OBSERVATIONS CONCERNING THE BACILLUS AEROGENES CAPSULATUS.

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In November, 1891, one of us (Welch *), at a meeting of the Johns Hopkins Hospital Medical Society, reported with demonstrations the discovery of a gas-forming bacillus found in the emphysematous tissues and blood of a man dead of aneurism of the aorta. In July-August, 1892, Welch and Nuttall published a full report of this case and described the characters of the bacillus, for which they proposed the name *Bacillus aerogenes capsulatus*. Since this report there have been published, both in this country and in Europe, additional observations of the occurrence of this bacillus, and we have had the opportunity of studying a considerable number of cases in which this organism was found. We purpose in the present article, upon the basis of these published reports and of our further observations, to consider the distribution and characters of this micro-organism, and more particularly its relations to various affections and conditions of human beings.

We must refer to the original paper of Welch and Nuttall for the full report of the case in which the bacillus aerogenes capsulatus was first found, for the detailed description of the morphological and cultural characters and the effects of intravenous inoculation of this bacillus, and for the deductions which were then drawn as to the probable relation of the bacillus to conditions characterized by the presence of gas in the blood and tissues. Here we shall give a summary of some of the salient points contained in this paper.

* The references to literature are arranged alphabetically at the end of this article.

The patient was a mulatto man, aged thirty-eight, with tuberculosis and with aneurism of the ascending aorta which had perforated by a small opening through the anterior thoracic wall, and which had given rise to repeated external hæmorrhages, the last occurring two days before death, which was sudden. No subcutaneous emphysema was noted during life. The autopsy was made in cool weather, eight hours after death, the body being still warm. There was no odour, greenish colour, or other evidence of post-mortem decomposition. There existed emphysema of the subcutaneous tissues of the greater part of the body. The blood vessels and heart contained abundant gas bubbles. The blood was lake-coloured, and the lining membrane of the heart and blood vessels showed diffuse imbibition of blood-colouring matter. There was gas in the blood-stained serum in the pericardial sac and in the peritonæum. Gas bubbles were present abundantly in the internal tissues, notably in the myocardium, the liver, spleen, and kidneys, these organs presenting the appearances described by German writers as those of *Schaumorgane.* Gas bubbles were numerous in the discoloured, whitish, ante-mortem coagula which nearly filled the aneurismal sac. The gas burned with a pale bluish, almost colourless flame, a slight detonation being heard at the moment of ignition.

Upon microscopical examination of the organs there were ob served around masses of bacilli frequently, but not always, disappearance of the nuclei and degenerative changes in the cardiac muscle cells and the epithelial cells of the liver and kidney, especially in the neighbourhood of gas blebs, in the walls of which the bacilli were often densely accumulated.

By examination of cover-slip preparations a single species of bacillus was found in very large numbers in the blood and in all other situations in which gas was present. Aerobic cultures from the blood and organs remained sterile. Anaerobic cultures yielded numerous colonies of the same bacillus found in cover-glass preparations from the fresh blood and organs, no other species developing.

The morphological and cultural characters of the bacillus were

described in full detail. Only the leading characters will here be recapitulated.

The bacillus is non-motile, straight or sometimes slightly curved, variable in size, but averaging about the thickness of the anthrax bacillus and 3 to 6 μ in length, with adjacent ends slightly rounded or sometimes square-cut; occurs singly, in pairs, in clumps, and sometimes in short chains, less frequently in threads and long chains; and stains readily with the ordinary aniline dyes, including Gram's and Weigert's fibrin stain, either uniformly or with small unstained spots, less frequently with isolated deeply staining granules. Capsules, although not constant, were frequently demonstrated, especially by Welch's method for staining capsules, in specimens from the animal body and sometimes from agar cultures. No spores were found either in the animal body or in cultures.

The bacillus grows upon all ordinary culture media—rapidly at body temperature, slowly at temperatures as low as 18° to 20° C. It is anaerobic, no growth occurring on the surface of solid media or in ordinary fluid cultures in test tubes exposed to the air. There is growth in the depth of solid media exposed to the air. Under anaerobic conditions growth occurs both upon the surface and in the depth of solid media.

Gas is produced in all cultures containing fermentable material. In our plain nutrient agar or gelatin there is usually some formation of gas,* and in media to which one per cent of glucose has been added there is at body temperature a rapid and very abundant development of gas.

The colonies in agar are grayish-white to a more opaque white or brownish-white colour by transmitted light, sometimes with a central darker dot. At the end of twenty-four hours they do not

* As has been pointed out by Theobald Smith, the amount of sugar in ordinary meat bouillon varies with the character of the meat and the length of time it has been kept. In some meat and meat kept a considerable time there may be no sugar. The gas produced by fermentation of carbohydrate, therefore, varies in amount in different lots of media made with plain bouillon, and may be absent altogether. These facts will explain many of the discrepancies of statement of different observers as to the production of acid and of gas by various bacterial species in nutrient media to which sugar has not been added.

exceed 0·5 to 1 millimetre, but they may subsequently attain a diameter of 2 to 3 millimetres, or even larger. Those in the depth are spheres or ovals, generally more or less flattened, usually, but not always, with irregular contours, the irregularity being due to knoblike or feathery projections. No putrescent or distinctive odour could be detected in the cultures, except sometimes a foul odour when masses of agar culture were crushed in a little bouillon.

In gelatin cultures there was observed a slow and limited liquefaction of the medium, manifested by a settling of the growth and by slight displacement of the gas bubbles in changing the position of the tube.

The bacillus produces at first diffuse cloudiness of sugar bouillon; later the fluid becomes clearer, with an abundant whitish, more or less viscid sediment. In twenty-four to forty-eight hours milk is coagulated, the clot being generally firm, retracted, and furrowed with the marks of gas bubbles. In anaerobic potato cultures there is either no visible growth or a thin, moist, grayish-white growth on the surface and abundant formation of gas in the fluid accumulated about the bottom and sides of the potato. In ascitic fluid there is abundant growth with formation of gas bubbles.

The vitality of the cultures is of very variable duration, according to the character of the medium and the mode of cultivation. Cultures in sugar bouillon in Liborius tubes filled with hydrogen were found to be dead in three days or less. On the other hand, sugar-bouillon cultures in Buchner's jar may survive four months and longer. Cultures in sugar media are shorter lived than those in plain media. Cultures in tubes hermetically sealed after two or three days' growth survived several months. The thermal death point, determined by Sternberg's method, was found to be 58° C. for ten minutes.

Experiments upon animals were made chiefly to elucidate the relation of the bacillus to the conditions found at the autopsy upon the patient. With one important exception, to be mentioned subsequently, it was determined that the bacillus is not pathogenic for rabbits when introduced directly into the circulation.

If the animal be killed immediately or soon after the intravenous injection of 0·5 to 1 cubic centimetre of bouillon culture, after eighteen to twenty-four hours at the temperature of 18° to 20° C., and after four to six hours at temperatures from 30° to 35° C., the bacilli are found abundantly, together with great formation of gas, in the blood vessels and organs. The viscera present the typical characters of *Schaumorgane*. All of the conditions relating to the bacilli and their production of gas which existed at the post-mortem examination of the patient were reproduced experimentally in animals.

When the bacilli are introduced at one place in the vascular system soon after death, they develop in the course of the vessels into which they have been introduced, and the time required for them to appear with gas formation throughout the vessels is much longer than when they have been distributed throughout the circulation just before death.

These experiments upon animals were considered to favour the view that in the patient the bacilli had entered the circulation before death, and probably primarily from without through the opening in the thoracic wall into the aneurismal sac. The multiplication of the bacilli in the vessels and the formation of gas were regarded as occurring mainly post mortem.

The bearing of these observations upon various conditions of the body characterized by the presence of gas was considered, particularly upon the reported cases of death from the entrance of air into the circulation and upon cases in which gas, unassociated with ordinary cadaveric decomposition, was found in the blood vessels after death without the existence of any opening through which air could enter the circulation.

In view of the positive result of an intravenous inoculation of a pregnant rabbit with a culture of the bacillus aerogenes capsulatus, especial emphasis was laid upon the possible relationship of this bacillus to the reported deaths attributed to the entrance of air into the uterine veins in the puerperal state, after abortions, and after injections into the uterine cavity. As the explanation of these cases suggested by Welch and Nuttall has since been confirmed, we will

introduce here the protocol of the original experiment upon the rabbit.

Experiment 9.—Pregnant rabbit, 1 cubic centimetre of sugar-bouillon culture (ninth generation), forty-eight hours old, into ear vein. Rabbit was found dead twenty-one hours after the inoculation, the body being still warm, although stiff. The death was sudden. The rabbit was alive half an hour previously, and apparently in good condition. The autopsy was made six hours after death. By this time the body, which has been in a room at the temperature of about 18° C., is much swollen, the abdomen distended, and emphysematous crackling can be felt over the abdomen and the lower part of the thorax. Bloody fluid containing gas bubbles oozes from the vagina. On opening the peritoneal cavity gas escapes freely, which burns with a colourless flame, a slight explosive sound being heard upon first applying the match. This cavity contains blood-stained fluid. Blood vessels, both veins and arteries, contain gas. The heart cavities on both sides contain soft dark clots with gas bubbles. Spleen is somewhat enlarged, soft, and dark red. Liver does not contain gas blebs, but gas is present in the hepatic vessels. The abdominal vena cava is blown up with gas. The uterus contains six embryos about three centimetres long. The sacs of the uterus corresponding to these embryos are greatly distended with gas. Two of the sacs are more distended than the rest, their walls are very thin, contain gas bubbles, and look as if they were just ready to burst. The embryos in these two sacs are macerated, dark livid red, partly destroyed and smaller than the others, which are intact. The placentæ contain gas bubbles in large amount.

Cover-slip preparations show an enormous number of characteristic capsulated bacilli in the distended uterine sacs, and a large but not so great number in the liver, spleen, heart, and blood vessels. Cultures from the uterus, spleen, and left ventricle are pure of the typical gas-forming bacillus which was used for the injection.

It seems probable from the autopsy that two of the embryos in the uterus were already dead when the injection was made, and that in these embryos and the part of the uterus containing them the bacilli were able to gain a foothold and develop. The extent of development of the bacillus and of gas was much greater than is observed at so short a period after death (six hours) when the animal is killed immediately or shortly after intravenous injection of the cultures and is kept at the temperature of the room.

Inasmuch as we now know, from observations made since Welch and Nuttall's publication, that the bacillus aerogenes capsulatus is a widely distributed organism, of not infrequent occurrence in the human

body, and that it may be associated with various pathological conditions, we have searched through the literature in order to find whether it may not have been recognised by earlier observers. It seems highly probable that it must have been seen before its isolation and description by Welch and Nuttall.

