likely to recur. It is not always possible even to suspect its presence, but whenever it is found the best treatment is excision.

Lectures

ON

THE PASSAGE OF FOOD THROUGH THE HUMAN ALIMENTARY CANAL.

DELIVERED AT GUY'S HOSPITAL FOR LONDON UNIVERSITY
ADVANCED STUDENTS DURING OCTOBER, 1907.

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(Continued from p. 137.)

III—THE MOVEMENTS OF THE SMALL INTESTINES.

The old experimental methods, in which the viscera of an animal were exposed to view, demonstrated the occurrence of peristaltic waves, which propelled the contents of the small intestines slowly towards the caecum. Cannon,²⁸ by means of *x*-ray examinations in cats and dogs, discovered that another and equally important type of movement occurred, which he termed "segmentation." This probably is the normal form of the "swaying pendular movements," first described by Ludwig, which are seen in the exposed gut of animals whose splanchnic nerves have been cut.

The function of segmentation is to mix the food thoroughly with the bile, pancreatic juice, and intestinal juice, and at the same time to bring every portion into frequent contact with the absorbing mucous membrane. Mall²⁹ has also pointed out that it assists in the pumping of blood from the submucous venous plexuses into the radicles of the superior mesenteric vein and in the discharge of chyle from the lacteals of the villi into the larger lymph vessels of the mesentery.

Plaff and Nelson,³⁰ on the strength of 60 negative experiments, have recently denied the existence of segmentation, even in cats; this is difficult to understand, as on the only occasion on which we watched the intestinal movements in a cat, segmentation—exactly as described by Cannon—was perfectly obvious.

The shadow of the small intestines cannot, as a rule, be very definitely seen in man, owing to the rapid passage of the bismuth through them, and the diminished concentration of the salt due to the large quantities of digestive juices present. This probably accounts for the fact that when we began our investigations segmentation had never been observed in man. But in three healthy individuals and in three patients who had been given bismuth meals for diagnostic purposes, we have seen the shadow of a short length of small intestine and have watched its movements at intervals over a period of half an hour. Apparently a small quantity of food, containing more bismuth than the rest, kept together as it passed along the gut on these occasions. We were, in the first place, able to trace the onward movement of the shadow as a whole, due, no doubt, to ordinary peristalsis. It was obviously impossible to ascertain the rate of progress, as the movement occurs in such varying directions and in more than one plane. We also saw well-marked segmentation. The shadow of the short length of small intestine, at first of uniform thickness, became constricted in its centre; the constriction increased until the single shadow was more or less completely divided into two. Then each half underwent a similar division, but the two central segments of the four thus produced joined together. The new central segment then divided again, the segmentation continuing in one case at the rate of ten divisions in a minute and a half. The process, as seen with the *x* rays, is shown somewhat diagrammatically in Fig. 3.

On eight occasions we made skiagraphic observations at short intervals on normal individuals who had taken an ordinary meal, to which one or two ounces of bismuth carbonate had been added, in order to determine how soon the first traces of the stomach contents reached the caecum. We found that the shadow of the caecum began to appear between three and a half and five hours, with an average of four and three-eighths hours, after the food

had been taken, and numerous other observations, less accurately carried out, were all in accord with these times. Thus the shadow of the caecum is always obvious before that of the stomach has disappeared. Presuming, as we are probably justified in doing, that some of its contents begin to leave the stomach within half an hour of the beginning of a meal, it is clear that the average rate at which the contents of the small intestines travel is $22\frac{1}{2}$ ft. in four hours, or 5 ft. and 7 in. per hour, which is equivalent to about one inch per minute.

Fig. 3.—Diagram of segmentation in human small intestine occurring simultaneously with peristalsis.

Cannon hoped to obtain evidence of the occurrence of antiperistalsis in the colon by auscultation, but he came to the conclusion that the sounds often heard in the ascending colon were due to the oscillating contractions of the walls of the sacculi described by Elliott and Barclay-Smith. It occurred to me that the sounds heard over the caecum would more probably be due to the entry of the fluid contents of the ileum through the ileo-caecal valve. In order to test this view we listened on a number of occasions, at short intervals throughout the day, to the sounds heard when the stethoscope was placed over the caecum of normal individuals. Before deciding that any series of sounds originated in the caecum we listened to other parts of the abdomen, in order to determine whether anything similar in character and rhythm could be heard elsewhere.

