An Address

ON

IRREGULAR ACTION OF THE HEART.

DELIVERED AT THE ANNUAL MEETING OF THE KENT BRANCH
OF THE BRITISH MEDICAL ASSOCIATION.

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IN selecting this subject for my address to the Branch I have been influenced by the following considerations:

1. Irregularity of the pulse and of the cardiac rhythm is a phenomenon which, though it confronts us every day and, when noticed, invariably arrests attention, has very generally puzzled the thoughtful observer. It has long been known that it may convey grave warning, or that it may be almost negligible. But, until quite lately, it has not been possible to differentiate the serious from the harmless varieties of arrhythmia. The chief reason for this ignorance lay in the fact that our usual methods of clinical investigation (the pulse, the apex beat, and almost all heart sounds) refer us to the ventricles alone. The importance of the auricles was unsuspected, and no means were at hand whereby to examine their action.

2. Within recent years a flood of light has been thrown upon this question, primarily by James Mackenzie, who, working with the polygraph, was enabled, chiefly by a careful analysis of the undulations of the jugular vein, to differentiate the auricular from the ventricular contractions. This paved the way for Thomas Lewis, who, with the electrocardiograph, first demonstrated the condition known as fibrillation, and thus cleared up and explained certain points which Mackenzie's work had left obscure. Other names might be mentioned, but it is mainly due to the work of these two clinicians, supplementing the researches of certain anatomists and physiologists, that our knowledge of the cardiac mechanism, both in health and disease, has been greatly extended, and that we are now for the first time in a position to understand and to classify the various irregularities of the heart and the pulse.

3. The prognosis of heart cases, and their management, more especially as regards permission or limitation of effort, is a matter of prime moment to our patients. We can hardly do a man a worse turn than to cut him off needlessly from his work or his recreation—yet to allow him freedom to his undoing is a still more serious mistake. Few more difficult decisions confront us in our daily work, and a careful survey of all the aspects of a case should be made before a conclusion is reached. Mistakes are often made, and anything which helps us towards a right decision is of value. The ability to differentiate the variety of a pulse irregularity puts an important weapon in our hands, and one which will not infrequently turn the scale.

4. My last reason for selecting this subject is that, in addition to being new, it is far from easy, and its importance is not universally recognized. Medicine is wide and widening, and we can none of us keep up with it all round. The interest of some has not yet been awakened to these matters, and others have yet to realize that such terms as "sinus arrhythmia" and "extrasystole," "heart-block" and "auricular fibrillation" refer, not to new and rare conditions, but to the ordinary cases of irregular heart action, with or without valve lesion, which we meet with on our daily rounds. Further, the conclusion is easily drawn that the recognition of such conditions is too complicated for the routine of general practice. The papers which appear in the journals are generally illustrated by numerous tracings of the synchronous undulations of various blood vessels, obtained by ingenious appliances, with which we are most of us unfamiliar; and the meaning of these tracings is not only by no means self-evident, but is sometimes revealed only after close scrutiny even to the experts, who are, in Lewis's words, "fully conscious of the burden which awaits the student or practitioner who has yet to bring himself abreast the times in this field of knowledge"; and it is, indeed, the difficulty I have myself experienced in attempting to extract the kernel from the large amount

of material now available, which has given me the courage to hope that, in endeavouring to put these matters before you in as simple a manner as possible, I may be employing the time usefully. But the task of reducing so technical a subject to simple terms is not light, and in its attempt I feel sure I may rely upon the sympathy and the indulgence of those who have already mastered its intricacies.

Methods of Investigation.

Though our present knowledge of cardiac irregularities and their significance could not have been arrived at without the use of the polygraph and the electrocardiograph, and though doubtful cases can only be differentiated by recourse to these methods, yet, thanks mainly to the patient labours of Mackenzie, the underlying principles can be grasped without much difficulty, and typical examples of each variety of arrhythmia can be recognized by the simple and familiar means of the finger and the stethoscope. It is this aspect of the subject that I wish to emphasize to-day; but, while I do not propose to depart from my aim of simplicity by referring you to diagrams and tracings, there are one or two points in this connexion to which it may be helpful briefly to allude.

When we "feel" the pulse at the wrist, we should learn a good deal about the action of one—but only one—of the four chambers of the heart—namely, the left ventricle. Further, we learn of it only during that period when the aortic valves are open—that is to say, not quite the whole of systole; and the sphygmograph and stethoscope, though amplifying, refer us in the main to the same portion of the ventricular cycle. Still, while an irregularity of the pulse doubtless indicates an irregularity of the left ventricle, it does not follow that all irregularities originate there. Some do, but some originate in the auricles, and others again are due to delay in transmission of the impulse from the upper to the lower chambers; and the way to find out more about any individual case is to take a tracing from the internal jugular vein, from which we may learn much both about the systole and the diastole of both auricles and ventricles. The "venous pulse" is not invariably present, but it is present in most hearts, healthy or diseased. There is a "ventricular type" present in certain conditions where the undulations correspond to those of the carotid artery, but the normal or "auricular type" is that from which we learn most, and to the characteristics of this tracing I wish very briefly to allude. The contraction of the right auricle gives, so to speak, a back-kick to the blood in the jugulars, and a wave—the "auricular wave"—is produced. Later the contraction of the right ventricle, stretching the closed tricuspid valve, or not uncommonly causing a slight regurgitation through it, gives a second back-kick and produces a "ventricular wave." Again, the proximity of the carotid artery gives a third or "carotid wave," which, in point of time, comes between the other two. In this tracing, then, we get a direct record from three different chambers of the heart—the right auricle and both ventricles. Much skill is needed in interpreting some of these records, for it will be obvious that in varying types of irregularity the characters of these various waves and the spacing between them will vary, and synchronous tracings from the heart itself or from an artery are commonly needed to point out which wave is which.

