THE NATURE AND SIGNIFICANCE OF HEART SYMPTOMS.

BY

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I. STIMULI CONCERNED IN THE HEART BEAT.

INTRODUCTION.

IN 1905 I published in this JOURNAL a series of articles on "New methods of studying affections of the heart." The articles were the outcome of a research in which I had been engaged for nearly twenty years. A basis was laid for the differentiation of abnormal rhythms, and the practical importance of the research was illustrated by the action of digitalis. The varied and seemingly capricious effect of digitalis on the human heart was demonstrated to be due to the fact that digitalis may act in one way on a diseased heart and another on a normal heart, and that the drug may act differently in different diseases. Although the methods have been greatly improved, especially since the introduction of the ink polygraph and the electro-cardiograph, and a great deal of light has been thrown upon the mechanism of abnormal rhythms, little real advance has been made in the understanding of matters essential for the intelligent practice of medicine, such as the significance of symptoms and the effects of remedies. It has long been evident that a new concept was needed if these essentials were to be acquired. At the Institute for Clinical Research at St. Andrews we have given particular attention to this aspect of the subject, and we have been able to recognize some of the fundamental principles concerned in the production of the symptoms of disease. The application of these principles to the interpretation of cardiac phenomena has shed fresh light upon the subject which enables us to present the symptoms of cardiac affections in a way that brings out their peculiar significance and opens up new fields for exploration.

The Development of the Heart.

At an early stage of development the heart is represented by a tube, which is pulsatile, the contraction starting at a definite part which in later development becomes the sinus venosus. In the course of development pouches are formed on the side of the tube which ultimately become the auricle and ventricle. Sir Arthur Keith has drawn for me a diagram (Fig. 1) which represents a stage of development. Here the

FIG. 1.—Diagram representing an early stage in the development of the heart. P.C.T. is the primitive cardiac tube, on the sides of which there develop pouches A and V, which become the auricles and ventricles. The primitive cardiac tube in the fully developed heart is probably represented by the conducting system, shown in Fig. 2.

heart is represented by the primitive cardiac tube (P.C.T.), with the auricle (A) and ventricle (V) as pouches on its sides. In the further course of development the contractile function of the tube is lost and taken over entirely by the auricle and ventricle; but the tube remains as the conducting system, the sinus venosus being represented by the cells of the sino-auricular node.

Fig. 2 is a diagram of the fully developed heart; it shows that the primitive cardiac tube has been transformed into the conducting system (sino-auricular node, auriculo-ventricular node, and auriculo-ventricular bundle).

The cells from which the different parts of the heart

have been evolved were originally identical, but as development proceeded the cells became modified to meet the functions imposed upon them. At first each cell could not only contract but could produce the stimulus which caused contraction. Thus it is that while originally the cells of the primitive cardiac tube were contractile as well as stimulus-producing, they gradually lost their power of contraction, but developed the function of stimulus production and conduction, to meet the requirements of the new arrangements for contraction.

The cells of the auricle and ventricle, on the other hand, did not in any special degree develop the stimulus-production

or conductivity function, which remained primitive, but developed the contractile function. Though it is true that all cells of the heart have the power of stimulus production and of conductivity, they have them in a very unequal degree.

In the course of development some peculiar influence is acquired whereby the older tissues represented by the conducting system control the muscle cells of the auricle and ventricle, and it is the loss of this control that enables the muscle cells to show their peculiar nature, as in auricular fibrillation and the idio-ventricular rhythm.

The Constitution of the Heart.

From this way of looking at the matter we can recognize two main structures in the heart concerned in its action, differing widely in structure and in function:

(1) A conducting system, consisting of peculiar cells of two kinds:

- The pale filiform cells constituting the sino-auricular and auriculo-ventricular nodes.
- The large cells, known as the Purkinje cells, which constitute the auriculo-ventricular bundle, and are also found in the walls of the auricles and ventricles:

(2) A contracting system, consisting of the peculiar muscle cells of the auricular and ventricular walls.

There are also nerve cells and fibres, from the vagus and sympathetic nerves, which take part in regulating the sino-auricular node. The valve apparatus is, for the present, not considered.

The Manner of the Starting of the Heart's Contraction.

