THE HEART SOUNDS.1

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During the last few years renewed interest has been displayed in the interpretation of the heart sounds. The study of the heart sounds held pride of place as a clinical method, from the time of the introduction of the stethoscope until Mackenzie drew attention to the importance of the cardiac muscle. Prior to his time study was directed towards the description and elucidation of heart murmurs.

Mackenzie rightly stressed the importance of considering the heart muscle in any examination, but after his time there was a tendency to disregard murmurs to some extent. Lately there has again been a swing of the pendulum, and research workers and cardiologists again are intensely interested in heart sounds. This renewed interest has been brought about by the increase of our knowledge of the physiology of the heart and by the introduction of the electrocardiograph and later of the phonocardiograph or the stethograph.

The results of the study of the heart's action, the synchronous recording of the pressures of the heart's chambers and of the heart sounds, and the electrocardiogram have added enormously to the knowledge of the changes taking place during the cardiac cycle.

The Cardiac Cycle.

The succession of changes occurring in the heart during its contraction is referred to as the cardiac cycle. These changes occur very rapidly, so that
to understand their significance fully special recording apparatus is necessary. Harvey referred to the great difficulty of observing these changes, and it is very interesting to recall his words:

When I first tried animal experimentation for the purpose of discovering the motions and functions of the heart by actual inspection and not by other people's books, I found it so truly difficult that I almost believed with Præcatorius that the motion of the heart was to be understood by God alone.

I could not really tell when systole or diastole took place, or when or where dilation or constriction took place, because of the quickness of the movement.

In many animals this takes place in the twinkling of an eye, like a flash of lightning. Systole seemed at one here, diastole there, then all reversed, varied and confused.

So I could reach no decision, neither about what I might conclude myself nor believe from others. I did not marvel that, Andreas Laurentius wrote that the motion of the heart was as perplexing as the flux and reflux of Euripus was to Aristotle.

These changes in the heart during its action, which so perplexed Harvey, and which all who have watched the heart beating under the X ray screen have found so difficult to evaluate, have been studied very exhaustively in animals and man. Experiments in recording the intraauricular and intraventricular pressures in animals, the recording of aortic and venous pulsation in man by the polygraph, and the results of electrocardiography have enabled scientific workers to build up a not unimposing mass of precise knowledge of the heart's action.

To correlate the sounds that we hear with the stethoscope with what is actually taking place in the heart it is necessary for us to have a mental picture of the cardiac cycle.

We must remember that: (a) blood pours into the auricles from the great veins throughout the whole cycle, except for a short period, 0-1 of a second, during which the auricle is actually contracting, that is, the auricular systole; (b) filling of the ventricle (in the normal heart with adequate semilunar valves) takes place throughout the cycle, except during actual ventricular contraction and a short period subsequent to this (0-08 of a second), which represents the time between the closing of the semilunar valves (the aortic and pulmonary valves) and the opening of the auriculo-ventricular valves (the mitral and tricuspid valves).

Numerous methods have been used to register the pressure changes of the cardiac chambers and great vessels, including those of Marey, Tick and Hurtle; but the greatest assistance has been rendered by Wigger's modification of Frank's optical method.

Metal capsules, containing a diaphragm and mirror, are inserted into the lumina of the various parts, and changes of pressure are registered by reflected light falling on a moving photographic film. In this way the action of the various chambers of the heart is synchronously recorded. At the same time the electrocardiogram and the phonocardiogram may be registered on the same record.

The third positive wave, $V$, is due to the rise of the pressure in the auricle as the blood pours in from great veins during ventricular systole, that is, while the auriculo-ventricular valves are closed.
The negative wave, Y, is due to the fall of the auricular pressure when the auriculo-ventricular valves open. Sometimes a small notch is seen near the summit, which is ascribed to vibrations set up by the closing of the semilunar valves.

In actual practice the effect of auricular contraction does not appear to account for very much—it is only one-tenth of the cardiac cycle—and when it ceases to contract, as in auricular fibrillation, filling of the ventricle does not appear to be interfered with.

A wave of the auricular curve and is due to auricular systole.

When the ventricle contracts, the pressure of its contents almost immediately rises above the auricular pressure; this causes firm closure of the auriculo-ventricular valves, which actually bulge into the auricular cavity to produce the C wave in the auricular pressure curve.

