greater in connexion with dismissals from Belvidere Hospital than with those from Parliamentary-road Hospital. Theoretically the Belvidere Hospital results should be much better than those in the other hospital, but in the period under observation it has not been so, and, although wider observation might correct the impression, the assumed advantage of the separate system of bathing is not at all apparent in the present investigation; indeed, it raises a doubt whether the *nimbus* of infection which attends a convalescent scarlet fever patient, even beyond the gates of the hospital, is capable of removal by soap and water at all.

2. *Reappearance of desquamation and other lesions.*—In a few cases certain lesions—chiefly desquamation and discharges from the ear and nose—will recur. In the present investigation evidence thereof was present in 19 per cent. of the dismissals associated with return cases. This recurrence would appear to be dependent on the altered conditions which surround patients on their dismissal from hospital.

3. *Influence of overcrowded wards.*—In the majority of dismissals associated with return cases there is no visible lesion, and the endeavour to impugn overlooked or insufficiently disinfected clothing is rarely satisfactory. But there is a tendency in return cases to associate themselves with dismissals from wards where the beds are kept well occupied, and as a very large proportion of scarlet fever patients are children there is some reason to question the accuracy of our present estimate of the smaller cubic space required for them. This could only be finally established by concerted observation of individual wards extending over a long period. From a collective measurement of the ward space the average monthly numbers under treatment in Parliamentary-road Hospital for nine months had an allowance per head ranging between 1250 and 1500 cubic feet, and it is doubtful if at any time the numbers under treatment were within the estimated accommodation at 2000 cubic feet per head. Continued occupancy on a restricted estimate of the requirements, rather than acute but temporary overcrowding, would appear to tend to produce the condition from which many return cases arise.

4. *Interval after dismissal within which the return cases occur.*—Ninety-three per cent. of these are shown to have occurred within fourteen days, and in every case there was community of life either in sleeping or while at meals or play. As a practical instruction to parents the lesson is plain. Every effort should be made to prevent commingling of the recently recovered with healthy children. *The restriction placed on their sleeping together should be absolute.* Where, moreover, children are treated at home, and the isolation has been successful, special care should be taken of other children during the period of disinfection. All this would seem to point broadly to the necessity for convalescent homes being established as a resting place between the hospital and the patient's home, so that, if the expression be permitted, the system might be washed by the constant breathing of untainted air. But here, again, there would finally arise a scarlet fever laden atmosphere, and if my impression of the effect of this is correct, we shall avoid the consequences rather by regarding the 2000 cubic feet per patient, or its equivalent in air-supply, as an irreducible minimum irrespectively of the age of the patient. I have purposely omitted to compare the higher percentage of return cases associated with dismissals from Knightswood Hospital because the numbers are small, but it will not have escaped notice that patients' clothing is not here exposed to steam disinfection, as in the other hospitals.

Sanitary Chambers, Glasgow.

CASES OF LIVER AND GALL-DUCT SURGERY.

By JOHN D. MALCOLM, M.B., C.M., F.R.C.S. EDIN.,
SURGEON TO THE SAMARITAN FREE HOSPITAL.

(Continued from p. 1507.)

CASE 5. *Operation for hydatids in a child five and a half years old.*—This case was that of a child five and a half years of age, whose father's father had died from cancer and whose mother's sister had died from an internal tumour after middle life. The child was one of six—two older and three younger, all being very healthy and strong. A lump in the upper part of the patient's abdomen had been noticed for two