Before dealing with the features of the different rhythms of the heart it may be as well to indicate the view accepted as to the rôle each part plays in a cardiac revolution.

It is recognized that all the tissues of the conducting and contracting systems just mentioned have the power of starting a contraction. It is recognized that in the normally acting heart the contraction first starts in a collection of peculiar cells situated at the mouth of the superior vena cava—the sino-auricular node (S.A.N., Fig. 2).

It is assumed that these cells have the power of obtaining material from the blood which, when a sufficient quantity has been stored, renders this node so susceptible to stimulation that it readily discharges a stimulus which causes the auricle to contract. The stimulus passes through the auricle to the auriculo-ventricular node (A.V.N., Fig. 2). Here the same process has been going on as that described in the sino-auricular node, and in response to the impulse from the sino-auricular node the auriculo-ventricular node discharges its stimulus. From the auriculo-ventricular node the impulse is conveyed by the auriculo-ventricular bundle (A.V.B., Fig. 2) to the ventricle, which responds by a contraction.

Such in brief is the view which the present state of knowledge enables us to give of the normal rhythm of the heart. It will be seen that the functions of the conducting system are (1) to originate a stimulus which excites the auricle and ventricle to contract—hence we speak of this function as stimulus production; and (2) to convey the stimulus by a special path—hence we speak of the function of conduction.

There are many abnormal rhythms, due to the fact that the cells, both of the conducting system and the contracting system, possess under certain circumstances the power of starting a contraction. The reason that these cells do not start independently in the normal state is that the sino-auricular node reaches the susceptible stage and "goes off"

FIG. 2.—Diagram representing the two main systems concerned in the heart beat. (1) The conducting system, represented by the sino-auricular node (S.A.N.) and the auriculo-ventricular node (A.V.N.) and bundle (A.V.B.). In both auricles and ventricles are also Purkinje fibres which belong to this system, represented by the scattered cells (r) in the auricle. The vagus (vag.) and sympathetic (sy.) also belong to this system. (2) The contracting system, represented by the muscle cells of the auricle (A) and ventricle (V).

earlier than the other parts of the conducting system, so that before they are ready to start off by a local stimulus they receive the stimulus from the sino-auricular node. The starting places in the conducting system lower than the sino-auricular node become stimutable later than the sino-auricular node; the auriculo-ventricular bundle, for instance, if it does not receive the stimulus from above goes off about thirty times a minute.

Under abnormal circumstances the heart beat may start from a stimulus arising in any part of the conducting system and also in the muscle cells of the auricle and ventricle. There is a marked difference in the heart beat which arises in any part of the conducting system from that which arises in the muscle cells of the contracting system (auricle and ventricle).

The Character of the Heart Beat Originating in the Conducting System.

The normal heart beat, starting at the sino-auricular node, sends a stimulus which affects in orderly sequence the parts below. It is well regulated and proceeds at a pace which leaves time for the cells in all parts to perform their function in a manner likely to be efficient—that is, with sufficient time for them to rest, and to accumulate a sufficient store of nutritive material for the efficient performance of their functions.

The normal beat takes place when all tissues have time to be completely restored. Moreover, the beats which originate lower down in the conducting system, in the auricle (in tissue which I hypothesize is present, as distinct from the ordinary auricular muscle fibres), in the auriculo-ventricular node and bundle; all result in a well-ordered, powerful contraction of the ventricle.

The Electro-cardiogram.

When a muscle contracts it generates a current which can be led from the body and made to activate a string galvanometer. The movements of the string or thread that result can be photographed. In such a photograph certain characteristic movements are recorded, due to the contraction of the auricles and ventricles, which permit some useful deductions to be made as to the place where the heart's contractions start.

The electro-cardiogram of the normal heart beat is distinctive. It is shown in the last part of Fig. 3, where each cardiac revolution is represented by the waves P.R.T.; P is due to the auricular systole, while R and T are due to the ventricular systole. In this record the beats marked P.R.T. are normal beats.