It is not a little remarkable that of the considerable number of reported cases of suspected entrance of air into the blood vessels, none seem to have been previously the subject of bacteriological study. For some of the cases in which gas was found at the fresh autopsy widely distributed in the blood vessels and tissues several writers have recognised the difficulties involved in the usual explanation that the gas was atmospheric air or the result of ordinary cadaveric putrefaction. When this condition was found associated at autopsy with an emphysematous phlegmon or gangrene, some observers have recognised the specific bacterium causing the latter affection during life as also the cause of the development of gas in the blood and internal organs either during life or after death.

In the various reports of cases of gas in cysts, joints, serous cavities, urinary passages, and uterus we have been unable to find at a date prior to that of Welch and Nuttall's publication any description of a bacterium resembling the bacillus aerogenes capsulatus.

On the other hand, we have little or no doubt that in the cases reported before 1892 under the names malignant œdema, emphysematous or gaseous gangrene, gaseous phlegmon, emphysematous cellulitis, gangrenous septicæmia, gangrène gazeuse foudroyante, etc., the bacilli usually described as those of malignant œdema were in some instances identical with the bacillus aerogenes capsulatus. We shall consider subsequently in this article the possible relationship of these bacterial species, but in this connection it may be said that when in the class of cases under consideration the identification of an anaerobic bacillus, as that of malignant œdema, is based solely upon general morphological resemblances and similar pathogenic effects, without determination of motility and development of spores, the bacillus in question may, in the light of our present knowledge, equally well be regarded as the bacillus aerogenes capsulatus.

There are not a few cases which fall under this latter category, but in these the characters of the bacilli have not been described with such detail as to permit their positive identification. On this account it does not seem to us worth while in this article to attempt to disentangle as to this matter the generally unsatisfactory and incomplete descriptions of supposed malignant œdema bacilli in this group of diseases in human beings.

The case reported in 1888 by Bremer as one of malignant œdema may serve as an illustration of the cases which we should regard as probably referable to the bacillus aerogenes capsulatus. In this case, at an autopsy made seventeen hours after death of a woman who developed as a sequel to an abortion emphysematous swelling of the right pectoral region and adjacent arm, Bremer found most extensive development of gas in the blood vessels, the tissues, and the thoracic and abdominal viscera, with an enormous number of bacilli, devoid of spores, in the uterus, blood, organs, and serous cavities. The bacilli were said to resemble the bacillus œdematis maligni. Nothing is said as to motility or threadlike forms of the bacillus, nor was it obtained in culture. The inoculation of guinea-pigs with serosanguinolent fluid containing the bacilli was fatal in twenty-four hours, with lesions said to be like those of malignant œdema.

Of cases of gaseous phlegmon reported before 1892 in which anaerobic bacilli somewhat resembling the bacillus of malignant œdema, but not identified with it, were found, those of F. J. Rosenbach, Wicklein, and Levy have received special consideration by E. Fraenkel in his monograph *Ueber Gasphlegmonen*. He comes to the conclusion that only the bacillus described by Levy in 1891 is probably identical with the bacillus aerogenes capsulatus.

Rosenbach's bacillus formed spores and he was unable to cultivate it. The bacillus emphysematis maligni of Wicklein was motile, grew in long, jointed threads, formed spores both in cultures and in the animal body, and was pathogenic only for guinea-pigs. In spite of the contrary conclusion reached by Wicklein, Fraenkel is inclined to identify this bacillus with that of malignant œdema.

The bacillus isolated by Levy in 1891 from a gaseous phlegmon

of the pelvis and thigh of a puerperal woman was anaerobic, gas-producing, non-motile, short, small, delicate, stained by Gram, grew in long threads and chains of thirty and more members, and formed anthraxlike colonies. It grew only at body temperature, and was of so short viability that it was cultivated only in the first generation. No experiments upon animals were made. The rapid healing of the abscess was attributed by Levy to the short viability of the bacillus. In a subsequent article published in 1895 Levy declares this bacillus to be identical with Fraenkel's bacillus phlegmones emphysematosæ, but we do not consider that Levy's original description of this bacillus suffices for such identification, especially in the absence of experiments on animals; nor can his description of the bacillus as short, small, and delicate, ("*kurze, kleine, feine Bacillen*"), and as incapable of growth below the body temperature, be reconciled with the characters of the bacillus aerogenes capsulatus.

As stated by Welch and Nuttall, the bacillus described by E. Fraenkel, in 1889, in a case of gastritis emphysematosa may be identical with our bacillus, but it was studied only on hardened specimens of the stomach.

It would not be surprising if the bacillus aerogenes capsulatus should be found among the considerable number of anaerobic gas-producing bacilli which have been isolated from the soil, the fæces, decomposing infusions of animal or vegetable matter, and other sources. Most of these bacilli are motile and sporogenic. Many differ from each other only in such minor characters that their separation into distinct species is difficult or impossible. As there is reason to believe that the bacillus aerogenes capsulatus may exist in the soil, we have examined especially the descriptions of the various bacilli isolated from this source by Liborius, Lüderitz, Sanfelice, and others. But we have not found a bacillus described which we are able to identify in all respects with our bacillus, although we can by no means exclude in every case the possibility of identity. The same statement applies to the several varieties of malignant œdema, pseudo-œdema, and Rauschbrand bacilli which have been described. There is usually some point regarding motility or spore formation

or conditions of growth or odour or other cultural character or the result of or absence of animal experiment which prevented such identification. We shall have something to say subsequently as to the value of such points as these in the differentiation of species among this group of anaerobic bacilli.

The first observations of the bacillus aerogenes capsulatus following the report of Welch and Nuttall were made by E. Fraenkel, who published, in January, 1893, a preliminary report, and later in the same year a monograph concerning gaseous phlegmons. Fraenkel makes no mention of the previous discovery of the same organism by Welch and Nuttall, and doubtless was unacquainted with their work. To Fraenkel belongs the credit of demonstrating the causal relation of the bacillus aerogenes capsulatus to the affection called variously gaseous phlegmon, emphysematous cellulitis or gangrene, gangrène gazeuse, etc.

Fraenkel in these communications reported the results of his examination of four cases of gaseous phlegmon, in one of which the gas bacillus was found unmixed with other bacteria, whereas in the remaining three it was mixed with other bacteria, chiefly pyogenic cocci. In the case of pure infection with the gas bacillus there was no suppuration in any part of the enormous emphysematous swelling of the right lower extremity. On incision a turbid brownish fluid, without offensive odour and containing gas bubbles, escaped. The muscles were completely disintegrated into an opaque reddish-gray pulp filled with bubbles of gas. It is noteworthy that in two of the cases the gaseous phlegmon followed hypodermic injections, in one case of camphor oil and ether and in the other of a dilute solution in water of sulphuric acid and chloride of morphine. The latter was the case of unmixed infection and pursued a rapidly fatal course, death occurring two days after the injection. Three of the cases terminated fatally; in one the issue is not stated. In none of the cases was gas found at autopsy in the internal organs or blood vessels.

The bacillus isolated by Fraenkel from these cases corresponded in all essential morphological and cultural characters with the bacil-

lus aerogenes capsulatus. To it Fraenkel gave the name of bacillus phlegmones emphysematosæ. As regards the formation of spores, he states that this is inconstant and exceptional, and was observed by him only in a few of the bacilli in cultures in one lot of agar containing formate of sodium. Spores were not noticed in other agar cultures, even when the medium was made according to the same formula with formate of sodium. A clear zone was noticed around bacilli from the animal body and from surface agar cultures, but no capsule was stained. The probable identity of Fraenkel's bacillus of gaseous phlegmon with the bacillus aerogenes capsulatus was recognised by Mann, in an article published in February, 1894, who worked in our laboratory, and by one of us (Welch) in a published article on The General Bacteriology of Surgical Infections. Through the kindness of Dr. Fraenkel we have been enabled to examine cultures of his bacillus which he has sent us, and we have found this organism in every respect identical with that described by Welch and Nuttall. This identity is admitted in a recent communication by Goebel, whose observations come from the same hospital in Hamburg with those of Fraenkel, and in a personal communication from Dr. Fraenkel to one of us (Welch) the same opinion is expressed.

As the experiments of Welch and Nuttall were conducted to throw light upon the relationship of the gas bacillus to conditions found in their patient, so those of Fraenkel were for the purpose of determining its relation to gaseous phlegmons. Conducted thus from different points of view, these two sets of experiments are mutually complemental, and taken together they have established the main facts pertaining to the effects of inoculation of animals with this micro-organism. Fraenkel's experiments were made by inoculation of mice, rabbits, and guinea-pigs. No result followed subcutaneous injection of cultures into mice. Rabbits survived intravenous inoculation without any apparent disturbance. Sometimes, but not constantly, the subcutaneous inoculation of rabbits was followed by local œdema with necrosis of the overlying skin, from which the animal recovered. The presence of gas in the swelling is not mentioned.

In guinea-pigs, however, subcutaneous inoculation of cultures of the bacillus caused a process essentially identical with the condition observed in the human patients. The first effect was a painful infiltration of the tissues with a blood-stained fluid extending from the site of inoculation. In more than half of the cases gas appeared in the swelling within the first twenty-four hours, in the remainder at a later period. Death may occur in twenty-nine to thirty-six hours after inoculation or at a later period. In a considerable number of cases the skin bursts over the infiltrated area, and then after prolonged necrosis and ulceration recovery by cicatrization may occur. There was no actual suppuration unless pyogenic bacteria were mixed with the gas bacillus. At autopsy the muscles of the affected area were converted into a soft, pulpy mass and blood-stained fluid infiltrated the part, which contained gas bubbles in large number. There may be direct extension of the inflammation to the peritoneal and pleural membranes. The bacilli were found only in the actually inflamed and necrotic parts, but here in enormous number, occurring in the form both of rods and of threads.

The next publications concerning the bacillus aerogenes capsulatus were those of Graham, Steward and Baldwin, and of P. Ernst, both of these articles appearing in August, 1893. The case reported by Graham, Steward and Baldwin is of extraordinary interest. The patient was a labouring woman, married, aged thirty-five. About fourteen hours before death the woman, who had previously been well, was seized with what she described as a severe chill, which lasted more than four hours. This was followed by pain in the region of the uterus and ovaries and by vomiting and purging.