In the morning before breakfast, about twelve hours after the last meal had been eaten, no sounds could ever be heard over the caecum. The silence continued until between four and four and a half hours after breakfast, when a few sounds could be heard, which were quite distinct from anything present in other parts of the abdomen. The sounds gradually became louder and more frequent, until they reached a maximum in one hour to two and a half hours after their commencement. After this it is not of much use to listen again to the caecum, as the relation of the sounds to the time at which breakfast was taken is confused by the taking of other meals.

An ounce and a half of bismuth carbonate were taken with the breakfast on one occasion by four of the five individuals investigated. It was found that the appearance of a shadow in the caecum, when examined by the *x* rays, coincided in point of time with the occurrence of the earliest sounds in the right iliac fossa. In those investigations in which auscultation was practised without skiagraphy, the first caecal sounds were always heard at about the time that *x* ray observations had previously shown that the first traces of the food would reach the caecum. Hence it seems clear that in auscultation we have a means by which we can time the rate at which the contents of the small intestine pass from the stomach to the caecum. Auscultation may thus take the place of skiagraphy, when the latter cannot for some reason be used, in the diagnosis of the rare cases in which constipation is due in part to the slow passage of food through the small intestines.

The sounds heard over the caecum are in all probability due to the actual entry of the fluid contents of the ileum into the gas-containing caecum. Their loudness varies considerably in different individuals. When at a later period the gas is largely replaced by faecal material, the sounds diminish in intensity and become less continuous. At all times they are louder in the upright than in the horizontal position, but for the first quarter or half minute after lying down the sounds are generally loud and

almost continuous, owing probably to the movements of the fluid contents produced by the action of gravity.

It is said that in typhoid fever "gurgling in the right iliac fossa exists in a large proportion of cases." This is, however, not a distinctive sign, as it occurs in all individuals who have small fevers repeated frequently, as in them fluid contents will be entering the caecum continuously instead of only for a limited period, beginning about four hours after each meal.

IV.—THE MOVEMENTS OF THE COLON.

In normal individuals the caecum and ascending colon are almost empty in the morning. This can be demonstrated by the resonant note found on percussion and by the feeling of emptiness found on palpation. Between one and two hours after the sounds indicating the earliest arrival of material in the caecum are heard, we have observed that, if the individual is examined in the vertical position, the resonant note previously present over the caecum is replaced by a dull note which gradually extends upwards.

When sufficient material is present in the caecum and ascending colon to produce slight distension, movements in the previously inactive large intestine begin. Ordinary peristaltic waves, which occur much less frequently than in the small intestine, carry the contents towards the rectum. But for a considerable period very little escapes beyond the centre of the transverse colon, owing to the periodical occurrence of a series of antiperistaltic waves. The existence of these was accidentally discovered by Jacobi³¹ in the course of some experiments on colchicum poisoning. Antiperistalsis was subsequently investigated by Cannon³² by x-ray observations on cats and by Elliott and Barclay-Smith³³ in the exposed intestines of various animals. A comparison between the anatomy of the colon in these animals and in man renders it probable that the antiperistaltic waves begin in man somewhere near the centre of the transverse colon, whence they travel slowly to the caecum. Several waves are often present simultaneously, and they force the contents of the colon towards the caecum. The ileo-caecal sphincter, which will be described later, prevents the regurgitation of the contents of the colon into the small intestine. Hence antiperistalsis has the same effect on the large intestine that peristalsis has on the gastric contents when the pylorus is closed; a central reflux occurs when a wave reaches the caecum, so that the contents of the ascending colon and part of the transverse colon are caused to circulate and come into frequent intimate contact with the mucous membrane, with the result that absorption of fluid and nutrient material occurs rapidly.

The change in consistency of the contents of the caecum as absorption occurs can be traced by means of percussion. When first present the dull note over the caecum disappears entirely if the supine position is assumed, as the contents are fluid, and therefore spread along the posterior wall of the ascending colon when the individual lies down. But two or three hours later the upper border of dullness alters only slightly or not at all on lying down.* By means of palpation, also, it is possible to determine the changes taking place in the caecum. Five or six hours after a meal a sensation of splashing or gurgling can be detected on palpation, where previously only the empty gut could be felt. Some hours later the splashing is no longer present, and the caecum can be felt to be filled with semi-solid material.

As the contents of the caecum and ascending colon become more solid, antiperistalsis becomes less active and finally ceases, and forward peristalsis drives increasing quantities into the more distal part of the colon. Here no antiperistalsis occurs, the faeces being slowly propelled towards the rectum. They finally remain in the descending and pelvic colon until defaecation occurs.

