With Photographs

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ENTITLED -

The Behaviour of Free Bodies and Particles in the Peritoneal cavity, with special reference to the influence exerted by the movements of the Diaphragm upon Small Particles. An experimental inquiry.

BY

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The Behaviour of Free Bodies and Particles in the Peritoneal Cavity: with special reference to the influence exerted by the movements of the Diaphragm upon Small Particles.

An Experimental Inquiry.

The investigations of Dr. William Hunter (Journ. Anat. & Physiol. Vol. XXI, 1887, pp.138,264 & 450.)on intra-peritoneal blood transfusion and the fate of absorbed blood,resulted in his drawing the conclusions among others, that the diaphragm in the human subject acts in such a way as to promote the absorption of even the smallest quantity of fluid,however distantly situated,and that very many of the red blood corpuscles of the effused blood are absorbed by the lymphatics of the diaphragm,and passed back again into the general circulation. Thus are opened up the questions, What is the behaviour of small particles lying free in the peritoneal cavity? and how far, if at all, is their behaviour influenced by diaphragmatic action? Further, it seemed to me desirable to ascertain the behaviour of bodies generally when they lay free in the peritoneal cavity, since their movements, if any, and the position they assume, do not appear to have been largely studied. In the case of bodies of appreciable size, it seems always to have been taken for granted that they obeyed the law of gravity and found

their way into the most dependant part of the abdominal cavity.

The first part of this paper therefore is occupied with the consideration of free bodies of appreciable bulk - meaning thereby bodies which can be easily handled with the naked hand, and whose size does not go below that of an ordinary small glass bead - whilst in the second part is discussed the behaviour of minute particles, such as those of finely powdered substances - e.g. lampblack cinnabar.

The experiments were carried out in the Pathological Laboratory of University College, Liverpool, under a license granted to me by the Secretary for State.

I shall first describe the experiments made with free bodies of appreciable size:-

Operative technique -

Anaesthetic: ether was always employed.

Antiseptics were rigidly employed: asepsis in my opinion, being insufficient for animals.

Instruments were all washed in 1 in 20 carbolic lotion before use.

Sutures: catgut and silk were both used. I found that wounds healed better when catgut was employed. The silk seemed to cause irritation, even where it had

been soaked in a 1 in 1000 solution of perchloride of mercury for many days previously. Ligatures were never required.

The foreign bodies introduced into the peritoneal cavity were sterilised - by boiling for a quarter of an hour, in the cases of marble, beads and shot. The balls of rubber and wax were soaked in a solution of perchloride of mercury, (1 in 1000) for two days, and then in weak carbolic lotion, and finally washed in sterilised water, from which they were transferred to the abdominal cavity.

Animals: rabbits were always employed. It was more easy to obtain a license from the Home Office for the performance of experiments on rabbits than on other animals: they themselves are easy to obtain, and they are to be had cheaply. However, in the rabbit the great omentum. though a double fold of peritoneum 3 inches in length, is rolled up and lies along the greater curvature of the stomach, so that it was less likely to interfere with the experiments, either at the time of operation or subsequently.

Operation: The rabbit to be operated on was etherised and tied down in the dorsal position on the usual operating frame. The hair was removed from the ventral aspect of the abdominal wall, and the skin

washed with warm carbolic lotion, 1 in 20, or corrosive sublimate solution, 1 in 4000. An incision of varying length, according to requirements, was made in the middle third of the median line, passing through skin and fascia only. This exposed a thin white fascial line marking the junction of the two halves of the abdominal wall. The knife was carried through this line, and as a rule peritoneum was visible at once, though in very fat rabbits there was a thin layer of subperitoneal fatty tissue. The peritoneum was then pinched up with forceps and divided, and the opening enlarged to the required size by slitting upward or downward with a probe-pointed bistoury carried along a director. In the closure of the wound I tried different plans - using sometimes three or two layers of continuous sutures, the buried ones uniting peritoneum or muscular layer being always of catgut - sometimes only one layer of continuous suturing being employed. There was practically no bleeding: and healing took place usually within a week. The animals seem depressed, and refused food, for the first 24 hours: but they had entirely recovered by the second day.

SERIES A.

Experiment I. Nov. 4th, 1895.

Doe rabbit: being etherised, a glass marble weighing 14 grammes, which had been boiled for half

an hour to sterilise it, was introduced into the abdominal cavity through an incision in the linea alba, and pushed upwards and backwards until it lay in relation with the posterior part of the lower surface of the liver. The wound was then closed.

On different occasions subsequently the rabbit's abdomen was palpated and the marble was easily felt lying in the most dependant part, i.e. on the ventral wall. It changed its position to a certain extent when the animal's position was altered, sinking towards the pelvis when the animal was held vertically with its head uppermost.

On January 29th 1896, the marble was felt to occupy this position, and moreover it was quite moveable. The animal was etherised, placed on its back and the abdomen opened. The marble was found lying free on the left side just above the pelvic brim. It was covered by a thin layer of transparent lymph which was continued on to the surrounding intestines as a delicate membrane. This did not interfere in any way with the mobility of the marble. The peritoneum everywhere appeared normal.

It was remarkable how little irritation this heavy marble had caused. Only delicate adhesions had formed which interfered scarcely at all with its mobility. Very different was the behaviour of the foreign body in the next experiment.

Experiment II. Nov. 19th, 1895.

A buck rabbit was anaesthetised and an incision made in the median line in the anterior part of the middle third. A sterilised red rubber ball, about 1 inch in diameter, and weighing 10 grammes, was introduced into the peritoneal cavity and pushed gently upwards till it lay in relation with the posterior, inferior margin of the liver where it was left. The wound was closed.

Dec. 11th, 1895. Palpation of the abdomen discovered the ball apparently lying in the most dependant part. Its mobility was very limited. After death the abdomen was opened. The ball lay in the midst of intestions which were matted together by dense adhesions about $\frac{1}{16}$ inch in thickness. An incision through this capsule between its intestinal components disclosed the ball imbedded in thick caseous material.

The weight of this ball was less than that of the marble, though its bulk was greater. It had not come at all into contact with the ventral abdominal wall, but having excited what must have been a considerable amount of localised inflamation, it became fixed amongst the intestines - an exception to Von Dembowski's statement that "foreign bodies simply "placed in the abdominal cavity always become encap- "suled in the mesenteric folds or omentum." (T. Von

Dembowski, "Ueber die Ursachen der peritoneale Adhäsionem nach chirurgischen Eingriffin,"Langenbeck's Archiv: XXXVII.)

Experiment III. Nov. 7th, 1895.

A doe rabbit being etherised, a sterilised ball of white paraffin about half an inch in diameter and weighing 135 centigrammes was introduced into the abdominal cavity, and pushed upwards and backwards to the posterior border of the liver. The wound was then closed.

Jan. 29th, 1896. Never at any time could the ball be felt as in the case of the marble in Exp. To-day under anaesthesia the abdomen was opened, and the ball found lying in the right flank between intestines and abdominal wall. It was compressed, covered with lymph, and attached by a fine pedicle of lymph to the right lateral abdominal wall.

Probably in this case the ball lay on the ventral wall when the rabbit lay in its natural position. The reversal of this to the dorsal in my opinion accounts for the position in which it was found. Compare the change which took place in the position of the marble in Exp.I. This experiment is interesting on account of the process of encapsulation which was in progress, because Stern found that mutton-fat or paraffin when introduced into the peritoneal cavity,

prevented the formation of adhesions and were in no way encapsuled. (W.Stern "Ueber pseudomembranöse Verwachsungen bei intra-peritoneale Wunden."Beitrage 3rd Klinische Chirurgie. IV. 3 Heft.)

Experiment IV. Nov. 12th 1895.

A doe rabbit was etherised, and an incision an inch long made in the middle third of the abdomen. Two glass beads, each $\frac{1}{3}$ inch in diameter and weighing respectively 61 and 62 centigrammes, were introduced into the peritoneal cavity, and pushed up to the posterior part of the under surface of the liver. The wound was then closed.

Dec. 5th, 1895. On investigation of the abdomen nothing could be felt by external palpation. Under anaesthesia, the abdomen was opened in the middle line. The peritoneum covering the intestines was slightly injected, and a few flakes of lymph lay on them, and a larger mass of lymph was attached to the ventral wall on the left side of the incision. On elevating the abdominal wall the lymph came with it and revealed the two beads lying between two coils of intestines. The beads were covered with a thin layer of lymph, which extended through their canals and bound them together; but the united pair were lying quite free in the abdominal cavity.

The beads had travelled down from their original

situation, and lay in the lowest part of the cavity between intestines and ventral abdominal wall.

Experiment V. Nov. 12th, 1895.

A doe rabbit was anaesthetised, and the abdomen opened in its middle third. Thirty sterilised small glass beads, 6 of which weighed a decigramme, were introduced - one or two at a time - by means of dissecting forceps, and pushed in various directions - towards the diaphragm, the dorsum, and the pelvis. The wound was closed.

Dec. 5th, External examination revealed nothing, but after death the abdomen was opened, and on the left side of the former incision in the middle third of the median line were found the beads arranged in a rosette-like mass, covered and bound together by lymph. Nineteen beads were visible on the surface of the rosette. Three beads were found adherent to the mesentery.

A photograph of the rosette was taken and is here presented - see Photo. No.1.

With the exception of the three adherent to the mesentery, all the beads had descended to the lowest part of the abdominal cavity, and in their passage downward they had excited little or no inflammatory reaction, so that they escaped fixation and became aggregated together. This is in keeping with

Bardeleben's statement that foreign bodies of insignificant size, smooth surface, and but slightly irritating quality cause only an inflammation in their environs of so moderate a degree that they become encapsuled. (quoted by Salzer in "Clinical Lectures," New Sydenham Society's publication, 1894.)

Experiment VI. Nov. 18th, 1896.

A buck rabbit was anaesthetised, and the abdomen opened in the middle line at the junction of the middle and posterior thirds. Two hundred sterilised glass beads, varying slightly in size, and each weighing on an average 1 decigramme, together with four pieces of fine glass tubule measuring from half an inch to an inch and a quarter in length, were introduced into the peritoneal cavity and pushed in various directions with the finger. The wound was closed.

Jan. 16th, 1896. On palpation of the abdomen a hard irregular mass could be felt in its upper third, after killing the rabbit the abdominal cavity was opened up. Two clusters of beads were seen (containing respectively 13 and 11) adherent to the intestine - see Photo. No. 2. A mass of adhesions extended from the old incision to the intestines - this mass contained many beads. One bead was attached by a fine lymph pedicle to the bladder. The others were scattered singly and in twos and threes about the intestines, always adhering to them, and generally covered

by lymph. The peritoneum appeared quite normal elsewhere.