She was first seen by Dr. Steward at 1 P. M., about five hours after the onset of the first symptoms. She was then extremely restless and suffering from "distress and pain" in the lower abdominal region. There was a slight flow of bright-red blood from the uterus. Abortion was suspected. The pulse was about 120. Morphine was administered hypodermically. The patient when seen at 3.30 P. M. appeared much relieved and dozed off to sleep. She was not visited again by Dr. Steward until half past nine in the evening, when he

found her "emphysematous from the top of the head to the soles of the feet." Emphysematous crackling could be felt over the entire surface of the body. There was a diffuse blood-red colour of the whole surface of the body. The skin was smooth. The husband said that the swelling, redness, and crackling began about 5.30 P. M. The pulse was weak; the breathing somewhat rapid. We quote from Dr. Steward's report: "The patient said that she was not now suffering so much pain, but that she felt bloated, with a sense of numbness over the entire surface of the body. She had not passed urine since morning. I introduced a catheter and drew only a few drops of bloody urine. Noticing that her breathing was becoming very short and quick, I felt for the pulse. It was gone. The heart had stopped beating. The woman was dead. There was no death struggle. The patient was entirely conscious and talking to within three minutes of death. There was no change in the ruby appearance of the skin at the approach or instant of death."

The emphysematous condition increased so rapidly after death as to alarm the undertaker. Eighteen hours after death the body was bloated to more than double its natural size. The autopsy was made about twenty hours after death. The uterus gave evidences of a recent abortion at about the third month. It contained bloody fluid and placental *débris*, and its interior presented suspicious marks, but no positive evidence of criminality was obtained. The vessels, tissues, and organs were enormously distended with gas, which ignited with an explosive sound, and was determined by chemical examination to be largely hydrogen. The bacteriological examination made by Graham showed in the blood in very large number and pure culture bacilli, which were identified by microscopical examination, cultures, and the inoculation of animals as the bacillus aerogenes capsulatus. Dr. Graham kindly sent one of us (Welch) microscopical specimens and photographs of the bacillus, which in the characters thus revealed we found to be indistinguishable from our bacillus.

This case was recognised by Baldwin and Graham before the autopsy as probably referable to the bacillus previously described

by Welch and Nuttall, and reference is made by Baldwin to the brief report of a case presenting similar post-mortem appearances in the same journal of October, 1892.

The significance of the remarkable case reported by Graham, Steward and Baldwin is that it affords positive evidence that the gas bacillus may invade the blood and produce gas widely distributed over the body during life. The development of extensive emphysema of the entire subcutaneous tissue of the body in this case during life and within the space of four hours can not well be explained otherwise than upon this supposition. The portal of entry of the bacillus was manifestly the uterus, which presented unmistakable evidences of a recent abortion, possibly artificially produced by the insertion of some instrument. This case therefore confirms the explanation suggested by Welch and Nuttall of deaths previously reported as due to the entrance of air into the uterine veins after abortions.

The attention of P. Ernst was arrested especially by the formation of foam upon the cut surface of the liver at autopsy, this foam being due to the development of gas by the bacillus aerogenes capsulatus. He reported in August, 1893, two observations of this foaming liver (*Schaumleber*). These cases were observed prior to the publication of Welch and Nuttall, which led Ernst not to delay longer the report of his own studies upon the same subject.

The first case was that of a woman who developed putrid endometritis and septic peritonitis after removal of a macerated four months' fœtus, the uterus, through doubt as to the diagnosis, having been previously curetted, sounded, and tamponed. No development of gas in the tissues was noted during life. At the autopsy, made only three hours after death, the entire uterine wall crepitated from the contained gas. Coagula in the right iliac vein and conus pulmonalis contained gas. Gas was found also in the myocardium, and especially in the liver, from the cut surface of which gas oozed up and in a few hours formed a layer of foam several centimetres thick.

A similar condition of the liver was observed at an autopsy made

eighteen hours after death upon a case of peritonitis resulting from traumatic perforation of intestine in a hernial sac. The patient died four hours after a hernio-laparotomy. Green discoloration of the liver and other parts indicated advanced cadaveric decomposition. Gas was found in the liver and gas blebs in the intestinal mucosa.

The organism found in these two cases was a non-motile, anaerobic bacillus corresponding in its essential features with the bacillus aerogenes capsulatus, with which it was identified by Ernst. Rods exceeding 5 μ in length were met only very exceptionally. Capsules were not stained and growth in gelatin at room temperature was not obtained, but it is not clear how thoroughly examinations were made as to these points. Only a few experiments upon animals were made. It is noteworthy, in view of the negative results of Fraenkel, that Ernst succeeded in killing two mice by subcutaneous inoculation with the bloody fluid from the livers, the characteristic bacilli being found, at least in one of the mice, in the heart's blood, liver, and spleen. Subcutaneous inoculation of a guinea-pig with hepatic fluid from the first case caused death in less than twenty-four hours, with foul-smelling gangrene of the skin and sanguinolent œdema, which contained a variety of cocci and bacilli besides the typical gas bacillus. The guinea-pig inoculated with material from the second case survived. A rabbit inoculated into the ear vein with blood rich in bacilli from the first case became manifestly ill and voided turbid bloody urine containing the characteristic bacillus and long threads, which were regarded as possibly belonging to the same species. Contrary to expectation, the rabbit recovered.

Ernst describes with much detail the histological changes in the liver, these being characterized, as pointed out by Welch and Nuttall, by disappearance of nuclei and degenerative changes around masses of bacilli. The characters of these alterations are believed by Ernst to indicate the lodgment of the bacilli in the liver during life. The development of gas holes in the liver, however, he regards as post mortem.

In February, 1894, Mann reported a case of emphysematous gangrene of the hand due to the bacillus aerogenes capsulatus associated with the streptococcus pyogenes. The patient was in Dr. Tiffany's clinic at the University of Maryland. The affection began as a small black blister on the palmar surface and near the end of the left ring finger. The entire hand became swollen and œdematous, and upon palpation emphysematous crackling could be felt up to the wrist. The temperature rose to 105·5° F. and the pulse to 130. Free incisions were made and the hand placed in a hot sublimate bath. Recovery, with loss of the gangrenous extremity of the middle finger, took place.

Aerobic cultures were pure of the streptococcus pyogenes. By means of anaerobic plate cultures the bacillus aerogenes capsulatus was isolated in purity and was fully identified by Mann, who kindly submitted to me his cultures. Mann calls attention to the similarity of the lesions produced by the bacillus œdematis maligni and the bacillus aerogenes capsulatus, which he regards as distinct species.

In May, 1895, Levy, under the title of pneumothorax without perforation, published an observation of the bacillus aerogenes capsulatus. In a patient forty-eight years old, after repeated aspirations of clear fluid from the left pleural cavity, there developed pneumothorax. The slightly turbid serous fluid withdrawn by aseptic aspiration eight days after the first appearance of the signs of pneumothorax, as well as the opaque fluid removed a week later by resection of a rib, furnished in anaerobic cultures a short, thick, plump, non-motile, gas-producing bacillus, devoid of spores, staining by Gram, occurring usually as a diplobacillus, but not infrequently also as jointed threads, and growing both at body and room temperatures. Bouillon cultures possessed a peculiar viscid consistence, such as is customary with capsulated bacteria, but no distinct capsule could be demonstrated. Subcutaneous or intraperitoneal inoculation of guinea-pigs caused reddish serous exudate filled with gas bubbles at the site of inoculation. In one guinea-pig a few bacilli were found in the blood as well as in the exudate.

Levy interprets the case as primarily one of tuberculous pleurisy

to which in some unknown way the gas bacillus gained access and caused during life gas formation without perforation. At the autopsy by von Recklinghausen a fibrous mass the size of an egg containing caseous foci was found in the upper part of the right lung, and a small caseous focus was found in the lower lobe of the left lung without rupture of the pleura. The possibility of a healed perforation of the pleura could not be positively excluded, but this was considered by von Recklinghausen to be improbable. Unfortunately, nothing is said as to the results of aerobic cultures, nor whether other bacilli than the one described were present, nor as to the direct microscopical examination for bacteria of the pleuritic exudate.

Levy identifies the bacillus isolated from this case with that obtained from the case of rapidly healing gas abscess already cited, although the bacillus from the latter case was described as small and delicate and incapable of growth at ordinary temperatures and was only imperfectly studied. He doubtless correctly identifies the bacillus from the case of pneumopleuritis with Fraenkel's bacillus of gaseous phlegmon. With the exception of his own first doubtful observation of this bacillus and of Fraenkel's studies, he makes no mention of any of the other observations of the same bacillus.

In July, 1895, Goebel* published an article concerning the bacillus of *Schaumorgane*, confirming the results of Welch and Nuttall, and demonstrating that this bacillus is identical with the bacillus phlegmones emphysematosæ of Fraenkel. He cultivated the bacillus from three cases at autopsy. The first was a case of pyelonephritis consecutive to papilloma of the bladder and abscesses of the prostate and seminal vesicles. Gas blebs were found in the heart muscle, liver, spleen, adrenals, and stomach. Around many, but not all, of the blebs in the heart and liver the cells were necrotic. Necroses were not present in the spleen around the gas holes.

* This article of Goebel is described as an extract from an elaborate paper which is to appear in the *Jahrbücher der Hamburgischen Staatskrankenanstalten*. In the latter Goebel promises a detailed consideration of the differential diagnosis of the bacillus aerogenes capsulatus from other similar anaerobes (malignant œdema, *Rauschbrand*, etc.), and further conclusions to be drawn from his observations. This volume of the *Jahrbücher* has not yet appeared (December, 1895), so far as we have been able to learn.

The second case was one of enlarged prostate which had been catheterized. There existed general arteriosclerosis, pulmonary emphysema, lobular pneumonia, and embolism of branches of the pulmonary artery. Numerous gas blebs were found at autopsy beneath the mucous membrane of the urinary bladder. Necroses were absent from the walls of these blebs.

The third case was one of pyæmia following endophlebitis of the cutaneous veins of the left foot. Beneath the gastric and intestinal mucosa were gas blebs resembling those in the preceding case, except that necroses were present in the neighbourhood of the blebs.

The gas vesicles in all of these cases contained numerous bacilli in their walls and interior. The characters of the bacillus isolated from these cases correspond in all particulars with the bacillus aerogenes capsulatus of Welch and Nuttall and the bacillus phlegmones emphysematosæ of Fraenkel. Capsules were stained by Goebel around bacilli from the animal body, but apparently only once around bacilli from cultures. The experiments of Welch and Nuttall were repeated with identical results both with the bacillus isolated from foaming organs and with that from gaseous phlegmons. Necroses were absent from the walls of gaseous blebs which formed in the organs of rabbits which had been killed a few minutes after intravenous injection of cultures. Spore formation was observed only in one culture, this being a forty-eight-hour stab culture in sodium-formate agar. Liquefaction of gelatin with cultures from the first case was slow and limited; with those from the second it was rapid and marked. Subcutaneous inoculation of guinea-pigs produced the same effects as those described by Fraenkel in his monograph on gas phlegmons.

