more the selachian type of arrangement from which they only differ by the constant gap between the oculomotor and trochlear nucleus, the more dorsal position of the trigeminus nucleus and the less dorsal extension of the abducens cells and roots.

Physiology. *"On esophageal auscultation and the recording of esophageal heart sounds"*. By Dr. C. E. BENJAMINS. (Communicated by Prof. Dr. H. ZWAARDEMAKER).

(Communicated in the meeting of February 28, 1914).

When performing an esophagoscopy our notice is surprisingly attracted by distinct considerable pulsations at 32—35 c.m. from the incisor teeth. Here an expansion may repeatedly be seen to appear and to disappear rapidly after some complex to-and-fro motions. Anatomically it has been shown that in this very place the left auricle is located against the esophagus, from which it is separated only by the pericardium, and, therefore, admits of immediate experimentation.

Following the lead of RAUTENBERG [1]) and MINKOWSKI [2]) I availed myself of this circumstance by taking along this path cardiograms as illustrated in Fig. 5. The results achieved in this investigation, which was conducted in a way differing from the method generally employed, will be given elsewhere. In this paper I propose to publish my experience about the esophageal heart sounds.

I first wish to give some preliminary details of the technique of examination. To the extremity of a strong grey india-rubber tube (75 c.m. long, 5 m m. bore, thickness of the rubber 1 m.m.), graduated from 20—40 c.m., a knob-shaped appendage is fitted. Over this appendage a rubber finger stall (from which the hard rim has been removed) is tied so as to leave an elongation of 3—4 c.m.

The subject, whose pharynx had, or had not, been sprinkled beforehand with a spray of a 5 % cocain solution, to which some drops of adrenalin had been added, swallows the lubricated tube without difficulty, only being aided a little as at the insertion of a stomach-tube. When the tube is inserted as low as ± 35 c.m. from the labial curve, it is adjusted by means of a T-piece to the binaural stethoscope. (The T-piece has to protect the tympanic membranes the moment the subject displays signs of choking). When he keeps quiet, the T-piece is closed with the finger, so that we hear distinctly

[1]) RAUTENBERG. Die Registrierung der Vorhofpulsation von der Speiseröhre aus. Deutsches Arch. f. klin. Medicin 1907. Bd. 91. S. 251.

[2]) O. MINKOWSKI Die Registrierung der Herzbewegungen am linken Vorhof. Berl. klin. Wochenschr. 1907. No. 21.

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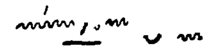
all the sounds in the chest. In order to examine the heart sounds the subject must hold his breath for a few seconds.

It requires some practice to distinguish the heart sounds. At first a confusion of rustling, blowing, and crackling sounds is heard. However, the moment the subject holds his breath only the well-marked heart sounds can be made out, and then we become conscious of *four murmurs, not two.* When first listening to the two loudest more defined sounds we distinctly hear one long, coarse sound, and a second which is short and faint: the ordinary type of the heart sounds over the apex. If we can divert our attention from these sounds and try to single out the two much softer murmurs, which seem to come from afar, we become aware that the first of them *commences before the first ventricular sound and undoubtedly runs up till the latter is heard and even seems to coincide with it for a short time. In the pause between the first and the second ventricular sound an additional short and faint murmur is noticeable.*

Passing the tube lower down or moving it a little higher up causes the two faint murmurs to disappear, in order to re-appear again, whenever contact with the auricle is again effected.

No doubt, we are here dealing with the auricular sounds that have given rise to so much controversy. To raise the plausibility of this assertion, I may add that, with persons subjected to esophagoscopy, the site of the auricle was ascertained by measurement and that it was always at this very spot that the auricular sounds occurred. Besides the four murmurs under consideration one of our subjects exhibited a fifth faint murmur, taking place after the second ventricular sound. It may be typified as follows. 

It appeared to me essential that these auricular sounds should be recorded.

The chief obstacle was that, besides the sound vibrations impulses arise from the movement of the heart, viz. at the apex beat, owing to the impact against the chest-wall, and along the esophageal path in consequence of the pressure on the rubber ball. Various methods have been suggested to preclude the passage of these foreign impulses. Einthoven [1]) and his pupils made the tube, connecting the

[1]) W. Einthoven and Geluk. On the recording of heart sounds. Researches in the physiol. lab. of Leyden. Sec. Series 1896.