Owing to the absorption of fluid in the proximal part of the colon it is found that the intestinal contents distal to the middle of the transverse colon are always moderately firm. In order to determine the rate in which the faeces pass along the colon we have made x-ray examinations in sixteen normal individuals at various intervals after a bismuth meal, in some cases as often as four times on the first day, as well as once or more on subsequent days if

necessary. It has already been stated that the shadow of the caecum appears on an average in four and three-eighths hours after the meal has been eaten.

Between five and eight hours after the meal the hepatic flexure is reached; in from seven to ten hours the splenic flexure is reached, so that about two hours are required for the passage of both the ascending colon and the transverse colon. The average times taken are four and three-eighths hours to the caecum, six and a half hours to the hepatic flexure, eight hours to the middle of the transverse colon, and nine hours to the splenic flexure.

After a bismuth breakfast the shadow rarely reaches beyond the splenic flexure by four or five o'clock in the afternoon. On one occasion, however, the iliac crest was reached in eight hours, and on another the end of the iliac colon in nine hours.

If the bowels are not opened before the skiagraphic examination at 10 a.m., the remains of a bismuth breakfast of the previous day are found to have reached some point between the iliac crest and the rectum.

Fig. 4 shows the average time at which various points of the colon are reached if a bismuth breakfast is taken at 8 a.m. It does not, however, give much information as to the rate at which the last part of the colon is traversed, as after arriving at a certain point, which depends on the amount of faeces already present in the colon, the contents make no further progress until the

Fig. 4.—Average time at which various points of the colon are reached after a bismuth breakfast taken at 8 a.m.

bowels are opened. But on the somewhat unusual occasions on which part of the colon below the splenic flexure still contains bismuth after defaecation, the rate of progress through the pelvic colon can be measured. Thus on two occasions the bismuth was found to pass from the junction of the iliac colon with the pelvic colon to the junction of the latter with the rectum in six hours.

The movements of the colon appear to be considerably more sluggish during the night than the day. Thus in the same individual, in whom only eight hours were required for bismuth taken at breakfast to reach the end of the descending colon, bismuth taken at 10.30 p.m. had only reached the hepatic flexure by 10.30 the following morning.

When the shadow of the caecum first becomes visible, four and a half hours after a meal, that of the stomach can almost always be still seen. The remnant of food in the stomach at this period will probably also take about four and a half hours to reach the caecum, so that it will be at least nine hours after a meal has been taken before the last traces of the products of its digestion pass through the ileo-caecal valve. In nine hours the splenic flexure is generally reached by the material which first arrived in the colon, so that it is not surprising that the shadows of the caecum, ascending colon, and transverse colon are normally still visible when that of the splenic flexure is first seen. By the time the descending colon is filled, the caecum and ascending colon, and occasionally half of the transverse colon, though generally unaltered,

* For further details on this subject see my paper in *Guy's Hospital Reports*, 1907.

may be seen only as a comparatively faint shadow. But when the iliac colon is reached, the ascending colon, and half or all the transverse colon, are, as a rule, no longer seen, though frequently a faint shadow still marks the caecum, which finally disappears when the end of the pelvic colon has been passed.

Fig. 5.—Series of colon skiagrams in a normal individual. The numbers represent the hours after bismuth breakfast was taken.

Fig. 5 is reproduced from actual tracings made on the fluorescent screen at various periods after a bismuth breakfast had been eaten by a normal individual.

Antiperistalsis is of practical importance in connexion with the local treatment of diseases of the colon by rectal injections and with the administration of nutrient enemata. I have myself observed with the *x* rays fluid containing bismuth reach the proximal part of the transverse colon when injected per rectum without producing any discomfort. It is probable that if very large quantities are injected they can be forced to the caecum. But even comparatively small amounts can be carried to the caecum by antiperistalsis if part once reaches the region in which this type of movement occurs. Hence it is quite reasonable to treat disease of the caecum and ascending colon by rectal injections, and the absorption of large nutrient enemata probably occurs from all parts of the colon, and not only, as formerly believed, from the sigmoid flexure and rectum.

It is doubtful whether segmentation, as it occurs in the small intestine, ever takes place in the colon. But both Elliott and Cannon have noticed oscillating movements of single sacculi in the exposed colon of animals, which give rise to a thorough churning of their contents. These movements have the same function as segmentation in the small intestine, and are probably the normal form of the "pendular movements" which had previously been observed in the large intestines by Starling and others.

The Ileo-caecal Valve and Sphincter.