Photo. No. 3. represents the right, and No. 4. the left side of the mass of adhesions.

Only about a quarter of the beads introduced found their way to the lowest level.

Experiment VII. Jan. 20th, 1896.

A doe rabbit was anaesthetised. Thirty sterilised beads, 6 of which weighed 1 decigramme, were introduced through an incision in the middle third of the median line of the abdomen, and pushed in all directions, up towards the liver, down into the pelvis, and laterally.

March 4th, 1896. After being killed, the abdomen of the animal was opened. The large intestine was adherent to the scar of the old wound. Several beads were entangled in the adhesions. One inch to the right of this, 9 beads are arranged in more or less zigzag manner, (see Photo No. 5.), on the enormous caecum to which they are attached by lymph. Just below the site of the old wound one bead was adherent to the ventral parietal peritoneum, and 2 more $\frac{3}{4}$ inch posterior to this one. Opposite the latter two one bead had become fixed to the large intestine. One bead only lay amongst the small intestines, and it was adherent to them. Two were found lying free, though adherent to one another, between the small

intestine and the left dorsal parietal peritoneum, about one inch external to the left kidney. One was adherent to the ventral aspect of the great omentum as it joins the stomach: and one was attached to the pubic lamina of the right broad ligament. This was the only one in the pelvis.

In this experiment the majority of the beads found their way to the lowest level.

Experiment VIII. Jan. 31st, 1896.

A doe rabbit was anaesthetised and its abdomen opened in the median line in its middle third - Twenty sterilised No.5 shot were introduced and pushed about in various directions.

March 13th, 1896. On examination, the rabbit was found to have developed a ventral hernia which formed a projection the size of a tangerine orange. In this, two shots could be distinctly felt. The animal was killed, the sac opened, and found to consist of all the layers of the abdominal wall, except in the centre of the most dependant part, which appeared to consist of skin and peritoneum only. Three shots were found attached to the sac wall - (see Photo No. 6.). the neck of the sac easily admitted four fingers - the ventral abdominal wall was removed in one piece, and the remaining shot were found in four pediculated clusters. One, attached to the caecum by a pedicle 2 cm. long, consisted of one shot. The other three

were attached to the junction of small gut with mesentery. Two were composed each of two shots, and their 1 cm. long pedicles were adjacent at the point of attachment. The third cluster was composed of 7 shots, with a pedicle 2 cm. long, and 1 cm. broad at its attachment to mesentery. All the shots are surrounded by lymph which obscures their outline. The portions of intestine and mesentery to which the shots are attached lie close to the ventral wall.

Photo. No. ٢. shows the pediculated clusters of shots.

Experiment IX. Jan. 31st 1896.

A buck rabbit was anaesthetised and its abdomen opened just as in the previous experiment. Twenty No.5 shot which had had their surfaces roughened by subjecting them to a grinding movement between a file and a piece of hard wood, were introduced into, and pushed into various positions in the peritoneal cavity.

March 7th, 1896. No shot could be made out on abdominal palpation. After the death of the animal, the abdomen was opened and the caecum was found adherent to the scar of the old wound. On the surface of the caecum are :-

(a) 2 shots adherent to it, and to one another.

(b) 6 shots contained in the adhesion to the cicatrix of the old wound.

(c) 8 shots in an adhesion between caecum and large intestine.

((c) was distant 1¼ inches from (a) & (b)).

(d) 1 shot lying adherent to the mesentery at the point of union of caecum and small gut.

Two shots were adherent to a fold of the mesentery of the large intestine. None were free in the peritoneal cavity. There was no sign of peritonitis beyond the localised and limited production of lymph which bound the shots to the viscera.

Photo. No. 8. shows some of the shots in situ, as seen through a 3 inch incision in the abdominal wall.

In this experiment the shots have almost all gravitated to the lowest part of the abdomen. The size of the shot was small, but the weight was great in comparison with the size, so that their mere weight would exercise a mechanical pressure which would irritate the peritoneum on which they lay. One would have thought that the rough surfaces presented by the shots used in this experiment would certainly have increased the irritant effect. Yet it is curious that almost all these roughened shot should have found their way into the lowest part of the cavity and there become fixed, whilst in Experiment VIII the smooth shot lay in the most dependant part of the abdominal cavity, but were attached by pedicles to viscera at a higher

level. The weight in each case was the same, the positions in which the shot were placed were the same, yet in the case of the smooth-surfaced shot they were fixed at a higher level, and therefore presumably sooner than the roughened shot. I think this can only be explained by taking into account the personal equation as it were, of the animals. It cannot be expected that all peritonei will respond in the same manner to stimuli of equal intensity. This point is shown again in Experiments V and VII, in the former of which most of the beads had time to gravitate into, and collect together in the most dependant part of the abdominal cavity before enough lymph was secreted by the peritoneum to fix them. In Exp. VII most of the beads lay at a low level but they were scattered, having been fixed before they had time to collect together.

From these experiments the following conclusions may be drawn:-

1. Foreign solid bodies of appreciable size which lie free in the peritoneal acvity, tend, in obedience to the laws of gravity, to sink from higher levels to lower.

2. Such foreign bodies if detained or lying in, any particular locality for a certain time (unknown), become surrounded with lymph, and adhere firmly to the surface with which they are in contact.

3. There is no evidence that the diaphragm exerts any influence on bodies of appreciable size.

First, with regard to position, there is very little evidence of an experimental nature to be obtained. Professor C.S.Sherrington, of Liverpool, has kindly consented to allow me to make use of an observation made by him when he and Mr.C.A.Ballance were carrying out their investigations on the formation of scar tissue. (Journ.Physiol.Vol.X. p.569.) He informed me, orally, that in these investigations, "Ziegler's cells," (made by causing two cover-slips to adhere to an intervening tin-foil rim which was interrupted at one part) were slipped into the peritoneal cavity of the rabbit through a small incision in its ventral abdominal wall. At the autopsis the "Ziegler's cells" were generally found above the intestines, in contact with the mesentery, and therefore they had ascended from a lower to a higher level.

I was not able to obtain access to Müller's paper on free bodies in the peritoneal cavities of animals ("Ueber die freie Körper in der Banchhöhle bei Hansthieren", Zeitschrift d. R.R. d. Aertze Zu Wien, 1851. VII. p.428.) which is practically the only reference I obtained bearing on animals. Let me therefore direct attention to foreign bodies found free in the peritoneal cavity of man. Many cases of such bodies have been published, but in very few is their weight stated, or the position in which they

were found reported. Vercoutre, in his paper on the subject of intra-peritoneal foreign bodies, (A. Vercoutre,"Etude sur les corps libres intra-peritoneaux," Paris 1873.) states that they are usually found in the lowest parts of the abdominal cavity,but he founds his statement on an insufficient number of cases in which the position was noted at the time of discovery, and moreover, some of his cases are incorrectly quoted from English literature.

I have collected the following cases from different sources. In all of them the position of the free body was noted at the time of its discovery.

C A S E S :-

I. OGLE. (Trans. Path. Soc. Lond. Vol VI p.208) describes a foreign body which was found at the post-mortem examination, when during the displacement of the intestines, it was seen to fall down from between the diaphragm and the upper surface of the liver, in whose right lobe was a deep depression in which the foreign body had evidently lain.

The author considers that this body had been formed from some tissue between liver and diaphragm, and had remained in situ until displacement of the liver allowed it to escape.

II. SHAW. (Trans. Path. Soc. Lond. Vol VI p.204,) found a loose body in a hernial (inguinal) sac which extended into the scrotum. During effort this body had been suddenly forced, in front of intestine, down the inguinal canal into the sac of the already existing hernia, in which position it was felt before operation. The latter was undertaken as the foreign body could not be reduced, and its presence prevented the wearing of a truss. It was found to measure

1½ inches by 1¼ inches in size.

III. VAN DER BYL. (Trans. Path. Soc. Lond. Vol VI. p.211) removed a foreign body the size of a bean during the course of a post-mortem examination. It was found lying free "below the posterior thick border of the liver."

The report does nor state whether the patient had been ill for some time and confined to bed or not. Presuming that this were so, the position in which the foreign body was found would be one of the lowest parts of the abdominal cavity, and the influence of gravity would easily explain the position assumed.

IV. VAN DER BYL. (Trans. Path. Soc. Lond. Vol VIII. p.216) relates another case of a loose body found lying loose in the pelvic cavity of a woman.

V. JOHN REID. (Edin. Jour. Med. and Surg. 1836) found a foreign body in the peritoneal cavity, which Hughes Bennett. (Tr. Path. Soc. Lond. Vol VIII.p.212)

describes. It lay about the upper region of the pelvis in a dissecting-room subject, and was somewhat larger than a billiard ball.

VI. HARLEY. (Tr. Path. Soc. Lond. Vol XIV. p.158.) found a calculus lying between the bladder and the rectum. It was oval and flattened in shape and it measured $\frac{1}{3}$ inch in length, $\frac{1}{4}$ inch in breadth, and $\frac{1}{8}$ inch in thickness. It was formed mainly of carbonate of lime.

VII. MURCHISON. (Tr. Path. Soc. Lond. Vol XV. p.96.) found a loose body 6 lines in length, 4 lines in breadth, $3\frac{1}{2}$ lines in thickness, lying at the bottom of a hernial sac in the scrotum.

VIII. BROWN. (Tr. Path. Soc. Lond. Vol VIII. p.214) found a free foreign body in a dissecting-room subject at Guy's Hospital. It was the size and shape of a bean and lay on the left side of the body in contact with the small intestine.

IX. GREENHOW. (Tr. Path. Soc. Lond. Vol XXIII.p.241) found a foreign body of the shape and size of a hen's egg lying in a pouch formed by invagination of the cardiac end of the stomach. The patient - a woman - had died of bronchitis.

X. W. TURNER. (Edin. Med. Jour. 1861., p.698.) describes a free body found lying on the floor of the recto-vaginal pouch in a dissecting-room subject aged 79. In this case the left ovary had become detached with part of the left fallopian tube and had formed adhesions with the peritoneum covering the bodies of the last lumbar and first sacral vertebrae, and with the omentum above. The ovary was cystic and as large as a foetal head. Attached to the uterus by a thin broad pedicle was a calcified fibroid the size of a walnut.

XI. O. LECONTE. (Soc. de Biol. Nov.1853.) relates the case of a man in whose peritoneal cavity was found a free foreign body the size of a billiard ball. It lay in the centre of the floor of the recto-vesical pouch.