I have said, perhaps, enough to indicate how much information may be gained in this way by a sufficiently skilled observer, and, with this short allusion to an all-important subject, I turn for one moment to the visible undulations sometimes seen in the neck in cardiac cases. They merit study, and occasionally give us direct help; but, as they may originate in the superficial or the deep veins, or in the carotid artery, or may be due to a mingling of these causes, it is only in exceptional cases that their characteristics are sufficiently defined to be distinctive, though in the ventricular type of venous pulse they are often sufficiently obvious.

Illustrative Cases.

Having now explained my reasons for selecting the subject of cardiac irregularities, and having briefly alluded to the measures by which their differentiation has been rendered possible, it may be useful, before proceeding further, to cite a typical instance of each of the four varieties of arrhythmia already referred to, and in so

doing to select cases which can be at once pigeon-holed by very simple means, and in each of which important information is secured by so doing.

While these four groups do not exhaust all the varieties of arrhythmia which have been differentiated, they probably embrace nearly 90 per cent. of the cases met with in general practice, and if we understand these types we shall possess a key which will render the further study of the subject comparatively easy.

Case I.

We are asked to examine a boy or girl as to general fitness, or perhaps on account of a tendency, not uncommon in perfectly healthy adolescents, to occasional attacks of syncope; and we find a marked irregularity of the pulse. The heart sounds are normal and their rhythm corresponds with that noticed at the wrist. On careful timing, the irregularity is found to bear a definite relation to respiration, the pulse quickening during inspiration and slowing during expiration. The patient is told to run quickly up and down a flight of stairs, after which the pulse, though quickened, is found to have become quite regular, only to become more irregular than before when the heart has had time to slow down. The case is one of *sinus arrhythmia*, and it may be quite ignored, and indeed is only found in healthy hearts. Such a patient should on no account be debarred from any form of exercise he may feel equal to.

Case II.

A patient comes complaining that he feels his heart stop now and then, and that this gives him some concern; and we notice an occasional intermission of the pulse, or, perhaps, many. The stethoscope detects an occasional irregular flutter of the heart, which is found on careful timing to synchronize with the intermissions of the pulse. The case is one of *extra-systole*, and this, too, may be ignored. The thing is of no consequence in an otherwise healthy heart, while in case of a valvular lesion the prognosis is no worse than if the pulse were regular.

Case III.

In a patient recovering from an attack of acute rheumatism, or it may be from influenza or from some other fever, we notice, on feeling the pulse, precisely the same phenomenon as in the last case—an occasional intermission. On auscultation, however, we find a silence of the ventricle corresponding with the dropped beat at the wrist. The intermission is due to *heart-block*, and it means that a widespread implication of the myocardium has resulted from the illness. A guarded prognosis is indicated, and great care and limitation will have to be imposed to secure the best chance that a temporary condition shall not become permanent.

Case IV.

We are sent for to see a patient whom we have known for years as the subject of mitral stenosis, but who has suffered comparatively little therefrom, and whose pulse has always been regular. He may have sent on account of urgent cardiac symptoms, or his wife may have sent simply because "he has not been so well the last few days." We find a very irregular pulse, and that his pre-systolic murmur is no longer recognizable. This is sufficient to establish a diagnosis, though we may probably also observe an obvious pulsation in the jugular synchronizing with the ventricular systole. The patient has developed *auricular fibrillation*, and it indicates serious disease of the heart muscle. He may live for some years if the pulse be fairly slow, or if it can be slowed down under treatment, and he may be able to resume his occupation. But the irregular rhythm in the majority of cases will be permanent, and if so his days are numbered. Few cases, says Lewis, have been known to survive the onset of this rhythm for ten years; while, on the other side, rapid progress towards a fatal conclusion is not uncommon.

The Normal Heart Beat.

The first step towards understanding the nature and significance of these irregularities is to grasp something of the mechanism of the normal heart beat, a matter on which much light has been shed since the days when most of us studied physiology in the schools. In referring to

these matters I must confine myself to such points as have a direct bearing on our subject.

In the early embryo the heart is represented by a cylindrical dilatation of the simple vascular system—the *primitive cardiac tube*. It is divided both anatomically and physiologically into three parts: (1) the "sinus venosus" at the back, where the veins enter; (2) the auricular canal in the middle; and (3) the ventricular portion in front, which becomes continuous with the aorta. As development proceeds the lumen of the tube becomes lost, the auricles and ventricles being developed as diverticula (and not as dilatations), from their respective portions of the tube, while the sinus venosus shrinks.