No mixing takes place under normal conditions between the contents of the small and the large intestines, so that material which has once reached the caecum can never

return into the ileum in spite of the occurrence of antiperistalsis in the colon. This has been believed to be due to the mechanical action of the ileo-caecal valve ever since Caspar Bauhin, who discovered it in 1579, found that after death it can resist a moderate pressure from the side of the colon but very little from the side of the small intestine. Though this explanation might be sufficient in man, it cannot be applied to the many animals in which, though the valve is absent, the relative consistency of the contents of the small and large intestines shows that no mixing between them occurs. In 1903 Keith suggested from anatomical considerations that a strong ileo-caecal sphincter exists in man and most animals, as the transverse layer of the muscular coat of the ileum is greatly thickened where it enters the colon. In the following year Elliott³¹ proved experimentally that such a sphincter exists. He found that it was kept in a condition of moderate tonic contraction by impulses carried by the splanchnic nerves; when these were cut it became permanently relaxed and the contents of the small and large intestines mixed freely with each other. Stimulation of the splanchnic nerves caused the sphincter to contract tightly, although the movements of the rest of the intestines were simultaneously inhibited. Stimulation of the vagus and pelvic nerves had no influence on it.

It is still uncertain whether the peristalsis of the small intestine is sufficient to cause its contents to pass into the colon without relaxation of the sphincter, or whether it is necessary for active relaxation to occur each time a peristaltic wave reaches it. The sphincter probably contracts whenever an antiperistaltic wave of the colon arrives at the caecum, so that regurgitation of the contents of the colon into the small intestine is prevented.

As the ileo-caecal sphincter prevents the regurgitation of the colon contents into the small intestines, it is possible that the anatomical arrangement of the mucous membrane, known as the ileo-caecal valve, is not concerned in this, but has some other function. The contents of the small intestine have been seen through a caecal fistula to enter the colon in spirals which occur at regular intervals. Mr. Ralph Thomson³² has shown that the ileo-caecal valve in man is so formed that these spirals are directed downwards towards the centre of the external haustrum of the caecum. As the orifice of the appendix is situated in the internal haustrum, the arrangement of the ileo-caecal valve diminishes the likelihood of food passing into the lumen of the appendix. Were it not for this, it seems possible that appendicitis would be even more common than it is.

NERVOUS CONTROL OF GASTRO-INTESTINAL MOVEMENTS.

The muscles of the stomach and intestines receive through the splanchnic nerves sympathetic fibres, which originate in the lower dorsal and upper lumbar region of the spinal cord. The stomach and small intestines are also supplied with fibres from the vagi; the large intestines are supplied by the nervi erigentes with fibres from the sacral cord, which are unconnected with the sympathetic system and are physiologically equivalent to the vagi. The nerves end in connexion with ganglion cells situated between the circular and longitudinal muscular layers, where they constitute Auerbach's plexus.

Stimulation of the splanchnic nerves diminishes the tone of the gastric and intestinal muscles, and inhibits their normal movements. On the other hand, stimulation of the vagus, or, in the case of the colon, the nervi erigentes, increases the muscular tone and the strength of the movements after producing a temporary inhibition.

In spite of the fact that they possess this double nerve supply, the stomach and intestines can perform their functions to a great extent independently of the central nervous system. Thus, peristalsis has been frequently observed in excised stomachs and intestines which have been kept moist and warm. Aldehoff and v. Mering³³ have shown, moreover, that the tone and movements of the stomach and intestines, as well as the reflex regulation of the pylorus, remained normal for months after both vagi had been cut just above the diaphragm, and also after destruction of the coeliac plexus.

These results have been confirmed by Cannon³⁷ by means of *x*-ray observations on cats. He found that the movements of the stomach and the regulation of the pylorus are quite unaffected by cutting the splanchnic nerves of both sides. If both vagi are cut, gastric peri-

stalsis is impaired for a short time only, but the passage of food through the pylorus remains permanently slower than before. If both the splanchnic nerves and the vagi are divided, there is no initial depression of gastric peristalsis, as when the vagi are alone cut, but the passage of food from the stomach into the duodenum is delayed. Thus gastric peristalsis is less upset after section of the vagi if the inhibitory action of the splanchnics is simultaneously thrown out of action.

From these experiments it is clear that the tone of the cardiac part of the stomach, the control of the pylorus, and the peristalsis of the stomach and intestines are to a great extent independent of the central nervous system. Magnus has shown that separated strips of intestinal muscle contract rhythmically only if the local nerve plexus is removed with them. It is therefore probable that the motor functions of the stomach and intestines depend on reflexes which have their centre in the nerve cells of Auerbach's plexus.

