dry fæces are boiled with hydrochloric acid, neutralized, and filtered as in the preceding method. The sugar in the filtrate is then estimated by the Volhard-Pflüger process. Into a beaker are placed 50 c.c. of the clear filtrate, 60 c.c. of Fehling's solution, and 35 c.c. of distilled water. The beaker is covered with a watch-glass and heated in a water-bath that is not quite boiling, for half an hour. Its contents are then diluted with about 130 c.c. of cold distilled water and filtered through an asbestos filter by the aid of a suction pump. The copper oxide precipitate is carefully washed from the sides of the filter on to the asbestos plug, and dissolved in nitric acid (sp. gr. 1·2), the solution being collected in a flask connected to a suction-pump. After well washing the filter with distilled water and adding the washings to the filtrate, the green solution is poured into an evaporating basin, 0·5 to 1 c.c. of concentrated sulphuric acid added, and the mixture evaporated until all the nitric acid has been driven off. The crystals of copper sulphate that remain are dissolved in water, and the solution is transferred to a 300 c.c. flask. A few drops of a concentrated solution of caustic soda are now added, to combine with any excess of sulphuric acid, until a persistent precipitate forms. The solution is then mixed with 50 c.c. of a cold saturated watery solution of sulphurous acid, which dissolves the precipitate. The mixture is boiled for a minute, and decinormal ammonium sulphocyanide solution is run in from a burette until the blue-green colour is discharged. The end-point is not always easy to determine, but as a rule 2 grams of fæces need about 50 c.c. of the decinormal solution. After the fluid has cooled, the flask is filled up to the 300 c.c. mark with water, and well shaken. The precipitate of copper-sulphocyanide is then filtered off through a dry filter, the filtration being repeated until a perfectly clear fluid is obtained. A hundred c.c. of the filtrate are now placed in a beaker, and mixed with 50 c.c. of nitric acid (sp. gr. 1·2) to which a few crystals of urea have been added, 10 c.c. of a cold saturated solution of ammonia-iron-alum, and 100 c.c. of water. The red solution that results is titrated with a decinormal solution of silver nitrate until a faint yellowish-red colour shows that the end-point has been reached, or an excess of the silver nitrate solution may be added and titrated back with ammonium sulphocyanide until a yellowish-brown colour results. As only a third part of the solution was employed for the titration, the number of c.c. of silver solution used must be multiplied by three. On subtracting this from the volume of ammonium sulphocyanide solution used, the value of the cyanide and copper can be calculated, for 1 c.c. of decinormal ammonium sulphocyanide corresponds to 6·32 mgrams of copper. From this the quantity of sugar derived from the weight of fæces taken can be reckoned by the use of Pflüger's table :—

Copper mgrams	Sugar mgrams	Copper mgrams	Sugar mgrams	Copper mgrams	Sugar mgrams	Copper mgrams	Sugar mgrams	Copper mgrams	Sugar mgrams
18·94 =	6·25	51·7 =	21	72·3 =	31	92·6 =	41	112·8 =	51
32·8 =	12	53·8 =	22	74·3 =	32	94·6 =	42	114·9 =	52
34·9 =	13	55·9 =	23	76·3 =	33	96·6 =	43	116·9 =	53
37·0 =	14	58·0 =	24	78·4 =	34	98·6 =	44	119·0 =	54
39·1 =	15	60·1 =	25	80·4 =	35	100·7 =	45	121·0 =	55
41·2 =	16	62·1 =	26	82·4 =	36	102·7 =	46	123·0 =	56
43·3 =	17	64·2 =	27	84·4 =	37	104·7 =	47	125·1 =	57
45·4 =	18	66·2 =	28	86·5 =	38	106·7 =	48	127·1 =	58
47·5 =	19	68·2 =	29	88·5 =	39	108·8 =	49	129·2 =	59
49·6 =	20	70·2 =	30	90·5 =	40	110·8 =	50	131·2 =	60

The starch content of the weight of fæces taken is then calculated by multiplying the sugar value by 0·94. The theoretical factor for converting dextrose into starch is 0·9, but as only some 95 per cent of the starch is turned into sugar by boiling for an hour and a half, according to Allihn and Strasburger, this is allowed for by the use of the figures mentioned. If only a small quantity of sugar—under about 6 mgrams—is present, the method does not give satisfactory results, and it is then advisable to add a known quantity of dextrose to the solution and allow for it in the final calculations. It has already been pointed out that mucus must be removed as much as possible before the fæces are dried down, for this substance gives, on hydrolysis with an acid, a reducing body that will influence the result, but when the mucus is intimately mixed with the fæces in small masses this cannot be done by mechanical means. Strasburger advises that in such cases the stools should be extracted with lime-water. Another source of error is the sugars (hexoses and pentoses) derived from the hemi-cellulose contained in the fæces on heating with hydrochloric acid. This, however, only assumes great importance in persons taking a diet rich in vegetables. In such cases a control analysis should be carried out, and the starch be estimated from the difference between the results.

The Pentosans in the fæces are determined by Tollens' method, which depends upon the fact that when the pentoses and pentosans are distilled with hydrochloric acid, they give rise to furfurol.

The distillation is carried out with 2 to 5 grams of the dry fæces, or with a measured quantity of the acid sugar solution. This is mixed with hydrochloric acid (sp. gr. 1·06) in a distillation flask and heated. When about 30 c.c. have distilled over, the same quantity of the acid is added to the contents of the flask and the process repeated until 400 c.c. have passed over. The furfurol in the distillate is then precipitated with phloroglucin, the precipitate collected on asbestos in a weighed Gooch crucible, and washed with 150 c.c. of water. The crucible and its contents are now dried in a drying-cupboard at 97° to 98° C. for four hours, cooled in an exsiccator, and weighed. To calculate the pentose present the following formulæ (Kröber) are used, where *a* represents the weight of phloroglucide found :—

Under 0·03 gram pentose = $(a + 0{\cdot}0052) \times 1{\cdot}017$.

From 0·03 to 0·3 gram pentose = $(a + 0{\cdot}0052) \times 1{\cdot}0075$.

Over 0·3 gram pentose = $(a + 0{\cdot}0052) \times 1{\cdot}0026$.

The Hexosans.—The galactans in the fæces are determined from the acid sugar filtrate of the fæces by evaporating it to a syrupy consistency, heating this with nitric acid (sp. gr. 1·15) on the water-bath, and determining the galactose from the amount of mucic acid that is formed, 0·75 gram of mucic acid, dried at 110° C., being approximately equivalent to galactose.*

The Reducing Sugars present in the fæces as such are estimated by the Strasburger process in a watery solution prepared by Uffelmann's or Blauberg's method.

Uffelmann's Method.—The dried fæces are extracted with alcohol, and the alcohol evaporated off from the filtrate on the water-bath. The residue is then dissolved in water and used for the estimation.

Blauberg's Method.—About 3 grams of the dried fæces are extracted with thymol water by gently heating the mixture in a water-bath for a few hours. The solid material is then filtered off and washed with thymol water, the washings being added to the filtrate. The proteins are next removed by treating the solution with lead acetate and basic lead acetate, and filtering. The excess of lead in the filtrate is removed by a stream of carbon dioxide, and the filtrate is then evaporated down to dryness. The residue is dissolved in water, and used for the estimation.

The sugar solution prepared by either method is made up to a definite volume with water (200 to 300 c.c.), and a part of this (50 to 100 c.c.), the quantity depending upon the amount of sugar expected

* See Cammidge, "Glycosuria and Allied Conditions." Arnold, 1913.

to be present, boiled with Fehling's solution. The sugar is then estimated by the copper-ammonium-cyanide method. If only traces of sugar have been found in the qualitative tests, a known quantity of dextrose must be added to the solution before boiling with the Fehling's solution, and be allowed for in the subsequent calculations.

ESTIMATION OF THE CELLULOSE AND WOODY FIBRE IN THE FÆCES.

Several methods of carrying out these estimations have been described by Lohrisch, Scheunert and Lötsch, and others, but the simplest are those devised by König.

About 3 grams of the dry, finely-powdered fæces are heated in a flask provided with a reflux-condenser, at a temperature of 133° to 137° C., with 200 c.c. of glycerin (sp. gr. 1·23) containing 20 grams of concentrated sulphuric acid to the litre, for one hour. After being cooled, the mixture is diluted to about 500 c.c., heated again, and filtered hot through asbestos contained in a Gooch crucible, by the help of a suction-pump. The residue on the filter is then well washed with hot water, warm alcohol, alcohol-ether, and ether successively, until the filtrate comes through quite colourless. The precipitate is now loosened from the asbestos, and the crucible and its contents dried at 105° C. It is then cooled and weighed. The crucible is now heated in the flame until its contents are reduced to ash. It is then again cooled and weighed. The difference between the two weighings gives the weight of the ash-free woody fibre contained in the weight of fæces taken.

To estimate the cellulose, the dried powdered fæces are heated with glycerin-sulphuric acid, filtered through a Gooch crucible, and the residue washed as above. The residue and the asbestos are transferred to an 800 c.c. beaker and treated with about 150 c.c. of pure 30 per cent hydrogen peroxide and 10 c.c. of 24 per cent ammonia. The mixture is allowed to stand for about twelve hours. It is then warmed for two hours on a water-bath, and filtered at once through asbestos. The well-washed residue, with the asbestos, is now warmed with 75 c.c. of ammoniacal copper oxide, and again filtered through asbestos contained in a Gooch crucible. The filtrate is mixed with 300 c.c. of 80 per cent alcohol, and well stirred. The cellulose, which precipitates out in large flocculi, is collected on a filter, washed, dried, weighed, and ashed. The difference between the dry weight and the weight of the ash gives the weight of the cellulose in the quantity of fæces taken.

INORGANIC CONSTITUENTS.

In recent years much more attention has been devoted to the metabolism of inorganic salts than was formerly the case, and although the requirements of the body in this respect have not been determined with the same degree of accuracy as its need for energy-producing materials, there is abundant evidence that the mineral elements of the diet exert an important influence on the chemical and vital process of the organism. Some inorganic elements, such as iron, calcium, and phosphorus, appear to be as essential as the proteins, but they are needed in much smaller amounts. Animals fed on a salt-free diet which contained an abundance of protein carbohydrate and fat, have been shown by Forster to live only from twenty to thirty days.

An adult derives an average of about 14·81 grams of inorganic salts from ordinary mixed diet, and takes about 10 grams of sodium chloride for seasoning, and in the drinking water. According to Gaultier, the average mineral loss in twenty-four hours is 19·6 grams in the urine, 4·3 grams in the fæces, and 2·0 grams in the perspiration, leaving, therefore, a balance of about 1 gram which is supposed to come from the oxidation of organic phosphorus and sulphur :—

	Urine in 24 hours	Fæces in 24 hours	Perspiration in 24 hours	Average per day
Chlorine	4·9 – 7·2	0·015 – 0·035	1·12	7·40
Phosphoric anhydride (P_2O_5)	1·6 – 3·0	0·76 – 0·82	tr.	3·05
Sulphuric anhydride (SO_3)	1·8 – 2·8	0·06 – 0·17	0·005	3·00
Silicon anhydride (SiO_2)	0·003 – 0·004	0·17 – 0·35	—	0·26
Carbonic anhydride (CO_2)	—	0·05	—	0·05
Potassium oxide (K_2O)	1·6 – 3·1	0·75 – 0·30	0·178	2·88
Sodium oxide (Na_2O) . .	4·16 – 5·9	0·25 – 0·35	0·80	5·60
Calcium oxide (CaO) . .	0·25 – 0·36	0·65 – 0·70	tr.	0·85
Magnesium oxide (MgO)	0·56	—	tr.	0·56
Iron peroxide (FeO) . .	0·004 – 0·013	0·023 – 0·04	nil	0·004
Total average gms.	19·6	4·3	2·0	25·9

The inorganic constituents of the fæces, like the nitrogen and possibly also the fat, are derived in part from the intestinal secretions, and in part from the food. The proportion which comes from the food varies with the nature of the diet. Thus Rübner found that, with eggs, the inorganic ash constituted 10·9 per cent of the dry weight of the fæces, with bread from 17·3 to 25·4 per cent, with meat from 15 to 21·2 per cent, while with milk it varied from 44·5 to 48·2 per cent, when these substances were taken by a healthy adult. The origin of a portion of the inorganic material from the intestinal secretions is shown by the results of analyses of meconium and the fæces of fasting individuals. In meconium Müller found 6·2 per cent of inorganic ash, reckoned on the dry weight, and Zweifel an average of 5·1 per cent. The ash content of the dry fæces of the fasting men, Cetti and Breithaupt, were shown by Müller to be 12·477 per cent and 12·57 per cent respectively.

	Meconium					Hunger Fæces	
	(Müller) per cent	(Zweifel I.) per cent	(Zweifel II.) per cent	(Zweifel III.) per cent	(Zweifel IV.) per cent	Cetti per cent	Breithaupt per cent
Insoluble in HCl	0·67	—	—	—	—	1·213	1·780
Fe_2O_3	0·87	1·36	2·60	0·86	0·80	1·530	3·03
CaO	8·00	31·80	5·70	5·09	9·50	14·516	12·53
MgO	4·32	3·60	4·00	7·23	7·92	1·200	4·12
P_2O_5	10·66	7·80	5·40	3·20	8·58	43·132	55·75
SO_3	47·04	22·30	23·00	39·50	31·90	6·341	3·71
K and Na ..	24·42	—	30·20	—	23·02	19·620	12·649
ClH	—	3·78	2·53	8·68	3·90	1·320	1·96

The most striking differences between the inorganic constituents of meconium and hunger fæces are the excess of sulphur and alkalies in the former, and the higher proportions of calcium, iron, and phosphorus in the latter. These are probably to be explained by the different physiology of the new-born child and the adult. Most of the alkali in meconium is combined with sulphuric acid, and the latter is no doubt derived from the taurin of the bile, which is not absorbed as it is in extra-uterine life. Part also comes probably from the shed epithelium of the intestinal tract. The lower proportions of calcium, iron, and phosphorus can be explained by the greater need for these elements in the growing organism as compared with the adult.

Ury has endeavoured to differentiate the inorganic salts and nitrogen excreted by the alimentary tract from those derived from the food, by comparing the proportions present in watery extracts of the fæces with those found in the whole stool, and these again with the urine :—

	Watery Extract of Fæces	Total Fæces	Per cent in Extract	Urine	Total Excretion	
					Per cent in Urine	Per cent in Watery Extract
Nitrogen (N) ..	1·051	3·2495	32·5	33·516	97·0	3·0
Hydrochloric acid (HCl)	0·0624	0·1347	46·34	22·240	99·7	0·3
Sulphuric acid (SO_2)	0·017	0·0279	60·9	5·384	99·7	0·3
Lime (CaO)	0·242	2·245	10·08	0·701	74·3	25·7
Magnesia (MgO) ..	0·2223	0·5492	40·05	3·323	59·3	40·7
Phosphorus as P_2O_5	0·7509	2·8573	26·2	6·441	89·6	10·4
Phosphorus as P	0·3279	1·2476		2·812		

These results, taken in conjunction with the analyses of hunger fæces, suggest that calcium and magnesium, with to a less extent phosphorus and iron, are the chief inorganic elements excreted by the intestinal tract. Other experiments tend to confirm this conclusion, and point to the intestine being an important route by which the body rids itself of unneeded heavy metals. It is usually considered that the excretion takes place chiefly through the large intestine, but Kobert and Koch have shown that the isolated human large intestine contains only traces (1·006 mgram) of iron, and Voit calculated that from 1 gram of the mucous membrane from the colon of a dog, only 6 to 9 mgrams of iron and 0·09 to 0·16 gr. of calcium could be obtained. It seems probable therefore that, under normal conditions at least, the greater part of the excretion takes place through the mucous membrane of the small intestine, and possibly also, to some extent, through the secretion of the pancreas and the bile.

Quantitative Estimation of the Ash.—A weighed quantity of the dry and finely-powdered fæces is placed in a platinum, quartz, or porcelain crucible, covered with a lid, and cautiously heated until every trace of visible carbon has disappeared. The crucible is then cooled and weighed, and, its original weight being known, the amount of ash derived from the quantity of fæces taken can be estimated, and from this the percentage of ash in the dry stool calculated. It is important that the heating should be done carefully, especially with fatty fæces, as they are apt to boil over, and as low a temperature as possible should be employed, in order to avoid excessive loss through volatilization. A low temperature also prevents fusion of the material and allows access of air, thus making the process more rapid. In the early stages of the experiment at least, the capsule must be kept covered, as the albuminous matter is likely to crepitate and so bring about a loss. Later, when the ashing is nearly complete, the lid may be removed with advantage.

The presence of sulphates, chlorides, phosphates, carbonates, lime, potassium, sodium, magnesium, and iron can be demonstrated in a watery extract or the residue, by the ordinary chemical tests.

It has been pointed out by Hoppe-Seyler, that a great part of the phosphorus and sulphuric acid in the fæces is not present as inorganic salts, but occurs as sulphur in proteins, and phosphorus in lecithin and similar substances; also, that in the process of ashing above described, the hydrochloric and carbonic acids are set free by the action of the other less volatile acids present. He therefore proposes that the analysis should be made by extracting with alcohol, acetic acid, and hydrochloric acid, and then examining these solutions.

The fæces are ground up with a large excess of alcohol, and filtered. The residue is then rubbed up with dilute acetic acid, and filtered. The residue from this is again extracted with dilute hydrochloric acid. The alcoholic and acetic acid extracts are now united, evaporated down, and ashed. At first the residue is only heated sufficiently to carbonize it. As a considerable amount of crepitation, etc., takes place at this stage, a large crucible must be used, and the precautions as to covering and regulation of the temperature previously mentioned must be carried out. When all signs of gas-formation have ceased, and the material is carbonized, it is cooled, well mixed with water added a little at a time, brought to the boil, and filtered through an ash-free filter, which has previously been washed with hot water. The crucible, the filter, and the carbonized material are then dried, and the dry substance, with the filter, is placed in the crucible, which is heated to a faint red glow. It is then cooled, and its contents are extracted with water and filtered as before, the filtrate being added to that first obtained. The crucible, the filter, and its contents are again dried, and are now heated until all the carbon has disappeared, or at most only a trace remains. As the ash still contains traces of soluble salts, it is extracted with water, filtered, and the filtrate combined with those previously obtained. The whole of the watery solution is then evaporated down to a small bulk on the water-bath. The insoluble residue is warmed with dilute hydrochloric acid, and if a residue of iron still remains, this is dissolved by digesting it with concentrated hydrochloric acid on the water-bath. The composition of the various extracts is then determined. The watery solution from the ash will contain alkaline carbonates and phosphates, sulphates, chlorides, and phosphates of calcium, sodium, and potassium, and also the silica compounds. In the hydrochloric acid extract of the ash will be calcium, magnesium, iron, and phosphoric acid, while the hydrochloric acid solution prepared direct from the fæces, which is evaporated down and ashed, and the ash extracted with hydrochloric acid, will contain phosphorus and iron.

Neumann has suggested that the metals and non-volatile fatty acids should be estimated in the moist material by oxidizing with a mixture of nitric and sulphuric acids, and the carbon be removed by prolonged heating with this mixture.

A weighed quantity of the moist stool, or of the dried material, is mixed with equal parts of concentrated nitric and sulphuric acids in a round-bottomed flask, and heated until the brown fumes that arise abundantly at first, have diminished. A further quantity of the acid mixture is then added drop by drop, and the heating continued until brown fumes are no longer given off and the fluid is colourless or light yellow. It is then cooled and mixed with water, using three times the volume of the acid mixture employed. This solution is now heated for five to ten minutes to drive off the brown fumes that arise, and is then used for the qualitative or quantitative determination of the bases present, with the exception of ammonia.

The amount of ash in the fæces of a healthy individual on an ordinary mixed diet ranges, in my experience, between 10 and 15 per cent, with an average of 12·5 reckoned on the dry weight. Ranke found 11·14–12·44 per cent, Oefele 8–18 per cent, Prausnitz 11–15 per cent, and Grundzach 12·44–12·48 per cent. The quantities of the various inorganic elements found in the ash are shown in the following table :—

Percentage Content of Ash—Adults on Mixed Diet.

	Fleitmann	Porter	Grundzach
Sodium chloride (NaCl) ..	0·58	4·33	Cl 0·344
Potassium chloride (KCl) ..	0·07	—	
Potassium oxide (K_2O) ..	18·49	6·10	12·000
Sodium oxide (Na_2O) ..	0·75	5·07	3·821
Calcium oxide (CaO)	21·36	26·46	29·250
Magnesium oxide (MgO) ..	10·67	10·54	7·570
Iron oxide (Fe_2O_3)	2·09	2·50	2·445
Phosphoric anhydride (P_2O_5) ..	30·98	36·03	13·760
Sulphuric anhydride (SO_3) ..	1·13	3·13	0·653
Silicon anhydride (SiO_2) ..	1·44	—	0·052
Sand	7·39	30·00	4·460

The difference in the percentages of phosphoric and sulphuric acids obtained by Grundzach and the other two authors, is to be explained by the fact that the former only took into account the preformed acids in the hydrochloric acid extract of the stools, while the other observers also reckoned in the organic compounds yielding these substances.

A purely meat diet results in a lowering of the ash-content of the fæces, while with a milk diet the ash is increased, owing to the presence of unabsorbed lime. The mean of three analyses of milk-fæces, made by Müller, gave 32·8 per cent of ash, while Rübner found from 27–35 per cent, and of this 41·2 per cent (13·2 per cent of the dry fæces) consisted of lime. A vegetable diet yields fæces with a low percentage of ash. Voit found 11·32 per cent, and Rübner from 8·81 to 16·4 per cent.

The fæces of infants fed on mother's milk have been shown by Blauberg to yield 9·27 per cent of the dry weight as ash, and of this 6·17 per cent was soluble in hydrochloric acid, leaving 3·1 per cent of insoluble matter ; 3·1 per cent was also insoluble in 5 per cent sodium hydrate, and 8·63 per cent insoluble in water. He found that the fæces of children fed on cow's milk are richer in ash, 15·62 per cent, and that 9·27 per cent was soluble in hydrochloric acid, leaving insoluble 6·35 per cent ; insoluble in 5 per cent soda 5·6 per cent, and insoluble in water 13·88 per cent. The percentages of the various inorganic constituents in the soluble ash are shown in the following table, compared with the quantities present in breast milk and cow's milk.

Per cent	Fæces, Breast-fed Child		Mother's Milk	Fæces, Child on Cow's Milk		Cow's Milk
	grams	per cent	per cent	grams	per cent	per cent
K_2O ..	0·950	15·00	31·36	1·090	11·75	22·01
Na_2O ..	0·323	4·20	6·77	—	—	6·99
CaO ..	1·925	31·15	16·59	2·930	34·63	21·88
MgO ..	0·502	8·75	2·74	0·600	6·47	2·81
Fe_2O_3 ..	0·298	1·91	0·20	0·104	1·50	0·33
Cl_2 ..	0·203	3·45	18·86	0·251	2·70	15·47
SO_3 ..	0·219	3·81	2·48	0·230	2·50	0·58
P_2O_5 ..	0·806	11·81	22·65	1·440	15·53	27·01

The most striking differences between the ash of the fæces of the adult and the infant are seen in the calcium, iron, and phosphorus. The higher percentage of calcium is to be explained by the different composition of the food, and is most marked in infants fed on cow's milk. Boiling the milk does not apparently make any difference. The lower proportion of iron and phosphorus is probably due to the greater need of the growing child for these elements. In the fæces of infants, the greater part of the calcium is present in combination with butyric and various fatty acids.

Comparatively little has been done yet on the alterations brought about by disease in the ash-content of the fæces. In my experience the most striking increase is met with in cases of chronic colitis, in which as much as 45 to 50 per cent of the dry weight of the stool may consist occasionally of inorganic ash. In thirty consecutive cases I found an average of 25·3 per cent. A similar but less marked increase is found in all catarrhal affections of the large intestine, and even when the condition is localized, the raised percentage of ash, when taken in conjunction with other signs and symptoms, may be of use in diagnosis. On several occasions I have been able to diagnose correctly a malignant ulcer of the colon in this way.

Acute catarrhal conditions of the small intestine and stomach raise the percentage of inorganic ash in the stools, chiefly owing to the presence of alkaline salts; but in chronic affections, where the colon is not also affected, the proportion is usually about normal, and may be even sub-normal. Although the absolute amount of inorganic ash in the fæces is increased when the food is imperfectly digested or absorbed, as in cases of serious pancreatic disease or jaundice, the proportion is often found to be abnormally low, owing to the increased bulk of the stools from the excess of fat, etc., present.

According to Blauberg, the inorganic ash in the fæces of atrophic infants is increased, about 20·7 per cent of the dry weight being found in the cases he examined. Of this 22·36 per cent consisted of lime and 87·58 per cent of soda. Contrary to what might be expected, the fæces of rickety children do not show a marked excess of inorganic ash, and the proportion of calcium is not usually abnormal. A larger proportion than usual is excreted, however, in combination with phosphorus, and less as calcium soaps of the fatty acids. In fatty diarrhœa the reverse is found, the calcium soaps being increased and the phosphorus compounds diminished, the proportion of phosphorus pentoxide in the urine being at the same time nearly doubled.

CALORIMETRY OF THE FÆCES.

The researches of Meyer and Joule have shown that the amount of energy, or power, that can be obtained from a given weight of matter, is connected with, and is proportional to, the heat given out during its combustion, and as heat is the simplest measure of potential energy that can be obtained, it is convenient to calculate the potential energy of the food, and also the work done by the organism, in terms of heat units. The standard measure of heat, or heat unit, is the *calorie*. This is the amount of energy required to raise 1 gram of water 1° C., and is equivalent to 425·5 units of work, or gram-metres; that is to say, the energy required to raise 1 gram of water 1° C. would lift a weight of 425·5 grams to a height of 1 metre. In practice it is usual to employ a larger unit than this, viz., the *kilo*, or *large, calorie,* which represents the amount of energy required to raise 1000 grams of water 1° C. Food materials which on oxidation give out the greatest amount of heat, should have theoretically the greatest capacity for producing work; but the heat equivalent of organic substances cannot be calculated from their chemical composition, for part of the heat, varying with different substances, is used in the process of dissociation, and the heat equivalent has, therefore, to be determined by direct calorimetric methods.

Rübner, as the result of his experiments, came to the conclusion that the energy value of 1 gram of protein in an average diet is 4·1 calories, although slight differences exist between different forms (e.g., casein 4·4, meat protein 4·233, vegetable protein 3·96 calories). For fats, Stohmann's figures were: olive-oil 9·384, animal fat 9·372, butter fat 9·179 calories. Rübner therefore adopted 9·3 as the average energy value of 1 gram of fat in a mixed diet. The following energy values have been found for carbohydrates: dextrose 3·692 to 3·755, milk-sugar 3·877, cane-sugar 3·959 to 4·001, starch 4·116 calories. Taking into account the predominating importance of starch in an average diet, Rübner gave the carbohydrate group an energy value of 4·1 calories. These standard values proposed by Rübner have been very widely adopted, and are generally used in calculating the energy value of a mixed diet. Atwater and Bryant, as the result of over 400 experiments, obtained slightly different results, viz., 1 gram protein = 4·0 cal., 1 gram fat = 8·9 cal., 1 gram carbohydrate = 4·0 cal., which they consider are the values absolutely available.

The amount of energy lost by the organism in the fæces can be calculated from the amount of nitrogen, fat, carbohydrate, etc., found to be present, using the same factors as are employed in determining the energy value of the food, and remembering that 1 gram of nitrogen is equivalent to 6·25 grams of protein. The labour involved in the preliminary estimations is, however very great, and it is more usual to employ a direct calorimetric method, Hempel's calorimeter being the best for the purpose.

This consists of an apparatus in which the dry and finely-powdered fæces are compressed into a block, an autoclave with a capacity of about 250 c.c., an instrument for supplying an atmosphere of oxygen, and the calorimeter itself. About a gram of the thoroughly dried and finely-powdered fæces is pressed into a block, to which is attached a linen thread 11 cm. long, the weight and heat value of which are known. The block is then weighed and suspended in the electric autoclave over the platinum receptacle that it contains by means of the thread. The apparatus is now tightly closed, and filled with oxygen at a pressure of 20 to 21 atmospheres, and placed in the calorimeter, which is filled with a litre of distilled water at a temperature about one and a half degrees below that of the air. After making all secure and closing the apparatus, the electrodes are connected with the terminals of an accumulator, and a current of electricity passed through. The water in the calorimeter is stirred with the special apparatus provided until a constant temperature is reached, and this is then read off with a delicate thermometer. From the temperature attained by the litre of water in the calorimeter, and the known weight of the fæces burnt, the number of calories in the stool can be calculated, allowance being made for the heat value of the thread and the constant factor of the calorimeter itself, which must be determined for each apparatus. In every case the average of at least two determinations should be taken, but the difference should not be more than ·1 per cent.

The values obtained by direct calorimetry are always higher than those reckoned from the analytical results, owing to the bile pigments, bile acids, etc., being included in the former. In either case it cannot be assumed that the caloric value of the fæces is an exact measure of the amount of food energy lost to the organism, for the intestinal secretions and bacteria contribute to the result.

According to Lohrisch, about 3·7 per cent of the calories in the food are lost in the fæces by a healthy adult on a test diet, while in chronic constipation only 2·35 per cent of the energy value of the ingested material is wasted in this way, when the result is calculated on the chemical composition of the stools. By direct calorimetry the loss by a healthy adult is about 12 per cent. Schlossmann considers that an energy loss of more than 10 per cent by infants is pathological, and according to his findings the energy loss with cow's milk is not quite as great as with mother's milk :—

Six-months-old Child	Calories Ingested	Loss in Fæces	
		Calories	per cent
5 days dilute cream	2070	122	5·9
5 days mother's milk ..	2700	221	8·2
5 days butter-milk	2985	155	5·2
5 days butter-milk and cream	4260	460	1·1

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Chapter VIII.

THE CHEMICAL EXAMINATION OF CALCULI AND CONCRETIONS MET WITH IN THE FAECES.

THE nature of many of the concretions met with in the fæces can be established with a considerable degree of certainty by naked-eye inspection and microscopical examination; but with others it is necessary to make a chemical analysis before their source can be determined, and in all cases it is advisable that their chemical composition should be ascertained before a definite conclusion is arrived at.

GALL-STONES.

Gall-stones are the concretions most commonly met with in the fæces. Like similar bodies formed in other situations, they consist of a mixture of the constituents of the fluid in which they are produced. One or other of these constituents may, and often does, form the main bulk of the stone, so that it possesses particular physical and chemical properties, but they never consist of that one substance alone. Cholesterin is present in all gall-stones, and forms the greater part of most. Calcium salts of the bile pigments are also always present in greater or less amounts, and occasionally form the chief part of the stone. Inorganic salts of calcium, generally carbonates and phosphates, usually occur, while traces of fats, soaps, lecithin, mucus, and occasionally copper, iron, manganese, and even mercury, can be detected. For clinical purposes gall-stones are classified according to their chief constituents, and the following groups described by Naunyn are generally recognized :—

1. "**Pure" Cholesterin Stones.**—These vary in colour from white to yellow, or more rarely brown or greenish on the surface. They are oval or spherical, and are seldom faceted (*Fig.* 79 D). They are translucent, and on section show a crystalline structure, but are not markedly stratified. The amount of cholesterin present is usually over 90, and may be as high as 98, per cent, but even the purest contain some pigment, a nucleus, and a stroma, which go to make up the balance.

2. **Laminated Cholesterin Stones.**—These stones differ from the preceding in containing more calcium salts of the bile pigments, which are found in yellow, brown, or green layers, alternating with the whiter layers of cholesterin. The green portions consist of calcium biliverdin, while the brown parts contain calcium bilirubin. Cholesterin, however, forms from about 75 to as much as 90 per cent of the weight of the stone. A considerable amount of calcium carbonate is also usually present, especially in the green layers. In size and shape they resemble " pure " cholesterin calculi, but are often faceted.

3. **Common Gall-bladder Stones.**—As their name implies, these are formed in the gall-bladder. Their chemical composition differs but little from that of the preceding, but in structure they vary considerably. Externally, there is a firm laminated non-crystalline crust which surrounds a softer pigmented nucleus, and

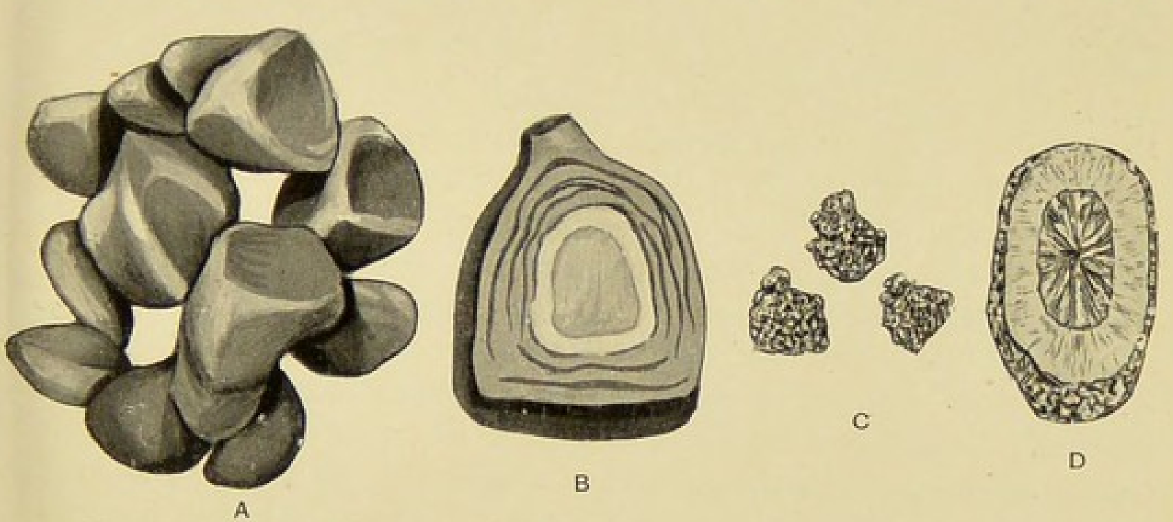


Fig. 79.—Gall-stones. A, Faceted common gall-bladder stones. B, Section of gall-bladder stone. C, Bilirubin calculi. D, Section of large cholesterin stones.

this frequently contains a cavity filled with a yellow alkaline fluid (*Fig.* 79 A, B) They vary considerably in size, shape, and colour, but are seldom larger than a cherry. The surface is generally yellow, but may be white or brown. They are usually distinctly faceted.

4. **Mixed Bilirubin-calcium Calculi.**—These stones are generally of large size, and occur singly, but when present in groups are faceted. Their chief constituent is bilirubin calcium, but they always contain much cholesterin, often 25 per cent or more. A crystalline mass of cholesterin sometimes forms a nucleus, round which the dark brown pigmented material is disposed in layers.

5. **" Pure " Bilirubin-calcium Calculi.**—Although bilirubin calcium is the chief constituent of these stones, there are always present, in addition, biliverdin calcium, the more highly oxidized

bilifuscin, and the still more highly oxidized bilihumin, the last-named occasionally forming over half their substance. There is always some cholesterin, although at times only traces can be detected. These calculi are always small, rarely larger than a pea (*Fig.* 79 C), and occur in two distinct forms :—

(*a*). A form of wax-like consistency, with rough irregular surface, and of a brownish-black colour.

(*b*). A form that is hard and brittle, steel-grey or black in colour, and with a metallic lustre.

6. Rarer Forms :—

(*a*). *Amorphous and Incompletely Crystalline Cholesterin Gravel.*—These calculi have a nucleus of bilirubin calcium, surrounded by a coating of cholesterin, which gives them a pearly lustre. They vary in size from a grain of sand to a pea.

(*b*). *Calcareous Stones* consist chiefly of a mixture of calcium carbonate with bilirubin calcium. They are extremely rare in man, but are more common in cattle and other herbivorous animals.

(*c*). *Concretions with Included Bodies.*—Foreign bodies, such as ligatures, needles, plum-stones, or flukes, have been met with as the nucleus round which gall-stones have formed.

Gall-stones, which when small are spoken of as biliary sand, may vary in size from a concretion just perceptible to the naked eye, up to a mass the size of a tennis ball, or even larger. They may be spherical, oval, barrel-shaped, elongated with pointed ends, or angular—the surface being smooth, mammilated, or irregularly faceted. Gall-stones larger than a hazel-nut probably never reach the intestine through the natural passages, but by a fistula formed between the bile-passages and the bowel. Large stones may become impacted in the bowel, and give rise to intestinal obstruction. The presence of well-marked facets on the surface of a gall-stone points to its origin in the gall-bladder, and shows that others are also present, but the absence of facets does not prove that the calculus is a solitary one. As a rule, gall-stones are much softer and lighter than typcial enteroliths.

Analysis.—(*a*) A fragment of the stone, heated on platinum foil in a Bunsen burner, melts, catches fire, and burns, leaving only a little ash unless the calculus is rich in calcium salts, when a considerable residue may remain ; (*b*) The remainder of the stone is powdered and dried at 100° C.

1. About 2 grams of the powder are boiled in a flask with distilled water to remove the bile acids and other substances soluble in water. The filtered extract is divided into two equal parts. One (*a*) is evaporated to dryness and weighed, thus giving the weight of the water-soluble material in the amount of dry material taken. It is

then incinerated and again weighed, the weight now obtained giving the quantity of water-soluble ash. The other half (*b*) is evaporated to dryness, and the sodium glycolate extracted with a mixture of alcohol and ether from the dry residue.

2. The residue from the water extract is dried and extracted with warm alcohol, thus separating the fats, along with a small proportion of the cholesterin.

3. The residue from this is now extracted with ether, which dissolves the cholesterin. On evaporating off the ether, the cholesterin may be weighed and recognized by its microscopical characters, best seen after re-crystallizing from hot alcohol, and its chemical reactions. (*a*) The crystals treated with sulphuric acid (5 vols. concentrated acid and 1 vol. water) melt at the edges and turn crimson. On adding a small quantity of a solution of iodine a play of colours (violet, blue, green, and red) is seen. (*b*) A small quantity of the material evaporated on the cover of a porcelain crucible with hydrochloric acid and a trace of ferric chloride gives a blue colour. (*c*) Dry cholesterin dissolved in chloroform and mixed with an equal volume of concentrated sulphuric acid gives, on shaking, a blood-red upper layer of chloroform, which changes to cherry-red and finally to purple, and a lower green fluorescent layer of sulphuric acid. With very dilute solutions, the chloroform solution is yellow to rose-red, while the sulphuric acid is yellow with a green fluorescence. (*d*) A small quantity of dry cholesterin dissolved in chloroform, mixed with a few drops of acetic anhydride, gives a rose colour changing to blue and then to blue-green on adding concentrated sulphuric acid drop by drop (Liebermann-Buchard reaction). With dilute solutions the green colour only develops on standing for some minutes. The last two reactions are equally delicate, but are given not only by cholesterin but also its esters, such as those of palmitic and stearic acids. (*e*) A specimen purified by repeated re-crystallization from hot absolute alcohol, and dried, should melt at 145° C.

4. The residue left after the treatment with ether is extracted with dilute hydrochloric acid (1-3) and filtered. The presence of calcium salts in the filtrate is shown by making a portion of the solution alkaline with ammonia and adding acetic acid and ammonium oxalate solution. Sometimes traces of copper may be demonstrated by adding a few drops of potassium ferrocyanide, when a brown colour or brown precipitate of copper ferrocyanide will be seen.

5. The residue remaining on the filter is washed with water until the washings are free from hydrochloric acid. The filter is then dried, cut into pieces, and warmed in a dry flask with chloroform. The brownish-yellow fluid that results is filtered through a dry filter and examined for bilirubin. (*a*) A small portion of the chloroform solution evaporated spontaneously on a watch-glass, shows under the microscope small, ill-defined, elongated, rhombic plates, or indistinct crystalline grains, which, on being moistened with yellow nitric acid, give the play of colours of Gmelin's reaction. (*b*) On shaking the chloroform extract with dilute sodium hydroxide, the pigment passes over into the alkaline solution, while the chloroform is more or less completely decolorized. The separated alkaline solution, on being left to stand in the air, turns green from the formation of biliverdin.

(c) The presence of hydrobilirubin can be recognized by the spectroscope.*

The fæces should always be examined for calculi in cases of "gall-stone colic," but repeated and careful search often fails to show them. This is partly due to the fact that the essential features of the attack are produced by inflammation of the bile-passages and the resulting spasmodic peristalsis, rather than by the mechanical passage of a stone through the narrower portions of the ducts, so that the presence of gall-stones is not necessary for their production. Stones in the cystic duct may fall back into the gall-bladder, and calculi impacted in the common bile-duct may give rise to a series of attacks with quiescent intervals, without passing into the bowel. Even when gall-stones reach the intestine it does not follow that they are passed as such in the stools, for Naunyn's experiments suggest that only the more solid stones escape disintegration in the bowel, the majority being broken up and so escaping detection. For this reason it is probable, in the majority of cases at least, that the passage of "biliary sand or gravel" by the bowel is a mistaken diagnosis, and that the numerous small calculi found in such cases are not gall-stones, but intestinal sand or pseudo-gall-stones, consisting of vegetable tissue impregnated with calcareous salts. A chemical examination of the material will establish the true state of affairs, and in the latter the microscope will show characteristic woody cells and tissue.

Another form of pseudo-gall-stone which has often been mistaken for the true variety, is the concretions of fats, fatty acids, and soaps found in the stools after the administration of large quantities of olive oil in the treatment of cholelithiasis. These are soft, transparent, and of a greasy consistency. If the bile-ducts are not occluded, they are of a greenish colour, due to impregnation with bile. Microscopical, and especially chemical examination, reveals their true nature, showing the absence of cholesterin in appreciable amount, and a high percentage of fats, etc.

PANCREATIC CALCULI.

Pancreatic lithiasis is a very rare condition, under a hundred cases being on record. As a rule, the concretions have been found at operation or post mortem, but in a few cases they have been recovered from the stools. At a recent meeting of the Royal Imperial Society of Physicians of Vienna, Glaessner showed two

* For a detailed account of the method of separating and estimating the pigments, etc., in gall-stones, see Abderhalden's "Handbuch der Biochemischen Arbeitsmethoden," Bd. ii., p. 635.

small pancreatic calculi the size of peas, and bearing a general resemblance to oxalic acid stones, that had been expelled in the fæces. There had been a history of repeated attacks of colic, with eventually icterus and enlargement of the liver and spleen. There was also marked salivation, achylia gastrica, alimentary glycosuria, and choluria. The patient had become cachectic and, although the fæces showed muscle fibres and well-preserved nuclei, there were no other symptoms of pancreatic insufficiency.

Pancreatic calculi (*Fig.* 80) are always small, of a greyish-white colour, and have a rough surface which does not show the facets seen on many gall-stones. Heated on platinum foil they yield a large amount of white ash, and, according to Minnich, give an aromatic odour. They are said to be readily soluble in chloroform. For diagnostic purposes, chemical analysis gives the most important information as to their nature. As a rule they contain 50 per cent or more of lime, either in the form of carbonate or phosphate or, as in one reported by Shattock, of oxalate. The stone in the latter case was found, however, in a pancreatic cyst. In addition, there may be traces of magnesium, fats, fatty acids, soaps, and traces of protein, with occasionally small quantities of cholesterin and bile pigments. The pigments and cholesterin are only found in the external layers, and are no doubt added to the calculus in the ampulla of Vater during its passage through that portion of the common duct.

Fig. 80.—Pancreatic calculi (R.C.S. 2834).

Analysis.—A qualitative analysis of the calculus may be carried out in the following way. A portion of the pulverized stone is treated in a test-tube with dilute hydrochloric acid and warmed. If gas develops on the addition of the acid, carbonates are present. Any insoluble residue is separated by filtration or centrifugalization, and examined for proteins, fats, etc. The filtrate is diluted with water and made strongly alkaline with ammonia. If a precipitate is produced, it is separated from the solution by centrifugalization, and treated with acetic acid. Ammonium magnesium (triple) phosphates and earthy (calcium and magnesium) phosphates are dissolved, while calcium oxalate remains undissolved and can be recognized with the microscope. The filtered acetic acid solution is treated with ammonium molybdate and nitric acid, and heated to 60° C. If a yellow precipitate is produced, phosphoric acid is present. One-half of the ammoniacal solution of the stone is treated with ammonium oxalate; if a precipitate of calcium oxalate results, calcium carbonate is present. To the other half a solution of sodium phosphate is added; a precipitate of triple phosphates shows the presence of magnesium carbonate.

The quantitative analysis is carried out according to the accepted methods described in chemical text-books; but, as a rule, the amount of material is too small for very satisfactory results to be obtained.

Johnston gives the following analyses of two pancreatic calculi :—

Phosphorus salts	per cent	72·3	Carbon salts	per cent	91·65
Carbon salts	,,	18·9	Magnesium carb.	,,	4·15
Organic matter	,,	8·8	Organic matter	,,	3·00

Milroy reported as follows on a pancreatic calculus removed by Moynihan at operation: "The stone contains nearly 50 per cent of calcium carbonate. A small portion of the solution in which magnesium was estimated was used for quantitative testing, so that the exact quantity of magnesium present cannot be stated. These were the only inorganic substances found. I was somewhat surprised to find phosphates absent. The organic substances consisted almost entirely of proteid. Traces of organic substance soluble in alcohol and ether were present. In the residue from the alcoholic and ethereal solutions, cholesterin and fat were the only bodies identified. Purin bases and uric acid were absent. The quantity of the original powder was rather too small for an accurate estimation of the constituents."

The high proportion of calcium found in pancreatic calculi is remarkable, for the normal pancreatic secretion contains no calcium carbonate. It appears that this substance is secreted as the result of the irritation of the pancreas arising from the stasis and infection on which the formation of the stones depends. As calcium oxalate crystals are found in the urine in a large proportion of cases of chronic pancreatitis, in my experience, and as Mayo Robson has pointed out, there is a hæmorrhagic tendency which can be controlled by the administration of calcium salts; it would appear likely that in inflammatory conditions of the pancreas there is a fundamental disturbance of calcium metabolism which, given suitable local conditions, may result in the excretion of calcium salts into the pancreatic ducts, etc., and give rise to the formation of calculi rich in salts of this base.

INTESTINAL SAND.

Although a considerable number of cases of intestinal sand have been investigated and reported on the Continent of Europe, very few have been described in English and American literature. This may be due to the stools being examined more frequently and with greater care by Continental observers, but that it is not the entire explanation is suggested by my own experience, in which I have made microscopical and chemical analyses of several thousand specimens of fæces and only found true intestinal sand on three occasions. All of these were cases of chronic colitis, the condition with which it has been most frequently found to be associated by others, and all were females. I have already pointed out that a high percentage of inorganic ash is a very characteristic feature of chronic colitis; but even when chemical analysis of the fæces shows as much as 40 per cent of ash, it does not necessarily follow that macroscopically or microscopically sand will be found in the stools, so that some other condition besides chronic colitis appears to be necessary for its formation. Dieulafoy, who has recorded a series of cases, states that there is commonly a family history of gout, and he regards the condition as one of the irregular manifestations of that disorder. Other writers have also noticed a similar association. Harley and Goodbody state that intestinal sand has only been found by them in cases where the diet was largely composed of milk; but this is not my experience. The subjects of the disorder have been women in about two-thirds of the cases, and the average age has been about thirty-five years, although examples have been recorded in children under four years of age. In many cases the passage of the sand has been preceded by paroxysms of pain, similar to those associated with biliary or renal colic, and has been attended by much flatulent distention, and in some instances by vomiting. Diarrhœa occurs in some cases and constipation in others, and mucus casts and shreds are often passed with the motions containing the gritty material. Most frequently the sand passed by these patients is of a red colour, rather duller than the common deposit of uric acid in the urine, but it may be light brown, or white, with dark patches intermingled. The amount varies considerably. Sometimes a teaspoonful or less can be recovered, but Hale White has recorded a case in which the material passed in twenty-four hours amounted to three or four teaspoonfuls when dried, and his patient described herself as a "gravel pit." As a rule, the sand is only present at intervals, the stools being free from it in the intervening periods.