In the fully developed heart the primitive tube is recognized in three groups of neuro-muscular tissue which correspond to the three portions of the tube.

1. The *sino-auricular node* in the right auricle, and near to which both the veins and the nerves enter the heart. From this point, the only recognizable remnant of the sinus venosus, fibrils doubtless permeate the auricles.

2. The *auriculo-ventricular node*, situated also in the right auricle, and doubtless representing the ventricular end of the primitive auricular canal.

3. The *auriculo-ventricular band* or *bundle of His*, a well defined structure which, starting from the auriculo-ventricular node, traverses the auriculo-ventricular septum, and splits into two branches, one going to each ventricle, where they again split up into fibrils which become incorporated in the muscle wall.

Physiologically, the primitive cardiac tube, and the tissues which represent it in the developed heart, are those which alone in the vascular system are capable, on stimulation, of originating contraction and of conducting it. The sinus venosus in the primitive tube, and its representative the sino-auricular node in the developed heart, are the most sensitive parts of the tube and the heart respectively, and consequently a stimulus acting generally is first taken up here, and it is at this point that the normal heart beat starts.

But the tissues of the primitive tube are capable of originating contraction if stimulated anywhere; though if the stimulation be applied to any other point than the sinus venosus, the character of the resulting contraction will be abnormal. Experiment has shown that each of the three portions of the tube is capable of originating a rhythm of its own. Much the same is true of the heart. The natural stimulus, which is supposed to be of the nature of a secretion evolved by the heart cells during their contraction, reacts first upon the most sensitive part—the sino-auricular node. The systole spreads rapidly through the auricles, which contract simultaneously; the stimulus is then taken up at the auriculo-ventricular node, and travels by the bundle of His to the ventricles, which again contract synchronously. Then comes the "pause" and the process is repeated; the normal regular cardiac rhythm results.

But stimulation at any other point than the sino-auricular node will produce an abnormal rhythm; while if the bundle of His be divided, or its integrity completely broken, say by a gumma, the ventricles take on a rhythm of their own. To this "blocking" of the route by which the contraction impulse travels from the auricles to the ventricles the name "heart-block" has been given, and we are thus led to the study of the irregularities.

THE IRREGULARITIES.

Heart-block.

In the study of the irregularities, I take heart-block first, partly because we have been led up to it by a natural process, and partly because it seems logical to take first the only type in which one half of the heart—the auricles—continues to act with uniform regularity. Further, heart-block, though in its more typical phases somewhat rare, is capable of causing great diversity of pulse irregularity; and to understand its variations and its degrees is to travel far upon the road towards understanding the general problem of the arrhythmias.

Heart-block means that there is some interference, little or much, with the conducting power of the auriculo-ventricular bundle, and this, though sometimes due to toxic and perhaps to functional causes, is frequently the result of organic disease. The lesion may be limited to the bundle, or to a part of it; but more commonly

it is an indication of a widespread implication of the myocardium, and hence the importance of recognizing the condition. The disease may be permanent, the result of syphilitic, of chronic rheumatic, or of senile sclerotic change; or it may be temporary, left as a legacy by any of the acute fevers—rheumatic, scarlet, pneumonia, diphtheria, or influenza. And while in all of these the myocardial changes may subside, leaving a healthy heart unimpaired for the activities of life, in all of them, on the other hand, and especially in rheumatic fever, there is danger that the temporary condition may become permanent, and leave a legacy of enduring cardiac inefficiency. There may or may not be a murmur, depending on dilatation or on endocarditis. Of these matters we know enough, and on them we are apt to lay at least sufficient stress. Of far more importance is the integrity of the cardiac muscle; and after any fever the presence or absence of minor degrees of heart-block will go far to show whether the myocardium has been seriously involved or not, and consequently whether convalescence may be safely hastened, or should, on the other hand, be guided by what may seem an over-cautious hand. The clinical manifestations of heart-block are seldom continuous—they come and go. A quick heart action seems to push impulses through which get "blocked" when the rate is slower, and it is during the phase of slow pulse that often follows fevers that a careful watch should be kept for the slightest indications of this condition. Digitalis, which tends to slow the heart's action, has a marked effect in emphasizing heart-block, and it often renders latent cases manifest. The drug should be prescribed with caution after fevers, and should be discontinued if signs of blocking are discovered.

Heart-block is divided into two groups—"partial" and "complete." The first comprises those cases in which there is merely delay in the transmission of the impulse, and those also in which some of the auricular contractions fail altogether to reach the ventricles.

In *complete heart-block* no impulses get through at all, and in this case, while the auricles continue to beat at the normal pace of 70 or thereabouts, or at an accelerated rate, the ventricles take up a regular rhythm of their own, which is usually at the rate of about 30, though it may be more. Here we have complete dissociation between the action of the upper and lower chambers, and the time relations of the two contractions, which are apt to vary independently, bear no relation whatever to each other. The condition is a clinical curiosity, and possibly none of us will ever see a case.