The patient lived at the "Invalides",Paris, and he died from heart disease at the age of 67: so that it may be presumed that he was ailing for some time previous to his death, and would occupy mainly a position in which the shoulders were raised. Thus the recto-vesical pouch would be the most dependant part of the peritoneal cavity, and into it would gravitate the loose body. With this case should be compared Van der Byl's first case related on page 19 of this paper.

XII. M.MICHEL. (Bull. Soc. Anat. April 1859.) describes a free foreign body, found in the peritoneal cavity of an individual who died of phthisis pulmona-lis at the age of 42. The free body was the size of a small nut and lay in the pelvic cavity. A similar body was attached by a long pedicle to the psoas muscle.

XIII. ROKITANSKY. (Allgem. Wiener. Medizin. Zeitung Nos. 2, 3, 4, January 1860) relates the case of a young woman aged 18, who died of a tubercular affection. In the recto-vaginal

pouch was found a free foreign body, about the size of a small nut. The left ovary, the outer part of the left fallopian tube, and the corresponding part of the left broad ligament were all wanting. Rokitansky believed that the free body was the altered left ovary.

XIV. BELL. (Lancet 1890 Vol II. p.562.) discovered during the post-mortem examination of a woman aged 50, who had died of pernicious anaemia, a loose body lying on the right side of Douglas' pouch, with its long axis across the pelvis. It weighed 295 grains and measured $1\frac{3}{4}$ inches in length, $1\frac{3}{8}$ inches in breadth, and $1\frac{7}{8}$ inches in thickness.

The right ovary was wanting, and Bell believes that it had become detached and formed the loose body found.

Briefly summarised, then, the positions assumed by these foreign bodies are :-

In the pelvic cavity Nos.IV,VI,X,XI,XII,XII,XIV.

In the upper region of the pelvis V.

In a scrotal hernial sac II, VII.

On the left side of the body, in contact with the small intestine } VIII

On the posterior abdominal wall _ III

Invaginating the cardiac end of the stomach _ IX

Between the diaphragm and the liver, lying in a depression on the upper surface of the liver. } I

Out of 14 cases, 9 had reached points below which they could descend no further, presuming them to have originated in situations on a higher level than those in which they were found. In one case(V) the body was found in the upper region of the pelvis. It may be supposed that these ten bodies had gravitated downwards in obedience to the law of gravity, the tenth one being caught as it were, in the process of descent. The same might be said of cases III and VIII; but it is impossible to say where these bodies had originated or how long they had been free. Relatively to the size of the peritoneal cavity, they were small - the size of beans - they were not calcified, and therefore were light, so that very little

support would suffice to maintain them in an elevated position; indeed one might almost look on them as being bandied about at the mercy of intestinal movements. However, even in the case of very light bodies which originate at a distance from the lowest levels, it is probable that they will ultimately arrive on those levels, as I can find no evidence in man of any free body having become adherent to any peritoneal surface at a high level.

Of the free bodies which were found at the bottom of scrotal hernial sacs,(Cases II and VII) No.II was forced suddenly down the inguinal canal into the sac by a sudden increase of intra-abdominal pressure, in front of intestine; whilst No VII can only be supposed to have passed in with the gut, or to have been pushed down before it, as it was of small size; or to have been formed in situ.

Either may have been descending at the time, or as No.VII was small, it may have been carried about the abdominal cavity by intestinal movements, and have slipped or been pushed by accident into the inguinal canal and then have gravitated, or have been

urged by peristalsis of the gut, to the bottom of the sac.

The remaining two cases, I and IX, require no consideration, as they were practically sealed up in small cavities, near which they had probably been formed, as was considered to be the case in I.

The sites in which the free bodies were formed originally may exercise an influence on the positions assumed when free. Bodies formed and liberated at a low level are more likely than not, to come to lie permanently at a low level. With the question of site of formation associates itself the question of mode of formation. On this not very material point, I merely quote the conclusions arrived at by Vercoutre :-

(VERCOUTRE - LOC. CIT.)

Free intra-peritoneal bodies may be formed :-

(1) By the deposition on different nuclei of successive layers of coagulable material derived from the peritoneum.

(2) By the liberation of pediculated tumours,

such as, lipomata or appendices epiploicae, fibromata, (fibroids of the uterus especially), cysts, &c.

(3) By the detachment of normal permanent organs, such as ovaries.

(4) By the escape of ova into the abdominal cavity.

Of these modes of formation, the detachment of appendices epiploicae accounts for many free bodies The detachment of ovaries is rare - Rokitansky reported 7 cases (Allgam Wiener. Medizin. Zeitung. Nos. 2, 3, 4, January 1860.) Turner one case (Edin. Med. Jour. 1861. p.698.) Bell one case (Lancet 1890 Vol II. p.562.) Knowsley Thornton reported (Birt. Med. Jour. 1882, Vol II.) a case where a dermoid cyst of the ovary became freed.

Vercoutre's fourth method of formation has never been verified in the human female; and the cases recorded as having occurred in birds rest on no trustworthy evidence. Rayer. (Soc. de Biol, 1863.) reported such a case. Müller of Vienna, (Ann. de med.

veter. Bruxelles, mai.1853.) mentions others.

Modern views regard the detachment of small tumours such as lipomata, uterine fibroids and the appendices epiploicae of the large intestine as the commonest sources of free intra-peritoneal bodies in the human subject.

I consider that I am justified in asserting that clinical & post-mortem evidence supports the conclusion arrived at experimentally, that foreign bodies of appreciable size, lying free in the peritoneal cavity, tend to obey the laws of gravity, and therefore to pass from higher to lower levels.

I pass now to the second conclusion arrived at experimentally, viz. the process of encapsulation and anchoring of free solid foreign bodies which goes on in the peritoneal cavity.

Stern introduced vaseline, mutton-fat, paraffin, olive oil and collodium in different experiments into the peritoneal cavity. He found that they were never encapsuled, but rather prevented the formation of adhesions. (H.Stern. "Ueber pseudo-"membranose" Verwachsungen bei intra-peritonealen Wunden."

Beiträge zur klinische Chirurgie, IV. 3 Heft.)

Von Dembowski placed quantities of iodoform, blood coagula, and irritating antiseptic fluids (Solutions of carbolic acid and corrosive sublimate) in the peritoneal cavities of animals, and found that adhesions were not produced. Turpentine and oil of marjoram gave the same result. On the other hand, he found that ligatures, pieces of dead tissue and eschars did produce adhesions, as also did celloidin, though the adhesions in this case disappeared after a time. Catgut ligatures and pieces of ligatured tissue were as a rule encapsuled after ten days. Eschars gave rise to adhesions with intestines, omentum or abdominal wall, but not with the liver. The adhesions which had soldered the eschars to the abdominal walls persisted several months after the carbonised particles had been absorbed; whereas in the case of celloidin only the thickened serous membrane remained covered with connective tissue-like layers. Iodoform gauze appeared to cause considerable irritation, for, two weeks after its introduction it was found to be encapsuled by the greatly thickened

omentum and parietal peritoneum. (Th. von Dembowski. "Ueber die Ursachen der peritoneale adhäsionen nach chirurgische Eingriffen." Langenbeck's Archiv:XXXVII).

Rosenberger introduced pieces of tissue, sometimes fresh, sometimes dead, into the abdominal cavity. He found that dead tissue is enclosed, in from three to four days, by a capsule from which cells migrate into the foreign tissue. He frequently found giant cells between the dead tissue and its capsule, and he, following Langhanns, supposed that they acted as absorptive agents. Fresh tissues, he found, became loosely connected with the abdominal organs and continued to live. He makes the remark however, "sometimes a purulent dissolving process takes place in the centre." (A.Rosenberger, "Ueber Einheilen unter antiseptischen Cantelen &c." Langenbeck's Archiv: XXV.)

Héricourt and Richet introduced pieces of the fresh spleen of dogs into the peritoneal cavities of rabbits, taking antiseptic precautions. The animals were killed at periods varying from one to four

and a half months later. In all cases where suppuration had not occurred, the peritoneum appeared normal and no trace of the spleen could be found.
(J.Héricourt et Ch. Richet. "De l'introduction de la rate de chien dans le peritoine des lapins." Archiv: de Physiol. Vol IV. 1892. p.597.) This is, I may remark, a result directly opposed to Rosenberger's experiences.

Hallwachs imbedded a sponge for eight months in the abdominal cavity. He found at the end of that period that the sponge had become surrounded by a capsule composed of an inner vascular connective tissue layer, resembling granulation tissue; and outside this was a firm yellowish-white fibrous layer. Some particles of the sponge were entirely surrounded by, and interwoven with, vascular granulation tissue.
(H.Hallwachs. "Ueber Einheilung von organischem Materiale unter antiseptischen Cantelen."Langenbeck's Archiv: XXIV.)

Tillmanns implanted pieces of liver, kidney, &c. which had been hardened in alcohol, in the abdomi-

nal cavity of animals, in order to study the process of cicatrisation. He found that these foreign bodies became encapsuled, and their interstices filled up with colourless blood cells, and finally vascular connective tissue finally formed within them.
(Tillmanns. Virchow's Archiv: Vol LXXVIII.)

Tillmanns was one of the supporters of the Cohnheim - Ziegler doctrine that migrated white-blood-corpuscles are the primary source of cicatricial tissue. This theory has been supported by, among others, Seuftleben (Virchow's Archiv: LXXII), B. Haidenhain ("Ueber d. Verfettung fremden Körper in d. Banchhöhle," 1872.) Schede (Archiv: für klinische Chirurgie., XV), and Bizzozero (Annali universi di Medicina., 1868. It has been controverted by many writers, among others, by Hamilton, (Edin. Med. Jour. 1881;) Pick, (Zeitschrift f. Heilkunde, Bd.VI. 1886); Henking and Thoma, (Virchow's Archiv: CIX); and recently by C.S.Sherrington and C.A.Ballance who repeated Ziegler's experiments with cover-glass cells. (Journ. Physiol. Vol X. 1889. p.550.) The latter two observers found in the serous moisture of the

abdominal cavity of the rabbit and guinea-pig and in the tissue plasma, two kinds of cells :- (1) cells indistinguishable from the leucocytes of the blood, (2) larger cells termed plasma-cells, which are the daughter cells of the tissue corpuscles. Foreign bodies are first surrounded by leucocytes, and their substance - if of organic nature - invaded by them. Later occurs the attack of plasma-cells which invade along the paths made and traversed previously by the leucocytes. Indeed the function of the leucocytes seems to be to break up the foreign body by passing into it in all directions, preparing roads for the plasma-cells, and exposing a large surface for them to act upon. Doubtless, the leucocytes also serve as food for the plasma-cells.