years. It was gradually increasing in size and seemed to be the cause of attacks of pain by which the child was occasionally seized. She was under the care of Mr. Soffe of Harling, in Norfolk, and Dr. Benjafield of Lower Edmonton had seen her with him. As the diagnosis was obscure, Dr. Benjafield brought the patient to consult Mr. Knowsley Thornton, who expressed the opinion that the swelling was a hydatid tumour, and it was arranged that I should operate. When I saw the child there was a tense rounded prominence on the front of the liver, measuring about two inches in diameter, and its central part being behind the upper portion of the right rectus muscle. It exhibited a distinct hydatid thrill on percussion. The outline of the liver dulness was not altered, but it was rather lower than is usual even in a child. The patient was the daughter of a farmer who kept and bred dogs, and this child was particularly fond of them, and was especially pleased when playing with the puppies, which are often infested with tapeworms. The child was brought to lodgings near my house, and on April 21st, 1892, assisted by Dr. Benjafield, I cut down upon the swelling, opened a hydatid about the size of an orange, and removed the lining capsule and the daughter cysts. I found that there was a slightly smaller cyst above and close to the first. This was opened and cleaned out through the cavity of the first. On examining the parts around I found a large number of small growths scattered apparently irregularly over the peritoneum. They were about the size of hazel nuts, and I supposed them to be hydatid cysts. Three of them were very slightly attached to the omentum and were removed. I did not cut into these growths for some months, and when I did I found that they were lymphatic glands. They were very large glands, even for a child, and I was then under the impression that lymphatic glands were not to be found in the omentum. I was, of course, prepared to find hydatid cysts in the sub-peritoneal connective tissue by the conditions I had observed in the case last related. The opening in the liver was secured to the abdominal incision and the sacs were drained by rubber tubing. During convalescence there was little trouble except from the fractiousness of a somewhat spoilt child. The temperature, taken in the groin, and the pulse rose respectively to 102.6° F. and 120 on the second day after the operation. By the end of a week they were down to 97.6° and 96. On the ninth day the temperature rose to 103.2° and the pulse to 120 without any cause that I could discover. The drainage-tubes had been removed, washed, and reinserted some days before, and the bowels had also been moved freely before this time. By the tenth morning the temperature was again down to 97.6°, the pulse to 96, and a temperature of 99° was the highest recorded after this until the child had gone home. The drainage-tubes were gradually shortened, and the patient left London five weeks after the operation, on May 25th. The tube was then about an inch long, and it was finally removed a week later, but the wound did not completely heal till the beginning of August. By this time the child had grown much stronger and stouter, but a short time after the wound healed she complained of much pain in the abdomen and of feeling sick. There was some swelling round the scar, and the abdomen was very hard, but there was little if any tympanites. The patient vomited at times, was disinclined for food and lost flesh, and her temperature rose as high as 102°. Dr. Benjafield saw her with Mr. Soffe, and opium and belladonna were administered, with hot applications locally. On Sept. 13th Dr. Benjafield reported a steady fall of temperature, relief of pain, and improvement of appetite. The attack passed off without further trouble, the patient soon grew fat and strong again, and she has had no trouble since. Later, two years and ten months after the operation, the child's mother wrote that she is "perfectly well and strong, and never has an ache or a pain." The cause of the attack of fever and pain four months after the operation in this case is obscure. I am inclined to think that as the child grew stronger the adhesions of the liver to the abdominal wall became gradually weaker by the constant movements of the parts on each other, and that the liver finally broke loose by a rapid rupture of the remaining adhesions. If this explanation is correct the child's liver is probably as free now as if there had been no operation.

CASE 6. *Operation for 789 stones in the gall-bladder.*—The first patient on whom I operated for gall-stones had consulted Dr. Stephen Mackenzie and Mr. Knowsley Thornton,