Partial heart-block is probably much more often present than discovered, even when looked for. Its minor phases can only be determined by very careful examination of instrumental tracings, while its more obvious manifestations are apt to come and go, and consequently may easily be missed unless prolonged and frequent examinations are made. On the other hand, we may happen upon it any day, and we shall all of us see recognizable cases before long if we look for them.

In the normal heart beat the commencement of the ventricular contraction takes place about one-tenth of a second after the commencement of the auricular contraction. This period is called the *auriculo-ventricular interval*, and it is shown on the jugular tracing in the distance between the auricular and carotid waves, where the normal interval is one-fifth of a second.* In the slightest grades of heart-block this interval is more prolonged in some beats than in others—that is to say, in some beats the impulse takes longer than the normal time to travel from the auricles to the ventricles. A more advanced phase—the first recognizable by ordinary clinical methods, and the type which should be looked for—is where occasionally the stimulus from an auricular systole fails altogether to reach the ventricles. Here we get (1) a dropped pulse beat, (2) absent heart sounds, and (3) a missed apex beat. The same complex may sometimes occur in the case of extra-systole, and it will be referred to under that head; but in heart-block a polygraph tracing will show that the auricle did not miss the beat, and probably some "interval" irregularities will also be detected.

A little thought will show that a wide diversity of pulse irregularities can be evolved from these premisses, and the

actualities correspond with what can be reasoned out. Where all the auricular impulses get through to the ventricle, though at varying rates, the arterial pulse is not, as a rule, recognizably affected, but minor irregularities may be shown by the sphygmograph, and may sometimes be detected by the finger. When, however, some or many auricular stimuli fail to reach the ventricle, the effect upon the pulse is very marked. A single missed beat produces a single intermission of the pulse, and several consecutive misses produce a long pause; dropped beats, single or in sequence, and occurring at frequent or irregular intervals, will obviously produce great variety of pulse irregularity.

But in heart-block there is apt to be a method in the madness of the pulse, and regularly recurring dropped beats at varying intervals produce conditions which are sufficiently common to have received definite names. Sometimes every alternate auricular contraction fails to get through, and "2:1 (two to one) heart-block" results. Here we get a regular radial pulse, perhaps about 40, while the auricles are beating at exactly double the pace. Similarly we may have "3:1 heart-block," where one beat in three gets through. Again, if every third beat is missed, we get one cause of "pulsus bigeminus," where, after each two beats, an intermission occurs, and similarly a "pulsus trigeminus" may be caused. Similar phenomena may be due to other causes, and often enough no diagnosis can be made without a jugular tracing; but nearly all heart-block phases are apt to come and go, and these regular irregularities may alternate with periods where odd beats alone are missed; and, when these are detected, accompanied by heart silence, the nature of the other manifestations can be inferred.

Heart-block may occur at all ages, but as a large proportion of cases are due to sclerotic change the condition becomes commoner as years advance. The minor phases, though generally indicating some organic change, are seldom of grave import, but the lesion giving rise to them may be progressive, and definite dropped beats have a decided prognostic significance. The higher grades are associated with infrequency of the pulse, and in advancing years a slow and regular pulse, alternating with a quicker rate, is highly suggestive of this condition; undulations in the neck may suggest that the auricles are acting much more rapidly than the ventricles, and during the quicker pulse phases a watch should be kept for the characteristic occasional dropped beat of the ventricle and the pulse. Complete heart block, once permanently established, is compatible with considerable cardiac efficiency, but when occurring intermittently it resembles high grades of the "incomplete" variety in producing symptoms which culminate in what is called the "Adams-Stokes syndrome." Attacks of giddiness, fainting, and transient loss of consciousness, associated with marked slowing of the pulse, are caused by deficient cerebral blood supply, and in the epileptic form (Adams-Stokes fits) venous congestion is added to deficiency of arterial supply.

Definite heart-block is always serious, and the patient should be kept well within his limits, as his life is insecure. Rapid heart failure may occur, and probably many cases of sudden death, where no heart disease had been ever suspected, may be due to this cause; for until some simple method is contrived by which the auricular systole can be easily observed, a large proportion of these cases will doubtless remain undetected. Still, by following the lines already indicated, the serious cases will generally be recognized, provided the possibility is kept in mind.

Sinus Arrhythmia.

Turning from a condition comparatively rare, decidedly serious, and in many cases difficult of recognition, we approach one of which precisely the opposite may be said. Sinus irregularity is immensely common, occurring frequently in healthy children and adolescents whose hearts never come under suspicion. It is absolutely innocent, and its nature need never be mistaken. Yet the pulse irregularity may be very pronounced; and as a matter of fact doubts often arise in the mind of the medical adviser, to the profound disadvantage of the patient, who is frequently debarred from beneficial occupations, and rendered both apprehensive and introspective.

Sinus irregularity, though not universal, may be said to be physiological in the young, and in a certain proportion of individuals it persists throughout life. It is, however, comparatively rare after 20.

* The extra tenth of a second is accounted for by what is called the "presphygmie interval."