With regard to the plasma-cells, the authors remark, "We found them traceable up from forms of an "amoeboid kind, different in many ways from the amoe- "boid cell-forms of blood & lymph, through individual "types of almost endless diversity of figure with the "utmost variety of combination and interdependence, "onward finally to the fixed corpuscle of fusiform or "of stellate shape imbedded in fibrillated material."

Giants cells round foreign bodies were first observed by Haidenhain, ("Ueber die Verfettung fremden Körper in der Banchhohle." Breslan 1872.) Marchand who found them around healed-in silk fibres or particles of sponge, believed they were formed from one fixed tissue. ("Ueber die Bildungsweise von Riesenzellen um Fremdkörper und den Einfluss des Jodoform hierauf." Virchow's Archiv: XCIII.) Ziegler, (Lehrbuch der Pathologische Anatomie); Tillmanns, (loc.cit;) and Cohnhein ("Vorlesungen"); maintained that they originated from white blood corpuscles. Arnold believed they were the products of degeneration, (Arnold. "Anatomische Beiträge zur Lehre von den Schusswunden." Heidelberg. 1873.)

Weiss believed that giant cells originated from the confluence of several smaller cells, and that they were always doomed to fatty metamorphosis, and were never converted into connective tissue (Weiss. "Ueber die Bildung und Bedentung von Riesenzellen und ueber epithelähuliche Zellen, welche um Fremd Körper in organisums sich bilden." Virchow's Archiv: LXVIII.)

Sherrington and Ballance (loc.Cit.)

corroborate Weiss' statement that giant cells originate from the confluence of several smaller cells, that is to say, the plasma-cells. They also record that a giant cell may be formed by nuclear multiplication in a single cell which itself did not separate up into daughter cells. Further, they state " by the " union of cell with cell, by means of long pseudo "modium-like processes, it was sometimes found that " a whole field under the lens was occupied by the " net like ramifications of one huge multinucleated " cell - better described perhaps as an unbroken " sheet of anastomosing cells."

"On the position of the giant cells depends " partially the arrangement of fibrillated tissue " which is ultimately produced. The run of bundles " of fibrillae is often from and between giant cells" The plasma-cells become arranged in lines, assume a fusiform shape and a fibrillated intercellular cement substance is formed between them. Once thus imbedded, all active processes do not cease in the cells - "encapsulation does not arrest absorption " (Sherrington and Ballance, loc. cit.). Foreign bodies,

however slightly penetrable, are subjected to a process of breaking-up removal - even silver cannot resist, though gold and platinum appear to hold an impregnable position.

Thus then, it is seen that the process of fixation of free intra-peritoneal bodies by plastic exudation, is but a step in the mechanism by which Nature effects their removal. The more penetrable they are, the sooner do they disappear; the more resistent, the longer is the time required to bring about absorption. Even then, the foreign body has at any rate, become anchored, and cannot wander about, possibly irritating or injuring the delicate serous covering of the viscera amongst which it lies. Rokitansky remarked (loc. cit) of free intra-peritoneal bodies that there were three episodes in their "life-history"; they hung suspended by their pedicles in the peritoneal cavity, then they fell free into it, and lastly they became fixed by adhesions. He might have added a fourth stage, disintegration and disappearance, since free intra-peritoneal bodies in the

human subject are formed of dead tissue, which affords a rich field for the activities of leucocytes and plasma-cells.

I have already referred to W.Hunter's investigations on the fate of blood extravasated into the peritoneal cavity of the rabbit. He found on examining the animals shortly after injection, that fluid blood was most abundant between the under surface of the diaphragm and the upper surface of the liver. (W.Hunter. loc. cit.) He also reports two cases of experiments on rabbits where death occurred from peritonitis within periods of 24 to 36 hours after injection. The inflammatory process was observed to be most intense on the under surface of the diaphragm and the upper surface of the liver, both of which " were covered with a thickish layer of lymph and "nodules of lymph and leucocytes. It seemed as if " the septic poison introduced had acted most viru- " lently at the seat of its absorption." Hunter quotes also a case of a similar kind which occurred in the human subject, where death occurred after removal of a fallopian tube. The pelvic organs were

much involved in the inflammatory process, and the peritoneum covering the small intestines was injected. A small quantity of pus was found about the hilus of the liver, and the upper surface of the latter, and the under surface of the diaphragm were covered with an almost continuous layer of fibrinous lymph.

Hunter considers that these facts prove that diaphragmatic movements promote the absorption of even the smallest quantity of fluid however distant.

Part of fluid lying free in the peritoneal cavity and in contact with the intestines,would be spread in a thin layer over the visceral and part of the parietal peritoneum simply by the peristaltic movements of the gut; for by these movements, successive areas of visceral peritoneum would come into contact with the fluid and would pass away with moistened surfaces. In the case of a fluid containing small particles, many of the latter would be carried off on the moistened surfaces. This method of diffusion however, does not explain the presence of fluid between the upper surface of the liver and the under surface of the diaphragm.

Starling and Tubby, (Jour. Physiol. Vol 16.

1894. p.140.) have demonstrated by experiment that fluids containing colouring matters in solution when placed in serous cavities are absorbed directly and rapidly by the blood vessels, this absorption being accompanied by an interchange between the fluid in the cavities and the blood in the vessels. Hunter also remarked that the quantity of fluid in the peritoneal cavity after extravasation of blood, was increased by exudation.

Klein (E. Klein & E. Noble Smith, "Atlas of Histology," 1880, p.174) regards the diaphragm with its lymphatics as acting like a pump with two cylinders. A description of the arrangement of the lymphatics is necessary in order to comprehend this. Klein describes the arrangement of the lymphatics of the central tendon of the diaphragm in rodents. Their arrangement in the muscular portion is similar to that in the central tendon, according to Bizzozero and Salvioli (Arch. p. le sci. med. 1876 & 1877.) whilst Rajewsky has demonstrated that the arrangement of the lymphatics of the human central tendon is the same as in rodents. I cannot do better than quote

Klein's description of the central tendon of the diaphragm of rodents :-

" The matrix of this is a double layer of " tendon bundles; one layer, nearest to the peritoneum "is composed of bundles more or less radiating from " the centre towards the periphery, while the other, "nearest to the pleura, contains more or less circular " bundles, crossing the former under a right angle. " Between groups of these bundles are lymphatic chan- " nels (Ludwig and Schweigger-Seidel); they are lym- " phatic capillaries, the wall of which is a single " layer of endothelial plates with sinuous outlines: " they are the straight lymphatic capillaries (Klein). " Those of them that belong to the radiating layer of " tendon bundles possess naturally a radiating direc- " tion, and represent the superficial, while those of "the circular layer are arranged circularly, crossing " the former under a right angle and represent the " deep straight lymph-capillaries. But the vessels " of both layers form an intercommunicating and there- " fore single system, being connected with each other " by small openings, chiefly at the point of crossing.

"This matrix of tendon bundles is covered
" on the pleural surface with a delicate but dense
" connective-tissue membrane, the pleura, which on its
"free surface is covered with a layer of ordinary flat-
" tened endothelial plates. There is always a more
" or less continuous subendothelial membrana propria,
" a single layer of flattened cell. These are either
" unbranched, and touch each other in straight lines
" like an endothelium, or they are branched and form a
" network. The peritoneal surface of the tendon
" bundles is also covered with a delicate connective-
" tissue membrane, the peritoneum; but this membrane
" is complete only where it stretches over the tendon
" bundles themselves, while that portion of it that
" covers the radiating or superficial straight lymph-
" capillaries is a fenestrated membrane (Ludwig and
" Schweigger-Seidel), viz. a plexus of anastomosing
" trabeculae with smaller or larger oval or spherical
" meshes. The endothelium covering this fenestrated
" part, that is above the straight lymph-channels, is
" composed of small or less germinating endothelial
"cells, while that above the tendon bundles consists of
" the ordinary large endothelial plates, as mentioned
"

" Between the pleural serosa and the circu-
" lar layer of tendon bundles lies a dense plexus of
" lymphatic vessels with valves, their wall is a
" single layer of elongated endothelial cells (see
" fig. XII. Plate VI.). In connection with this
" plexus, which represents the 'plexus of pleural
" lymphatics of the central tendon,' are (a) cappil-
" laries that have their roots in the lymph-canalicu-
" lar system of the pleural serosa itself, and (b) the
" circular or deep straight lymphatics, which, as we
" mentioned above, form, with the radiating or super-
" ficial straight lymphatics, an intercommunicating
" system.

The plexus of pleural lymphatics is arranged
" as an anterior and posterior system (Klein); the
" former is symmetrically distributed over the two
" anterior quadrants, and the same is the case with the
" latter, viz. one for each of the two posterior
" quadrants. The pleural lymphatics of both sides
" of the anterior system, as well as those of both of
" the posterior system, communicate with each other
" by intermediary branches.

" The efferent trunks of the anterior
" system run near the margin of the central tendon
"towards the xyphoid cartilage, where the branches of
" the two sides anastomose withnone another and, free-
" ly intercommunicating, ascend on the posterior sur-
" face of the sternum towards the jugular incision of
" the manubrium sterni, and finally enter a lymphatic
"gland, one for each side. The efferent trunks of
" the posterior system are fewer and larger, and
" finally collect into one or two short large vessels
" for each side, which freely empty themselves into
" the thoracic duct.

The superficial or radiating straight lym-
" phatic capillaries are in open communication with
" the peritoneal cavity through stomata (Oedmanson,
" v. Recklinghausen); the meshes of the fenestrated
" portion (Ludwig and Schweigger-Seidel) of the peri-
" toneum mentioned above as bridging over those capil-
" laries, and in man the holes of the subendothelial
" limiting membrane (Bizzozero and Salvioli), together
" with discontinuities in the endothelium of the sur-
" face and of the straight lymphatic capillaries,

" contribute to form those stomata. I have shown
" that the endothelial cells surrounding or rather
" lining them (stomata vera) are germinating cells.

The deep or circular straight lymphatic
" capillaries, which, as has been mentioned above
" are in open communication with the superficial or
"radiating ones, empty themselves into the pleural
" lymphatics (Ludwig and Schweigger-Seidel), both the
" anterior and posterior system, so that they are able
to discharge their contents in two directions at the
" same time (Klein), viz. towards the lymphatics con-
" stituting the anterior as well as towards those
" constituting the posterior system.