Chemically, true intestinal sand consists chiefly of calcium phosphate, with a much smaller quantity of calcium carbonate, and in some cases traces of calcium oxalate, magnesia, iron, and silica. A variable amount of organic material, usually considerably less than 50 per cent, is present. The differing proportions of the latter found by different observers is probably dependent to a certain extent upon the thoroughness with which the material has been separated from adherent fæcal material, etc., before the analysis was made. Some of the published analyses are summarized in the following tables :—

	Mathieu and Richaud (1)	Mathieu and Richaud (2)	Thomson and Ferguson	Biaggi
Organic matter	30·800	45·80	28·5	29·28
Calcium phosphate	64·206	46·68	87·3	—
Calcium carbonate	3·418	5·14	11·7	43·90
Magnesium phosphate ..	—	—	—	26·82
Inorganic residue	1·576	2·38	1·0	—

	Duckworth and Garrod	Ryffel (1)	Ryffel (2)	Cammidge
Water	12·40	16·44	13·93	25·50
Organic matter	26·69	33·60	33·56	42·14
Inorganic matter	61·31	46·96	52·51	33·38
Calcium oxide	54·89	59·84	58·42	58·27
Phosp. pentoxide	42·35	33·37	28·90	37·31
Carbon dioxide	2·20	—	8·33	4·41
Mg, Fe, etc.	0·47	—	—	trace

It will be noticed that in all of these there is a marked similarity, excepting in Biaggi's case, where the calcium was present as a carbonate and not chiefly as a phosphate, and there was also a considerable proportion of magnesium phosphate instead of the traces met with by all the other investigators. A considerable quantity of magnesia was also found by Berlioz, who gives the following analysis :—

Water	11·25 per cent.
Nitrogenous organic material of fæcal origin	22·24 ,,
Fatty substances	traces
Phosphoric acid	17·56 ,,
Lime	26·22 ,,
Magnesia	14·05 ,,
Silica	8·68 ,,

The material in the case recorded by Biaggi was agglutinated into balls 6 to 8 cm. in diameter, which readily disintegrated into sand. In a case described by Mongour, gravel—varying in size from an orange pip to a hazel nut—rather than sand was passed, and chemical examination showed a high proportion of magnesium phosphate :—

Organic material	29·28 per cent.
Magnesium phosphate	26·82 ,,
Calcium carbonate	43·90 ,,

Cases of this description occupy an intermediate position between those in which intestinal sand is passed and those in which large intestinal calculi, usually composed for the most part of ammonium magnesium phosphate, are found in the stools.

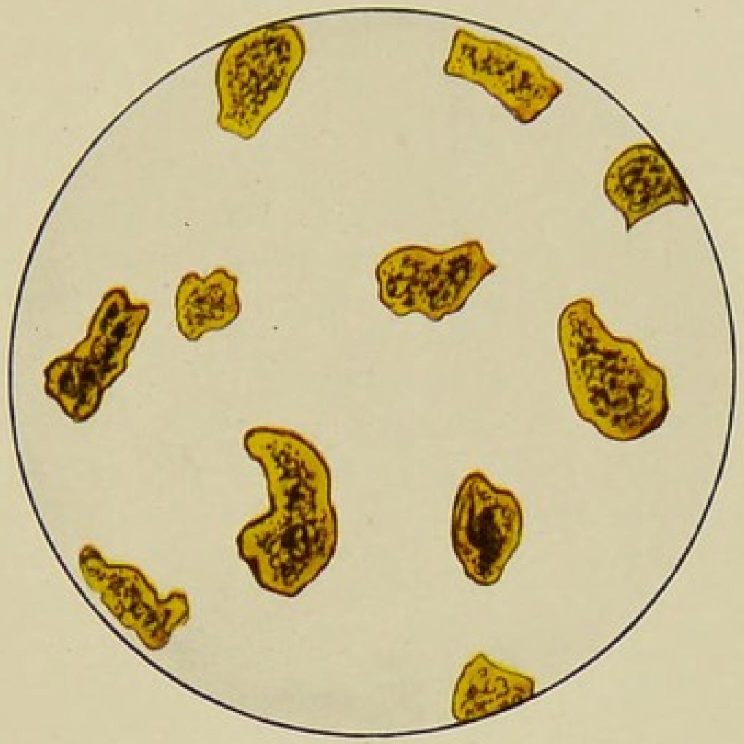
A very exhaustive analysis of a specimen of intestinal sand was made by O. T. Williams in Harley and Goodbody's laboratory, with the following results :—

Organic matter	55·6 per cent.
Inorganic matter	44·4 ,,
Calcium present as $Ca_3P_2O_8$	15·5 ,,
Calcium not present as $Ca_3P_2O_8$ ..	14·34 ,,
Iron calculated as Fe_2O_3	2·96 ,,
Magnesium calculated as Mg_2O	0·07 ,,
Phosphates calculated as P_2O_5	10·5 ,,
Carbonates	1·5 ,,
Sulphates	0·6 ,,
Chlorides	traces

The organic matter was found to contain 10 per cent of substances soluble in ether, and this ethereal extract contained 22·5 per cent as free fatty acids, and 13·4 per cent as combined fatty acids. On acidifying the residue from the ether extraction and again extracting with ether, a yield of 8 per cent of fatty acids combined as soaps insoluble in ether was obtained. The remaining portion of the first ethereal extract gave an iodine absorption value by Hube's method of 117, which is higher than that of oleic acid and lower than that of linoleic acid, so that it is possible that this, the unsaponifiable matter that it contained, consisted of a mixture of these two acids or their salts. The comparatively high percentage of fatty material (18 per cent) found in this case is in striking contrast to the traces noted by Berlioz, and also in the cases that I have investigated, where only quantities too small for measurement were obtained. Williams has published other cases in which he found that nearly one-fifth of the material consisted of fatty acids, and that about half the calcium was present as a soap in combination

EXPLANATION OF PLATE XII

1. Microscopical appearance of true intestinal sand.
2. Microscopical appearance of false intestinal sand, following the ingestion of pears.



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with saturated fatty acids, and from this he argues that intestinal sand and other intestinal concretions, which he states also contain fatty acid compounds, are formed as the result of an exaggeration of a normal excretory function of the bowel for the waste products of fat metabolism. The absence of any considerable quantity of fat in some cases is against such an explanation being invariably true, and I am inclined to think that the association of a milk diet with the presence of intestinal sand in the fæces noted by Harley and Goodbody may offer an explanation of the fat met with in some instances.

Cholesterin is never found as a constituent of intestinal sand, and bile pigments are only present in traces, thus excluding a biliary origin. Its association with intestinal disorders; the large number of included bacteria always present; and the characters of the organic bases, which are chiefly of a protein nature,—all suggest that it is formed in the intestine. The richness of the material in hydrobilirubin, and its poverty in unaltered bile pigments, point to its formation in a region where the conversion of bile pigments into hydrobilirubin is well advanced, that is to say, in the upper part of the colon. The nature of the inorganic constituents also tends to confirm this inference, for calcium phosphate and carbonate can hardly be laid down in any but an alkaline medium such as exists in the large intestine. The anatomical structure of the large intestine would also seem to be more suitable than the small bowel for the stagnation of the intestinal contents required for the formation of agglomerations of earthy salts, such as intestinal sand is largely composed of.

The chemical analysis of intestinal sand is carried out on the same lines as those suggested for pancreatic calculi, from which it is distinguished by the existence of the calcium chiefly in the form of phosphates rather than as carbonates, and by the richness of the material in hydrobilirubin.

False Intestinal Sand, consisting of the remains of vegetable foods which have resisted the action of the digestive fluids and which may or may not have acquired an incrustation of earthy salts, is much more common than the true variety. It must be carefully distinguished, since, although the passage of the former is sometimes associated with severe colicky pains, it is of no pathological significance. The occurrence of such material in the fæces was described by Marcet in 1817, and again by C. Robin in 1873. Some at least of the recorded cases of intestinal sand, such as those of Laboulbène, are no doubt of this nature. Eichhorst described a case in 1889, and in 1892 Fürbringer called special attention to the liability of confusing this material with small biliary concretions. Naunyn also pointed out that it is probably the explanation of many cases of so-called "biliary sand." In this country, specimens of false intestinal sand have been described by Delépine and Shattock. The sclerenchymatous particles which are so abundantly present in the flesh of pears, and especially in that of some varieties, is the most common cause of the condition, although other woody and indigestible materials may also be passed in the fæces as gritty particles. Bates and other American authors have described the passage of black sand-like material, consisting of the cells of bananas which have become coloured during their passage through the intestine. False intestinal sand can be most quickly differentiated from the true form by the microscope, the vegetable nature of the particles being at once obvious (*Plate XII*, 1, 2). On chemical analysis, it is found to yield only 2 or 3 per cent of inorganic ash, in sharp contrast to the very much higher proportion met with in true intestinal sand.

ENTEROLITHS—COPROLITHS—DRUG CALCULI.

Enteroliths (*Fig.* 81), or intestinal stones, are rare in man and the carnivora, but are not uncommon in herbivorous animals. They

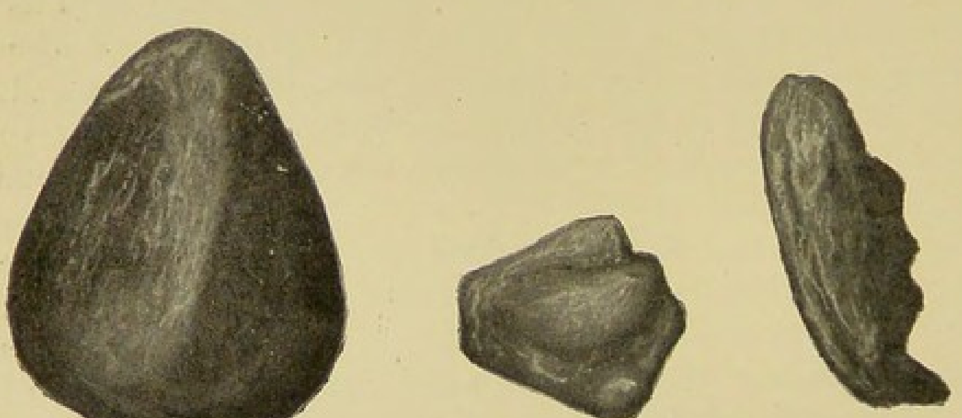

Fig. 81.—Enteroliths.

are usually round or oval, of stone-like hardness, and vary in size from a pea to a nut. On section, they are found to be concentrically stratified around a central nucleus, which often consists of a foreign body. Chemically, they consist mainly of ammonium magnesium phosphate or calcium phosphate, with a varying amount of fatty material and pigment. The latter is principally hydrobilirubin, although traces of unaltered bile pigment may be found sometimes. The nucleus may consist of fruit stones or pips, fish bones, blood-clot, shreds of vegetable material or particles of fæces, etc.

Like intestinal sand, they are formed in the large intestine, especially in the cæcum and sacculi of the colon, where the anatomical and chemical conditions necessary for their production exist.

Light Enteroliths are composed principally of undigested vegetable food particles encrusted with phosphates. They are not stratified and have no distinct nucleus. To this group belong the so-called "oatmeal-stones," which may be passed after a liberal and prolonged ingestion of oatmeal. These consist of the remains of the oat-bran arranged in concentric layers around some foreign body as a nucleus. On being ignited on platinum foil they leave a small amount of inorganic residue, and chemical examination shows the presence of calcium magnesium phosphate, with small quantities of soaps and fats. Specimens examined by Hammersten gave the following composition :—

Calcium magnesium phosphate ..	70 per cent.
Oat bran	15–18 ,,
Soaps and fats	10 ,,

Coproliths (*Fig.* 82), or fæcal concretions, are stone-like bodies composed of hardened fæcal material. They are formed as a rule in those situations in the large intestine at which stagnation of fæcal matter can most easily take place, as for example, the flexures of the colon. They are usually much larger than enteroliths, and may be of sufficient size and compactness to cause complete intestinal obstruction. They consist almost entirely of organic matter, and burn with an odour of melting fat and organic material, and leave little inorganic residue. They are largely soluble in boiling caustic potash and ether, but are insoluble in alcohol.

Fig. 82.—Coprolith.

The chemical analysis of coproliths and enteroliths is carried out by the methods previously described for intestinal sand, etc. The following results have been obtained by the observers mentioned, according to Gorup-Besanez :—

	Thomsen	Children	Robiquet	Lassaigne
Amm. mag. phosphate	5	5	30	4
Calcium phosphate ..	46	46		
Soluble salts	—	25	—	1
Protein material ..	25	4	8	21
Fat	—	—	60	74
Vegetable tissue ..	24	20	—	—

Drug Calculi.—The habitual use of insoluble, or difficultly soluble, drugs which have been taken in the form of powders, such as salol, magnesia, calcium carbonate, benzoic acid, etc., may be followed by the appearance of concretions consisting mainly of these materials in the fæces. They are always of small size, and chemical analysis based upon the nature of the drug known to have been taken, will demonstrate their nature.

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Chapter IX.

THE DIAGNOSTIC VALUE OF EXAMINATIONS OF THE FÆCES.

IN certain conditions the appearance of the stools is sufficient for a diagnosis to be made, especially at some stages of the disease, while in others a microscopical, chemical, or bacteriological examination may be necessary before any abnormality to account for the symptoms can be discovered. The methods by which these investigations are carried out have been dealt with in detail, but it will now be advisable to attack the problems of fæcal analysis from the converse aspect, and to consider the characters of the stools in the more common pathological conditions arising from disturbances of the gastro-intestinal tract and its appendages. Before doing so it will be convenient to recapitulate the characters of the *normal stools* passed under various conditions.

1. THE FÆCES DURING FASTING.

The fact that fæces are formed in starving animals was first proved by Bidder and Schmidt, and C. v. Voit, who also carried out analyses of such "hunger fæces." Our present knowledge of the composition of the intestinal contents in both starving men and animals is, however, largely based upon the classical work of Friedrich Müller.

Starving dogs excrete at several days' intervals, a dark-coloured bituminous material with a faint fæcal odour, the amount varying with the size and condition of the animal. Dogs with an average weight of 6 kilograms excrete about 0·87 gram per diem, while dogs with an average weight of 3·7 kilograms pass about 4·84 grams of fæces, calculated on the dry weight, during absolute starvation. Starving men appear to pass a smaller quantity in proportion to their body weight than dogs, for in the cases of the starving men Cetti and Breithaupt, the average weights of the stools were 3·8 grams and 2·0 grams per day respectively.

In dogs, the dried fæces contain from 5·04 to 7·96 per cent of nitrogen, with a mean of 6·5 per cent. In the two men mentioned, the nitrogen was found to be 5·67 and 8·28 per cent of the dry weight of the stools. It is as yet uncertain to what portion of the fæces the high nitrogen content in starvation is due, but no doubt detached epithelial cells, mucus from the intestinal walls, nucleins, lecithins, bile pigments, and bacteria all contribute.

An exact knowledge of the nature of the ether-soluble portion of the fæces during starvation is also lacking. Hofmann found 47·9 per cent of ether-soluble material in the dried fæces of a dog after twenty-eight days' abstinence from food, and in another animal found 34·1 per cent of "total fat," 19·8 per cent of neutral fat and free fatty acids, and 14·3 per cent of combined fatty acids. The figures for starving men are similar, namely, 34·56 per cent of total fat, 28·42 per cent of neutral fat and free fatty acids, and 6·14 per cent of combined fatty acids. The ether-soluble material appears to consist chiefly of saponified fats derived from the intestinal secretions, epithelial cells, and mucus. Unsaponifiable cholesterins only constitute a small proportion of the whole.

The total ash in the fæces of starving dogs has been found to vary between 27·2 and 18·9 per cent. In Cetti and Breithaupt it constituted 12·47 and 12·57 per cent of the dry weight respectively, corresponding to the normal values for well-nourished men. It is remarkable that, in contrast to meconium, lime and magnesia are excreted in relatively large amounts during starvation, while sulphates, chlorides, and alkalies are present in diminished quantities.

The colouring matter of hunger fæces was found by Müller to be hydrobilirubin, thus showing that even during starvation putrefactive changes which reduce the bile pigments go on in the intestine. That putrefaction does occur, although to a much diminished degree, is also proved by the formation of indol and phenol, and by the occurrence of phenol and ethereal sulphates in the urine. Müller also found cholecyanin, a pigment which is met with in normal fæces, and is related to hydrobilirubin. The unchanged bilirubin that occurs in meconium and in the stools of the newly-born is absent from the fæces in hunger.

2. MECONIUM.

During the first two days of life a material is passed out of the rectum which differs in composition and physical characters from the ordinary stool of the infant. This so-called meconium is of a dark green colour and of a thick tenacious character. On microscopical examination it is found to contain epithelial cells in various stages of degeneration, numerous cholesterin crystals, a few fat droplets, many bilirubin crystals, lanugo hairs, and the so-called meconium corpuscles (*Plate VIII*, 1). The latter are homogeneous rounded globules of a yellowish colour. Their origin is uncertain, but they are probably of an albuminous nature. At first sterile, meconium soon begins to show the presence of bacteria, generally within ten to seventeen hours of birth. The flora, although relatively scanty, is very diverse, consisting of B. coli, which is usually the first to appear (ten hours), and numerous forms of cocci and bacilli derived from the air. Even at an early stage anaerobic bacteria have been proved to be present. Meconium is, however, a poor medium for the growth of bacteria, so that it is eminently fitted for one of its main physiological functions, the exclusion of foreign organisms and the encouragement of bacteria that are destined to become the permanent inhabitants of the infant's digestive tract.

Meconium is sometimes viewed as an assimilation product, since the liquor amnii and vernix caseosa are of subordinate importance to meconium formation. It is usually passed four to six times a day, but owing to its viscous consistency and to the fact that the bowel is emptied at death, it is difficult to estimate the total amount in the human fœtus. An idea of its general composition may be formed from the following table given by Zweifel :—

Water	79·8–80·5 per cent.
Solids	19·5–20·2 ,,
Mineral matter ..	0·978 ,,
Cholesterin	0·797 ,,
Fats	0·772 ,,

There are not many observations available as to the nitrogen content of meconium, but it would seem to correspond to that of the fæces in hunger. This is rather remarkable in view of the absence of bacteria. The percentage of ether-extractable matter is considerable, although not as high as in hunger fæces, namely 13·47 per cent (lamb), 22·53 per cent (horse). The exact nature of the ether-soluble material is not known, but it contains neutral fats, higher fatty acids, wax-like bodies, cholesterin, and other unsaponifiable bodies. The total ash, according to Zweifel, is 5·1 per cent, according to Müller 6·2 per cent (man) and 9·3 per cent (horse), of the dry weight. It will be seen that these figures are lower than for hunger fæces. Meconium contains a relatively high percentage of alkalies and sulphuric acid, the latter being combined with the alkalies. The high percentage of sulphur is partly explained by the presence of taurine, which in extra-uterine life is reabsorbed after being split off from cholalic acid, whereas in meconium it is excreted unchanged. The abundant epithelial cells are also no doubt a source of sulphur. In contrast to the fæces in starvation, lime and magnesia are comparatively unimportant constituents. A characteristic feature of meconium is the presence of considerable quantities of bilirubin—about 1 per cent in the calf, according to Hoppe-Seyler. The excretion of unchanged bilirubin and its next higher oxidation product, biliverdin, to which the green colour of meconium is due, is rendered possible by the absence of putrefactive changes in the fœtal intestine. For the same reason hydrobilirubin, indol, phenol, leucin, and tyrosin are absent, but unchanged bile acids occur. According to Voit, the products of the splitting and condensation of bile acids are lacking.

3. THE FÆCES ON A FLESH DIET.

The passage of the fæces on an exclusively flesh diet is much delayed both in men and dogs. In appearance, the stools resemble those passed during starvation, and are likewise free from any pronounced fæcal odour. According to Rübner, unchanged muscle fibres are generally found in the human subject, but are usually absent in dogs. The weight of the dry fæces on a diet of 500 to 600 grams of meat is only about a couple of grams per day more than during starvation. When the diet is increased there is not the proportional rise in the weight of the stools that might be expected. Thus, when 1000 grams of meat are ingested, the dry weight of the fæces only rises to 9·2 grams, and with 1500 grams to 10·2 grams. Voit found that in dogs with a biliary fistula, there was a relation between the weight of the fæces on a flesh diet and the quantity of bile excreted. When a sufficient amount of food is given, it has been shown by Frentzel and Schreuer that the nitrogen content of the fæces averages about 8·33 per cent on a flesh diet, but when an insufficient supply is given, as in Voit's experiments, the quantity of nitrogen approaches that in hunger stools (i.e., about 6·5 per cent). As the intake of meat is increased, the percentage of nitrogen rises, until it approaches the value for undigested protein (i.e., 15·4 per cent). The average percentage of nitrogen present in the stools in any particular case furnishes therefore data from which the extent to which the food is being absorbed can be estimated. According to Frentzel and Schreuer, the ether-soluble material of the fæces on an exclusively meat diet is comparatively low, averaging in four experiments 12·72 per cent. Müller, who fed a dog of 17·9 kilos for thirteen days with 592·5 grams of meat, found 24·9 per cent, but this figure is explained by the fact that the diet was insufficient, and therefore tended to approach the percentage for a fasting animal (47·9 per cent). If absorption is defective, the percentage of ether extractives falls; thus Pflüger found 5·8 per cent in one case. It also falls if too much food is given. That the ether extract is not the residue of the food fat, but comes mostly, or exclusively, from the changed products of the intestinal glands, is shown by the saponification number, which is less than half that of the value for beef fat (83·4 : 181·6), by the different nitrogen percentage, and by the lower melting-point (39·5 to 40° : 42 to 42·5°). If fat absorption is defective, however, these values approach each other. Beside neutral fats and fatty acids, the ether extract of the fæces on a flesh diet contains cholesterin, lecithin, and cholalic acid. The ash content of the fæces averages from 13 per cent to 16 per cent in man, and 20 per cent to 34 per cent in dogs. In contrast to the fæces during starvation, the magnesium content is high (no doubt owing to the large quantity of magnesium contained in meat) and the percentage of sulphur is low. Estimations of the calcium show that in flesh-eaters almost the whole is excreted by the intestine, whereas magnesium and phosphoric acid are largely passed in the urine.

4. "NORMAL" FÆCES.

If small quantities of fat, in the form of butter or bacon, or sugar are added to a meat diet, no alteration in the fæces results; but if a large amount is given, the appearance and composition of the stools are changed owing to the presence of unchanged fat, etc. A number of other foodstuffs may also be introduced into the diet without appreciably altering the characters of the stools, if they are completely absorbed in the intestine and leave no residue to appear in the fæces. The total quantity of food, and also the amount of each variety, must not, however, exceed the assimilative capacity of the intestine, and they must also be in such a form that no hindrance is offered to their digestion and absorption. There is no essential difference in this respect between food materials of animal and vegetable origin. Well-cooked rice, bread made from finely ground flour, etc., carefully dressed meat, white of egg, and butter, all leave no appreciable residue to appear in the fæces. On what may be termed a "normal" diet consisting of such substances, the fæces consist mostly, or entirely, of the remains of the digestive secretions and the materials excreted by the gastro-intestinal tract. Prausnitz, who fed various persons on a diet consisting of easily absorbed foods, found that almost constant percentages of nitrogen (8·65 per cent), ether extract (16·39 per cent), and ash (13·82 per cent) were present in the fæces, no matter whether animal or vegetable food-

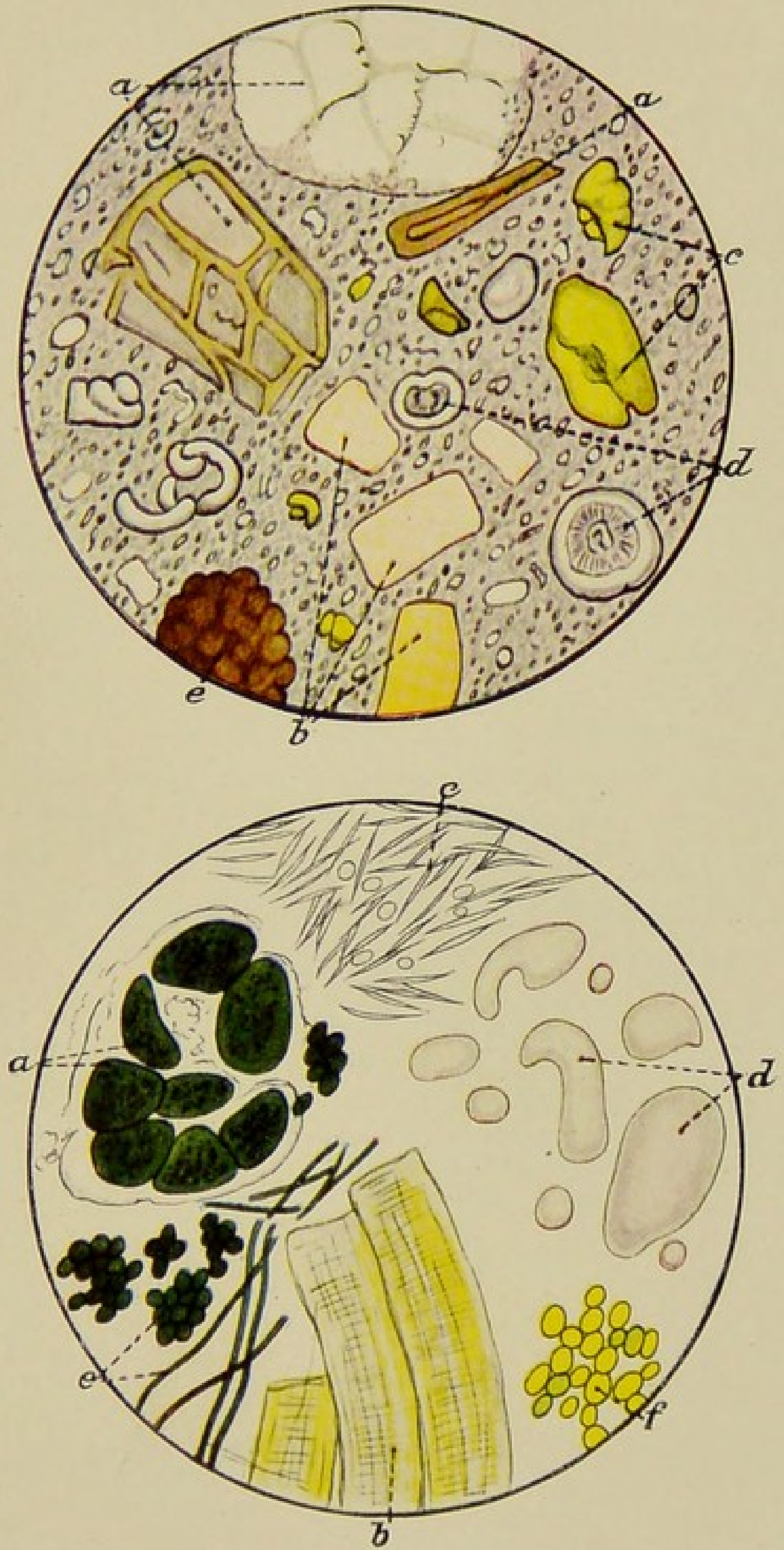
EXPLANATION OF PLATE XIII.

Food residues, etc., met with in the fæces after the use of Schmidt's test diet :—

1. In a normal individual—
   (*a*). Vegetable cells.
   (*b*). Muscle remains.
   (*c*). Bile-stained salts of fatty acids.
   (*d*). Soap crystals in ring formation.
   (*e*). Cocoa remains.

2. In pathological conditions of the gastro-intestinal tract—
   (*a*). Starch granules stained with iodine.
   (*b*). Undigested muscle fibres.
   (*c*). Fatty acid crystals.
   (*d*). Neutral fat globules.
   (*e*). Streptothrix and moulds stained with iodine.
   (*f*). Yeast cells stained with iodine.

PLATE XIII.



stuffs predominated. The figures he obtained are very similar to those given by the stools of meat-eaters, the most noteworthy difference being in the percentage of ether extract, which is a little higher. It is not certain to which constituent of the fæces this excess is due. Möller has investigated the microscopical characters of the fæces formed with various vegetable foods, and found that finely-ground wheat or oats, and white bread, also potato and vegetable purées, leave no starch residues ; but the accuracy of his statement that starches can be absorbed if they are only mechanically enclosed, as in rice, chipped potatoes, etc., is doubtful, according to Schmidt and Strasburger. These authors, making use of a test diet containing carefully prepared porridge, potato, minced beef, butter, eggs, and milk, found that they were absorbed almost without residue by the normal intestinal tract. When, however, the digestive and absorptive functions of the intestine are defective, starches and proteins appear in the fæces in a more or less unaltered condition, and by means of the " fermentation test " they distinguish between the carbohydrate and protein residues met with in pathological stools. Quantitative estimations of the mineral content of the fæces on Schmidt's diet have been made by Albu, but his results need confirmation. The stools on this diet are generally well formed, of a light brownish-yellow colour, and have a peculiar earthy smell. They are frequently brittle, and easily break into a fine powder on being dried.

5. THE FÆCES ON A MILK DIET.

It might be thought that milk, being an easily absorbed food, would furnish an ideal diet and leave no residue to appear in the fæces. This assumption is not, however, borne out by the facts. We have seen that on a diet of meat the weight of the fæces is not proportional to the amount of food taken ; on a milk diet, on the contrary, it has been shown by Rübner that there is a parallelism between the quantity of milk and the bulk of the stools. Thus, when 1025 grams of milk were given, the fæces weighed 11·4 grams, with 2050 grams of milk 22·5 grams, and with 4100 grams of milk the weight of the fæces was 50·0 grams. It would therefore seem that a definite portion of the milk taken is absorbed in the intestine, and that a definite portion is passed in the stools. A large percentage of the latter, sometimes as much as one-third of the dry weight, consists of inorganic ash. This is explained by the fact that milk is rich in calcium salts, which are not absorbed. The composition of the fæces of adults on a milk diet, obtained by various observers, is shown in the following table :—

	1 day: 2050 gr. (Rübner) per cent	2 days: 2200 gr. (F. Müller) per cent	3 days: 2438 gr (Rübner) per cent	2 days: 2500 gr. (Rübner) per cent	2 days: 3000 gr. (F. Müller) per cent	1 day: 3000 gr. (Prauss-nitz) per cent	1 day: 3000 gr. (Rübner) per cent	1 day: 4100 gr. (Rübner) per cent
Weight (dry) ..	8·4	8·1	7·8	5·7	6·1	8·96	11·2	9·4
Nitrogen	7·0	5·9	6·5	7·0	4·8	11·2	12·9	12·0
Fat ..	7·1	7·2	3·3	2·6	6·9	5·05	7·1	4·6
Ash ..	46·8	38·2	48·8	24·3	39·4	37·1	41·45	44·5

Although these figures do not give an exact indication of the proportion of food lost in the stools, since an unknown quantity is not derived from the ingesta, they show that the ash of milk is badly utilized, while the fat is almost entirely absorbed. The nitrogen content of the fæces suggests that the nitrogen of the food is imperfectly made use of. According to Müller, the latter defect is more apparent than real, since he failed to find casein residues in the fæces when an exclusively milk diet was taken. He considers that the high percentage of nitrogen is due to increased intestinal secretion, so that milk is not as badly utilized a foodstuff as might at first sight be thought, but merely a substance that gives rise to an increased formation of fæces. Even if this be allowed, however, the fact remains that on an exculsively milk diet, oxidizable substances are excreted unutilized in the stools by adults. Camerer has investigated the effect of an exclusive milk diet on the fæces of children between the ages of four and twelve years, and obtained very similar results.

With infants the state of affairs is very different. Lange has shown that the nitrogen absorption of young children on a milk diet is very much better than in adults, and that the mineral matter is also more completely utilized. The latter, he suggests, is explained by the fact that growing individuals, and especially infants, require lime for bone-formation, so that there is a diminished excretion of this substance by the intestine; at the same time there is less phosphoric acid excreted, owing to its being combined with the calcium in the bones. According to Rübner, a well-nourished infant of seven and a half months, taking a litre of milk a day, passes in its fæces 6·4 per cent of nitrogen, 35·9 per cent of ash, and 3·5 per cent of fat. In younger children fat absorption is, however, not as complete as this. If the percentage of dried fæces to fat is taken in adults, it will have a value of 11·9 to 13·4 per cent, in an infant of four to five months old 23·2 per cent, and during the first month 30 to 45 per cent.

The ether extract of the fæces in infants on a milk diet is chiefly neutral fat, the saponified fats being of secondary importance, but in adults the reverse condition obtains, 75 per cent of the ether extract consisting of free fatty acids and soaps. It is therefore evident that in early life the fat-splitting power of the pancreas is undeveloped.

The ash contents of the fæces of infants brought up on the breast and on cow's milk show only a slight difference, the composition of the milk in the two cases explaining the higher percentage of lime and phosphoric acid found in the latter.

In the first few days of life, the colouring matter of the stools is exclusively bilirubin. According to Schorlemmer, hydrobilirubin first appears in the fæces of artificially-fed infants after about seven days, and in breast-fed children after about fourteen to fifteen days.

6. THE FÆCES ON A MIXED DIET.

The colour of the fæces on a mixed diet varies according to the character of the food, being light brown or greenish, when carbohydrates or vegetables containing chlorophyll preponderate, and dark brown or slate-coloured when a considerable proportion of meat is taken. Moreover, the colour varies from day to day. As a rule, they are of firm consistency, and on being dried are readily ground down to a fine powder. The total amount may vary between 30 and 280 grams, with an average of about 102 grams, but the quantity is largely dependent upon the nature of the diet, a preponderance of meat giving small stools, and of vegetables large ones.

A determination of the nitrogen content, together with the percentage of fat and ash, permits of conclusions being drawn as to the way in which the food is being utilized. If a sufficient diet is being taken, the percentage of nitrogen approaches the mean value for normal fæces, namely 8·65 per cent. An increased nitrogen percentage would point to the imperfect utilization of a diet too rich in nitrogen, while a low nitrogen percentage would point to a deficiency of absorbable nitrogenous food. It has been shown by Müller that by feeding dogs entirely on black bread, the nitrogen content of the fæces may be reduced to that of the bread, suggesting that in such a case the food is excreted almost unchanged.

In support of this are the microscopical investigations of Möller, who found that the starch granules of cereals, vegetables, etc., and also those enclosed in vegetable albumin, are almost completely undigested, the cellulose envelopes not only being themselves undigested, but also protecting their contents from the intestinal secretions. They consequently appear in the fæces in a more or less unaltered condition. In a similar way, the elastic and white fibrous tissue of tendons and muscle sheaths, etc., interfere with the disintegration and digestion of the enclosed muscular tissue by the gastric and intestinal secretions. Since white fibrous tissue is acted upon by the gastric juice, especially after it has been cooked, muscle fibres are only found in the fæces in very small numbers under normal conditions. Egg albumin and serum albumin are also absent if the digestive functions are being well carried out.

The extent to which fats are absorbed depends upon three factors: the quantity taken, its melting-point, and the amount and condition of the enveloping tissues. When large quantities of fat, of a high melting-point, and enclosed in undigestible material, are consumed, it is excreted in a more or less unaltered condition in the stools; but since Hösslin has shown that on a diet poor in fat more may be excreted in the fæces than has been ingested, it is not possible to say in any particular case how much comes from the food and how much is derived from the intestinal secretions.

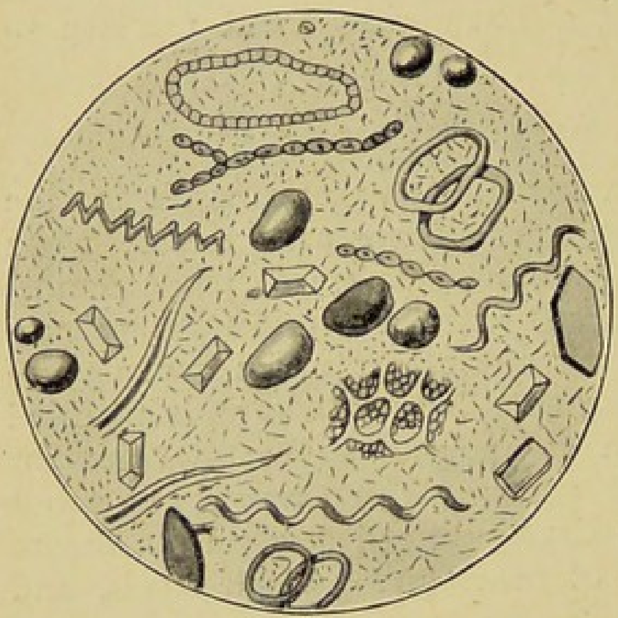


Fig. 83.—Normal fæces—plant hairs, vegetable sclerenchyma, yeast cells, fat crystals, triple phosphate crystals, etc.

The ash of the fæces may be as low as 7 or 8 per cent when large quantities of bread are taken, or rise to 20 or 25 per cent when meat preponderates in the diet; but as a rule for an average mixed diet it ranges between 10 and 15 per cent of the dry weight of the stool.

THE FÆCES IN PATHOLOGICAL CONDITIONS.

The commonest and most readily recognized abnormality met with in investigations of the fæces is a variation in the frequency of their passage, associated with a more or less marked alteration in the consistency. When the bowels are opened with insufficient frequency, the stools are unnaturally small in amount, or they are abnormally hard and dry, the condition is known as constipation; whereas when the contents of the bowel are evacuated with too great frequency, and are liquid or watery in character, diarrhœa is said to exist. The latter term is sometimes also used to describe abnormal frequency of the motions alone, but as many perfectly normal individuals pass two or three solid stools daily, it is better to confine it to states where the fæces are of a fluid or pultaceous character.

CONSTIPATION.

The frequency with which the bowels are evacuated is a personal idiosyncrasy. Although it is often considered that a normal individual should have one action of the bowels daily, it is not rare to meet with perfectly healthy people who defæcate two or three times every day, or with others who regularly empty their bowels only once in two or three days. It is therefore impossible to lay down any hard and fast rule, and although for practical purposes it may be taken that constipation exists if the bowels are not opened at least once every forty-eight hours, the usual habits of the patient should be enquired into before a definite diagnosis is made. Hertz points out that on an average nine hours are required for the residue of a meal to reach the splenic flexure, and that in defæcation all the contents of the large intestine beyond that point are excreted; if, therefore, the longest period that can elapse after a meal before the splenic flexure is reached is allowed to be sixteen hours, some of the residue of a meal taken eight hours after defæcation should be excreted in the next motion passed by individuals whose bowels are opened regularly every twenty-four hours. If, however, the bowels are opened only on alternate mornings, forty-eight hours would elapse before the residue of the meal would commence to appear. He therefore defines constipation as a condition in which none of the residue of a meal taken eight hours after defæcation is excreted within forty hours. This definition embraces the varieties of constipation already referred to, and also includes the "cumulative constipation" described by Field and the "fragmentary constipation" referred to by Boas. In cumulative constipation, although the bowels are opened every day, the contents of the large intestine beyond the splenic flexure are not completely evacuated, so that an accumulation, analogous to the collection of urine that occurs in retention with overflow, takes place. Fragmentary constipation is a variety of this condition. It is met with chiefly in men, and is characterized by a constant feeling of fullness in the rectum, which leads to attempts at defæcation many times a day, with an unsuccessful result, or the passage of a small hard fæcal fragment after great effort.

The fæces in constipation may be passed as sausage-shaped rolls or as scybalous masses varying in size from a pea to a walnut. They are usually darker than normal, and may be almost black. The scybala are sometimes very hard, and the fæces are always drier than normal. The surface is often coated with thick tenacious mucus, which is sometimes streaked with blood. Unless there is an associated catarrhal affection of the bowel, the stools are, as a rule, not offensive, and the harder the motions are, the less odour they have. If there is also catarrh, or purgatives have been given, very foul-smelling stools may be passed. A microscopical examination of the fæces is of some importance, for although in many instances only the usual remains of vegetable tissue, epithelial cells, etc., met with after a mixed diet, are found, the presence of an excess of leucocytes may indicate that there is a tendency to catarrh of the bowels or a retention of scybala causing irritation of the intestinal walls. In other cases, again, the absence, or diminished amount, of the residues usually met with on a mixed diet, will suggest that the food is of an improper kind or is being too completely digested. Crystals of ammonium magnesium phosphate are commonly found, and sometimes calcium oxalate and numerous cholesterin crystals may be seen. Chemical analysis of the fæces shows that mucus is nearly always present, but it is not intimately mixed with the fæces, and usually only coats the exterior. A watery extract of the stool generally gives no reaction for albumin. Blood may be met with on the surface of scybalous masses, owing to injury caused to the mucous surfaces and anus during their passage; and in cases where there is congestion of the liver with venous engorgement of the intestine or an associated ulcer of the gastro-intestinal tract, either simple or malignant, occult blood may be detected intimately mixed with the stool. A quantitative analysis nearly always reveals a marked diminution in the percentage of water, which may vary from 40 to 70 per cent. In spite of the abnormal length of time the fæces are retained in the bowel, there is no increased absorption of nitrogen or fat, and the percentage of these in the dry stool is usually about normal. The proportion of inorganic ash is usually not much changed, unless there is an associated intestinal catarrh, when an abnormally high percentage will be found.

With the exception of the water content of the stool, and possibly the absence of a normal amount of undigested residue, the fæces in constipation do not show any striking variation by which the condition can be recognized or its cause diagnosed in the laboratory. Reliance has to be placed more on the history of the case and the results of a clinical examination. In doubtful cases, the number of hours which the food takes to pass from the mouth to the anus, and the probable cause of any delay, can be determined by radiography after a bismuth meal or by giving a drachm of charcoal, or 6 to 7 grains of carmine, with food eight hours after defæcation, and watching for the appearance of the colouring matter in the fæces. In the latter case, the patient cannot be regarded as constipated, if a coloured stool is passed within forty hours.

The causes of constipation may be naturally grouped as follows :—

1. **Faults in the Diet.**—Since the composition of the diet is an important factor in the stimulation of peristalsis, foods which are very completely absorbed, owing either to their composition or mode of preparation, tend to produce constipation. A diet consisting largely of meat, or milk, is for this reason apt to produce sluggishness of the bowels, especially when all indigestible residues are removed from the meat, as is so frequently done by the expert cook. Carbohydrates, on the other hand, no matter how carefully prepared, do not tend to induce constipation, for, although they leave very little mechanical residue, they give rise to various acid products and gases which stimulate peristalsis. The fatty acids and soaps formed in the digestion of fats also act as stimulants to the movements of the intestine, so that a diet which is deficient in fat may cause constipation. A diet consisting principally of vegetables leaves a large cellulose residue which mechanically stimulates the intestine. If too little water is taken, or an excess of fluid is by any means drained from the body, the fæces tend to become dry and remain too long in the bowel. On the other hand, astringent drinks, such as strong tea, claret, etc., in excess, may confine the bowels. It is obvious, therefore, that an inquiry into the diet of a patient will often throw considerable light on the cause of his constipation.

2. **Psychic.**—Owing to prudery, lack of time, or indolence, many people, and especially women and business men, neglect the call to stool and do not form a regular habit. In such cases the normal sensitiveness of the rectum is gradually lost and chronic constipation is established. It is sometimes claimed that constipation may be inherited, but it is probable that inattention to the child in securing a regular movement of the bowels, and improper feeding, are more important causes. Grief, fright, or anger often cause indigestion by paralyzing the motor and sensory fibres, thus inhibiting secretion, and may bring about constipation, although diarrhœa is a more common result.

3. **Age.**—In addition to the congenital causes of constipation in infants, and the psychic causes met with in later life already

mentioned, it must be remembered that old age plays an important part in the etiology of constipation, not only because of the numerous diseases incidental to that time of life, especially cardio-renal and vascular disorders, stomach and bowel affections which restrict the diet, and prostatic hypertrophy; but also because the lack of appetite may lead to small and too concentrated meals being taken, so that satisfactory stimulation of the bowels is not effected.

4. **Diminished Power of Expulsion.**—Insufficient exercise, sedentary occupations, and obesity all tend to induce constipation by diminishing the tonicity of the abdominal and intestinal muscles, as do also many diseases inducing atrophy of muscles, disease of the heart and lungs, disorders of metabolism, congenital or acquired enteroptosis, the latter more particularly in women who have borne children and have diastasis of the recti muscles and pendulous abdomens, also a relaxed perineum following lacerations during child-birth.

5. **Diseases of the Stomach.**—In chronic gastritis, ulcer, dilatation and malignant disease of the stomach, and also in various functional disorders where the consumption of food is followed by a feeling of pressure and fullness in the epigastrium, a diet is often taken which leaves little residue and so causes constipation.

6. **Diseases of the Intestine.**—Chronic catarrh of the intestine, more particularly of the flexures, cæcum, and rectum, frequently causes chronic constipation which may alternate with diarrhœa, owing apparently to the spastic condition of the musculature of the colon that is induced. The treatment of appendicitis and typhlitis with large doses of opium frequently leaves behind it chronic constipation. Laparotomy also brings about a similar result, which may be temporary or permanent. The former is dependent upon the paralyzing influence of the anæsthetic and exposure of the intestine, and passes off; but a permanent weakening of the muscles that are concerned in downward abdominal pressure may also result.

7. **Affections of the Nervous System.**—Hysteria, diseases of the brain and spinal cord, tabes dorsalis and mental affections, may cause constipation from impairment of the innervation of the intestinal wall. In chronic lead poisoning it is well known that constipation is a constant symptom, which frequently develops into attacks of lead colic. It is believed that the constipation is a result of a paralysis of the splanchnic nerves which inhibits the automatic ganglia of the intestinal wall. The colic is merely an acute exacerbation of the intoxication.

8. **Mechanical Obstructions** giving rise to constipation may be divided into those which arise within the bowel and those compressing the intestine from without.

(*a*). *Obstruction from within* may be caused by fæcal impactions, stricture, foreign bodies, calculi from the bile-passages, pancreas, or intestine, volvulus, invagination, hernia, tumours, deformity, displacement, angulation of the intestine, splanchnoptosis, enteroptosis, hypertrophy of the valves of the rectum, the recto-sigmoid muscle, or sphincters, rectocele, piles, fissures, and fistulæ.

(*b*). *Obstruction from outside* may arise from tumours and displacements of neighbouring organs, including the spleen, liver, stomach, kidneys, pancreas, uterus, and ovaries. These act at first by diminishing the lumen of the intestine by pressure, and later by exciting a catarrhal inflammation, and also in some cases by kinking the bowel through the formation of adhesions. Adhesions formed after operation on the intestine or neighbouring organs may obstruct the bowel. Effusions into the peritoneum, or very large ovarian cysts, etc., may crowd the intestines together, and so interfere with their functions.

For purposes of diagnosis and treatment, most Continental authorities divide cases of chronic constipation into two great classes: (1) The atonic; (2) The spastic, the latter being in many instances a sequel of the former. Cohnheim maintains that all cases of chronic constipation, excepting where the condition is due to "neurasthenia," pass through an atonic stage; but the researches of Schmidt and Strasburger suggest that in many it may arise, not from muscular weakness, but through a too complete digestion and absorption of the food, which consequently does not leave sufficient residue for the growth of bacteria and the formation of the acids and gas by which peristalsis is largely stimulated. Lorisch's experiments tend to confirm Schmidt and Strasburger's conclusions. After a patient has suffered for some time from intermittent or persistent constipation, whatever may be its cause, mucus will make its appearance in the stools, usually in jelly-like masses round scybala. Although this is often considered to mark the commencement of the catarrhal stage, there can be no doubt that catarrh of the intestinal wall exists long before any mucus becomes obvious. For a time the patient may now suffer from alternating constipation and diarrhœa, with occasional distention of the bowels, flatulency, etc., the diarrhœa, according to Ewald, being produced by fermentative changes in the stagnant stercoraceous material in the ileocæcal region. At this stage scybala are apt to accumulate in the colon, especially at the flexures, and, setting up irritation in the mucous membrane, cause a marked increase in the quantity of mucus secreted. If now the fæces are retained for any length of time, their liquid contents are absorbed, so that they become very hard, and the mucus is converted into a tenaceous stringy mass. Owing to further irritation of the intestine, muscular contractions are set up, pain, tenderness, and colicky symptoms supervene, and the passage of large masses or strings of thick mucus, with hard fæcal collections, mark the onset of the spastic stage of constipation. If we follow Cohnheim, it may be laid down as a general rule that constipation without pain is of the atonic variety, constipation with associated gas and mucous colic is of the spastic type. The two conditions often overlap, however, to a certain extent, and may be combined, especially in patients with neurasthenia, hysteria, and enteroptosis. According to Cohnheim, they may be differentiated by the following characters :—

	Atonic Constipation	Spastic Constipation
Frequency	Very common	Comparatively rare
Onset ..	Slow	Sudden, with mucus and colic
Pain ..	Early, none; later, slight discomfort after some foods	May be severe or slight
Laxatives	Effective	Effective only in large doses
Enemata ..	Effective..	Of little use
Stools ..	Normal form and consistency	Often ribbon-like and thin
Rectum ..	Full	Empty, or filled with large fæcal mass
Palpation	Sigmoid flexure and transverse colon full of fæces	Colon sensitive to pressure, sigmoid flexure and transverse colon felt as hard cords
Mucus ..	Not excessive	Frequently found in form of a membrane

Before making a diagnosis of spastic constipation, it is necessary that the anus should be carefully searched for piles, erosions, and fissures, and the entire intestinal tract be examined for stenosis, ulcers, and irritable conditions of the peritoneum, which might excite reflex muscular spasm.

Hertz considers that, although a considerable number of cases of constipation are due to atony or spasm of the intestinal muscles, many are dependent upon neither. He considers that they can be more satisfactorily classified according to the way in which the two great physiological processes which maintain the regularity of the bowels are deranged. There are consequently two main classes: (1) Intestinal constipation, in which the passage of the food residue from the stomach to the pelvic colon is delayed, whilst defæction is normal; (2) Pelvi-rectal constipation or dyschezia, in which there is no delay in the arrival of the fæces in the pelvic colon, but their final excretion is not adequately performed. These two types of constipation can only be separated with certainty, and the predominant condition be determined when they are present together, by a series of examinations of the abdomen with the x-rays after two ounces of bismuth oxychloride, mixed with porridge or bread and milk, have been taken. In intestinal constipation, delay is observed during the passage of the bismuth through some part, or all, of the colon, and occasionally in the small intestine, while in dyschezia no delay occurs in the intestines, but the act of defæcation does not completely empty the pelvic colon and rectum.