It will be recalled that the normal cardiac contraction starts at the sino-auricular node, and that this node corresponds with the sinus venosus of the embryo. Sinus irregularities start at this point; hence the name. Lewis has suggestively called the node the "pace-maker" of the heart. It is here that the nerves enter, and here that the heart rate is determined. Many factors are concerned in determining the rate at which the heart beats, and among them nervous impulses are notorious. Emotional and reflex influences, the effects of exertion and repose, make their impression at the sino-auricular node, and the heart's action is quickened or slowed accordingly. Emotional influences are self-evident to all, and various forms of irregularity may be affected thereby, but in adults, though the pulse rate may be thus profoundly altered, no true "irregularity" results from this cause alone.

In the young, however, *vagus* influence is often exerted on individual beats and groups of beats, and pulse irregularity having special characteristics results. These irregularities start at the normal starting-point, and spread through the auricles and ventricles, and on to the radials, in a perfectly healthy manner. The irregularity is essentially one of time. If carefully observed, it will be found that the strength and volume of the pulse varies but little, and, further, that the time differences are due exclusively to differences in the duration of the heart's "pause." Yet, to the finger, the pulse may be constantly varying, and the sphygmograph may show great irregularity. Frequently, however, the arrhythmia bears an obvious relation to respiration, the pulse quickening during inspiration, and slowing during expiration; and, even when this factor is not obvious, it can often be rendered so by telling the patient to take long, slow breaths. In occasional cases the respiratory influence is absent or barely recognizable, but a polygraph tracing will always clear up any doubt by demonstrating that the auricle participates, and varies precisely with the radial pulse—a condition peculiar to this type of irregularity.

Sinus irregularities are occasional and not constant; they are abolished by atropine, which paralyzes the *vagus*, and by exercise, or by any other influence, such as fever, which quickens cardiac action. But during the slow pulse which so often follows fevers this condition is often very evident, and here it is obviously important to recognize its nature and to distinguish it from other forms of irregularity, and especially from heart-block, for, according to Mackenzie, its presence, even though a murmur should exist, is strong presumptive evidence that the heart muscle is essentially healthy—stronger evidence, indeed, than if the pulse were uniformly regular, for sinus irregularity would seem to occur only in healthy hearts.

It follows that no boy or girl exhibiting this form of arrhythmia should be debarred from any occupation or recreation suited to the general physique, nor should any treatment be prescribed except on other grounds.

Extra-systoles.

If among the forms of arrhythmia sinus irregularities are really the commonest type, it is not because we encounter them most frequently, but because they exist in numberless cases where they are never suspected, and consequently never discovered. Among the pulse irregularities noticed by the physician extra-systoles are certainly the commonest, accounting, perhaps, for 50 per cent. of those recognized in general practice; while in the case of the patients themselves becoming conscious of intermittent "bumpings" or of the "heart stopping," probably 90 per cent. are of this type; though far more frequently still extra-systoles cause no sensations at all. Extra-systoles can generally, though not always, be recognized with comparative ease, and their prognostic significance is important and reassuring, for in an otherwise healthy heart they may be safely ignored, while in cases presenting evidence of disease the prognosis, based on other data, is not adversely modified by their presence. But the condition may give rise to sensations which often cause anxiety to the patient, and it is capable of causing such variety of pulse irregularity that an astonishing series of dissimilar tracings can sometimes be obtained from a single case. Consequently a serious idea not infrequently arises in the mind of the physician, and the patient's activities are often needlessly limited and his spirits needlessly and injuriously depressed.

This term, "extra-systole," has now been long enough in use to have become fairly fixed, and it will probably endure; though, as Lewis points out, "premature systole" is more accurate, for the cardiac contractions which produce the irregularity are not "extra," and they are premature. The condition is defined by Mackenzie as cardiac contraction originating at some point other than the normal. For reasons not yet understood, some portion of the heart muscle (doubtless always in the remains of the embryonic tissue) becomes temporarily more excitable than the normal point of maximum excitability (the sino-auricular node), and contraction arises in the auricles, or in the ventricles, or in the "bundle" connecting them. In all these cases a premature and weak contraction results, producing either a feeble and premature pulse beat, or a wave which fails altogether to reach the wrist.

If, then, we come across a pulse which occasionally "intermits," we palpate and auscultate the heart while still "feeling" the pulse, and, in this case, instead of an entire absence of impulse and sounds as in heart-block, we feel an irregular and premature flutter, and we hear a couple of quick, short, premature sounds. A longer pause than usual ensues, and then the normal beating recommences. This, then, is a single "extra," or "premature" systole. It is easily recognized, and is what we must look out for in a case where this form of irregularity is suspected. Whether the auricle or the ventricle be the starting point (a matter difficult to decide and generally immaterial) the effect upon the heart sounds is the same; for, with the exception of diastolic and presystolic murmurs, all heart sounds refer us exclusively to the ventricles. The normal heart sounds are commonly described as resembling the vocal sounds "loob-dup," and not less truly does the extra-systole bear resemblance to the word "bubble"; and, apart from other evidence, this "bubble" sound ensuing quickly after a normal second sound and followed by a noticeable pause, is practically diagnostic of this condition; the single extra-systole cannot fail to be detected. It is true that occasionally the systole may be so feeble as to give rise to no audible sounds, and here the confusion with heart-block is obvious. But heart-block is rare, whereas extra-systoles are common, and it will not be all the extra-systoles that fail to produce the characteristic sound. The co-existence of the two conditions is possible, but is rare; and here, as with other instances of extra-systoles co-existing with other forms of arrhythmia, we must look for other signs to help us out, and we shall seldom look in vain.