There is, however, no doubt that under certain conditions the central nervous system can influence the movements of the stomach and intestines. Thus Pawlow discovered that intestinal peristalsis was excited in dogs by the smell or taste of food, and Cannon found that the movements in his cats ceased when they were excited or angry, an observation which explains the indigestion so frequently caused by unpleasant emotions. This effect of anger still occurred when both vagi were cut, so it must be due to impulses which pass along the splanchnic nerves. Pawlow, moreover, showed that reflex inhibition of the gastro-intestinal movements was produced by stimulation of many sensory nerves, the efferent impulse being carried by sympathetic nerve fibres. This is no doubt one of the principal factors in the causation of the deficient digestion which often accompanies pain in any situation.

The most important reflex inhibition is protective in character. It occurs when the peritoneum is stimulated by the presence of abnormal material in the peritoneal cavity, as after the perforation of a gastric or intestinal ulcer or after perforation of the appendix. The immediate result is that the spread of irritating material in the peritoneal cavity is delayed by the inhibition of the movements of the stomach and intestines. The reflex from the peritoneum is very easily aroused, mere exposure to the air being sufficient to give rise to temporary inhibition of most of the movements. This accounts for the fact that the stomach and intestines are nearly always at rest when an abdominal operation is in progress, and that in animals the movements can only be observed after the splanchnic nerves have been divided, so that the efferent branch of the reflex is broken. Cannon has, however, shown that the effect of exposure only lasts so long as the exposure continues. As neither cooling of the intestines nor anaesthesia have any effect on the subsequent activity of the intestines, the paralysis of the bowels which may occur after abdominal operations is due, as the important observations of Cannon and Murphy³³ show, to the effects of handling the viscera.

Various stimuli give rise to the local reflexes which result in the production of peristalsis and segmentation. Bayliss and Starling discovered that mechanical irritation of any part of the intestines causes contraction to occur in the 3 in. above and relaxation in the 12 in. below. This combination of a proximal contraction with a distal relaxation causing the irritating contents to move onward, with the result that a wave of contraction preceded by a wave of relaxation passes down the intestines; such a compound wave constitutes typical peristalsis. X-ray observations show that the contractions which give rise to segmentation depend mainly on mechanical stimuli, as they occur when distension is greatest.

Cellulose is the chief constituent of the food which gives rise to mechanical stimulation of the motor activity of the gut. Being indigestible, it also adds bulk to the intestinal contents, and may therefore stimulate by producing tension as well as by mere mechanical irritation. On the other hand, meat, fish, and eggs leave less than 5 per cent. indigestible residue. This explains the greater activity of peristalsis in herbivorous than in carnivorous animals, and in vegetarians than in people who take a mixed diet.

Most of the normal activity of the intestines depends probably on the chemical stimulus of certain constituents

of the food and of the products of their digestion and bacterial decomposition. Thus sugars, organic acids produced by fermentation or present naturally in fruit, fats and fatty acids, salt in excess, carbon dioxide, and sulphuretted hydrogen, are among the numerous chemical substances which stimulate peristalsis. It is still uncertain whether bile has any action of this sort.

Finally, electrical and thermal stimuli can increase intestinal movements. The latter are only of importance before breakfast when the stomach is empty, as then cold or hot water can enter the intestine without being retained in the stomach until the body temperature is reached. This explains why a glass of cold or hot water taken on rising in the morning acts so favourably in promoting the action of the bowels in many individuals.

V.—DEFAECATION.

A good deal of work has been done on the nervous control of defaecation in animals, but very little is known about the actual process as it occurs in normal human beings. The only observation made under physiological conditions appears to be one of Cannon's, who watched the process by means of the x rays in a cat, which had been previously given food mixed with bismuth.³⁹

If bismuth carbonate is given with the food two or three times during the course of a day instead of on one occasion only, the shadow of the whole colon can generally be seen with the x rays the next day. We have once watched the changes in the shadow which occurred during defaecation in a healthy individual prepared in this way. On six other occasions we have made tracings of the shadow immediately before and immediately after defaecation in order to find out how much of the colon takes part in the process.

Fig. 6.—Normal defaecation.