The pressure in the ventricle continues to rise rapidly, giving us the almost perpendicular upstroke of the curve; when it rises to just above the pressure in the aorta and pulmonary artery respectively the semilunar valves are forced open and the blood issues forth from the heart, the ventricular and aortic pressures rising together to the summit of the wave. Then as the ventricles relax there is a rapid fall of pressure. This rapid fall produces an incisura in the aortic curve. As the pressure falls it rapidly reaches a point which is less than the diastolic pressure, and the semilunar valves close. The further relaxation of the ventricle during diastole allows the pressure to fall below the auricular pressure, and the auriculo-ventricular valves open, so that the cavities of the auricle and ventricle freely communicate and allow the blood to pass from the great veins and auricle into the ventricle, in which, as it fills, a slight rise in pressure occurs.

From the figure we see that ventricular systole is divided into two periods by the opening of the semilunar valves. The first period is called the presphygmic period or period of isometric contraction; that is, first, a period of ventricular systole which is not registered in the arterial tracing or...
blood pressure curve, and, secondly, a period in which the muscular fibres are contracting on an incompressible mass of blood and are not shortened.

The second period of systole is called the sphygmic or ejection period when blood passes from the heart into the aorta and pulmonary artery. The short period at the beginning of diastole following the ejection period and leading to the opening of the auriculo-ventricular valves is called the post-sphygmic period or period of isometric relaxation. Both the semilunar and the auriculo-ventricular valves are closed and no blood is entering the heart, the heart is relaxing, but the fibres are not lengthening.

The first heart sound corresponds to the isometric contraction period and period of maximum ejection.

The end of the period of ejection corresponds to the commencement of the second sound. The period of systole in man is that taken from the beginning of the first sound to the second. This period also corresponds to the time as measured from the beginning of P (in the electrocardiogram) to the end of T. Wiggers divides the ejection period into a period of maximum ejection and a period of reduced ejection; he refers to that part in the early diastolic period corresponding to the incisura of the carotid pulse and aorta curve just before the opening of the semilunar valves as the protodiastolic period.

After the auriculo-ventricular valves open the pressure rapidly falls. This is the period of “rapid filling” of the heart. This is followed by a period when the ventricle is nearly full, little blood is entering and the pressure is low. This is referred to as the period of diastasis. This again is followed by auricular systole, giving us the first small wave. The period of diastasis lengthens as the heart slows. Diastasis is followed by auricular contraction.

Let us now compare the curve of the heart cycle with the records of cardiac sounds.

Einthoven and Gelut in 1894, using an instrument made up of a stethoscope, a carbon microphone and a capillary electrometer, were the first to make satisfactory records of the heart sounds. The instrument was later improved by the introduction of the string galvanometer instead of the capillary electrometer. They published their records in 1907. In these early instruments great difficulty was encountered, first in attempts to eliminate extraneous noises, and secondly in an attempt to develop an instrument in which the inertia of the moving parts was decreased to a minimum. Wiggers and Dean, and later Williams and Dodge, introduced types of sound-recording machines, all of which had certain drawbacks.

Lockhart last year introduced his electrostethoscope, which appears to be the most practical instrument of this type so far to come forward (Figure IV). By the instrument sound waves in the desirable band of frequencies, that is, 75 to 550 cycles per second, are picked up and are amplified. Room noises much above this band are largely excluded.

The human ear has the greatest difficulty in hearing the vibrations at either end of the “sound
mitral valve. Others consider that it is due to the vibrations set up by the blood rushing into the empty ventricle during the period of "rapid filling" which immediately follows the opening of the mitral and tricuspid valves.

The fact that the period between the second sound of the heart and the third sound is always constant in the same reading, and that the mitral diastolic murmur always follows or replaces this sound, rather suggests that it corresponds to the opening of the mitral valve.

This third heart sound is frequently increased in mitral stenosis.

The fourth heart sound is undoubtedly due to auricular activity. Auricular sounds are almost always heard in cases of complete heart block, when the auricles are beating independently of the ventricles.

Clrighton Bramwell has called attention to the part which the auricular sound plays in producing a peculiar roughening of the first sound. This he found to be most noticeable in athletes who were accustomed to long periods of strenuous exercise, such as long-distance swimmers, runners and cyclists. It was not so noticeable in sprinters or middle-distance athletes.

Bramwell has shown by phonogrammatic tracings how the auricular sound accentuates the first sound when the auricular contraction happens to syn-
chronize with the ventricular contraction (Figures VII and VIII).