In the first and third cases it was considered, in view of the presence of necroses, that the gas bacilli invaded during life the organs containing the blebs at autopsy, whereas, in the second case, the invasion of the bacillus is regarded as post mortem.

Passow has recently reported a case of gaseous phlegmon of the right shoulder joint which was observed in November, 1893. Three

weeks after a superficial wound of the hand which healed slowly by suppuration the patient developed septicæmia with purulent panophthalmitis, and a few days later an emphysematous swelling around the right shoulder joint and extending down the arm. Upon incision, stinking, brownish, non-purulent fluid containing gas with the odour of sulphuretted hydrogen was evacuated. Three days later the patient died. Gas was not found at the autopsy in the blood or internal organs. The bacillus isolated from the gaseous phlegmon was imperfectly studied, but is identified by Passow with Fraenkel's bacillus of gaseous phlegmon. It caused rapid liquefaction of gelatin which gave a penetrating odour of sulphuretted hydrogen. Clear spaces were seen in the stained bacilli, but it was not determined whether these were spores. Cultures and the wound secretion were not pathogenic for mice and rabbits. Passow's description of his bacillus hardly suffices for its identification, and the strong odour of sulphuretted hydrogen in gelatin cultures is not in favour of its being the bacillus aerogenes capsulatus, if the culture was pure. It is not even clear from Passow's statements that the bacillus was incapable of aerobic growth, or that it was separated in culture from the staphylococci which were also present in the phlegmon.

The preceding observations are all which we have found relating to the bacillus aerogenes capsulatus in the literature since the publication of Welch and Nuttall. There have been reports of cases by Pantzer, Ross, and others of gas in the tissues and serous cavities, in which the opinion has been expressed that this bacillus was concerned, but bacteriological examinations were not made. Reference will be made subsequently to reports of cases of gaseous phlegmon, gas cysts, etc., in which other bacteria than our bacillus were found.

We will now report our personal observations of additional, hitherto unpublished, cases in which the bacillus aerogenes capsulatus was found either during life or at autopsy. Only such details of these cases will be given as are necessary for an understanding of the relations of the bacillus to the case.

The methods of bacteriological examination adopted have been

essentially those described by Welch and Nuttall, and their description need not be repeated in connection with the report of each case. In all cases cover-glass preparations were examined from the original material. Anaerobic cultures were made usually in one-per-cent glucose agar. Occasionally sodium-formate agar was used. We employed, as a rule, the Buchner method, less frequently displacement of the oxygen by hydrogen. Pure cultures were obtained from single colonies, and were planted in various media.

We made continual use of the intravenous inoculation of rabbits, which were killed by a blow at the back of the neck a few minutes after the inoculation. At suitable temperatures the development of the bacilli and of gas in these dead rabbits is rapid and extensive. In this procedure the body of the dead rabbit previously inoculated in the manner described may be regarded as a receptacle containing the best possible nutritive medium and presenting the best conditions for anaerobic growth so far as this bacillus is concerned. By making cultures from these rabbits at a period not too long after the inoculation it was often possible to separate the bacillus from other micro-organisms which might be mixed with it.

Rabbits, guinea-pigs, pigeons, and mice were inoculated subcutaneously and pathogenic effects noted. The results of the experiments upon these animals will be described after consideration of the cases in which the gas bacillus was found. We shall also reserve to a later consideration certain variations observed in the characters of the bacillus and its differentiation from allied anaerobic bacteria.

Unless otherwise stated, the cases were observed in the Johns Hopkins Hospital and Pathological Laboratory. They are arranged as far as possible in groups, but not in the chronological order of their occurrence. On account of their number they are presented in as abbreviated a form as is consistent with clearness. Our autopsies are, as a rule, unusually fresh, and the bodies are kept after death in a large ice chamber. They were made by one of us (Flexner), also by Drs. Barker and Blumer for whose assistance in our studies we desire to express our thanks.

I. Boy, thirteen years old, admitted to the service of Dr. Halsted, March 29th, fourteen hours after gunshot wound of left knee. Examination upon admission showed an ecchymosed bullet wound at the lower outer edge of the patella, with effusion into the knee joint. Flexion and extension gave rise to a peculiar sound, resembling the passage of gas along the intestine. The diagnosis of gas in the joint was made. No emphysema of extra-articular tissues. Temperature, 101·5° F. Twenty-three hours after the injury the joint was freely opened by Dr. Halsted. It contained partly coagulated blood and bloody fluid in which many gas bubbles were present. Tissues about the joint œdematous. A large conical bullet was chiselled from the head of the tibia a short distance below the cartilage. The operation was aseptic throughout, only sterilized instruments coming into contact with the bullet. After the operation the joint was freely irrigated with sublimate solution (1 to 1,000). On account of the persistence of high temperature and the extensive infection of the tissues above and below the joint, the thigh was amputated at the upper third on April 5th. The wound was treated by the open method in the bath, and there was ultimate recovery. Examination of the amputated leg showed extensive soft, reddish-yellow necrosis of the muscles, with separation of the muscles by bloody œdema and sloughy tissue. Gas bubbles were present in various parts of the affected tissues in moderate number. There were some foci of pus, but, in general, the process was one of necrosis with œdema rather than of suppuration.

Cover slips from the blood in the joint at the first operation showed numerous bacilli with the morphology of the gas bacillus and a smaller number of cocci. Anaerobic and aerobic agar cultures were made both from this bloody fluid and from the bullet, which, seized by sterile forceps, was immediately dropped into a tube of high melted agar. Numerous colonies of the bacillus aerogenes capsulatus developed in the anaerobic cultures, most rapidly and abundantly from the one inoculated with the bullet. In smaller number there grew colonies of the staphylococcus aureus and the streptococcus pyogenes. Cultures and cover slips from the second operation still showed the gas bacillus, but now the streptococci predominated. Typical gas development in blood and organs followed intravenous inoculation of rabbits which were killed soon after the inoculation. The bacillus caused the death of pigeons in seven to twenty-four hours, with the characteristic lesions. Gaseous phlegmon followed subcutaneous inoculation of guinea-pigs.

The notable features of this case are the infection of the joint by a bullet carrying the gas bacillus, the rapid development of gas in the joint, so that its presence could be recognised by manipulation fourteen hours after the injury and before the joint was opened by the surgeon, the rapid extension of the necrotic and gaseous inflammation to the surrounding tissues, and the ultimate recovery after amputation.

II. November 9th, man admitted to the service of Dr. Halsted with the history that his left leg had been run over by a car and shortly before admission had been amputated at about the junction of the middle and lower third of the leg. On removing the dressings, which were saturated with blood, there was so much bleeding from the stump that an Esmarch bandage was applied above the knee. The skin was covered with dirt and sand, and showed no evidence of having been cleansed before the amputation. The wound was opened and irrigated, and after ligation of the vessels it was partly closed and drained with gauze. At this time there was no emphysema of the tissues. Twenty-four hours later the temperature rose with a chill to 104° F., the pulse ranged from 120 to 160, and there was much pain and tenderness in the leg. Extending from the edges of the wound nearly to the patella, the skin, which was not much reddened, was the seat of emphysematous crackling over the anterior and lateral aspects of the leg. Free incisions were made and gas was found in the subcutaneous and intermuscular tissues with extravasated blood and bloody turbid exudate. Although temporarily relieved, the condition of the patient became critical, and amputation was done at the lower third of the thigh by Dr. Bloodgood. After this the patient made a good recovery.

Cover slips from the blood-stained fluid, which escaped at the first incision into the emphysematous tissues, contained numerous bacilli with the morphology of the gas bacillus, many being contained within leucocytes with polymorphous nuclei, and many also being free. Chains and clumps of cocci were also seen. Cultures gave the bacillus aerogenes capsulatus with typical reactions and, in addition, the staphylococcus albus.

This case belongs also to the group of gaseous phlegmons, infection with the gas bacillus being probably referable to the dirt which was ground into the leg by the passage over it of a car wheel. As in the preceding case, the gas bacillus was associated with pyogenic cocci. Here also recovery followed amputation, the previous treatment by free incisions not having held the infectious process in check.

III. June 2d, man admitted to the service of Dr. Halsted with the history that eight days previously he had fallen from a wagon and injured his right hip and thigh. On admission, temperature 101° F., subsequently rising to 104° ; pulse, 80 to 90. Thigh flexed on the pelvis, the leg on the thigh, the limb being abducted and rotated outward. No external wound of integument. The thigh, especially on the inner and posterior aspects, much swollen and tender, with emphysematous crackling on the inner side and in the popliteal space. The skin over these parts is reddened. A similar condition in the gluteal region. By rectal examination a tender swelling can be felt about four centimetres above the anus. An incision was made from the tuberosity of the ischium to the popliteal space. The subcutaneous tissues were infiltrated with serum. The deep fascia was

tense and thickened by a fibrinous exudate. Upon incising this tense fascia a turbid grayish fluid mixed with gas bubbles and having a fæcal odour escaped. The muscles and tissues were much disintegrated. As the process extended down the leg, incisions were continued to the heel, the whole lower extremity being red, swollen, and emphysematous.

Death on June 7th. Autopsy twelve hours after death. The tissues of the gluteal region and right lower extremity extensively necrotic and infiltrated with offensive, dirty, turbid, grayish-red exudate. The muscles are friable and disintegrated. In places there is pus. Gas bubbles are present, most abundantly in the gluteal region. The necrotic inflammation which has dissected out the sciatic nerve can be followed through the sciatic notch into the pelvis, where there is a perirectal phlegmon the size of an orange pushing up the peritonæum, which is greenish in colour over the prominence but not inflamed. The perirectal abscess communicates by two perforations with the rectum. Moderately large probes can be passed from the rectum through these openings. Peritonæum smooth, without excess of fluid. No gas in the heart, vessels, or viscera. No fracture of the pelvis.

Cover slips from the gas-containing fluid which escaped at the incision into the thigh during life showed a large number of bacilli with the morphology of the gas bacillus. This was the predominant organism, but in addition were seen a short, oval bacillus, slender bacilli, and cocci in long and short chains, the picture being suggestive of that of intestinal bacteria. The cultures gave abundant colonies of the bacillus aerogenes capsulatus, which was tested upon animals, and also streptococci. The same bacteria were found by cover slips and cultures at autopsy in the necrotic inflamed tissues. Aerobic and anaerobic cultures from the blood and organs were sterile except that the gas bacillus was isolated in anærobic culture from the congested lower lobes of the lungs, where it was also demonstrated by direct microscopical examination.