When the starting place of the heart's contraction is at some other place than the sino-auricular node the position and character of the P wave are altered. In the rhythm arising in the auricle the P wave is inverted. I suggest that in such an instance the contraction arises in some part of the conducting system in the auricles. Hitherto there has not been discovered a direct connexion between the sino-auricular node and the auriculo-ventricular node; but G. A. Gibson² pointed out thirteen years ago that Purkinje cells were to be found in the auricle, an observation confirmed lately by Holmes.³

Such cells must be there for a purpose, and that purpose is likely to be the same as in other parts of the heart. There is a great difference between heart beats which presumably start in these cells and the beats which start in the muscle cells (as in auricular flutter and fibrillation), as we shall see later. Moreover, such an electro-cardiogram as Fig. 4 shows an inverted P wave at the beginning, which gradually changes

its character till it becomes upright and normal, suggesting that the stimulus arose at first outside the sino-auricular node, but gradually crept back along a path to the sino-auricular node.

Characteristic electro-cardiograms arise in the auriculo-ventricular node and bundle. All electro-cardiograph records of the ventricular contraction when the stimulus enters the ventricle by the bundle show the R.T. waves. When the stimulus for contraction arises in the ventricle the electro-cardiogram is different, representing usually the features shown by the extra-systole (*ex-sys.*) in Fig. 3.

The Idio-ventricular Rhythm.

The term "idio-ventricular rhythm" is used here to describe the contractions that arise in the muscle cells of the ventricle. It has been used variously, as for the ventricular contraction in complete heart-block, but there the contraction does not arise in the cells of the ventricle but in the cells of the remains of the bundle, and the electro-cardiogram shows the usual ventricular R.T. waves, indicating that the stimulus

entered the ventricle by way of the bundle. There are several kinds of ventricular rhythms, but one form only is dealt with here.

The occasional irregularity which goes under the term of ventricular extra-systole is

due to a contraction which arises in the ventricle, and is quite independent of the stimulus coming down the bundle from the auricle, as shown in Fig. 3, where the large movement (*ex-sys.*) is due to a ventricular extra-systole. In place of a solitary contraction, which is usual, a number of these ventricular systoles may occur and produce a persistent abnormal rhythm (the idio-ventricular rhythm). This rhythm, however, is rarely entirely composed of these beats, but is interrupted by a pause, followed by a beat arising in the normal way. The abnormal rhythm is therefore characterized by groups of small beats interrupted at varying intervals by one or two large normal beats, as shown in Fig. 5, where there are two groups of these idio-ventricular beats. The diagram (Fig. 6) explains the tracing, and shows that the auricle is pursuing one rhythm, and that for the most part the ventricle is pursuing another and more rapid rhythm, interrupted by a beat which comes down from the auricle in a normal manner, shown in the diagram by a line passing across the space of the A.C. interval. The electro-cardiogram of the

idio-ventricular beat shows a series of large waves like those of the extra-systole in Fig. 3.

The Output of the Ventricles.

While the electro-cardiograms show

characters distinctive of the places from which the heart's rhythm starts, there is other evidence which throws an unexpected light on the heart beat, the most important being the effect of the abnormal rhythm on the output of the ventricles. The consideration of this part of the subject gave rise to an inquiry into the cause of ineffective beats, which has led to a new field of investigation, and for this purpose we have to go back to the study of the sphygmogram of the radial pulse. We recognize that sphygmographic records give a somewhat imperfect conception of the output, but, imperfect as they are, they are the best we have and are of real value.

But these pulse records are of value also in that they throw light on processes going on within the heart whose recognition is essential to the understanding of the mechanism—such, for instance, as the part played by the conducting system and by the muscle cells of the left ventricle during abnormal rhythms. We will therefore consider the subject here from this point of view.

FIG. 3.—The electro-cardiogram of ventricular extra-systoles. In the first part of the record are three normal beats, P.R.T., followed each by an extra-systole (*ex-sys.*). The beats (P.R.T.) at the end are normal. The type of radial pulse which the extra-systoles produced is seen in the latter part of Fig. 11, where the extra-systolic beats failed to reach the radial artery.

FIG. 4.—Electro-cardiogram of a rhythm starting in the conducting tissue of the auricle and passing to the sino-auricular node. This is shown by the inversion of the P wave at the beginning of the record, and the gradual change of the wave in the upright at the end of the tracing, where the record is normal. (Cohn.)