These tracings also show how the early part of the first sound is made up of these auricular vibrations.

It has been shown that the auricular sound does not bear a fixed relationship to the P wave of the electrocardiogram; it usually follows it at some distance, this distance being much greater than that between the R wave and the ventricular contraction.

This pause between the P wave and the auricular sound suggests that it is not the actual contraction of the auricle that we hear, but that the sound is produced by vibrations of the auriculo-ventricular valves and of the ventricular walls set up by the inflow of blood when the auricle contracts.

The importance of this sound is well seen in the discussion of "gallop rhythm".

Findings in Rheumatic Children.

One hundred and thirty-six children who had a definite rheumatic history were examined by Margaret McKee. All the children had had polyarthritis, chorea, or a carditis of a rheumatic type. The cases were divided into groups according to the classification of the New York Association: (a) cases of possible or potential heart disease, (b) cases of mitral incompetence, (c) cases of mitral incompetence and mitral stenosis, (d) cases of mitral stenosis and aortic incompetence, (e) cases of mitral stenosis and aortic stenosis.

Potential Heart Disease.—There were eleven patients in this group of possible and potential rheumatic heart disease according to the classification of the New York Association. All had had rheumatism; all had systolic murmurs. There was no cardiac enlargement, either clinically or radiographically. The systolic murmurs in the tracings were exactly the same as those which were audible in normal children (Figure IX). One case showed only some waving of the base line after the second sound, but no diastolic murmur was ever heard.

Mitral Incompetence.—The New York Heart Association lays down that for the condition to be diagnosed there must be cardiac enlargement and a systolic murmur at the apex.

All in this group had cardiac enlargement and a blowing systolic murmur at the apex; 30% of them had in addition a faint, short, inconstant diastolic murmur at the apex. These were included in this group because of the murmur being inconstant and of the fact that there was no evidence of an enlarged left auricle. In five cases the second pulmonary sound was increased in intensity, that is, accentuated pulmonary second sound of ordinary auscultation.

The systolic murmurs were most intense early in systole and tended to fade out. Diastolic murmurs occurred in 86%. These diastolic murmurs were
faint. They followed the third heart sound; their sounds changed with respiration, sometimes there was a third heart sound, and sometimes a diastolic murmur.

**Mitral Insufficiency and Questionable Mitral Stenosis.**—There were six in the group of mitral insufficiency and questionable mitral stenosis, which

were divided into: (a) those having a systolic and a short diastolic murmur at the apex—the diastolic murmur was not of a rumbling character, but there were signs of cardiac enlargement; (b) those having an apical systolic murmur and a rumbling diastolic murmur, but no evidence of cardiac enlargement.

**Mitral Insufficiency and Stenosis.**—The group of mitral insufficiency and stenosis could include many of the previous group, but it was reserved for those cases, 57 in number, in which there were a loud systolic and a diastolic murmur at the apex, with definite signs of cardiac enlargement. Of these, 14% showed definite accentuation of the pulmonary second sound.

The systolic murmurs were all loud, some being louder than the first sound. The diastolic murmurs varied somewhat (Figure XI). These diastolic murmurs were louder than in the previous group, and extended right through diastole from the third heart sound to the fourth heart sound. In three cases there was an increase of the intensity of the diastolic murmur in the presystolic period. In 12% of cases there was evidence of a sound, as shown by large vibrations between the auricular sound and the first sound. This corresponds to the presystolic murmur so assiduously searched for by the careful examiner. These records were taken with the patient at rest; it is suggested that if the patients had been exercised this presystolic accentuation would have shown out more frequently.

From these records we can see that the characteristic murmur of mitral stenosis is a diastolic murmur, which commences at the time of the third heart sound, continues through diastole and may or may not have the crescendo presystolic ending.

There is always a definite space between the second sound and the beginning of the diastolic murmur. This silent period corresponds to the isometric relaxation period between the closing of the semilunar valves and the auriculo-ventricular valves; in other words, the time between the closing of the aortic valves and the opening of the aortic valves. This pause helps sometimes to distinguish a mitral from an aortic diastolic murmur.

**Mitral Stenosis and Aortic Deficiency.**—The next group are those with mitral stenosis and aortic deficiency. Sixteen patients were in this group. Here clinically, in addition to the systolic and diastolic murmurs at the apex, there was present a high-pitched blow in the aortic area during
diastole, following immediately the second sound (Figure XI).