In this case a most extensive fatal emphysematous cellulitis followed traumatic rupture of the rectum, the process extending rapidly from the ischio-rectal tissues through the sciatic notch into the gluteal region and down the thigh, nearly the whole lower extremity becoming involved. It is clear that the bacillus aerogenes capsulatus in this case escaped with other bacteria from the intestine through the rectal perforations, and grew during life abundantly in the tissues.

IV. For the following unpublished case we are indebted to Dr. Tiffany, Professor of Surgery in the University of Maryland, who has kindly furnished us the history. A vigorous telegraph lineman, twenty-seven years old, at 10.30 A. M. fell from a telegraph pole, striking his right knee against the curbstone, which produced a compound comminuted fracture of the

patella. The trousers were not torn through, but the underclothing was ground into the wound. He was seen an hour and a half after the injury by Dr. Tiffany, who opened the joint freely, removed the small fragments of patella, and stitched the fibrous capsule. The patient that night became incoherent. The next morning the temperature was 101·5° F., the pulse 118. Delirium occurred in the afternoon The temperature continued to rise, the pulse became more and more rapid and thready, and the next morning the patient died, less than forty-eight hours after the injury. Gas was detected by the resident physician in the tissues a short distance from the wound a few hours before death, and Dr. Tiffany, within two minutes after death, found by palpation emphysematous crackling in the tissues three inches above the site of the patella, and also in a dusky area over the tibia five inches below the patella. The tissues in these situations were somewhat swollen and œdematous. Upon incision a reddish serous exudate containing gas bubbles escaped. There was no pus. An autopsy was not permitted.

Cultures made by Dr. Mann gave the bacillus aerogenes capsulatus with its characteristic reactions. No other organism developed in the anaerobic cultures, and aerobic agar plate cultures were sterile.

This case of emphysematous cellulitis is notable for its extremely rapid and fatal course, death occurring within less than forty-eight hours after the injury. As the outer clothing was not torn, it seems probable that the gas bacillus entered through bits of cloth from the drawers having been ground into the wound. The infection was apparently due exclusively to the gas bacillus.

V. For the following case we are likewise indebted to Dr. Tiffany. At 12.30 A. M. the right forearm of a healthy railway brakeman was crushed between the buffers of two cars and the clothing was ground into the wound. The wound was dressed by two physicians near the scene of accident, and the patient was transferred by train a distance of forty-three miles to Baltimore, where he was seen in the hospital about ten hours after the injury by Dr. Tiffany, who tried to save the limb, which was much mangled. The following morning, thirty-three hours after the injury, emphysematous crackling was noticed about the wrist. The tissues were becoming œdematous. The skin over the doughy crepitating swelling was pale. Two hours later amputation midway between the elbow and shoulder was performed. The ulnar and radial arteries were destroyed. The patient made a good recovery.

Cover-slip preparations and cultures were made both before the operation and immediately after amputation. The cover slips showed bacilli like the gas bacillus and streptococci. Cultures yielded the bacillus aerogenes capsulatus and pyogenic cocci. There was also a spore-producing anaerobe which appeared with the gas bacillus in pigeons and guinea-pigs inoculated with the cultures of the first generation, but which did not appear in the

subsequent cultures and did not grow in the sugar agar cultures made from these animals. The gas bacillus gave characteristic reactions in cultures and in inoculated animals.

VI. Dr. Mann has kindly furnished the notes of the following case. Woman, seventy-four years old. When first seen by Dr. Mann on January 18th the hand, forearm, and arm were much swollen, with red lines extending upward from the elbow. The hand was gangrenous, green, with blebs containing bloody offensive fluid. Emphysematous crackling could be felt over the whole extremity as far as to the deltoid muscle. The general condition of the patient was bad, there being high fever, rapid pulse, and delirium. The arm was amputated near the insertion of the deltoid. Examination of the amputated arm showed that the tissues were disorganized and infiltrated with offensive bloody exudate. Gas bubbles were present throughout the tissues and exudate. The patient's general condition was improved the day after the amputation, and the crackling disappeared in the tissues above the line of amputation. Four days after the operation symptoms of tetanus appeared, and death occurred from tetanus on January 24th. No autopsy was obtained.

Cultures made from the amputated arm gave streptococci and the bacillus aerogenes capsulatus, which was fully identified. Cultures made from the wound after amputation did not show the gas bacillus.

The preceding six cases belong to the category of gaseous phlegmons, emphysematous cellulitis, or emphysematous gangrene. All were severe infections, three terminating in recovery after amputation and three ending fatally. In only one of the fatal cases was an autopsy performed, and in this gas was not present in the blood and internal organs, although the gas bacillus was cultivated from the lung in Case III.

The following case is inserted in this connection as there was severe phlegmonous inflammation, although gas and the gas bacillus were found only at the autopsy:

VII. Woman, admitted to the service of Dr. Halsted June 24th with phlegmonous infection of the hand and forearm, the joints of the wrist, hand, and fingers being involved. Fever and rapid pulse. June 25th, free incisions into the hand and forearm with sublimate irrigation. The sheaths of the anterior tendons of the fingers contained pus. June 27th, general condition bad; no tendency to wound repair. Offensive odour of the discharges. No emphysema detected. Amputation at the middle of upper arm. Tissues œdematous and vessels thrombosed. Patient died June 30th.

Bacteriological examination of the phlegmon and wound during life showed streptococci and staphylococci. No gas bacilli were detected nor emphysema of the tissues. Cultures from the blood during life were sterile.

At the autopsy, twenty-four hours after death, the spleen was large and soft, the kidneys large, smooth, and pale, being the seat of chronic diffuse nephritis. Sticky purulent discharge covered the exposed surface of the amputation wound. Gas was present in moderate amount in the blood of the heart and vessels; none in the parenchyma of the organs.

Cover slips from the heart's blood showed many bacilli resembling the gas bacillus. Aerobic cultures from the blood, liver, kidney, and lungs were crowded with colonies of the bacillus coli communis. Anaerobic cultures from the same situations and from the spleen gave numerous colonies of the bacillus aerogenes capsulatus with typical reactions. A pigeon inoculated subcutaneously and into the breast muscle with one cubic centimetre of the heart's blood of a rabbit containing numerous bacilli developed after a few hours an emphysematous swelling, but subsequently recovered.

As the presence of the gas bacillus was not determined during life, its development in the blood with the formation of gas is probably to be regarded as occurring after death. No positive statement can be made as to whether the invasion of the bacillus was through the wound.

We pass now to our observations of a group of cases of perforative peritonitis in which the bacillus aerogenes capsulatus was found.

VIII. Woman, admitted to the service of Dr. Osler February 1st with history of pain in the region of the stomach, vomiting, and emaciation extending over three months and increasing in severity during last three weeks. On day of admission she was suddenly seized with a sharp paroxysm of intense pain localized over the stomach. Vomited reddish fluid containing red blood-corpuscles. The abdomen became distended, tympanitic, and tender on pressure. The patient passed into a state of collapse and died at 5.20 P. M. on the day following admission to the hospital.

Autopsy fourteen hours after death. The abdomen is greatly distended and tympanitic, and upon incision there is a free escape of gas from the peritoneal cavity. There is a thin fibrinous exudate over the general peritoneal surfaces. The cavity contains about 2,000 cubic centimetres of thin, grayish, turbid fluid holding flakes of fibrin. An infarcted multilocular ovarian cystoma with twisted pedicle nearly fills the pelvic cavity. The intestines are markedly distended with gas. There are multiple necroses in the fat about the pancreas and in the omentum and mesentery. One and a half centimetre below the pylorus there is an ulceration with thickened indurated walls, and 12 millimetres below this a second similar ulceration through all of the coats of the duodenum. The floor of one ulcer is completely closed by adhesion to the pancreas, but that of the other is only partly closed by adhesions, so that there exists here a perforation 5 millimetres in diameter leading into the general peritoneal cavity. Microscopical examination of the thickened edges of the duodenal ulcers showed them to be carcinomatous. The gastro-hepatic lymphatic glands

are the seat of cancerous infiltration. No metastases in the liver. The rootlets of the portal vein contain small gas bubbles, but no gas bubbles are found in the vessels elsewhere, in the liver or in other parts than those mentioned.

Cover-slip preparations from the fibrinous exudate in the peritoneal cavity showed many bacilli with the morphology of the bacillus aerogenes capsulatus. No other bacterial species was found in these preparations. Polynuclear leucocytes were present in only moderate number. Anaerobic cultures from the fibrinous exudate covering the peritoneal surface of the liver gave numerous colonies of the gas bacillus with all of the characteristic reactions. No other species developed. Cultures from the heart's blood sterile. The bacillus isolated from this case was used for numerous experiments on rabbits, pigeons, and guinea-pigs. In rabbits subcutaneous inoculation produced gaseous œdema with recovery. For pigeons and guinea-pigs the bacillus was highly pathogenic with typical lesions, including the production of peritonitis by intraperitoneal inoculation.

This case of fibrino-purulent pneumoperitonitis following perforation of a cancerous ulcer of the duodenum is of especial interest from the fact that at the autopsy fourteen hours after death, the body having been kept in an ice box, the bacillus aerogenes capsulatus was present in large number, and apparently in pure culture in the exudate. Other bacteria, if present at all, were in such small number that they were not detected either in cover-slip preparations or in aerobic or anaerobic cultures. We have occasionally observed in other cases of perforative peritonitis the predominant or apparently exclusive presence of a single bacterial species. Gas bubbles were absent from the blood with the exception of the rootlets of the portal vein. The peritoneal exudate was fibrino-serous without many pus cells.

IX. Service of Dr. Osler. Man, forty-four years old, died July 30th from typhoid fever, on the eighteenth day of the disease, with symptoms of perforative peritonitis. Autopsy five hours after death. The abdomen is greatly distended and very tense. Upon incision there is free escape of gas from the peritoneal cavity. Intestines tympanitic. There is diffuse fibrinous exudate over the visceral and parietal peritonæum with a moderate amount of fluid, which in some places is pus, in other places turbid serum. Thirty-nine centimetres above the valve is a circular perforation, 3 millimetres in diameter, of a typhoid ulcer. There are many ulcers of the ileum, for the most part clean, and the other usual lesions of typhoid fever. There is acute hæmorrhagic nephritis and many small abscesses are scattered through the kidney containing typhoid bacilli. Gas bubbles are not present in the blood vessels and viscera.