Defaecation is normally started by the voluntary contraction of the abdominal muscles and the diaphragm. Owing to the simultaneous closure of the glottis, this leads to the production of greatly increased abdominal pressure. It is remarkable that in most physiological textbooks no mention is made of the contraction of the diaphragm, which appears to be of much greater importance than that of the abdominal muscles in producing the rise of intra-abdominal pressure. By means of the x rays we were able to see the diaphragm move down to the lowest position it could possibly attain, where it remained with slight variations during the straining which resulted in defaecation. The lower border of the caecum descended about $\frac{1}{2}$ in., but the hepatic flexure was depressed to exactly the same extent as the diaphragm, and almost reached the level of the umbilicus, so that the ascending colon was compressed to an almost globular form. The transverse colon descended from 1 in. above to 1 in. below the umbilicus. The splenic flexure was depressed to the same extent as the hepatic flexure, but owing to the junction of the descending colon with the iliac colon being more mobile than the caecum, it could be more depressed, so that the descending colon did not assume such a broad shape as the ascending colon. Fig. 6 (a) is a reproduction

of a tracing taken of the colon immediately before defaecation, and (b) is reproduced from a tracing made during the act. After the straining ceases the ascending and descending colon rapidly return to their normal position, but the transverse colon rises very slowly, and may not return

Fig. 7.—Normal defaecation.

to its former height for over an hour. This is seen in (c) and (d) of Fig. 6, and also in Fig. 7.

It is often stated that "in healthy individuals, except just before defaecation, the rectum is empty, and the pressure of faeces in this part of the bowel at once gives rise to discomfort, and to a desire to defaecate." This is not strictly accurate, as when a rectal examination is made on a normal individual, whatever interval may have elapsed since the last defaecation occurred, the rectum is found to contain more or less faeces. It is quite exceptional to find the rectum empty. It is probable that the desire to defaecate is felt only when the rectum is to some extent distended.

The increased intra abdominal pressure produced by the contraction of the diaphragm and abdominal muscles causes faeces in the pelvic colon to move towards the anus, which is the direction of least resistance. Thus the rectum becomes more distended, and faeces are forced into the anal canal, which is normally quite empty. Both the distension of the rectum and the irritation of the mucous membrane of the anal canal by faeces give rise to afferent nervous impulses, which pass to a centre in the lumbar spinal cord, where they set in action the efferent impulses upon which depends the reflex act required to complete the process of defaecation. This is generally described as consisting of "strong peristaltic contractions, which take place along the whole of the descending colon, sigmoid flexure, and rectum, while both sphincters are relaxed." But our observations lead to the conclusion that the caecum, ascending colon, and transverse colon are also active in defaecation. Thus on the occasion on which we watched the actual process of defaecation, active peristaltic contractions appeared to occur in the caecum and ascending colon. But even more conclusive evidence was obtained by comparing the tracings obtained immediately before and immediately after defaecation. The shadow of the caecum, ascending colon, and a small part of the transverse colon generally become thinner and much fainter; this must be due to the peristaltic contraction of their walls, causing their contents to pass further along the colon. This is seen in the tracings of the two cases reproduced in Figs. 6 and 7.

In another case the activity of the ascending colon was shown in a different way. At 9 a.m. the individual concerned felt, as usual, the desire to defaecate, but as he had on the previous day taken a bismuth supper, he wished to give us the opportunity in the evening of examining his colon before and after defaecation. He therefore restrained the desire. The desire to defaecate, at one time almost irresistible, soon disappeared, but on examination at 10 a.m. no shadow was seen in any of the colon, except in the iliac and pelvic parts, the latter being much distended. This suggested that the violent desire to defaecate at 9 a.m. had resulted in the whole of the first part of the colon emptying itself into the distal part. Another $\frac{1}{2}$ oz. of bismuth was taken at noon. At 8 p.m. this had reached the hepatic flexure, so that the caecum and ascending colon could be seen, as well as the iliac colon and pelvic colon (Fig. 8, a). After defaecation, some minutes later, the distended pelvic colon was found to have rid itself of the excess of faeces it contained. The caecum and ascending colon had partly emptied their contents into the transverse colon, the first part of which was now visible (Fig. 8, b). The descending colon, previously containing no bismuth, could now be clearly seen. The source of its new contents was not obvious, as the greater part of the transverse colon was still invisible.

Most probably it came from the transverse colon, where it may previously have been too diffused to throw a definite shadow.

In most cases the shadow of the whole of the large intestines below the splenic flexure disappears during defaecation (as in Fig. 7), showing that this part empties itself completely. In Fig. 6 the descending colon, iliac colon and part of the pelvic colon are still seen, as only a few small scybala were passed in spite of the active peristalsis which almost emptied the caecum and ascending colon. This was no doubt due to the fact that the individual concerned put off defaecation for twelve hours after the desire was first felt, in order that we might be able to observe the act. Consequently water must have been absorbed from the faeces in the rectum, and the reflex brought about by voluntary contraction of the abdominal muscles and the diaphragm, at a time when the desire to defaecate was no longer felt, was insufficiently active to enable the rectum to rid itself of the hard faeces it contained. The same explanation holds for the case shown in Fig. 8.