(a) *The Output of the Ventricle in Beats arising in any Part of the Conducting System.*

We expect that under normal circumstances the contraction of the muscle cells of the ventricle will be so organized that they will contract in such a manner as to facilitate the expulsion of the contents. This organized mechanism is dependent on the manner in which the stimulus enters the ventricle and on the nature of the stimulus. In the various electro-cardiograms the stimulus which arises above the ventricle, whether in the sino-auricular node, the auricle, the auriculo-ventricular node, or the auriculo-ventricular bundle, all produce the same type of ventricular electro-cardiogram. Moreover, in all the rhythms arising in the conducting system there is also an effective contraction of the ventricle. The size and force of the beat depend, within certain limits, on the rate, inasmuch as more blood will have accumulated in the ventricle, and consequently more will be expelled when the rate is infrequent than when it is frequent. The infrequent radial pulse in complete heart-block is strong and forcible.

FIG. 5.—Tracings of the jugular and radial pulses showing the idio-ventricular rhythm. The jugular tracing shows the waves due to the auricle (a) occurring regularly unaffected by the rapid action of the ventricle—shown by the radial beats. There are two groups of these idio-ventricular beats separated by two normal beats of the heart. (See diagram, Fig. 6.)

FIG. 6.—Diagram of Fig. 5 showing the relation of the auricle to the ventricle. The auricular and ventricular beats pursue independent rhythms except when the radial beats are large, and the diagram shows that the stimulus passes the a-c space and stimulates the ventricle.

(b) *The Output of the Ventricle in Beats due to Extra-systole.*

In extra-systoles of the auricle the impulse travels from the auricle by the bundle and enters the ventricle by the usual path, producing usually an effective output. Hence an extra-systole of the auricle may be of good size—smaller than the normal beat merely because it is premature, and in consequence the ventricle is not as full when it contracts in response to the premature auricular stimulus as it does to the normal.

Extra-systoles in the ventricle arise in some part of the muscle cells, and the wave of contraction therefore does not sweep through the walls of the chamber in the normal manner. This is seen in the character of the electro-cardiogram, as in Fig. 3. As the contraction spreads to the muscle cells in a way different from the normal the output is greatly diminished; this is well seen in the small beat which usually results from a ventricular extra-systole, or in the absence of a beat in the radial pulse, as in Fig. 11.

(c) *The Output of the Ventricle with the Idio-ventricular Rhythm.*

As the idio-ventricular beats are of the same nature as ventricular extra-systolic beats, the output of the ventricle is greatly lessened, and the radial beats are in consequence very small. This is brought out in Fig. 5, where there are a series of small beats, due to beats arising from a stimulus in the ventricle, interrupted by large beats arising in the normal way. In the tracing from the jugular pulse it will be seen that the beats of the auricle (a) are regular, and undisturbed by the numerous small ventricular beats. These latter occur in groups, and at the end of a group there is a pause followed by a large beat, which (as shown in the diagram, Fig. 6) is due to the stimulus entering the ventricle in the normal way.

(d) *The Output of the Ventricle in Auricular Fibrillation.*

The ventricular beat in auricular fibrillation is started by a stimulus entering by the auriculo-ventricular bundle, and so we would expect a normal and efficient beat. Apparently

when the rate is infrequent the beat may be efficient, but when the rate is increased the beats tend to become less efficient in a curious manner. When the rate is moderate or slow the rhythm is irregular and there is often a distinct relation between the size of the beat and the preceding pause. But with increase of rate this relationship may be lost, and we have beats of various sizes without any relation to the duration of the preceding pause. This is brought out in Fig. 7, which shows the features characteristic of auricular fibrillation—irregularity in force and rhythm, with the typical ventricular form of jugular pulse. The tracings sometimes

have a superficial resemblance to those of the idio-ventricular rhythm, but there is no pause before the big radial beat, and there is no evidence of an auricular contraction preceding it. Moreover, it must be borne in mind that the stimulus for contraction in the idio-ventricular rhythm arises in the ventricle, while in auricular fibrillation the stimulus enters by the auriculo-ventricular bundle.

The radial tracing (Fig. 7) shows the characters peculiar to auricular fibrillation in that there is often no relation between the size of the beat and the preceding pause, the pause before a small beat sometimes being longer than the pause preceding the larger beats. The jugular tracing shows that the radial beats corresponded with the ventricular contraction, for each radial beat has a corresponding v wave.