So much, then, for single extra-systoles; but following the argument already discussed under heart-block, it is evident that a series of extra-systoles occurring in various sequences, or quite irregularly, may give rise to a pulsus bigeminus, or trigeminus, or that a bewildering irregularity of pulse may result. In all these cases the "bubble" sounds will help us, and as the condition is occasional and not constant, we shall be sure with patient observation to detect instances of the single extra-systole. A polygraph tracing, too, may be a help, but in the doubtful cases the tracing is apt to be complex, and to require very careful analysis.

Extra-systoles, as already stated, are not constant; they are occasional, or they come in bouts, with periods of normal rhythm between them. Quickened cardiac action tends to abolish them, but in the slow pulse which follows a quick one they, like the other forms of arrhythmia already studied, are exceptionally frequent. They occur at all ages, but in advanced years they may be considered as almost physiological in undamaged hearts. While common in healthy hearts, no form of heart disease is exempt from them, and they are frequently present in all sorts of systemic disorder. Sometimes the erect posture seems to favour them, sometimes the recumbent; and excitement, dietetic indiscretions, and tobacco may induce them.

Speaking generally, patients showing this form of arrhythmia may be reassured, and encouraged to exercise their activities to the extent of comfort, even where heart disease exists, and they need not live in fear of sudden death; while where there is no direct evidence of cardiac mischief, the irregularity may be absolutely ignored. Digitalis and strychnine are apt to emphasize and exaggerate the tendency to extra-systole, while in those cases in which the subjective sensations are from time to time

disquieting, much relief is generally afforded by a few days' course of bromides prescribed in liberal doses.

Auricular Fibrillation.

The word "fibrillation" is an abbreviation for "fibrillary contraction." The auricles in this condition are in diastole, and they never contract as a whole or even partially. Their musculature is, however, not at rest, but, on the contrary, in a state of constant ineffective fibrillary movement. This has been observed experimentally, and is demonstrated by electrocardiograms. The auricular walls may be thin or hypertrophied, but in either case remain in diastolic dilatation. The auricles, as a part of the circulatory mechanism, are put out of action, and they become practically mere extensions of the great veins. One result of this is that the venous pulse tracing loses all signs of auricular activity, and exhibits what is called the "ventricular type," where only a single jugular wave exists, a wave corresponding with the ventricular systole. This characteristic ventricular type of venous pulse had been recognized by Mackenzie before Lewis demonstrated fibrillation, and Mackenzie, unable to account otherwise for the fact that the jugular and carotid pulses corresponded, and that there was no evidence of separate auricular activity, concluded that a simultaneous contraction must occur in auricles and ventricles, and that any such contraction must commence in the tissues between the two, most likely at the auriculo-ventricular node, and he named the condition "*nodal rhythm*," a term now discarded, but with the meaning and origin of which it is well to be familiar.

What effect has the fibrillating auricle upon the ventricle? In the first place the ventricle may fibrillate too, but in this case speedy death ensues. This state has been observed in chloroform poisoning, and it may take place in cases of sudden cardiac failure, where its existence can only be inferred. Ordinarily, however, the ventricles continue to contract, but in a manner which is characteristic. Tiny impulses from the trembling auricles are constantly reaching the auriculo-ventricular node, where we may assume they collect until a sufficient "current" (to use an electrical simile) has accumulated to produce a ventricular contraction. This assumption will account for the extreme irregularity of pulse which characterizes auricular fibrillation; "absolute irregularity" is the accepted descriptive epithet, and it implies an irregularity both of time and volume so marked that a sphygmogram seldom shows two consecutive beats of like character and duration.

Auricular fibrillation is never found in healthy hearts, but it may occur in hearts whose musculature has been damaged by any and every kind of inflammation and degeneration. As a single cause rheumatic damage is far the commonest factor, and among hearts damaged by rheumatic fever those showing evidence of mitral stenosis are especially prone. It is evident that the narrowed orifice must throw an extra strain upon the auricle, which eventually gives up the struggle and ceases to contract. An obvious result of this is that the characteristic pre-systolic murmur, which depends upon the systole of the auricle, abruptly ceases with the onset of fibrillation, though a softer murmur placed earlier in the diastolic period may persist or may develop.