G. Fahr. On simultaneous records of the heart sounds and the electro-cardiogram. Heart. Vol. 4. No. 2. 1912.

P. J T. A. Battaerd. Further graphical experiments on the acoustic phenomena of the heart.

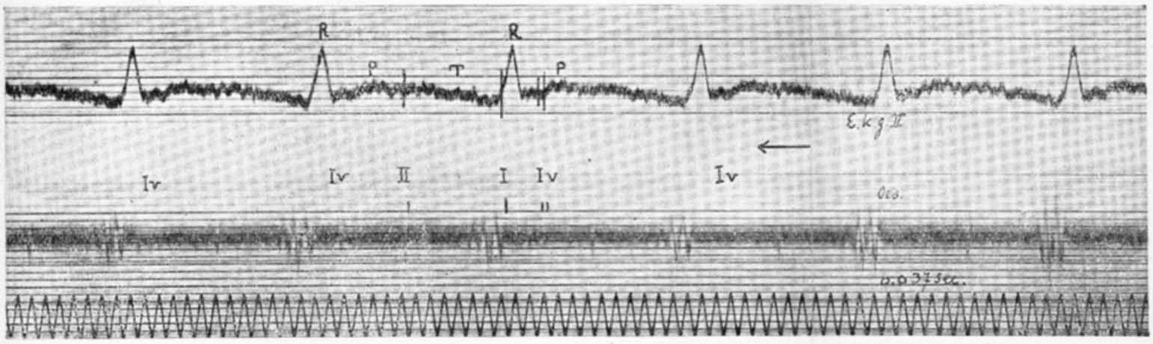


Fig. 2.

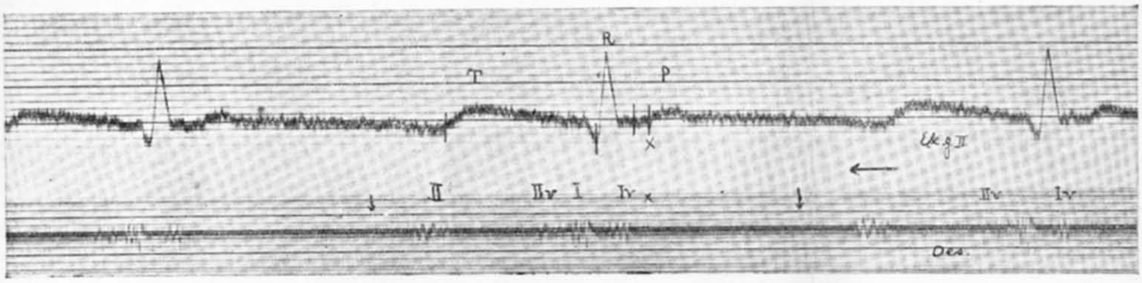


Fig. 3.

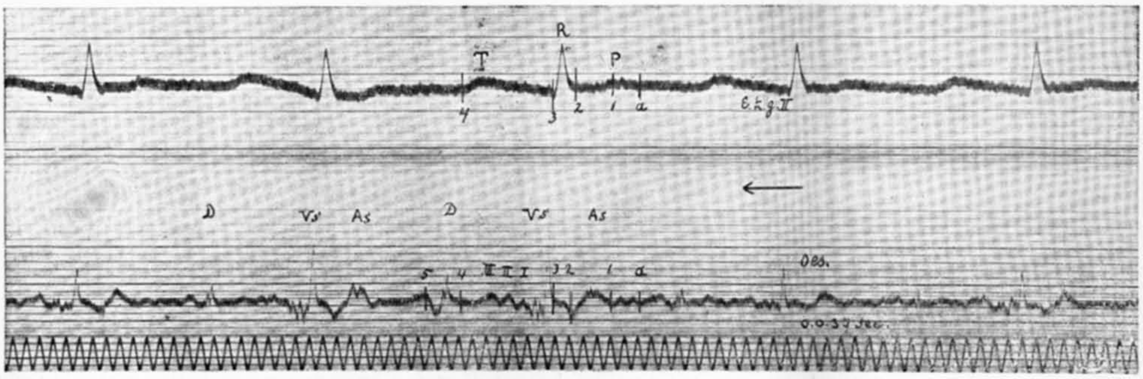


Fig. 4.