The causes of intestinal constipation are subdivided into :—

1. Those due to deficiency in motor activity, including :

(*a*) Weakness of the intestinal musculature—as from congenital hypoplasia, senile hypoplasia, flatulency, obesity, chlorosis, cachectic conditions, rickets, etc.

(*b*) Deficient reflex activity—arising from (i) Insufficient stimulation of the intestinal movements owing to insufficient or unsuitable food, too complete absorption of the food ("greedy colon"), lack of exercise, œsophageal or pyloric obstruction; (ii) Deficient sensibility of the intestinal mucous membrane, such as may arise from excessive tea-drinking or the habitual use of purgatives, an excess of mucus as in catarrhal colitis; (iii) Depression of the nervous system, as in neurasthenia, hypochondriasis, insanity.

(*c*) Inhibition of the motor activity of the intestine: (i) Directly, by lead poisoning; (ii) Centrally, by shock, annoyance, or worry; (iii) Reflexly, by painful diseases of the abdominal and pelvic viscera, particularly the vermiform appendix, female genitals, stomach, duodenum, and gall-bladder.

(*d*) Irregular spasmodic contraction of the intestine, particularly of the colon, and most frequently in the iliac and pelvic portions.

2. Those in which excessive force is required to carry the fæces to the pelvic colon, arising from :

(*a*) Obstruction by fæces which are abnormally dry from insufficient water being consumed or from an excessive loss by other channels.

(*b*) Narrowing of the intestine by kinks, intussusception, malignant or simple strictures, etc., or from the pressure of tumours, etc., from without.

The causes of pelvi-colon constipation are divided into those dependent upon :—

1. Weakness of the voluntary muscles of defæcation, which is especially common in women who have been pregnant, persons who

suffer from ascites, have had large abdominal tumours, or are very fat, and may also occur in asthma and emphysema.

(*a*) Habitual disregard of the call to defæcation from modesty, laziness, or lack of time.

(*b*) Unfavourable posture during defæcation.

(*c*) Primary weakness of the defæcation reflex, particularly in infants.

(*d*) Organic nervous diseases, such as tabes dorsalis, myelitis, meningitis, etc.

(*e*) Hysteria.

2. Obstacles to efficient defæcation arising from :

(*a*) Hard and bulky fæces, from intestinal constipation or loss of fluid.

(*b*) Spasms of the sphincter ani, due to fissures, ulcers, etc., of the anus, or reflexly from affections of the genito-urinary organs.

(*c*) Organic stricture of the rectum or anus, which may be congenital, or the result of disease.

(*d*) Pressure on the rectum from without by pelvic tumours, etc.

(*e*) Invagination of the mucous membrane of the upper part of the rectum into the lower.

Constipation in Infants is most commonly due to faults in the diet, and is much more frequently met with in children fed by the bottle than in breast-fed infants. The intestines are normally stimulated to perform their functions by the fat and lactose contained in the milk. Up to the age of four months the bowels are opened from two to four times a day, and for the remainder of the first year are usually opened twice, but in some infants only once, daily. At first defæcation is a purely reflex act, but after the second or third month the infant is gradually educated to defæcate in response to external stimuli, the act subsequently coming more and more under the control of the will. Constipation in infants, as in adults, may be shown by the stools being pasty, firm, or hard and dry, when they usually lose their bright orange colour and become pale grey or white ; or by infrequency of defæcation ; but so long as the motions retain their normal physical characters, diminished frequency is not a source of inconvenience, and the infant who passes one such stool a day should not be considered constipated. Analyses of the firm dry fæces will show that they are deficient in water and fats, and that the ash content is abnormally high. This is a result that might be expected to follow the administration of cow's milk, for it is rich in calcium salts, and to reduce the percentage of protein to approximately that of human milk, it must be diluted, with the result that the fat and sugar are present in very inadequate quantities. Although undiluted cow's milk contains about the same percentage of fat as breast milk, the lactose is about 30 per cent too low, and by dilution it is still further reduced ;

unless, therefore, a proper proportion of fat and of sugar, in the form of cream and lactose, are added to the dilution, it cannot be expected to have the same stimulating effect on the intestine as human milk. The use of artificial foods is very apt to be followed by constipation, for they are generally deficient in fats and contain more or less unaltered starch. The premature use of starchy foods usually leads to a condition in which constipation alternates with diarrhœa. Occasionally constipation in infants is due to congenital hypoplasia of the intestinal muscles, kinks in an abnormally long pelvic colon, imperfect development of the defæcation reflex, weakness of the abdominal muscles due to malnutrition or stretching from flatulent distention of the stomach and intestine, or to congenital narrowness of the anal orifice.

DIARRHŒA.

In the healthy individual, a great part of the water taken in the food is absorbed in the upper part of the small intestine, but even at the lower end of the ileum the intestinal contents normally contain about 90 per cent of water. When the chyme enters the cæcum and ascending colon, absorption takes place rapidly, but the contained material is still quite soft. In the transverse colon further absorption occurs and the fæces become firmer. Very little change in consistency results from their passage through the descending colon, and it is only when the pelvic colon is reached that the normal firm character of the stools is arrived at. They are then found to contain about 75 per cent of water. Abnormally fluid stools may arise from a too rapid transit of the intestinal contents through the bowel, so that absorption is interfered with; from the presence of salts or other bodies which raise the osmotic tension and so interfere with absorption; or an excessive transudation or secretion of fluid by the walls of the gastro-intestinal tract. Each of these may be dependent upon a variety of local or general causes. In most cases of diarrhœa more than one factor is involved, although in many the excess of fluid can be attributed predominantly to one or other of the physical conditions mentioned.

Diarrhœa may be acute, or occasional, and chronic. The acute form arises from faults in the diet, constipation, cold, the presence of some poison or toxin in the blood resulting from faulty metabolism, or from an infection. The chronic form may result from an acute affection not being arrested, from the occurrence of complications such as ulcers of the intestine, etc., or be consequent on intercurrent chronic affections of other organs. It is also often primarily due to chronic disease of other organs, or may depend upon infections or toxæmia. For clinical purposes the causes of diarrhœa may be most conveniently classified into three great groups: (1) *Intestinal*; (2) *Nervous*; and (3) *Vicarious*.

1. **Diarrhœas of Intestinal Origin** are the most important. They may be divided into those due to :—

(*a*). *The irritating character of the intestinal contents,* such as coarse hard food, especially vegetables, etc., rich in cellulose, and putrefying meat or other proteins, which set up a localized catarrh leading to increased peristalsis. An excess of sugar in the diet is a common cause of diarrhœa in infants, owing to the formation of acids and gases which stimulate the intestines to abnormal activity. If the contents of the intestine are too acid, as in some cases of hyperchlorhydria, or are too alkaline, as in achylia gastrica, the growth of certain forms of bacteria may be favoured, with the result that peristalsis is powerfully stimulated by the gas and waste products to which they give rise. Irritating toxins, acids, and gases may also result from the ingestion of foods that contain poisons or bacteria that form them, as in ptomaine poisoning. Certain drugs, such as arsenic, antimony, perchloride of mercury, and the ordinary purgatives, may directly bring about irritation of the intestinal wall. Parasites, such as tape-worms, round-worms, and trichinæ, may induce diarrhœa, either by the irritation they produce or by the chemical effects of their secretions.

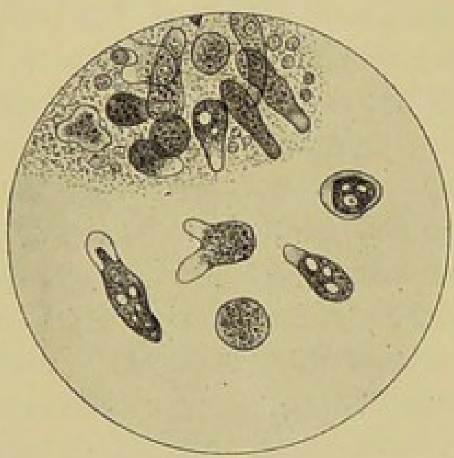


Fig. 84.—Amœbic dysentery.

(*b*). *Infections* are by far the most common cause of diarrhœa. They may be due to the cholera vibrio, typhoid or paratyphoid bacilli, the dysentery bacillus, amœba coli (*Fig.* 84), Morgan's bacillus, the malaria plasmodium, the influenza bacillus, the tubercle bacillus, and many others, including the unknown organisms of sprue and summer diarrhœa in children. The causative organism sometimes reaches the intestine from the blood, and at other times from the mouth. Buchner found that on injecting hypodermically a pure culture of cholera vibrios into guinea-pigs, the organisms soon after made their appearance in the intestinal contents. Miller and Baumgarten have shown that bacteria swallowed with the saliva may, under certain circumstances, pass through the stomach unaffected by the gastric juice and appear in the fæces in an unaltered condition. In a healthy individual, the acid reaction of the gastric contents acts as an effective check upon the growth of non-sporulating bacteria, and is actually destructive to many varieties, while the dilution of the intestinal contents with bile, pancreatic juice, and the secretions of the bowels, together with their rapid passage, militate against a rich bacterial flora in the small intestine. It is only when the lower ileum and cæcum are reached that the bacteria multiply to any great extent, and even here the development of "wild" varieties appears, according to the researches of Herter and others, to be held in check under normal conditions by the activity of the obligate parasites, and particularly coliform organisms. Should large numbers of a pathogenic variety be ingested, a certain proportion may run the gauntlet of the various defensive mechanisms and, reaching the lower part of the small intestine and colon, develop, giving rise to pathological changes in the intestinal wall, and thus cause diarrhœa. This seems to be especially liable to happen when the bacteria are taken into an empty stomach, or into a stomach the motility of which is defective, and that secretes only small quantities of gastric juice with a low content of hydrochloric acid. An examination of the stomach contents should therefore be made in all cases of chronic diarrhœa not yielding to the usual treatment.

(*c*). *Catarrhal inflammations* of the small and large intestine, either singly or together, are a very common cause of diarrhœa, and may arise from a great variety of causes, including impacted scybala, habitual constipation, indigestion, intoxication, alcoholism, colds, infections, tuberculosis, dysentery, ulcers, tumours, cirrhosis of the liver, passive congestion from cardiac disease, arterio-sclerosis, nephritis, etc. Impaction is a very common cause of catarrh of the intestine, and it should always be borne in mind that diarrhœa is consequently one of the frequent symptoms of chronic constipation. Diarrhœa is often due to catarrhal inflammation of the whole intestinal tract, and in some instances of such a chronic entero-colitis there is alternating constipation and diarrhœa. Appendicitis may begin with acute diarrhœa, and the possibility of this should be remembered.

(*d*). *Local conditions* in the rectum, chronic intussusception, catarrhal or ulcerative colitis, etc., may also be associated with diarrhœa.

2. **Nervous Diarrhœa** may arise from (*a*) irritation or paralysis of the peripheral nerves supplying the intestine; (*b*) affections of the central nervous system producing similar effects; (*c*) psychic or purely nervous causes. It is possible that the diarrhœa arising

from exposure to cold, wet feet, etc., may be partly of nervous origin, peristalsis and the intestinal secretions being stimulated or arrested, so that in the latter case the development of bacteria is encouraged, with the result that fermentation and gas-formation are increased. Vasomotor paralysis is in some cases probably the explanation of the diarrhœa that results from fright and great anxiety, the transudation of water setting up contractions of the intestinal wall and giving rise to copious water-stools. Psychical or habit diarrhœa is undoubtedly of nervous origin, and is a form of nervousness which brings about a desire to empty the bowels whenever the necessary facilities are available, immediately after meals or under the influence of excitement. Many cases of chronic diarrhœa are neurasthenic or hysterical, and as auto-intoxication is possibly the cause of these conditions in some instances, it is not unlikely that they are in reality primarily intestinal. The so-called "morning diarrhœa" may be of this type, but according to Hoof it is often dependent upon gastric anacidity, and results from the absence of the acid control normally exerted by the duodenum over the stomach.

3. **General Diseases,** such as nephritis, gout, and pulmonary affections, may be associated with diarrhœa. In these, the condition is due to the presence of toxic substances in the blood and may be regarded as vicarious, the frequent and fluid motions being a means adopted by the organism to rid itself of the poison. In pernicious anæmia, Addison's disease, and Basedow's disease, periodic attacks of diarrhœa are apt to occur, which in the case of pernicious anæmia may, however, be due to an abnormal intestinal flora and not be dependent upon the general metabolic changes.

The characters and composition of the stools in diarrhœa vary considerably, ranging from almost pure water in some instances to pultaceous material in others. Where the diarrhœa succeeds a period of constipation, scybalous masses may be mixed with the more fluid motion. The colour depends partly on the cause of the diarrhœa and partly upon the diet. It may vary from a colourless fluid, through a pale cream colour, to a dark brown. At the commencement of an attack, and especially when there has been previous constipation, the odour of the stools may be extremely offensive; but as the condition progresses and the frequency of the motions increases, the odour diminishes, so that in cases where the small intestine as well as the large is involved, the fæces may have little or no smell.

A microscopical examination usually shows an increase in the food residues, materials such as muscle, connective tissue, and starch, which are not usually met with in an undigested condition, being found in larger numbers the higher the seat of the pathological state extends (*Fig.* 85). A yellowish-green colour of the stools and lientery point to an affection of the stomach or upper intestine, although it must not be forgotten that an ulcer or carcinoma of the stomach may perforate into the transverse colon, and cause stools consisting almost entirely of undigested food to be passed. The diarrhœa due to extreme gastric hyperacidity, like that of nervous origin, often follows at once on food being taken. In addition to food residues, crystals of ammonium-magnesium-phosphate, calcium oxalate, and calcium salts of the bile acids are not uncommonly found; but the most important point to determine is the presence or absence of epithelial cells, free or mixed with mucus, for by this means a catarrhal inflammation of the intestine can be distinguished from a simple diarrhœa due to increased peristalsis, etc. Mucus is present in nearly all cases in sufficient amount to be recognized by the naked eye; but in affections involving the upper intestine, where there is also increased peristalsis of the large bowel, it is found intimately mixed with the fæces, and may be stained green with biliverdin. The more intimate the mixture, the smaller the masses of mucus, and the deeper the bile staining, the higher is its source, as a rule.

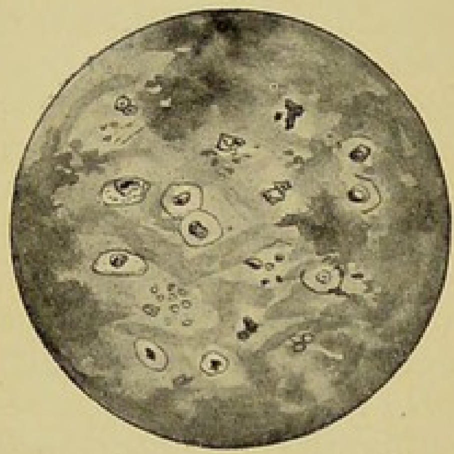


Fig. 85.—Acute Diarrhœa.

Chemical examination of the fæces usually shows that in cases due to imperfect digestion in the upper intestine, they are acid in reaction, while with catarrhs of the lower bowel they are strongly alkaline. Albumin is often present in considerable quantities, especially in the watery diarrhœa associated with catarrh of the bowel. In cases of ulcer or malignant disease, frank and occult blood may be found. The constant presence of the latter on four or five successive days is strongly suggestive of a malignant growth. Unaltered bile pigments may be met with in cases where there has been rapid transit of the intestinal contents through the bowel, and more especially in jejunal catarrh. In such cases the stools may give only a slight, or no, reaction for hydrobilirubin. A subnormal reaction is also given by the motions passed in most persistent diarrhœas, even when no altered bile pigment is present; but in the early stages an excess may be found. The most important determination in the quantitative analysis is the percentage of water, for an excess (over 75 per cent) differentiates true from spurious diarrhœa. In many cases an increase in the fats, and especially the combined fatty acids, will be found. This is the case in children even with the mild diarrhœas accompanying dentition. In some instances the nitrogen content of the fæces is increased, more especially when the upper part of the intestine is affected, but in others no marked alteration is found. Catarrhal affections of the intestine are usually associated with an abnormal percentage of inorganic ash in the stools, the increase being most marked in chronic catarrhal affections of the large intestine.

Diarrhœa in Infants is most commonly due to errors in the diet. The food may be excessive, or deficient in quantity or in the proportions in which its constituents are present. In hand-fed children it may have undergone fermentative, putrefactive, or allied changes, or contain pathogenic bacteria. Even though good in quality, it may be unsuited to the digestive powers of the child.

In infants at the breast, over-feeding is the most common cause of digestive disturbances, either owing to frequent suckling or, more rarely, from the milk being too rich. The bowels are at first constipated, but later a motion is passed after each feed. If the condition persists, the stools lose their normal golden-yellow colour, and become green. In mild cases the change of colour only takes place after the stool has been passed; in the more severe it occurs within the intestine. In either case it is dependent upon the oxidation of the contained bilirubin to biliverdin. At the same time there is an increase in the number of motions, which are more fluid than in health, owing to the increased peristalsis. The motions are usually strongly acid, often producing excoriation of the buttocks and neighbouring parts. If the cause of the disorder is not discovered and removed, the motions become slimy, owing to an increased secretion of mucus by the large intestine. There is also a considerable formation of gas, which produces distention and colic. Consequently, the motions are often expelled with explosive violence. The severer forms of chronic catarrhal enteritis are, however, comparatively rare in children fed exclusively on mother's milk.

In infants brought up by hand, intestinal disturbances and catarrhal enteritis are much more frequently met with. The symptoms are generally of a severer type, and the condition is less likely to be localized. The early stages are similar to those described in suckling infants, but as the disease progresses the symptoms differ according to the nature and seat of the predominant lesion. In some the symptoms are mainly referable to the small intestine; in others evidences of gastric disturbances become prominent; while in others again, the most pronounced symptoms are those of colitis.

Acute gastro-enteritis may occur in children of any age, but is most frequently met with in those between two and three years old who have suffered from repeated attacks of gastro-intestinal catarrh. The motions are always increased in frequency. At first, two or three stools, consisting of fæcal masses suspended in a brownish fluid, are passed; subsequently they become slimy and contain little feculent matter, but often scraps of curd and other undigested food particles are present. At times the stools are streaked with blood. Later the motions, which are now passed more frequently, become small, brown, or slightly blood-stained, and are often extremely offensive. Tenesmus is frequently a marked symptom. On examining the abdomen, it is found to be distended, tympanitic, and tender along the course of the colon.

Acute summer diarrhœa is the name applied to the gastro-intestinal disorder attended by diarrhœa and vomiting, which occurs in large numbers of children in temperate climates during the summer months. It is favoured by over-crowding, bad ventilation, and accumulations of filth, and is most frequently met with in dry hot weather when the temperature of the earth at a depth of 4 feet has reached 56° F. There can be no doubt that it is of microbic origin, and that the conditions mentioned are factors in its production, since they favour the infection of foodstuffs, and particularly milk. It is also probable that they lessen the resisting power of the body and bring about conditions favouring the development of organisms in the gastro-intestinal tract.

Escherich in Germany, and Booker in the United States, were among the first to study the bacteriology of the condition, but they were unable to find evidence of the presence of pathogenic organisms of a specific type in the diarrhœic stools. Lesage described a special group of cases characterized by green stools, which he attributed to infection with a specific chromogenic microbe. In others B. pyocyaneus has been isolated. Neither of these organisms is present in the majority of cases of acute summer diarrhœa, however. Flügge isolated a spore-bearing bacillus that grew anaerobically and broke down proteins, with the production of toxic bodies, which he considered to be capable of causing the diarrhœa. Klein and other observers have described B. enteritidis sporogenes and allied anaerobic organisms as being present in some cases. After the isolation of B. dysenteriæ by Shiga from the stools in acute epidemic dysentery, a fresh impulse was given to the investigation of the bacteriology of acute infantile diarrhœa. In 1902 Duval and Basset announced that the dysentery bacillus "is an important, if not the most important, cause of the summer diarrhœa of children." Subsequently Flexner stated that Shiga's type of B. dysenteriæ was only exceptionally present, but that the "Flexner-Harris" organism could be isolated from the stools in many cases. Flexner and his associates also noticed that large numbers of streptococci were associated with B. dysenteriæ in some instances. The presence of vast numbers of streptococci was also observed by Charlton and Jehle in some cases; but they came to the conclusion that the disease is not due to any one organism, but may be caused by a considerable variety. B. coli is, however, in their opinion the most common. Morgan, who investigated fifty-six cases of summer diarrhœa in this country in 1906, isolated and studied eighteen different types of bacteria from the stools. The most frequently met with was a bacillus that resembled the bacillus of hog-cholera (McFadyean) in some respects, but differed from it in certain essential particulars. This organism, which is now described as Morgan's No. 1 bacillus, was found in twenty-eight instances, or 48 per cent of the cases. Bacilli resembling in some respects Flexner's B. dysenteriæ were met with in eight cases, and an organism akin to Shiga's bacillus in four. In one case, a bacillus corresponding fairly closely to the B. enteritidis of Gaertner was isolated, and in two, an organism resembling B. paratyphosus (*B*) of Schott-Müller was obtained. In three cases streptococci, and in two others cocci, seemed to be the predominant organisms. Other observers have isolated an organism having the characters of B. typhosus. It would therefore seem that, as Baginsky has stated, there is no one specific organism, and that even ordinary saprophytic bacteria may, under suitable conditions, become pathogenic and give rise to acute diarrhœa in children.

The majority of cases of summer diarrhœa are examples of an acute gastro-enteritis with profuse discharges from the bowel, but in some there is little actual diarrhœa, death taking place at an early stage from toxæmia. Cases of this type are usually described as "cholera infantum." The child, who has previously been in good health, or may have suffered for a few days from malaise and dyspeptic symptoms, is suddenly seized with vomiting and diarrhœa. The stools are at first yellow and contain the remains of food, but they soon become liquid and of a brown colour. The depth of the colour then rapidly diminishes and the motions become transparent, until finally they consist of a colourless, slightly opalescent liquid which does not stain the napkins (*Fig.* 86). The diarrhœa and vomiting then cease, and death takes place with collapse.

Chronic gastro-enteritis in children is very frequently a sequel of the acute form, but it may also develop independently. When it is well established, and the colon is involved, the bowels act frequently, and the motions consist mainly of brown mucus or gelatinous material containing food remains, often streaked with blood. The stools are generally very offensive and may have a putrid odour. In many cases the entrance of food into the stomach sets up rapid and painful peristalsis, so that a foul mucoid stool is passed after each meal. The term "lienteric diarrhœa" is often applied to this condition. Even after mild attacks of gastro-enteritis the colon may be seriously affected. If the sigmoid and rectum are most involved, small quantities of mucus, which may contain small scybala, are passed at frequent intervals, sometimes several times an hour, and there may be serious and continuous tenesmus. If the colon alone is affected, the stools still consist largely of mucus, but they are voided less frequently, and there may even be constipation. Colic rather than tenesmus is then the prominent symptom. The attacks of colic are often commenced by the ingestion of food, and may, or may not, end in the bowels being opened. The symptoms closely resemble those due to tuberculous enteritis in some cases, and although a search for tubercle bacilli may give results that are of some use when taken in association with other signs, their presence on the one hand is not conclusive evidence of a tuberculous lesion of the intestine, and on the other their absence cannot be taken to prove that such a lesion does not exist, for the reasons already mentioned. Tuberculous enteritis is, however, rare in infants and in young children, and is usually associated with signs and symptoms indicating the involvement of other organs.

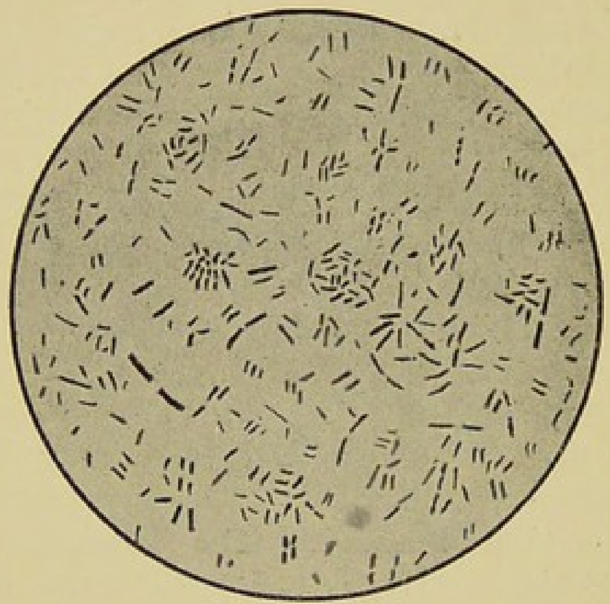


Fig 86.—Cholera infantum—cover-glass preparation

ACUTE ENTERITIS.

In acute enteritis the diagnosis depends to a large extent upon examination of the stools. Such an examination also affords indications as to the seat of the inflammatory process, which may affect individual portions of the gut, such as the duodenum and jejunum, or involve the whole length of the bowel. As a rule, it is only a serious condition in children, in old and decrepit persons, and in those who suffer from arteriosclerosis. The commoner causes of acute enteritis, in the order of their frequency, are indigestion, infections, intoxications, and exposure to cold.

Unless very limited in extent, the condition is always associated with more or less marked diarrhœa. The fæces are fluid, partly from an increased content of water, and partly from the presence of an excess of mucus which is poured out by the inflamed intestine. The motions vary in number from one to ten or fifteen a day, but a catarrh limited to the small intestine may run its course without giving rise to any increased frequency. It is usually only when the colon is involved that a marked variation from the normal is seen. The frequency of the stools then depends chiefly upon the extent to which the large intestine, and particularly the transverse and descending colon, is involved. At the onset, one or more stools of a semi-solid character may be passed, but they rapidly become fluid, and later tend to become slimy and frothy. Even at the height of the attack there may be an occasional well-formed motion, and it is not uncommon to find scybalous masses in the liquid stools. The passage of the characteristic watery stools is often associated with much foul-smelling gas, the quantity and odour depending to a great extent upon the nature of the diet and the seat of the catarrh. Carbohydrates make the stools acid and give rise to much gas; milk also modifies the reaction, and gives to the stools the smell of butyric acid. The first motions are often much more offensive than later in the attack, when the bacilli and their products have been largely got rid of. If the inflammatory process is confined to the colon, the food is normally digested in the small intestine, and the character of the fæces is then determined largely by the exudate from the walls of the bowels.

The colour of the stools varies from a darker brown than is seen in normal fæces to light golden-brown or greenish. The last is, however, rare in adults. These variations in colour depend upon the degree to which the bile pigments have been changed, and afford a most important indication as to the seat of the catarrh. If the stools are green or golden-yellow, owing to the presence of biliverdin or bilirubin, it indicates that the small intestine is involved, and that the intestinal contents are being hurried so rapidly through the bowel that the bile pigments are not being reduced to hydrobilirubin in the ordinary way. In children, the stools may be green, not from the presence of biliverdin but owing to an infection with chromogenic bacteria. When there is a very profuse diarrhœa, and particularly when it is due to inflammatory changes in the colon, the motions may be perfectly colourless. This condition is most common in some of the specific enteric inflammations, such as cholera and dysentery.

Mucus is practically always present, its amount and distribution affording a valuable indication as to the severity and seat of the inflammation. If it occurs in small masses intimately mingled with a more or less fluid stool, it points to a catarrh of the small intestine, while the presence of more or less voluminous collections merely coating the exterior of the fæces, indicates involvement of the colon. In acute proctitis and inflammations of the lower colon, solid masses of pure mucus may be passed (*Fig.* 87). If the mucus is coloured with unaltered bile pigment, it is a further point in favour of a high localization of the catarrh. On naked-eye examination the mucus may be clear, hyaline, and transparent, or turbid and opaque, when it is usually described as muco-purulent. Microscopical examination shows, however, that in the latter case the opacity is not due to pus, but to desquamated epithelial cells, which may be fairly well preserved if coming from the large intestine, but are usually degenerate and fragmented if coming from the higher portions of the bowel. Pus is very rarely found in simple acute enteritis, and its presence usually indicates an associated ulceration. Blood is never present unless there is ulceration. When the small intestine is involved and there is increased peristalsis, with decreased digestion and absorption, the constituents of the diet may be found in fæces in a more or less unaltered condition. Careful and repeated

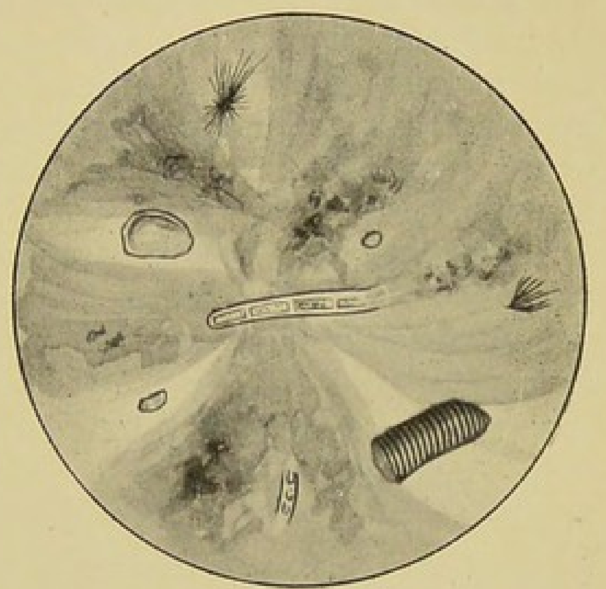


Fig. 87.—Intestinal Catarrh — mucus, muscle, vegetable tissue, fat crystals.

examination of the stools may then reveal the irritant cause of the diarrhœa in the shape of some particular food, eaten perhaps some two or three days previous to its passage.

Chemical analysis of the fæces gives very different results according to the nature and extent of the catarrh. When the condition is confined to the small intestine, the stools may show only a slight excess of water, their soft character being then chiefly due to the presence of an excess of mucus. But when the large intestine is involved, the motions often consist almost entirely of water, and contain a considerable excess of inorganic ash. Although the percentage of total unabsorbed fat may not be excessive, the relation of the neutral fats and free fatty acids (unsoaped fat) to the combined fatty acids is generally disturbed, an excess of the latter over the former being found. The stools in acute catarrh usually give a well-marked reaction for hydrobilirubin, and in cases where the upper part of the small intestine is involved, a reaction for bile may also be obtained. The fæces, or a watery extract of them, usually give a marked reaction for albumin.

Acute enteritis due to infection with some specific organism varies in its intensity with the nature of the infection, and also with the virulence of the organism. As a rule it occurs in epidemic form.

ASIATIC CHOLERA.

In mild cases the stools present the characters of those met with in simple diarrhœa, and in some there may be even no diarrhœa (cholera sicca); but in the majority the motions are very characteristic. They then no longer resemble fæces, but are thin and nearly colourless or greyish. Such stools consist of a clear fluid poured out by the intestinal walls, in which are suspended small grey flecks that on microscopical examination are seen to be composed of masses of epithelial cells, numerous cholera spirilla, crystals of ammonio-magnesium phosphate, and fat droplets. These are the so-called "rice-water" stools. They are passed with great frequency, and several litres of fluid may be lost in the course of twenty-four hours. The odour of the stools is no longer fæcal, but more like spermatic fluid. Occasionally the fluid is tinged with blood, and then resembles beef extract. The reaction of the motions is alkaline or neutral. Chemical examination shows that cholera stools usually contain about 2 per cent of solids, and of this the greater part is sodium chloride, with very little protein. As the condition improves, the stools gradually assume a fæcal appearance.

CHOLERA NOSTRAS.

In some cases of cholera nostras the motions are indistinguishable in appearance and chemical characters from those met with in Asiatic cholera, and it is only by a bacteriological examination that the two diseases can be distinguished with certainty, a variety of micro-organisms, including Finkler-Prior bacilli, streptococci, etc., being found instead of the specific cholera vibrio. In other cases the stools are more or less bile-stained, in contrast to the acholic stools of the more serious disease.

TYPHOID FEVER.

The stools passed in typhoid fever are generally described as being of a " pea-soup " appearance, copious, watery, of foul odour, alkaline in reaction, and containing many triple-phosphate crystals. On standing, they separate into a whitish-yellow, crumbling sediment, and a turbid supernatant fluid. It is now well recognized that such " typical " stools do not occur in all cases, and that some patients pass through the disease without any diarrhœa whatever: in fact they may be constipated. The cause of these variations is not well understood, but the experience of those who have been using " the high calorie diet " for typhoid fever suggests that the diarrhœa that so often occurs is probably dependent to a considerable extent upon the nature of the food. In some epidemics, however, where the patients have been treated by the accepted milk diet, it has been noticed that diarrhœa has been exceptional. It is possible that these may really have been outbreaks of paratyphoid fever. The stools are frequently tinged with blood, and as this is sometimes a warning of subsequent serious hæmorrhage, it is important that it should be recognized. Sometimes the blood is seen as streaks on the fæces, when it has come from low down in the bowel, but at others it is intimately mixed with the fæcal matter, and can only be recognized with certainty by chemical or microscopical examination. Pus is rarely found except in severe cases with extensive ulceration. Mucus is present in small quantities in many cases.

PARATYPHOID FEVER.

The clinical symptoms of paratyphoid fever are indistinguishable from those of mild typhoid, and the character of the stools is also the same, although diarrhœa is not so common. Netter found that of thirty-seven patients suffering from a " typhoid " condition, twenty-nine were the results of infection with paratyphoid bacilli, the organism most frequently found being paratyphoid *A* (twenty-two cases). An exact diagnosis can only be made by means of the serum test. The prognosis is good, the disease rarely proving fatal, and the mortality being only about 1·8 per cent. Intestinal hæmorrhage and perforation have apparently not been met with as complications of paratyphoid fever. Young adults from fifteen to twenty-five years of age are particularly susceptible to the infection. Nine-tenths of the cases occur from April to October.

CHRONIC ENTERITIS.

Chronic catarrh of the intestines is not separated from the acute condition by any hard and fast line, and the causes are much the same, namely indigestion, infections such as tubercle, dysentery, etc., intoxications, cold, and also the abuse of laxatives, the presence of entozoa, habitual constipation, and mechanical irritation from scybala. In many instances chronic entero-colitis is preceded by chronic gastritis, the intestinal catarrh being secondary to hyperchlorhydria, or the irritation produced by the entrance of improperly digested or masticated food into the gut. Both affections may also arise simultaneously from the same cause, such as the excessive use of alcohol. It is advisable that the condition of the stomach should be investigated by a test-meal in all cases. A diagnosis of chronic intestinal catarrh is frequently made clinically where there is diarrhœa or constipation from muscular atrophy or spasm, vascular disturbances, and organic diseases of the bowel; but these can be readily distinguished by an examination of the motions.

The most characteristic feature of the stools in true enteritis is the presence of mucus, which varies, however, very much in amount. In some cases the stool may contain only a small quantity intimately mixed with the fæces, while in others the motions may consist of little else. It must be remembered, however, that while the absence of mucus tends to exclude a chronic inflammatory process in the intestine, its presence is not of necessity an indication of catarrh, for mucus may be excreted by the rectum and colon in constipation, and it may also be met with in cases of cancer or ulcer. As in acute catarrhs, blood and pus are absent in simple cases, but epithelial cells are found in abundance, and ammonium-magnesium-phosphate crystals are also often seen in large numbers.

The frequency of the stools varies much in different cases, and in the same case at different times. Alternating periods of diarrhœa and constipation, each lasting some days, weeks, or even months, are most characteristic, but in others there is persistent constipation or, more rarely, continuous diarrhœa. The colour, odour, reaction, and composition of the stools vary also. They are usually offensive —more so than in simple constipation—alkaline in reaction, give a marked reaction for albumin and for hydrobilirubin, and contain an excess of inorganic ash. The combined fatty acids are generally in excess of the "unsoaped fats," although the total quantity of fat is not necessarily high. In mild cases the stools are firm in consistency, are usually small in calibre, and are surrounded by a coating of mucus. Where the catarrh is of moderate severity, solid and liquid stools often alternate with each other and with those of a pulpy consistency. In the more severe cases the stools are generally semi-solid, semi-liquid, or liquid, and are mixed with large shreds of mucus. On standing, the surface of the motion may have a varnished appearance from the partially dried mucus. If ulceration or erosions complicate the catarrh, the stools are often mixed with blood-stained or purulent mucus. If the inflammation is limited to the upper part of the small intestine, the stools will contain an excess of fat, undigested muscle fibres, and sometimes free starch granules, while the mucus can only be recognized microscopically. When the ileum is involved, the stools are formed, but of soft consistency, and microscopically, muscle fibres and starch granules are less commonly seen (*Figs.* 88, 89). A catarrh limited to the colon is usually associated with constipation, or a sluggish condition of the bowels, and only in severe cases are they of pulpy consistency. They are then surrounded by membranous mucus, which is frequently not recognized until the motion has been

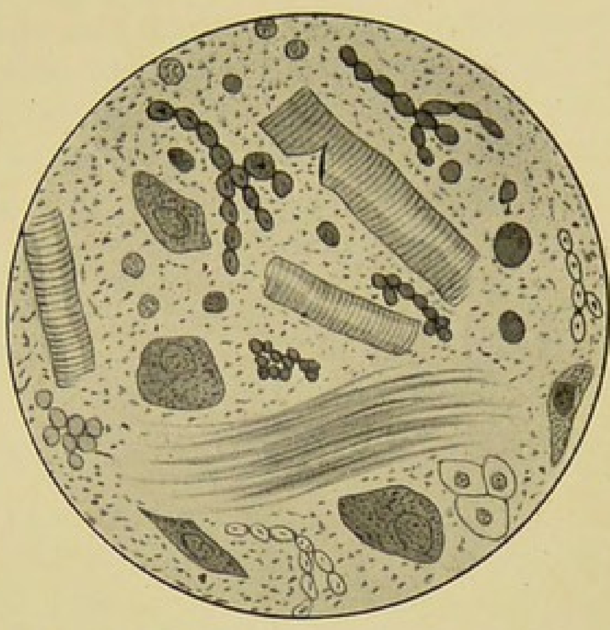


Fig. 88.—Chronic Enteritis—muscle, yeast cells, epithelium, fatty acid crystals etc.

Fig. 89.—Chronic Intestinal Catarrh—epithelial cells, partly digested muscle, yeasts, bacteria.

placed in warm water. When a catarrh involves the whole intestinal tract, including both the large and small intestine, diarrhœa is almost invariably present, and the more extensive and serious the inflammation the more severe is the diarrhœa. If there are more than six motions in the twenty-four hours, ulceration is probably present. Movements of the bowels are generally more frequent in the early morning, probably owing to fermentative changes that take place in the fæces during the night.

DIPHTHERITIC (CROUPOUS) ENTERITIS.

Since the term "diphtheritic" has now become associated with the diphtheria bacillus, it is better to term this condition "croupous enteritis," for, rare under any conditions, it is exceedingly uncommon to find that it is due to the activities of B. diphtheriæ. A case of true diphtheritic enteritis has recently been reported by Cargin. Croupous enteritis is most commonly met with in cases of pneumonia, general septicæmia, scarlatina, small-pox, tuberculosis or carcinoma associated with cachexia, and may result from the effect of certain poisons such as perchloride of mercury, especially in persons who are run down. Diarrhœa is always present, and is usually associated with tenesmus. The stools are fluid, but occasionally formed fæces are passed. They consist chiefly of pus, blood, and mucus, mixed with more or less altered food residues when food has been taken. Sometimes the stools consist almost entirely of pus, and a careful search may show macroscopic particles of tissue derived from the bowel wall. A microscopical examination of such material may reveal its structure, but it is usually so altered and necrosed as to be unrecognizable. In tuberculous, carcinomatous, and other cachectic cases, where the condition is chronic, it is often associated with some amyloid change in the intestinal walls, resulting in the passage of grey or almost white motions of an extremely thin and fluid character, in which the microscope reveals numerous pus cells and much mucus. The name "blenorrhœa intestinalis" is often given to this condition.

It should be noted that according to recent researches made by Delano, diphtheria bacilli are passed in the fæces in many cases of diphtheria, while Conradi and Dicrast have shown that they are excreted in the urine. Disinfection of the excreta is therefore an important means of combating the spread of the disease.

COLITIS.

In recent years colitis has attracted so much attention, and is so frequently looked upon as a distinct disease, that it will be convenient to consider it separately. But in spite of the clinical convenience of such an arrangement, it is important to remember that disorders of the mucous membrane, or mucous secretion, of the colon differ in no essential particular from similar affections of other parts of the bowel, with which they are often associated. The causes of colitis are the same as those already considered in connection with enteritis, and may range in their effects from a simple catarrh of the mucous membrane, or a mere disorder of mucus secretion, to a condition in which all the coats of the bowel are involved, leading to a more or less severe pericolitis, with local peritoneal inflammation, and possibly suppuration.

Cases of colitis may be divided into three great groups, with, however, no sharp line of demarcation between them, and each having several subdivisions.

1. **Catarrhal or Simple Mucous Colitis.**—This is met with as :—

(*i*). AN ACUTE FORM, due to various infective agencies, or secondary to general morbid states, such as Bright's disease, specific fevers, toxæmias, etc. It is characterized by diarrhœa with excess of mucus, and sometimes blood in the stools, colicky pains, in some cases tenesmus, and invariably more or less tenderness, particularly in the region of the cæcum, ascending colon, and sigmoid flexure. There is usually some fever, and may be severe general toxæmia. Acute catarrhal colitis is often only part of a general enterocolitis, as in some cases of "inflammatory diarrhœa" in children, when the distinctive symptoms of colitis may be of comparatively late development.

(*ii*). THE CHRONIC VARIETY is much more commonly met with in practice. Its etiology is at present uncertain. There are some who look upon it as a purely nervous disease which arises as a result of morbid changes in the nervous mechanism controlling the mucus-secretory functions of the colon, while others consider that it is primarily an organic disease of the colon, and that the nervous phenomena with which it is often associated are secondary. My own experience would suggest that in most instances the condition of the colon is primary, and that the nervous symptoms are usually a consequence of the toxæmia ; in a few, however, a hypersecretion by the colon wall apparently results from morbid changes in the nervous system. The symptoms vary very considerably in different cases. In some, the condition is only discovered by accident, but in others there are evidences of serious metabolic changes, associated with weakness, lassitude, and wasting. Chronic catarrhal colitis sometimes follows an acute attack of diarrhœa, of which perhaps but little notice was taken at the time, but it more commonly comes on insidiously as a result of constipation and chronic indigestion in persons of a neuropathic or arthritic type. Chronic colitis can be divided into two sub-groups :—

(*a*) *An irritative form*, characterized by loose motions and attacks of periodical, or more or less chronic, diarrhœa. When the descending colon and sigmoid flexure are especially affected, the stools are very characteristic. A test meal shows that the food is evacuated five to eight hours after its ingestion ; the colour, the hydrobilirubin test, and the microscopical characters show that digestion in the small intestine is normal, but the stools are of pea-soup consistency, and contain many small masses of mucus, which may be blood-stained. Microscopically, the red cells and leucocytes contained in the mucus are in an almost perfect condition. The motions are not passed very frequently, perhaps four or five times a day, showing that the rectum is normal. Such a condition may persist for ten or twenty years without any intervening period of constipation. Morning diarrhœa, lasting for months or even years, is often due to colitis. Associated with the symptoms mentioned there may be irregular colicky pains and local tenderness over various parts of the colon.

(*b*) *An atonic and spastic type*, in which there is constipation with an excess of mucus in the stools, usually in the form of viscid masses or ropy strings. At times scybala coated with mucus may be passed. On examining the abdomen, the colon may either be dilated, and then often contains masses of fæces in the region of the sigmoid, or, if the case is of the spastic type, the sigmoid will be felt to be contracted. In the spastic variety, spasm and pain are more marked symptoms than in the atonic variety. Most cases of chronic colitis belong to this second group, constipation, with, may be, intervals of diarrhœa, being usually present. The irritative form, with persistently loose motions and frequent attacks of diarrhœa, is comparatively rare. A test meal, with charcoal or carmine added, will show that in the latter the food traverses the gastro-intestinal tract in some six or eight hours, while with the atonic or spastic form, the appearance of the colouring matter may be delayed for from fifty to a hundred and fifty hours. Examination of the fæces shows an excess of mucus in every instance, the amount varying, however, in different cases and in the same case at different times, even from day to day. Part of the mucus may appear as separate masses, but part is always intimately mixed with the stools. It is important that the mucus that may appear in the stools as a result of an excessive use of purgatives should be clearly differentiated from that which results from a true primary colitis, and that a diagnosis of colitis should not be based on the presence of mucus alone. The former soon disappears with suitable dieting and other hygienic measures.

Microscopical examination of the fæces usually shows no excess of undigested starch, muscle, or other food materials, but triple-phosphate crystals are usually present in abundance. The mucus is transparent, is not coloured with bile pigment, and contains very few leucocytes or epithelial cells, by which fact it is distinguished from that met with in inflammatory catarrhs.

The stools are always alkaline in reaction, generally strongly so. A watery extract does not usually give a distinct reaction for albumin; but occasionally it may be fairly well marked. Unaltered bile and blood are always absent in uncomplicated cases, and there is no tendency to an excess of hydrobilirubin as in catarrh of the intestine. A quantitative analysis of the motions shows in nearly all instances a high percentage of inorganic ash, reaching in some cases as much as 35 or 40 per cent of the dry weight. There is usually no excess of unabsorbed fat, but the relation between the "unsoaped" fats and the combined fatty acids is disturbed, the latter being nearly always in marked excess of the former.

2. **Membranous or Muco-membranous Colitis.**—This may be regarded as an extension of the simple atonic or spastic type in which the mucus is passed from the anus in the form of a membrane. Patients suffering from this condition are nearly always constipated. A few complain of diarrhœa, but in most it will be found that, although the bowels are opened frequently, they really suffer from constipation. Colicky pains of more or less severity often usher in an attack, and are followed in two or three days by the passage of membrane. The patient then feels better until the recurrence of a similar attack. In the intervals no special intestinal symptoms may be complained of except constipation, but an examination of the stools will usually show an excess of mucus. In characteristic cases the stools passed during an attack are composed in great part, or exclusively, of mucus. The mucus is of tough leathery consistency, and assumes and retains certain definite shapes, usually representing more or less complete casts of the bowel, thus re embling in this respect the casts brought up in some forms of bronchitis The membrane may present most fantastic forms, sometimes mimicking at first sight various other elements that are met with in the fæces, such as fascia, undigested tendon, arteries and veins,

orange peelings, curds of milk, or even intestinal parasites or conglomerates of intestinal micro-organisms such as leptothrix. On being floated out in water the true nature of the membrane is apparent, and it is then seen to be tubular or tape-like, although it is occasionally branched, and may present elevations and depressions which are assumed to be casts of the tænia and haustra of the large intestine. The tubes are usually about 1½ in. in diameter, but may vary in length from an inch or so to 3 ft. or 4 ft. The casts are either transparent or greyish and semi-opaque, but may be stained brown by admixture with fæcal material, or be red from the presence of blood.

Microscopically the membranes are seen to consist of typical mucus, and give the ordinary cloudy striation on the addition of acetic acid. Numbers of epithelial cells are usually present, sometimes in a well-preserved condition, but more often altered and degenerate. Leucocytes are absent, or very sparsely present. Stained preparations often show eosinophile cells similar to those met with in bronchial asthma. Crystals of ammonia-magnesium phosphate, cholesterin, and occasionally Charcot-Leyden crystals are also seen. In some cases the membrane appears to be in layers, between which food remains may sometimes be seen.

Chemical analysis of the membranes, washed free from epithelial cells, shows that, in most cases at least, they consist principally of mucin, with traces of nucleo-proteins and globulins. In some instances, however, it would appear that the latter may exceed the mucin in amount. According to Leathes, the membranes passed in some cases are composed of chitin derived from carbohydrates. Guttmann has claimed that fibrin is present in considerable quantities, but most observers are agreed that it is usually absent or, at most, traces occur exceptionally.

The composition of the fæces in cases of muco-membranous colitis appears to differ in no way from that of the stools passed in simple mucous colitis with constipation. Their most striking characters are the strongly alkaline reaction, the excess of combined fatty acids relative to unsoaped fats, and the high percentage of inorganic ash. The excess of ash in the stools in these cases is very striking and constant, and, although the ash in mild types of the disease may only constitute some 18 or 20 per cent of the dry weight of the stool, in others a very much higher proportion is met with. In a few where a severe form exists, accumulations of calcium salts may be passed in the form of sand, as much as half an ounce or more being present in one stool. Chemically, such intestinal sand consists of phosphates and carbonates of calcium, fatty acids, and traces of organic matter, magnesium, and iron. The true intestinal sand of this type is yellowish-brown or greyish in colour, and is very hard and gritty to the touch. The granules are 1 or 2 mm. in diameter, and may be spherical or irregular in outline. False intestinal sand, consisting of fruit seeds and sclerenchymatous tissue more or less impregnated with lime salts, may be passed in the stools in mucous colitis also. Microscopical and chemical examination of the material readily differentiates the two, and it will be found that the patient has been taking considerable quantities of fruit, especially pears, figs, or bananas; in the latter case, the sand is said to be often black in colour. Occasionally persons suffering from colitis pass in their stools small white shell-like masses. These consist of agglomerations of bacteria, combined fatty acids, and lime salts that have accumulated on the walls of the dilated sacculæ of an atonic colon, to which their shape is due.