Cover slips of the peritoneal exudate show various bacteria, including streptococci, bacilli with the morphology of the colon bacillus, slender bacilli, and plump, capsulated bacilli resembling the bacillus aerogenes capsulatus. The last species was present in large numbers. The bacillus aerogenes capsulatus with other species was obtained from the peritoneal exudate, and from the organs the bacillus typhosus (in the bile, bone marrow, mesenteric glands, and kidneys) and the bacillus coli communis grew in the cultures.

X. Service of Dr. Osler. Man, died September 9th from typhoid fever in the third week of the disease. Twenty-four hours before death there was severe abdominal pain, followed by symptoms of perforative peritonitis.

Autopsy eighteen hours after death. Abdomen much distended and drumlike. Upon incision of the peritoneal cavity there is violent escape of gas. There is diffuse fibrinous peritoneal exudate. The cavity contains about 1,000 cubic centimetres of turbid fluid mixed with fæcal material. There are two small perforations of typhoid ulcers of the ileum. There are many typhoid ulcers, some with necrotic base. The spleen is large and soft. Focal necroses are in the liver. No gas in the heart or viscera.

Microscopical examination of the peritoneal exudate shows the presence of comparatively few cells, but an enormous number of bacteria of various kinds. The bacillus aerogenes capsulatus was obtained from the exudate, being present in fair numbers, but the predominating organism was the colon bacillus. There were a few streptococci.

XI. Service of Dr. Osler. Man, died November 26th from typhoid fever, in the fourth week, with symptoms of perforative peritonitis, which developed two days before death.

Autopsy twenty-two hours after death. Abdomen distended, tympanitic, and with beginning greenish discoloration. Gas escaped abundantly on opening the peritoneal cavity. There is extensive fibrino-purulent exudation, most abundant in the lower half of the peritoneal cavity. There is considerable brownish-yellow fluid with fæcal odour. The serosa is intensely hyperæmic. There are two pin-hole perforations of typhoid ulcers in the vermiform appendix, which lies buried in a mass of fibrinous exudate. There are several typhoid ulcers in the small and large intestine. Gas bubbles are present in the inferior vena cava, the systemic and portal veins, and in the right heart.

Cover slips and cultures from the peritoneal exudate gave the bacillus aerogenes capsulatus, the bacillus coli communis, and streptococci. The gas bacillus predominated. This same bacillus was found in large number and pure culture in the blood, with the exception of one colony of the colon bacillus in a gelatin roll from the heart's blood. Aerobic cultures from the spleen and liver were sterile.

The three last cases are all examples of pneumoperitonitis due to perforation of typhoid ulcers. The bacillus aerogenes capsulatus was mixed with various intestinal bacteria in the exudate, and in

such numbers as to indicate its multiplication in the peritoneal cavity, although to what extent this occurred during life can not be determined. Inasmuch as we have evidence that this bacillus is capable of causing peritonitis, with formation of gas, its presence under these circumstances is not a matter of indifference, even when associated with such recognised pathogenic species as the pyogenic cocci and the colon bacillus. The amount of gas in cases of peritonitis due to intestinal perforation is extremely variable, and it is noticeable that in the preceding cases it was in large quantity in the peritoneal cavity, and that the intestines were markedly tympanitic. The gas found in the heart and vessels in the last case was doubtless referable to post-mortem development of the gas bacillus, the autopsy being twenty-two hours after death with evidences of beginning cadaveric decomposition.

XII. Service of Dr. Kelly. Negress, aged thirty-nine, admitted June 26th with strangulated umbilical hernia and fæcal vomiting. The strangulation had existed for two days before admission. Temperature 102° F. General condition bad. Herniotomy was performed. Strangulated omentum was excised and the gangrenous gut stitched to the abdominal wall. Death after forty-eight hours.

Autopsy twelve hours after death. Gas in the peritoneal cavity, which is shut off from the artificial anus formed at the umbilicus, this anus being in a loop of intestine 185 centimetres above the valve. Visceral and parietal peritonæum hyperæmic and coated with a thin layer of fibrin. The intestinal loops are adherent to each other and to the omentum by fresh fibrin. Old fibrous adhesions in pelvic peritonæum and over liver and spleen. General arterio-sclerosis. Several small old ulcers in the cæcum.

Cover slips from the fibrinous exudate on the peritonæum show as the predominating organism the bacillus aerogenes capsulatus. In addition a few smaller bacilli and cocci are seen. Cultures furnished the bacillus aerogenes capsulatus and also the bacillus coli communis and a few streptococcus colonies. Cultures from the blood negative; from the kidney, liver, and spleen, the colon bacillus.

In this case the gas bacillus doubtless entered the peritoneal cavity from the strangulated gut, but whether or not before the operation was not determined. The exudate was fibrinous, not purulent. The predominance of the gas bacillus in the exudate at the fresh autopsy indicates that it was a factor in the production of the peritonitis.

The last five cases, together with Case III, afford conclusive proof that the bacillus aerogenes capsulatus is sometimes an inhabitant of the intestinal canal, from which it may invade other parts of the body. That it may occur also in the alimentary canal of animals is proved by the following observation:

On the morning of December 10th one of the laboratory stock of rabbits which had not been used for experiment refused to eat and remained quiet in its cage. It was found dead in the afternoon at three o'clock. It was alive an hour before. The body was still warm and not stiff. The rabbit was placed on ice and the autopsy made two hours later. The peritoneal cavity was greatly distended with gas. It contained some blood-stained fluid which had accumulated, especially about the omentum, which was of a deep-red colour. The stomach was moderately distended with gas, and in its anterior wall was a perforation 2 millimetres in size, through which food extruded. On opening the stomach there were found, in addition to the perforated ulcer, two other circular ulcers, with red edges, one 3 millimetres and the other 4 millimetres in diameter, extending into the submucosa. The intestines were not especially tympanitic. There was no pus in the peritoneal sac. No other lesions were found. There was no gas in the vessels or viscera.

Cover slips from the bloody fluid in the peritonæum showed in large numbers, bacilli with the morphology of the gas bacillus and here and there a coccus. Anaerobic cultures from the fluid yielded numerous colonies of the bacillus aerogenes capsulatus with typical reactions and a few colonies of a white staphylococcus.

The occurrence of perforating gastric ulcer as a spontaneous disease in the rabbit is of much interest. The ulcers seemed to be of hæmorrhagic origin. The presence at the autopsy, made shortly after death, of a hæmorrhagic condition of the omentum and of bloody fluid and of gas in large amount in the peritoneal cavity indicates that the perforation occurred during life. No other cause of death was found. Under these circumstances the large number of gas bacilli, predominating greatly over the other bacteria, in the peritonæum is significant. There was no trace of the post-portem digestion of the stomach sometimes found in rabbits.

The following case presents many points of interest, especially the evidence of the production by the gas bacillus of pneumoperitonitis without perforation, of gas in diabetic urine, and of gas cysts in the intestine:

XIII. Service of Dr. Osler. Man with diabetes mellitus and cirrhosis of the liver. Had been ill for nearly two years. Had several profuse hæmorrhages from the stomach during the six months preceding death. Developed thrombosis of right femoral vein three months before death. Abdomen became distended and tender. A week before death severe abdominal pain, most marked in right hypochondrium, set in and the abdomen became very much distended. There was a uniform tympanitic sound over the anterior surface of the abdomen. The region of liver dulness was tympanitic. The patient died comatose April 6th. Peritonitis from perforation of a gastric or duodenal ulcer was the clinical diagnosis. Autopsy was made six hours after death. No trace of cadaveric decomposition. Considerable subcutaneous emphysema, especially in the neck and thighs. Heart and blood vessels contain gas bubbles. On opening the distended and tympanitic peritoneal cavity a large amount of gas, free from foul odour, escapes. Intestines moderately distended with gas. Considerable amount of blood-stained turbid serous fluid in the peritoneal sac. No actual pus. Visceral peritonæum hyperæmic. There is a general fibrinous exudate, in most places thin, but thicker over hæmorrhagic areas in the intestine. There is hæmorrhagic infarction of the jejunum in three places, the largest being twenty-five centimetres in length. Here the coats of the intestine are firm, thickened, and of a uniform reddish-black colour, from infiltration with extravasated blood. There is no perforation of the intestine or stomach. The mesenteric veins are extensively thrombosed, likewise the splenic and portal. There is a collection of cystic cavities filled with gas extending over an area ten centimetres long in the jejunum, which is here not infarcted. These cysts form projections into the lumen of the intestine, some being as large as a bean. They lie in the submucous and mucous membranes. Similar gas cysts are present in the mesentery near its attachment to the intestine. Gas bubbles are present in the omentum. The capsule of the liver is much thickened by diffuse fibrous growth and there is cirrhosis. The urinary bladder is distended with pale, frothy urine due to mixture with gas bubbles. Gas holes are not present in the liver and solid organs, with the exception of the mesenteric glands, which contain small gas vesicles. The endocardium, particularly of the right side, shows diffuse imbibition of blood-colouring matter.

Cover slips of the blood show bacilli with the morphology of the gas bacillus. Those from the peritonæum show the gas bacillus in large numbers; in much smaller numbers also bacilli resembling the colon bacillus. Gas bacilli are in apparently pure culture in the various thrombi in the abdominal veins. They are found mixed with other bacteria in the intestine.

Aerobic plate cultures from the heart's blood, lungs, spleen, kidneys, peritonæum, and liver gave colonies of the colon bacillus. Anaerobic plates from the blood, peritonæum, and urine gave numerous colonies of the bacillus aerogenes capsulatus with typical reactions. From the intestine the gas bacillus and the colon bacillus were cultivated.

Microscopical examination of sections of the intestine showed extensive invasion by the gas bacillus of the coats in the infarcted areas, where the

mucous and submucous coats were necrotic and filled with fibrin, red and white blood-corpuscles. Sections through intestine which is not the seat of infarction showed dense masses of gas bacilli upon the surface of the mucosa.

The gas cysts of the intestine occupy both the mucosa and the submucosa. Those which begin in the mucosa and remain there lie next to the muscularis mucosæ. Others beginning in the submucosa may involve the mucosa, which is sometimes spread out so as to form a thin film over the surface. The part of the intestine containing these cysts stains poorly, and contains numerous gas bacilli.