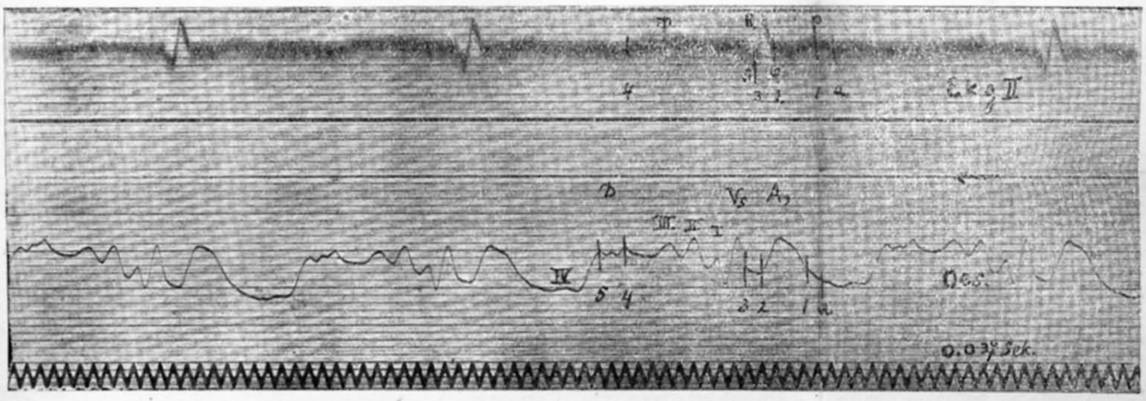


Fig. 5.

stethoscope with the recording apparatus, to communicate with the air of the room through a side opening, so that the impulses were allowed to escape. GERHARTZ [1]) points out that, though this contrivance may enfeeble the sound as well as the extraneous impulses, it does not eliminate the latter altogether. In the different heart-sound figures he clearly sees indications of the apex-beat.

Still, considering the extremely beautiful curves taken in EINTHOVEN's laboratory, I daresay his method will do for recording heart sounds through the chestwall; not, however, for registering them along the esophagus. It soon became evident that the jerky compressions of the rubber-ball could not be excluded from the curve. For esophageal records the insertion of a stout stiff membrane serves our purpose better. Various glass and mica membranes were tried, but discarded as either enfeebling the sound or permitting the accidental impulses to be recorded along with the heart sounds. Then a common phonendoscope on a solid ebonite plate was inserted; I chose this material because it had proved to transmit heart sounds. The phonendoscope *P*, in leaden case (*o*), was attached hermetically to an afferent tube and had thus been adapted for a circuit with esophagus-tube and microphone. If the second aperture was left open, no effect was produced on the recording apparatus either by blowing into the tubes or by squeezing them. It is certain, therefore, that the ebonite membrane is not thrown into vibration by the impulsive beats of the air. Our greatest obstacle was now overcome. It is true, the sounds were considerably weaker, but what we wanted to hear, was clearly audible. For further records we used a microphone (in camera plumbica) and a small string galvanometer. This combination had in previous researches proved suitable for recording the low sounds. (For the heart sounds WEISZ [2]) and GERHARTZ determined the number of vibrations at 50—100).

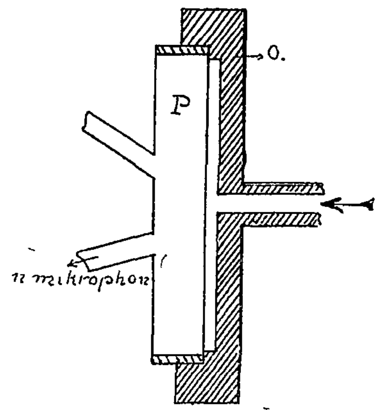


Fig. 1.

At the same time the electrocardiogram was taken in lead II by means of the large string galvanometer, with an arc-light of its own. With the aid of a screen the cone of either lamp was intercepted,

[1]) K. GERHARTZ. Die Registrierung der Herzschalles. Berlin 1911.

[2]) O. WEISZ. Phono-kardiogramme. GAUPP und NAGEL's Sammlung No. 7 Jena 1909.

so that each lamp directed its light upon one half of the field. Likewise the esophagogram was sometimes taken simultaneously.