Opinions differ greatly as to the frequency with which muco-membranous colitis occurs during childhood. Bottentuit has described a series of sixty cases of "infectious follicular entero-colitis," in which there were frequent and scanty stools containing membrane, due apparently to disturbances of nutrition in the first year of life. Dieulafoy has observed two cases in which intestinal sand was passed by children, along with mucus, blood, and pus. He states that the disease is much more severe in children than in adults, and is associated with marked fever and signs of auto-intoxication. In discussing Dieulafoy's statement, it has been pointed out by Mattieu that even in adults acute attacks occur, and he considers with Comby that there is a connection between this disease and appendicitis.

3. **Ulcerative Colitis.**—As a further manifestation of an original mucous colitis, ulceration may occur, and we then have what may be termed simple or idiopathic ulcerative colitis. A similar condition may also be met with as a secondary phenomenon in the course of some general or local disease such as syphilis, tuberculosis, cancer, stricture, etc. Acute ulcerative colitis also occurs, and is an essential feature of tropical dysentery and epidemics of asylum dysentery.

Acute Ulcerative Colitis—Tropical Dysentery.—The stools in this disease are characteristic of a rectal diarrhœa; that is to say, they are not profuse, but are voided frequently and with difficulty. In mild forms they number five to twelve a day, but in the severe types they may reach 100, 120, or even 200 in the twenty-four hours. As the number of evacuations increases, the amount of material passed in each motion diminishes, so that it may not be more than 10 or 15 grams. Soon after the commencement of the attack the stools lose their fæcal character and become slimy, like white of egg or frog spawn; they then assume a mucopurulent character, and finally, as the intestinal lesion progresses, become sanguino-purulent or sero-sanguinous.

According to the appearance of the stools, cases of dysentery are popularly divided into "white" flux and "red" flux, the former being those in which the loss of blood is small, the latter those in which the quantity of blood present is sufficient to colour the motion distinctly. Peculiar firm reddish or white fragments consisting of blood-stained mucus (the "carunculæ" of the older writers) and masses of desquamated necrotic mucous membrane are sometimes seen. The stools are often odourless, but in serious cases they may have a foul gangrenous smell ("gangrenous flux.")

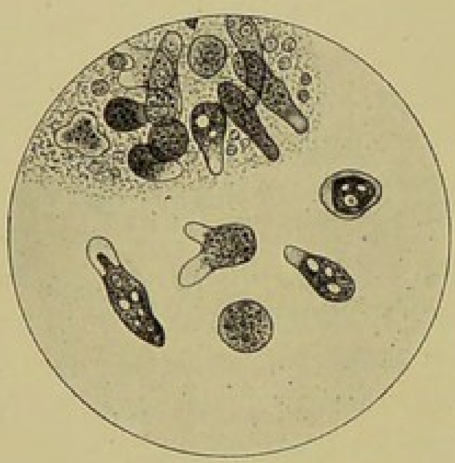


Fig. 90—Amœbic dysentery.

During the acute exacerbations of amœbic dysentery, the motions are fluid and frequent, three to six a day. They usually contain a large amount of mucus, and very often distinct traces of blood. They have a fæcal colour and a peculiar mucilaginous odour. The reaction is invariably alkaline. Microscopical examination of the fresh mucus shows the characteristic amœbæ, epithelial cells, and red blood corpuscles (*Fig.* 90). Attacks of this character are separated by periods, sometimes years in duration, in which normal motions are passed, or even constipation may exist. A careful examination of the fæces will, however, show the presence of amœbæ. A routine examination of the motions is therefore of importance in all cases with a history of dysenteric attacks, especially when there are symptoms of liver trouble and irregular fever.

Asylum Dysentery.—One of the most frequent and troublesome causes of illness in lunatic asylums is the condition commonly spoken of as asylum dysentery. In a typical case the motions consist of mucus and blood with very little else, although scybala are also often found. The proportions of fæcal material, mucus, and blood passed, vary according to the degree to which the bowel is affected, but even in mild cases a careful examination will reveal the presence of the last two constituents. In some instances a typical stool may be followed on the next day by a loose motion, and this in its turn be succeeded by two or three days of constipation; yet the fæces will be found to be coated with patches of mucus and be streaked with blood. The mucus passed in asylum dysentery is generally translucent or slightly opaque, and of a tenacious jelly-like consistency. It may be of a greenish hue, or red from the presence of blood. Microscopical examination of the stools shows numerous leucocytes, but as a rule only a few epithelial cells are found.

There is a general agreement that asylum dysentery is of microbic origin, but there is some difference of opinion as to the nature of the organism involved. There seems to be little doubt that in many instances it is the same disease as that which exists in epidemic form in the tropics and Japan to-day, and was at one time rife in England and Ireland, and is dependent upon the activities of Shiga's bacillus or some closely related organism. Some authorities maintain that it may be also due to other bacteria. Knobel claims that asylum dysentery may arise from an alteration in the normal control exercised by the intestine over the growth of colon bacteria, or from constipation causing an abnormal multiplication of bacteria normally present in the large intestine, so that not one but many organisms can give rise to the disease in patients where the trophic innervation of the intestine is disturbed as the result of cortical degeneration.

Chronic "Simple or Idiopathic" Ulcerative Colitis.—Since Hale White published a series of cases in 1888, many writers have described a form of ulceration of the colon which occurs in temperate climates, but is claimed to be distinct from dysentery. It has been pointed out by Saundby and others, that the opinion that dysentery is only a disease of the tropics is not justified by the history of medicine, and that the symptoms, morbid anatomy, and treatment of idiopathic ulcerative colitis and dysentery are the same. Bacteriological investigations have also tended to bridge over the apparent gap between the various forms of ulcerative colitis and approximate them to dysentery proper. In typical cases the diagnosis is clear, owing to the presence of intensely acute colitis, with diarrhœa, pain, tenesmus, and characteristic brownish-red stools, containing viscid mucus and blood. In some cases, however, the characteristic symptoms may not make their appearance until quite late in the disease, and severe diarrhœa may be the only prominent feature. Even then, a careful examination of the stools will show an excess of mucus, and very often the presence of blood.

ULCERS OF THE INTESTINE.

An examination of the fæces often gives results that are of great importance in the diagnosis of ulcers of the intestine. The frequency of the stools varies considerably according to the situation and nature of the ulcers. In certain parts of the digestive tract ulcers may be both numerous and extensive without there being any diarrhœa. Thus the small intestine, the cæcum, and ascending colon may be seriously affected without there being any increased frequency of the motions; in fact, constipation may be present; but ulceration of the transverse or descending colon, of the sigmoid, and especially of the rectum, is almost invariably associated with diarrhœa. The stools are, as a rule, softer than usual, and may be fluid, the lower the seat of the ulceration the greater being the tendency to fluid motions. The most characteristic features are the presence of blood, pus, and particles of tissue in the fæces. The blood may only occur as minute traces, the so-called "occult blood," which cannot be recognized except by delicate chemical tests, or may be in quantities easily recognized by the naked eye. The nearer the seat of the ulcer to the anus the less will the blood be altered, and if fresh red blood is seen macroscopically, and microscopical examination shows unaltered red blood corpuscles, the ulcer is probably situated in the lower part of the colon or rectum. The occurrence of crystals of hæmatin microscopically, or occult blood chemically, suggests an ulcer higher in the gastro-intestinal tract. The intermittent presence of occult blood points to the presence of a simple ulcer, while a positive reaction on four or five consecutive days is suggestive of a malignant growth, if accidental sources of blood, such as a diet rich in underdone meat, bleeding from the nose, teeth, piles, etc., can be excluded. Some ulcers bleed much more readily than others: typhoidal and dysenteric ulcers, for instance, far more frequently give rise to blood in the stools than those due to tuberculosis or syphilis. While, therefore, the occurrence of blood in the stools under circumstances which suggest the presence of ulcers, tends to confirm the diagnosis, the absence of blood does not exclude their presence. It is also important to remember that even when obvious sources of blood, such as a meat diet, epistaxis, piles, etc., have been excluded, it may occasionally be met with in the fæces without any obvious breach of surface being found post mortem, in anæmias, cases of portal obstruction, advanced chronic pancreatitis, and other conditions.

Although pus (*Fig.* 91) is met with in the fæces in certain rare conditions, such as extra-intestinal abscesses opening into the bowel, it may be regarded practically as pathognomonic of ulceration. At times, large quantities of almost pure pus may be passed, especially in cases of severe dysentery, ulcerating carcinoma, and also perforating abscesses; but in the majority of cases of ulceration only a small amount is present, and careful search may be needed to demonstrate it. In many cases, the leucocytes are digested and disintegrated beyond recognition, especially if the ulcer is situated high up in the intestine; but in some, yellowish-white particles, which on microscopical examination are seen to be clusters of pus cells, may be found. Certain forms of ulcer, such as those met with in the stomach and duodenum, are never associated with the presence of pus in the stools, so that its absence cannot be taken to exclude ulceration. Pure pus is met with in practically only two conditions, extra-intestinal abscesses and diphtheritic enteritis. In dysenteric ulcerations and ulcerating carcinoma of the lower colon and rectum, the pus is often mixed in almost equal proportions with mucus and blood.

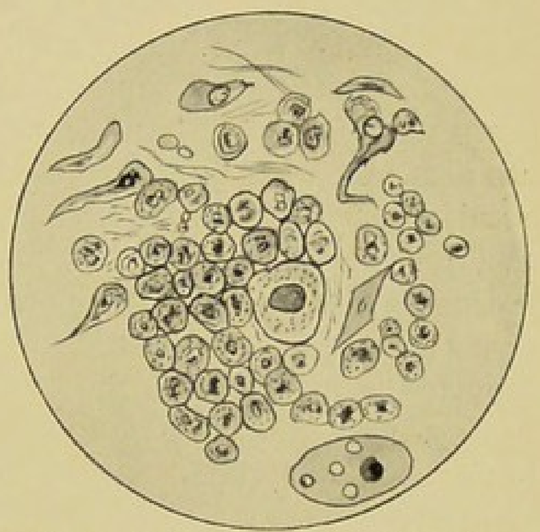


Fig. 91.—Pus in stools. Chronic Diarrhœa.

Recognizable shreds of tissue furnish direct evidence of ulceration, but they cannot always be differentiated with certainty from food remnants. They are met with most frequently in dysentery, but may also be found in cases of ulcerating malignant disease of the lower bowel. In typhoidal and other ulcerations of the intestine they are very rarely met with. If Gram-stained smears are made from the fæcal material or from particles of the isolated pus, it will sometimes be found that Gram-positive organisms, and especially cocci, are present in abnormal numbers. Not every case of streptococcal enteritis is of necessity ulcerative, but such a change in the character of the intestinal flora is suggestive. A search for specific organisms is more difficult and liable to error, but the discovery of typhoid bacilli, or one of the various forms of the dysentery bacillus, with other evidence of ulceration, may aid in the diagnosis.

The most common ulcers of the gastro-intestinal tract are the simple ulcers of the stomach and duodenum. Duodenal ulcers may also be secondary to cutaneous burns. Embolic and thrombotic ulcers of the jejunum, ileum, and colon associated with endocarditis, atheromatous degeneration of the aorta, endarteritis, and cases with suppurating foci, were first described by Parenski in 1876. Amyloid ulcers are very rare, and are associated with diarrhœa and a deficient absorption from the intestine. They are met with in cases of long-continued suppuration, cachexia, tuberculosis, syphilis, rickets, and leukæmia. Catarrhal and follicular ulcers may occur in the course of a catarrhal inflammation of the intestinal mucous membrane. Stercoral or decubital ulcers are produced by the pressure of hardened and stagnant fæces on the mucous membrane of the cæcum, flexures of the colon, sigmoid flexure, and rectum, where stasis is most apt to occur. The ulcers of acute infectious diseases, including typhoid, dysentery, sepsis, variola, pneumonia, acute pemphigus, pellagra, and diphtheritic ulceration, have already been mentioned. In constitutional diseases, such as acute leukæmia, lymphoid tumours of the intestine may break down and give rise to an ulcerated surface. Ulcers of the intestine are also met with in scurvy, and very rarely in gout. Toxic ulcers occasionally form in nephritis where there are uræmic symptoms and an intestinal catarrh. They are also met with in mercury poisoning, whether the drug has been taken by the mouth, rectum, or by inunction. Syphilitic ulcers are rare, and have been chiefly reported in infants with the inherited disease, only a very few cases having been described in adults. Primary chancres of the rectum have been observed. Ulcers from gonorrhœa, traumatism, and hæmorrhoids may also be met with in the rectum. A case of fatal ulceration from intestinal myiasis has been reported by Schleisinger.

Intestinal Tuberculosis.—Tuberculosis is a frequent cause of ulceration of the intestine. The infection may be (*a*) Primary in the mucous membrane; (*b*) Secondary to disease of the lungs or to tuberculous peritonitis, etc.

(*a*). *Primary Intestinal Tuberculosis* is most frequently met with in children, and is often associated with tuberculosis of the mesenteric glands or peritoneum. The lower ileum is generally first involved, and subsequently the remainder of the small intestine and the colon are affected. The earliest symptom is usually irregular diarrhœa, resembling that due to a chronic catarrh. The stools are light-coloured and soft, but gradually become darker and more fluid as the number of motions increases, until finally they are very dark brown, or even tarry, owing to the bleeding from the ulcers. In its later stages the diarrhœa is often very profuse, the stools are watery, very offensive, and may be retained with difficulty. It is not uncommon to be able to elicit a history of an acute diarrhœa with colic some weeks or months before the onset of the more persistent diarrhœa. Examination of the stools may reveal the presence of tubercle bacilli, especially in the small masses of mucus. Tuberculosis beginning in the cæcum is associated with symptoms suggestive of appendicitis, and may be accompanied by constipation or irregular diarrhœa.

(*b*). *Secondary Intestinal Tuberculosis* is very common in tubercle of the lungs, the infection coming from the swallowed sputum. The lowest part of the ileum is chiefly affected, but the disease often extends downwards to the cæcum, colon, or rectum, and upward to the jejunum, or even to the duodenum or stomach. Frerichs found tuberculosis of the ileum in 80 per cent of cases of chronic pulmonary tuberculosis. Although tubercle bacilli may be found in the fæces, their presence does not prove the existence of tuberculous ulcers of the intestine, for they may come from the swallowed sputum, especially in children. The stools may not show any striking variation from the normal unless the mesenteric glands are also seriously affected, when they will contain an excess of unabsorbed fat, as much as 60 to 70 per cent being then present in some instances, mostly in the form of combined fatty acids. Tuberculosis of the mesenteric glands produces, however, no characteristic symptoms until they attain a large size and interfere with the absorption of food from the intestine. There are then alternating diarrhœa and constipation, with tympanites, and the stools contain the excess of fat mentioned. Secondary infection of the intestine from the peritoneum, either primarily diseased or extending from the mesenteric glands or Fallopian tubes, may give rise to ulcers and be associated with the symptoms described above. A localization of the condition, with chronic hyperplasia in the ileo-cæcal region, may give rise to a tumour simulating a new growth and cause constriction of the bowel with constipation.

CARCINOMA.

The stools in carcinoma of the intestine are only characteristic in cases where the new growth is situated in the large intestine, for although the presence of occult blood on four or five consecutive days is suggestive of malignant disease of the stomach, intestine, pancreas, or bile-passages, it is not conclusive evidence. When the new growth is situated in the colon or rectum, and has attained any considerable size, several factors combine to alter the characters of the stools. In some cases the stenosis caused by the tumour may give rise to constipation lasting for several days. This may be followed by the passage of blood, pus, and fragments of tissue, with diarrhœa of a very offensive character consequent on ulceration of the growth. In other cases, owing to the catarrh which so frequently accompanies carcinoma of the bowel, periods of severe diarrhœa may occur; but it is unusual for diarrhœa to persist throughout the course of the disease. As a rule, diarrhœa and constipation alternate. Mucus may be absent, or present in large quantities, depending upon the degree of the coincident catarrh. Blood, as we have seen, is usually present, although it may be only in minute quantities recognizable by delicate chemical tests. Pus is only met with in cases where there is ulceration, and generally occurs in quantities directly commensurate with the loss of surface. In deeply ulcerated growths of the colon, pus may be fairly plentiful. The existence of any two of these pathological conditions points to a diagnosis of cancer of the colon; in fact, a mixture of blood and muco-purulent masses occurs practically in only one other condition, dysenteric ulceration, which is differentiated by other symptoms. In carcinoma of the rectum all the above symptoms occur with increased intensity. The stools are very frequent, much blood and pus are passed, and they often have a gangrenous odour. In rare cases where the growth has ulcerated extensively, particles of the sloughed material may be found in the stools. Chemical analysis of the fæces in cases of malignant disease of the intestine, excepting for the very frequent occurrence of occult blood, does not help in the diagnosis. An excess of mucus may be found, a well-marked reaction for albumin may be obtained, and there may be a high percentage of inorganic ash, especially when the growth is situated in the colon. When the mesenteric glands are involved, so that absorption by the lacteals is interfered with, an abnormally high proportion of unabsorbed fat will be found, and this is also the case when the pancreas or its ducts are affected.

INTESTINAL INDIGESTION.

Disturbances of digestion are the commonest of disorders, and while in a considerable number of cases they are comparatively trivial in character and quickly yield to dietetic and medicinal treatment, in others they are of a more chronic type and drag on for months or years. Surgery may relieve some of these cases when there is a structural lesion, such as ulcer or dilatation of the stomach, underlying the condition, but in many there is no such gross anatomical change to account for the continuance of the symptoms, which are due to the chemical and bacteriological abnormalities in the contents of the alimentary tract arising from functional changes in the digestive organs.

The work of Pawlow, Bayliss and Starling, and others, has done much to extend our knowledge of the processes involved in normal digestion, and to furnish a sound basis for pathological research. The outstanding results of their investigations have been to show, first, that digestion does not consist of a series of isolated phenomena, as was at one time taught, but that each step in the process follows in an orderly manner as the result of the one which precedes it; and, secondly, that the chemical changes in the foodstuffs that fit them for absorption take place almost entirely in the upper part of the small intestine, chiefly through the agency of the various ferments contained in the secretion of the pancreas. The pathological importance of the interdependence of the various digestive processes is considerable, for if from any cause one or other of the steps is interfered with, it will break the normal sequence of events and tend to bring about alterations in the chemistry, and subsequently in the flora, of the intestine, that may have far-reaching results. There is, no doubt, a certain amount of compensatory activity between the various parts of the digestive system, and for a time a diminution of function in one may be more or less completely covered by the action of another, but in the end this compensation generally fails, or, as the condition becomes chronic, ceases to be adequate, and so only serves to tide over a temporary difficulty.

The actual digestive changes that take place in the stomach under ordinary conditions are comparatively unimportant. Starches are not affected at all, fats are but little changed, and the proteolytic ferment of the gastric juice works very slowly, only splitting up the more readily acted-on proteins to any appreciable extent. The collective pancreatic ferments are capable of acting upon all forms of foodstuff; proteins are easily and rapidly broken down into simple and readily absorbable cleavage products by the powerful tryptic ferment; starches are converted into dextrin and maltose by the amylopsin; and fats are split into their constituent fatty acids and glycerin by the steapsin. It is important to remember, however, that collagen, the chief constituent of connective tissue, is not digested by pancreatic juice unless it has been previously acted on by a dilute acid or boiled in water, so that the appearance of connective tissue in the fæces points to a disturbance of gastric digestion. The intestinal secretion, beside the "ferment of ferments," enterokinase, by which the inactive trypsinogen of the pancreatic juice is converted into active trypsin, contains erepsin, which has the power of splitting up proteoses and peptones, but not the native proteins, except casein, into simpler chemical bodies, and a series of ferments which convert cane-sugar, lactose, and maltose into dextrose and levulose. The succus entericus thus appears to act as a supplement of the pancreatic secretion, particularly as regards the digestion of proteins and carbohydrates.

Disturbances of the digestive functions of the pancreas and alterations in the intestinal secretion, may induce abnormal changes in the food materials which will not only interfere with absorption, but also give rise to the formation of unusual chemical products, the presence of which irritates the walls of the intestine. The altered reaction and composition of the intestinal contents existing under these conditions also tend to bring about a modification of the flora; micro-organisms which are usually only met with in small numbers may find the conditions more suitable for their growth, and so multiply to an abnormal extent; others which are normally present in large numbers in the lower bowel but are scanty in the upper part of the intestine, may spread to the ileum and duodenum, and even infect the pancreatic and bile-ducts, and by a process of adaptation to their environment some may develop activities which were formerly insignificant or perhaps even altogether in abeyance. Hence putrefactive decomposition may take place in the undigested, or partly digested, proteins, fats may be decomposed by fat-splitting bacteria, and carbohydrates be broken down along unusual lines into irritating organic acids, etc., with the formation of a large amount of gas, so that the small intestine becomes the seat of changes which normally only take place to a small extent in the colon and sigmoid flexure.

In some instances the disease appears to be due to a bacterial infection from the commencement, and may occasionally be traced to an antecedent attack of influenza or typhoid fever. In such cases there are nearly always an associated pancreatitis and cholangitis, and it is to the former that the disturbances of digestion are chiefly due. The attacks in these cases are often of a remittent character, but, although the patient may be comparatively well in the intervals, he is never quite free from discomfort. Certain articles of diet and particular forms of food material are frequently found to increase the discomfort and to precipitate an attack; fatty foods, and particularly some forms of fat, are often digested with difficulty.

The diagnosis of intestinal indigestion is made, partly from the clinical symptoms and partly from the results of an analysis of the fæces, urine, and stomach contents. Each supplies a certain amount of information, but no one affords a pathognomonic sign. A correct conception of the conditions present in any particular case can only be arrived at by taking into consideration the information to be obtained from them all. The presence of abdominal discomfort, more marked two or three hours after food, loss of appetite and distaste for certain articles of diet—fat or milk, for example—lassitude, inability to concentrate the attention, with often persistent headache, a dirty tongue which is frequently fissured, fœtid breath with eructations of gas, abdominal distention and occasional tenderness on deep pressure in the region of the head of the pancreas, the passage of much flatus with often foul-smelling stools, and either diarrhœa or constipation, are suggestive of the condition.

The analysis of the fæces should be as complete and exhaustive as possible, for the macroscopical, microscopical, chemical, and bacteriological characters all assist in arriving at a conclusion as to the nature and extent of the disease. Although much may be learnt from an investigation of the fæces passed on an ordinary mixed diet, it is advisable in some instances to place the patient on a test diet, such as that suggested by Schmidt, when a more accurate estimate of the digestive disturbances can be made.

In the analysis of the urine, attention must be particularly devoted to the "pancreatic" reaction, a positive result or a high iodine co-efficient* suggesting a disturbance of carbohydrate metabolism resulting from interference with the functions of the pancreas or degenerative changes in the gland, the presence of an excess of indican and a disturbed relation between the preformed and ethereal sulphates, showing abnormal putrefactive changes in the intestinal contents, with catarrh of the walls, and a marked reaction for urobilin, which in my experience points to an associated cholangitis and disturbance of the liver.

The stomach contents should be examined both before and after a test meal, for evidences of hyperchlorhydria, catarrh, dilatation, etc., as the intestinal condition is often associated with, and secondary to, disease of the stomach.

Cases of intestinal indigestion may be divided into two main classes: (1) *Those in which there is excessive fermentation of carbohydrates,* and (2) *Those in which there is excessive putrefaction of proteins.*

1. **Fermentative Intestinal Indigestion.**—Four well-recognized types of fermentation may take place in the upper part of the gastro-intestinal tract, namely alcoholic, acetic, lactic, and butyric. Frequently two or more of these coexist, but usually one preponderates. According to some observers, a fifth form which results in the formation of oxalic acid, is not uncommon.

* Cammidge, "Glycosuria and Allied Conditions," Arnold, 1913, p. 275.

Although some bacteria are capable of setting up alcoholic fermentation, it is usually due to the activities of yeasts, and most commonly occurs in the stomach. Lactic acid fermentation is a much more common type both in the stomach and intestine, and may be due to a variety of organisms, chiefly those of the B. acidi lactici and B. coli types. The conditions favourable to the formation of lactic acid are a neutral or faintly acid medium, such as is furnished in gastric diseases with impaired secretory activity, and the presence of sugar and protein. We know very little about the conditions that lead to the formation of acetic acid, but it may often be found in the fæces in cases where intestinal fermentation is active. Associated with the acetic acid there is not uncommonly some butyric acid, which is no doubt formed by various micro-organisms from carbohydrates, and possibly also from proteins, in the intestine. Butyric fermentation only takes place in a neutral or alkaline medium, and hence is most common in persons who secrete little or no hydrochloric acid. It is often stated that the oxalate crystals found in the urine of some persons are derived entirely from the food, but that this is not always their origin is suggested by the experiments of Baldwin, who showed that on giving sugars to dogs in large quantities for many weeks, oxaluria is produced. My experience has also been that in most cases of persistent oxaluria there are abnormal fermentative changes going on in the intestine, and that the flora of the fæces is distinctly changed. A diminution or absence of the hydrochloric acid of the stomach appears to be a condition favourable to the development of fermentative oxaluria, and it is probable that the presence of proteins is also necessary. The excessive use of carbohydrates, and especially of sugar, impaired motor or secretory activity of the stomach, and pancreatic insufficiency, are all apt to bring about conditions that favour excessive fermentative changes in the contents of the upper part of the gastro-intestinal tract. It is to the products of such fermentation, including the acids, gases, and alcohols, and the loss of caloric potential which their formation entails, that the flatulence, diarrhœa, colic, and loss of weight and strength are due.

In cases of fermentative indigestion, the fæces are generally soft, of light colour, and float on water, owing to the gas mixed with them. They are acid in reaction from the acetic, lactic, and butyric acids that they contain. Microscopical examination will show evidences of a catarrh of the upper part of the intestine in the shape of undigested starch granules, small particles of mucus, which may be bile-stained, etc. Chemically, a fair reaction for mucus will be obtained, but the fats are normal and there is no excess of inorganic ash. A normal reaction for hydrobilirubin will be obtained in spite of the light colour of the stools. The fermentative changes begun in the intestine continue actively outside the body, so that when a specimen of the stool is placed in a Schmidt fermentation apparatus, it gives rise to a large volume of gas and becomes more intensely acid in reaction. The gas formed consists of carbon dioxide, methane, and free hydrogen, usually in the proportions of 17 : 4 : 1. The acids produced are chiefly butyric and acetic, sometimes one and sometimes the other predominating.

Cultures of the fæces made in acid dextrose broth may demonstrate the presence of B. bifidus and other acidophilous organisms in some cases. In others, cultures in plain sugar broths reveal an excess of streptococci or coliform organisms and give a subnormal percentage of gas. Tissier found that B. perfringens is very frequently present in the stools of infants suffering from fermentative diarrhœa, and that as recovery takes place a very rapid change occurs in the bacterial contents of the fæces, the abnormal forms disappearing and B. bifidus reappearing, to ultimately assume its position as the preponderating organism. He found that in culture media containing a sufficiency of carbohydrate, B. bifidus inhibits the growth of B. perfringens, but that in media without carbohydrate, B. perfringens outgrows B. bifidus. He therefore concludes that the predominance of the disease in artificially-fed children is to be attributed to the excess of protein in cow's milk causing more unutilized protein to pass into the intestine and so favour the growth of B. perfringens. Other observers have found B. enteritidis sporogenes as the predominant organism in cases of fermentative indigestion, and especially in the enteric catarrh of children that follows the ingestion of an excessive quantity of sugar. Experiment has shown that when this organism is grown in special media—essentially albuminous material subjected to tryptic digestion with the subsequent addition of sugar—it produces a substance which is exceedingly poisonous to animals, even in small doses. Under normal conditions, sugar digestion and absorption are practically complete before the lower part of the small intestine is reached, but with large amounts of sugar in the diet this is no longer the case, and an abnormal medium, similar to that used experimentally, is provided for the growth of the anaerobic inhabitants of this part of the alimentary tract. The points urged in favour of this conclusion are, (1) That in the stools of enteric catarrh, B. enteritidis is often the predominant organism; (2) The disease is most prevalent in children who have consumed an excess of sugar; (3) The elimination of sugar from the diet brings about an improvement in the symptoms and is accompanied by a change in the intestinal flora; and (4) On one occasion at least it has been possible to obtain the characteristic poison from the stools by extracting them with alcohol. The poison is apparently not a toxin in the bacteriological sense, for it is relatively very stable to heat and preservatives, it can be extracted with alcohol, and attempts to obtain an antitoxin have been unsuccessful. In its formation the presence of both sugar and the products of tryptic digestion appears to be essential. Whether or not this toxic substance is identical with the butyric acid produced by the organism is not settled, but McCampbell has obtained a poisonous effect with a solution of butyric acid of similar strength to that of the cultures. Passini states, however, that neutralization or even alkalinity of the medium does not affect its toxicity.

An examination of the urine may show an increased acidity, although in some cases the acidity is low, owing probably to the formation of carbonates. An excess of uric acid relative to total nitrogen, and the presence of volatile fatty acids, such as acetic, formic, etc., is also found in some instances. Occasionally there is also more or less marked oxaluria. In some cases the acidity of the urine brings about increased frequency of micturition.

The flatulence due to fermentative intestinal indigestion must be distinguished from that dependent upon an exogenous intake of gas in which the functions of the intestine are not disturbed. This is chiefly met with in nervous individuals who swallow air with their food and in persons who eat quickly. The gas eructated, or passed downward, is free from smell, and the flatulence is independent of the kind of food taken. Macroscopical, microscopical, and bacteriological examinations of the stools reveal nothing abnormal, and the fermentation tests show no unusual gas formation.

2. **Putrefactive Intestinal Indigestion.**—The putrefactive processes in proteins that go on in the intestinal tract are of distinctly greater importance than the fermentative changes that occur in carbohydrates. The products of fermentation are for the most part harmless, excepting when they are formed in considerable quantities; but the substances formed in the putrefactive disintegration of proteins being to a great extent toxic nitrogenous bases, an abnormal formation is much more likely to give rise to serious symptoms. Even in healthy individuals a certain amount of protein decomposition goes on in the contents of the lower parts of the intestine, and chemical investigation may show that these are considerably increased without there being any obvious clinical symptoms. It is only when the putrefactive changes are so great,

or have persisted long enough to overcome the defensive mechanisms of the organism, that unequivocal clinical signs make their appearance. According to Combe, the body possesses a triple line of defence against the action of intestinal toxins. The first of these is the intestinal mucous membrane; the second is the liver, which intercepts such toxic materials as have escaped the action of the intestinal mucous membrane, transforming amines and ammonia into urea, and combining aromatic bodies with sulphuric acid and glucuronic acid to form comparatively soluble innocuous compounds; and the third line of defence consists of the thyroid, suprarenals, and other ductless glands, including in children probably the thymus. These apparently have the power of dealing to some extent with toxins which have escaped the intestinal mucous membrane and liver.

Owing to the fact that the products of intestinal putrefaction contain an aromatic nucleus that cannot be disrupted by the ordinary cellular activities of the body, they appear in the urine, and afford a valuable index of the extent and character of the changes that are going on in the intestine. An analysis of the urine is therefore not only useful in making a diagnosis when clinical symptoms are present, but may also serve to detect the condition before any serious symptoms arise.

The presence of indol, skatol, phenol, and similar substances in the urine in excess, is the most easily obtained sign of abnormal putrefactive changes in the intestinal contents. A well-marked reaction for glucuronic acid with Tollen's naphthoresorcinol test is also helpful, but as a rule a determination of the relation existing between the ethereal and preformed sulphates is regarded as the most reliable index. In a state of health the proportion of ethereal to preformed sulphates is from 1 : 10 to 1 : 16 in adults on a mixed diet, but in disease it often rises to 1 : 7 or 1 : 5, and sometimes the amount of ethereal sulphates is greater than the quantity of preformed sulphates. Some observers employ Amann's co-efficient, that is, the ratio between the ethereal sulphates and the total nitrogen of the urine. Normally, the former are about 1·4 to 1·5 per cent of the latter, and in vegetarians 1·8 to 1·9 per cent. Others make use of Combe's coefficient or his capillary constant. The latter is based upon the fact that the surface tension of the urine is dependent upon the quantity of uric acid, hippuric acid, and aromatic bodies that it contains, so that the number of drops of urine corresponding to 100 drops of distilled water, less 100, and divided by the difference between the specific gravity of the urine and the specific gravity of water, gives a figure that, with certain reservations, may be taken as an index of the lowering of the surface tension of the urine brought about by the presence of the products of putrefaction. By a determination of the relation of the neutral sulphur to the total sulphur, and the urea and ammonia nitrogen of the urine to the total nitrogen, an idea can be obtained as to the functional activity of the liver, which it is obviously important to ascertain in cases of intestinal toxæmia. Normally the urea nitrogen constitutes at least 83 per cent of the total nitrogen; a lower proportion is suggestive of hepatic insufficiency. With the exception of about 5 per cent, the ammonia formed during digestion in the intestine is converted into urea by the liver, so that a ratio of over 5 parts of ammonia to 100 of nitrogen, points to there being some defect in the protective powers of that organ. It has also been proposed to test the functional capacity of the liver by the administration of 150 grams of dextrose or 80 grams of lactose in a single dose, on the hypothesis that its glycogenic and antitoxic powers are directly related; but as yet no very useful information has been obtained.

The considerable variations in the clinical manifestations and pathological accompaniments of chronic excessive intestinal putrefaction suggest that the etiological conditions are not the same in all cases. Herter accordingly divides them into three, or four, groups.

(*a*). *The Indolic Type*, which is characterized by marked indicanuria, and depends upon excessive putrefactive changes induced mainly by organisms of the B. coli type. In cases belonging to this group, Gram-stained smears show an excessive proportion of Gram-negative organisms. With Schmidt's fermentation test no gas is formed within twenty-four hours, and the reaction is strongly alkaline. Gelatin is rapidly liquefied, and cultures in sugar broths do not give rise to an excessive gas-formation. Cover-glass preparations from the sediment of the sugar-tubes show large numbers of coliform organisms. Litmus milk is rendered acid and coagulated. The clot is partially peptonized, and some 80 or 90 per cent of gas is formed. In this group are included certain cases of chronic dyspepsia associated with incomplete digestion of the proteins of the food, due to gastric, pancreatic, and hepatic insufficiency, also some cases of chronic indigestion in children in which there are retarded growth, gaseous distention of the abdomen, intolerance of carbohydrates, voluminous light-coloured stools, and sweating about the head. In adults the symptoms are similar, consisting of flatulence, abdominal distention, and indigestion following slight divergence from a strict diet. The readiness with which fatigue is induced is a prominent feature in both adults and children.

(*b*). *The Saccharo-butyric Type.*—This is due to the abnormal development of spore-bearing anaerobic organisms of the subtiloid type. Cover-glass preparations show a high proportion of Gram-positive forms, especially stout bacilli and cocci. Gelatin is not liquefied, or only slowly. Cultures in sugar broths give only a small percentage of gas, often half, a quarter, or a fifth of the normal. In some cases only traces appear in twenty-four hours. Cover-glass preparations from the sediment show stout Gram-positive bacilli and streptococci, with only comparatively few coliform organisms. Litmus milk is rendered acid and coagulated. The clot is broken up by a stormy fermentation, and there is considerable gas-formation, Cover-glass preparations show numerous subtiloid organisms resembling B. aerogenes capsulatus. It is a common condition in adults, and accounts for many cases of so-called dyspepsia, but is comparatively rare in children. A frequent symptom is the occurrence of diarrhœa, or flatulence, after a relatively slight excess of starchy food, owing apparently to the fermentation products formed acting upon the irritable mucous membrane more readily than in normal individuals. According to Herter, the organisms found in this type give rise to hæmolytic substances, with resulting anæmia in many cases, and he thus explains the onset of the "pernicious anæmia," that is known to be associated with intestinal disturbances.

(*c*). *The Skatolic Type.*—Herter hesitates to distinguish a skatolic type of intestinal indigestion, but in my experience there is a form of intestinal disturbance in which an excess of skatol with little or no indol is found in the urine, and that is associated with a fairly definite intestinal flora. Gram-stained smears are strongly positive. Gelatin is not liquefied very rapidly. Sugar broths give an abnormally high proportion of gas, and Gram-stained preparations from the sediment show an excess of streptococci, with usually some subtiloid and coliform organisms. Litmus milk is coagulated, the clot is peptonized, and the sediment shows streptococci and subtiloid organisms. Schmidt's test gives no gas, and the reaction is rendered strongly alkaline in twenty-four hours. Symptoms of enteritis, but more particularly of colitis, are very common, and nerve symptoms are frequently prominent.

(*d*). *Mixed Types* are much more common than any of the above-mentioned varieties, and of these the combined indolic and saccharo-butyric is the most frequently met with. It is characterized by marked indicanuria, combined with the presence of an excess of putrefactive anaerobic organisms in the fæces. Nervous symptoms are nearly always prominent, and many of the cases present the characteristic picture of what for want of a better term is usually called "neurasthenia."

The symptoms and course of any particular case are determined by the type of intestinal putrefaction, the integrity of the defences of the organism, and the relative vulnerability of the tissues of the body. Thus, in some cases the nervous system may be chiefly affected, in others the joints or muscles, or the blood may bear the brunt of the toxæmia, with the result that the clinical picture varies and may be that of neurasthenia, neuritis, osteo-arthritis, gout, anæmia, or some other manifestation of autointoxication. It is only by a thorough investigation of the fæces, combined with the results of an analysis of the urine, that the primary cause of the trouble and its exact nature can be determined. Putrefactive intestinal indigestion is probably set up by a large variety of causes, but the most common are irregular and hurried meals, imperfect mastication of the food, diminished secretion of free hydrochloric acid by the stomach, impaired secretion on the part of the pancreas and intestine, and an excess of protein food.

DISEASES OF THE PANCREAS.

There appears to be a general impression that disease of the pancreas is always accompanied by an alteration in the appearance and physical characters of the fæces. This is far from being the case, for, apart from biliary obstruction, the pale bulky motions of a white or oily appearance described in text-books are uncommon, being seen only in very advanced cases. They then present characters which to the experienced eye distinguish them from those met with in other diseases. They are whiter, more glistening, and sometimes contain masses of yellow, oily, undigested fat. Their smell, like that of rancid bacon, is very typical. Their lack of colour is partly due to the excess of fat they contain, particularly to the free fatty-acid crystals, and partly to a reduction of the normal colouring matter to a colourless derivative through the action of anaerobic bacteria. The reaction is frequently acid, sometimes very markedly so. With intestinal catarrhs and biliary obstruction, on the other hand, the stools are usually alkaline, so that when a pancreatitis is due to intestinal or biliary trouble the acid reaction may be masked by the alkalinity arising from this cause. In some cases of pancreatic disease the acid reaction is so marked that it produces considerable irritation of the bowels, and I have met with several cases of chronic pancreatitis in which this was so great that the patient's life was only made bearable by washing out the rectum several times a day with an alkaline solution.

The digestion of proteids is an important function of the pancreas, and the appearance of numerous undigested muscle fibres in the fæces is suggestive of serious pancreatic mischief; but it is not justifiable to conclude from this alone that the functions of the pancreas are interfered with, for, excluding their presence from an excess of meat in the food, undigested muscle may also be found in cases where, owing to increased peristalsis or putrefactive changes leading to secondary diarrhœa, the food is hurried through the intestine before it has had time to be digested. Defective gastric secretion may also lead to imperfect digestion of muscle.

Schmidt's "cell nuclei test" for pancreatic insufficiency is not in my experience of great value, but may be useful in providing confirmatory evidence. Schlecht's serum-plate test, and the more convenient casein digestion tests of Gross and Heiberg, are of considerable value in showing serious interference with the digestive functions of the pancreas, such as is met with in advanced cirrhosis of the gland and cancer; but they do not distinguish the early stages of chronic inflammatory conditions which are most amenable to treatment.

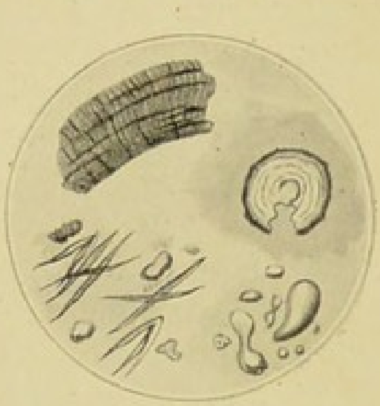


Fig. 92.—Pancreatic Disease and Biliary obstruction—muscle, fat, and fatty acids.

Reduction or failure of the secretion of the pancreas might be expected to lead to impaired digestion of starchy foods and the appearance of an excess of starch in the fæces. Observation has shown, however, that only a small proportion, or none at all, is excreted unchanged in such conditions. The discovery of unaltered starch granules in the stools is more commonly an evidence of a catarrhal condition of the upper part of the intestine than of pancreatic disease. An estimation of the amount of diastase in the fæces by Robert and Strasburger's modification of Goiffon and Tallarico's method may be a useful aid in diagnosis, although the test is subject to the same limitations as the digestive tests for casein, etc. Fedeli and Romanelli's application of the discovery made by Robert and Simon that saliva, inhibited in its activity by gastric juice, recovers its digestive powers when transferred to an alkaline medium and a little pancreatic juice, such as can be obtained from normal fæces, is added, may give confirmatory evidence of pancreatic insufficiency.

One of the most important and characteristic functions of the pancreas is to prepare the fats of the food for absorption by splitting them into fatty acids and glycerin; the former combine with bases in the intestine to form soaps, and these, in the presence of bile, are absorbed by the epithelial cells of the intestinal wall. Any disease of the pancreas interfering with its digestive powers, such as advanced cirrhosis or cancer, leads to an increase in the proportion of unabsorbed fat, and the greater part of this is usually found to be in the form of neutral fat and free fatty acids. On the other hand, with diseases of the intestine or obstruction of the bile-flow, where fat absorption is interfered with, the combined fatty acids are found to be in excess. If there is both interference with the digestive functions of the pancreas, and biliary obstruction or intestinal disease, the relation between the combined fatty acids and unsoaped fats will depend upon the relative extent and intensity of the two conditions. In interpreting the results of an analysis of the fæces for fats, one must therefore take into account the other indications given by the clinical symptoms and analyses of the urine and fæces.

In the early stages of chronic pancreatitis, when as yet the disease is of the purely catarrhal type, there is probably an increased flow of pancreatic juice analogous to the salivation seen in parotitis; hence fat digestion is often more active than usual, so that a low reading of total fat is obtained on analysing the fæces, and an excessive proportion of the fat is found to be in the saponified form. Cirrhosis of the pancreas may show as much as 50, and rarely even 80, per cent of unabsorbed fat in the fæces. In cancer of the pancreas the total fat is always high, averaging 71 per cent for the cases I have examined. With simple obstruction of the bile-flow, almost as high readings are sometimes obtained, and in cases of growth of the common bile-duct I have found as much as 70 per cent of the dry weight of the fæces to consist of fat. Intestinal diseases interfering with absorption may also show 50 or 60 per cent of unabsorbed fat in the stools. Other conditions associated with an excess of fat in the fæces, which must also be taken into account, are disorders of the stomach which prevent the breaking-down of the connective septa binding the fat together, and a diet containing an abnormal amount of fat, particularly when this is of a kind that is digested with difficulty. The use of liquid paraffin medicinally causes very high readings of total and "unsoaped" fats. The mere presence or absence of an excess of fat in the fæces is not therefore by any means conclusive evidence as to the existence or not of disease of the pancreas.

The relation between the combined fatty acids and unsoaped fats is of much more importance; but even here the modifications produced by the causes mentioned must be borne in mind when making a diagnosis. Further help may be obtained by determining the relation between the neutral fats and free fatty acids, a marked disturbance of the normal proportion of about one part of the former to ten of the latter tending to confirm a diagnosis of pancreatic mischief, as a result of which there is interference with the digestive functions of the gland.

The existence of defective pancreatic digestion does not, necessarily mean that the pancreas is diseased, for in order that its functions may be satisfactorily carried out it is necessary: (1) That the stomach should supply a stimulus in the shape of an acid chyme which will act upon the duodenal mucous membrane, giving rise to the " secretin " which will rouse the pancreas into activity; (2) That the pancreas itself should be able to respond and secrete the necessary ferments; (3) That bile should reach the intestine to aid in digestion and absorption; and (4) That the intestine should secrete the " enterokinase " by which the inactive proteolytic ferment, trypsogen, of the pancreatic juice can be converted into active trypsin. Failure of any one of these may lead to symptoms of pancreatic insufficiency, each of which will require a particular line of treatment.

1. Considering first pancreatic insufficiency dependent upon gastric troubles, if the secretion of hydrochloric acid by the stomach is deficient or absent, the pancreas will act imperfectly or not at all, for although fats and a few other substances appear to have the power of forming secretin from the intestinal mucous membrane, their activity in this respect is much less than that possessed by hydrochloric acid. In such cases, too, the pylorus opens at an abnormally early stage in digestion, so that the intestine is faced with the problem of dealing with materials in which there is not only a deficiency or absence of pancreatic ferments, but which have also been imperfectly prepared for the action of any ferment that may be there, with the result that the symptoms of " intestinal " indigestion ensue, and an examination of the fæces shows an abnormal amount of undigested food material. The absence of hydrochloric acid also tends to favour the growth of an abnormal intestinal flora. If, on the other hand, an excess of acid is poured out by the stomach, the pancreas may for a time be able to cope with it by secreting a corresponding amount of its alkaline juice; but the over-stimulation of the gland leads to degenerative changes, which are indicated by a marked pancreatic reaction in the urine, and eventually these bring about a diminished secretion. If the hyperchlorhydria continues, it will cause an abnormally acid

condition of the intestinal contents, and thus interfere with the activity of any pancreatic ferments that may be present, for these are quickly destroyed by free mineral acids, so that pancreatic insufficiency is again brought about, but in an altogether different way. In either case, the only certain way to diagnose the cause of the condition is by the administration of a test meal. Walko investigated the gastric functions of sixteen cases of chronic pancreatitis in this way, and found achlorhydria in eight, hyperchlorhydria in three, and a normal condition in five. He points out the danger of confusing chronic pancreatitis in which there is an epigastric tumour, achlorhydria, and cachexia, with malignant disease, and particularly with cancer of the stomach.

2. The part that the bile takes as an adjuvant in the digestion and absorption of fats has been mentioned, but it also appears to exert a very material influence on the digestion of proteids. It is therefore very necessary for satisfactory digestion that bile should be present in the intestine, and its absence is often a contributory factor in the production of pancreatic insufficiency. This is an additional reason why any cause of biliary obstruction should be removed as soon as possible, or failing that, the bile should be enabled to reach the intestine by a cholecystenterostomy.

3. Another important adjuvant to the digestive action of the pancreatic juice is enterokinase, a ferment present in the succus entericus, which has the power of augmenting the activity of the pancreatic ferments, and more particularly the proteolytic, to a striking degree. This "ferment of ferments" is secreted by the intestinal mucous membrane, chiefly in the duodenum, apparently through the stimulus afforded by the pancreatic juice. In certain diseases of the intestine it is probable that its formation is interfered with, and there may consequently be defective pancreatic digestion, not from true pancreatic insufficiency, but from a lack of the activating ferment. The diagnosis of such a condition is not easy, but its presence can be inferred when an analysis of the fæces reveals imperfect digestion, particularly of proteins, and there is no evidence of pancreatic disease or true pancreatic insufficiency.

4. The fourth variety of pancreatic insufficiency is the true form in which, owing to lesions of pancreas or obstruction of the ducts, there is imperfect digestion from diminution or absence of the pancreatic ferments. This is seen in advanced cases of cirrhosis of the pancreas, in some cases of pancreatic calculi and cysts, in cancer of the pancreas, particularly of the head of the gland, and in occlusion of the ampulla of Vater by gall-stones, growths, or stricture.

In acute hæmorrhagic pancreatitis there is usually intractable constipation at first, which, if the patient lives, is often succeeded by an equally intractable diarrhœa. Examination of the stools shows fat globules, fatty acid crystals, and undigested muscle fibres microscopically, and in some cases masses of oily fat have been seen with the naked eye. In gangrenous pancreatitis, persistent diarrhœa, sometimes with involuntary stools, is the rule. The motions are thin, copious, very fœtid, and may contain blood. In one recorded case they are stated to have been green, and much resembled vomitus. Abscess of the pancreas is usually associated with severe diarrhœa. The stools are, as a rule, profuse, watery, and fœtid, although they may be solid and very offensive. In one fatal case there were over twenty motions a day. In another there was a profuse hæmorrhage, about a litre of blood being passed by the bowel. The macroscopic presence of fat in the stools has been reported in only one instance, but in several pus was visible to the naked eye. The condition of the fæces in cases of pancreatic cyst will depend upon the extent of the associated injury of the pancreas. If there is advanced cirrhosis, an excess of fat, muscle fibres, and the other evidences of pancreatic insufficiency will be obtained; but in cases where the parenchyma of the gland is not much affected, little or no deviation from the normal will be found. The evacuation of the cyst through the bowel, which sometimes occurs, is accompanied by profuse diarrhœa. When the pancreatic ducts contain calculi there is usually considerable interference with the digestive powers of the gland, and the evidences of pancreatic insufficiency are found to a more or less marked degree.