both of whom had diagnosed the presence of calculi and had recommended operative treatment. The patient was admitted to the Samaritan Free Hospital under my care on June 20th, 1892. She was a healthy, strong woman fifty-eight years of age and had suffered from frequently recurring attacks of pain in the region of the gall-bladder for three years. These attacks began with a very severe one, lasting a week, but not accompanied by sickness or jaundice. A year later, in July, 1890, there was another severe attack, with sickness, jaundice, and clay-coloured stools. The condition of the urine was not noted. This attack ceased suddenly, and after it two small calculi were passed by stool. The patient was free from pain for some months, and then had frequent slight attacks with varying intervals. In February, 1892, she had intense pain for a day and a night, ending, as most of the attacks had done, suddenly. After this the patient never felt well, having always a sense of discomfort and often a dull aching in the hepatic region. Jaundice had only been present on one occasion. There was nothing that seemed to bear on the patient's condition in her family history. She came of a healthy stock, and except for the conditions described and for constipation her own health was excellent. On examination by inspection and by percussion there was nothing abnormal in the abdomen, and by palpation I could not detect any enlargement of the gall-bladder, but in its situation there was some tenderness which varied from time to time, being sometimes diffused over a considerable area, and sometimes hardly present at all. There was always one tender spot on deep palpation, and I judged that this was about the situation of the common bile-duct or cystic duct. The patient wished to go to visit a son in a part of Canada where she would be out of the way of medical assistance, and this was taken into consideration in advising her to submit to operation. On July 12th, 1892, I cut down upon the gall-bladder and found it enlarged but flaccid. On grasping it between my fingers I could bring its opposite sides together, and here and there I could feel and catch hold of a small stone. The impression I got was that there were very few calculi, but when I had drawn off about an ounce of bile by means of an aspirator I found that there was a very large number of stones in the bladder. I made an incision in the fundus and cleared out the contents of the gall-bladder by means of forceps, a lithotomy scoop, and sponges. The opening in the gall-bladder was fixed by silk sutures to the abdominal wound so as to make a fistula. The rest of the incision was secured in the usual way, and the gall-bladder was drained by means of a rubber tube. Of course, great care was taken to prevent fouling of the peritoneum. There were 789 stones collected and counted. The largest was broken. It measured about three-quarters of an inch in its longest diameter, and was of irregularly rounded shape. The greater part of the stones were smaller than a split pea, many were smaller than hemp seeds, and the total bulk in fluid measure when they were dried and well shaken down was a little over an ounce. Besides those counted there were innumerable very small calculi which came freely through the aspirating needle and were seen as mere specks in the bile. Convalescence was very smooth. The temperature rose to 101° F. before midnight of the day of operation, and it was never above 100° in the vagina after the second day. The highest pulse was 80. There was at first a copious discharge of bile, but after a fortnight it diminished greatly. The tube was removed on the twenty-fifth day. There was very little discharge after this, and the patient went home a month after the operation; but it was about three weeks longer before the wound finally healed. The patient gradually regained her strength. I last saw her at the end of August, 1893, thirteen months after the operation. She was then about to start for Canada, having been detained by the illness and death of a son, which had entailed on her much work and worry, but there had been no recurrence of gall-stone symptoms.

CASE 7. Operation for gall-stones.—The next case was that of one of Mr. Alban Doran's patients, but he has kindly permitted me to record it here, as I had charge of the case and performed an operation on the patient during his temporary absence. "A woman aged forty-two years, a widow, came under my care at the Samaritan Free Hospital in October, 1893. She was a laundress, tall and once strong. On Aug. 4th, 1893, she lifted an unusually heavy basket of linen. Three days later she was seized with abdominal pains, vomiting, and sweating. There was no