The stethograph tracing in these cases shows the diastolic murmur badly because of its low intensity. The low intensity of this murmur makes it difficult to record, though it can be heard quite well with the stethoscope.

The last group of cases have well marked mitral and aortic stenosis. The tracings are similar to the last, but there is a pronounced systolic murmur at the base.

Tracings were also taken in certain cases during the attacks of rheumatic carditis. The sinus arrhythmia in 30% disappeared from time to time, and in the others was less marked. This is partly but not wholly obtained by the increase in rate which usually accompanies carditis. The tracings show that the increased rate occurs at the expense of the diastolic period, chiefly of the period of diastasis.

During active rheumatic carditis there is an increase in any murmurs present, and the murmurs may change. They usually become louder and more highly pitched. In some cases the stethoscope suggested the presence of gallop rhythm, that is, there was a definite triple rhythm (Figure XII). This is shown in such a case to be due to an accentuation of the normal third heart sound, with some weakening of the first heart sound. This should not really be referred to as gallop. It is much better to give this the term "triple rhythm" and to reserve the term gallop for those grave cases in which the production of this true gallop rhythm is of the gravest significance. This type of triple rhythm has been referred to as proto-diastolic gallop. This is a misnomer, as the period of proto-diastole is quite definite and is recognized at that part of the early diastolic period corresponding to the notch on the carotid curve. In this type of gallop it is the third heart sound which gives the triple rhythm. This occurs after the period of isometric dilatation and is not infrequent in mitral stenosis.

Crichton Bramwell has shown that in true gallop, the presence of which is an indication for the gravest possible prognosis, the particulars of triple rhythm are brought about by auricular systole in special circumstances.

1. There must be tachycardia, usually over 100 beats per minute.
2. There must be sinus rhythm and auricular contractions. Gallop has been seen to disappear with the onset of auricular fibrillation.
3. There must be advanced dilatation of the ventricles.
4. Mitral stenosis is not present. This type of gallop makes up a definite clinical entity, and we should reserve the term "gallop" for it. The term "gallop" should not be loosely used and should rank with the term "angina". This again should be reserved for a definite clinical entity and should never be used except to express the pain from...
coronary incompetence, and should thus bear with it its grave prognosis.

In true “gallop” the third sound is probably due to a marked increase of the ordinary fourth heart sound or auricular sound, it is usually associated with a lengthening of the P-R interval, so that the auricular contraction approaches the time of opening of the auriculo-ventricular valves; that is, the auricular contraction takes place during the period of “rapid filling” and the flow of the blood is rapidly ejected into the dilated ventricle.

The vibrations set up under these conditions produce this form of triple rhythm.

Summary.

1. During the last few years there has been renewed interest in the study of heart sounds and murmurs.

2. Much light has been thrown on the actual happenings of the cardiac cycle by the synchronous recording of the intraauricular and intraventricular pressures, the electrocardiogram and the phonocardiogram.

3. Lockhart’s electrostethograph has been shown to be of the greatest help in the study of the heart sounds.

4. Margaret McKee has shown that sinus arrhythmia and systolic murmurs are normal in the hearts of healthy children.

5. The third and fourth heart sounds are present in all sound tracings of normal hearts.

6. Diastolic murmurs never occur in healthy hearts under ordinary conditions.

7. Mitral diastolic murmurs in mitral stenosis always follow immediately or replace the normal third heart sound.

8. In mitral stenosis there is a period of relative silence between the second heart sound and the diastolic murmur corresponding to the time in the cardiac cycle between the closing of the semilunar valves and the opening of the auriculo-ventricular valves.

9. In aortic incompetence the diastolic murmur follows the second aortic sound immediately and may replace it.

10. Gallop rhythm occurs under certain conditions involving a dilated ventricle, tachycardia, and the absence of auricular fibrillation.

11. The term “gallop” should be strictly reserved to the above clinical syndrome.

12. True gallop rhythm is of the gravest significance.

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SOME OBSERVATIONS UPON PELVICEPHALOMETRY IN LATE PREGNANCY.

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The following is a résumé of fifty pelvicephalometric measurements carried out at the Women’s Hospital, Crown Street, Sydney, and a brief summary of the conclusions resulting from this method of investigation during the later stages of pregnancy.

The radiographic examination of the pregnant woman is of great value to the obstetrician as an aid to the diagnosis of position, presentation and