It is most important that chronic pancreatitis with jaundice should be distinguished from malignant disease of the head of the pancreas, which clinically it resembles very closely. In addition to the indications already considered, the results of an examination of the fæces for hydrobilirubin is most helpful. With malignant disease of the head of the pancreas absolute blocking of the common bile-duct is the rule, so that no reaction for hydrobilirubin is obtained with the fæces; but in cases of chronic pancreatitis, whether associated with gall-stones in the common duct or not, some bile-pigment always finds its way into the intestine, so that a more or less marked reaction for hydrobilirubin is obtained. The soft growths originating in the common duct or gall-bladder also allow some bile to percolate through in most instances; hence the presence of hydrobilirubin in the fæces does not of itself absolutely exclude malignant disease.

Sometimes chronic pancreatitis is the result of invasion of the pancreas by growths or ulcers of the stomach or intestine, and the discovery of occult blood in the fæces is suggestive of one or the other. If the blood is found in every specimen on four or five consecutive days, it points to a malignant growth, whereas its intermittent presence is suggestive of a duodenal or gastric ulcer, which may be invading the pancreas or simply be associated with a catarrhal condition of the upper part of the intestine, to which the pancreatitis is secondary. Occult blood is also found very constantly in cases of cancer of the pancreas and with growths of the common

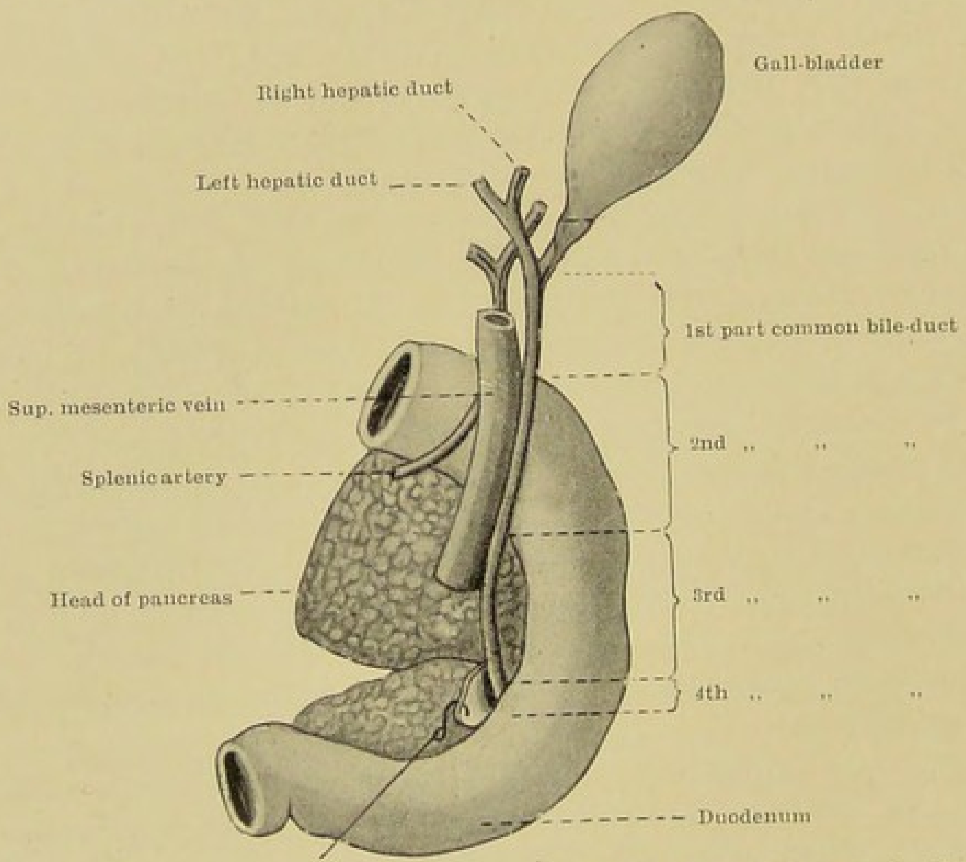


Fig. 93.—Relation of Common Bile-duct to Head of Pancreas. From behind—[*after Testut*].

bile-duct or gall-bladder. Occasionally it is met with in advanced pancreatitis without actual ulceration of the intestinal mucous membrane, probably as a result of the hæmorrhagic tendency.

EXOPHTHALMIC GOITRE.

The alimentary system is apt to be affected in various ways in this disease. During the early stages the appetite is frequently increased, and vomiting may occur from time to time. An increased frequency of defæcation is a striking symptom in some instances, two or three stools being passed in the twenty-four hours. This symptom must be distinguished from diarrhœa, for the motions, although frequent, are of normal appearance. True diarrhœa may, however, occur at intervals, coming on in sudden, short, painless attacks of one, two, or three days' duration, without any apparent cause. Some three or four light-coloured watery stools are then passed in the twenty-four hours, while the tongue remains clean, and there is little or no constitutional disturbance. The attacks may recur from time to time, and although often slight are sometimes severe, the bowels being occasionally opened thirty or forty times a day. Murray met with diarrhœa in fifty-three, or more than a quarter, of his cases, while constipation was only present in sixteen. Schmidt and Salomon made an analysis of the stools in exophthalmic goitre, and found an excess of fat. Their observations were subsequently extended and confirmed by Falta. I have examined specimens of fæces from three cases of exophthalmic goitre, but found an abnormally high percentage in only one of them. Bearing in mind the relation that is known to exist between the ductless glands, and particularly the thyroid, pancreas, and supra-renals, it has been suggested that the excess of fat in the fæces may be explained by an abnormal activity of the thyroid checking the functions of the pancreas, either directly, or by stimulating the activity of the chromaffin system. In favour of the latter view are the observations of Kraus and Friedenthal and Fraenkel, who detected an increase of adrenalin in the blood of patients with Graves' disease. Cecil quotes a case in which the pancreas was small and atrophic. Murray has recorded cases which strongly suggest that even when exophthalmic goitre is recovered from, it may leave behind irreparable damage of the pancreas. Falta and Salomon found, however, that in their cases there was not the excess of neutral fats that might be expected in a steatorrhœa of pancreatic origin, and they showed that fat absorption was not materially improved by the administration of pancreon. As it appears not unlikely that the internal, as well as the external, secretion of the pancreas is concerned in fat absorption and metabolism, and preparations of the pancreas given by the mouth can only supply the former, even when they reach the intestine in an active condition, too much stress cannot be laid on such therapeutic failures. In my case in which there was an excess of unabsorbed fat in the fæces, the unsoaped fats were in considerable excess of the combined fatty acids, 22·2 per cent of the former to 8·6 per cent of the latter; while in one of the cases where the total fat content of the stool was not abnormally high, there was 10·4 per cent of unsoaped fat to 8·2 per cent of combined fatty acids. The latter patient, who was under the care of Dr. Garrod in St. Bartholomew's Hospital, is particularly interesting, as his urine contained sugar. The fæces, besides containing 25·5 per cent of inorganic ash, showed only imperfect digestion of protein by Gross' test, suggesting that there was some functional derangement of the pancreas.

JAUNDICE.

Two principal types of jaundice are met with: (1) Those cases in which there is gross and frank blocking of the larger bile-ducts,

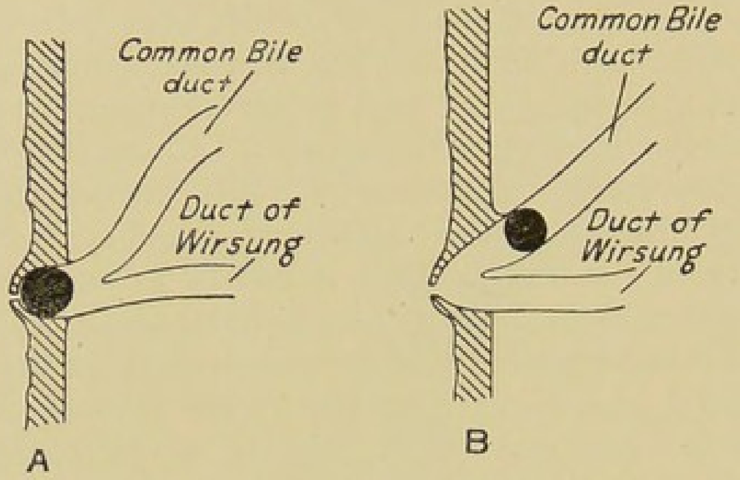


Fig. 94.—A, Gall-stone in Ampulla of Vater. B, Gall-stone in Common Bile-duct.

without abnormal blood destruction; (2) Those in which the obstruction is due to an increase in the viscidity of the bile in the smaller ducts, and in which there is a pathological destruction of red blood cells. In the first group the obstruction may be due to: (*a*) Mechanical blocking of the lumen of the ducts by gall-stones (*Figs.* 94, 95), malignant growths, or stricture, or by an inflammatory swelling of the mucous membrane or lymphoid tissue at the duodenal outlet; (*b*) Compression of the ducts from without by swellings of the pancreas (*Fig.* 93), enlarged lymph-glands in the portal fissure, lesions of the stomach, duodenum, kidney, etc., or by pressure from an aneurysm of the aorta, hepatic or mesenteric arteries, and other rarer causes, such as uterine tumours, etc. In the second, or toxæmic, group, the jaundice occurs as an incidental complication in the course of an infectious disease such as pyæmia, septicæmia, relapsing fever, pneumonia, scarlet fever, epidemic jaundice, Weil's disease, acute yellow atrophy, or as

Fig. 95.—Gall-stone in act of Extrusion into Duodenum. [R.C.S.]

the result of the action of certain poisons or drugs such as phosphorus, toluylenediamene, snake poison, chloroform, chloral, acetanilide, santonin, arseniuretted hydrogen, aniline, copper sulphate, mushrooms, etc.

More than four-fifths of all cases of jaundice met with in ordinary practice belong to the first group, the obstruction to the bile-flow being of an obvious mechanical character, the most common causes, in my experience, being biliary calculi and malignant disease of the pancreas. It may be pointed out in passing, that it is possible for gall-stones to be present in the common bile-duct without producing jaundice, and that unless this is borne in mind the symptoms to which they give rise may be attributed to the wrong cause, notably to "indigestion."

Analysis of the fæces is of importance in all cases of jaundice, and the results are particularly valuable where there is a suspicion of malignant disease. The percentage of unabsorbed fat, the relation between the combined fatty acids and the unsoaped fats,

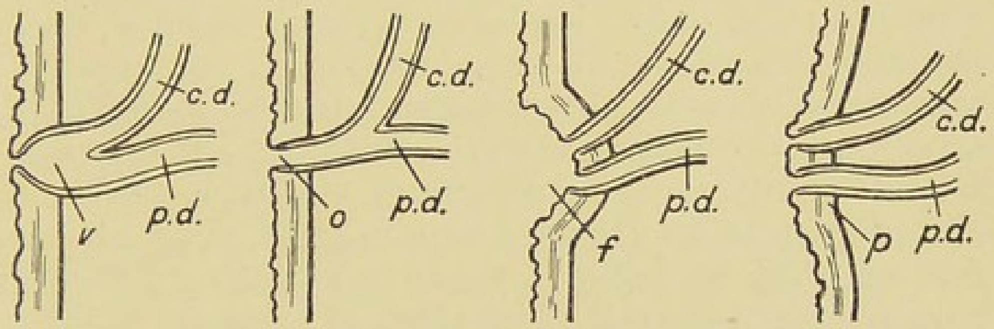


Fig. 96.—Four Methods of Termination of the Common Bile-duct and Pancreatic Duct. *c.d.*, Common bile-duct; *p.d.*, Pancreatic duct (Duct of Wirsung); *v*, Ampulla of Vater; *o*, Common orifice of ducts; *f*, Cup-shaped depression in wall of duodenum; *p*, Papilla.

and between the neutral fats and free fatty acids, the presence of hydrobilirubin and of occult blood, the results of the pancreatic insufficiency tests, and the proportion of inorganic ash, must be determined and carefully considered, for from them one can determine with a considerable degree of accuracy the extent of the pancreatic mischief, also whether the biliary obstruction is complete or not, and then infer whether one is dealing with a case of growth, or simple obstruction.

The effects of the exclusion of bile from the intestine are shown in the fæces mainly by: (1) Defective absorption of fat; (2) An increase in intestinal putrefaction; and (3) Loss of the fæcal colouring matter.

1. If bile is excluded from the intestine, the total amount of fat in the fæces will be increased, and the greater part should consist

of combined fatty acids or soaps. Such, in fact, is usually found to be the case in simple gall-stone obstruction and malignant disease of the common bile-duct or gall-bladder, when the fat-splitting functions of the pancreas are being normally carried out. If, however, the digestive powers of the pancreas are interfered with, from obstruction of the duct of Wirsung by a stone, malignant disease of the head of the gland, or advanced cirrhosis, the cleavage of fats is also defective, and they appear in the fæces mainly in the form of neutral fats and free fatty acids. The absence of digestive ferments does not, however, cause an entire cessation of the fat-splitting process, for, even in health, a certain amount of fat is broken down into fatty acids and glycerin through the activity of organisms of the colon group in the lower part of the small, and upper part of the large, intestine. If the activity and number of these bacteria is increased, as appears to be the case in intestinal catarrhs, they may bring about a considerable amount of fat digestion; but, since the fatty acids formed in this way are not absorbed during their passage through the colon and sigmoid, but combine with alkalies, they appear in the fæces as soaps, chiefly of calcium and magnesium. Hence, in catarrhal conditions of the intestine, and also in catarrhal jaundice, it is usual to find the combined fatty acids in excess and the inorganic ash also increased.

The greatest increase in the amount of total fat is seen in cancer of the pancreas, where I have found as much as 93 per cent of the dry weight of the fæces to consist of fat. In gall-stone cases where there is jaundice and pancreatitis, the total fat in my cases averaged 56 per cent, and in 60 per cent of them the unsoaped fats have been in excess of the combined fatty acids. Simple jaundice due to gall-stones, where there has been no involvement of the pancreas, has given about the same reading of total fat in many instances, but in 75 per cent the combined fatty acids have exceeded the unsoaped fats. Growths of the common bile-duct, or gall-bladder involving the common duct, produce much the same effects as gall-stones, the combined fatty acids exceeding the unsoaped fats, except when the growth is situated at the ampulla of Vater or is invading the pancreas, when the unsoaped fats are in excess.

2. The antiseptic action of bile has been much overrated. Its influence on putrefactive bacteria is very slight, and is quickly lost. Indirectly, however, the bile in the intestine has an important function in keeping the putrefactive processes within bounds by stimulating peristalsis, and so preventing stagnation of the intestinal contents. It also acts indirectly on putrefactive processes by aiding fat absorption, and so allowing more complete

digestion of the proteid elements of the food. Absence of bile from the intestine, therefore, tends to favour constipation and irregular action of the bowels. The effects of the consequent excessive putrefaction are shown by the offensive smell and markedly alkaline reaction of the stools, and are seen in the urine in the shape of an increase in the ethereal sulphates, an excess of phenol and aromatic oxy-acids, and sometimes by a well-marked reaction for indican. These effects are more marked when there is an associated intestinal catarrh and a mixed diet is being taken, and are more commonly seen in catarrhal jaundice than in jaundice due to gall-stone obstruction. The presence of pancreatic disease modifies the condition of the stools. If the functions of the pancreas are seriously interfered with, the motions become more bulky (often very strikingly so), are more frequent, and have an acid reaction ; the odour, too, is somewhat different, resembling more that of rancid bacon.

3. Complete diversion of the bile from the intestine gives to the fæces a light grey or slatey tint, producing the so-called "clay-coloured" stools. It should be remembered, however, that although the presence of the normal brown colour of the fæces may be taken as satisfactory evidence that bile is freely passing into the intestine, the existence of "clay-coloured" motions is not of itself a conclusive sign that there is complete biliary obstruction. This is a most important point to determine with certainty, for while complete obstruction is the exception in gall-stone cases, it is the rule when the obstruction is due to malignant disease of the head of the pancreas. Chemical examination of the fæces in the cases I have investigated has shown that in over 60 per cent with cancer of the pancreas no hydrobilirubin could be found, and in 34 per cent only traces could be discovered, whereas traces at least of hydrobilirubin were found in every instance where the obstruction was due to gall-stones, and in 82 per cent a well-marked reaction was obtained, in spite of the fact that in many of them the fæces were quite white to the naked eye. Traces of hydrobilirubin are usually found with malignant disease of the common bile-duct, and cancer of the gall-bladder invading the common duct, in contrast to the negative result usually obtained when there is a scirrhous growth of the head of the pancreas compressing the duct tightly from without. The white appearance of the fæces is usually most striking when the obstruction of the bile-flow is associated with well-marked pancreatic disease. When a common-duct obstruction is suddenly relieved, the fæces sometimes assume a bright orange colour, due to the presence of unchanged bilirubin.

In catarrhal jaundice, the unabsorbed fat is intimately mixed with the other constituents of the fæces and the exudates from the intestinal walls, so that the motions are of a light-grey colour and have a peculiar salve-like consistency. They give a well-marked reaction for stercobilin on chemical analysis.

A negative pancreatic insufficiency test in jaundice cases is against a diagnosis of malignant disease of the pancreas. A well-marked positive result points to malignant disease, advanced cirrhosis of the gland, or blocking of the duct of Wirsung by a gall-stone impacted in the ampulla of Vater. With cirrhosis of the pancreas and blocking of the duct by gall-stones one almost always finds, however, that there is some casein digestion, so that the more incomplete the digestion the more likely is it that the jaundice is due to obstruction of the common bile-duct by malignant disease of the head of the pancreas.

In cases of cancer of the pancreas, common bile-duct, or gall-bladder, occult blood occurs in the fæces with great constancy, so that a positive reaction in a case of deep jaundice, especially if it is found on four or five consecutive days, points to the jaundice being due to a growth in one or other of these situations. A positive result may also be due to malignant disease of the stomach or intestine with glands in the portal fissure, or more rarely to advanced simple chronic pancreatitis ; but a consideration of the results obtained by other methods of examination will usually decide to which of these it is to be attributed.

One usually finds that there is an excess of inorganic ash in catarrhal jaundice and in cases where the jaundice is secondary to growths of the intestinal canal, particularly of the colon.

INTESTINAL ATROPHY.

By an analysis of the fæces it is possible to distinguish atrophy of the mucous membrane from atrophy of the muscular tissue, and to differentiate these again from conditions with which they may be confused.

1. **Atrophy of the Mucous Membrane.**—In this condition, although the number of motions passed each day may be excessive, a test meal will show that the passage is delayed and that added colouring matter does not make its appearance in the fæces for forty-eight hours or more subsequent. The motions are generally offensive, and of porridge-like consistency, varying in colour from reddish to a dark brown. Harley and Goodbody noticed a distinct smell of sulphuretted hydrogen in the stools of a case they examined, and also obtained chemical reactions for that substance.

Microscopically, the fæces contain fat globules, fatty acid crystals, muscle, casein, and other undigested food particles. Leucocytes, epithelial cells and blood corpuscles may also be met with, and although mucus is occasionally present, it does not occur in membranous shreds or masses. Chemical analysis of the stools usually gives only a slight reaction for mucus, but a watery extract shows a marked reaction for albumin. Unaltered bile is not present, but an excess of hydrobilirubin is often met with. A distinct reaction for blood is usually obtained. A quantitative analysis will show that although there is some excess of water, it is not as great as might be expected from the diarrhœa that is present. Fat absorption is frequently not seriously interfered with, although an excess of combined fatty acids over unsoaped fat will often be found.

2. **Atrophy of the Muscular Tissue.**—Constipation with flatulency is the most striking clinical feature of this condition, and a test meal will show that there is delayed passage. The stools are not offensive and are of the usual constipated character, although more fluid motions containing mucus are passed at times. Chemical analysis of the fæces shows an abnormally low content of water, a considerable quantity of mucus, but no albumin, blood, or unaltered bile. The quantities of fat and inorganic ash do not usually vary markedly from the normal.

SPRUE.

Sprue is a disease occurring in the East, characterized by atrophy of the mucous membrane from the mouth to the anus, due to an as yet unrecognized bacterial invasion. Cases of the disease in patients who have resided in the tropics are not very uncommon in this country. The chronic destructive inflammation of the mucous membrane that occurs in this disease interferes to a greater or less extent with the digestion and absorption of food, hence the fæces are bulky, and show on microscopical examination an abnormally high proportion of food residues. On chemical analysis, from 34 to 58 per cent of the dry weight of the stool may consist of fat, even in uncomplicated cases, and where the pancreas is involved, as it not uncommonly is, the fat may rise to 70 or even 80 per cent. The greater part of the fat is in the form of neutral fat and free fatty acids, especially when the pancreas is affected; but sometimes, owing probably to the activity of fat-splitting bacteria in the lower part of the intestine, the combined fatty acids may be in excess. The presence of fat, and particularly of fatty acid crystals, explains in part the white appearance of the stools. Another important factor is, however, the chemical change brought about in the bile pigments by the action of the abnormal intestinal flora ; for, although the fæces in sprue invariably give a marked reaction for hydrobilirubin, no colouring matter can be detected by the naked eye in the characteristically pale stools. The reaction of the fæces is always strongly acid, owing to the increased peristalsis with consequent diarrhœa, that is a feature of the disease. Unlike catarrhal affections of the intestine, and especially those affecting the large bowel, the fæces in sprue do not contain an excess of inorganic ash ; in fact, there is usually a sub-normal percentage, owing to the high fat content. I have not obtained a reaction for occult blood in any of the twenty-four cases that I have examined.

INFANTILISM.

A generalized delay or arrest of development in children may arise from a number of causes, including disease of the heart, liver, pancreas, thymus, thyroid, etc., or from intoxication with the poisons of syphilis, rheumatic or scarlet fevers, alcohol, tobacco, lead, bacteria, etc. ; but the only types in which the fæces appear to have been investigated are those dependent upon disturbance of the functions of the pancreas and certain intoxications.

Pancreatic Infantilism was first described by Byrom Bramwell in 1904. The patient in whom this diagnosis was made was a youth of nineteen, whose bodily development had apparently been arrested about the age of eleven years. He was bright and intelligent, perfectly formed, and presented none of the physical alterations suggestive of sporadic cretinism. The abdomen was swollen and tympanitic, and for nine years before he came under observation, he had suffered from chronic diarrhœa. The urine was free from sugar. From a careful investigation of the urine and fæces it was concluded that the pancreatic secretion was defective or completely absent. That this was the case was proved by the remarkable improvement that was brought about by the administration of a glycerin extract of pancreas. As a result of the treatment, the stools were reduced in number from five or six loose motions a day to two, one of which was formed ; in two years he grew five inches and increased one stone eight pounds in weight, although for the previous eight years he was said not to have grown at all ; the sexual development, which before treatment was infantile, progressed in a normal manner, the patient looked much older, and his voice, which had been previously high-pitched and childish, became low-toned and rough. Thomson has described two similar cases in males, and Rentoul has reported the case of a female with similar symptoms. I have had two cases under observation in which it seemed that the lack of development was associated with some defect of the pancreas, for in both the fæces contained a high percentage of unabsorbed fat, of which the greater part was in the form of unsoaped fat, with an excess of neutral fat relative to free fatty acids, and in both an extract of the stools had very little digestive power on casein solutions. Whether, as some have suggested, the condition of the pancreas is dependent upon a general fibrosis of the gland from congenital syphilis, or it arises from a congenital insufficiency or atrophy of the organ, there can be little doubt that in cases presenting these symptoms the pancreas is sufficient for the metabolic needs of the body for the first few years of life, but that subsequently it is unable to keep pace with the calls upon it, so that nutrition and development suffer in consequence. It is worthy of note, however, that the deficiency appears to be confined to the digestive functions of the gland, and does not interfere with carbohydrate metabolism, for in none of the recorded cases has there been glycosuria. Whether diabetes may ultimately develop is uncertain, but no cases have as yet been reported in which such a complication has occurred.

Toxic Infantilism.—The arrest of development due to the action of various toxic substances is probably dependent in part upon their general effect on the tissues of the body, and in part upon the changes they induce in the ductless glands, and particularly the thyroid and pancreas. In some instances the nature of the poison is well recognized, but in others that probably belong to this group, it is unknown. Under the name of "intestinal infantilism," Herter and Kendall have described a condition in which an arrest of bodily growth and a slight retardation of cerebral development is associated with intestinal troubles and diarrhœa. These symptoms they ascribe to the presence in the digestive tract of an organism which they have called B. infantilis. It is a spore-bearing bacillus which is found in limited numbers in the fæces of some, but not all, normal infants. They consider that under certain, as yet undetermined, conditions, it finds a suitable environment for its proliferation, and gives rise to toxic products which, being absorbed, interfere with development. The organisms produce no agglutinins, and there is no direct evidence of its relation to infantilism; but animal experiments indicate that irritating products formed in its growth may give rise to diarrhœa. In cultures, B. infantilis produces a considerable quantity of volatile bases, consisting chiefly of ammonia, but amines, including probably methylamine and ethylamine, and possibly diamines, such as putrescerin and cadaverin, are also formed. None of the ordinary products of putrefaction, including indol, skatol, phenol, aromatic oxy-acids, hydrogen sulphide, and mercaptan, were discovered.

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Chapter X.

INDICATIONS FOR TREATMENT.

A DETAILED discussion of the treatment of diseases of the gastro-intestinal tract would be beyond the scope of this work, and it is only proposed in the following pages to consider the indications which examinations and analyses of the fæces suggest as the most useful means of dealing with the commoner pathological conditions.

I. DIET.

A.—General Considerations.

Since the primary function of the alimentary canal is to prepare the food for absorption, it is obvious that the question of diet is one of paramount importance in all gastro-intestinal disorders. The food supply necessary for the satisfactory working of the healthy organism is determined by a number of factors, among which the most important are the age, sex, and weight of the individual, the amount of mechanical and mental work done, and the extent to which heat is lost by exposure of the body, etc. In early life the metabolic processes of the body are more intense than later, and the constructive, or anabolic, changes outstrip the destructive, or katabolic, with the result that the body grows. Relatively, therefore, more food is required. In later life the two processes are more nearly balanced, and after growth has ceased they should be approximately equal if the individual is to remain healthy. As a rule women require less food than men, owing to their smaller stature and less arduous occupations, but there is apparently no intrinsic difference in their metabolic processes. Since human beings by their clothing shut themselves off from the reflex action of cold upon the skin, the greatest factor which tends to increase metabolism—and hence the need for food—is mechanical work. An average adult man expends daily about 34 or 35 calories for each kilogram of his body weight when taking moderate exercise, when at rest about 10 to 15 per cent less, and when taking active exercise about 10 to 15 per cent more, so that a man weighing 70 kilos (154 lb.), doing light work, would require about 2500 calories in the twenty-four hours. Theoretically, this amount of energy would be supplied by a diet suggested by Voit, containing :—

118 grams of protein	.. ..	484 calories
56 grams of fat	.. .. ..	521 ,,
500 grams of carbohydrate	.. ..	2050 ,,
		3055 calories

provided that all the food materials were fully utilized for the purposes of heat production in the body. As a matter of fact, although it is generally taken that :—

1 gram of protein yields	.. ..	4·1 calories
1 gram of fat yields	.. ..	9·3 ,,
1 gram of carbohydrate yields	..	4·1 ,,

the heat value of the foods to the body is a little less than is shown by the calorimeter, owing to the loss of unoxidized products in the excretions, etc. Atwater, in his most recent experiments, estimates that 4½ per cent of the nourishment taken is unutilized by the organism, while Rübner gives a slightly higher figure (5 to 5½ per cent). Even in health, a certain proportion of the food ingested is rendered valueless to the body as the result of putrefactive and fermentative changes in the stomach and intestine, or is lost in the fæces, so that the actual caloric value of the food to the body is always less than the theoretical value of that taken by the mouth. As a rule, probably somewhere from 10 to 25 per cent should be deducted from the calculated value to represent this loss. In cases where digestion is defective, absorption is interfered with, or abnormal putrefactive or fermentative changes are going on in the gastro-intestinal tract, a much larger loss occurs.

According to Rübner, an average healthy infant requires 100 calories per kilogram of its body weight for normal nutrition during the first three months of life, 90 calories during the second three months, and 80 or less subsequently ; but the total energy value of the food should not fall below 70 calories per kilogram, as this is about the maintenance minimum. Atwater states that children under two years require 0·3 of the food of a man doing ordinary work ; from three to five years, 0·4 ; from six to nine years, 0·5 ; from ten to thirteen years, 0·6 ; from fourteen to sixteen years in the case of females, 0·7, and in the case of males, 0·8. Camerer's diet, which he considers sufficient for a youth of sixteen years, contains 75 grams of protein, 42 grams of fat, and 325 grams of carbohydrate daily, with a total energy yield of 2040 calories.

According to Rose, the average energy requirement of children is approximately as follows :—

Under 1 year ..	.. 100	calories per kilogram
From 1 to 2 years	100 to 90	,, ,,
,, 2 ,, 5 ,,	90 ,, 80	,, ,,
,, 6 ,, 9 ,,	80 ,, 70	,, ,,
,, 10 ,, 13 ,,	70 ,, 60	,, ,,
,, 14 ,, 17 ,,	60 ,, 45	,, ,,

As the food is needed quite as much for growth as for heat and energy production in children, and especially in infants, the caloric method of arranging the diet is not so important as in adults, and should only be used as a check on other methods.

In old age the rate of metabolism is diminished, the amount of external work done is usually less, and the ability of the body to deal with an excess of food is diminished, so that the energy requirement per unit of body weight declines. Although senility cannot be accurately measured by years, it is usual to consider that persons between sixty and seventy require about 10 per cent less than an average adult, between seventy and eighty about 20 per cent less, and that over eighty, a reduction of 30 per cent in the total energy requirement is advisable.

The proportions of protein, fat, and carbohydrate in a mixed diet may be varied within limits, but generally it is found that one part of protein food is taken to each four or five of non-protein, and that of the latter one part of fat is taken to five or ten of carbohydrate. According to Voit, one-third of the protein should be animal and two-thirds vegetable. Wide variations, however, exist among different races and among different social grades of the same race. Fats and carbohydrates are the chief source of energy to the body, and are much more economical both financially and physiologically than protein. To obtain equivalent amounts of energy, for instance, from protein and fat, eleven and a half times more of the former by weight must be destroyed than of the latter, since every gram of nitrogen that is lost in the urine corresponds to a diminution of body weight by 33 grams of "flesh," with an energy yield of 0·8 calorie per gram, while the oxidation of 1 gram of fat simply means a loss of 1 gram of body weight, with an energy yield of 9·3 calories. The ingestion of fat or carbohydrate alone, however, while supplying energy to the organism, does not prevent tissue waste, and although death is delayed by a fatty or carbohydrate diet, it eventually ensues from gradual weakening of the vital organs, due to the loss of nitrogen which cannot be made up. Proteins are therefore an essential constituent of the diet, for they alone can supply the nitrogen that is necessary for the nutrition of the tissues.

The amount of protein required to keep the body in health is a much debated question. Voit, by a statistical method, arrived at 100 to 120 grams, which represent from 1·4 to 1·7 grams per kilogram of the body weight, as the correct amount. Rübner obtained a higher figure, 127 grams, and Atwater allows 125 grams. For men doing hard work, Voit gives 145 grams, Rübner 165 grams, and Atwater 150 grams. Chittenden found that well-nourished men, following different occupations, maintained good health for several months on a mixed diet containing 40 to 60 grams of protein, and came to the conclusion that the Voit standard contains about twice the necessary amount. Chittenden's results have been much criticised, on the ground that the men tested were all of the better classes, and could therefore undergo a greater restriction than the poorer classes, who are not so well nourished; also that the subsequent health of the cases was not reported; so that it remains to be seen whether the quantity of protein in his ration, which is not greater than would be metabolized in starvation, is advisable as a permanent standard. It cannot be denied, however, that 50 grams of protein, containing 8 grams of nitrogen, are apparently sufficient to maintain the machinery of the body in good repair. Voit himself has stated that a vegetarian can live in nitrogenous equilibrium on a diet containing 48·5 grams of protein, and that an active man weighing 74 kilos may remain in good condition on less than the 118 grams he advises as the average. As a rule it seems probable that a protein supply of one gram per kilogram of the body weight is adequate.

In children the requirement is much higher in proportion to the weight, as the protein is needed as a building material. At the time of most rapid growth, nature provides about $2\frac{1}{2}$ grams per kilogram of the body weight per day. This is about 10 per cent of the energy requirement per kilogram, a proportion corresponding to that taken in the form of nitrogenous food by a man doing moderately active work who is receiving one gram of protein per kilogram. After the age of sixty-five, less protein is certainly required than in middle age and early adult life, for the tissue changes progress more slowly, and there is less bodily wear and tear. As a rule the quantity of protein can be reduced with advantage to a half or even a third of that taken by a man doing an average amount of work. According to Moleschott it cannot be safely cut down to less than 45 grams a day, as this will yield 15 grams of urea, the quantity excreted by a starving individual which represents the minimum waste derived from ordinary wear and tear of the human organism.

Assuming that some 10 or 15 per cent of the total food requirement of the body is supplied by nitrogenous food, the remainder will have to be made up with fat and carbohydrate. The quantity of fat that can be taken differs with the individual and the form in which it is consumed, but as a rule 200 grams is the average quantity that can be digested without difficulty. The quantity of carbohydrate that can be consumed varies greatly, and is mainly dependent upon the form. The assimilation limit for sugar is much lower than for starch, and for this among other reasons the latter is the form in which carbohydrates should be chiefly taken. As a rule 500 grams or more of starchy food can be consumed in a day without difficulty.

Inorganic salts play an important part in metabolism, and there is abundant evidence that some of the mineral elements of the diet are as necessary as the protein, although they are needed in very much smaller amounts. Those which seem to be most important are phosphorus, calcium, and iron. Foods such as milk, eggs, whole grain, peas, beans, green vegetables, and fruit, rich in these elements, should therefore be adequately represented in the diet. As a rule, it is not necessary to calculate the ash content separately, for if the diet is selected from a wide range of food materials, or from a more limited one in which milk forms a predominant feature, it may be taken that the inorganic elements necessary for health are probably present in sufficient quantities.

MILK.

The best food for an infant is undoubtedly its mother's milk, for the milk of each species of animal is specifically adapted to the growth of the offspring of that species. Bunge showed that the ash content of dog's milk has exactly the same composition as the ash of the new-born puppy, and that it is entirely different in composition from human, cow's, or other milk, also that the casein of the milk of various races of animals differs in its chemical composition. The observations of Kiesel further suggest that the rennin of the stomach is specifically adapted for the coagulation of the casein produced by the female of the same race. The percentage quantity of the constituents of the milk is related to the rapidity of growth of the organism, so that the milk of cows, which attain maturity much more rapidly than human beings, differs considerably from that furnished by nature for the nutrition of the growing infant. This is well shown on comparing the percentage distribution of the calories in cow's and human milk :—

	Cow's Milk	Human Milk
Protein ..	21·3	7·4
Fat	49·8	43·9
Carbohydrate ..	28·9	48·7

The high protein content of cow's milk unsuits it for use in the feeding of infants, partly owing to the large heavy clot it forms in the stomach, and partly from the fact that even when digested, it is much above the requirement of the organism. If the milk is diluted with two or more parts of water, its protein content is reduced to approximately that of human milk, and the casein coagulum in the stomach is precipitated in the form of flakes. For the latter purpose barley-water is more efficient than plain water, owing to the 1 per cent or so of dissolved starch that it contains. By diluting cow's milk, however, the quantity of fat and carbohydrate is at the same time reduced, and these must therefore be added to form a proper diet for the child. To increase the fat, cream may be added, or " top milk " taken from milk which has been standing may be mixed with water. The deficiency in carbohydrate can be made up by adding sugar, but for this purpose milk-sugar, and not cane-sugar, should be used, as it does not so readily undergo fermentative changes in the stomach and intestine. Such a milk is called " modified milk," and can be used with success where for any reason mother's milk is not available. Experiments by Wilson and others have shown that milk-sugar may replace fat in isodynamic proportions without interfering with the normal growth and development of the organism, and this observation is of considerable importance in the feeding of infants with whom fats do not agree well. As, however, fats are not only an important source of energy, but also facilitate the absorption of calcium and magnesium salts from the intestine by forming soluble soaps with them, a deficiency of fat will deprive the skeleton of the earthy salts necessary for its growth.

One important difference between mother's milk and cow's milk, especially in towns, is the large and varied bacterial flora of the latter. The bacteria may be destroyed by heat, but the products of their growth cannot be removed in this way. Moreover, by heating the milk the solubility of the casein is diminished, the milk sugar may be partly converted into caramel, and the various anti-bodies that are present are destroyed. The latter are also probably different in human and cow's milk, thus accounting to some extent for the greater vigour and resistance to disease exhibited by most infants brought up wholly, or partly, on mother's milk.

Pawlow's experiments have shown that of all protein foods, milk requires for its digestion the smallest secretion of gastric and pancreatic juice; that is to say, it needs the weakest digestive secretion in proportion to its content of nitrogen. This is an important consideration in estimating the nutritive value of a food material, for if the amount of work done by the digestive glands is too large in proportion to the energy value of the food, the process of nutrition is being carried out in an uneconomical way. The nitrogen of milk appears to be more readily retained in the body than is the nitrogen of most other foods, since it has been found that with dogs on a milk diet the output of nitrogen as urea is increased only 12 to 15 per cent of the nitrogen ingested, whereas with a bread diet containing an equal quantity of nitrogen the increase of urea nitrogen may be 50 per cent of that taken in the food. In cases of disease of the gastro-intestinal tract, such as acute and chronic gastro-enteritis, where as much physiological rest as possible is required and yet the strength of the patient needs to be maintained, milk is consequently a most useful food. Another important property of milk is the power that it has of reducing the putrefactive changes that go on in the intestine on a mixed diet, so that it is useful in many cases of impaired digestion where an examination of the urine and fæces shows that an abnormal amount of putrefactive products is being formed.

In order to supply the needs of a healthy adult, from three to four litres of milk a day would be required if it were used exclusively. Such a large quantity of fluid is often objectionable, and is likely to cause discomfort by its mere bulk. A purely milk diet is therefore not advisable excepting for a brief period. As milk is poor in iron and chlorides, a diet consisting entirely of milk tends to favour the development of anæmia, diminish osmosis, and interfere with digestion. The nausea sometimes produced by milk may often be overcome by mixing it with Vichy or lime-water. Some people have a strong objection to the taste of milk, but this can be met by flavouring it, or using it in the form of junket, etc. In other persons, excessive peristalsis is set up soon after the milk has been taken; but if it is warmed and drunk in sips, instead of being gulped down like water, the difficulty generally disappears. A more serious objection is the constipation that is induced in some people by the use of a considerable quantity of milk. This is probably due to its too complete digestion and absorption, and may be counteracted by increasing the quantity of fat or prescribing vegetable foods that leave a large amount of residue. In an average individual some 9 per cent of residue appears in the fæces on a milk diet. In young children and infants, on the other hand, diarrhœa, vomiting, and regurgitation may be due to the milk containing too much fat, and will cease on its being reduced.

Some cases of gastritis and intestinal indigestion both in children and adults are made distinctly worse by a milk diet, and in children the disease may have arisen when milk has been the only, or staple, food. An examination of the fæces will often show that the flora of the intestine is abnormal, and contains an excessive proportion of subtiloid organisms that give rise to stormy fermentation in milk cultures. In such, the use of milk is contraindicated, and it should be replaced by carbohydrates and fats, particularly milk sugar and cream, as much as possible. In some instances butter is found to be better borne than cream. Skimmed milk, butter-milk, and whey may be advantageously substituted for whole milk when an excess of fat is to be avoided. Whey is particularly useful in the treatment of some acute digestive disturbances in young infants, and will often be retained if given cold and in small quantities at a time, when everything else is rejected. Peptonized milk may be used as a temporary expedient to tide over digestive difficulties in acute cases where the proteolytic activities of the stomach and intestine are being imperfectly carried out. Most condensed milks contain too little fat and casein to be employed as an exclusive food for long periods; but they are often retained by infants with feeble digestions when other foods disagree, by virtue of their poverty in these ingredients. Condensed milk has also the advantage that it is sterile and contains an abundance of sugar, which is the easiest food for an infant to digest and absorb. Children fed largely on condensed milk often grow fat and flabby from the use of so much sugar, and are likely to develop rickets owing to its poverty in fat. In cases where milk causes discomfort or there is distaste from the bulk of fluid, one or other of the dried milk preparations now on the market may be added to it, or to other foods, or be used in the form of a jelly. They may also be substituted for meat with advantage in digestive troubles dependent upon an excessive flow of hydrochloric acid in the stomach.

CHEESE.

Cheese is a very nourishing foodstuff, containing a high proportion of fat and protein. An ounce of cream, Cheddar, or Stilton cheese yields about as many calories as 6 or 7 oz. of milk. While many patients suffering from gastro-intestinal disorders can take a small quantity of fresh cream or soft cheese without any bad effect, the use of old and hard cheese gives rise to discomfort and accentuates the trouble. As the investigations of Vaughan have shown that most cheeses contain an indol-producing bacillus of the colon group, it is, however, probably better not to allow them at all in cases of acute and subacute gastro-enteritis, especially when there is evidence of abnormal putrefactive changes in the intestinal contents.

EGGS.

Eggs, next to milk, are the most generally useful food material in cases of gastro-intestinal disturbance. The protein portion is easily and rapidly digested when in a raw or lightly-cooked condition, provided that it is well subdivided, and the yolk contains a large amount of easily absorbed fat. Two average-sized hen's eggs contain about the same number of calories as a glass (8 oz.) of whole milk, and the yolks of five eggs are approximately equivalent to four whole ones. Eggs yield about 5 per cent of waste in the fæces under normal conditions. Some people find that eggs disagree with them. This is as a rule due to the white or albuminous portion. If this is rejected and the yolk only is consumed, the difficulty often disappears. Occasionally the yolks disagree, especially in persons who are constipated, and a good plan then is to give the whites of three eggs with the yolk of one. The free use of eggs is often useful in the treatment of intestinal indigestion associated with excessive carbohydrate fermentation, as they contain no material suitable for the growth of fermentative organisms.

MEAT.

The observations of Chittenden have shown that health can be maintained on much less protein than has previously been allowed in most standard dietaries, and whether his results are accepted in their entirety or not, there can be no doubt that they have drawn attention to the fact that most people consume too much meat. Very frequently the use of an excessive quantity of meat goes hand in hand with imperfect mastication, so that masses of undigested, or partly digested, muscle find their way into the lower ileum and large intestine, where they are attacked by putrefactive bacteria which find a suitable soil for their development and multiplication. The discovery of large numbers of muscle fibres or meat fragments in the fæces may indicate that this condition of things exists, and suggest an investigation of the habits of the patient, the condition of his teeth, and a regulation of the quantity of meat taken. Even in cases where no meat residues can be discovered in the stools, the state of the intestinal flora may suggest that an undue amount of protein food is being taken. Where there is evidence of saccharo-butyric fermentation, and large numbers of anaerobic gas-forming bacilli are found in the fæces, the patient often benefits by restricting the meat to one meal a day and keeping the quantity within very moderate limits, or even discontinuing the use of any meat at all for a time. In cases where the digestive powers are diminished, chicken, game, tripe, sweetbread, and white fish, which contain a relatively small quantity of connective tissue, free from fat, are usually more easily digested than red meats. The flesh of young undeveloped animals, which contain a relative abundance of connective tissue, should be avoided. Protein foods that hold much fat, such as pork, duck, goose, salmon, mackerel, etc., are contraindicated, as they are digested with difficulty. Re-cooked meats, hashes, stews, etc., should be avoided by all patients with weak digestions. Curries and highly seasoned dishes, as well as those containing intimately mixed oils, such as mayonnaise, increase any tendency that there may be to gastric or intestinal indigestion. On the average, meat yields about 5 per cent of residue in the fæces under normal conditions.

MEAT EXTRACTS.

Meat extracts and beef-tea differ somewhat in the percentages of extractives, salts, and soluble albumin they contain, and therefore vary in their nutritive value; but in any case it is not large, and they are chiefly useful for their stimulating and refreshing properties. In cases where digestion and absorption are defective, the use of meat extract, previous to or with other food, is often useful, as it stimulates the flow of digestive ferments, and so aids in their assimilation.

GELATIN.

Although gelatin contains nitrogen, it must be regarded as a non-protein food. Like the carbohydrates and fats, it is a protein-sparer, and may be used to replace protein to an amount equal to about twice the caloric value of the gelatin. According to some observers, about one-fifth of the ordinary quantity of protein may be so replaced, but others think that even a larger quantity may be substituted. It seems clear that gelatin is a more efficient sparer of protein than either fat or carbohydrate, and it may therefore be used with advantage for this purpose, especially in cases of pancreatic insufficiency, as it is readily digested and absorbed, and does not throw an excessive strain on the patient's powers of carbohydrate metabolism, which are probably defective. In its decomposition, gelatin yields no tyrosin, and therefore does not give rise to phenol, etc., so that by replacing a quarter or a fifth of the protein of the food by gelatin, it is possible to control the output of aromatic decomposition products in cases where there is excessive putrefactive cleavage in the intestine. As most patients soon tire of it, gelatin cannot be used for long, however. The addition of small quantities of gelatin to milk prevents the formation of large curds, and it is consequently useful in the feeding of infants and adults who are on a milk diet.

FATS.

The caloric value of fats is very high, and, although they do not protect the tissues from wasting so effectually as carbohydrates, they can be used in place of starchy foods to a considerable extent, or even exclusively for short periods at a time. Such a replacement of carbohydrates by fat is often useful in cases where starchy foods are imperfectly digested and undergo abnormal fermentative changes. In acute catarrhal conditions of the alimentary tract, both in children and adults, on the other hand, the use of fat in considerable quantities is objectionable, as it is not absorbed, and mechanically interferes with the digestion of proteins, thus favouring putrefactive changes. The absence of bile and the pancreatic secretion also interfere with the digestion and absorption of fats, and favour putrefactive changes in the proteins of the food in a similar way. How much fat should be given in the food in such cases is best determined by an analysis of the fæces. If the total fat does not exceed 25 or 30 per cent of the dry weight of the stool, no alteration in the diet need be made; but if a higher proportion is found, the fat in the food should be reduced. In health as a rule, only about 5 per cent of the fat taken passes in the stools. In pancreatic disease and jaundice, emulsified fats, such as milk, are better utilized than solid fats, and fats with a low melting-point are more easily absorbed than those that melt at comparatively high temperatures. Fats increase the peristalsis of the small intestine, and the products of their digestion and bacterial decomposition act on both the colon and small bowel. As a certain proportion always remains unabsorbed, their presence in the food softens the fæces. The absence of fat, or too low a proportion in the diet, therefore, tends to induce constipation, while the presence of a reasonable amount helps to maintain the regularity of the bowels. This fact is of considerable importance in the treatment of constipation, especially in children. During the first six months of life the fat content of the milk should be raised to about 3 per cent; by the end of the first year it should be increased to about 4 or 4½ per cent, which is usually sufficient to prevent constipation. When regurgitation or diarrhœa occurs, it is advisable to reduce the milk fat to 1 or 2 per cent temporarily. The observations of Pawlow and others have shown that fats exert a considerable influence on the secretion of the digestive juices. The inhibitory effect which oils have on the formation of hydrochloric acid by the stomach is taken advantage of in the treatment of hyperchlorhydria, a drachm or more of olive oil or liquid paraffin being given before each meal. The formation of secretin by the duodenal mucous membrane is stimulated by fats, although they are much less active than acids in this respect; but in cases of pancreatic insufficiency, due to an absence of hydrochloric acid from the stomach, fats may be used, with acid drinks, to induce the flow of pancreatic juice necessary for digestion.

Most English people have a more or less marked constitutional antipathy to fatty foods, and, as the choice of fats that may be added to the diet is somewhat limited, it is not an easy matter readily to increase the amount. Cream, taken with tea, coffee, sweets of various kinds, and in porridge, is one of the least objectionable methods, but it is not well tolerated in all cases. Many people, and particularly those who suffer from indigestion, can take butter in abundance when cream is badly borne. It can be used with bread, or in the melted form with vegetables. Bacon fat is one of the most useful forms of fatty food, but, like mayonnaise, is often not well tolerated by those with gastric disturbances. Salad oil, either alone, or with vinegar as a dressing for lettuce, tomatoes, etc., is a means of raising the fat content of the diet that is to be recommended in the treatment of constipation. Cod-liver oil, in the simple form, or as an emulsion, is often well borne when other fats are not tolerated.

CARBOHYDRATES.

Experiments made by Zuntz and Heinemann have shown that there is little difference in the efficiency of the body as a machine whether carbohydrates or fats are taken, but it is a common experience that muscular fatigue is delayed and more work is done when carbohydrates are available. The experiments of Lee and Harrold on muscle fatigue in cats confirm this. Carbohydrates are the most economical foodstuffs from every point of view. They are the greatest sparers of protein, they may almost completely replace fat in the food, and they are more readily digested and completely absorbed from the intestine than fat, when given in the form of sugar or cooked starch, although the form in which the starch is given has a marked influence on the extent to which absorption takes place: thus starch in the form of arrowroot or cornflour leaves about 1 per cent of residue; taken as macaroni, rice, or bread, about 4 per cent; as potato, 11 per cent; as peas or beans, from 9 to 15 per cent; while with vegetables such as spinach, lettuce, and cabbage, the carbohydrate content of which is low relative to their bulk, a much larger proportion may escape in the fæces in an undigested condition. After being absorbed, carbohydrates are much more quickly oxidized than other foodstuffs, and are therefore desirable when a quick supply of heat or energy is required. Further, they can be given in a greater variety of forms than fat, so that appetite, which after all is a most important factor in dietetics, is not blunted by lack of change. They are also relatively inexpensive.