The Interpretation of the Radial Tracing in Auricular Fibrillation.

This lack of correspondence between the size of beat and preceding pause seems to be peculiar to this abnormal rhythm. It is possible that the same influence is present in auricular flutter, but that awaits further investigation. At one time I suspected that the small beats might be due to ventricular extra-systoles, but the electro-cardiograph has shown that this is not the case. The only explanation seems to be that the variation in the size of the radial beats is due to differences in the contraction of the muscle cells of the ventricle. Probably they do not all contract at the same time—the varying size of the beat being due to the variation in the number of cells stimulated to contract.

In the patient from whom Fig. 7 was obtained the rhythm of the ventricle would suddenly pass from fibrillation to the normal, and the radial pulse would show the character of a good-sized regular pulse indicative of a good acting ventricle. In considering the reason for the peculiar effect one can only infer that there was some difference in the nature of the stimulus which entered the ventricle, and it is therefore necessary to inquire into the nature of the stimulus to see if it be the same in auricular fibrillation as in the normal rhythm.

The Effect of Auricular Fibrillation and Flutter on the Auriculo-ventricular Node and Bundle.

When the auricle is fibrillating it has been reasoned that each muscle cell throws out a stimulus in its contraction, so that there is an incessant shower thrown upon the auriculo-ventricular node. How many of these pass depends on the susceptibility of the node, and this is estimated by the number of ventricular responses. When the ventricular rate

FIG. 7.—Simultaneous tracings of the radial and jugular pulses. The jugular pulse (c.v.) is of the ventricular type. The beats in the radial are very unequal, and there is no constant relation between the size of the beat and the preceding pause—a large beat sometimes following a short pause and vice versa. This kind of irregularity with a want of relation between the size of beat and the length of the preceding pause occurs only in auricular fibrillation.

is slow it is inferred that the auriculo-ventricular node is less susceptible to stimulation. When the rate is increased in frequency it is assumed that the auriculo-ventricular node is more susceptible. But there is more in the matter than that.

We note such facts as these. When bodily effort is made the ventricular contractions are more numerous than when the rhythm is normal. Thus a patient at rest with auricular fibrillation may have a ventricular rate of 70. On moderate effort it may readily rise to 130 to 150 beats per minute—the same effort raising a normal heart only 10 to 15 beats.

While there is this suggestion of undue susceptibility in a positive sense, we have more convincing evidence of an undue susceptibility in the contrary sense. A patient with a normal rhythm but with a slight delay in the passage of the stimulus from auricle to ventricle, as shown by an abnormally wide *a-c* interval, developed auricular fibrillation. His ventricular rate with the normal rhythm was wonderfully uniform, about 60 beats per minute. With the onset of auricular fibrillation it fell to 40 beats per minute.

The Effect of Digitalis.

The most striking evidence of a difference in the nature of the stimulus is seen in the action of digitalis. The slowing that takes place in auricular fibrillation is much greater than can be produced in patients with a normal rhythm. Not infrequently, after a few doses, the rate would fall from 130 to 50 or 40 beats per minute. When the drug was stopped, in a few days the rate would rise again to 130.

The most dramatic evidence of the effect of digitalis is seen in certain cases of auricular flutter. In some patients with this condition digitalis speedily causes a great fall in the ventricular rate, accompanied evidently with the passage of the auricular flutter into auricular fibrillation. The record in Fig. 8 shows a pulse or ventricular rate of 140 and an auricular rate of 280. After 1 drachm of tincture of digitalis taken for five days the pulse rate fell to 40 beats per minute, as in Fig. 9, and the rhythm had altered to auricular fibrillation, as shown by the jugular pulse. On the sixth day, periods of

the normal rhythm with a rate of 70 per minute (Fig. 10) varied with periods of auricular fibrillation with a ventricular rate of 40 (Fig. 9). It is manifest that the slow ventricular rate is not due to heart-block, for in the periods of the normal rhythm the stimulus was conducted at the rate of 70 per minute, while during the auricular fibrillation it was conducted at the rate of 40 per minute. Moreover, the *a-c* interval in Fig. 10 indicates a normal state of the conducting system (auriculo-ventricular node and bundle).