The current passing through the lymphatics
" of the diaphragm is then: from the free peritoneal
surface of the diaphragm, that is the peritoneal cavity
" through the stomata vera into the superficial or
" radiating straight lymphatic capillaries, hence into
" the deep or circular straight ones: hence the current
" may pass in two directions viz. (a) into the plexus
of lymphatic vessels forming the anterior system, and
" (b) into that of the posterior system; through the

" efferent trunks of the former the current passes a
" long and circuitous way (along the sternum) into a
" lymphatic gland, whereas through the efferent trunks
" of the latter it reaches in a short and unimpeded
"manner directly the thoracic duct. Hence the pleural
" lymphatics of the posterior system are easier filled
" and easier emptied than those of the anterior system
"(Ludwig and Schweigger-Seidel, Klein).

The respiratory action of the diaphragm is
" the principal moving cause of the circulation in the
" lymphatics of the latter (Ludwig and Schweigger-
" Seidel) thus: during inspiration the straight lym-
" phatics (both the superficial and deep ones) become
" distended owing to the descent of the central tendon
" and consequently the greater separation of its
" bundles from one another, while at the same time
" the pleural lymphatics become compressed; in this
distended state of the superficial straight lymphatic
" capillaries the above stomata necessarily are wide
open, and there exists therefore a tendency on the
" part of the straight lymphatic capillaries to absorb
" plasma cells, or other formed matter that happens to

" be present on the peritoneal surface of the diaphragm
" But at the same time, owing to the compression of
" the pleural lymphatics, these will discharge their
" contents into the efferent trunks. During expira-
" tion the straight lymphatics become compressed owing
" to the tendon bundles becoming again closer, the
"pleural lymphatics being at the same time distended
" for during the ascent of the central tendon the
" area of its pleural surface becomes enlarged.
" Hence the effect of the movement of the diaphragm
"on its lymphatics in inspiration is the reverse from
" that in expiration, since during the latter the
"straight lymphatic capillaries become compressed and
"therefore discharge their contents; these are readily
"reveived by the pleural lymphatics, distended during
" this period.

The direct absorption of formed matter, milk
" blood, &c.,placed on the peritoneal surface of the
"central tendon of rabbit by the lymphatics of this
" organ has been first shown by v.Recklinghausen, and
" Rajewski proved the same also for the human diaphragm
" Ludwig and Schweigger-Seidel then proved this to be
" dependent chiefly on the respiratory movements;
"Klein demonstrated the lymphatics in their different
"relations to one another by injecting Berlin blue into

"the peritoneal cavity of the living rabbit and examin-
"ing the diaphragm after several hours.

Fluids then, can be absorbed from the peritoneal cavity either directly by the blood-vessels or may be "pumped" into the lymphatic system by the diaphragm through the agency of respiratory movements; though absolute proof of this agency is still required for cases where the fluid is situated at a distance from the diaphragm.

Free fluid in the peritoneal cavity has been supposed to gravitate into its most dependant part. This statement may be found in most text-books on Medicine and Gynaecology, and it is supported by the clinical evidence afforded by cases ascites and pelvic haematocele where the blood is not encysted - (e.g. Pozzi, "Traité de Gynécologie" 2nd Ed. p.842.) P.Delbet, ("Recherches expérimentales sur le lavage du péritoine" Paris, 1889.) in the course of some experiments on the human cadaver, allowed water to flow into the abdominal cavity down a tube passed into it through a small opening in the anterior wall. He then applied pressure to the abdominal walls, and found that even after the application of considerable force, a variable quantity of fluid remained in the abdomen - some in the pelvic cavity, some in the iliac fossae, and even more in the lumbar fossae. When the subject was placed in the sitting posture some of the liquid in the Lumbar fossae flowed down into the iliac fossae and thence to the pelvis, though the quantity in the

iliac fossae did not tend to diminish. This result obtained from the cadaver can scarcely be applied to fluid in the peritoneal cavity during life, when the conditions are quite different, but it suggested to me an experiment which I carried out on the rabbit in order to ascertain the behaviour of free fluid lying at a high level in the peritoneal cavity.

I have described the operative technique fully further on.

Experiments: S E R I E S B.

Experiment I. A rabbit was etherised and tied to the frame which was then placed obliquely so that the pedal extremity met the table at an angle of 45 degrees. 36 cc. of sterilised gelatine stained with methylene blue, and having a specific gravity of 1020 and a temperature of 30° c.,were ejected into the peritoneal cavity through a small incision made just below the xiphoid cartilage. The incision was sutured, and the animal still tied to the frame, placed in the vertical position, and allowed to live for half an hour under anaesthesia. It was then killed with chloroform, and placed without alteration in position in a freezing mixture of powdered ice and salt.Several hours afterwards a sagittal mesial section was made of the animal and the two halves examined. The gelatine

had lost most of its blue colour, and had acquired a yellowish green tint. Wherever it had come into contact with peritoneum the latter was stained with blue.

Right half: Neither gelatine nor blue staining found above point of injection - a broad blue band of staining was found running down the posterior parietal peritoneum diminishing in width as it passed downward. There was no trace of the gelatine on this. The main mass of gelatine had run irregularly between the coils of intestine, blue staining only being found in some parts, in others a small thin layer of decolourised gelatine, whilst here and there, the latter had collected into small pea-sized masses, irregularly facetted by the intestinal coils which they had displaced. The abdominal cavity of a distance of one inch above the pelvic brim, was clear of any trace of gelatine or staining.

Left half: Here also was a blue track coursing down the posterior abdominal wall with occasional small accumulations of more or less discoloured gelatine. Another blue track marked the front of the mesentery, and had also small masses of gelatine lying in relation to it. There was neither gelatine nor staining above the size of injection, nor below a point about one inch above the pelvic brim.

This is an experiment which I have not yet been able to repeat, and in view of the results I obtained in Series C. of my investigations, I do not feel justified in drawing any conclusion from it. It is however interesting to note the considerable period of time required for the gelatine to descend as far as it did. Two questions are suggested at once, was absorption of the gelatine proceeding at so rapid a rate that it disappeared too quickly to have any chance of descending far? or did diaphragmatic action retard descent?

Another experiment was carried out with cacao-butter, which possesses the advantages of melting at a low temperature, about 35° C. though it solidifies at about 25° C. , and forms a fairly solid mass when cold.

Experiment II.

Under the same conditions as in the previous experiment, 36 cc. of melted cacao-butter at a temperature of 25° C. and a specific gravity of about ·9, were injected just below the xiphoid cartilage of a buck rabbit into its peritoneal cavity. The animal was kept in the vertical position for a quarter of an

hour, anaesthesia being maintained with ether. At the end of that time death was brought about with chloroform. The rabbit was then frozen in a mixture of salt and powdered ice. Long crucial incisions exposed the contents of the abdomen to view. A large mass of cacao-butter was found lying below the ventral abdominal wall at the site of injection: it extended up between the diaphragm and the upper surface of the liver, thinning very rapidly so that only the faintest trace of butter was found at the highest point of the superior surface of that organ. From the mass irregular "streams" of cacao-butter had wandered downwards with diminishing volume between the coils of intestines. There was a small collection of cacao-butter in each flank, but none in the pelvis.

The presence of cacao-butter between liver and diaphragm, the persistence of a considerable quantity of butter at a high level and its entire absence from the pelvis are all points of interest. They seem to indicate the existence of some intra-peritoneal pressure dependant it may be on the muscular walls of the cavity or on some intra-visceral tension of its contained hollow viscera:and it is probable that conditions of the

circulation in the abdominal cavity exercise more or less influence. The question of intra-peritoneal pressure is an obscure one. That such a pressure exists I maintain from the two experiments I have related; what other explanation can be given from the failure of the fluids to follow the law of gravity? Intra-peritoneal pressure will probably explain the situation of the free foreign bodies found in cases III and VIII, and that of the great majority of the beads in experiment VI, Series A. In many cases of spontaneous perforation or of incised wounds of the intestines their contents fail to escape. As long ago as 1812, Travers ("An inquiry into the repairing of injuries of the intestines," London,1812.)noticed this and attributed it to the existence of pressure within the abdomen. Ziegler ("Ueber die intestinale Form der Peritonitis," Munich, 1893) relates 15 cases of wound of the intestine : faecal extravasation occurred in six only. Treves (Lettsomian Lectures on Peritonitis," Brit. Med. Jour. Vol.I. 1894), points out that many cases of abdominal disease, such as tubercular disease of the peritoneum, have been cured by simple laparotomy and the evacuation of fluid. He can only explain this by supposing that changes in the intra-peritoneal physical conditions must have

followed the opening of the abdominal cavity.

A case which occurred under my own care if further illustrative of this point. An unmarried woman aged 44 suffered from a papillomatous cyst of the ovary of a malignant character. It was found impossible to remove the disease, as the whole of the pelvic peritoneum was covered with papillomatous growths. The patient recovered from the operation and three weeks later began to suffer from ascites which rapidly caused great distension of the abdomen, so the latter was opened again and after the fluid had been evacuated, a glass drainage-tube was inserted. This was forced out in a week, and for the following seven weeks no sign of fluid could be detected, the patient's general condition remaining practically the same.

It is necessary to bear in mind that a peritoneal cavity does not exist. There is no free space between the viscera of the abdominal cavity: an exceedingly thin layer of serous moisture is all that separates their peritoneal coverings. There is merely, as it were, a potential cavity In the proformance of a laparotomy, when all the coats of the abdominal wall have been divided except the peritoneum, that membrane can be seen to bulge slightly. If it be pinched up with a pair of forceps and pulled gently towards the operator it is seen that either the intestines

follow in close apposition or the component halves of the fold collapse and come into contact. If a minute opening be made in the fold the intestines sink down, or the fold fills out, as air rushes in. In short the potential peritoneal cavity behaves like a vacuum. Enclosing it are walls of fibrous tissue (aponeuroses), and muscular tissue more or less continuously in a state of action. Lying within it are more or less hollow structures - liver, spleen, stomach and intestines and blood vessels separated from one another by an exceeding thin - almost inappreciable - layer of serous moisture, and containing gases and fluids in varying states of tension. One of the fibres - muscular walls - the diaphragm - has been proved to act as a pump in the case of fluids, and it has been shown that fluid can be absorbed directly by the blood vessels of serous cavities. I have demonstrated the obedience of large solid bodies to the law of gravity, and I purpose now to consider the behaviour of small particles.

Wegner ("Chirurgische Bemerkungen über die Peritonealhöhle, mit besonderer Berücksichtigung der Ovariotomie," Langenbeck's Archiv: XX.) injected granules of Indian ink into the peritoneal cavity. He found that parts only were absorbed. The granules

were found enclosed partly in the endothelial cells of the serous membrane, partly in delicate connective tissue.