jaundice. After resting three weeks in bed she went to work. Early in September another attack of pain came on, without sickness. Dr. Nias and Mr. Arathoon attended her at the Marylebone General Dispensary. She recovered from the pain, and I saw her on Oct. 10th. There was a swelling in the region of the gall-bladder. On Oct. 14th a severe attack of pain occurred. On the 19th the patient was admitted. An attack occurred on Oct. 22nd. The swelling grew larger, and the skin over it became reddened. In a few days the pain went away, but the redness increased and the integuments were oedematous. I suspected obstruction of the gall-ducts. Mr. Knowsley Thornton, who kindly examined the patient, was of a similar opinion, though he thought that possibly the swelling might be an inflamed hydatid cyst. On Nov. 7th I, assisted by Mr. Malcolm, made an exploratory incision along the outer border of the right rectus over the middle of the swelling. I found under the muscular layers an irregular cavity containing pus, clots, and shreds of broken-down tissue. There was hardness behind the cavity. A pocket trocar and cannula was thrust into the hard surface, but nothing oozed out nor did the trocar touch anything that felt like a calculus. I then believed that the cavity might represent an abscess in the abdominal walls, developed early in August after a bruise from a heavy clothes-basket. I washed out the cavity with iodine water and drained it. I did so, believing that if the disease was simple abscess it would thus be cured; if it were more than abscess further operation could be more safely undertaken when the cavity was rendered aseptic. For a few days the patient seemed to be better. I then, on account of severe indisposition, left her in Mr. Malcolm's charge.¹ At this time the patient was not jaundiced. The abscess gradually contracted until only a sinus remained, but this showed no tendency to heal, and a thin mucous fluid oozed up from the bottom of the wound. On examining the parts towards the end of November I discovered that I could pass a probe through the wound into the gall-bladder, which was evidently full of stones. It was arranged that I should remove them, and on Dec. 2nd I enlarged the opening upwards and extracted a number of stones, but, when I had removed all I could find, no bile escaped. It was evident that if I did nothing more the secretion from the gall-bladder would prevent the closing of the fistula, and but little, if any, good would result from the operation. I therefore made a free incision upwards and downwards about three and a half inches long, opening the peritoneum, separating the adhesions of the bladder to the abdominal wall, and cutting out the track of the fistula. It was still impossible to handle the gall-bladder because the omentum and transverse colon were adherent to it and to the lower surface of the liver. These adhesions were also separated until I could manipulate the gall-bladder freely. By means of the fingers outside the bladder, and a finger or instrument in it, I found and extracted some more stones, making 134 in all. The smallest of these was about a quarter of an inch in its longest diameter; most of them were rather larger than this, and three or four measured half an inch across; one large one was broken. Still no bile escaped, and although I explored thoroughly all the under surface of the liver and the parts along the course of the ducts I could not find any other stones. I was, therefore, reluctantly compelled to close the wound, the gall-bladder being fixed and drained as in the previous case. In this instance I also inserted a glass drainage-tube into the right loin pouch of the peritoneal cavity to remove quickly any discharge from the divided adhesions. Very little serum escaped through this tube, and it was removed forty hours after the operation. The highest temperature after operation was 101° F. on the first day, the pulse did not rise above 100, and the fever quickly subsided. There was very little discharge from the gall-bladder at first, but after the third day it increased and was distinctly tinged with bile. On the sixth day some fragments of stone escaped, and on the ninth day the dressings were soaked with bile. On the tenth day another piece of stone, nearly as large as a pea, was found in one of the drainage-tubes, but now no bile escaped; and after this there was never more than a tinge of bile occasionally in the discharge, which was again scanty. Mr. Doran resumed the charge of the case on Dec. 19th, and "the patient was discharged in the middle of January, 1894, with a fistula. She called on me

¹ Mr. Doran has kindly written the portion in inverted commas for me.

occasionally. She was readmitted in May. As the fistula had not closed and as a hard body could be felt by the probe and the attacks of pain continued I operated on May 26th, assisted by Mr. Malcolm. First I passed a long probe up the fistula. The patient was well under chloroform, yet I could not feel anything like a calculus, though two days before I had made the probe touch a body which felt precisely like a gall-stone. I opened the upper part of the old cicatrix and cut through the fistula in the parietes. After cautious probing I found that the gall-bladder could be entered. By means of a probe-pointed hernia knife the fistulous opening was enlarged. The finger could be then passed into the fundus of the gall-bladder, which was found to be just below the level of the fistula. Therefore I cut upwards to the extent of an inch and a half. Then I passed in my right forefinger and felt a small stone. By manipulation it was extracted. Then I passed a child's lithotomy sound and found the cystic duct dilated with calculi. I pressed my fingers on the parietes immediately over the upper end of the wound and pushed the stones forward into the gall-bladder. They were then extracted with long-handled forceps. They were two in number, one an eighth of an inch in its longest diameter, the other over half an inch and much faceted. I then passed the lithotomy sound four inches up the bladder and duct, reckoning from the wound on the surface of the bladder. After deliberate exploration no calculi could be felt. A stout red rubber tube was placed in the bladder, the thick edges of the wound were united with silkworm gut sutures, but the walls of the gall-bladder were not included in the sutures as they adhered firmly to the parietes. The wound was dressed with alembroth gauze; towels covered externally by a mackintosh were placed over the part and round the right flank. The operation was concluded at 10.35 A.M. Free oozing took place; at 7.20 P.M. it was simply sanious, but at 9 P.M. bright-green bile escaped. At 9 A.M. on May 27th much yellow bile came away. On the morning of the 28th the temperature reached its highest, 100.2° in the axilla; a very free discharge of bile occurred; the patient then declared that she was at last absolutely free from pain. After the 29th the temperature fell to normal. On June 16th the patient left the hospital; the fistula had closed. On July 17th I saw her; she was in good health; there was neither pallor nor jaundice, nor swelling in the region of the gall-bladder. On Oct. 19th she had a severe attack of pain, followed by jaundice next day. On the 24th I saw her; the jaundice was passing off. The fistula remained closed. Early in December I saw her again; she had felt local pain on the day before. On Dec. 28th the patient was seized with severe pain in the region of the gall-bladder; next day her friends noticed that she was deeply jaundiced. On Jan. 1st, 1895, she felt better and came to see me at the hospital. The conjunctivæ were yellow. No enlargement of the gall-bladder could be detected. A few days later she was attacked with bronchitis and was laid up nearly a month. There was much local pain all the time. After getting up and working for a few days she felt a sharp attack of pain; no jaundice was observed, and the suffering soon passed off. On Feb. 21st I saw her again. She had grown thinner, but her complexion and appearance were healthier than at any other time since she had been under treatment. On June 15, 1895, she visited the hospital in excellent health, free from jaundice and pain. The fistula remained closed."²