Auricular fibrillation may occur in paroxysms lasting from a few minutes to a few weeks; but, as a rule, when once established, it continues as a permanent condition to the end of life. It imposes a considerable extra burden upon the ventricle, whose reserve power in response to extra calls is notably diminished, while the tendency to heart failure is increased, and becomes, indeed, a constant menace. The tenure of life becomes extremely insecure, and, though the end may be delayed for years, it may come suddenly, or be heralded by the usual signs of cardiac failure at any time. Fortunately, if the condition be recognized, much may be done both to prolong life and to make the most of it. Effort must be limited, and if there be signs of failure, complete rest must be enjoined. It is in these cases too, and especially in the class which own rheumatic origin, that the triumphs of digitalis are most marked. By pushing the drug, patients apparently moribund may be recalled to a life of useful if limited activity; and, while such disquieting signs as dropsy and orthopnoea subside, a quick and violently irregular pulse is reduced to one of fairly normal rate, sometimes so

nearly regular in rhythm that only by careful measurement of the intervals shown on sphygmographic tracings can the presence of continuous irregularity be recognized. It is seldom necessary to reduce the pulse rate to below about 70, after which digitalis may be discontinued for a time, to be resumed, when the pulse again quickens, in smaller doses, varying in different cases, but just sufficient to keep the pulse rate down. Patients soon learn to regulate the dose themselves, and may keep at their occupation for months and years without having to call in medical assistance. But in some cases digitalis fails, and in all a time comes sooner or later when the cardiac muscle ceases to respond, and when this period comes the end is not far off.

Auricular fibrillation can often be diagnosed simply from feeling the pulse. An "absolute irregularity" which persists is in itself sufficient, but where the arrhythmia is not characteristic there is one difference between this type and all of those hitherto discussed which will seldom fail us. In heart-block, sinus arrhythmia, and extra-systole, exertion or any influence which quickens the pulse, tends to reduce or perhaps abolish the irregularity, while in fibrillation precisely the opposite effect is produced. In a bed-ridden patient such slight exertion as a change of posture may be sufficient to elicit this point, while in others simple tests to this end are easily devised. In fibrillation the quicker the pulse rate, the more obvious is the irregularity.

Auricular fibrillation is very common in damaged hearts. A majority of the cases of heart failure exhibiting dropsy are associated with this condition. Cases described as "delirium cordis," and many cases described as "heart strain," are simply good examples of fibrillation. I conclude with a quotation from Mackenzie's last edition: "The recognition of this condition and the symptoms associated with its presence, is the most important discovery yet made in the domain of the functional pathology of the heart; and few physicians are aware of its significance."

Having now discussed, in, I trust, sufficient detail to render clear their nature and significance, the four leading types of pulse arrhythmia, it must suffice to allude in the briefest possible manner to the three remaining forms which have been isolated.

Paroxysmal tachycardia is a condition we all see now and then. It may occur with irregular rhythm in the course of fibrillation, or it may be due to auricular flutter, but "simple paroxysmal tachycardia" exists as an entity *per se*. In this condition the rhythm is regular and the pulse rate often reaches 150 or 200; it lasts from a few seconds to a few hours, and occasionally a few days, and its onset and subsidence are always absolutely abrupt. It may occur at any age, but is rare in childhood, and it may or may not be associated with cardiac disease. It is sometimes fatal, but more often passes and leaves the patient but little worse till the next attack occurs, which may come soon or may be delayed for years. In its origin it is supposed to resemble extra-systole in that the impulse appears to start at some abnormal point. It often gives rise to very distressing symptoms, which are sometimes relieved by alterations of posture and often by strong sedatives.

Auricular flutter is generally associated with the sclerotic changes of advancing years. It is a condition in which the auricle beats at rates of 250 or 300, or even more. The ventricle may follow suit, and an uncountable tachycardia results. But varying degrees of heart-block commonly co-exist, producing almost any variety of rhythm and irregularity. Often, however, the 2:1 heart-block rhythm is established, so that an auricular rate of 300 is represented by a pulse of 150, and sometimes the ventricular rate may be extremely slow, while the venous pulse shows very rapid visible oscillations. The condition has been but lately discovered, but is believed by Mackenzie to be less rare than general clinical experience would suppose. It may occur as transient attacks of short duration, but it may persist with fair cardiac efficiency for long periods, or, again, may be the precursor of fibrillation. A persistent rapidity of pulse, regular or irregular, in an elderly man, or a slowish pulse with rapid visible jugular pulsation, suggests its presence. A jugular tracing may elucidate a

doubtful case, but often only by means of the electro-cardiograph can its presence be definitely proved.

Pulsus alternans differs in many particulars from all of the forms of arrhythmia already discussed. It is essentially an irregularity of strength and volume and not of time, and even as such it is a regular irregularity, in which each second heart beat is a weak one. More often than not the differences in the volume of pulse wave are so slight as to escape detection by the finger, even when suspected, though a sphygmogram will render them plain enough. The condition depends on a physiological principle not as yet alluded to in this paper—the law, that is, that each cardiac systole uses up the whole available energy of which the heart is capable at the moment of contraction. In *pulsus alternans* the available energy is so reduced after each full beat that the succeeding systole is a weak one. The condition often occurs only as a terminal phenomenon and as a prelude to early dissolution, and as such it has, when recognized, a grave prognostic significance.

Rare and undifferentiated types of arrhythmia are alluded to in a special chapter by Mackenzie. Some of them afford problems for future investigation, and their complete elucidation may throw much light on the cardiac mechanism; for, far as we have travelled on this road of knowledge, all investigators agree that there is much still remaining obscure. The differentiated rhythms, though largely explained as to their mechanism, leave many problems as yet incompletely solved.