I employed finely divided carbo animalis in my first experiment. It was mixed with water and the mixture was then boiled for 15 or 20 minutes. The open top of the vessel was plugged with singed cotton wool, and the mixture cooled. When the temperature was sufficiently reduced, the vessel was violently shaken and set down for half a minute until the heavier particles had subsided. The sterilised syringe was then slipped into the vessel between its side and the cotton wool and filled with the "charcoal-water" which was immediately injected into the animal's abdominal cavity.

It occurred to me however, that a more finely divided form of amorphous carbon than powdered carbo animalis was lampblack. It is not an absolutely pure form of carbon, as it contains appreciable quantities of hydrocarbons. It did not seem likely that these would interfere with the purpose for which I required it: therefore I tried it, and with satisfactory results. It was treated in a similar way to that described above for charcoal, and I shall speak therefore of "lampblack-water". Water was employed to prevent the dry powder clogging in masses when intro-

duced into the peritoneal cavity. The water was very rapidly absorbed. In the case of a cat which had had its spinal cord divided and the day after died half an hour after injection of "lampblack-water", no trace of water was to be found, merely moist lampblack.

Operative Technique:-

Anaesthetics: ether was invariably employed for rabbits and generally for cats. In the case of the latter it was sometimes found necessary to employ chloroform, either mixed with ether in equal parts, or by itself. Well-grown savage cats could not be properly controlled with ether alone, and they took chloroform well.

Instruments: All operations were conducted on strictly antiseptic principles.

(a) Glass syringes were sterilised in hot air ovens at a temperature of 130° c. The syringes employed had capacities of 15 cc. each.

(b) Knives, Forceps, Needles &c. were well washed in carcolic lotion (1 in 20) before use.

(c) Sutures and Ligatures: chromicised catgut of different sizes was employed, as it gave better results than silk, causing less irritation from cutting

through the skin, and not requiring to be removed afterwards. The catgut was soaked in warm carbolic lotion (1 in 20) for half an hour before use.

Substances introduced into the peritoneal cavity were sterilised previously by boiling for at least a quarter of an hour.

Animals: were placed in the dorsal position the hair removed freely and widely from the area to be operated upon. The exposed skin was then washed with a hot 1 in 4000 solution of perchloride of mercury.

Operation: in the earlier experiments I made a small incision about ¾ inch long, through the abdominal wall, taking care to go through the muscular layer exactly in the median line, which is visible as a white fascial line both in rabbits and cats. By this means there was practically no bleeding. Beginning below on the left side, I passed a needle threaded with chromicised catgut backwards and forwards through the left edge of the wound, including both muscle and peritoneum, doubled it back down the right edge and brought it out close to the point of entry on the left side. This gave a loop which was tightened on the nozzle of a glass syringe introduced into the peritoneal cavity. As the syringe was slowly withdrawn

the loop was tightened up and tied after removal of the syringe. The same syringe was used throughout - it held 15 c.c. of water. By tilting up the head end of the frame to which the animal was tied, the fluid was prevented from running diffusely over the peritoneum.

The skin in all cases was sutured separately with interrupted sutures. The wounds were healed in a week as a rule

Only in two cases did the "lampblack-water" have any fatal effect - the first, a rabbit died promptly on injection, respiratory and cardiac action both ceasing: the second, the case of the cat already mentioned, died half an hour after injection, without having ever recovered properly from the anaesthetic.

Cinnabar caused two deaths immediately on its injection. By washing it well previous to use, any soluble sulphate present was removed, and there was no further trouble.

Photography.

The Camera was a half-plate one, but generally only quarter plate photographs were taken. The Ilford medium isochromatic plates gave the best results, though the ordinary Cadett plates produced good pictures in some cases. The arc electric light was

employed - at first naked, with an aperture of F.16 and exposures varying from one to five seconds - However, I soon found that if the light were shaded with a piece of ordinary ground glass, and the aperture reduced to F.32, with an exposure of five or six minutes, or ten to fifteen minutes with F.64, that much more detailed pictures could be obtained. The majority of the photographs were taken in this way.

The Ilford white P.O.P. (gelatine chloride) paper was employed for the prints.

Experiments: S E R I E S C.

Experiment I. Doe rabbit.

December 2nd, 1895 Etherised 15 cc. "Charcoal-water" syringed into the peritoneal cavity just above the pubes.

Jan. 2nd, 1896. The animal was killed. The charcoal was found in the form of isolated sharply defined black patches adherent to the ventral abdominal wall, and the intestines, chiefly towards the pelvic extremity of the abdominal cavity. The omentum was blackened: there was no marking on the hepatic peritoneum but the diaphragm was much mottled, especially on the left side, as is indicated in Photo No. 10.

Experiment II. Doe rabbit.

December 10th 1895. Etherised; 15 cc. of lamp-black water was syringed into the abdominal cavity a little distance above the pubes.

January 3rd, 1896. The animal was killed. The intestines were adherent to the cicatrix left by the heating of the wound through which the syringe had been introduced. The lampblack was found in the form of isolated black patches which occurred diffusely over the ventral abdominal wall and intestines. On the ordsal abdominal wall between the lower extremities of the kidneys and the pelvic brim were sharply defined, irregularly shaped areas of fine grey mottling, shown in Photo No. 12. The diaphragm was less mottled than in the previous experiment; but lines radiating outward from centre to periphery of the diaphragm were much more clearly visible. These lines were broken, and seldom ran on directly for more than half an inch. Sometimes several occurred together running parallel. They were present both in the tendinous and in the muscular portions.

The appearance of the diaphragm is not well shown in Photo No. 11. , which was one of the first photographs taken and is not a good one.

It is noteworthy that experiment II is the only one in which I detected the fine grey mottling on the dorsal of abdominal wall.

A distinction requires to be drawn between "mottling" and "streaking", "mottling" may be fine, where the individual dark points are scarcely distinguishable as in experiment II, or coarse, as in the case of the black patches and streaks found scattered over the viscera. These patches are always adherent to the peritoneum. The "streaks" on the other hand occur only on the diaphragm, not on its surface, but sunk below it, and running between and parallel with the radial fibres of tendinous and muscular portions - though in a few instances they pursue an undulating semi-circular course at right angles to them.

Experiment No.III. Doe rabbit.

January 8th, 1896. Etherised. 15 cc. of a mixture of lampblack and a solution of gum arabic, of the consistence of thin syrup, introduced by means of a syringe into the peritoneal cavity about two inches above the pubes.

February 3rd, 1896. The animal was killed. The lampblack was found almost universally distributed

and in a finer state of division than in experiments where water alone was employed with lampblack. The patches were smaller and fewer (vide photo No.13) The diaphragm showed well-marked lines of injection running parallel to the course of the muscular fibres on both sides. The upper surface of the liver showed several marks, angular in shape and small (vide Photo No. 14).

The solution of gum appeared, as would have been expected, to hold the lampblack in suspension longer than pure water, and so allow of its greater diffusion.

Experiment IV. Buck-rabbit.

January 8th, 1896. Etherised. 15 cc. lampblack water were introduced by means of a syringe into the peritoneal cavity, about two inches above the pubes.

February 20th, 1896. The animal was killed. The lampblack was found scattered all over the peritoneum chiefly on that covering the caecum and large gut. There were patches on the bladder, but very few on the mesentery of the small intestine. The large omentum was deeply injected, and there were

several large patches on the ventral abdominal wall. The liver was free, but the diaphragm was markedly injected - lines, streaks and patches being present on both halves - (Vide photo No. 16. - though they do not show as well on the photograph as on the original peretoneum).

Experiment V. Doe-rabbit.

March 8th. Etherised. 15 cc. lampblack-water syringed into the lower third of the abdominal cavity.

March 27th. Killed. The lampblack was found diffused over the almost whole of the peritoneal surface in the form of small, pin-head-sized bodies which were present on all the abdominal viscera, particularly on the large and small intestines, mesentery, stomach, omenta and on the ventral abdominal wall. The diaphragm was markedly mottled and injected - the striae being brilliantly marked.

Photo No. 17. shows the appearance presented by the diaphragm.

Thus far the experiments tended to show that the lampblack could be diffused more or less over the whole abdominal cavity; in every experiment finding its way from the pelvic end of the cavity towards the diaphragmatic, and from its dependent

ventral portion to the more elevated dorsal.

Finally it arrived between the diaphragm and liver, and became absorbed by the radial diaphragmatic lymphatics, and even reached the circular vessels.

Of course intestinal movements would to a great extent diffuse the lampblack. But how would the diffusion obtained in the preceding experiments compare with that occurring in cases where the diaphragm acted imperfectly or not at all?

In the rabbit the diaphragm is unfortunately the principal muscle of respiration. The animal is so little an intercostal breather that paralysis of the diaphragm causes speedy death from asphyxia. But it is possible to paralyse one half of the diaphragm, the animal continuing to live in perfect comfort afterwards. This, accordingly, was carried out.

A transverse incision about 1½ to 2 inches in length, at the level of the sterno-clavicular joint, exposed the external jugular vein. Keeping to the outer side of this, it was easy to strike the cellular interval which separated the central and lateral muscular masses of the neck. On separating these masses

the muscles lying in front of the spinal column were reached and from between their fibres was seen issuing the phrenic nerve of the particular side. It lay outside the pneumogastric nerve which accompanied the carotid artery and internal jugular vein. If it were pinched the half of the diaphragm supplied by it contracted violently, and when it was divided the same phenomenon was observed.

Experiment VI. Buck rabbit.

Jan.23rd,1896. Etherised. Left phrenic nerve exposed and divided. The left half of the diaphragm ceased acting at once. 15 c.c. lampblack water introduced by syringe into lower part of abdominal cavity.

Feb.27th. The animal was killed :- Irregular patches of lampblack were found chiefly in the posterior third of the abdominal cavity, attached to parietal and visceral peritoneum by lymph. Similar patches were scattered over the caecum, and a few on the mesentery of the small intestine. The great omentum was very slightly pigmented. Diaphragm showed very little marking - (vide photo No. 18.). There

are two small patches near the middle line in front and a few fine streaks on the right half close to the large blood-vessel running across it, and still fewer on the left half in a corresponding situation:

Diffusion of lampblack over the peritoreal cavity generally was less marked than in previous experiments, The great omentum showed a striking diminution of pigmentation. The paralysed half of the diaphragm was scarcely streaked at all - the normal half much less streaked than normal -

Experiment VII Doe rabbit.