At the last operation Mr. Doran suggested that the large stone he removed might have come down the hepatic duct after my operation, and it seems to me almost impossible that a stone of irregularly rounded shape, and more than half an inch in diameter, could have been passed over in the thorough examination which I made if it were anywhere outside the liver. Moreover, it would appear from the history that other stones had been left after Mr. Doran's last operation. There is also evidence to support the view that the bile-ducts may be dilated within the liver substance and may form a receptacle for calculi. Mr. Knowsley Thornton has put on record a case in which he removed over 400 stones from a cavity in the liver close to its anterior surface—a cavity which from its situation must have been a dilatation of a comparatively small duct. On the other hand, in the case under consideration it is obvious that from the commencement of the patient's illness until the bile flowed freely from the wound

after Mr. Doran's last operation the chief trouble was due to obstruction of the cystic duct, and that during the whole of that time there was only occasional obstruction of the hepatic or common bile-ducts. There seems to me to be a considerable weight of evidence in favour of the view that when the patient lifted the heavy basket in August, 1893, the big calculus which Mr. Doran removed at the third operation was forced into, and became jammed with others in the cystic duct and that I failed to discover them. The difficulty in this case is not unique, for from what I know of other men's work there can be no doubt that stones of considerable size may quickly pass down the hepatic duct or that they may be hidden away in corners of the ducts in a most extraordinary manner.

CASE 8. *Operation for four gall-stones found respectively in the gall-bladder and in the cystic, hepatic, and common ducts.*—The last of these cases was that of a woman who was under the care of Dr. Tresilian of Enfield, and she sought advice mainly on account of yellowness of the skin. She was twenty-eight years of age, had been married nearly five years, and had no children. Early in 1892 she had had an attack of pain in the region of the gall-bladder, lasting a few hours, accompanied by slight jaundice and followed by discomfort for a week. She got quite well, and remained so till Dec. 11th, 1893, when she had another and more severe attack of pain lasting three days. This was accompanied by jaundice, the absence of bile from the stools, and its presence in the urine. These symptoms did not pass off and the patient began to lose flesh. In January, 1894, there was another attack of pain followed by a constant aching in the hepatic region. The patient was admitted to the Samaritan Free Hospital on Feb. 12th. Constipation was then extreme, but a stool passed the day before the operation, although very pale, was not absolutely devoid of bile. The gall-bladder was felt distended and tender, and the liver dulness was slightly enlarged. The patient was not a strong woman; she said she had had rheumatic fever four times, and there was a slight, harsh systolic aortic murmur. Otherwise she seemed fairly healthy, but was of nervous type. Her mother was supposed to have shown symptoms of gall-stones. On Feb. 17th I opened the abdomen over the gall-bladder. There was no adhesion to the abdominal wall, but the omentum was extensively adherent around the gall-bladder. After separating the adhesions I opened the bladder. It contained no bile, but about an ounce of white secretion and two stones. The first of these was barrel-shaped, with a facet at each end, although there was no sign of a stone having been placed in front of it. Probably before the ducts became occluded, when the gall-bladder was liable to distend and collapse, this stone occasionally changed its position, sometimes one end and sometimes the other being opposed to the deeper calculus. The second calculus was of similar shape, but its inner end had two facets on it and was therefore somewhat wedge-shaped. These stones were removed with the greatest ease. After I had sponged out the fluid in the gall-bladder I passed a finger into it, and by manipulation with the fingers of the other hand in the peritoneal cavity I felt two openings very far back in the cavity of the bladder and could touch a stone in each, whilst outside the bladder I could define these. I judged that my finger was in the dilated cystic duct, the curves of which had been to a great extent straightened, and that I felt one stone in the hepatic duct and one in the common bile-duct, both these stones being of elongated shape. I attempted to remove the lower one, but it was necessary first to dilate the opening. In endeavouring to pass a forceps into the duct I suddenly found that I was able to push its closed blades a considerable distance onwards, and after this I could not find the stone. A careful examination failed to show any sign of rupture of the duct, and therefore I presume that the stone was pushed into the bowel. It was never found in the stools although carefully watched for, but possibly it was broken up by the forceps into small fragments. I next endeavoured to get out the upper stone, but although I could feel the lower end of it distinctly I failed by any means that I tried to extract it until I enlarged the opening upwards with a knife, in doing which I pierced the stone, and it at once broke into many pieces. Almost immediately after the stone broke bile flowed into the bladder, and this facilitated the removal of the fragments. When these had been extracted or pushed out by the fingers in the peritoneal cavity the fundus of the gall-bladder was sewn to the edge of the external wound, and a drainage-tube was inserted as in the two other cases. In