Mixed rhythms and changes from one type to another are known to occur, and have already been incidentally alluded to more than once. Deficiency of conducting power—in other words, partial heart-block—enters as an integral factor into most cases of flutter, and into the slower pulses of fibrillation, while the action of digitalis is largely operative in depressing undue conductivity. Extra-systoles may occur in children and be mixed up with respiratory rhythm. Again, extra-systoles of ventricular origin may occur in the course of fibrillation, or may even co-exist with heart-block, while not infrequently a damaged heart which has shown frequent extra-systoles for years may suddenly take on the rhythm of absolute irregularity, which proves that the auricles have passed into a state of fibrillation. These facts may somewhat disconcert the student at first sight, but a little thought will show that the general conclusions based upon the diagnosis of each type of arrhythmia are but little affected thereby. In two types only—sinus arrhythmia and extra-systole—is the prognosis quite reassuring, and should these co-exist the conclusion is not vitiated. As to extra-systole alone, the prognosis is only good where no evidence of heart disease exists; and in cases that eventually turn to fibrillation evidence of heart disease will certainly be present, very likely in the shape of presystolic murmur. Here, of course, the possibility of eventual fibrillation amounts almost to likelihood, but none the less does the rule hold good that the irregularity due to extra-systole may be ignored, and the patient allowed to exert himself as much as he can do without undue discomfort.

CONCLUSION.

Many aspects of cardiac pathology have received much elucidation within recent years, yet we and our patients have as much to look for in the work which is now being done and in that which lies ahead as in what has already been accomplished. But among the latter, Mackenzie's work on arrhythmia and its developments are of epoch-making importance, and form solid ground on which we can base more accurate opinions and more definite statements than were formerly possible. Two baleful influences in connexion with heart cases have long been at work—vague speaking, and the needless limitation of our patients' activities—and it was the recognition of these facts years ago that led me to take a somewhat special interest in the heart. I came across numerous cases where patients had been told they had "weak hearts," and in which, though there occasionally was a murmur, and sometimes a loud one, I could discern no more evidence of "weak heart" than one might discover in a biceps whose owner had been told that he must only use it with great caution. "The heart is a muscle," said Oertel; "by exercise a muscle becomes hypertrophied, and its functional power increased. Also for the heart

muscle exercise is the only means we have of strengthening it." What Oertel accomplished even for badly damaged hearts was marvellous, and only too often do we ensure that a weak heart shall remain weak by withholding from it its physiological opportunities for gaining strength. Yet we fear to be bold because we fear catastrophe. But many means are at our disposal for estimating a heart's reserve capacity; and among them a knowledge of the irregularities and their significance now occupies a prominent position. Ability to differentiate the rhythms will restore far more patients to activity than it will condemn, while in the case of those who may have to be restricted it brings to us the satisfactory assurance that our patients' lives will not be limited on insufficient grounds.

REFERENCES.

- ¹ *Clinical Disorders of the Heart Beat*, preface to second edition.
² *Diseases of the Heart*, third edition, 1914, p. 211. ³ Von Ziemssen, vol. vii, p. 247.

SOME FACTORS CONCERNING AMPUTATIONS WITH REFERENCE TO THE PRESENT WAR.

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BEFORE the outbreak of the present war in August last operations for amputation of limbs had received little attention for many years. This was due to the fact that modern surgical methods of asepsis had rendered surgeons more and more conservative with regard to diseases and injuries of the limbs, so that the necessity for amputations but seldom arose; in fact, except in hospitals which, owing to their situation, dealt largely with accidents from large machinery works or railways, amputations were very seldom performed. I think it is no exaggeration to say that many of the large hospitals did not have more than half a dozen major amputations in the course of a year. Amputation had, indeed, become a very rare operation. War unfortunately results in injuries of such a nature that amputation is frequently necessary, and an enormous increase in the number of amputations performed has resulted from the present war. A good deal of the facility with which the patient will subsequently be able to make use of an artificial limb depends upon the method in which the amputation is performed, and I venture to bring forward the following remarks and suggestions in the hope that they may correct some fallacies which still appear to be prevalent in medical textbooks, and may so assist in rendering more tolerable the condition of those of our fighting forces who may have the misfortune to lose a limb.

It is often supposed that in the case of the amputation of the lower limbs the weight in standing and walking is borne upon the end of the stump. This is, of course, not the case. Where the amputation has necessitated saving through the bone the end of the stump will never be able to withstand the pressure which must be borne by the stump in standing and walking, no matter how cunningly the stump may be formed. In practice the weight of the body is supported upon the bony structures, around the joint immediately above the amputation. Thus, in the case of amputation of the leg, the weight is borne upon the head of the tibia and fibula and the sides of the stump, while in the case of amputations above the knee the patient practically sits upon the top of the artificial limb. The only stumps in which it is possible for the weight to be taken on the end of the stump are Syme's amputation at the ankle-joint and amputation through the knee-joint. With these exceptions the weight cannot be taken on the extremity of the stump. As a rule, the end of the stump is not allowed to touch the bottom of the bucket of the artificial limb as it is impossible for it to bear any useful weight, and if it does so it soon gets sore. No matter how much muscle flap has been left over the bone ends the resulting stump will ultimately be the same, as the muscle left over the end of the bone will, in time, completely waste, and there will be little more than