A certain amount of carbohydrate food can be advantageously taken in the form of sugar. Cane sugar and the lævulose of fruits and honey are those most commonly employed. These are highly soluble, and are readily and quickly absorbed in a state of health, but where there is chronic gastro-intestinal catarrh, considerable delay may occur. Under these circumstances the sugars undergo fermentative changes, and are not only lost to the organism as a source of energy, but give rise to discomfort, flatulence, colic, and perhaps diarrhœa. Milk sugar is not so sweet as cane sugar, and may therefore be used in larger quantities without producing nausea, a fact that is taken advantage of in the "high calorie diet" treatment of typhoid fever. Milk sugar is less quickly absorbed than saccharose, but it is not so readily attacked by fermentative organisms, so that it can be used with advantage in some cases of gastritis and enteritis in which cane sugar and dextrose give rise to flatulence and discomfort. For the same reason it is to be preferred to cane sugar for sweetening modified milk for infants, but an excess may give rise to diarrhœa, owing to its relative slow absorption and tendency to undergo lactic-acid fermentation.

Maltose is the most quickly absorbed of the disaccharides, so that when there is excessive fermentation of sugar with consequent intestinal indigestion, especially in infants, maltose is often better borne during the convalescent stage than lactose. Maltose is, however, contraindicated in the treatment of diarrhœa due to the gas bacillus and similar organisms, and is less useful than lactose in the treatment of that caused by the dysentery bacillus. Maltose is one of the most important constituents of the majority of the proprietary foods for infants, and children brought up on such foods often weigh more than others of the same age who have been properly fed; but they are pale, their muscles are flabby, and they have little muscular power. This is due to the ease with which the sugar and dextrins with which it is mixed are absorbed and utilized for conversion into fat, while there is also a diminished elimination of water by the kidneys. Under normal conditions lactose is to be preferred to maltose for infants, for it favours the development of B. bifidus, the normally predominant organism of the large intestine, whereas maltose conduces to the growth of B. acidophilus, which, although normally present in small numbers, is liable to cause an excessive degree of acidity, with consequent increased irritation of the intestine and intolerance for sugar if developed to any great extent. The laxative action of malted foods may be taken advantage of in the treatment of a tendency to constipation, and more especially in children. Adults who have taken an excess of carbohydrate food for long periods sometimes exhibit a lack of strength and superabundance of adipose tissue similar to that seen in infants brought up on dextrinized proprietary foods, and for the same reasons.

The effects of an excessive amount of carbohydrate food in the form of starch are similar to those that follow an excess of sugar, but the symptoms are not so readily produced, and flatulence is not so marked, owing probably to the fact that the starch is only gradually converted into sugar, from the fermentation of which the symptoms arise. In almost all forms of gastro-intestinal disturbance the digestion and absorption of starch is interfered with, so that its use should be carefully regulated and controlled by a microscopical and chemical examination of the stools. Sugars should be avoided as much as possible, milk sugar being substituted for cane sugar if circumstances permit, and the quantity of bread and potato should be reduced. Most persons with chronic digestive troubles tolerate starch in the form in which it occurs in vegetables better than as bread, potato, rice, and other simple starchy foods, owing to the fact that it is only slowly set free. Unless the vegetables have been very well cooked, a considerable part of the starch may escape in the fæces still enclosed in its cellulose envelopes. The woody fibre and cellulose of the vegetables stimulate peristalsis, and by ensuring a more rapid transit of the food through the intestine, still further interfere with the absorption of the starch.

There has been considerable controversy as to the relative merits of whole meal and white bread. When the grain is crushed in the simplest method of milling wheat, it is reduced more or less completely to a powder, and the meal thus prepared contains coarse particles of bran, the outer coverings of the seed. Bread made from such wheat meal will obviously contain all the nutrients of the original wheat ; but the bread will be coarse in texture, dark in colour, and rather strong in flavour. Sifting the wheat meal to remove the coarser particles was the first step towards the making of white flour. The early methods of the manufacture of fine flour from starchy wheats resulted in flours relatively low in inorganic ingredients and protein, and rich in carbohydrate, so that flours with no more than 8 per cent of protein and 0·3 per cent of ash were not uncommon. This feature is said to have inspired Liebig to recommend a return to the more albuminous wheat meal, and to have given Graham the basis for his crusade in favour of bread made from unbolted wheat meal.

Despite these chemical facts, and the vigorous propaganda against it, the use of fine bolted flour and the preference for white bread rapidly increased with the progress of the years. The investigations of Lawes and Gilbert, and subsequent nutrition studies in Germany, gave indication that although whole-wheat bread actually contains more protein and ash than white bread, it yields up relatively less of these to the digestive and metabolic processes. It is further maintained by some that an increased peristaltic action, due to the mechanical irritation produced by the bran on the lining of the intestine, also tends to offset the supposed chemical advantage in the whole-wheat bread ; others state that this mechanical irritation is beneficial, especially for those with a tendency to constipation.

The advent of the later roller-process methods of milling has continued the essential feature of the earlier schemes in separating the bran from the interior of the grain ; but it has materially improved the bread flours in common use, until the standard flours from hard wheat contain more protein than almost any whole-meal flour in the market thirty years ago, and as much as many now offered for sale. More recent methods of agriculture in wheat production have assisted in increasing the gluten content of wheat flour through the altered composition of the newer varieties of the cereal.

The most reliable available nutrition experiments in respect to the digestibility and available energy of bread made from the different types of flour afford these data :—

	Digestibility of Protein, per cent	Availability of Energy, per cent
Graham flour ..	.. 81	83
Entire wheat flour	.. 83	87
Standard patent flour	.. 89	91

These have been corroborated by the observations of Newman, Robinson, Halman, and Neville, who have shown that with respect to the availability of their total energy, the breads differ little ; with regard to the protein there is a slight advantage on the side of the white bread. At present, the differences in the composition of flours are due not only to the method of milling, but also and especially to the variety of wheat used in their manufacture. It is as important, therefore, to know the kinds of wheat as any other factor in making intelligent comparison of flours.

It is possible that the white-flour milling process may remove certain unknown constituents from the cortex of the grain which, as in the case of rice, have some special nutritive significance ; but ordinary metabolic experiments give no clue to the importance of these accessory factors. Presumably, however, they can only have a predominating influence when bread forms a very large proportion of the dietary. So far as digestibility is concerned, there is no justification at present for extreme views as to the advantages or disadvantages possessed by different kinds of bread of the commoner types, at any rate as regards the availability of the more familiar nutritive constituents, and it may be concluded that wheat flour of all kinds is an economical food.

FLUIDS.

As water, according to Rübner, constitutes about 63 per cent of the total weight of the body, and there is a constant loss through the urine, the perspiration, in the fæces, and through the exhalations from the lungs, it is obvious that a considerable amount of fluid must be ingested each day, in order that the functions of the organism may be properly carried out. On the average, about one-sixth of the daily loss is made up by the water contained in the food, and the remainder is taken in the form of fluids, of which an adult man should consume about three pints daily. Many people habitually take too little fluid, and this is a not uncommon cause of constipation. Some, on the other hand, take too much. It was at one time taught that an excess of water increased protein destruction, but this has now been disproved. The continued use of large quantities in excess of the requirements of the body, however, no doubt tends to impair the functions of the various organs by increasing the volume of the blood and thus embarrassing the action of the heart, lessening the activity of the digestive juices, and thus causing indigestion and leading to faulty metabolism.

It has generally been accepted, on theoretical grounds, that water taken with meals dilutes the digestive juices and so retards digestion, and that therefore it is better that fluids should be consumed at the end of or after meals. The experiments of Hawk and his fellow workers suggest, however, that the copious ingestion of water with meals promotes economical metabolism. Hawk carried out a series of experiments in which healthy young men were put on a uniform diet and their food and excreta analyzed quantitatively. The experiments were divided into three periods: a preliminary period, during which the subjects were brought into a state of approximate nitrogenous equilibrium by several days of uniform diet and light exercise; an experimental period, in which definite quantities of water were added to each meal; and a period during which the effects of the experiment were watched for a number of days on a uniform diet without the added water. In some cases 500 c.c. and in others 1000 c.c. of water were taken with each meal, in addition to the amount normally consumed. The subjects were weighed daily, and analyses were made of the collected twenty-four hours' excreta.

An expected result was the immediate increase in the quantity and decrease in the specific gravity of the urine. Accompanying this was a decided increase in the ammonia-nitrogen and chlorine excretion. Hawk explains this as a result of the increased secretion of hydrochloric acid by the stomach, due to the stimulating effect of the water. This acid, being neutralized by the ammonia formed as a result of protein consumption in the tissues, gave the increased output of ammonia and chlorine, probably as ammonium chloride. There was also a decrease in the uric acid content and an increased allantoin output, which is tentatively attributed to the more complete oxidation of the waste products. Analyses of the stools showed a decrease in the fæcal output, both wet and dried. This was accompanied by a decrease in the fats and carbohydrates excreted, in the fæcal nitrogen, and in the actual bacterial content. The intestinal putrefaction was decreased as measured by the indican output. This is ascribed to the inhibition of the indol-forming bacteria due to the accelerated absorption of the products of protein digestion. More complete absorption of all foods leaves less culture medium for bacteria, which may explain the decrease in fæcal bacterial content. Though the nitrogen of the urine was increased, the fæcal nitrogen was decreased, and quantitative analysis of the total nitrogen ingested and excreted showed that the body was storing nitrogen. In other words, the system was laying up protein material. All this would indicate that the digestion, absorption, and economical utilization of proteins, fats, and carbohydrates had been promoted by ingestion of water with meals.

The amylolytic activity of the fæces, denoting, according to Wohlgemuth, the content of pancreatic ferment present, was increased over that of the period of average water ingestion. Hawk interprets this reservedly as indicating a stimulation of the pancreatic function.

The subjects showed increase in body weight and a general improvement in physical and mental condition. There were many desirable and no undesirable results. The effects were more pronounced when larger quantities of water were taken. The results were not temporary, but persisted after the close of the experiment.

The copious drinking of water with meals should not, however, be practised indiscriminately, and certain pathological conditions would be a distinct contraindication. As experiments have established that digestion is retarded until the stomach contents have been brought to the body temperature, large quantities of very cold water would not be beneficial. It would be of interest to know whether equally favourable results would follow if the increased amount of water were taken between meals instead of with meals; but as the matter stands, the experimental evidence seems to refute the theories previously held regarding the effect of water taken with meals.

STIMULANTS.

The food and drink of all races and types of people from the earliest times have contained stimulants such as tea, coffee, wine, beer, etc. Their use tends to abolish feelings of fatigue, depression, and despondency, and in moderation they may assist the digestive processes and stimulate appetite. An excess taken for a considerable time is, however, no doubt harmful, and as a healthy individual needs no such adventitious aids to digestion, their use should be discouraged in children and young adults. Without entering into the keen controversy that has raged around the use of alcoholic drinks, it may be stated as a generally accepted fact that they are unnecessary for, and should be avoided by, all persons under the age of thirty years, except in pathological conditions, where their stimulating effect on the circulation, and anæsthetic action on the nervous system, call for their use. In middle life the occasional use of alcohol may be advisable, and after fifty its use is often beneficial, if consumed in moderation. When alcohol is taken, it should always be in the purest form, whisky, sherry, and Rhine wines being the best; but they should be well diluted with water, as strong alcohol is a local irritant to the stomach and may cause catarrhal gastritis.

CONDIMENTS AND SPICES.

Spices and condiments are not foods, but their addition to the diet stimulates the appetite, promotes the flow of the digestive secretions, and stimulates the movements of the stomach and intestine in virtue of the aromatic oils and other substances that they contain. Like the stimulants, therefore, they are most useful for the aged and feeble, whose functions in these respects are defective, but are unnecessary and may be harmful for healthy persons with a normal digestion, and especially for children. An abuse of such substances gives rise to catarrh of the stomach, and causes hyperæmia of the liver.

COOKING.

The cooking of food and the manner in which it is prepared for the table and served, are matters that do not receive the attention that they deserve. It is not enough to prescribe a diet for a patient: one should be able to advise as to the most suitable way in which the constituents may be prepared to suit the needs of the case. The object of cookery is to ensure that the greatest nutritive and æsthetic advantage may be derived from the consumption of the food we take. The æsthetic factor is an important one, especially in invalids, but it is often overlooked. The experiments of Pawlow have demonstrated that the sight and smell of food give rise to a flow of digestive juice into the stomach, thus preparing the way for its digestion, and there can be no doubt that badly cooked or unappetizing food is not so well assimilated as that which is well cooked and daintily served. The alterations produced by cooking are partly chemical and partly mechanical. The albumin of meat is coagulated, so that it is more easily disintegrated and acted on by the digestive secretions; the connective tissue is rendered more soluble by the heat, and aromatic substances are developed which are agreeable to the palate and encourage appetite.

Meat may be baked in an oven, roasted in front of a fire, broiled or grilled over clear red-hot cinders, fried in fat, or boiled in water. Liebig states that beef or mutton is not cooked until it has attained a temperature of 158° F. throughout the whole mass; but poultry and game, although requiring a hotter oven for baking than butcher's meat, are more quickly cooked, and need only attain a uniform temperature of 130° to 140° F. Baked meat is not so easily digested as roasted, owing to the greater retention of the oils, which are rendered empyreumatic and indigestible by great heat. In broiling and grilling meat, the exterior is quickly browned and hardened, so that evaporation is prevented and the meat is cooked in its own juices, thus imparting to it a peculiar flavour and tenderness. Frying is the most objectionable method of cooking, since the heat is applied through the medium of boiling fat or oil, which makes it indigestible and liable to disagree. In boiling meat, the process varies according to the result desired. If the meat itself is to be eaten, it is placed at once into boiling water, which coagulates the external layers and thus retains the flavour. If, on the other hand, soup is to be made, the meat is placed in cold water and gradually brought to the boiling-point, affording an opportunity for the flavouring matter, some of the albumin, and part of the gelatin, to soak out before the outer layers are rendered impermeable.

Most foods lose more or less of their bulk in cooking. Beef loses a quarter and mutton a fifth on boiling, and more on being roasted. Although roasted and baked meats are more appetizing and nutritious than boiled, the latter, if properly prepared, are more digestible.

By cooking vegetables, the cellulose envelopes are softened and burst asunder, so that the digestive ferments can more readily reach the contained starch and albuminous matter. The starch granules are at the same time caused to swell, and the starch assumes a more soluble form. In green vegetables, the fibres are softened, the albumin is coagulated, and part of the saline, saccharine, gummy, and oily matter is dissolved in the water. If it is desired to retain the saline constituents of the vegetables, they should be cooked in a double saucepan in their own juices, or in oiled butter. In preparing some green vegetables it is advisable to remove as much as possible of the contained oils, which give them an objectionable flavour, and are liable to cause flatulence; they are consequently boiled rapidly, with the lid off the saucepan, and frequently skimmed. Rain-water is to be preferred for cooking, owing to the absence of salts of lime and magnesia, which are apt to be deposited on the surface of the food, hindering the penetration of the heat into the interior, and preventing the abstraction of soluble materials. All food materials containing much free starch must be carefully prepared by being mixed into a thin paste with cold water before being heated; otherwise, lumps are apt to be formed and the starch in the interior of these remains in an unaltered condition.

While cooking is as a rule an advantage, rendering the food more digestible and palatable, the application of heat destroys the natural digestive ferments present in some, so that they are better eaten raw. This is particularly true of oysters, new milk, and certain fruits, such as pineapple, etc. Lightly boiled white of egg is more readily digested than the raw material if well masticated, but raw white of egg, when subdivided by beating, either with water or milk, is more easily attacked by the juices of the stomach than the same material hard-boiled and swallowed in lumps.

MASTICATION.

It would seem superfluous to insist on the thorough mastication of the food, but the experience of all who have opportunities of seeing many cases of dyspepsia shows that they are more frequently due to want of proper mastication and bolting of the food than to almost any other cause. In this respect, unfortunately, members of the medical profession rarely set a good example. The hurried swallowing of the food results in too little saliva being secreted, and the absence of the normal nervous stimulus which sapid substances give to the flow of gastric juice. The first step in the process of digestion is thus imperfectly taken, and the others are consequently more or less at fault; starchy foods are therefore not thoroughly broken down, and proteins are not disintegrated in a proper manner. The presence of these imperfectly digested materials in the intestine encourages the growth of an abnormal intestinal flora, and eventually the symptoms of dyspepsia make their appearance. Bolting the food is most common among busy people, and those of active habits who look upon feeding as a necessary evil. If the teeth are bad, so that proper mastication is impossible, they should be seen to; but where the hurried swallowing of food is only a habit, it must be broken by prescribing a definite period for each meal, or by making the patient count the bites in the way recommended by the late Sir Andrew Clark: "Thirty-two teeth in the mouth, thirty-two bites to each mouthful, and for every tooth that is missing a corresponding increase in the number of bites."

GENERAL HYGIENE, ETC.

So many gastro-intestinal disorders are of bacterial origin that the avoidance of contamination of the food and drink is an important prophylactic measure. The care of the water supply is now vested largely in corporate bodies, who take due precautions to prevent its pollution. Milk is one of the most fruitful sources of infection, especially among children and in the summer time. Until its collection, storage, and distribution are more efficiently controlled than at present, it is likely to remain a constant menace to the health of the community. A rough idea as to the number of putrefactive organisms present in a sample of milk can be formed by permitting a portion to stand in fermentation tubes in the incubator, after being subjected to partial sterilization by the process of pasteurization. By this procedure, the lactic acid organisms, which restrain putrefactive decomposition, are destroyed, while any surviving spore-bearing putrefactive bacteria reveal their presence by the stormy fermentation they set up. Since the skins of uncooked fruits are not infrequently contaminated with B. putrificus and other organisms, they should always be peeled before being eaten. Vegetables should be sterilized by heat as far as possible, since sewage organisms and the eggs of various intestinal parasites are sometimes present on the surface. Washing is not sufficient, and the soaking in brine often given by cooks, only serves to detach insects and adult parasites. The cooking of meat goes a long way in inducing a condition of sterility, but it does not necessarily destroy the toxins that have formed, or the enzymes which may subsequently bring about deleterious changes. "High" game, for instance, is in an early stage of putrefaction brought about by the activities of organisms which are always floating in the air. These settle on the meat, and by a process allied to fermentation, produce changes in the protein and other constituents which give the "gamey" flavour. In the process of cooking the organisms are destroyed, but their ferments may escape and continue to give rise to toxic bodies, thus explaining how it is that high game and tainted meat may often be eaten with safety while hot, but will give rise to symptoms of food-poisoning when taken cold a few hours later. Besides tainted meat and game, meat pies, sausages, potted meat, and tinned foods are the most common causes of ptomaine poisoning.

The proper cleansing of the mouth has some bearing on the introduction of putrefactive organisms into the intestine. Such bacteria are not uncommon in the mouth, especially when there is dental caries, and the cure of the latter, and the intelligent use of the tooth-brush and a soft toothpick, may be of material assistance in minimizing a possible source of infection. This is particularly the case when a distinct odour of butyric acid or a putrefactive smell makes its appearance within an hour or so after a meal; but it is easy to exaggerate the importance of oral conditions in gastro-intestinal affections, and as a rule they are, at the most, only contributory.

The avoidance of chemical and mechanical irritants is a matter that should receive attention in all gastro-intestinal diseases. The proper use of condiments and spices arouses a flagging appetite, excites the digestive secretions, and stimulates the movements of the stomach and bowels; but their abuse gives rise to chronic catarrh and may cause hyperæmia and congestion of the liver. In moderation, they are of distinct value in the diet of the middle-aged, of old people, and those who are feeble and have a poor appetite, but healthy persons with a normal digestion do not need them. They should never be given to children, in whom the habit of taking highly-spiced and seasoned food is very quickly acquired. Patients suffering from putrefactive disorders, and particularly those in whom there is associated neurasthenia, will often be found to have taken large quantities of pepper, mustard, pickles, or salt. Indulgence in these, and also in substances containing free acids, such as lemon juice and vinegar, should be prohibited. Chronic catarrhs of the stomach and intestine dependent upon the abuse of condiments cannot obviously be successfully treated until their use is stopped.

The property that some essential oils, and particularly those derived from members of the natural orders labiatæ and umbelliferæ, have of relieving flatulent distention due to fermentation in the intestine, is of some medicinal importance. Their use may often relieve the symptoms and tide over a difficulty, especially when taken in a hot infusion. Some essential oils, such as thymol, cloves, eucalyptus, cinnamon, etc., have a distinct antiseptic action, and may be of service from that point of view. Even weak solutions of acids, such as citric, tartaric, and acetic acids, have been shown to be inimical to the growth of certain pathogenic organisms, so that the taking of lemon juice or vinegar with raw shell-fish, and as an adjunct in salads, has a scientific basis. It has long been known that deep natural mineral waters and artificial waters highly charged with carbonic acid gas, exhibit a remarkable freedom from living organisms. This is apparently due to the germicidal action of the carbonic acid, for it is greater as the pressure of the gas is increased, and is slowly lost.

Fatigue has a most important influence on the digestive processes, and rest from work of a taxing character is of material assistance in restoring the digestion to a normal condition. In all chronic digestive disorders, the possible relationship of the disease to bodily, mental, emotional, and sexual fatigue should be carefully enquired into. The nervous exhaustion resulting from business worries, some kinds of recreation, and especially from sexual excess, have a particularly harmful influence on the digestion, and, so long as they exist, no permanent benefit will result from the treatment of the local conditions. A quarter of an hour's complete rest before, and at least half an hour after, each meal, should be insisted on for all persons with weak digestions, or who are suffering from dyspeptic troubles. Bodily rest and sleep both favour digestion and allow time for its chemical processes to be completed. A prolonged loss of sleep always lessens the appetite and interferes with digestion, and in patients suffering from indigestion, insomnia is common. Each may be considered as a cause of the other. If sound sleep can be induced, the indigestion will often disappear. Sunshine, a moderate even temperature, and a dry climate, which will permit of the patient obtaining open-air exercise, promote metabolism and materially aid the digestive processes. Dyspeptic disorders are exceedingly common among those of no occupation, and are generally worst in those who cultivate habits of introspection. An agreeable occupation, on the other hand, occupies the mind, leads to optimism and happiness, and promotes digestion. The suggestion of ways and means by which a more wholesome and useful existence may be lived, will frequently do more for patients whose digestive organs are for them the centre of the universe, than any amount of medical or other treatment; in fact, drugs aimed at the dyspepsia or nerve condition may do more harm than good, by further confirming their demoralizing habits of thought.

B.—Special Indications.

Functional and anatomical defects in the organs of digestion play an important part in many chronic gastro-intestinal affections, and in arranging the diet it is necessary that these should be recognized and allowed for. By careful examination and analysis of the fæces, aided in some instances by investigation of the stomach contents after a test-meal, it is usually possible to determine the nature and probable extent of such defects, and to arrange a suitable dietary accordingly.

GASTRIC DISORDERS.

The chief function of the stomach is to prepare the food for digestion in the intestine, where absorption mainly takes place. Impaired gastric digestion does not therefore necessarily mean that the patient is badly nourished, but it throws unnecessary and unaccustomed work on the intestine, which may in consequence be secondarily involved. It is particularly important that the food should be carefully selected, thoroughly cooked, and be well divided and thoroughly mixed with the saliva. It should be of such a character that it is discharged from the stomach as quickly as possible.

Atony.—When the stomach fails to empty itself within seven hours, whether as the result of simple atony, or in consequence of some obstruction to the outlet, the diet should consist of easily-digested solids, and in severe cases be entirely liquid or semi-liquid. The meals should be frequent, only a small quantity should be taken at a time, and the food should be as nourishing as possible. No effervescent drinks should be allowed, and carbohydrates that readily ferment should be avoided, as also should all coarse vegetables and other irritating substances. The diet should consist chiefly of milk, not more than six or eight ounces at a time, gruel in similar quantities, cream, lightly-boiled eggs, vegetable purées, scraped beef, chicken, lamb, dry toast with butter, and cooked fruits deprived of their skins and seeds. Milk sugar should be used for sweetening in preference to cane sugar, as it is less readily fermented. Atony of the stomach is often associated with a diminished formation or absence of hydrochloric acid, and as such a condition is favourable to fermentative and putrefactive decomposition of the food, that will continue at a lower level, it is advisable that micro-organisms should be excluded as much as possible by thorough cooking and by protecting from contamination all articles of the diet. In some cases, systematic lavage of the stomach may be necessary to free it from putrefactive bacteria, and will often give relief from many of the symptoms of auto-intoxication, and particularly headache, more quickly than any other measure. Even when there is no pronounced dilatation, lavage each day before breakfast will frequently be helpful by preventing putrefactive organisms from gaining a footing high up in the intestine, and initiating there processes which normally take place at a lower level. In severe cases of dilatation, gastro-enterostomy may be necessary.

In cases where an examination of the fæces shows that the stomach is unable to digest proteins, owing to a deficiency of gastric juice, hydrochloric acid, or ferments, they should be excluded from the diet for a time in the form of meat, etc., and be given only in the shape of peptone or semi-digested albumins, casein preparations, and so forth. The free use of salt, by helping to form hydrochloric acid and by checking fermentative processes, may be useful. Carbohydrates, which are normally digested in the intestine, are well borne, but they should be thoroughly cooked and masticated in order to relieve that part of the alimentary tract from as much work as possible. Fats also are not dependent upon gastric digestion for their absorption, and their use is indicated since the experiments of Pawlow and Fleig have shown that they excite a flow of pancreatic juice. Wertheimer found that irritating substances, such as oil of mustard, stimulate the pancreatic secretion, but as it is not improbable that, as Starling has suggested, the secretin to which they give rise is formed by a process of hydrolysis in the over-stimulated cells of the intestine as a stage in their death, their use should be avoided.

Gastric Hypersecretion is frequently divided into *simple hypersecretion,* in which there is an increase in the amount of gastric juice of normal acidity, and *hyperchlorhydria,* where an excessively acid gastric juice is poured out. According to the researches of the Pawlow school, however, it would appear that the concentration of the gastric juice is always the same, and the acidity, therefore, depends upon the number of cubic centimetres secreted. In any case the dietetic treatment is practically the same. When the condition is dependent upon irritation of the glands of the stomach by stagnation of the gastric contents due to ulcer and stenosis, the diet is essentially the same as for gastric ulcer, but the quantity of food need not be limited, and no preliminary fast is necessary. When it depends upon gastritis caused by alcoholism, excessive smoking, or faults in the diet, etc., solid food should only be allowed gradually, after a day or two on equal parts of milk and lime-water given in small quantities at frequent intervals. The foods selected should be those which tend to suppress the secretion as much as possible, and also combine with the acid as quickly as it is formed. Pawlow and many others have shown that fats, taken before or with a meal, lessen the gastric secretion more than any other form of food material. It is therefore advisable to begin each meal with a tablespoonful of olive or almond oil. For the same reason, cream and butter should be freely used, especially with the earlier courses. Milk is a useful addition to the diet if not taken in too large quantities, for the fat it contains tends to limit secretion, while the casein combines with the acid. In cases where "heart-burn" is troublesome, and the use of alkalies might be harmful or they cannot be readily obtained, a drink of milk will generally give temporary relief. Casein preparations, gelatin, and meat, all combine with the acid, and are generally allowed in moderate quantities. Meats comparatively free from purin bodies should be selected by preference. Soups should be avoided in view of their stimulating effect on secretion and their small nutritive value. Vegetables are best given in the form of purées, as they can then be mixed with a considerable quantity of fat. All indigestible foods which leave a large residue for long periods in the stomach are to be avoided, as also are condiments and salt. Small quantities of Vichy water may be taken with meals, and larger amounts in the intervals between.

Some authors question the wisdom of giving proteins in hyperchlorhydria, for they contend that, although they relieve the symptoms by combining with the acid, they perpetuate the condition by stimulating its secretion. They therefore hold that the diet should be mainly carbohydrate. In support of this it is pointed out that hyperacidity is rare among Eastern races, who live largely on carbohydrates. Hemmeter has also shown that the acidity of the gastric juice can be diminished in carnivora by the administration of carbohydrates for long periods. On the other hand, it is well known that the digestion of starches initiated in the mouth is very quickly put an end to by an early rise in the acid contents of the stomach, and that the presence of such unaltered starch in large quantities may give rise to serious discomfort.

Cohnheim advises a purely lacto-vegetable diet ; but, although this is frequently successful in controlling the hypersecretion, it often leads to a great loss of weight. If, after treating a case of hypersecretion with the diet outlined above, which follows a middle course, combined with the ordinary medical means, no marked improvement has occurred in a few weeks, it is wise to regard the case as one of ulcer. and institute the regular diet for that condition. Constipation is frequently associated with gastric hyperacidity, and until it is controlled little or no improvement generally takes place. The addition of oil and fat to the diet will give relief in some cases; in others, liquid paraffin before each meal gives a better result. In others, again, a small daily dose of Carlsbad salts, or some similar saline purge, taken in hot water before breakfast, may be necessary. The addition of vegetables containing much cellulose, and similar methods of stimulating the action of the bowels, must, however, be avoided.

Gastric Ulcer.—Two distinct plans for dieting cases of gastric ulcer are advocated at the present time. In the older method no food is given by the mouth for some days, rectal alimentation being used meanwhile. Subsequently, von Leube's graduated diet is followed (*see* APPENDIX). In the other method, originated by Lenhartz, food is given by the mouth from the first. The object of the former plan is to give time for the clots which form over any bleeding vessels to organize, and to facilitate healing of the ulcer by keeping the parts clean and at rest. Lenhartz contends that since a flow of gastric juice has been shown to take place at the sight or thought of food, and may be excited by nutrient enemata, it is better that it should occur in a stomach that contains food to combine with the acid than in an empty one. Further, the treatment with saline injections and nutrient enemata cannot supply sufficient food to meet the needs of the body or improve the anæmia from which most gastric-ulcer patients suffer. If, however, food can be introduced into the stomach from the beginning, the strength of the patient is better maintained, the anæmia is more likely to be rapidly recovered from, and the process of healing will therefore be quicker. The opponents of Lenhartz's method urge that the presence of food in the stomach necessitates the contraction of the organ, and that such movements of its walls are likely to dislodge clots in any opened vessels and cause a recurrence of the hæmorrhage. To this he replies, that the danger of a clot being dislodged in this way is no greater than the danger of its being dissolved by gastric juice in an empty stomach, while if small quantities of protein food are supplied, the hydrochloric acid of any gastric juice that may be poured out combines with the protein and is neutralized. To this end teaspoonful doses of beaten-up milk and egg are prescribed. Such a combination is calculated to excite the least possible secretion and to combine most efficiently with the acid of whatever gastric juice is secreted, for the fat of the egg yolk and milk inhibit the secretion, the albumin of the white of egg and the milk combine with the acid, and it is well known that milk calls forth less secretory activity in the stomach than any other food. As the mixture is given in very small quantities at a time, distention of the stomach is avoided and the necessary movements are reduced to a minimum. The food is easily swallowed and requires no mastication, so that the flow of gastric juice from this cause is avoided. The rest cure with von Leube's diet has been advocated by many physicians of authority, including F. Müller, Riedel, Boas, Ewald, von Noorden, and Cohnheim, while others have reported good results with Lenhartz's method. The tendency at the present time is to combine the two to a certain extent by commencing feeding by the mouth earlier than in the strict von Leube method, but not so soon as Lenhartz advises. The diet too, is more gradually increased than in the latter method, and solid food is not so speedily or extensively used (*see* APPENDIX).

INTESTINAL DISORDERS.

The diet in *duodenal ulcer* is essentially the same as for gastric ulcer; but since the duodenum is not subject to the constant irritation of an acid secretion each time food is taken, rectal feeding is not necessary, and the diet may be much more liberal from the first, as the healing process is not being constantly interfered with by movements of the walls. Care should be taken, however, to reduce the acid secretion of the stomach as much as possible, and the food should be of such a kind as will produce the least irritation in passing over the duodenum. After a hæmorrhage the alimentary tract should be given a complete rest for twenty-four to forty-eight hours. Then for three or four days the food may consist of milk and lime-water, cream, gruel, and soft-boiled eggs. Subsequently, pounded meat or a soufflé of chicken, consisting of boiled pounded chicken mixed with white of egg and steamed for half an hour, and gelatin may be added to the diet. According to Herschell, gelatin, to the extent of half to one ounce a day, relieves the pain very quickly and expedites the healing of the ulcer in a striking manner. Small feeds at frequent intervals, say 7 a.m., 10 a.m., 1 p.m., 4 p.m., 7 p.m., and 10 p.m., should be given, rather than larger quantities with a longer interval between.

In all cases of intestinal disease, a thorough examination and analysis of the fæces is of the utmost importance in arranging the diet, for it is otherwise almost impossible to determine the excretory and absorptive power of the bowel with any degree of certainty. In interpreting the results of such investigations, attention cannot be directed to the intestine alone, for the part played by the pancreas, liver, and stomach in the preparation of the food for assimilation, and the effects of interference with their functions, must always be taken into account at the same time. Many intestinal affections are associated with disorders of these organs, and, although often not sufficiently marked to attract attention clinically, they may yet markedly modify digestion and absorption in the intestine. The existence of such functional disorders can only be ascertained by analytical means. By inspection and microscopical examinations of the fæces we can ascertain how one particular form of protein (muscle fibre), and one form of carbohydrate (starch), are being utilized, and may also obtain information as to the presence of an intestinal catarrh, its probable seat and extent; but for a wider knowledge of the digestive powers of the individual for proteins, carbohydrates, and fats, for the probable cause of the defects that exist, and the extent to which the morbid process involves the intestine and its diverticula, we are dependent upon chemical and bacteriological analyses.

In dealing with the diet in diseases of the intestine, it is convenient to divide the latter into those where there is diarrhœa, those in which constipation is a prominent feature, those in which there are abnormal putrefactive or fermentative changes, and finally, cases in which a disturbance of the functions of the pancreas or liver are the outstanding features. It must be clearly understood, however that such a division is only for purposes of description, and that in practice, combinations or alternations of these conditions occur, so that the diet for each case must be worked out according to the analytical findings.

Diarrhœa arising from the ingestion of irritating, indigestible, or decomposing substances must obviously be treated first by removal of the offending matter. In acute cases, complete rest to the gastro-intestinal tract for a short period is then advisable. Subsequently, a light diet consisting of boiled milk, either plain or peptonized, diluted with lime-water or barley-water, rice-milk made by boiling rice in milk and straining, or milk thickened with arrowroot or cornflour, may be given. Five or six ounces of milk into which the white of an egg has been beaten, flavoured with nutmeg, cinnamon, or brandy, is often well borne. If the diarrhœa persists and undigested curds appear in the stools, rice, sago, or tapioca cooked in water until a jelly results, flavoured with nutmeg, etc., and mixed with cream before being eaten, should be tried. Soup or meat essence thickened with flour, arrowroot, ground rice, or a beaten-up egg, will give a welcome change.

As the diarrhœa passes off, an ordinary simple diet should be gradually returned to, giving first a little clear soup, mutton broth or chicken broth, with dry toast or stale bread; then custard, blanc-mange, or milk pudding; later sole, plaice, or whiting, with a little mashed potato; and finally, boiled mutton or chicken.

In chronic cases, a rearrangement of the diet and a careful avoidance of all indigestible articles are usually all that is required.

The fact that diarrhœa may be due to gastric disorders, usually a deficiency of hydrochloric acid, is not so generally recognized as it should be. The most striking feature in such cases is its occurrence in the early morning and during the forenoon. The motions are usually liquid and inoffensive, and contain particles of undigested food; but in some instances the fæces are merely soft and yellow, and on analysis show an abnormal percentage of fatty acids. Gastric symptoms are often absent, or are overshadowed by those dependent upon the secondary intestinal changes. This condition furnishes a very striking example of the dependence of the intestine on the stomach for the proper preparation of the food, and demonstrates to a more than usual extent how an impairment of the protective functions of that organ may disturb the action of all the parts lower in the alimentary canal. The diet should be of an easily digested and light character. It should be well salted, so that there is an abundance of chlorine for the production of hydrochloric acid. The lack of hydrochloric acid may also be made up by administering large doses well diluted, say 30 minims in a glassful of water, half an hour after meals, and a similar dose in another half an hour, making a total of 180 minims daily. The usual dose of 10 minims is, according to Vander Hoof, quite insufficient. To stimulate the gastric glands to resume their function, full doses of tincture of nux vomica should be given before meals, which should begin with strong meat broths. Meat should not be taken except in small quantities, and must be well cooked. Buttermilk is a valuable article of diet in these cases, and most patients can take three pints daily. If the general nutrition is impaired, and there is associated visceroptosis and motor insufficiency of the stomach, as is often the case, recumbency on the right side after meals will be beneficial.

Even when diarrhœa results primarily from chemical or mechanical irritation of the bowels, the alterations that result in the bacterial flora of the intestine probably play an important part in the production of the symptoms, chiefly owing to the changes brought about in the numbers or virulence of the normal intestinal organisms. In some cases similar alterations appear to be the first cause of the condition, while in others the entrance and multiplication of abnormal species are responsible for the pathological changes that occur. When mechanical or chemical irritation is obviously the primary cause of the diarrhœa, its removal, and a diet arranged on the lines already suggested, will usually result in a return to a more normal state of things; but when the diarrhœa is dependent upon alterations in the bacterial flora in the first instance, the selection of the food must be based upon the results of analyses of the stools, particularly from a bacteriological standpoint. It is well known that the contents of the small intestine remain acid, in spite of their being constantly neutralized by the alkaline succus entericus, in consequence of the production of acids by the action of bacteria on carbohydrates. The object of this, apparently, is to restrain the growth of putrefactive organisms which may find their way from their normal habitat in the colon, and thus prevent protein decomposition in this part of the intestine. If, therefore, an analysis of the fæces shows that putrefactive bacteria are predominant, and an examination of the urine, together with the clinical symptoms, points to there being abnormal putrefactive changes in the contents of the upper part of the intestine, an increase in the carbohydrates of the diet will probably raise the protective acidity of the small intestine. Further assistance in this direction may be given by the administration of cultures of harmless microbes, such as lactic acid bacilli, which ferment sugars with the formation of acids. The beneficial effects of fermented milks such as Kefir, Kumyss, and Matozoon, are no doubt due to the restraining action exerted on putrefactive organisms by the acid they contain, but partly also on the antagonism that exists between the lactic-acid-forming bacteria concerned in the fermentation and abnormal strains of bacteria in the intestine. The presence of yeasts in some of these preparations is, however, a drawback to their use in disorders of the intestinal tract, and for that reason it is preferable to use pure cultures, or sterilized milk fermented by pure cultures, of lactic acid bacilli. These should be taken in considerable quantities, starting with half a pint of the fermented milk a day, and gradually increasing the dose until lactic acid bacilli are found in abundance in the fæces. Carbohydrate foods, particularly sugar and more especially milk sugar, should be given at the same time, to provide material in which the bacilli can continue their growth in the intestine. At the same time the proteins should be limited in amount and be replaced as far as possible by milk and milk preparations. By using digestive enzymes such as pepsin, and active preparations of the pancreas, more complete digestion of any proteins given can be ensured, and so less material is provided for the growth of putrefactive organisms. All foods should be thoroughly sterilized by heat before being taken, and the mouth should be kept as clean as possible.

Where fæcal analysis shows that fermentative organisms are predominant in the intestinal flora, and there is evidence of a catarrh of the upper part of the intestine associated with their abnormal activity, it is obvious that the treatment must be the reverse of that recommended for the preceding condition. Carbohydrates and milk should be excluded from the diet, which must consist only of proteins and fat. Treatment with cultures of lactic acid bacilli is not only useless, but is likely to aggravate the symptoms. In chronic cases, the utilization of carbohydrates can be often considerably improved by the administration of diastase or an efficient pancreatic ferment. Less material is then left for the growth of fermentative organisms.

The diet in specific infections of the intestinal tract associated with diarrhœa must be as little irritating as possible, and for this reason milk is largely, or exclusively, given as a rule. Although there is something to be said for such a procedure, and a milk diet is probably the best in short acute conditions, since it is easily digested, leaves comparatively little residue, and contains all the essential food elements—and moreover, the fermentation of the lactose may be useful in controlling the multiplication of putrefactive organisms,—it is difficult, and in fact almost impossible, to maintain a patient's strength on milk alone for more than a short period. In all subacute and chronic conditions, therefore, it is advisable to raise the caloric value of the diet by the addition of easily-digested food-stuffs, such as cream, thoroughly cooked starches, and gruel, soft-boiled eggs, pounded or scraped meat, and dry toast with butter. Weak tea, coffee, or cocoa may be used to flavour the milk, and will form a useful vehicle to which considerable quantities of milk sugar may be added. Milk sugar is to be preferred to cane sugar owing to its not being so readily fermented, while it also has the advantage of not being so sweet, so that larger quantities can be easily used and the food value of the diet be raised very considerably without nauseating the patient. Such a diet is of particular advantage in typhoid fever, and according to Coleman, if carefully carried out does not introduce any additional risk, while it shortens convalescence, rendering the patient better able to meet complications, and lowers the mortality (*see* APPENDIX).

In diarrhœas dependent upon a perversion of peristalsis due to nervous influences, little can be done in the way of diet. All irritating substances should of course be avoided, but as much nourishing food as possible be taken. Regular hours for meals, resting, and sleep should be insisted on, and the confidence of the patient restored.

It is generally recognized that a child with diarrhœa cannot be cured until the intestines have been thoroughly cleansed. The folds of mucous membrane which are necessary in health to retard the passage of the food, so that proper digestion and absorption take place, form pockets in which abnormal bacteria and putrefying food materials find a lodgment in diseases of the intestinal tract. The administration of a suitable cathartic, followed by thorough washing with water, is therefore the first indication for the treatment of infantile diarrhœa. Long years of experience have demonstrated that the most generally useful cathartic is castor oil. To a child from three to six months old a teaspoonful should be given, from nine months to a year a dessertspoonful, and from one and a half to two years a tablespoonful. If given ice cold, it does not as a rule cause nausea; but should the first dose be vomited a second should be given in about an hour. The oil should be taken on an empty stomach, no food having been given for at least two hours previously, and nothing should be taken after, not even water, for two hours. For the next twenty-four hours, and in some cases longer, only water should be allowed, preferably hot. If there is much vomiting, a few drops of hot water on the tongue every ten minutes will sometimes quickly check it. To stimulate the gastro-intestinal secretions, and aid in clearing the bowels, 10 gr. of bicarbonate of soda, with a $\frac{1}{4}$ gr. of rhubarb, in a teaspoonful of water, may be given every two hours.

The cause having been eradicated, the next question is, How and when is the child to be fed? Some writers advise barley-water, veal broth, chicken broth, or the white of an egg in a teacupful of boiled water, to which a quarter of a teaspoonful of salt, or the same quantity of brandy, has been added. But, as Winter has pointed out, one half the dry weight of the body of an infant at birth consists of fat, and fat is an absolute necessity for the growing child; the expenditure of heat in an infant five months old is 130 calories per kilogram of the body weight, but a food such as egg albumin contains only 0·25 per cent of fat, and barley-water 0·02 per cent, so that they cannot meet even the ordinary needs of the body. It must also be remembered that the intestinal exudates contain from 4 to 6 per cent of protein, and unless this loss is quickly made up the general nutrition is bound to suffer seriously. By giving the top half-ounce from a quart of milk, which contains 3 per cent of protein and the proper amount of fat, the necessary nourishment can be obtained in a readily assimilable form.

For children from three to six months of age suffering from diarrhœa, Winter's food prescription is to take the top half-ounce from each of two quarts of milk sixteen hours after milking, the milk having been kept on ice from the time of collection, and in an upright position, in suitable wide-mouthed quart bottles, for six hours before the top cream is removed. A teaspoonful of this cream is mixed with an ounce of cold, unboiled, filtered water, to which two teaspoonfuls of lime-water have been added. The mixture is warmed to the feeding temperature and given in ounce doses every four hours after the twenty-four, thirty-six, or forty-eight hours' plain-water treatment are completed. Between the hours of feeding, on alternate four hours, an ounce or two of water should be given, so that at this period food and water alternate every two hours. After each feed the remainder of the cream mixture should be thrown away, and a fresh lot be prepared the next time it is required. After two days, if the child is doing well and there are no digestive disturbances, the water may be discontinued and an ounce of the food be given every three hours. If the improvement continues, an ounce and a half may be given in the next twenty-four hours at three-hourly intervals. The strength of the food is then increased by taking the top half-ounce from three or four quarts of milk and mixing two teaspoonfuls with one and a half ounces of water, and adding three teaspoonfuls of lime-water. Two ounces of this mixture are given every three hours. In five days the strength of the food may be still further increased.

For children from six to twelve months old the same mixture as that last mentioned is used, excepting that the upper ounce from two quarts of milk is taken for the cream. Feeds of one and a half ounces of this are used to commence with, the amount and strength of the food being increased as the child improves. Chronic and subacute cases often do well on condensed milk, one teaspoonful in twenty-four of boiling water cooled to the feeding temperature and then mixed with two teaspoonfuls of lime-water for each ounce. This may be given in ounce feeds for a child of three months old every four hours, and alternated with an ounce of hot water and two teaspoonfuls of lime-water. As the child improves, the strength of the mixture and the frequency of the feeds is gradually increased, until a teaspoonful of the condensed milk in fifteen or sixteen of boiling water is being used, and three-ounce doses, with half an ounce of added lime-water, are being taken every three hours. As soon as the condition of the child is sufficiently good, the condensed milk should be replaced by ordinary modified cow's milk, or if possible by mother's milk.

Constipation is as a rule the result of defects of diet combined with an unhygienic mode of life. This is particularly the case with persons in the middle and upper classes, from whose food all material which is not nutritious is largely eliminated, so that the residue remaining is not sufficient to stimulate the intestine. The tendency to take excessive quantities of meat, and substitute this for the carbohydrates which give rise to the organic acids and gases that help peristalsis, is probably also a contributory factor. The exclusive use of tea, coffee, wines, and other more or less astringent drinks in comparatively limited quantities, in place of copious draughts of water, tends still further to increase the difficulty. In some instances, however, constipation arises from general or local pathological causes, and defects in the diet have little or no relation to the condition. Each case must therefore be investigated from every point of view before dietetic treatment is commenced, and for this purpose an analysis of the fæces often gives information of great value. If the diet can be shown to be at fault, a marked improvement may quickly follow its adjustment in cases of short duration; but in patients with blunted reflexes, where the condition has persisted for a long time and purgatives have frequently been freely used, no immediate effect will be produced by the establishment of a suitable diet. It is important that this should be impressed on the patient; otherwise, the treatment may be given up as useless before it has had a fair chance.

In simple chronic *atonic constipation*, the diet should be nourishing; it should contain a large amount of cellulose, so that a considerable residue appears in the fæces, it must have a fairly high fat content, and contain plenty of fruit, sugar, and salt, but only a moderate proportion of protein; sufficient fluid must be taken, and astringent substances should be avoided. All vegetables, but especially those that contain much fibre, cellulose, organic acid, or sugar, are of value in the treatment of this form of constipation. Cabbage, celery, spinach, asparagus, onions, turnips, carrots, artichokes, tomatoes, watercress, lettuce, and endive are to be particularly recommended, and one or more should be taken with at least two meals in the day. Their action is increased by taking them with fat in the form of salad oil or butter. Oatmeal, either as porridge or oat-cake, is a useful addition to the diet in constipation. Wholemeal bread contains a considerable proportion of cellulose, and is therefore of use in stimulating the action of the bowels. When wholemeal bread is not easily obtainable, " bran gems " can be employed instead, and are very useful in treating constipation in children. They are made by mixing two cupfuls of flour, two of bran, one of milk, and a quarter of a cupful of treacle, with half a teaspoonful of baking powder dissolved in a little hot water, half a teaspoonful of butter and half of lard, with salt to taste, then baking the mixture in a slow oven for three-quarters of an hour. Some uncooked or stewed fruit should be taken with the morning meal, as well as at lunch and dinner, in all cases of habitual constipation. Some fruits, like oranges, apples, melons, etc., do not contain a high percentage of cellulose; but the sugars and organic acids that are present act as chemical stimulants to the intestinal movements. Others, such as dried figs, raisins, prunes, raspberries, strawberries, and currants, act both as chemical and mechanical irritants to the intestines. Jams and marmalade may be used when fresh fruit is not obtainable. Jam made from seed fruits, such as blackberries, currants, and strawberries, are most useful, for, like marmalade, they contain indigestible irritating particles and also a high proportion of sugar, being thus both mechanical and chemical stimulants. For elderly people, and those suffering from heart or vascular disease, nephritis, and faulty metabolism generally, thoroughly cooked fruits, or even the juices alone, give better results than raw fruits. Each patient must be studied with reference to his tolerance for carbohydrates and fats, and until the constipation yields they should be cautiously increased, remembering that one form of vegetable food, like one form of fat, may give better results than another. It is always advisable to allow the patient a large choice, emphasizing those substances which it is most necessary for him to take. Only in this way can monotony in the diet be avoided and the best results be obtained (see Appendix).