Fig. 8.—Normal defaecation. June 4th.—11 p.m., bism. carb. 3jss. June 5th.—9 a.m., violent desire to defaecate. Noon, bism. carb., 5ss. 8 p.m., tracing (a) made; then defaecation, after which tracing (b) made.

If a bismuth breakfast be eaten one morning and the bowels are opened well the next morning, some of the bismuth is often found in the faeces. In a number of cases, however, it only appears in the faeces for the first time on the second morning after the bismuth breakfast. In one individual, whose stools passed at 8.30 a.m. were not abnormally soft or copious, all the bismuth taken on the previous morning was excreted, as no trace of a shadow could be seen when a skiagraphic examination was made at 10 a.m. Generally, however, the bismuth is not completely excreted for forty-eight hours, or sometimes for seventy-two hours. In one individual, who was not in the least constipated but whose splenic flexure formed a very acute angle, a shadow was still present in the proximal part of the splenic flexure on three consecutive mornings following the day on which a bismuth breakfast had been taken. Already twenty-four hours after the meal the shadow was not very dark; the next morning it was fainter still, and on the third morning it could only be seen with difficulty.

If the lumbar spinal cord is destroyed in animals or injured or diseased in man, all voluntary control of defaecation is lost. The tone of the anal sphincters disappears; though, in animals at any rate, it may return after some time. The consequence is that with normal faeces constipation occurs, but the independent peristalsis of the colon, together with the voluntary contraction of the diaphragm and the abdominal muscles are sufficient to push the rectal contents through the slack sphincters and so prevent the production of faecal impaction. If, however, the contents of the rectum happen to be abnormally fluid incontinence with diarrhoea results, as the tone of the anal sphincters is lost and cannot be increased by a voluntary effort.

The influence of the central nervous system is thus as important in defaecation as in deglutition, although the intermediate part of the alimentary canal works to a great extent automatically. Hence both the taking of food and the excretion of faeces can be timed to suit the convenience of an animal, whereas the rest of the alimentary canal is always active without

requiring attention and without giving rise to any sensation.

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STATUS LYMPHATICUS IN RELATION TO GENERAL ANAESTHESIA.*

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How often, in looking for the particular, is the general overlooked! Much as we know of the mechanism of death under anaesthesia and the action of narcotics on special organs, the influence of the general condition of the patient on the course of anaesthesia is still obscure. We need to take a broad view of our patient's constitution. On this occasion I wish to bring to your notice a definite pathological entity, known as the "status lymphaticus," or "status thymicus."

HISTORY.

According to Griffiths, Plater, in 1614, called attention to the fact that the thymus was enlarged in certain cases of sudden death. Later, in 1723, Bichat made the same observation, and Kopp, in 1829, associated enlarged thymus with laryngo spasm. Friedleben denied the then common assumption that an enlarged thymus could cause death by compression of the air passages. The merit of having directed into the right path the investigation of many hitherto inexplicable cases of sudden death is undoubtedly due to Paltauf. Graulitz of Greifswald had previously noted the occurrence of the enlargement of the thymus gland in two sudden deaths, and had emphasized the possibility of a connexion between such enlargement and sudden death.

Paltauf, in 1889 and 1890, was the first to collect a large number of cases of sudden death in adults, which, on *post-mortem* examination, gave, in an extreme degree, characteristically similar proofs of the correctness of his theory. There was found an enlargement of the tonsils, of the lymphatic gland system, of the follicles at the base of the tongue, of the spleen, and, lastly, an enlarged thymus gland, which varied in size in different subjects; in most cases also there was narrowing of the aorta. This combination of conditions the investigator called the "lymphatico-chlorotic constitution," and referred the sudden deaths of certain patients of this type to cardiac paralysis and acute heart dilatation, putting aside a theory advanced as to the possibility of mechanical interference by pressure of the enlarged thymus on the circulatory and respiratory organs. Paltauf's first case was that of a girl, aged 9, who sat up in bed and died suddenly. He speaks of sudden death during bathing, etc. Nordmann and Recklinghausen recorded similar cases of young people who died suddenly during or after a cold bath, and in whom, *post mortem*, status lymphaticus was found. According to Laqueur, Pott saw death occur in eight children who suffered from spasm of the glottis after introduction of a tongue spatula, and was convinced that they did not die from suffocation but from cardiac paralysis, for artificial respiration after the attack was useless. In other cases where autopsy took place a markedly enlarged thymus was observed. Kundrat next published in 1895 ten cases of death under or immediately after anaesthesia by chloroform, or a mixture containing it, collected from *post-mortem* records in Vienna, all on section presenting markedly the characteristics of the lymphatic diathesis; and also one case in which ether was the anaesthetic. He pointed out that in some of his cases danger symptoms began with the heart, respiration lasting some time after cessation of the pulse. Kundrat noted, too, the association of status lymphaticus with Basedow's disease in one of his cases, and he laid stress on the remarkable floccidity and recent dilatation of the ventricles of heart found *post mortem*. He instanced other