Jan. 27th,1896. Etherised. Right phrenic nerve exposed and divided. Right half of diaphragm ceased acting at once.

Feb.1st. Etherised. 15 c.c. lampblack water syringed into the lower part of the abdominal cavity.

Two days later, Feb.3rd, the animal, which had appeared in good health, died suddenly. On examination, no cause to account for the death was discovered. The peritoneum seemed normal except for

small isolated patches and streaks of adherent lamp-black. These black bodies were most abundant on the right side of the posterior abdominal wall for a distance of two inches above the pelvis: there were fewer on the left side, but they were scattered all over the pelvic viscera and almost blackened the lower surface of the caecum. The left side of the ventral abdominal wall was marked for a distance of three inches above the pelvis: the pancreas was slightly marked, and there were a few free particles on the upper surface of the liver. The diaphragm showed no streaks, but mottling was present to a slight extent, and there were a few free particles lying on it. There did not appear to be any preponderance of the marks on the left side over those of the right -

Photo. No. 19. shows the paucity of lampblack markings.

Experiment VIII. Doe rabbit.

Feb.1st. Etherised: left phrenic nerve exposed and didvided. Left half of diaphragm ceased acting at once.

Nothing further was done until Feb 12th., the animal being kept under supervision in order to watch its diaphragmatic movements. The left side never recovered its activity, so on the date mentioned 15 c.c. of lampblack water were syringed into the lower part of the abdominal cavity.

On Feb.24th, the animal was killed with chloroform. The lampblack was found mostly in the posterior position of the abdomen and in the pelvis, in small masses on the posterior right half of the ventral abdominal wall and on the lowest parts of the caecum and large gut. The great omentum was tinted grey, to a much less extent than was the case in rabbits whose diaphragm acted normally. The diaphragm showed streaks on both halves principally along the line of the large vessels which on each half describes a curved course from xiphoid to spinal column - the streaks running at right angles to the vessels - They were more numerous on the right half than on the left.

Photo No. 20. shows the diaphragm, and No. 21. the isolated black masses of lampblack on

the right half of the anterior abdominal wall just above the pubes.

These three experiments show that interference with the action of one half of the diaphragm is associated with a limitation of the process of diffusion of the lampblack particles over the peritoneal surface, and that such limitation occurs quite irrespective of the half which is paralysed. Further, they show that with regard to the diaphragm itself there is a distinct diminution of the "streaking" on both sides, but particularly on the paralysed side.

It was now necessary to ascertain the effect of total paralysis of the diaphragm upon the diffusion of lampblack.

As division of both phrenic nerves would be fatal to a rabbit, an animal which depended largely upon its intercostal muscles for the production of respiratory movements had to be found.

Such an animal was found in the cat. If its normal respiratory movements be observed one can feel that there is marked and forcible elevation of the

ribs associated with each inspiratory movement, and that the "push" communicated to the abdominal viscera by the descending diaphragm is neither so forcible nor so extensive as in the case of a "diaphragm—breather" like the rabbit.

On the other hand was the disadvantage that the peritoneal surface in the cat was less extensive than in the rabbit. The latter, being a herbivorous animal, requires a long and capacious alimentary canal to deal with its food; whilst the nature of the food of the cat, a carnivore, only necessitates a comparatively short alimentary canal. In the cat however, is a long great omentum which reaches posteriorly as far as the brim of the pelvis. Still it is not in constant movement like the lengthy intestines of the rabbit, whose great omentum is rolled up and tucked along the great curvature of the stomach. Therefore, it cannot be said to compensate for the lesser area of peritoneal surface on the cats' short intestinal tract.

It was found that the great omentum of the cat interfered dicisively with the first experiment,

in which cinnabar was tried, with success as far as life was concerned, for the first time . Cinnabar was employed to ascertain if there was any difference in the diffusion of particles of different weights. It was prepared for injection in just the same way as the lampblack.

The normal abdominal cavity of the cat was first experimented with.

Experiment IX. Female Cat.

Feb.1st. Etherised: 15 cc. of cinnabar water syringed into the abdominal cavity immediately above the pubes.

March 2nd. The animal was killed. The omentum was found adherent to the site of injection. It had absorbed almost the whole of the cinnabar which was visible in the form of brilliant scarlet splashes with a tendency to a longitudinal arrangement. A little cinnabar was pressed in the form of coloured bodies of small size adherent to the pelvic viscera. A single scarlet star was found on the peritoneum covering the convex surface of the liver.

In this experiment the omentum had obviously frustrated the purpose in view. By absorbing the cinnabar it had almost entirely prevented its diffusion and had acted therefore as a protective apron. In future experiments it would be necessary to place the cat in the vertical position with its pelvis below so as to avoid the risk of the particles being intercepted entirely by the omentum when injected. In the experiment just related, the cinnabar water being injected under pressure probably forced a space for itself between the omentum and the ventral abdominal wall. Klein has demonstrated the presence of stomata on the omentum, hence its injection. The ventral parietal peritoneum being unprovided with stomata, was not marked.

It must also be borne in mind that the particles of cinnabar are heavier than those of lampblack, and that their greater inertia might be the cause of their resisting influences to which lampblack particles were more obedient.

The next experiment, performed with lampblack, was performed before the result of the

preceeding had been obtained, and therefore the cat was not placed in the vertical position.

Experiment X. Female cat.

Feb. 28th. Chloroformed. 15 cc. of lampblack water syringed into the abdominal cavity just above the pubes.

March 13th. The animal was killed. All the pelvic viscera were marked with dark patches which seemed to be imbedded in the peritoneum, not merely adherent. The omentum was adherent to the site of injection; it showed black splashes and irregular black areas. The intestines were sparsely dotted with small black bodies. The dorsal abdominal wall also showed patches, chiefly on the left side. The convex surface of the right lobe of the liver was marked by several black patches. The diaphragm was only slightly mottled and streaked, and that chiefly on the right half.

In this experiment diffusion had gone on to some extent in spite of the protective omentum. In the succeeding one, the precaution of placing the

animal in the upright position whilst injecting, and for a little time after, was carried out.

Experiment XI. Female cat - somewhat mangy.

March 3rd. Chloroformed. 15 cc. of lampblack syringed into the abdominal cavity just above the pubes.

March 24th. The omentum was adherent to the site of injection. It was much marked with black splashes; indeed it seemed to have absorbed most of the lampblack. There were one or two dots on the pelvic viscera and on the ventral abdominal wall. The mesentery of the small intestine was marked here and there, the spleen had a blackened splotched appearance, and the fold of peritoneum connecting it to the stomach was markedly darkened. The ventral aspect of the stomach carried a few marks, and there was an irregular black patch of the size of a threepenny bit on the anterior margin of the right lobe of the liver. The central tendon of the diaphragm showed a few small dots, and there were a few short streaks on the right half of the muscular portion.

The great omentum so persistently and

thoroughly absorbed the greater part of the injected small particles in the foregoing three experiments, that it is difficult to make more than a provisional deduction from them. The intestines in the case of the rabbit no doubt assisted diffusion somewhat; in the cat that assistance was practically prevented, except to a very slight extent, by the great omentum acting mechanically as a screen and shutting off the lampblack from the intestines. Some of the lampblack which reached the pelvis very probably came into contact with some portion of the gut there and part of it was thus diffused. Still, in both the lampblack experiments, the diaphragms showed undoubted streaking. Therefore I think I am justified in considering that Exp.s. X. and XI may be classed with those on the normal rabbit.

(Exp.s I. II. III. IV. and V.)

With regard to the division of the phrenic nerves in the cat, there is nothing more to add to what was said concerning the same operation on the

rabbit, except respecting the position in which the nerve was found. By cutting through the pectoralis major muscle, half an inch external to the middle line of the sternum, the fork formed by the union of the internal jugular and subclavian veins was exposed. By separating the cellular tissue between the two, the phrenic nerve was found immediately behind the fork, on its way into the thorax. I always made a point of excising fully half an inch of the nerve, in order to prevent any possibility of re-union. This applies to rabbits as well as cats. As in the rabbit, division of the nerve was accompanied by a sudden contraction of the corresponding half of the diaphragm, and the intercostal muscles could be seen to be labouring somewhat, but this rapidly passed off. Palpation of the abdomen however, could detect very little difference, if any, in the degree of descent of viscera in contact with the midriff.

Experiment XII. Male Cat.

March 17th. Chloroformed: both phrenic nerves were divided. 15 c.c. lampblack-water was then syringed into the abdominal cavity just above the pubes. No special precautions were taken with regard to the animal's position after injection.

April 1st. The animal was killed. The omentum was found adhering to the site of injection: and it was stained in the usual manner with irregular blackened, somewhat elongated areas. Small particles of lampblack were found sparsely scattered over the pelvic organs and intestines. The stomach and gastro-hepatic omentum were mottled: and the diaphragmatic (convex) surface of the liver showed the same condition. The diaphragm was much mottled, and showed considerably more streaking than in experiments X and XI in which the diaphragm was not paralysed. The markings were chiefly on the left half.

Experiment XIII. Male Cat.

March 20th. Chloroformed: both phrenic nerves divided. The animal was placed in the upright position, and 15 C.C. lampblack-water syringed into the abdominal cavity immediately above the pubes .

April 8th The cat was killed. Isolated black bodies were found universally scattered over the

whole of the abdominal cavity. No viseus appeared to have escaped. The ventral abdominal wall was particularly marked. The diaphragm showed simialr appearances to those in the preceding experiment.

The results of these two experiments were decidedly opposed to those obtained from rabbits under similar conditions.

I now determined to ascertain the effects of paralysing all the muscles forming the abdominal walls except the diaphragm. This was accomplished by excising a transverse slice ¼ inch in thickness from the spinal cord at the level of the sixth dorsal vertebra. The animal used, a fierce, strong, healthy cat, did well until the third day, when it died without giving any warning. Its bladder was intact.

Experiment XIV. Female Cat.

April 8th. Anaesthetised with chloroform. The spinal cord was divided at the level of the sixth dorsal vertebra. Thereafter, 15 c.c. of lampblack water were introduced into the abdominal cavity just above the pubes. The cat was then kept lying on an inclined plane with its head uppermost for an hour.

April 10th. The cat died suddenly. On examination, most of the lampblack was found absorbed by the great omentum; a few patches were found amongst the intestines and on the stomach. The diaphragm did not

show a trace of mottling or streaking. The superior surface of the right broad ligament showed a little mottling.

In order to ascertain the extent to which lamp-black had become diffused in the cat two days after injection, the abdominal walls being intact, a check experiment was performed.

Experiment XV. Female Cat.