FIG. 8.—Tracing of the jugular and radial pulses during auricular flutter. (Auricular rate, 280; ventricular, 140.) The reason for the varying height of the *a* wave is that every second auricular contraction falls during ventricular systole, so that more blood is thrown back into the veins, and the *a* waves are therefore larger.

FIG. 9.—Tracing of the jugular and radial pulses from the same patient as Fig. 8 after digitalis. Auricular fibrillation is present, and the ventricular rate is 40 per minute.

FIG. 10.—Tracings showing the normal rhythm, which varied with auricular fibrillation, as shown in Fig. 9. The heart rate is 70 per minute, and the *a-c* interval normal.

was very ill, with breathlessness and pain on exertion. Fig. 5 is a tracing typical of the radial pulse before the administration of digitalis. The response to the drug was very speedy, as after 3 drachms of the tincture the pulse became much slower and at times regular. This effect is seen in Fig. 11. At times the ventricle responds to each auricular beat, as in the first part of this tracing, while in the latter part of the tracing there is one radial beat to two auricular beats. This is due to the occurrence of ventricular extra-systoles so weak that they failed to produce a radial beat.

The digitalis was stopped, and in a few days the heart had increased in rate and resumed all the characters shown in Fig. 5, and the patient felt very poorly. The resumption.

of the digitalis had again the effect described, and he was told to continue the drug. Seen a year later, he was wonderfully well and had got so used to the digitalis that he could regulate the dose according to his necessity.

It is very likely that the effect of digitalis is the same in the fibrillating auricle as it is in the idio-ventricular rhythm. In both instances the auricle and ventricle have escaped from control of the conducting system, and a condition which is

FIG. 11.—Shows the effect of digitalis on the idio-ventricular rhythm. Before digitalis the pulse was very irregular, as in Fig. 5. Digitalis caused the resumption of the normal rhythm, as in the first five beats of this tracing; the rate is halved in the latter part of the tracing, due to the occurrence of extra-systoles, which fail to affect the radial pulse. The auricular rate (waves *a*) is constant throughout. The character of the electro-cardiogram of these extra-systoles is seen in Fig. 3.

susceptible to the influence of digitalis has been produced. Whether that is brought about by the direct influence of the drug modifying the stimulus or acting upon the muscle cells, or indirectly through the vagus, is not clear, but is a subject which awaits further investigation.

It is rare to get this form of idio-ventricular rhythm so persistent. In most of my cases it was transitory. In one other case I got a similar effect, but my opportunities were not sufficient for full observation. Dr. John Parkinson tells me that in one of his cases where this rhythm was persistent digitalis, though given in full doses, was without effect.

The Output of the Ventricle in Partial Heart-Block.

Further evidence of the difference between the two kinds of stimuli is found in what happens in partial heart-block. Here the bundle is damaged, so that the fibres are reduced in number, and the stimulus has a difficulty in passing from auricle to ventricle. However extreme the damage may be, and however weak the stimulus which manages to get through, the resultant contraction of the ventricle is always full and complete. In Fig. 12, where there is, as a rule, but one contraction of the ventricle to two contractions of the auricle, the radial beat is large and effective. In one instance the stimulus of the second auricular beat after some difficulty (as shown by the wide *a-c* interval) did get through to the ventricle, and here an efficient beat follows.

The inference from these facts is that a stimulus weakened in passing through the conducting system, on reaching the ventricle, gives rise to an effective ventricular systole, in contrast to the stimulus arising in the contracting system, as in auricular fibrillation, where the stimulus may not provoke a full systole.

The Different Origins of the Stimuli.

The normal stimulus which arises in the sino-auricular node and passes by the auriculo-ventricular node and bundle to the ventricle is a stimulus of a peculiar kind which arises in cells evolved for this particular purpose. The stimulus which arises in auricular fibrillation is produced by cells which were not evolved for this purpose, the stimulus being merely incidental to the contraction of the muscle cells. It is not likely that the same character of stimulus would be produced by cells evolved for the special purpose and by cells evolved for a totally different purpose.

The stimulus which arises in the conducting system apart from the sino-auricular node—that is, in the auricle and auriculo-ventricular node and bundle—is of the same quality as that which arises in the sino-auricular node. We can therefore recognize two kinds of stimuli: (1) a stimulus A, which arises in the conducting system, and (2) a stimulus B, which arises in the contracting system.