In the preceding case a man with diabetes and cirrhosis, who had repeatedly vomited blood, developed extensive thrombosis of the mesenteric, splenic, and portal veins, leading to hæmorrhagic infarction of the intestine. During the last few days of life the symptoms of perforative peritonitis manifested themselves, but the autopsy, made only six hours after death, showed that there was no perforation of the stomach or intestine, although the inflamed peritoneal cavity contained much gas. Gas had begun to make its appearance in the blood vessels, and there was subcutaneous emphysema. Gas cysts were in the intestinal wall, and there was pneumaturia. The bacillus aerogenes capsulatus had invaded the peritoneal cavity evidently through the infarcted wall of the intestine. In consideration of the symptoms of pneumoperitonitis during life, of the short time which had elapsed between the time of death and the autopsy, of the conditions found at autopsy, and of the experimental results from inoculation of the bacillus, it seems to us altogether probable, if not absolutely demonstrated, that in this instance the gas bacillus was the cause of pneumoperitonitis without the existence of any communication between the peritoneal cavity and an air-containing viscus or the exterior. It is true that the bacillus coli communis was also present, although in smaller number than the bacillus aerogenes capsulatus, and that the colon bacillus has been claimed, especially in cases of diabetes, as a cause of pneumaturia and gaseous phlegmon, but whatever its status as regards these affections may be, there are no observations which show that the colon bacillus can produce general subcutaneous emphysema, gas bubbles in the blood vessels, or gas in the serous cavities, whereas we have

positive evidence of the capacity of the bacillus aerogenes capsulatus to cause such conditions as were present in this case. Diabetes mellitus is doubtless a factor favourable to the fermentative production of gas, especially in the urine. Pneumaturia was not observed during life, but it is a symptom which can be readily overlooked when the gas is present in the urine in small amount, and it was not especially looked for.

In the following case the gas bacillus was also associated with non-perforative acute peritonitis, but the evidence as to its causative relation to the peritonitis is not conclusive:

XIV. Service of Dr. Kelly. Negress, sixty years old, with arteriosclerosis, chronic diffuse nephritis, anasarca, and ascites. During last two weeks of life she vomited almost incessantly and developed symptoms of acute peritonitis. Died July 5th.

Autopsy twenty-one hours after death; no greenish discoloration; about 4,000 cubic centimetres of cloudy yellowish-red fluid in peritoneal cavity. Visceral peritonæum congested and covered by a thin layer of fibrin. Gas was not noticed on opening the abdominal cavity, but it might have escaped observation. All of the cavities of the heart contain gas bubbles, which are present also in the blood vessels. No subcutaneous emphysema or gas holes in the organs. Diffuse red staining of endocardium and intima. Small contracted kidneys. Sclerosis of the arteries. Old fibrous adhesions about the lungs, liver, spleen, and pelvic viscera. Intestines normal save swelling of the lymphatic follicles.

Cover slips from the heart's blood and peritoneal cavity showed numerous bacilli with the morphology of the gas bacillus which was obtained in culture from these situations and when inoculated into pigeons produced characteristic gaseous phlegmon. Aerobic cultures yielded many colonies of the colon bacillus from the peritonæum and lungs and a few from the spleen, liver, and kidneys.

In the preceding case the possibility that the peritoneal cavity was invaded by the gas bacillus after death can not be denied. Doubtless the formation of gas bubbles in the heart and vessels was post mortem. As the presence of gas in the peritoneal cavity was not suspected, no especial attention was directed toward its detection. A moderate amount of gas in the peritoneal sac may be readily overlooked, as it escapes on free incision. The peritonitis was characterized by a thin fibrinous exudate, turbid blood-stained fluid, and redness of the visceral peritonæum, these being the char-

acters which we have found associated with the presence of the bacillus aerogenes capsulatus under conditions indicating the ante-mortem invasion of this organism. The peritonitis was associated with chronic Bright's disease.

In the preceding fifteen observations (including that of the rabbit) the bacillus aerogenes capsulatus invaded the body apparently either directly from without or from the stomach or intestine. In the two following cases it is probable that the bacillus entered by way of the lungs.

XV. Service of Dr. Osler. Woman with acute and chronic valvular endocarditis, chronic Bright's disease, ascites, and pleurisy. Died September 4th. Autopsy twelve hours after death. Peritoneal cavity contains several thousand cubic centimetres of clear straw-coloured serum. Peritonæum smooth. Left pleural cavity contains several hundred cubic centimetres of blood-stained serum. Visceral pleura coated with shaggy fibrin. Many subpleural ecchymoses. Left upper lobe and upper part of lower lobe compressed. Remainder of lower lobe solidified by extensive hæmorrhagic infarction. The branch of the pulmonary artery supplying left lower lobe occluded by firm reddish-gray thrombus, with central softening. Chronic and acute vegetative endocarditis of mitral valve. Hypertrophy and dilatation of heart with ante-mortem thrombi in right and left auricular appendages. Red, granular kidneys. No subcutaneous emphysema or gas bubbles in the heart, blood vessels, or organs.

Cover slips from the exudate in pleural cavity shows capsulated diplococci and also many encapsulated bacilli with the morphology of the bacillus aerogenes capsulatus, which was isolated in culture. The same bacillus was found in the infarcted area in the lung and in small numbers in the bronchial mucus. Aerobic and anaerobic cultures from the blood and other organs were sterile.

The presence of gas bacilli in this case at fresh autopsy in the infarcted lung and pleural cavity, and their absence from the blood vessels and other organs, indicate that this bacillus invaded the pleural cavity from the lung. The consolidation of the lung by hæmorrhagic infarction undoubtedly favoured the lodgment and survival of the bacillus in this situation. As the presence of gas in the pleural cavity was not suspected, the chest was freely opened at autopsy without taking any precaution to determine its presence. The lanceolate coccus was probably the primary cause of the pleurisy, but in view of Levy's observation, already cited, of the gas

bacillus in a case of pneumothorax without perforation, and of our Case XIII of pneumoperitonæum due to the gas bacillus without perforation, it is permissible to suppose that in the present case the gas bacillus may have multiplied in the pleural cavity and produced gas during life, although we can furnish no positive proof of this from the autopsy, and confirmatory evidence from examination of the chest during life is lacking.

XVI. Service of Dr. Osler. Man with thoracic aneurism, aortic insufficiency, and chronic passive congestion with pulmonary infarctions. Died February 14th. Autopsy twenty-four hours after death. Œdema of extremities. Bloody, frothy fluid oozes from nose and mouth. Intestines distended with gas. Peritonæum smooth. In right pleural cavity considerable quantity of blood-stained turbid fluid. Fresh fibrinous exudate over visceral pleura, which is ecchymosed. There are numerous hæmorrhagic infarctions in right middle and lower lobes, which contain very little air and a few scattered wedge-shaped infarctions in the upper lobe. The infarctions have a peculiar opaque colour and contain gas. The whole lung is congested, and contains abundant frothy, bloody fluid. Branches of the pulmonary artery contain many ante-mortem thrombi. The left lung likewise contains scattered hæmorrhagic infarctions, and presents a condition similar to that of the right. The corresponding pleura is coated with fibrin, but there is little fluid in the cavity. Heart is hypertrophied and dilated; aortic valve insufficient from chronic thickening; marantic thrombi in right auricular appendix and in apex of right ventricle. Aneurism about the size of a small orange involving ascending and part of transverse aortic arch. Atheroma of aorta. Moderate atrophic cirrhosis of liver. No abnormality of stomach or intestine.

The endocardium of the right heart and the intima of the pulmonary vessels and of the veins adjacent to heart are diffusely reddened. A similar reddening does not exist in the left endocardium or the systemic arteries. Gas bubbles are present in the pulmonary vessels, the right heart, the venæ cavæ, the jugular, femoral, and portal veins. They are absent from the left heart, the systemic arteries, and the abdominal viscera. No subcutaneous emphysema.

Cover slips from the blood in the right heart and the adjacent veins show many bacilli indistinguishable from the gas bacillus, and apparently unmixed with other bacteria. A surprisingly large number of the same bacilli, likewise without other bacteria, are seen in cover slips from infarcted areas in the lung. Cultures from the blood of the right heart, thrombi, infarcted lung, and veins containing gas furnished abundant colonies of the bacillus aerogenes capsulatus. No other organism was found except streptococci in an anaerobic culture from the heart's blood. Aerobic cultures from blood and organs were sterile. As in other cases, animals were inoculated with the cultures of the gas bacillus which caused the

characteristic lesions in guinea-pigs and pigeons, and gave the typical reaction when inoculated into the circulation of rabbits which were killed shortly afterward.

Microscopical examination of sections of the lung showed extensive desquamative pneumonia and older and fresh infarctions. The gas bacilli were demonstrated in large numbers in the larger pulmonary vessels and capillaries, in the lymphatics and in the alveoli of the lung. There was considerable infiltration of the margins of the infarctions with polynuclear leucocytes, which often filled up the lymphatics.

It may be mentioned that an autopsy was performed immediately after this one upon a man dying of phthisis and croupous pneumonia within an hour of the death of this patient, and that no gas or gas bacilli were found, so that the latter autopsy may serve as a control. There were no putrefactive changes in either case, the bodies having been kept on ice.

Inasmuch as in the preceding case gas bacilli were found in very large numbers in the pulmonary infarctions, more abundantly than elsewhere, and as gas bubbles were present only in the right heart and the vessels leading to and from this side of the heart, we consider it probable that the invasion of the bacillus in this case took place from the lungs. Invasion from the intestine can not be positively excluded, but if this had been the direction we should have expected to find development of gas in the liver. Welch and Nuttall demonstrated in their experiments that gas bacilli introduced after death into the right ventricle develop with formation of gas in the course of the vessels leading to and from this side of the heart, and that only after a certain time do they appear in the systemic arteries and the organs. We think it likely, from the conditions found at autopsy, that the bacilli entered the infarcted lung during life, but to what extent they may have multiplied during life we can not say. Nor can any positive statement be made as to whether the bacilli were conveyed to the lung from without through the air passages or were carried there by the circulation. Inasmuch as the gas bacillus is a not uncommon inhabitant of the intestinal canal, it seems to us probable that, like other intestinal bacteria, this organism may, under certain conditions, enter the circulation without doing any harm. Assuming such an invasion in the present case, it would not be surprising if the bacillus should find in infarcted areas of the lung conditions permitting its survival which did not exist

elsewhere. Infarcted areas of the lung are the seat not only of a dense hæmorrhagic infiltration, but of actual necrosis of the lung tissue. That the conditions in infarcted lung tissue are sufficiently anaerobic to permit the growth of the gas bacillus can scarcely be doubted when one considers the dark reddish-black colour of the extravasated blood in pulmonary infarctions. In Case III the gas bacillus seems also to have been localized in the lung, as it was found only there and in the gaseous phlegmon.