² See note 1.

this case also I placed a glass drainage-tube in the loin pouch. Convalescence was uneventful. The highest pulse was 96. The temperature in the vagina rose to 101.4° in the evening of the second day after the operation, but came well down, as low as 99° F., on the fourth day. On the fifth day the patient's condition was satisfactory in every respect. A saline purge was administered in repeated doses and was followed by sickness, distension, abdominal pain, and a rise of temperature to 101.2°. All attempts to move the bowels by purgatives were stopped, and although the patient vomited a great deal of green fluid the sickness gradually ceased, the temperature fell, and the pain passed off. On the seventh day some very hard masses of feces were passed after an enema had been administered, and the bowels gave no further trouble. The glass tube was removed forty-eight hours after the operation. There was little discharge of bile from the wound at any time, the urine quickly ceased to contain bile, the stools became normal, and the jaundice very slowly disappeared. The patient went home three weeks after the operation, but it was six weeks before the wound healed, and it reopened four times, discharging a little matter and quickly healing again each time. The last occasion was in July. On Feb. 22nd, 1895, more than a year after the operation, the woman was quite free from irritation; the cicatrix was merely a line with a slight pucker at the point where the drainage-tube had been. The patient had a very sallow complexion, and she said that this was sometimes more obvious than at others. She had had no pain in the region of her liver since the operation, and had been able to do her house-work without trouble. She said that she sometimes felt depressed and lazy, when a purgative would put her all right again. I think there is no doubt that she had been neglecting to attend to the condition of her bowels.

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THE PHYSICS OF CARDIAC SOUNDS AND MURMURS.

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(Concluded from p. 1509.)

It has been seen that the recoil of the aortic wall cannot throw the semilunar valves into sonorous vibrations, because a membrane is not thrown into sonorous vibrations when it is distended by a mass of liquid. If, however, the semilunar valves are incompetent then the recoil of the aortic wall will give rise to the production of a *stream* of liquid which will regurgitate into the ventricle. Here again there are the two necessary elements for the production of a sound or murmur—viz., a stream of liquid, and the aortic surface of the membranous semilunar valves against which this stream will impinge as it rushes past the aortic orifice, and, inasmuch as this stream will be a relatively slow one, a murmur and not a sound will result. The murmur will also be best heard near its seat of production.

If the semilunar valves are completely destroyed a ventricular diastolic murmur will still be heard. How is this murmur produced? Let the aorta of an excised heart be firmly ligatured; let the greater part of the left auricle be excised, as also the mitral valves; let water be now poured into the left ventricle from the mitral orifice. There are now exposed to view the left ventricle filled with water and the mitral orifice. Let the nozzle of a gum elastic syringe filled with water be introduced into the ventricle through the mitral orifice. If now the end piece of a binaural stethoscope be applied to any part of the external surface of the ventricle and the syringe be compressed, the direction of the nozzle being such that the stream of liquid will impinge against the inner surface of the ventricle in the vicinity of the stethoscope, then a well-marked blowing murmur is heard. It can thus be demonstrated that a muscular membrane enclosing a liquid can be thrown into sonorous vibrations, which will be heard as a blowing murmur when a stream of liquid is made to impinge against its internal surface. This is the explanation of the diastolic murmur heard in aortic incompetence even after complete destruction of the semilunar valves; the regurgitating stream of liquid impinges against the internal surface of the ventricular wall and throws

it into sonorous vibrations; the murmur is here best heard below the position of the semilunar valves, for it is there that its seat of origin lies.