It is most important that patients suffering from constipation should consume each day a sufficient amount of fluid. Cold carbonated water taken on an empty stomach is a powerful stimulant of peristalsis, and half a pint should be prescribed every night and morning. Salt added to the food, or used in cooking, as well as that contained in the meat and vegetables themselves, tends to increase the water in the intestinal contents, and by exciting thirst also causes the patient to drink more fluid. Provided that a reasonable amount of vegetables and fruit is taken, about two and a half pints of fluid a day are usually sufficient.

Chronic gastritis and some other chronic digestive disorders are apt to be associated with constipation, and in these, as also in *spastic constipation*, it might be assumed that benefit would arise from the use of a diet containing much cellulose; but considerable harm may be done by such a line of treatment. Vegetables and fruits which contain quantities of cellulose, seeds, or coarse skins, must be avoided. Asparagus tips, well-cooked spinach, celery, or cauliflower may be given, also well-stewed fruits, deprived of their skins, seeds, etc., fruit-juices, or seedless jams. By this means peristalsis can be stimulated chemically and without any irritation. Only white bread should be allowed, and greasy foods, excepting butter, cream, and in some cases fat bacon, should be avoided. To improve the general health, which is usually poor, proteins should be given freely, avoiding, however, gristle, much fat, and foods such as pork, duck, goose, veal, venison, smoked or salt meats, etc., that are only digested with difficulty. Milk, eggs, and light non-fatty fish should be prescribed largely, and may be given with advantage in quantities above the protein requirement in health.

A word may be said here about the dietetic treatment of *colitis*. In cases where there is a simple chronic catarrh of the colon, with or without the formation of membrane, the rich cellulose diet advocated by von Noorden, which is similar in its essentials to that outlined above for atonic constipation, is most useful, and will often bring about a great improvement; but when the colon is tender to pressure and attacks of colic occur at frequent intervals, it is worse than useless, and the diet should be more on the lines laid down for the treatment of spastic constipation.

Putrefactive and Fermentative Changes.—We have seen that experiment has shown that the bacterial flora of the intestine can be influenced by alterations in the diet, and that in diarrhœa associated with abnormal putrefaction or fermentation, benefit is derived from an exclusively carbohydrate or protein diet. It would therefore seem likely that chronic conditions of the intestinal tract associated with an alteration in the type of bacteria, might be similarly treated by suitably arranging the food. If an examination of the fæces shows that bacteria which grow best on a sugary or starchy medium predominate, it would be rational to exclude carbohydrates from the diet and so starve them out, while in cases where it is evident that proteolytic organisms are present in excess, protein foods might similarly be excluded. An exclusively carbohydrate or protein diet can be maintained for a short time, and is therefore useful in acute cases, but in chronic affections most patients tire of the restriction after a comparatively brief interval. Moreover, the general health often suffers in the course of time, when a very strict diet is persisted in. Since there is an antagonism between the normal bacteria of the intestine and wild strains, and the latter can only grow luxuriantly when frequently supplied with suitable food, whereas the former are able to resist adverse conditions more successfully, both proteins and carbohydrates can be given in quantities sufficient to furnish the patient with all he requires without encouraging the growth of abnormal organisms by suitably arranging the diet. If two meals only are taken in the twenty-four hours, one say at 8 a.m. and the other at 8 p.m., the first consisting entirely of carbohydrates and fats, while the second is entirely protein and fat, organisms which grow only on carbohydrates flourish on the first meal, but as soon as this is absorbed they tend to die out, partly from the lack of food, and partly from the overgrowth of more normal strains which are not so restricted in their choice of food. In a similar way, the proteolytic bacteria develop well on the evening protein meal, but for some twelve or fourteen hours out of the twenty-four at least, the conditions are not suitable for their growth, and they are gradually starved and crowded out. The process is of course a slow one, but in the end the results are often most satisfactory. I have had patients whose fæces showed a normal flora at the end of two or three months, when the only treatment adopted had been such a regulation of the diet, while all their symptoms have disappeared and they have put on flesh. The practice of taking three or four meals a day is only a habit, and although at first there is some discomfort when the two-meal plan is adopted, most people find that the desire for food at intermediate periods soon disappears, and that they are brighter, more energetic, and can do better work than was formerly possible. In some instances, however, this is not the case, and I then give a light meal at about mid-day, consisting of plasmon biscuits, cream cheese, and half a pint of milk, with a cup of weak tea and a little cream at 5 p.m. if desired by the patient. The intermediate meals should be avoided if possible, as they not only provide material on which micro-organisms can develop, but they prevent the physiological rest of the digestive organs, which is an important part of the treatment for many gastro-intestinal disorders.

For people who are well nourished and in whom the abnormal condition of the intestinal flora is probably dependent upon overfeeding, it is an advantage to precede the treatment just outlined by two or three days' starvation. No solid food, or food likely to leave a residue, is permitted, but the patient is allowed tea or coffee, with a small quantity of cream, meat extracts or clear broths, and as much water as he cares to drink. To assist in the clearance of the intestine, a large saline purge, say a pint or a pint and a half of water in which are dissolved ½ oz. of sodium sulphate and ½ oz. of magnesium sulphate, is given each morning on an empty stomach, as in the method suggested by Guelpa. After a week or so on the two-meal system, another two or three days of starvation-purgation may sometimes be advisable, and materially hasten the establishment of a more normal intestinal flora. The wisdom of this course is most satisfactorily determined by a bacteriological and chemical analysis of the fæces and urine. The starvation treatment must be used with discretion, and should not be recommended to patients with a low blood-pressure, in cases where there is wasting, or where complications, such as heart disease or nephritis, exist.

DISEASES OF THE PANCREAS.

The diet in acute inflammatory affections of the pancreas should be of a light and easily assimilable character, milk, cream, yolk of egg, jellies, and carbohydrates in the form of gruels, purées, etc., predominating. As much rest as possible should be given to the digestive organs, and at the commencement of the attack no food should be taken for a day or two.

The indications for the treatment of chronic inflammatory affections of the pancreas, are to obtain as much physiological rest as possible for the gland, and to deal with the infection of the ducts which is generally the exciting cause. The former end is attained mainly by regulating the diet and the times at which food is taken. The observations of Pawlow and his fellow-workers upon animals have shown that the work of the pancreas is specialized, both as regards the quantity and the property of its juices, and the rate of progress which the secretion takes for the different classes of foodstuffs. More recently Wohlgemuth and Heineke have confirmed these observations in the human subject, and shown that in a patient with a persistent fistula the amount of fluid discharged is dependent upon the composition of the food. With a fatty diet the secretion is very scanty; with an albuminous diet it is increased, and on the addition of carbohydrates it becomes very abundant. Further, the secretion is increased by acids and diminished by alkalies. My own observations on the urine have proved that the changes indicated by a positive "pancreatic" reaction are controlled by restricting the carbohydrates in the food and by the administration of alkalies. An "anti-diabetic" diet of proteins and fat with little or no carbohydrate, would therefore seem to be the most suitable, and has been recommended by Pawlow and others. While a limitation of the carbohydrates is no doubt beneficial in cases of advanced cirrhosis, and their total exclusion may be helpful in securing the closure of a fistula following operation for a pancreatic cyst, the inclusion of much protein is likely to accentuate the disease in cases of catarrhal inflammation. In most of these the inflammatory changes in the pancreas are due to an infection from the duodenum, either by way of the ducts or through the lymphatics, so that by giving much protein food, and thus favouring putrefactive changes in the intestine, the catarrh is perpetuated and the progress of the disease favoured. In prescribing a diet for a case of chronic pancreatitis in which there is evidence of an intestinal catarrh, I follow the plan already outlined for the treatment of chronic infections of the upper part of the intestine; that is to say, I advise that two meals, as far apart as possible, should be taken in the twenty-four hours. The first, in the morning, should consist of fats and carbohydrates, particularly the partially digested cereals and sugars. The second meal should consist entirely of proteids and fats as far as possible. By giving the carbohydrates in the morning, when the activity of the ptyalin of the saliva is most marked, the calls upon the pancreas are less than they would be later in the day, provided that mastication is thoroughly carried out. This is a most important point to insist on, as many of those who suffer from chronic pancreatitis, particularly when secondary to intestinal conditions, are habitual bolters of their food, and probably owe their condition to this to some extent. Partial neutralization of the acid contents of the stomach by an alkaline draught is advisable in some cases. The combination of fats with carbohydrates and proteids which I have suggested, is a further means by which the over-stimulation of the pancreas by the hydrochloric acid of the gastric secretion may be controlled. To ensure satisfactory digestion of the food and still further to relieve the pancreas, pancreatic ferments may be given two or three hours after each meal, but it is important to make certain that the preparation selected is active, as so many useless pancreatic extracts are now on the market.

When an analysis of the fæces, and loss of weight and strength, show that pancreatic insufficiency is present, means must be taken to aid digestion and improve absorption from the intestine. But to do so in a rational manner it is necessary to bear in mind the causes to which the insufficiency may be due, and to endeavour to determine which is operative in the case under consideration. It is obviously useless to treat the pancreas in cases of pancreatic insufficiency due either to achlorhydria or hyperchlorhydria. In the former condition the gland must be stimulated by the administration of secretin artificially prepared, or more simply by the use of acid drinks or dilute hydrochloric acid, an hour after food. In hyperchlorhydria the excess of acid may be neutralized by alkalies after meals, or its formation may be prevented by the administration of oil before meals or of hydrogen peroxide each morning fasting. When analyses of the fæces and urine, and a consideration of the symptoms, suggest that imperfect digestion of the food is dependent upon an absence of enterokinase, attention must be devoted to the intestine, and the diet should be arranged accordingly. The administration of enterokinase prepared from healthy mucous membrane may help the digestion temporarily. Absence or lack of bile may also be made up by its administration in keratin capsules, but as a rule operative interference is required. In cases where there is mechanical interference with the flow of pancreatic juice into the intestine from gall-stones, stricture of the ducts, cancer, or advanced cirrhosis, etc., surgery is obviously the first indication; but in some, removal of the obstruction is impossible or inadvisable, and in others so much damage has been done to the pancreas that it is unable fully to regain its functions. In these circumstances the natural functions of the gland must be augmented or replaced by the administration of artificial ferments and the selection of easily digested and assimilated foods. Where there is an associated disease of the intestine, and the activation of the pancreatic ferments is problematical, it is wise to combine enterokinase with the dose of pancreatic extract.

The diet in all cases of pancreatic insufficiency must be selected with care. A loss, or marked diminution in the amount, of the pancreatic ferments seriously interferes with metabolism, even when there is partial compensation by the use of artificial preparations, but much may be done to mitigate this if the physiology of digestion and the results of experiments on animals deprived of their pancreas are borne in mind. It is advisable that the diet should contain a considerable proportion of milk, and that other fats should be emulsified by the addition of desiccated bile or soaps. Solid fats, particularly those with a high melting-point, should be avoided, as they are liable to undergo chemical changes in the intestine, with the formation of irritating by-products, and consequently give rise to discomfort. If the functions of the stomach are being carried out satisfactorily, a considerable amount of protein may be digested, both in the stomach and upper part of the intestine, where the action of the gastric secretion will continue owing to the absence of the pancreatic juice; but even then less than half the albumin of the food is absorbed. Proteins which are digested with difficulty, such as pork, white of boiled egg, etc., must be excluded from the diet. The most useful protein in cases of pancreatic insufficiency is casein. It may be used in all cases, whether the stomach is functioning normally or not, for it alone among the proteins appears to be broken down without any preliminary preparation by the ferment erepsin discovered by Cohnheim in the succus entericus. It may be given in the form of milk, or in larger quantities as one of the artificially prepared powders, biscuits, etc., which are now so numerous. Gelatin may be used in place of a certain amount of protein with advantage. In cases of pancreatic insufficiency, the carbohydrate intake should be limited and should consist mainly of sugars and pre-digested starches, which will be rapidly absorbed. Even these must be given with caution, however, for although they make no call upon the external digestive secretions of the pancreas, they may readily over-tax its internal metabolic functions and give rise to alimentary glycosuria. The maximum amount that can be safely taken by each patient can only be learnt by experiment, and when this is found it is advisable that the diet should be arranged to contain slightly less. In cases where cane sugar or dextrose is not well borne, it is often found that lævulose can be assimilated with comparative ease. It is most important that in every case of pancreatic disease, and more especially in the chronic forms of pancreatitis, the possibility of alimentary glycosuria, and subsequently of frank diabetes, should be remembered, and that the urine should be tested from time to time. The onset may be long delayed—eight or ten years in some cases that I have had under my observation—but once it is established, the treatment can only be palliative. The better plan is to prevent such a serious complication by the diagnosis and rational treatment of the pancreatic disease in the early stages before serious and irreparable injury has been done to the gland.

DISEASES OF THE LIVER.

The liver does not play such an important part in the digestive processes as the pancreas, which furnishes enzymes that act upon all classes of food-stuffs, but disturbances of its functions are in many instances intimately connected with faults in the diet, and arise as the result of changes in the chemistry and bacteriology of the intestinal contents. The hepatic cells are probably the most versatile in the body, for besides their most obvious function of forming bile, they carry on processes connected with nitrogenous metabolism, they store carbohydrate in the form of glycogen for the future needs of the body, and destroy or convert toxic substances into less harmful products. If, therefore, the protein or the carbohydrate elements of the food are in excess of the requirements of the organism, and such an excess is long continued, an unnecessary strain will be thrown on the nitrogenous or glycogenic functions of the liver, while at the same time the abnormal putrefactive and fermentative changes in the contents of the intestine that are likely to result, may over-tax its detoxicating powers. As a result, we have acute or chronic manifestations of disordered metabolism which vary with the exact cause, the nature of the disturbance, and the "diathesis" of the individual.

Among the commonest functional disturbances of the liver are those to which the popular names of "bilious attack," "torpid liver," and "congestion of the liver" are given. They are most frequently met with in people who indulge in an excessive quantity of food, and especially meat, rich or highly-seasoned dishes, sauces, and alcohol. These, combined with lack of fresh air and exercise, luxurious habits, or working in hot and ill-ventilated rooms, bring about indigestion and imperfect performance of the functions of the liver, with resulting attacks of headache, sickness, and bilious diarrhœa, or weariness, inability to concentrate the attention, yellowness of the skin, and general discomfort. In some people the nervous system is more particularly affected, and "neurasthenia," sciatica, or neuralgia result; in others the joints or muscles are more especially involved, and the condition is variously diagnosed as gout or rheumatism; while in others, again, the blood-vessels are chiefly affected, and arteriosclerosis and kidney troubles result. Beside regulating the exercise, occupation, and general mode of life of such persons, it is necessary to influence the condition of the intestine, and through it the liver, by revising the dietary. As a preliminary, a day or two without food of any sort is often advisable. All rich, highly-seasoned, and spiced foods, sauces, pickles, and other substances likely to cause indigestion, must then be forbidden. A simple diet should be prescribed, and an excess of food, particularly those substances which analyses of the fæces and urine show are metabolized with difficulty, should be avoided. As a rule carbohydrates should be greatly restricted, a moderate amount of fat may be given, and a fair amount of protein with an abundance of fruit be allowed. Over-drinking, quite as much as over-eating, must be forbidden. Malt liquors and spirits are especially contra-indicated, but four or five glasses of plain or aerated water and a little light wine, such as Hock, Moselle, Bordeaux, Silery, or red Hungarian wine may be taken. Spa treatment is often useful on account of the water that is drunk, the absence of business and other worries, and the distraction from introspection that the regular life and exercise provide. The most suitable waters are those of Harrogate and Leamington in England, Carlsbad, Marienbad, Homburg, Kissingen, and Vichy on the Continent. If for any reason a visit to such a spa is impossible, the regular administration of bottled waters, or even plain water, with a definite amount of exercise, will often do almost, if not quite, as much good, if the treatment is carried out thoroughly. Regular action of the bowels should be ensured to keep down the formation of toxins and relieve the congestion in the portal system.

In cases where cirrhosis of the liver is present, the diet should be as nutritious as possible, but should not tend to increase the associated catarrh of the stomach and intestine. It should consist largely of eggs and milk, varied by thin oatmeal gruel, purée of vegetables, fruit, custard, junket, jelly, fish, chicken, and rabbit. Sweets, sugar, and foods containing a high percentage of starch, should be avoided. Fats should be considerably restricted, and only emulsified forms like cream, and yolk of egg, with butter and fat bacon, be allowed. If milk causes discomfort, it should be diluted with lime-water, barley-water, Vichy, Ems, Apollinaris, or some other alkaline water, or whey or buttermilk may be taken. One quart at least of milk should be taken each day, and as far as possible it should furnish both food and drink, for the total amount of liquid consumed daily should not exceed about two pints. When ascites develops, the quantity of liquid, and in consequence the amount of solids, may have to be diminished, so that unless the caloric value of the diet is carefully worked out, the nutrition of the patient may be seriously interfered with.

The absence, or the presence in much diminished quantities, of bile in the intestine, seriously impairs the absorption of fat, but of itself it does not markedly diminish the digestion of proteins and carbohydrates. As, however, the pancreas is more or less involved in many cases of jaundice, the digestion of these elements of the diet is also often imperfect. Before deciding on the diet for any particular case, it is therefore important that the presence and extent of any pancreatic insufficiency should be determined by analyses of the stools. If the pancreas is seriously involved, the diet will be the same as that already outlined for cases of pancreatic insufficiency ; but if the digestive functions of that organ are being normally carried out, attention should be chiefly directed to a limitation of the quantity of fat. This is necessary not only because fats are imperfectly absorbed, but also because their presence tends to promote intestinal putrefaction. One of the functions of the bile is to promote the passage of the food along the digestive tract, and thus prevent the stagnation of the intestinal contents which leads to increased protein decomposition, so that when it is absent constipation might be expected to result ; but clinical experience shows that, on the contrary, the motions tend to be rather copious and loose, owing to the presence of the unabsorbed fat. It is probable, therefore, that the excessive intestinal putrefaction that is met with in some cases of jaundice is dependent upon an intimate admixture of the fat with the protein elements of the diet in the intestine, which hinders in a mechanical way the absorption of the latter, thus affording a favourable opportunity for the activities of putrefactive organisms. According to Schmidt, the amount of gastric juice is increased, and there is consequently hyperacidity, when the bile is excluded from the intestine. The food should therefore be given often and in small quantities at a time.

To summarize: the diet in cases of uncomplicated obstructive jaundice should consist of carbohydrates and proteins, fats being excluded as much as possible. Bread, toast, biscuits, gruel, farinaceous puddings, stewed fruits, jam, marmalade, and the more readily digested vegetables, particularly potatoes, may be allowed. Skimmed milk, buttermilk, or whey, either alone, or with arrowroot, rice, tapioca, or one or other of the prepared infant foods, most of which are poor in fat; fish, lean meat, chicken, and fresh game may also be given. Each case is more or less a law unto itself, and the most suitable diet can only be determined by observation and analyses.

Most cases of chronic jaundice waste very considerably, even when the biliary obstruction is not due to malignant disease. This is chiefly due to the defective fat absorption, but it is possible that it is contributed to by the dyspepsia that is generally present and by excessive protein decomposition arising from the presence of bile in the blood. An attempt should therefore be made from the earliest stages to keep up the patient's condition by a judicious selection of the food and its administration in sufficient quantities.

OTHER BILIARY DISORDERS.

Catarrhal Jaundice is associated with such a characteristic condition of the fæces that its diagnosis is not as a rule a difficult matter. Since the obstruction to the flow of bile is secondary to a gastro-duodenitis, the diet should be similar to that indicated for an acute gastro-intestinal catarrh; but fats should be excluded, or only be allowed in a finely divided form, as in milk, cream, and a small quantity of butter. In the early stages a strict milk diet, preferably of skimmed milk, containing about 1 per cent of fat, is undoubtedly the best. After five or six days on this, broth or soup, and a moderate quantity of finely divided, well-cooked starchy food, may be added. Later, lightly boiled eggs and jellies may be allowed. Finally tripe, sweetbread, fish, chicken, and lean meat may be added if the pancreas is not involved, but if analyses of the fæces show that the jaundice is being kept up by the pressure of the swollen head of the pancreas on the common bile-duct, as is so often the case, proteins, and especially animal proteins, should be excluded from the diet. Eggs, cheese, milk, and casein preparations may, however, be given in moderate quantities. All irritating foods that contain skins, seeds, and indigestible fibre should be excluded in every case of catarrhal jaundice.

Cholangitis, Cholecystitis, and Cholelithiasis.—The diets in these are practically the same, and may therefore be considered together. During an acute attack the patient is better without food at all, or at least so long as there is any nausea. When this has subsided and the attack is passing off, a few ounces of milk diluted with lime-water, will be sufficient for the next two or three days, since anything that will excite peristalsis, and so lead to a return of the pain, is to be avoided. Subsequently the treatment should be directed toward the avoidance of anything likely to cause intestinal catarrh or promote infection of the bile-ducts, to the establishment of a healthy condition of the liver with a regular flow of bile, and as far as possible to normal metabolism in the body generally.

The meals should be taken at regular and frequent intervals. A simple mixed diet is better than one based upon the supposed influence that any particular form of food material may have upon the formation of gall-stones; but over-indulgence in sweets or starchy foods, as well as rich or made dishes, should be avoided, as they tend to induce gastro-intestinal catarrh. Alcohol should be allowed only in strict moderation, well diluted, and taken with food. As many patients who suffer from cholelithiasis habitually drink very little fluid, it is important that the consumption of a sufficient amount of water should be enjoined. This not only helps to dilute the body fluids and flush out the biliary passages, but also assists intestinal peristalsis. Regular movements of the bowels should be secured, and if necessary, some simple laxative should be used for the purpose. A tumblerful of natural Carlsbad water before breakfast, and a tumblerful of plain hot water before each of the remaining meals of the day, are often recommended; but as the regular use of Carlsbad salts induces a gastro-duodenal catarrh in some persons, the effervescent phosphate of soda may often be substituted with advantage. The general hygiene must be attended to at the same time. Fresh air, regular exercise, with systematic deep abdominal breathing, warm baths, and in women properly fitted straight-fronted corsets, should be prescribed. In some cases a systematic course of treatment at Carlsbad, Vichy, Aix-les-Bains, Cheltenham, Harrogate, Marienbad, or Châtel-Guyon may be of benefit.

II. DRUGS.

In most gastro-intestinal disorders treatment with drugs is of secondary importance to a careful selection of the diet and adjustment of the general hygiene. This is particularly the case in chronic affections, where analyses of the fæces are of most use clinically. Gastro-intestinal drugs may be conveniently divided into (1) *Stimulants*; (2) *Sedatives*; (3) *Digestive aids*; (4) *Emetics*; (5) *Purgatives*; (6) *Antiseptics*.

1. STIMULANTS.

The secretory and motor powers of the stomach and intestines may be increased by the administration of dilute alkalies, bitters such as calumba, gentian, quassia, etc., aromatics such as the various essential oils, alcohols and ethers, before meals. They increase the appetite, stimulate the flow of gastric secretion, and consequently also the digestive juices of the pancreas and intestine, while at the same time the movements of the gastro-intestinal contents are promoted, so that the consequences arising from abnormal fermentative or putrefactive changes are diminished. Their use is particularly indicated in cases where analyses of the fæces and stomach contents show that the digestive and motor functions of the stomach and upper part of the intestine are defective; in intestinal flatulence; and as aids to the dietetic and general treatment of mild dyspepsia.

2. SEDATIVES.

Opium, hydrocyanic acid, belladonna, and astringents such as tannic acid and substances containing it, bismuth, silver salts, copper salts, perchloride of iron, etc., lessen the irritability, and reduce the secretion in the gastro-intestinal tract, thus diminishing pain and preventing nausea, vomiting, and diarrhœa. Under this heading come large doses of alkalies, given after meals to neutralize an excessive excretion of hydrochloric acid by the stomach; also dilute hydrogen peroxide and demulcents such as olive oil and liquid paraffin, taken on an empty stomach before food to prevent its formation.

3. DIGESTIVE AIDS.

A deficiency, or lack, of digestive ferments may be made good by giving the food in a predigested form, or by the administration of the necessary enzymes, etc., by the mouth. Hydrochloric acid, or a diet rich in salt, may be used in cases of achlorhydria and pancreatic insufficiency due to a want of the normal acid stimulus to the pancreas. In the latter case, acid drinks and acid wines, oils and fats with meals are also useful. Pepsin, pancreatic preparations, inspissated bile, and enterokinase are all prepared commercially, and can be given in suitable capsules by the mouth to aid gastric, pancreatic, and intestinal digestion in cases where analyses of the fæces show that one or other of these ferments is being imperfectly formed or is probably absent. It is important, however, that it should be borne in mind that these enzymes deteriorate on keeping, so that they should be used as fresh as possible ; also that in the case of pancreatic preparations, many have little or no diastatic or fat-splitting power, so that the activity and particular digestive properties of each batch should be determined by experiment before being used clinically. Pepsin and hydrochloric acid may be taken with or immediately after a meal, but pancreatic preparations and enterokinase should be administered in specially prepared capsules one and a half to two hours after food, preferably with a large alkaline draught.

4. EMETICS.

These are used to remove the contents of the stomach when they have undergone fermentative changes and give rise to pain, discomfort, or secondary disturbances. They are most commonly employed in children who are suffering from the effects of unsuitable food.

5. PURGATIVES.

The indiscriminate and habitual use of purgatives is one of the most serious menaces to the health of the community at the present day. Owing to our modes of life, constipation is exceedingly common, but it is most unwise to treat every patient who complains of that condition, even when an examination of the stools shows it to be present, by purgative drugs. An attempt should always be made in the first instance to regulate the bowels by a suitable diet and other hygienic methods. If this fails, or is not entirely successful, and an examination of the fæces suggests that the constipation is due to digestion and absorption being too active, so that too small a quantity of fæces is formed to provide an efficient stimulus to defæcation, nature's methods should be imitated by administering some substance which passes through the intestine without undergoing decomposition or absorption. Schmidt has recommended agar-agar for the purpose. It can be obtained as a tasteless non-irritating powder which absorbs about twenty times its volume of water, and swells up in the intestine, giving bulk to the stools. It is taken in doses of one or more teaspoonfuls at the end of meals, either alone, in cachet, or mixed with mashed potato or apple, etc. The exact dose required for each individual can only be determined by experiment, but more than half an ounce is rarely required. To replace the stimulating decomposition products of the food, Schmidt combines the agar with a small quantity of cascara, and this product is now sold under the name of "regulin." A similar preparation, which also contains some ext. rhamni frangulæ, but has not the bitter taste of regulin, is on the market under the name of "thaolaxine." As a rule no benefit is experienced for two or three days, as it takes that time for the preparation to traverse the bowels. In some instances a course of treatment lasting two or three weeks will suffice to restore the regular functions of the bowels, but in others it has to be continued indefinitely, although very often in much reduced doses. Another substance which is not absorbed in the alimentary tract, and gives bulk to the fæces, is liquid paraffin. On the whole it is more generally useful than agar-agar, for it gives rise to very soft stools that are easily passed, and moreover tends to soothe the inflamed mucous membrane of the stomach and bowel in cases where there is a catarrhal affection. Neville Wood and Schmidt have both advocated its use, but the latter advises the addition of a small quantity of cascara to the paraffin, the mixture being known as "pararegulin." Liquid paraffin is given in doses of one to four or six drachms daily, the larger quantities in divided doses throughout the day, and the smaller in a single dose at night. It may be taken plain in capsules or in the form of an emulsion, of which the following is one that I frequently employ* :—

℞	Paraffini Liq.	ʒij	Calc. Lact.	gr. v
	Ol. Olivæ	ʒij	Ol. Amygd. Amar.	♏¼
	Ol. Ricini	ʒss	Aq. Chloroformi	ad ℥j
	Glycerini	ʒj		

Some use the semi-solid paraffin (paraffinum molle), and give it between bread as a sandwich.

A purely chemical stimulation of the intestinal mucous membrane, as compared with the mixed mechanical and chemical irritation produced by the measures already mentioned, can be induced by a variety of drugs. Some, such as the vegetable purgatives and various alkaloids, act on the nerve-endings and muscles of the intestinal walls, producing increased motor activity; others, like the salts of mercury, irritate the mucous membrane; while others again, as for example the saline purges, cause an increased flow of secretion into the bowel and so stimulate its activities. When selecting a purgative, the object to be attained must be borne in mind, and the choice be guided by several considerations. In the first place, it must of course be efficient, that is to say, the stool produced must at least be formed of all the fæces accumulated beyond the splenic flexure

* A similar preparation containing:

℞	Paraffini Liq.	ʒj	Casein.	gr. x
	Ol. Olivæ	ʒj	Ol. Amygd.	♏¼
	Ol. Ricini	♏x	Sod. Bicarb.	gr. v

has been placed on the market by Messrs. Callard & Co. under the name of "nutritive cream."

at the time of defæcation. If it is intended for habitual use, however, it is important that it should not act in such a way that the body is deprived of any of the water, salts, or nutritive materials that should be absorbed; but if on the other hand our object is to clear out the whole of the intestinal tract as completely as possible, in order to remove some irritating substance or product, a purgative which will act upon the small as well as the large intestine is desirable. Secondly, no pain should be produced by the action of the drug, and it should not irritate the intestinal mucous membrane sufficiently to produce inflammatory changes. Finally, in cases of chronic constipation, where it is probable that the drug will be required permanently, one should be selected which will not lose its effect by constant use, and the dose should be so regulated and its administration arranged, that a motion is passed every day and at the most convenient time.

The *saline purgatives* in appropriate doses produce a single copious semi-solid stool, and empty the whole of the large intestine from the cæcum to the rectum. They are particularly useful when it is desired to evacuate the colon without interfering with the digestive processes in the small intestine. It has been generally assumed that they act by increasing the osmotic tension of the intestinal contents and so abstracting water from the body, but the investigations of Hertz, Cook, and Schleisinger have shown that they are absorbed in the small intestine and act from the blood on the neuro-muscular mechanism of the colon, producing locally increased motor and secretory activity. Saline purgatives should be given in a considerable volume of water, as otherwise they remain in the stomach until their solution becomes isotonic with the body fluids by dilution with the secretions of the gastric mucous membrane. To ensure their rapid passage into the duodenum, they should be given on an empty stomach and a short time before food, since the action of the salt is then augmented by the normal stimulus to peristalsis. An action of the bowels should follow a suitable dose in from half an hour to an hour and a half. Sulphate of soda and sulphate of magnesia are the most commonly employed saline purgatives, and are equally reliable. In cases where constipation is associated with hyperchlorhydria, magnesium hydroxide is often prescribed to be taken in small doses at frequent intervals, as it neutralizes the acid gastric contents without producing distention, and at the same time acts as a mild purgative.

Some *vegetable purgatives*, like senna, act only on the large intestine, while others, such as cascara sagrada, affect both the large and small intestine. Senna, although a most useful mild laxative, sometimes gives rise to pain and nausea. This, according to Ebstein, is due to a resinous substance which is insoluble in cold water, so that such results can be avoided by the use of a cold watery extract. A very convenient way to prepare the infusion is to soak six, eight, ten, or twelve senna pods, the exact dose being determined for each individual by experiment, in four or five ounces of water over-night, and, after this has been taken in the morning, to set a fresh batch soaking ready for the next day.

Cascara sagrada is probably more frequently used than any other purgative for chronic constipation. Its great advantage is that the dose has not to be increased with the lapse of time, and in fact it may be often slowly diminished. The liquid extract is the most reliable preparation. It is to be preferred to compressed tablets and the solid extract in pill form, which sometimes produce very little effect. The great drawback is its bitter taste, but preparations freed from the bitter principles can now be obtained. The addition of nux vomica and belladonna increases the value of the drug as an habitual laxative.

Aloes is also an excellent purgative in habitual constipation, as a constant increase in the dose is not necessary to produce the desired effect. It only acts after it has dissolved in the bile, and is therefore useless in cases of biliary obstruction. It produces little or no effect in the small intestine, but powerfully stimulates the muscular walls of the colon. It gives rise to a formed dark-coloured motion that is not very soft, as there is no marked increase of the intestinal secretions, in from ten to twelve hours after it has been taken. Aloes is the most slowly acting of all purgatives. Its efficiency is increased by the addition of a little nux vomica, and to prevent the irregular muscular contractions with griping pains to which it sometimes gives rise, it is usually combined with extract of belladonna or hyoscyamus.

Rhubarb is commonly given as a purgative when there is indigestion due to errors of diet, as it stimulates the secretory and peristaltic functions of the stomach and intestine, thus clearing away undigested food materials. Owing to the tannic acid that it contains, its aperient action is generally followed by constipation, and for this reason it is not suitable in chronic conditions. Its after-astringency is, however, of service in the diarrhœa arising from the presence of undigested food, etc., in the intestine. A liquid motion, coloured yellow by the chrysophan, results in from four to eight hours after its administration. Rhubarb should never be given alone, owing to the griping that it causes.

Castor oil is perhaps the best simple purgative that we have, especially for children, owing to its mild but certain action, and absence of griping. It is of great use in senile constipation, and is often the only purgative which is effective in spastic constipation and muco-membranous colitis, especially when combined with belladonna or opium. A dose of castor oil with a small quantity of added laudanum is a favourite remedy for diarrhœa due to errors of diet. The purgative action of castor oil depends upon the ricinoleic acid split off from it by the action of the steapsin of the pancreatic secretion, and it is therefore useless as a purgative in cases of pancreatic insufficiency.

Mercury and its salts exert an irritant action on the intestine, and hence are useful as purgatives. The insoluble preparations alone are used for this purpose, as they do not affect the stomach and are only absorbed to a slight extent in the intestine. Calomel and blue pill are the forms most commonly employed. Either of these drugs when taken at night must be followed by a watery purge, such as mist. sennæ co., in the morning. Grey powder mixed with a little sugar is an excellent purgative for children, or even for adults when a very mild action is desired. With the exception perhaps of grey powder for the constipation of infants, mercurial preparations should not be used in the treatment of chronic constipation, as they produce too much irritation of the mucous membrane. Even comparatively small doses of calomel, frequently repeated, will often give rise to the appearance of occult blood in the stools, particularly in children. They are chiefly useful in gastro-intestinal disorders with symptoms of "biliousness," and in diarrhœa resulting from excessive putrefactive changes in the intestinal contents. According to Meyer-Betz and Gebhardt, calomel is the most thorough and searching purgative we possess, acting on every segment of the intestine.

6. ANTISEPTICS.

There is a very wide divergence of opinion as to the value of antiseptics in the treatment of bacterial disorders of the gastro-intestinal tract. Most observers allow that drugs such as sulphurous acid, carbolic acid, creosote, salicylate of bismuth, sulpho-carbolate of soda, salicylic acid, charcoal, etc., are of use in controlling fermentative changes in the stomach; but while some maintain that benefit also follows their use in intestinal affections associated with abnormal putrefactive and fermentative changes, others, relying mainly on the results of experimental observations on the bacterial content of the fæces, and observations on the ethereal sulphates in the urine, deny that they have any appreciable effect in restraining the growth of micro-organisms in the intestinal tract. Probably Bouchard, more than any other, can be regarded as the pioneer in advocating the use of intestinal antiseptics. He drew attention to the chain of symptoms grouped under the name "auto-intoxication," and attempted to diminish the putrefaction on which they depend by the administration of charcoal, naphthalin, and iodoform internally. Baumann, gauging the absorption of putrefactive products by the ethereal sulphates in the urine, placed calomel high in the list of intestinal antiseptics; but Morax, who repeated Baumann's experiments, came to the conclusion that calomel acts not in virtue of any true antiseptic property, but by reducing the ethereal sulphates and removing the bacteria and their putrefactive products from the bowel by the active peristalsis it sets up. Biernacki confirmed Morax's observations, and showed that a milk diet was quite as effectual as calomel in lowering the ethereal sulphates in the urine. Fürbringer proved by cultural methods that neither calomel nor naphthalin reduces the number of bacteria in the stools. Stern also demonstrated culturally that B. prodigiosus introduced into the alimentary canal along with the food is not appreciably restrained in its growth by calomel. Schütz proved conclusively that Spirillum metchnikovii, which ordinarily succumbs in the dog's intestine, appears in a viable condition in the fæces in large numbers following the administration of calomel. Harris and Feigen, using Strasburger's weighing method, have demonstrated that the bacterial content of the stools may be increased as much as twice the normal after calomel has been taken.

A very large number of other drugs have been tested by cultural and weighing methods by other authors, with conflicting results. Sucksdorff, for instance, claimed to have obtained a fall of one-third in the number of colonies in his own stools after taking 3·6 grams of quinine in divided doses, and a more marked drop following the administration of 2·1 grams of naphthalin. Kumawaga reported a reduction of over 30 per cent in the bacteria of the fæces of a dog after the use of 14 grams of acetanilid. Salkowski has stated that a considerable reduction in the bacterial content of the fæces of a dog followed the administration of chloroform water at intervals. On the other hand, Stern could find no diminution after the use of naphthalin, beta-naphthol, salol, or camphor. Von Mieczkowski tested the antiseptic action of bismuth, silver citrate, tannopin, beta-naphthol, and menthol in cases of ileocæcal fistula, and found that they were of no value, excepting that some reduction in the bacteria followed the administration of 10 to 13 grams of menthol in divided doses. Employing dogs fed on milk-rice and meat-rice diets, and using the cultural methods, Assmann reported negatively on guaiacol cinnamate (styracol), tanninformaldehyde (tannoform), tribromphenol - bismuth (xeroform), and bismuth subgallate. Naphthalin, thymol, silver citrate, beta-naphthol, and salicylic acid (doubtful) have been shown by Strasburger with his weighing method to have no appreciable effect on the number of bacteria in the stools. Feigen, using the same method, has also reported against the antiseptic action of magnesium dioxide and iodo-anisol. Negative results were obtained in cases of intestinal catarrh by Friedenwald and Leitz, using salicylicate of bismuth, salol, potassium guaiacol-sulphonate (thiacol), acetyl-salicylic acid (aspirin), and thymol; but favourable results were obtained with bichloride of mercury and ichthyol albuminate (ichthalbin). The sharpest fall in the bacterial content of the stools was, however, obtained by simply changing the diet in a case of intestinal catarrh with hyperacidity. Berger and Tsuchiya report a lessened bacterial output after the use of a patent preparation of agar-agar and hydrogen peroxide, while Klimmer and Assmann have had similar encouraging results with two silver-protein solutions (the so-called "colloidal" preparations) given in a solution of gum acacia along with food to dogs; but the probability that the silver will be laid down in the skin in man is a drawback to the use of the latter clinically. Steele found that in normal persons the administration of beta-naphthol and bismuth salicylate caused a slight fall in the number of bacteria excreted. Harris, working with beta-naphthol, salol, and guaiacol carbonate, was unable to prove that these drugs exerted any beneficial effect upon the intestinal flora.

An ideal intestinal antiseptic should fulfil the following conditions:—(*a*) It should have a strong bactericidal action; (*b*) It should be relatively non-toxic for the body as a whole, and should be harmless to the intestinal mucous membrane; (*c*) It should not be absorbed, except in very small amount; (*d*) It should suffer no chemical changes in the stomach or intestine whereby it loses any of the above requirements; (*e*) It should be so constituted that it mixes freely with the intestinal contents and is soluble in them; (*f*) It should act throughout the whole length of the gastro-intestinal tract.

It is obvious that none of the drugs so far described even approximate to this standard, and it is improbable that any one can be obtained which will comply with every condition. A drug which possesses a strong bactericidal action is liable to irritate the intestinal mucous membrane and set up a catarrhal condition favourable to the multiplication of the organisms which it is designed to destroy. Some antiseptics are rapidly absorbed from the field of action, and exert a harmful action on the body as a whole rather than on the intestinal contents. Others combine with the elements of the chyme, or are split up by the action of the gastro-intestinal secretions and are so rendered inert. One or more of these difficulties militates against the efficiency of most of the known antiseptics when applied to the disinfection of the alimentary tract, and at present there seems little prospect of overcoming them.

That nature makes an effort to keep a portion of the gastro-intestinal tract free from bacteria has been well known for some years. Briefly stated, it would seem that this self-sterilization depends upon several factors, namely, the hydrochloric acid in the gastric juice; the presence of bactericidal substances in the gastric secretion apart from the hydrochloric acid; bactericidal substances in the succus entericus, which according to Medowikow are more particularly produced when fat is present in the intestinal contents; the mechanical action of the mucus; the effects of peristalsis; and the retarding effect that the products of some varieties of bacteria have on the growth of other species. We have already seen how the flow of the digestive secretions can be controlled by alterations in the diet, and also that by providing suitable conditions for the growth of certain types of bacteria the multiplication of other varieties can be controlled. According to Medowikow, the the production of bactericidal substances in the gastric juice and succus entericus is dependent upon diet and the condition of the intestine, their formation being interfered with by over-feeding, starvation, exposure to great heat, insolation, and any cause promoting excessive irritation of the mucous membrane of the alimentary tract. Peristalsis, the other important factor in keeping within bounds the abnormal multiplication of intestinal bacteria, is also controlled by suitable arrangement of the diet, etc., so that it would seem that the flora of the intestine can be more certainly and effectually changed by suiting the food to the needs of the patient than by any so-called intestinal antiseptics at present at our disposal. Both clinical experience and laboratory experiment show that this is the case.

Insufflations of oxygen have been claimed by Schmidt to have a very favourable influence upon intestinal diseases associated with an abnormal intestinal flora. He states that small doses have a direct bactericidal effect, while large doses, by inducing transudation, promote the growth of bacteria, but eventually have a curative influence owing to the cleansing thus induced. In diseases of the duodenum, gastrogenous diarrhœa, fermentative dyspepsia, and intestinal catarrhs, he insufflates the oxygen by the mouth into the duodenum through a duodenal tube, injecting daily 500 c.c. or more, of the gas. If it is difficult to introduce the duodenal tube, he contents himself with insufflating the stomach, as Rotky has shown that oxygen passes rapidly into the duodenum from the stomach. With disease of the large intestine the oxygen is introduced through the rectum. Dyspepsia, etc., in children have also benefited by the introduction of 200 c.c. of oxygen into the stomach or rectum. Gross advises a species of continuous gas-bath lasting for one and a half to two hours, instead of the two insufflations a day recommended by Schmidt, and in one instance left the tube in from the morning to the evening, when the second insufflation was given. Gross insists on the importance of passing the tube well into the duodenum, about 30 centimetres beyond the pylorus, as this prevents the escape of a large part of the oxygen. The tube should be introduced in the morning on an empty stomach, and, when in position, its outer end is connected with the regulator of an ordinary oxygen cylinder, and the gas is allowed to flow in slowly. From time to time, when the patient complains of distention, the gas is shut off, and commenced again as soon as the distention has subsided.

The inhibitory effect that the products of the growth of some bacteria have upon the multiplication of other species suggested the idea that pathological bacterial processes in the intestinal tract might be favourably modified in a clinical sense by making use of the antagonistic properties of certain harmless micro-organisms. It had long seemed probable that the beneficial effects of fermented milks, such as kefir, kumyss, etc., were in part due to the restraining action exerted by the organisms contained in them upon the harmful bacteria of the digestive tract; but it was largely due to Metchnikoff that the therapeutic control of intestinal putrefaction by cultures of lactic acid bacilli, which Grigoroff had shown to be the important elements in such drinks, was due. The claims of those who recognized in fermented milk and cultures of lactic acid bacilli a universal panacea for all intestinal affections, have done much to bring discredit on a method of treatment which has much to recommend it. It is, however, only suitable in cases where chemical and bacteriological analyses of the fæces and urine show that excessive putrefaction exists, and is associated with the presence of organisms of the proteolytic type. When this has been determined, the treatment must be continued until the lactic acid bacilli have become thoroughly acclimatized, and examinations of the stools show that they are the predominant organisms. During the first week or two of the treatment it is not uncommon for there to be some diarrhœa, and even an accentuation of the symptoms of auto-intoxication, owing to the absorption of autolytic products from the dead proteolytic bacteria, but this passes off as the lactic acid bacilli gain the upper hand and the harmful bacteria are eliminated. During the treatment, the diet of the patient should be arranged so that the growth of the fermentative organisms is favoured, while the proteolytic bacteria are being provided with as little pabulum as possible for their multiplication. Finally, as pure and active a culture as possible of the lactic acid bacillus should be employed. Recently, Metchnikoff and Wollman have isolated from the fæces a bacillus, Glycobacter peptolyticus, which is said to have distinct amylolytic properties without the putrefactive propensities exhibited by most similar organisms. In the presence of a suitable carbohydrate pabulum, notably starch as it occurs in potatoes, the bacillus is said to check the production of phenols and indol through putrefactive changes in the intestine, so that the output of these substances in the urine is greatly reduced. Lactic-acid-bacillus therapy is thus supplemented by the potato-glycobacter regimen, for which there have been already published a few statistics quite as remarkable as those which accompanied the earlier B. bulgaricus propaganda.

As the result of experimental observations and clinical experience, Bassler has claimed that much benefit may result from raising the B. coli communis content of the intestine in cases of chronic intestinal putrefaction by instilling into the bowel either the autogenous mixed forms, or strains from other individuals. He states that by this means the proportion between Gram-negative and Gram-positive organisms in the fæces of persons with highly Gram-positive stools can be restored to the normal, and that at the same time the proportion of ethereal sulphates in the urine diminishes and the symptoms of auto-intoxication disappear. When anatomical conditions such as carcinoma, obstruction of the colon, organic disease of the pancreas or stomach, or gastro-intestinal atrophy, are present, the method is not applicable, but otherwise it is quick and effective in the majority of cases and harmful in none. He uses an autogenous mixed culture from the fæces for about four weeks, and then changes to a pure culture of B. coli. When a marked improvement follows, he then again changes to a culture of autogenous mixed bacteria. If no good effect is produced by cultures of B. coli alone, B. lactis aerogenes is added, and the growth resulting from the cultivation of the two in the same medium is tried for a length of time. Should no sustained or permanent benefit follow, it is probable that some anatomical complication exists, and surgical aid must be invoked.

III. VACCINES.

The possibility of checking the progress of bacterial processes in the intestine by means of specific bacterial vaccines, or sera, has received attention at the hands of several observers, and in some cases beneficial results have been found to follow their use. The difficulty of securing an appropriate vaccine in any particular case is considerable, and is a drawback to the method. Its most brilliant results have been secured so far in the prophylactic treatment of certain specific infections of the intestine, such as typhoid fever.

IV. OTHER THERAPEUTIC MEASURES.

In cases of dilatation of the stomach, and also in some cases of abnormal intestinal putrefaction and fermentation, lavage of the stomach may be helpful, and give not only temporary relief from many of the most distressing symptoms, but also tend to check a source of infection of the lower parts of the alimentary tract. Irrigation of the colon is another method of attacking bacterial and catarrhal affections of the bowel which has been much used in recent years. There can be no doubt that if it is practised cautiously, temporary benefit at least may result; but it can be looked upon only as an accessory method of treatment. I have never seen a complete cure of any intestinal disease result from its employment alone. An excessive quantity of fluid should be carefully avoided, or distention of the colon, with possibly troublesome atony, may result. It is better to employ lavage of the colon two or three times a week than to use it every day. In some cases of gastro-intestinal disease, surgical interference is the only certain method of dealing with the condition. In this connection may be mentioned gastro-enterostomy for dilatation of the stomach, and gastric and duodenal ulcer, cholecystotomy for persistent chronic pancreatitis, cholangitis, etc., and appendicostomy in chronic disease of the colon. Recently elimination, or short-circuiting, of the colon has been strongly advocated by some observers for conditions associated with excessive putrefaction in that part of the bowel, but it would seem that such a serious procedure can be very rarely necessary.

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APPENDIX.

THE ARTIFICIAL FEEDING OF CHILDREN.

THE method usually adopted in preparing artificial food for children is to add to cow's milk an equal, or larger, quantity of water, and a little cream, sugar, and lime-water. When adding cream to make up for the deficiency in fat, it must be remembered that the amount of fat varies very largely, according to the mode of separation. Good average cream contains about 20 per cent of fat. Cream also contains a considerable quantity of protein, practically the same amount as is present in the milk, or a little less. A mixture composed as follows closely resembles human milk (Cautley) :—

Cream	10 parts	.. e.g.	1 oz.
Milk	30 ,,	..	3 oz.
Water	40 ,,	..	4 oz.
Milk sugar	4 ,,	..	3 dr.

Rotch recommends a somewhat similar, but more complicated, mixture :

Cream	Centrifugal cream, 20 per cent fat, diluted ¼ or ⅓	2 oz.
Milk	..	1 oz.
Lime-water (diluted ¾)	..	2 oz.
Milk-sugar solution	Lactose 3⅜ oz. Water 3 oz.	3 oz.

This is richer in fat and poorer in protein, but it has the distinct advantage of being alkaline. The former mixture can be made alkaline by adding a pinch of bicarbonate of soda, or by replacing half an ounce of the plain water by a like quantity of lime-water.