Fig. 2 (a cardiogram taken from Miss B.) is illustrative of the slight oscillations of the heart sounds. Because we directed all our attention to the heart sounds, no notice was taken of the electrocardiogram, which accounts for its unsatisfactory record. However, for the present it serves our purpose. At *Iv* we observe most distinctly a constant, rather slow vibration of the string, *which occurs before the systolic portion of the electrocardiogram and is, therefore, of auricular origin.* (In the experiments, advisedly arranged, the recording apparatus exhibited only a scarcely measurable slowing). Here then we managed to record part of what is perceived by the ear. It does not amount to much; the second auricular sound is wanting, but the recording apparatus, on which moreover only weakened sounds are directed, will ever be inferior to our highly sensitive ear. It follows, that from these curves we cannot identify the real commencement and the real termination of the heart sounds, the initial and the terminal vibrations not having been well represented in the tracing.

Of the first auricular sound only the loudest portion has been traced. The ventricular sounds, which are much louder, yield much better tracings and confirm EINTHOVEN's experience with regard to the form of the heart sounds. They also point to his method being perfectly reliable for the sounds through the chestwall, since we gather from them that the first auricular sound is made up of three phases (a slow initial vibration, then the rapid main vibrations and finally a slower terminal oscillation), whereas the second sound consists of rapid vibrations only. We found the period of vibration of the first auricular sound to be rather low, viz. 50 per second. Further particulars are shown in Fig. 3, taken from subject t. D.; however, here also the amplitudes are small, owing to considerable damping. First of all we observe in one heart-rhythm three well-defined groups of large vibrations. I and II represent the ordinary ventricular sounds and commence at the familiar spots, viz. somewhere about S and at the end of T. The vibrations preceding I start at a point some way from the foot Q of the R-peak, and must, of course, be of ventricular origin. I marked them *Iv*. A couple of slight vibrations at X indicate the real commencement. It will be seen that the first sound like the first ventricular sounds is made up of different parts, with differing vibration frequency. At the end of the first ventricular sound we observe a couple of unlooked-for slow vibrations (II*v*) with the shortest possible gap between them.

Here I have been fortunate enough to record the short and faint second auricular sound.

At the auscultation this subject often exhibited clearly GIBSON-EINTHOVEN's third sound. In accordance with this I notice at ↓ a faint vibration of the string, which for the rest is perfectly quiet. However the tracing is not clear enough to convince others.

I have also endeavoured to record the heart murmurs by taking a superimposed curve, as suggested by GERHARTZ. If, for instance, we leave the impulses to themselves, the recording apparatus will take a cardiogram in which the more rapid vibrations of the heart sounds are represented.

The esophagus tube being directly in circuit with the microphone, with a side opening though, yielded the cardiogram (Fig. 4), taken from subject P In it we discern all the features of the so-called complex esophagogram as instanced in Fig. 5 for comparison.

The apex of the auricle is indicated by As; Vs is the ventricular apex; D the diastolic portion of the third elevation.

The systolic apices I, II, and III, which are so prominent in both curves, I shall not discuss any further in this communication. The points 1 to 5 are to be found in both tracings. A wave IV in the diastole, visible only in Fig. 5, I shall revert to later.

Though, for the rest, the string is rather quiet, we observe, especially with the aid of a magnifying glass, at the site of the first and the second auricular sound, vibrations which have been superimposed in the curve. Moreover at the auricle apex a good many fine oscillations are discernable together with some bolder amplitudes. *These are the vibrations of the first auricular sound, which run up to the commencement of the ventricular contraction.* Though less prominent, some vibrations, originating from the second auricular sound, are noticeable in the descending limb of peak I.

Now, how are these auricular sounds produced?

It has been generally admitted now, that heart sounds result from muscle murmurs, from vibrations of membranes (valves or cell-walls) and from eddies. An explanation for the first auricular sound is soon found. Most likely it is chiefly due to muscular contraction, but *then the auricular contraction must last till the ventricular systole,* more particularly till the closure of the atrio-ventricular valves. The continuance of the auricular systole in the isoelectric portion of the electrocardiogram, between P and Q, is moreover demonstrated by the fact that the largest vibrations of the auricular sound fall in this portion, nay the systole is even prolonged for some time while the R-peak is being formed (Fig. 3).

When scanning the oesophagogram I was led to think that the auricular systole runs into the ventricular systole without a previous dilatation. This view is borne out by the auscultatory results and the record of the auricular sounds.

Indeed, formerly it was taken for granted that only with cold-blooded animals, e. g. the frog, the ventricular systole commences only when the auricular systole has been completed, but that with mammals the relations are more complex.