Is the Difference in the Stimuli one of Quality or one of Strength?

Although it may seem that the difference between the two kinds of stimuli is one of strength, yet there are certain reasons which suggest that the difference is one of quality. We have seen, for instance, the peculiar effect of the stimulus on the contraction of the ventricle in auricular fibrillation. This peculiarity is more likely to be due to the quality of the stimulus than to its strength, for the presumably weak stimulus which reaches the ventricle in partial heart-block gives rise to an effective ventricular systole.

The suggestion that the quality of the stimulus is different when it arises in the Purkinje fibres in the ventricle from that when it arises in the muscle cells of the ventricle may account for some curious differences in other abnormal rhythms, as in auricular flutter, extra-systoles, and the idio-ventricular rhythm.

This presentation of the subject is of very real importance for the practice of medicine. The pulse rate and the character of the pulse are among the most instructive signs the doctor uses in estimating a patient's condition. The nature of pulse variations, even with the normal rhythm, is

still imperfectly understood, and, as a consequence, only a small part of the information which they are capable of yielding is available. In the foregoing description some light is thrown upon the variations in rate and character which are due to abnormal rhythms, and we get a little nearer to understanding the action of digitalis, in that a factor hitherto unsuspected has been revealed. This aspect of the subject raises other questions, such as the nature of the stimulus in other abnormal rhythms—auricular flutter, the extra-systole, the idio-ventricular rhythm, etc. It also involves the question of stimulus conduction by nerves and the Purkinje cells. Can they convey and propagate from cell to cell stimuli of different qualities? The muscle cell to muscle cell stimulation in auricular fibrillation raises the question whether such intercellular stimulation occurs in other organs.

Summary of the Difference in the Heart's Contraction arising in the Conducting and Contracting Systems.

1. The stimulus for the normal rhythm of the heart arises in tissues specially evolved for the purpose. The stimulus in auricular fibrillation arises in tissue specially evolved for contraction, the stimulus production being merely an incident in the contraction.

2. There is a remarkable difference between the rhythms which arise in the conducting and contracting systems of the heart, due to the difference in the stimuli. These differences are shown especially in the response of the ventricle. The ventricular systole in the normal rhythm, as well as in those rhythms arising in any part of the conducting system, is complete and effective.

3. The ventricular systole, when the stimulus arises in the muscle cells of the auricle, is often partial and ineffective, and when it arises in the muscle cells of the ventricle it is always ineffective.

4. When the contraction starts in the muscle cells of the auricle, as in auricular fibrillation, the stimulus which arises is much more sensitive to agents which favour or retard its passage to the ventricle.

5. The effect of digitalis is strikingly different, it having a far greater effect on auricular fibrillation and flutter and on the idio-ventricular rhythm than on any rhythm arising in the conducting system.

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THE VALUE OF THE COMPLEMENT FIXATION TEST IN THE EXCLUSION OF ACTIVE PULMONARY TUBERCULOSIS.

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A METHOD of performing the complement fixation test as a means of diagnosis in pulmonary tuberculosis has been published¹ by one of us (A. L. P.). By this method a positive result has been obtained in at least 98 per cent. of cases of definite pulmonary tuberculosis, while 140 cases selected as non-tuberculous controls gave a negative result in 137.

In all, the test has been performed in approximately 1,100 pulmonary cases or controls. Of these some 260 were definite cases of pulmonary tuberculosis, the criterion of a definite case being the undoubted presence of tubercle bacilli in the sputum. All save five of these gave a positive result. Of the five which gave a negative result three subsequently gave a positive. We do not propose here to enter into a discussion

FIG. 12.—Simultaneous tracings of the movements in the neck (*a*, *c*) and of the radial pulse. There are two auricular waves (*a*) to one carotid (*c*) and radial beat, except in one instance where two successive *a* waves are followed by two *c* waves, and the distance between *a* and *c* is much increased in the last of these two beats. In this case the impulse from the auricle is hindered in passing to the ventricle, so that only the impulse from every second beat of the auricle reaches the ventricle except in one instance when the passage of the stimulus is delayed, as shown by the wide *a-c* interval. It is to be noted that the resulting radial beat is large and full, as compared with the radial beats in auricular fibrillation in Fig. 7.