Such mixtures correspond more or less closely to the average composition of mother's milk, and are suitable for the average infant, but it not uncommonly happens that they do not agree well, and analyses of the fæces show that one or other of the constituents is present in excess. The modification of the milk must then be carried out to suit the needs of the case, and according to a formula worked out for the particular child. Given the prescribed formula, the principles on which the modification is carried out are not difficult if the percentage relation of the milk to be modified and the formula to be filled in, are clearly understood. The general principles are: (1) To select a milk of such composition as will have the same ratio of fat to protein as is desired in the mixture. This can be accomplished by taking advantage of the way milk separates when allowed to stand undisturbed, as is shown in the following table given by Sherman :—

AVERAGE COMPOSITION OF TOP MILK AFTER STANDING FROM TWELVE TO TWENTY-FOUR HOURS IN A QUART BOTTLE.

	Fat per cent	Protein per cent	Sugar per cent	Ratio of Fat to Protein
Upper 1 oz. ..	22·5	2·8	4·0	8·0 : 1
,, 2 ,, ..	21·5	2·8	4·0	7·7 : 1
,, 4 ,, ..	20·0	2·8	4·0	7·1 : 1
,, 6 ,, ..	17·0	2·9	4·2	5·9 : 1
,, 8 ,, ..	14·0	3·0	4·3	4·7 : 1
,, 10 ,, ..	11·5	3·0	4·3	3·8 : 1
,, 12 ,, ..	9·8	3·1	4·5	3·2 : 1
,, 16 ,, ..	7·6	3·1	4·6	2·5 : 1
,, 20 ,, ..	6·2	3·2	4·7	1·9 : 1
,, 24 ,, ..	5·2	3·2	4·8	1·6 : 1
,, 28 ,, ..	4·5	3·3	4·8	1·4 : 1
Whole quart ..	4·0	3·3	4·8	1·21 : 1

(2) The selected milk is then diluted with sufficient water to give the desired percentage of fat. (3) Having thus adjusted the fat, and at the same time the protein content of the milk, enough milk sugar is now added to give the desired percentage of carbohydrate. Thus, to obtain a milk with the composition of protein 2 per cent, fat 3 per cent, carbohydrate 7 per cent :—The upper 24 oz. from a quart bottle are taken, this having the desired ratio of fat to protein of 1·6 : 1·0. As, however, the percentage of fat is 1·67 times too high, it will need to be diluted 1·67 times; that is to say, the 24 oz. will have to be made up to 40 oz. An examination of the mixture thus obtained shows that it now only contains 28·7 per cent of carbohydrate, so that 4·13 per cent, or 1·65 oz., of milk sugar, must be added to make it up to the required 7 per cent.

Working on this plan the following formulæ have been given by Winter for the bottle-feeding of delicate infants :—

For a Child Three Months Old.—Take the upper 3½ oz. from each of three quart bottles of milk, about six to eight hours after the milk is delivered. To this add four teaspoonfuls of milk sugar, 12 oz. of filtered water, and 6 oz. of lime-water. This will furnish seven bottles of 4 oz. each, and 4 oz. should be the nutriment administered every three hours.

For a Child Six Months Old.—Take the upper 6½ oz. from each of two quart bottles of milk, as before. Add four teaspoonfuls of milk sugar, 14 oz. of filtered water, and 6 oz. of lime-water. This will furnish six bottles of 5½ oz. each. Feed this amount (5½ oz.) every three and a half hours for six feedings in twenty-four hours.

For a Child Nine Months Old.—Take the upper 9½ oz. from each of two quart bottles of milk at the same hour as above. Add 12½ oz. of filtered water and 6 oz. of lime-water. This will furnish five bottles of $7\frac{1}{2}$ oz. To each $7\frac{1}{2}$-oz. bottle, just before feeding, add 1 oz. of barley gruel, and administer this amount every four hours.

"**Malt Soup.**"—Owing to the lack of salivary and pancreatic ferments, a child under six months of age is theoretically incapable of digesting starches, but Finkelstein, Jacobi, Epstein, Schmidt, and other authorities have shown that practically this is not the case, and that the addition of starchy foods to cow's milk is not only allowable, but is to be warmly recommended, both for older children and even for young infants. The advantage of such modifications is shown by more complete digestion, a gain in weight, and the disappearance of soapy and dyspeptic stools in many cases. In the opinion of most who have given special attention to infant feeding, "malt soup" is the most valuable artificial food we have for children, particularly for those of four or five months of age, a time when the food supply has usually to be augmented even in breast-fed babies. For the preparation of the mixture any malt extract may be used, if about 15 grains of carbonate of potash are added to each ounce to neutralize the acidity. For a baby three months old or younger, begin with a teaspoonful of the malt extract for the day's supply, and increase very gradually, if the condition of the stools permit, to a tablespoonful. To this is added thoroughly baked or roasted flour, commencing with two teaspoonfuls, increasing to a tablespoonful, and then to two tablespoonfuls. The malt extract and flour are stirred into the required quantity of milk, with sufficient water to bring the total quantity up to the supply needed for the day. At first, 8 oz. of skimmed milk are used, but cream may be added after a few days. Thus, for a three-months-old baby, having 28 oz. of food a day in seven feeds of 4 oz. each, the mixture would have the following composition :—

Skimmed milk	8 oz.
Flour	2 teaspoonfuls
Malt extract	1 teaspoonful
Warm water	20 oz.

The flour and milk are mixed together in one receptacle, and the malt and water in another; the two mixtures are then united and heated slowly in a double boiler for thirty minutes. If the flour is carefully rubbed up with the milk, there should be no lumps or necessity to strain. To prevent the possibility of scurvy, the child should be given orange juice or grape juice each day, but if a safe supply of milk is available and the weather is cold, only the malt flour and water need be boiled, and the milk can be added when the mixture has partially cooled.

Malt soup must be used with care, as too much tends to loosen the bowels. With the added carbohydrate a three-months-old baby can seldom be expected to take more than 12 to 14 oz. of cow's milk, a six-months-old child 20 to 24 oz., and an eight- to ten-months-old infant one quart daily.

Condensed Milk.—Remarkably good results are frequently obtained by using condensed milk, especially the unsweetened variety, diluted with water, and many children who do not do well on other foods will thrive on such a mixture. Unsweetened condensed milk diluted one part to six of water gives approximately $1\frac{1}{2}$ per cent each of fat, protein, and sugar. If a teaspoonful is mixed with 6 oz. of water we obtain an eighth of these percentages, which, although a dilute food, is sufficient to start with. The strength can then be gradually increased to one or even two tablespoonfuls to the six ounces, and if circumstances permit, 2 or 3 per cent of sugar and 1 or 2 per cent of fat may be added. Sweetened condensed milk contains a large amount of cane sugar, and a 1–6 dilution nearly 9 per cent, so that it is impossible to give enough protein and fat without giving too much sugar. Even such a milk is, however, preferable to a poor natural product of doubtful quality, and may be of use for a time after sickness.

"Eiweiss Milch."—This was first suggested by Finkelstein to meet the requirements of children suffering from fermentative disturbances in which sugar, theoretically at least, has been the causative factor. It is prepared as follows: Heat a quart of whole milk to 100° F., add four teaspoonfuls of pepsin, and stir. Leave the mixture at 100° F. until the curd has formed, and then pour on to a linen cloth and strain off the whey. Remove the curd from the cloth, and press it through a fine sieve two or three times by means of a wooden spoon. During this process add one pint of water. The precipitate should now be very finely divided, and the mixture should have the appearance of milk. Add one pint of buttermilk. The mixture should then contain 2·5 per cent of fat, 1·5 per cent of sugar, and 3 per cent of protein.

As fat may be an important factor in producing diarrhœa in infants, the mixture is sometimes better prepared in the earlier stages from skimmed rather than from whole milk. As the condition improves, maltose and cream are added. This not only increases the nutritive value, but also improves the taste, thus making it more acceptable to the child. The use of "Eiweiss milch" is seldom necessary for more than a week or two, and is not advisable, as children do not thrive on it, as a rule.

The Size of the Child's Stomach and the Amount of Food Requisite for each Meal.—The most important facts to remember are, that the child's stomach is very small during the first week, holding about half an ounce to an ounce; that during the first two months it increases fairly rapidly to about three times this size, and then remains almost stationary for about three or four months. Of course the size depends to a certain extent upon the size of the child and the degree of nutrition. An average child at birth weighs 3000 to 4000 grams, and it is customary to take a hundredth part of the weight, 30 to 40 grams, as the amount of food the stomach will hold, and add 1 gram for each day during the first month.

An infant of 3000 grams ($6\frac{1}{2}$ lb.) would require, therefore, during the—

1st week	30 grams	= about	1 oz.
2nd ,,	37 ,,	= ,,	$1\frac{1}{4}$,,
3rd ,,	44 ,,	= ,,	$1\frac{1}{2}$,,
4th ,,	51 ,,	= ,,	$1\frac{3}{4}$,,

During the second month the amount may be increased gradually at the rate of a quarter of an ounce a week, the total amounting to three ounces by the end of the ninth week. After this the feeds should be regulated as follows :

Age	Number of feeds	Amount	Total in 24 hours
9 weeks to 6 months	6	3 to 4 oz.	18 to 24 oz.
6 to 9 months ..	6	5 to 6 ,,	30 to 36 ,,
9 to 12 months ..	6	6 to 8 ,,	36 to 48 ,,

The Intervals Between each Feed.—

Age	Length of interval	Number of feeds
1st week	2 hours	10
1 to 9 weeks ..	$2\frac{1}{2}$,,	8
9 weeks to 9 months	3 ,,	6

The first feed should be given at 5 a.m., and the time for the subsequent feeds calculated from that. The food should be warm, temperature 89° to 100° F. It should be given slowly ; a quarter of an hour is the average time for each feed. Care must be taken that the food is fresh and pure, and that it is alkaline. Each feed should be prepared at the time required. The practice of preparing the food twice a day, and warming up the amount required for each meal, should be strongly discountenanced.

SUGGESTIONS FOR DIET IN ADVANCED LIFE (Burney Yeo).

May take :—

Young and tender chicken, game, and other tender meats, especially if minced or potted. Sweetbread, tripe.

White fish, such as soles, whiting, smelts, etc., best boiled.

Bacon, eggs lightly cooked or beaten up with milk, etc.

Nutritious soups, broths, beef-tea.

Milk in all forms when well digested, best diluted with an equal quantity of Vichy water, barley-water, etc.

Bread and milk, made with the crumb of stale bread, without lumps. Porridge and oatmeal gruel.

Puddings of ground rice, tapioca, sago, macaroni, arrowroot, made with eggs and milk, and flavoured with warm spices or served with fruit juice or jelly.

Bread and butter (the bread at least a day old), rusks and biscuits.

Artificial foods consisting of pre-digested starches.

Vegetable purées of all kinds in moderation (potato, carrot, spinach, etc.), stewed celery, stewed Spanish onions.

Stewed or baked fruits, and the pulp of perfectly ripe fruit in small quantities.

Note :—

Small meals, at not too long intervals, should be taken.

Not more than one part of animal to three of vegetable food should be allowed.

All starchy foods and vegetables should be well cooked, so that the starch granules are rendered easy of digestion.

It is important that the use of potatoes and other vegetables should not be neglected, otherwise a scorbutic state is liable to arise.

The acidity of stewed fruits may be advantageously neutralized by the addition of enough bicarbonate of soda to cover a shilling for each pound, thus avoiding the use of a large quantity of cane sugar, which is apt to cause fermentation and flatulency.

A little milk or other fluid food should be taken during the night if awake, as sleep is often thereby induced.

DIET SCHEME IN ACUTE GASTRITIS (Hawkins).

1st day :—Hot water in teaspoonful doses up to 10 or 15 oz. in the day.

2nd day :—Milk and lime-water, soda-water, or barley-water (4 to 1), 20 or 30 oz. in small quantities at a time.

3rd day :—

8 a.m.—Milk 8 oz., rusks 2 oz.

10 a.m.—Broth 8 oz., one egg.

noon—Milk soup 8 oz., dry toast 2 oz.

3 p.m. —Milk 5 oz., rusks 2 oz.

7 p.m. —Milk soup with rice 8 oz., rusks 2 oz.

Fish, chicken, purée of vegetables, stale bread, etc., are then gradually added until a normal diet is reached.

DIET SCHEME IN CHRONIC GASTRITIS.

1st week or 10 days :—

8 oz. of milk and barley-water, lime-water, or soda-water (5 to 1) every three hours, six times in the day.

2nd and 3rd weeks :—

Gradually increase the amount of milk at each feed until some 2½ to 3 pints are being taken daily.

4th week :—

8 a.m.—Milk and lime-water, etc. (4 to 1) 8 oz., stale bread 2 oz., butter 1 oz.

10 a.m.—Two eggs, stale white bread 2 oz., butter 1 oz.

noon—Milk and lime-water (4 to 1) 8 oz., rice pudding made with milk and egg 8 oz., stewed prunes 3 oz.

3 p.m.—Milk 6 oz. with tea or coffee 2 oz., stale white bread 2 oz., butter 1 oz.

7 p.m.—Milk and lime-water 8 oz., rusks 2 oz.

5th or 6th week :—

8 a.m.—Tea with milk 8 oz., stale white bread 2 oz., butter ½ oz.

10 a.m.—Bread 2 oz., butter ½ oz., cold meat or ham 1½ to 2 oz., milk 10 oz.

2 p.m.—Milk or soup 8 oz., meat or fish 1½ to 2 oz., purée of vegetables 1½ to 2½ oz., stewed fruit 1 oz.

4.30 p.m.—Warm milk or cocoa, or milk and coffee (half and half) 10 oz.

7.30 p.m.—Soup 10 oz., stale white bread 2 oz., butter ½ oz.

10 p.m.—Milk 8 oz. rusks 2 oz.

Gradual additions are then made to the diet until an ordinary mixed diet is reached.

Where there is impairment of the digestive powers, Wegele recommends the following :—

Breakfast—Peptone cocoa 6 oz., dry toast 1 oz., butter ¼ oz.

Forenoon—One soft boiled egg, dry toast 1 oz., wine 3½ oz.

Noon—Oatmeal soup 8 oz., chicken 5 oz., carrot 7 oz., dry toast ½ oz.

Afternoon—Peptone cocoa 6 oz., dry biscuits 1 oz., butter ¼ oz.

Evening—One egg, scraped ham 3½ oz., macaroni with toasted bread crumbs 3½ oz., wine 3½ oz.

DIET SCHEME IN CHRONIC GASTRITIS (F. COHNHEIM).

7 a.m.—A glass of mineral water (Carlsbad or Vichy in hyperacid gastritis; Homburg, Kissingen, or Wiesbaden in subacid or anacid gastritis).

8 a.m.—Tea with milk or cream, white bread and butter, or if diarrhœa is present, cocoa or chocolate with bread and butter.

11 a.m.—Soup or broth, white bread and butter, one egg (cooked two minutes), scraped ham.

12.30 a.m.—A glass of mineral water.

1 p.m.—Soup, purée of peas, carrots, spinach, asparagus or cauliflower cooked in butter, macaroni or rice cooked in soup, the tender white meat of chicken, pigeon, veal, or fish, sweet fruit purées served warm, rice or sago pudding.

4 p.m.—As at 8 a.m.

6.30 p.m.—A glass of mineral water.
8 p.m.—Gruel or cocoa made with milk, white bread and butter with white meat or two soft eggs.

Avoid—Cabbage, beans, lentils, smoked and salted meats of all kinds, goose, duck, animal fats, salmon, acids, pastry, cold drinks.

Condiments are forbidden in hyperacidity, but are indicated in conditions associated with sub-acidity.

DIET SCHEME IN GASTRIC HYPERACIDITY (Hawkins).

8 a.m.—Hot water 8 oz. with a small dose of Carlsbad salts.
8.30 a.m.—Cocoa made with milk 10 oz., wholemeal bread toasted 2 oz., butter ⅔ oz., honey ½ oz., one or two eggs.
11 a.m.—Milk and soda water (6 to 1) 6 oz.
1 p.m.—Meat (preferably veal, mutton, or ham) 2 oz, (or fish, chicken, game, sweetbread, or savoury omelette), milk pudding, or custard, 2 oz., toast 1 oz., butter ⅓ oz., cheese ½ oz., diluted milk 6 oz.
5 p.m.—Diluted milk 6 oz., toast or rusk 1 oz.
7.30 p.m.—Milk soup flavoured with celery, turnip, or onion, 6 oz., fish or meat as at lunch, potato purée 1 oz. (or lentils), milk pudding 2 oz. (or blanc mange, jelly or custard), toast, butter and cheese as at lunch (or cheese straws), diluted milk 6 oz.
10 p.m.—Diluted milk as at 11 a.m.

PROTEIN DIET SCHEME IN HYPERCHLORHYDRIA (Wegele).

Morning—Milk (with tea) 4 oz., two soft boiled eggs, aleuronat toast 3 oz.
Forenoon—Raw ham 4 oz., cream 2 oz., aleuronat meal broth 7 oz. or oatmeal broth 9 oz.
Noon—Beefsteak 6 oz., mashed potato 7 oz., white wine (with Saratoga, Vichy, or Biliner water) 3 oz.
Afternoon—Tea 4 oz., cream 5 oz., aleuronat toast 3 oz.
Evening—Cold meat 2 oz., two scrambled eggs, wine 4 oz.
10 p.m.—Milk 8 oz.

DIET SCHEME IN GASTRIC AND DUODENAL ULCER.

Von Leube's Diet.—

1st 3 days :—

7 a.m.—Milk 5 oz. (150 c.c.).
8 a.m.—Milk 5 oz.
10 a.m.—Milk 5 oz. with strained barley-water.

11 a.m.—Milk 5 oz.
1 p.m.—Broth with peptone preparation, 5 oz.

4th to 11th day :—

7 to 9 a.m.—Milk 10 oz. (300 c.c.).
11 a.m.—Milk 10 oz. with barley, rice, or oatmeal-water.
1 p.m.—Clear broth 7 oz. (200 c.c.), with a beaten egg.
3 to 5 p.m.—Milk 10 oz.
7 p.m.—Milk 10 oz. with barley-water.
9 p.m.—Milk 10 oz.

11th to 14th day :—

7 to 9 a.m.—Milk 10 oz. (300 c.c.) two rusks softened.
11 a.m.—Milk 10 oz. with barley-water.
1 p.m.—Broth 7 oz. (200 c.c.), one egg, two rusks.
3 p.m.—Milk 10 oz.
5 p.m.—Milk 10 oz., two rusks.
7 p.m.—Milk 10 oz. with barley-water.
9 p.m.—Milk 10 oz.

14th to 17th day :—

7 to 9, to 11 a.m.—As above.
1 p.m.—Scraped beef $1\frac{3}{4}$ oz. (50 grams), two rusks, broth 7 oz. (200 c.c.).
3 p.m.—Milk 10 oz.
5 p.m.—Milk 10 oz., one soft boiled egg, two rusks.
7 p.m.—Milk 10 oz. with 2 teaspoonfuls of farina.
9 p.m.—Milk 10 oz.

17th to 24th day :—

7 a.m.—Two soft-boiled eggs, butter $\frac{1}{16}$ oz. (1 gram), toasted bread $1\frac{3}{4}$ oz. (50 grams), milk 10 oz. (300 c.c.).
10 a.m.—Milk 10 oz., rusk $1\frac{3}{4}$ oz., butter $\frac{3}{4}$ oz. (20 grams).
1 p.m.—Broiled lamb chop $1\frac{3}{4}$ oz. (50 grams), mashed potato $1\frac{3}{4}$ oz., toasted bread $1\frac{3}{4}$ oz., butter $\frac{1}{2}$ oz., broth 7 oz.
4 p.m.—Same as at 10 a.m.
6.30 p.m.—Milk 10 oz. with farina, rusk $1\frac{3}{4}$ oz., butter $\frac{3}{4}$ oz.
9 p.m.—Milk 10 oz.

Final diet :—

7 a.m.—Two soft-boiled eggs, butter $\frac{1}{16}$ oz. (1 gram), toasted bread or thin bread and butter (2 oz.), milk 10 oz. flavoured with coffee or cocoa.
10 a.m.—Milk 10 oz., rusk $1\frac{3}{4}$ oz., butter $\frac{3}{4}$ oz.
1 p.m.—Sole steamed or boiled, or pounded fish 2 oz., cauliflower or mashed potato 2 oz., milk pudding made with egg or custard 3 oz., toast and butter, or thin bread and butter 2 oz, milk 8 oz.
4 p.m.—As at 10 a.m.
6.30 p.m.—Clear soup, mutton broth, or chicken broth 6 oz., Chicken panada or soufflée 3 oz., mashed potato 2 oz.,

milk pudding, or custard, or junket and cream 3 oz., toast and butter or thin bread and butter 2 oz., milk 8 oz.

9 p.m.—As at 10 a.m.

Rectal Enemata.—

Leube :—Milk 10 oz. (300 c.c.), peptone $\frac{1}{5}$ oz. (6 grams), milk 10 oz. (300 c.c.), starch 2 oz. (60 grams), milk 10 oz. (300 c.c.), 3 eggs, salt $\frac{1}{10}$ oz. (3 grams), starch $1\frac{1}{2}$ oz. (40 grams)

Boas :—Milk 9 oz. (250 c.c.), 2 yolks of eggs, a pinch of salt, one tablespoonful of red wine, one tablespoonful of white flour.

Ewald :—Mix 2 or 3 eggs with a tablespoonful of cold water; a little flour is boiled in half a teacupful of 20 per cent dextrose solution and allowed to cool, a wineglass full of claret is added, the egg mixture is then stirred in, and the whole made to 9 oz. (250 c.c.) with water.

Lenhartz's Diet.—*1st day* :—Milk, 7 to 10 oz. Some authors commence with smaller quantities (e.g. $3\frac{1}{2}$ oz., Spriggs). 1 egg beaten up with sugar and water or wine, and iced. Given in small quantities, from a teaspoon, throughout the day. The quantity of milk is increased by $3\frac{1}{2}$ oz. a day, and one egg is added to the diet each day, until $1\frac{3}{4}$ pints of milk, and 6 or 8 eggs, are being taken.

3rd to 8th day :—1 oz. raw, or almost raw, minced beef or mutton, alone or beaten up with an egg, is introduced into the diet. If it is well borne, the quantity is increased to 2 oz.

7th or 8th day :—Boiled rice is added, followed by softened bread. Later a little bread and butter is given, and one or more of the eggs may be lightly boiled. The diet is then gradually increased by adding pounded fish, mince, etc., which replace a corresponding amount of egg, until an ordinary mixed diet is reached, care being taken, however, to exclude all indigestible solids. The patient must be cautioned to eat slowly and masticate his food thoroughly.

Smith's Diet.—This is a modification of Leube's diet, incorporating many of the features of Lenhartz's method. Nutrient enemata are given for two days, then feeding by the mouth is commenced, and divided into three stages ;—

1st stage—Liquids alone (about one week) :—For the first two days five or six feeds consisting of 2 oz. of milk diluted with an equal quantity of lime-water or Vichy water, are given. On the third day $\frac{1}{2}$ oz. of cream is added to each feed, using 3 oz. in the twenty-four hours, and the milk is only diluted one-quarter. Weak tea with cream, cocoa made with milk, milk gruels (made with water to which cream and milk have been added), beef albumin (made by soaking a pound of finely-chopped lean beefsteak in one pint of cold water in a refrigerator, and subsequently cooking for twenty minutes) are then gradually added. The whites of two to four eggs beaten up with a little salt and water may also be given. Only small feeds are allowed, and the food is varied as much as possible.

2nd stage—Liquids with Solids :—

7 a.m.—The juice of an orange, two soft-boiled eggs, or lamb chop or boiled tripe, a medium-sized baked potato, a piece of stale bread, 4 oz. of milk with 2 oz. of cream added.

10 a.m.—Six oz. of milk with 2 oz. of cream.

1 p.m.—Purée (potato, green peas, or asparagus), meat and vegetable stew, vegetables (potato, carrots, parsnips, green peas, asparagus tips, cauliflower), boiled rice or macaroni, a slice of stale bread, 4 oz. of milk with 2 oz. cream, one baked apple without the skin.

4 p.m.—6 oz. of milk with 2 oz. of cream, two or three rusks (or a cup of bouillon may be taken instead of the milk).

6 p.m.—Eggs (soft boiled, scrambled or poached), one baked potato, stale bread, 6 oz. of milk with 2 oz. of cream.

9 p.m.—6 oz. of milk with 2 oz. of cream.

3rd stage—Solids :—

7.30 a.m.—Eggs (soft-boiled, scrambled, or poached), lamb chop, boiled chicken, tripe, stale bread, baked potato, a glass of milk one-third cream.

10 a.m.—A slice of stale bread and a glass of milk one-third cream.

1 p.m.—Raw oysters, purée (potato, asparagus, or tomato), chops, tripe, steamed or boiled white fish, eggs (if not taken for breakfast), vegetables (potato, carrots, parsnips, new peas, asparagus tips, cauliflower), creamed rice, biscuits and soft cheese, a glass of milk.

4 p.m.—A glass of milk one-third cream, and rusks.

6 p.m.—Soup or purée as for dinner, eggs (if not taken previously), cold chicken, cold tongue (boiled six hours), mashed or creamed potato, meat and vegetable stews, stale bread, a glass of milk one-third cream.

9 p.m.—A glass of milk one-half cream.

Later stages :—

After this diet has been continued for two or three weeks, roast beef, mutton, etc., and other vegetables are gradually added, taking care to avoid vegetables that leave much residue or are likely to set up fermentation.

DIET SCHEME IN DILATATION OF THE STOMACH
(Hawkins).

Early stages of Treatment :—

8 a.m.—Milk 5 oz., one or two raw eggs, two thin pieces of toast with butter.

10.30 a.m.—Milk 5 oz. with plasmon, a rusk, two raw-meat sandwiches.

1 p.m.—Milk 5 oz., fish-cakes or fish soufflée, custard, toast and butter.

4.30 p.m.—As at 10.30 a.m.

7.30 p.m.—Milk 5 oz., one or two eggs, toast and butter.

10 p.m.—A cup of arrowroot with cream.

Later stages of Treatment :—

8 a.m.—Cocoa made with milk 5 oz. (or milk and plasmon), one or two eggs (or fish-cake 1 oz.), thin toast 1½ oz., butter ⅓ oz.

10.30 a.m.—Milk 5 oz., rusk, raw meat sandwich (½ oz. meat).

1 p.m.—Milk 5 oz., fish-cake or fish soufflée 2 oz. (or oysters), chicken panada 2 oz., potato purée 1 oz., blancmange 2 oz (or custard), toast 1½ oz., butter ⅓ oz.

4.30 p.m.—As at 10.30 a.m.

7.30 p.m.—Milk soup 5 oz. (or milk), sweetbread 2 oz. (or minced mutton), blancmange and cream 2 oz. (or grape-nuts), toast 1½ oz., butter ⅓ oz., water 6 oz.

10 p.m.—Arrowroot, with or without cream 6 oz.

DIET SCHEME IN ATONIC CONSTIPATION.

7.30 a.m.—A glass of Vichy water.

8 a.m.—A cup of *strong coffee* with cream and a tablespoonful of milk-sugar ; *porridge* with *cream* or *treacle* ; *fat bacon* ; fish (preferably herrings, mackerel, salmon, sardines) ; baked potato with plenty of butter ; eggs boiled or poached (every second day) ; wholemeal bread ; an abundance of *butter* ; *honey, jam* (strawberry, raspberry, blackberry, rhubarb), *marmalade* ; fruit (apples, pears, stewed *prunes, figs*, or *berries*, grapes, oranges, *grape-fruit*).

10.30 a.m.—A glass of Vichy water (or soured milk), a slice of wholemeal bread with butter.

1 p.m.—Raw oysters ; soup (preferably purée of meat and vegetables) ; a small quantity of boiled or roast meat or mutton ; vegetable of all kinds (especially *cabbage, spinach, celery, beet-root, Brussels sprouts*, potatoes, parsnips, *turnips*, cucumber, mushrooms, etc.) ; fresh salads (*lettuce, endive, celery, watercress*) made with French dressing containing an abundance of *salad oil* ; light puddings with fruit juices or stewed fruit ; cheese (cream or soft curd) ; *nuts* ; *raisins* ; fruit ; one glass of water, buttermilk, lager beer, or cider sweetened with a tablespoonful of milk sugar.

4 p.m.—A cup of weak tea with cream and a tablespoonful of milk-sugar ; wholemeal bread and butter ; jam or marmalade.

5 p.m.—A glass of cold water.

7 p.m.—Soup (purée); stews of meat and vegetables; cold meat; fish; wholemeal bread and butter; jam, honey, marmalade, stewed fruit, with cream; nuts, dates, figs, raisins, prunes; a glass of rich milk.

10 p.m.—A glass of Vichy water.

Note.—Take at least four or five of the foods in italic in the course of the day. Take a different kind of fruit at each meal. Take at least two vegetables, besides potato, with the mid-day meal. Drink at least 4 or 5 pints of liquid a day.

Avoid.—An excess of meat. Pea soup, lentil soup. Rice, sago, tapioca, gruel, etc.

DIET SCHEME IN SPASTIC CONSTIPATION.

7.30 a.m.—A cup of hot weak tea with cream, or a glass of hot peppermint water or valerian tea.

8 a.m.—A cup of weak tea with cream and a tablespoonful of milk sugar; dry toast or stale white bread; butter; soft-boiled or poached eggs; fat bacon; steamed or boiled white fish; baked apple, stewed plums, peaches or other fruit deprived of all seeds or skins and served with cream.

10 a.m.—A glass of buttermilk, soured milk, or water at the room temperature.

1 p.m.—A small plate of soup; raw oysters with lemon juice; a small quantity of boiled mutton or beef; tender vegetables (cauliflower, finely minced spinach, asparagus tops, green peas, etc.) with butter; stewed fruit (no skins or seeds); fruit jellies; light puddings, blanc-mange, with cream; cheese (cream or soft curd); dry biscuits; butter; a glass of Vichy water.

4 p.m.—A glass of milk (warm) or a glass of water; a little stale white bread and butter; jam or stewed fruit (no seeds or skins).

7 p.m.—Purée of vegetables; stale white bread; butter; honey; jam; or stewed fruit (no seeds or skins) with cream; a glass of whole milk with an ounce of cream added.

10 p.m.—A glass of buttermilk, soured milk, or warm milk.

Note.—Swallow nothing that has not either passed through a hair-sieve, or has been so thoroughly masticated that it is of the consistency of cream and would readily and completely pass through a hair-sieve.

For pain or abdominal distress between meals, sip hot milk, hot peppermint water, or hot water.

Avoid—Coarse or wholemeal bread. All seeds, skins, tendon, etc. All raw fruit. All coarse or imperfectly cooked vegetables (e.g., cabbage, etc.). Goose, duck, pork, salmon, herrings, mackerel.

CELLULOSE DIET IN MUCOUS COLITIS.

7.30 a.m.—A glass of hot water.

8 a.m.—Cocoa made with milk 8 oz., whole meal bread 3 oz., butter 1 oz., honey, jam, treacle, or marmalade, poached or scrambled eggs, fat bacon 2 oz., fruit (apples, pears, currants, grapes, gooseberries, blackberries, raspberries, etc.) with cream.

1 p.m.—Scrambled eggs or savoury omelette, toasted wholemeal bread 3 oz., butter 1 oz., vegetables 4 or 5 oz. (cabbage, Brussels sprouts, cauliflower, French beans, onions, turnips, carrots, artichokes, parsnips, beetroot), water 8 oz.

5 p.m.—Weak tea (half milk) 8 oz., toasted whole meal bread 2 oz., butter ½ oz.

7 p.m.—Milk soup (flavoured with celery, onion, etc) 6 oz., white fish (sole, plaice, whiting, etc.) 3 oz., vegetables as at 1 p.m., stewed figs, prunes, apples, currants, etc., with cream, wholemeal bread 2 oz., butter ½ oz., water or dilute whisky.

10 p.m.—A glass of hot water, a wholemeal biscuit.

DIET IN SEVERE MUCOUS COLITIS.

As for Spastic Constipation (q.v.), or

7.30 a.m.—A glass of hot water.

8 a.m.—Milk diluted with lime-water or barley-water (6 to 1) 8 oz., white bread or toast 3 oz., butter 1 oz., honey ½ oz., baked apple with cream.

11 a.m.—Milk hot or cold 8 oz.

1 p.m.—Milk soup flavoured with vegetables 8 oz., milk pudding (rice, tapioca, or macaroni) 2 oz., or custard 2 oz white bread or toast 2 oz., butter ½ oz., water 6 oz.

5 p.m.—Weak tea or cocoa made with milk 8 oz., white bread or toast 1 oz., butter ½ oz.

7 p.m.—Milk soup or lentil soup 6 oz., white fish 3 oz., potato purée (or potato salad with oil) 2 oz., well-cooked spinach or cauliflower 2 oz., milk pudding with cream or blancmange with fruit juice 2 oz., white bread 1 oz., butter ¼ oz., water 6 oz.

10 p.m.—Hot milk 6 oz., a couple of rusks.

DIET SCHEME IN INTESTINAL CATARRH WITH DIARRHŒA OR A TENDENCY TO DIARRHŒA (P. COHNHEIM).

7 a.m.—Mineral water (Carlsbad or Vichy in hyperchlorhydria, Homburg, Kissingen, or Wiesbaden in achlorhydria) 2½ to 5 oz. taken hot.

7.30 a.m.—Cocoa (two teaspoonfuls to a cup) in water, toasted white bread and butter.

10.30 a.m.—A cereal soup with butter, toast with butter, eggs and scraped ham.

1 p.m.—Broth with macaroni, etc., white meat, and in mild cases vegetable purée and one glass of red wine.

4 p.m.—As at 7.30 a.m.

6 p.m.—Mineral water $2\frac{1}{2}$ to 5 oz. as at 7 a.m.

8 p.m.—Tea with cream, toast, butter, cold white meat.

10 p.m.—A cup of hot peppermint tea.

Note:—In mild cases when the stools are of pulpy consistency, and after improvement in more severe cases, white bread, carrots, and fish may be allowed.

Avoid—Cold drinks, any kind of coarse vegetable (e.g., cabbage or potato), cheese, acids, cakes, pastry, coffee, all legumes (except when served in soups), goose, duck, salmon, animal fat, gravies, and raw fruit.

PROTEIN DIET IN CATARRHAL ENTERITIS.

8 a.m.—Cocoa made with water 8 oz., one or two eggs.

10 a.m.—Beef-tea 5 oz., with an egg.

noon—Chicken or fish, plasmon biscuits, butter, custard, a glass of Burgundy.

4 p.m.—One egg beaten up with water and a little brandy, plasmon biscuits.

7 p.m.—Chicken or fish, sweetbread, jelly and cream, a glass of Burgundy.

10 p.m.—Raw meat sandwich or beaten-up raw egg.

THE HIGH-CALORIE DIET IN TYPHOID FEVER (COLEMAN).

The minimum food requirement is about 40 calories per kilogram per day, so that a patient weighing 150 lb. would need about 3000 calories.

To supply 1000 *calories per day, use* :—Milk 1 quart (1000 c.c.).
Cream $1\frac{2}{3}$ oz. (50 c.c.).
Lactose $1\frac{2}{3}$ oz. (50 grams).
in 8 feeds each of milk 4 oz., cream 2 drachms, lactose 6 grams.

To supply 1500 *calories a day, use* :—Milk $1\frac{1}{2}$ quarts (1500 c.c.).
Cream $1\frac{2}{3}$ oz.
Lactose $3\frac{1}{3}$ oz. (100 grams).
in 6 feeds each of milk 8 oz., cream 2 drachms, lactose 16 grams.

To supply 2000 *calories per day, use* :—Milk $1\frac{1}{2}$ quarts.
Cream 8 oz. (240 c.c.)
Lactose 4 oz. (125 grams).
in 7 feeds of milk 7 oz., cream 1 oz., lactose 18 grams.

To supply 2500 *calories per day, use* :—Milk $1\frac{1}{2}$ quarts.
Cream 8 oz.
Lactose 8 oz. (250 grams).

in 7 feeds of milk 7 oz., cream 1 oz., lactose 36 grams.

To supply 3000 *calories per day, use* :—Milk $1\frac{1}{2}$ quarts.
Cream 1 pint (480 c.c.)
Lactose 8 oz.

in 8 feeds of milk 6 oz., cream 2 oz., lactose 1 oz.

To supply 3900 *calories per day, use* :—Milk $1\frac{1}{2}$ quarts.
Cream 1 pint.
Lactose 16 oz. (480 grams).

in 8 feeds of milk 6 oz., cream 2 oz., lactose 2 oz.

Other articles that may be included in the diet are :—

Apple sauce	1 oz.	30 cal.
Bread	1 slice (33 grams)	80 ,,
Butter	1 pat ($\frac{1}{3}$ oz.)	80 ,,
Cereals (cooked)	1 heaped tablespoonful ($1\frac{1}{2}$ oz.)	50 ,,
Crackers	1 oz.	114 ,,
Cream (20%)	1 oz.	60 ,,
Egg whole	1 (2 oz.)	80 ,,
,, white	1	30 ,,
,, yolk	1	50 ,,
Lactose	1 tablespoonful (9 grams)	36 ,,
Milk whole	1 oz.	20 ,,
Potato, whole	1 medium	90 ,,
,, mashed	1 tablespoonful	70 ,,
Rice, boiled	1 tablespoonful	60 ,,
Sugar, cane	1 lump	16 ,,
,, milk	1 tablespoonful	36 ,,
Toast	1 average slice	80 ,,

For example :—

1 a.m.	Milk 6 oz., cream 2 oz., lactose 10 grams	280 cal.
4 a.m.	,, ,, ,,	280 ,,
7 a.m.	,, ,, ,,	280 ,,
9 a.m.	,, ,, ,,	280 ,,
11 a.m.	Egg 1, mashed potato 1 oz., custard 4 oz., bread one slice, butter $\frac{3}{4}$ oz., coffee, cream 2 oz., lactose 20 grams	780 ,,
1 p.m.	Milk 6 oz., cream 2 oz., lactose 10 grams	280 ,,
3 p.m.	,, ,, ,,	280 ,,
5 p.m.	Egg 1, cereals 3 tablespoonfuls, cream 2 oz. apple sauce 1 oz., tea, cream 3 oz., lactose 20 grams	640 ,,

7 p.m.—Egg 1, toast one slice, butter ¾ oz., coffee, cream 2 oz., lactose 20 grams	.....	510 cal.
10 p.m.—Milk 6 oz., cream 2 oz., lactose 10 grams	.....	280 ,,
Total	..	3890 cal.

Note.—The amount of food required depends upon the individual, and should be chiefly determined by the weight and appetite. In the early stages 3000 calories can nearly always be taken, and later 4000 to 6000.

The high-calorie diet can be commenced at any stage if the patient is hungry and able to digest the food, but is more particularly useful in the later stages.

Give any food that can be digested easily, but leave out any article which is found to cause persistent disturbance of digestion.

The greater part of the energy required should be provided by carbohydrates, but fats are well borne as a rule, and may supply from a third to a half of the necessary calories.

The proteins should not fall below 62 grams, nor be raised much over 94 grams a day. Any deficiency is best made up with eggs.

INTESTINAL FLATULENCE.

May take :—White meat, lean red meats, sweetbread, tripe, calf's head, chicken, pheasant, partridge, tongue, lightly boiled or poached eggs, fresh butter, a little sweet cream, toast or old bread, crusts, wholemeal bread, light farinaceous foods with fruit juices, spinach, celery, asparagus, a little potato, unsweetened stewed apples or plums, raw apples not too sour, almonds, Brazil nuts, cocoa essence, meat extracts. One ounce of whisky in four ounces of hot water with two meals.

Must avoid :—Green vegetables (especially cabbage, radishes, peas, beans, lentils, salads), pears, raw plums, Mayonnaise, oily or greasy foods, milk, cheese, pastry, excess of sweets, fresh bread, pork, veal, venison, sausages, hare, goose, duck, pigeon, curries, re-cooked meats, smoked fish, eels, salmon, herrings, mackerel, tea, coffee, wine, malt liquors, soup, broth.

DIET SCHEME IN CHRONIC INTESTINAL AFFECTIONS ASSOCIATED WITH AN ABNORMAL FLORA.

On rising :—A glass of Vichy water.

Breakfast :—Fruit : apples (raw, baked, or stewed), oranges, grape-fruit, grapes, melon, berries, apricots, peaches, cherries. Jam, marmalade, stewed figs or prunes. Vegetables : spinach, celery, asparagus, cauliflower, French beans (with oiled butter), tomatoes, lettuce, endive. Farinaceous foods: rice, tapioca, sago, macaroni (with fruit juices). Oatmeal porridge, shredded wheat, etc. (with cream). Stale bread, toast, crusts of bread, brown or wholemeal bread. Fatty foods: yolk of egg, fat bacon, fresh butter. Cocoa essence with cream.

[*Lunch* :—Chocolate, Plasmon biscuits, a little (cream) cheese, a glass of Vichy water.]

[*Tea* :—A small cup of China tea with cream.]

Dinner :—Oysters. Clear soup, or meat extract (two tablespoonfuls). White fish, cod, hake, haddock, plaice, sole, whiting, halibut, turbot. Meat: lean beef or mutton, sweetbread, tripe, calf's head, tongue, chicken, fresh pheasant or partridge (with bacon, no bread sauce, crumbs, flour, bread, potatoes or starchy food). Eggs, plain jellies or creams (unsweetened). Brazil nuts or almonds. Whisky (two tablespoonfuls in half a tumbler of hot water) or Vichy water.

On Retiring :—A glass of Vichy water.

Note.—Omit lunch and tea if possible.

Must Avoid :—Pears, raw plums. Cabbage, radishes, peas, broad beans, lentils. Milk, ripe or hard cheese, pastry, excess sweets, fresh bread. Pork, veal, sausage, venison, hare, goose, duck, pigeon. Curries, hashed or re-cooked meats. Smoked fish or meat, eels, salmon, herrings, mackerel. Strong tea or coffee, beer, wine. Thick soup, and clear soup or broth in quantity.

DIET SCHEME IN OXALURIA.

7.30 a.m.—Glass of hot water.

8 a.m.—Fish (haddock, halibut, cod, hake, sole, plaice, mackerel, salmon, trout, etc.). Eggs (lightly boiled, poached, or scrambled), bacon, ham, chops or steak, stale bread or dry toast with plenty of butter, fruit (apples, oranges, pears, pineapple, peaches, melon).

11 a.m.—Glass of water.

1 p.m.—Soup (potato, onion, pea, carrot, asparagus), eggs when not taken at breakfast, chops or steak, cold meat, chicken, tongue, ham; vegetable salads with French dressing; fruit (as at breakfast), a glass of milk or water.

4 p.m.—Glass of water.

7 p.m.—Raw oysters, soup (as at lunch), fish (as at breakfast), beef, mutton, chicken, vegetables (potatoes, cauliflower, Brussels sprouts, French beans, peas, carrots, lettuce), fruit (as at breakfast), cheese, toast and butter, glass of water.

10 p.m.—Glass of hot water.

Note.—Take only easily digested vegetables. Avoid too much milk, but take an abundance of water.

Must avoid:—Spinach, sorrel, rhubarb, tomatoes, beet, celery, cucumber, broad beans, haricot beans, grapes, plums, gooseberries, currants, strawberries, raspberries. Cocoa, chocolate, tea. Much sugar or sweets. Pepper and all condiments and highly seasoned foods. Sweetbreads. Liqueurs and brandy.

RELATIVE AMOUNTS OF OXALIC ACID IN COMMONER FOODS.

Cocoa ..	3·52 to 4·50	Chocolate	0·724 to 0·90
Pepper	.. 3·25	Peas	.. 0·425
Sorrel ..	2·74 to 3·63	Broad beans	.. 0·280
Rhubarb	.. 2·47	Dry figs	.. 0·270
Tea ..	.. 2·06	Cucumber	.. 0·251
Spinach	1·91 to 3·17	Bread (white)	0·047 to 0·130
		Sweetbreads	0·011 to 0·250

DIET SCHEME IN INTERSTITIAL HEPATITIS.

7 a.m.—Glass of Vichy water.

8 a.m.—Eggs (soft boiled, poached, scrambled), white fish, tripe, stewed fruit without sugar, toast and butter, a glass of milk.

11 a.m.—Glass of milk.

1 p.m.—Raw oysters, white fish, a little cold lean meat, chicken, or tongue, vegetables (spinach, stewed celery, cauliflower, asparagus, tomatoes, French beans, onions, lettuce), stewed fruit without sugar, cheese, butter, toast, a glass of milk.

4 p.m.—Glass of milk with a couple of rusks.

7 p.m.—Purée of vegetables, white fish, eggs, a little lean meat, chicken or tongue, stale bread or toast and butter, stewed fruit without sugar or a little honey, jellies, a glass of milk.

10 p.m.—Glass of Vichy water.

Must avoid.—Strong soups, rich made dishes, new bread, pastry, cakes, preserved fish or meat, curries, too much sugar or starchy food, herrings, salmon, mackerel, eels, dried fruits, malt liquors, sweet wine, champagne.

DIET SCHEME IN CHRONIC CHOLECYSTITIS AND CHOLANGITIS.

7.30 a.m.—Glass of Vichy water.

8 a.m.—Dry toast with a little butter, white fish, fruit fresh or stewed with glycerin (no sugar), a cup of coffee without cream or sugar.

10 a.m.—Dry toast with a little honey, jam, or marmalade, a glass of milk.
12 noon.—Glass of Vichy water.
1 p.m.—White fish, lean cold meat, chicken, a baked potato with a little butter, a little stale bread or dry toast, cheese, a glass of water.
4 p.m.—A cup of tea without sugar, or a glass of milk, with a few rusks or a little dry toast and a small quantity of butter.
7 p.m.—Oysters, clear soup, white fish, lean meat or bird, vegetables (spinach, cauliflower, asparagus, French beans, tomatoes). Fruit cooked without sugar, jellies, dry toast, cheese, a glass of water or weak whisky and water.
10 p.m.—Glass of Vichy water.

Note.—Large quantities of starchy or sweet foods must be avoided, and should always be taken in a finely-divided condition. A reasonable amount of fat may be taken, but fat meats, goose, duck, salmon, herrings, mackerel, and eels should be avoided. Drink at least four pints of liquid a day, but take fluids only at the end of a meal.

DIET SCHEME IN SIMPLE JAUNDICE WITHOUT ASSOCIATED PANCREATIC INSUFFICIENCY.

7.30 a.m.—Glass of Vichy water.
8 a.m.—Toast or stale bread with a little butter, eggs soft-boiled or poached, not more than two or three times a week; lean steak or chop, tripe. Fruit (apples, baked, raw, or stewed, oranges, grape-fruit), a cup of coffee with milk but no sugar.
11 a.m.—A glass of cold water.
1 p.m.—Raw oysters, white fish, lean cold meat or bird, a baked potato with a little butter, dry toast with a little butter, a glass of water or buttermilk.
4 p.m.—A cup of weak tea with milk but no sugar, toast and a little butter.
7 p.m.—Soup, fish, if not taken at lunch, lean mutton, beef, chicken, turkey, or tongue, Vegetables (spinach, cauliflower, celery, asparagus, tomatoes, lettuce, potatoes). Fruit. Milk puddings (rice, sago, tapioca). Glass of water or buttermilk.
9 p.m.—Glass of Vichy water.

DIET SCHEME IN JAUNDICE WITH PANCREATIC INSUFFICIENCY.

7.30 a.m.—Glass of Vichy water.
8 a.m.—Soft boiled or poached eggs two or three times a week, baked potato with a little butter or boiled rice or well-

cooked fine oatmeal with skimmed milk, stale bread or toast with a little butter, fruit (apples, oranges, grape-fruit, grapes), a cup of coffee or tea with milk.

11 a.m.—Breakfast-cupful of gruel (fine oatmeal, barley, sago, tapioca) with milk, a glass of skimmed milk, or butter-milk.

1 p.m.—Raw oysters, vegetable purée (asparagus, peas, tomato, celery), baked macaroni or spaghetti and cheese, or dry toast with a little butter and cheese, jellies, a glass of Vichy water or skimmed milk.

4.30 p.m.—As at 11 a.m.

7 p.m.—Soup, potato baked or mashed, vegetables (spinach, tomatoes), milk pudding (rice, sago, tapioca), jellies, fruit, a glass of water.

10 p.m.—As at 11 a.m.

DIET SCHEME IN PANCREATIC INSUFFICIENCY.

7.30 a.m.—Glass of hot water.

8 a.m.—Yolk of egg (lightly boiled, poached, or beaten up with milk), porridge with milk, toast and butter, roast potato with butter, plasmon cocoa with milk.

11 a.m.—Glass of gruel or skimmed milk with added plasmon, a little toast with butter or rusk.

1 p.m.—Purée of vegetables (spinach, asparagus, tomatoes, potato, peas, etc.), casein biscuits with cheese, or macaroni with cheese, stewed fruit, milk puddings, jellies, toast and butter, a glass of skimmed milk or buttermilk.

4.30 p.m.—As at 11 a.m.

7 p.m.—Soup, a little lean meat, chicken, white fish, sweetbread or tripe (well masticated or minced), yolk of egg, baked potato with butter, milk puddings, blancmange, jellies, stewed fruit, cheese, toast, butter.

10 p.m.—Glass of milk with plasmon added.

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