In DONDERS' Physiology 2nd Edition 1859 page 27 I read. "dasz bei jedem Rhythmus zunachst die beiden stark ausgedehnten Vorböfe sich zusammenziehen und gleich darauf die beiden Kammern, ferner *die Vorhöfe sowohl wie die Kammern einen Augenblick im contrahirten Zustande verharren*". DONDERS holds that the old theory of HALLER, viz. that the auricular contraction and the ventricular systole occur alternately, has been disproved. SCHIFF's experience coincides with this view. It is remarkable that, in spite of this, HALLER's theory has found favour again in physiology. The second auricular sound cannot be accounted for so easily; it may be that eddies come into play; it has also been suggested by D. GERHARDT (cited by WENCKEBACH l. c) that it may possibly proceed from muscular movement at the auricular diastole.

The foregoing evidence has set the conjectures at rest concerning the first auricular sound, which has long been a subject of dispute in the literature. By what has been brought forward here KREHL's [1]) experience has been confirmed, HÜRTHLE's [2]) "Vorton", recorded by many researchers, has been substantiated; FAHR's [3]) initial vibrations have been transferred to the auricular systole; the discoveries of auricular sounds by BATTAERD [4]), WEISZ [5]) and others have been sustained, while moreover a second auricular sound has been added

Finally I wish to return once more to the diastolic sound mentioned heretofore. I presume this to be the third sound of GIBSON-EINTHOVEN. GIBSON [6]) detected in some individuals, with slow hearts, an additional wave, called "b" in the diastolic portion of the curve of the jugular vein and occasionally he heard a very feeble third

1) L. KREHL. Ueber den Herzmuskelton. Arch. f. (Anat. u) Physiol. 1889.

2) K HÜRTHLE. Ueber die mechanische Registrierung der Herztöne. Pflüger's Arch. Bd. 60 S. 263.

3) G. FAHR. l c.

4) P. J. T. A BATTAERD. l.c.

5) O. WEISS. l.c.

6) A. GIBSON. The significance of a hitherto undescribed wave in the jugular pulse. The Lancet, Nov. 16, 1907.

sound. EINTHOVEN [1]) found that third sound in his records as a faint vibration, at a distance of 0,13 sec. from the commencement of the second sound. In our subject, who has a slow heart (from 60 to 70 per minute) I, very often, *but not always*, noted this third sound as a faint diastolic murmur, which *got more distinct when the tube was slipped as far down as* 38 *c.m.* In fact the venous pulse of this person often, though not always, yielded a beautiful GIBSON "*b*"-peak in the diastolic portion of the cardiac cycle.

It is evident, therefore, that it is of ventricular origin. If we return again to Fig. 5, the esophagogram of the same subject, and look at wave IV in the diastole at 0,135 sec. after line 4, the place of the closure of the semilunar valves, we shall observe that this place corresponds to the site of EINTHOVEN's third sound.

FRÉDÉRICQ [2]) also sometimes found a similar diastolic wave in the auricular-pressure tracings.

When putting these facts together, viz. 1 ventricular origin; 2 inconstancy; 3 wave in the auricular-pressure tracings; 4 wave in the esophagogram; 5 wave in the venous pulse curve; GIBSON's explanation seems to me the most plausible. He ascribes the origin of this third sound to the fact that, at a high pressure or at a copious onflow of blood into the veins, the atrio-ventricular valves will close for some moments just before the diastole, on account of the blood rushing into the ventricle during the diastole, in consequence of which the membranes are swung up by the eddies. They produce a short sound and slightly check the blood in its passage to the ventricles.

The evidence presented in this article will, I hope, support the view that, together with the esophageal cardiography, the auscultation and the recording of heart sounds through the esophagus yields results not obtainable through the chestwall.

Physics. — "*A new relation between the critical quantities, and on the unity of all the substances in their thermic behaviour.*" (Continued.) By J. J. VAN LAAR. (Communicated by Prof. H. A. LORENTZ.)

(Communicated in the meeting of March 28, 1914).

13. If in the found [3]) expression $b = f(v)$, viz.

[1]) W. EINTHOVEN. A third heart sound. Ned Tijdschrift voor Geneesk. 1907 Vol. 2 p. 470.

[2]) L. FRÉDÉRICQ. La seconde ondulation positive (première ondulation systolique) du pouls veineux physiologique chez le chien. Arch. intern. de Physiol. 1907.

[3]) These Proc. XVI, p. 924 to be cited as II.