cases of death during anaesthesia in which many of the characteristics of status lymphaticus were found *post mortem*, but in which there was no mention of enlargement of the thymus gland.

To the writings of Paltauf and Kundrat little of importance can be added to-day. Ewing, Blake, and others in America have written on the subject, but there has been small mention of it in British medical literature. Since these observations of Paltauf and Kundrat many sudden deaths of children have been recorded apart from anaesthesia, in whom *post mortem* has been found the condition of status lymphaticus, and so constantly has the hypertrophy of the thymus gland been noted that the diathesis is often called the status thymicus. Lymphatism is a more modern name for the condition.

The subjects of the status are unusually subject to infectious diseases, to death from shock and fright, and to death during anaesthesia. Even comparatively slight lesions may in them end fatally. Perhaps some of those subjects who have been said to show idiosyncrasy to the action of chloroform have been lymphatic. (Hereafter in this paper status lymphaticus will be abbreviated to "S. L.")

Condition Found after Death.—According to Kundrat the results of autopsies in the subjects of S. L. are tolerably uniform and very remarkable. They are characterized by the presence of a thymus of greater or less size, by an enlarged spleen with varying degrees of prominence of its follicles, by tumescence and hypertrophy of lymphatic glands in various regions (especially of the mesenteric, retroperitoneal, and cervical), by noticeable prominence and multiplication of follicles at the base of the tongue and in the pharynx, by enlargement of the tonsils and swelling of solitary follicles and Peyer's patches in the intestine, by a dilated heart (especially is the right ventricle dilated) and extremely flaccid cardiac muscle. In addition, there is sometimes found a small heart, contraction of the aorta, and dark fluid blood in the heart cavities. To Kundrat's pathological complex may be added less constant features—namely, great pallor of the skin, enlargement of the tongue, enlargement of the thyroid gland, infantilism, oedema of the lungs and brain, fatty changes in the liver, and alterations in the bone marrow. As Kundrat remarks, similar more or less definitely characterized cases making the hypothesis of a lymphatic constitution probable are found scattered through the statistics of chloroform deaths.

Frequency.—According to Halstead, Kolisko, in a personal communication to Brickner, states that for many years he performed about six autopsies annually on persons dying from cardiac syncope under chloroform, in whom no previous lesion of the heart, lungs, or kidneys was known to exist, and always found the signs of S. L. In the children's clinic at Graz the records are said to show that during the last twenty years in every chloroform fatality there was present the lymphatic hyperplasia which is the principal feature of S. L. Hedinger states that the chloroform deaths in his clinic occur in patients of S. L. Blake recorded 3 anaesthetic and 2 non-anaesthetic cases of sudden death in hospital showing *post mortem* signs of S. L. in only a little longer than one year. Besides the number of deaths that have taken place, there must have been many cases of recovery from danger in patients of S. L. in whom the condition had not been recognized.

EFFECTS OF DIFFERENT ANAESTHETICS.

So frequently is death during chloroform anaesthesia associated with S. L. that the question has been asked, Does death under chloroform ever occur apart from the condition? It has been stated by Elser that when S. L. exists the administration of chloroform is nearly always fatal.

The first fatal case, so far as I know, in this country was recorded by Wolff in 1905, and was that of an infant, aged 11 months, whose eye had just been needed for cataract, when cyanosis appeared, and respiration and circulation quickly failed. The thymus weighed 1 oz., and the lymphatic glands were everywhere enlarged, but the spleen was quite normal.

The second case was that very typical one recorded by Mr. Harvey Hilliard at the last meeting of this society.

My fatal case occurred in 1903, but I have not hitherto published it.

In 30 cases of S. L. deaths during or after anaesthesia whose records I have examined, the anaesthetic used was

* Read before the Society of Anaesthetists, December 6th, 1907.