In the three following cases the bacillus aerogenes capsulatus was found in inflamed parts of the urinary tract:

XVII. Service of Dr. Halsted. Man, admitted December 25th with retention of urine due to urethral stricture following gonorrhœa. During six weeks preceding admission bladder had been catheterized three times daily. General condition septic. Fever, rapid pulse, tongue dry and coated. Urine contained albumin, casts, and pus. Perineal section performed two days after admission. Vesical symptoms relieved, but general condition remained critical, and patient died January 1st.

Autopsy by Dr. Blumer three quarters of an hour after death in cold weather. Gaping wound in perinæum, communicating with bladder, without signs of repair. Chronic purulent cystitis. Double pyo-ureter and pyonephrosis. Multiple miliary abscesses in the kidneys and the prostate. Stricture of urethra. Chronic interstitial orchitis. Chronic diffuse nephritis. Arterio-sclerosis. Multiple fat necroses in peripancreatic fat, omentum, and panniculus adiposus. Parenchymatous degeneration of heart and liver. A few gas bubbles in the left auricle detected upon first opening the chest.

Cover slips from renal abscesses, renal pelvis, ureters, bladder, and perineal wound showed a large number of bacilli with the morphology of the gas bacillus; also bacilli resembling the colon bacillus, streptococci, and a few rather long, thin bacilli. Contrary to our custom, cultures were not made at the time of the autopsy, but the organs, wrapped in wet cloths, were put on ice. Culture tubes inoculated the following day did not show the gas bacillus. The demonstration of the gas bacillus in this case, therefore, was not complete, and therefore not satisfactory.

In the following case Dr. Blumer cultivated the gas bacillus from the kidney at the autopsy, and the following day failed to obtain it in culture from the same organ, which had remained during twenty-four hours wrapped in wet cloths on ice.

XVIII. Service of Dr. Halsted. Man, with hypertrophied prostate, admitted December 6th with retention of urine and constant dribbling. Patient was in a stupid condition and no history could be obtained. Died comatose January 1st. Only a partial autopsy was permitted. Hypertrophy of prostate. Double pyo-ureter and pyonephrosis. Multiple miliary abscesses in the kidneys. The renal pelves and ureters were distended with gas and

contained pus mixed with bubbles of gas, and small gas cysts were present in the mucous membrane of the pelves, which in places is hæmorrhagic and coated with fibrinous exudate. Chronic diffuse nephritis. Spleen large and soft. Gas not present in the blood and organs other than the urinary.

Cover slips from the kidney, renal pelvis, ureters, and bladder showed as the predominant organism bacilli, sometimes encapsulated, with the morphological characters of the gas bacillus. In addition, bacilli resembling the colon bacillus, thin bacilli, and cocci, in pairs and groups, were present in the same situations. The bacillus aerogenes capsulatus, with its typical reactions, was isolated in culture from the kidneys and urinary passages.

XIX. For the following case we are indebted to Dr. Williams, of Buffalo, who will publish the report in full in the *Bulletin of the Johns Hopkins Hospital.* Through the kindness of Dr. Williams we were enabled to examine cultures from this case, and to confirm his diagnosis of the presence of the bacillus aerogenes capsulatus :

The autopsy was made in cold weather, thirty-one hours after death. The pelves and calyces of both kidneys were much dilated and contained pus. There was also double pyo-ureter. Many small gas cavities were present in the liver (*Schaumleber*) and myocardium. Cover slips from the pus in the renal pelves showed many bacilli like the gas bacillus, and also slender bacilli and streptococci. Gas bacilli and streptococci were found also in cover slips from the liver. The bacillus aerogenes capsulatus was isolated in pure culture from the liver and the pus, and the usual inoculations of rabbits, guinea-pigs, and pigeons were made with the characteristic results which will be described subsequently.

Although the records of the three preceding cases are not so complete as they might be, they furnish proof of the presence in suppurative inflammations of the upper urinary passages and the bladder of the bacillus aerogenes capsulatus in combination with other bacteria. In one of the cases there was gas in the renal pelves and ureters, and it may have been overlooked in the other cases. In one case there was no invasion of the gas bacillus beyond the urinary tract at the autopsy. It is interesting to note the presence of gas cysts in the pelvis of the kidney. The detection of gas bubbles in the left auricle in Case XVII three quarters of an hour after death is highly significant.

The following case is one of gas cysts of the intestine without invasion of the gas bacillus beyond the intestine :

XX. Service of Dr. Osler. Man in hospital for several weeks with choked disk, headache, and other symptoms of cerebral tumour. There was extremely obstinate constipation. Autopsy January 5th, fifteen hours

after death, in very cold weather, the body having been kept in an ice chamber. There was no evidence of post-mortem decomposition. There was a vascular sarcoma the size of a hen's egg in the right frontal lobe of the brain. Congestion of lower lobes of the lungs and bronchopneumonia. Chronic diffuse nephritis. The stomach contained dark-coloured fluid. The large intestine throughout contained hard scybalous masses. The intestines were not distended. The peritonæum was smooth, without excess of fluid. There were two areas in the jejunum, ten centimetres apart, each about five centimetres in length, occupied by gas blebs around the whole circumference of the gut. These cysts are visible through the serous coat as a mass of bubbles, and they form projections on the mucous surface. They occupy all of the coats of the intestine. The individual cysts are the size of a pea and smaller. Upon incision they collapse. There is no evidence of inflammation in the intestine. There is no gas in the other organs or in the blood vessels.

Cover-slip specimens show bacilli apparently identical with gas bacilli among the bacteria in the intestinal contents. Within the cysts the gas bacilli are so numerous that other bacteria are not recognised on the cover slips. Cultures from the intestine and from the cysts gave abundant growth of the bacillus aerogenes capsulatus. Cultures from other organs and the blood are sterile.

In the preceding case the invasion of the gas bacillus was limited to the intestinal wall, in which a mass of gas cysts was developed over two circumscribed areas. The bacillus was present in large numbers in the intestinal contents.

The following three cases are examples of the rapid development of gas after death. The first one is of very remarkable character:

XXI. For the report of this case we are indebted to Dr. Berkley, who brought the specimens to the laboratory for our examination. Negro, aged fifty-one, had been an inmate of the epileptic ward of the Bay View Asylum of Baltimore for eleven years. The attacks were of the nature of *grand mal*, and occurred often once or twice daily. On the evening of June 3d he appeared well. At five o'clock the following morning he was found by the attendant unconscious in bed with bubbles of reddish froth issuing from the mouth and nose. He died within twenty minutes of the time that he was found in this condition.

Within an hour after death the body was noticeably swollen and emphysematous. Six hours later the body was still more swollen and emphysematous, and purple blebs of various sizes had appeared over the upper part of the cadaver. The autopsy was held twelve hours after death. No rigor mortis. The body, especially the upper part, is enormously swollen. The eyelids are puffed out and emphysematous. The skin of the scalp is emphysematous. The tissues of the scrotum and penis are greatly distended with gas. The abdomen is enormously distended and tympanitic.

The extremities, shoulders, neck, and chest crackle on pressure, and there are large numbers of blebs. A large amount of gas free from putrefactive odour escapes upon opening the peritoneal cavity. The gas burns in jets of bluish flame with detonation on applying a lighted match. The large veins contain blood mixed with gas. The heart is distended with blood and gas bubbles. The blood vessels generally contain gas, but in relatively smaller amount than the subcutaneous tissues. Gas bubbles are present in the liver and spleen in large numbers. On section of the kidneys, blood mixed with gas bubbles oozes from the cut vessels. The lungs are congested, œdematous, of dark-red colour, and the gas which can be squeezed from the lungs burns with bluish flame. The stomach and intestine are only moderately distended with gas. Cover slips and cultures from all parts showed in very large numbers and in pure culture the gas bacillus which inoculated in pigeons and guinea-pigs caused typical gas phlegmons, not always fatal.

The rapid and diffuse development of gas in the preceding case within a short time after death can not well be explained, in the light of Welch and Nuttall's experiments, otherwise than as referable to a general distribution of the gas bacilli throughout the body during life by the circulation. No lesions were found to indicate the point of entrance of the bacilli into the circulation. We shall refer to this case again in considering the various conditions with which the gas bacillus is associated.

For the notes of the two following cases we are indebted to Dr. W. T. Howard, Jr., Professor of Pathology in the Western Reserve Medical College of Cleveland.

XXII. Man died in the third week of typhoid fever. Autopsy eighteen hours after death. No cadaveric decomposition. There was no emphysema or marked tympanites at the time of death. Emphysema of the subcutaneous tissues, especially of the neck, chest, axillæ, and scrotum, was found at autopsy. The heart and blood vessels generally contained gas. The endocardium and the intima of the vessels were diffusely reddened by imbibed colouring matter. The serous cavities contained gas and blood-stained serum. The mediastinal tissues were emphysematous. The liver and spleen contained gas holes, but were less distended with gas than the kidneys. In the small intestine were typical typhoid ulcers, rarely reaching to the muscle. There was no perforation or peritonitis.

The bacteriological examination by cover slips and cultures gave abundant gas bacilli with the usual reactions in cultures and when inoculated into animals.

XXIII. Man died in the second week of typhoid fever. The day before death there was marked tympanites. Autopsy eight hours after death. No odour or discoloration indicating decomposition. There was no swell-

ing of the body, but on careful examination, slight emphysematous crackling was detected on the outer side of the forearm just below the elbow, at the wrists, and along the outer side of the thighs. No gas in the superficial veins. No gas in the heart or blood vessels, or in any organ except the liver, which was large, pale in colour, and everywhere perforated with small gas holes. The gall bladder and the bile ducts contained a large amount of gas. The walls of the gall bladder and the surrounding connective tissue were emphysematous. There was extensive necrosis of the liver cells found upon microscopical examination. Peritonæum smooth, without excess of fluid. Many typhoid ulcers in the intestine without perforation.

Cover slips showed an enormous number of gas bacilli in the liver. A few were found in the heart. The bacillus aerogenes capsulatus was isolated in culture from the liver, and gave the typical reactions when inoculated into animals.

It is Dr. Howard's opinion—with which we agree—that in the last case the gas bacillus invaded the liver by way of the bile ducts. The large amount of gas in the gall bladder and biliary passages speaks for this view, as we have found that gas is late in appearing in these situations when the gas bacilli are conveyed to the liver by the blood vessels. Although in Case XXII there was far more extensive general development of gas throughout the body, the liver in the present case contained much more gas than in the former. The liver was the only organ which contained gas bubbles, and although gas bacilli had begun to make their appearance in the blood vessels, they had not at the time of the autopsy produced gas bubbles in the blood, although gas had appeared in a few situations in the subcutaneous tissue.

(*To be concluded in the following number.*)