I will now examine the mode of production of the first sound. The muscular origin of this sound may be easily dismissed, not only because, as has been theoretically demonstrated, a cardiac contraction cannot give rise to a sound, owing to its absence of tetanic character, but if a stethoscope be applied to the biceps of a man and this muscle be made to contract powerfully no sound is heard approaching to the first cardiac sound, although here the acoustic conditions would be much more favourable for the audition of a sound if a muscular contraction could give rise to it.¹ If the aorta of an excised heart be firmly ligatured and the left auricle be slit up or excised, so as to expose to view the auricular surface of the mitral orifice, and if now the liquid contents of a large gum elastic syringe be forcibly driven into the ventricle from the auricular surface of the mitral orifice the following takes place: the ventricle becomes distended with fluid, and in its distended condition the mitral valves close in and completely shut the mitral orifice. Exactly the same result is obtained if, instead of injecting liquid, air be forcibly injected into the ventricle. As in the case of the semilunar valves, so also here it is the anatomical relations existing between the mitral valves and the internal surface of the ventricle that force these valves to completely close the mitral orifice in diastole of the ventricle, when the distension of this cavity has been produced by the forcible injection of liquid or air. The valvular flaps are so attached between the fibrous ring of the orifice and the columnæ carneæ that, when the ventricle distends, a space is left between each flap and the ventricle wall. When liquid is made to distend the ventricular cavity it presses equally in all directions. Placed between the ventricular wall and the valvular flaps, it will tend to separate them, and, in doing so, will push the ventricular wall outwards and the mitral valves inwards and backwards. But the fluid which is exercising this liquid pressure is being introduced by the mitral orifice. Therefore a moment will arrive when the pressure within the ventricle will equal that which is being exercised at the mitral orifice, and when that moment arrives the valves which were closing will have closed completely. These valves have closed, however, not owing to any reaction on the part of the ventricular muscle; they have closed solely owing to the liquid pressure which was being exercised behind the flaps, and this liquid pressure was being directly introduced through the mitral orifice, the perfect closure of the valves being coincident with, and the result of, the last drop that entered the ventricle. By substituting the gum elastic syringe for the left auricle it is seen how the mitral valves are closed by the auricular contraction; and this closure, it is important to bear in mind, can only take place at the latter part of the contraction, for the first and greater part of the auricular contraction is occupied with the distension of the ventricle, which distension must of necessity first take place in order that the anatomical relations of the valves may place these under favourable conditions for their rapid and complete closure. Now, applying the principles of production of sounds and murmurs by means of fluid streams impinging against membrane, the nature of sounds and murmurs produced at the mitral orifice may be studied. During the auricular contraction a stream of liquid is rushing past the mitral orifice into the ventricle, but towards the end of the contraction the mitral valves are suddenly thrown in against the orifice, and the stream impinges against them in this act, and as this stream is passing rapidly the valves are thrown into sonorous vibrations, which produce a sound. The first sound is thus the direct result of the auricular contraction. Its intensity will depend upon the relative strength of the contraction; its pitch will depend upon the physical condition of the valves, being lower the thicker the membranes are.

A difficulty will at once be seen to arise with this interpretation of the first sound. We have been taught to consider the cardiac impulse as due to ventricular contraction and the first sound as synchronous with the impulse. Now I do not wish to digress from the main subject of this paper by discussing the cause of the cardiac impulse; suffice it to

¹ Over ten years ago, while occupying the post of house surgeon at the Royal Southern Hospital of Liverpool, I accidentally found out this experiment while washing out a heart under a water-tap after a post-mortem examination. I then showed this experiment to some of the physicians and surgeons present at the hospital. Subsequently I learnt in Dr. Walshe's treatise on Disease of the Heart that this experiment had been previously performed by Baumgarten. It is strange that text-books on physiology make no mention of the experiment.