April 10th, Etherised: 15 c.c. lampblack-water introduced into the peritoneal cavity 2 inches above the pubes. The cat was then kept lying on an inclined plane in the same manner for a similar period of time, as in the preceding experiment.

April 12th. The animal was killed. The great omentum had as usual absorbed most of the lamp-black. There were found however, patches of adherent lamp-black on the intestines, mesemtery, stomach, and on the upper surface of the liver. The diaphragm showed no mottling, but it was marked by fine black streaks which occurred chiefly on the right half of the muscular portion and slightly on the central tendon. The streaks occurred irregularly, and were short, varying from $\frac{1}{6}$ to $\frac{1}{2}$ an inch. They did not lie on, but beneath, the peritoneum which covered the diaphragm.

The results of the experiments on cats appear to indicate -

(1) When lamp-black is injected into the normal abdominal cavity, the same tendency to diffusion of the particles exists, as was found to be present under similar, or almost similar circumstances in the rabbit; though to a less extent, by reason of the presence of a protecting apron, the great omentum. To obtain exactly similar conditions the great omentum should be excised before injecting lampblack into the cat's peritoneal cavity.

(2) Total paralysis of the diaphragm favours the diffusion of lampblack, exactly the opposite of what happens in the rabbit when only half of its diaphragm is paralysed.

(3) Paralysis of all muscular boundaries of the abdominal walls, with the exception of the daiphragm, appears to hinder the fusion.

(4) Heavy particles are less diffusible than lighter ones, which of course was to have been expected.

It is difficult to explain the second of these results. As mentioned before, it was not easy to detect any difference between the degree of descent of the abdominal viscera lying in juxtaposition with the diaphragm before and after division of the phrenic nerves. It was practically inappreciable to the human sense of touch, the mere filling of the thorax with air appearing to cause as much descent of the

paralysed diaphragm as occurred when the latter was intact. It is possible that some change in the conditions of intra-peritoneal pressure, the result of an alteration, however slight it may, in the amount of pressure exerted from the diaphragmatic end of the abdominal cavity, is accountable for the increased diffusion of the particles?

Diffusion of small particles is accomplished in two ways, (1) mechanically by intestinal movements, (2) by diaphragmatic action, as has been proved by the experiments on rabbits described in the present paper. For when the diaphragm acts normally, its lymphatic capillaries become injected with the particles and the latter are widely spread over the general peritoneal surface. When diaphragmatic action is interfered with, as in experiments VI, VII, and VIII, the lymphatic injection of the diaphragm diminishes considerably or disappears, and the diffusion over the general peritoneal surface lessens.

This has an important bearing on the action of the diaphragm on fluid at a distance. Small free particles are at the mercy either of the serous moisture of the peritoneum, or of the wandering cells in its cavity, these cells being also to some extent, at the mercy of the serous moisture. Currents in the latter will bear along small particles, or cells which

have ingested them. That there are currents, minute though they must be, my experiments show, for it cannot be imagined that the particles or cells travel towards the diaphragm by reason of some attraction it exercises on them. It is an attraction exercised on fluid - it is the attractions - the force - exercised by a pump, and when the fluid responds to this attraction its minute currents bear along with them all they are capable of sufficiently influencing. When the guiding hand (the phrenic nerves) that sets in motion the machinery of the pump (the diaphragm) is withdrawn, the pump ceases to act, the currents of fluid cease to be attracted towards it, and the small particles in them no longer arrive within its tubes.

Small particles then, appear to behave in the peritoneal cavity without any reference to the laws of gravity, to which larger free bodies in the cavity are decidedly subservient. The behaviour of the small particles depends on the behaviour of fluid currents which flow continuously towards the diaphragm in response to its pumping action.

Had the diaphragm any influence on the collection of melted cacao-butter described as existing in Experiment II, Series B. at the site of its injection? It was in process of being pumped into the diaphragmatic lymphatic capillaries undoubtedly: but there

is no evidence to show the diaphragmatic action alone maintained the fluid collection in such quantity at its level.

The third result of the experiments in Series C. viz: that paralysis of all the muscular boundaries of the abdominal wall except the diaphragm appears to hinder diffusion of small particles is probably explained thus: the resistence previously offered by the tonicity of the muscles which had been paralysed was abolished with section of the cord. Consequently the abdominal walls simply bulged when the diaphragm descended, and the latter did not meet with sufficient resistence to maintain its pumping function at its normal level.

To sum up the muscular fibres of the diaphragm, regulated by a nervous mechanism, contract and cause it to descend upon the viscera contained within the abdominal cavity: the resistence offered by these to such descent brings into play the pump-like action of its lymphatic capillaries whereby fluid is withdrawn from that part of the peritoneal cavity bounded by the diaphragm through openings (stomata) into the above mentioned lymphatic capillaries: such abstraction of fluid leads to the production of currents of moisture flowing towards the diaphragm to restore the balance of equilibrium interfered with by such abstraction: such currents are produced even in remote

part of the peritoneal cavity, as is shown by their conveying small particles from such remote parts of their lodgement of these particles in the lymphatic capillaries. When the regulating nerve mechanism is partially abolished, the muscular contraction of the diaphragm also is partially abolished and the injection of its capillaries is much lessened or no longer occurs. The particles therefore can no longer be carried to them by the serous currents. The latter therefore have entirely or partially ceased to flow - or have ceased to flow to the diaphragm, and are flowing else-where. But there is no evidence that they do flow elsewhere, therefore it is justifiable to conclude that they have ceased entirely or partially to flow on account of the partial abolition of diaphragmatic contraction.

In conclusion I desire to express my sense of my obligation to Professor Boyce for his valuable advice kindly and courteously given on numerous occasions, and for allowing me to make use so freely of the Pathological Laboratory.

Photographs

illustrating the Thesis presented
for the degree of

Doctor of Medicine,

and entitled,

"The Behaviour of Free Bodies and Particles in the Peritoneal Cavity; with special reference to the influence of the movements of the Diaphragm upon small Particles."

by

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April. 1896.

No. 1.

Exp. V. Series A. Rosette of glass beads.

No. 2.

Exp. VI Series A. Clusters of beads adherent to the intestines which are photographed undisturbed after the opening of the abdomen.

No. 3.

Exp. VI. Series A. Beads imbedded in the right side of the mass of adhesions.

No 4.

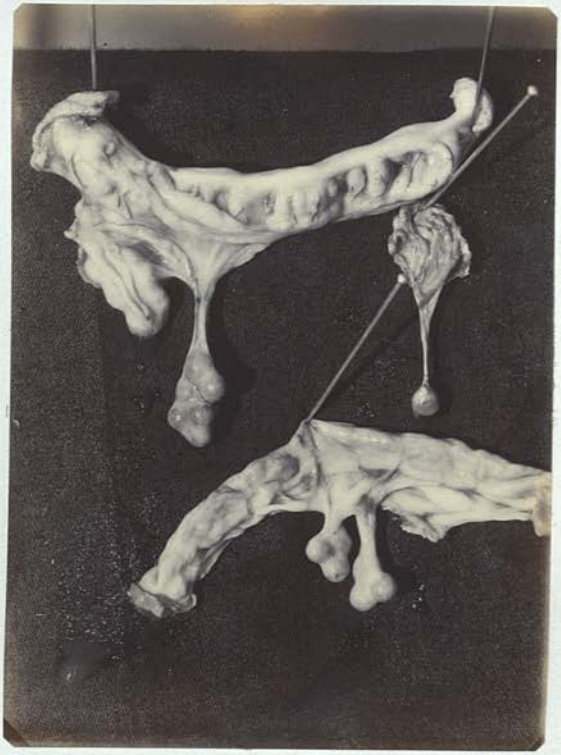
Exp. VI. Series A. Beads imbedded in the left side of the mass of adhesions.

No 5.

Exp. VII. Series A. Glass beads adherent to caecum. (ventral aspect).

№ 6.

Exp. VIII. Series A. Sac of ventral hernia laid open, showing two shot adherent to its inner surface. A slip of wood was placed across the opening to prevent the intestines from prolapsing.



No 7

Exp. VIII. Series A. Clusters of shot imbedded in lymph, and attached by pedicles to the junction of mesentery and small gut.

№ 8.

Exp IX. Series A. Shot adherent to large gut. (The latter has prolapsed through the incision in the abdominal wall.)

(Venter)

(Right)

(Left)

Dorsum

No. 9.

The normal Diaphragm of the rabbit.

No. 10.

Exp. 1. Series C. Diaphragm "mottled" by charcoal. This is one of the earlier photographs, and the definition is very bad.

(Dorsum)

ft-hand side
of rabbit.)

(Right-hand side
of rabbit.)

(Venter.)

No. 11.

Exp. II. Series C. Diaphragm "mottled" and "streaked" by lampblack. The left half is much more marked than the right.

No. 12.

Exp II. Series C. Shows the fine grey mottling on the posterior (dorsal) abdominal wall, with scattered larger black dots.

(Dorsum.)

(Left-hand side of rabbit.)

(Right side of rabbit)

(Venter.)

No. 13.

Exp. III. Series C. Diaphragm showing "mottling" and injection of lymphatic capillaries by lampblack. This is much more marked on the left side, especially along the line of the large blood-vessel.

No. 14.

Exp. III. Series C. Convex (diaphragmatic) surface of liver, showing angular patches of lamp-black marking.

No. 15.

Exp III. Series C. Peritoneal aspect of ventral wall, showing isolated, adherent, black lampblack bodies.

(Dorsum)

(Left side)

(Right side)

(Venter)

№ 16.

Exp. IV. Series C. This photograph shows the capillary injection very clearly.

(Dorsum)

(Left.)

(Right.)

Venter.

No. 14.

Exp V. Series C. Capillary injection of diaphragm.

(Dorsum)

(Left)

(Right)

(Venter.)

No. 18

Exp. VI. Series C. After division of the left phrenic nerve. The marking is chiefly on the right side.

(Dorsum)

(Left)

(Right)

(Venter)

No. 19.

Exp. VII. Series C. After division of the right phrenic nerve. The diaphragm is slightly mottled. There are a few free particles of lampblack lying on it.

(Dorsum)

(Left)

(Right)

(Venter.)

No. 20.

Exp. VIII. Series C. After division of the left phrenic nerve. The "streaks" are more marked on the right half than on the left.

№ 21.

Exp. VIII. Series C. The ~~Anal~~ Ventral abdominal wall of the right side has been raised after median incision, so as to show the isolated particles of lampblack.

No. 22.

Exp. X. Series C. A photograph of the "splashes" on the omentum of the Cat. The omentum was stretched and the light thrown through it from behind.