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REPORT CIX.

ON THE PRIMITIVE MUSCLE TISSUE OF THE HUMAN HEART.*

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[WITH SPECIAL PLATE.]

THE attention recently given to the more accurate analysis of the events taking place in the cardiac cycle of man has resulted in limiting the origin of the beat to certain regions. In the frog's heart we know that the beat originates in the sinus venosus, and it has been tentatively assumed that in mammalian hearts the beat originates in that part which represents the sinus venosus of the amphibia. Recent clinical work, as for instance that of G. A. Gibson and of K. F. Wenckebach, has directed attention chiefly to the superior vena cava as the probable site in man. In the search for a special muscular tissue originating the cardiac beat three important anatomical contributions to our knowledge have recently been made. Tawara,¹ in his investigations on the auricular connexions of His's bundle, is led to the conclusion that the region anterior to the orifice of the coronary sinus is the spot from which the fibres of this bundle originate, and he therefore infers that this region gives rise to the beat of the heart. Wenckebach² describes certain muscular bundles in the wall of the superior vena cava of a paler colour than those of the auricular muscle. They are seen as ring-like bundles surrounding the proximal part of the vein; single bundles stretch upwards away from the auricle. He describes a marked separation by connective tissue and fat of the musculature of the superior vena cava from that of the auricle when viewed from without. Muscle bands stretch from the superior vena cava to other parts of the heart, especially to the right auricle; these bands can be seen on dissecting the posterior aspect of the heart, and are especially marked in hypertrophic conditions that affect the auricles.

Keith and Flack³ have described a type of muscular tissue in the hearts of several species of animals, including man, which they suppose to be that in which the normal stimulus for the contraction of the heart arises. In the region of the orifice of the superior vena cava associated with a vessel which partially encircles the vein they have described a type of muscular tissue differing markedly from the ordinary muscular tissue of the auricle in being closely embedded in connective tissue, the fibres being fusiform with elongated nuclei and the fibres themselves having a plexiform arrangement. This tissue they describe as similar in its structure to that occurring at Tawara's node in the lower part of the interauricular septum.

OBJECTS AND SCOPE OF THE PRESENT RESEARCH.

This research was undertaken with the view of ascertaining by macroscopic and microscopic examina-

tion of the human heart what differences, if any, existed in the arrangement and type of muscle fibre in the regions in which most of the primitive and undifferentiated tissue was likely to exist, and from the results of this work to attempt to formulate some working hypothesis that would enable us to associate certain functions with definite anatomical parts of the cardiac musculature. The material used has been from the *post-mortem* room, but in all cases the hearts have been taken from young adults who had died from accident or disease not associated with the cardio-vascular system. The hearts were allowed to soak in running tap-water for twenty-four hours; then, having been stuffed with cotton-wool, they were placed in Kaiserling's formalin solution, afterwards in 90 per cent. alcohol, and finally, for preservation, in Kaiserling's glycerine solution. The portions cut out for microscopic examination having been washed well in running tap-water to remove all glycerine, were embedded in paraffin in the usual way. The stains used throughout for the ordinary examination of sections have been hematoxylin and Van Gieson's picric acid fuchsin; for special purposes Weigert's resorcin fuchsin and Cresylecht violet have been used.

THE NAKED-EYE FEATURES OF THE AURICULAR ENDOCARDIUM.

If a normal heart be opened and the right auricle examined from the inside, the endocardium will be seen to present certain thickenings arranged slightly differently in different specimens, and in very different degrees, but preserving some uniformity. Fig. 1 is intended to display these points; the region of the superior vena cava has a whitish endocardium, that near the orifice of the inferior vena cava is yellowish, towards the auriculo-ventricular ring the muscle becomes more visible owing to the endocardium becoming transparent. In the figure the portions where the muscle can easily be seen through the endocardium are dotted. It will be observed that the edge of this thickened

DESCRIPTION OF PLATE.

- Fig. a, Smooth muscle fibre.
Figs. b and c, Smooth muscle fibres showing an increase in thickness.
Fig. d, Fusiform fibre showing slight striation.
Fig. e, Smooth muscle fibre expanded at one end but showing no striation.
Fig. f, Fusiform muscle fibre with a tail-like process to which is attached a smooth muscle fibre.
Fig. g, A muscle syncytium showing cross-striation in one place, from the sino-auricular node (Keith and Flack).
Fig. h, A fusiform partly-striated muscle fibre and a nearly normal auricular muscle fibre with a tail-like unstriated process.
Fig. i, A thick fusiform fibre, with a tail-like process showing a faint suspicion of striation.
Fig. k, A reticular muscle fibre, partly striated.
Fig. l, A bundle of smooth fibres, the cytoplasm of which is increasing in amount.
Fig. m, A muscle syncytium; another section of this showed a slight cross striation.
Fig. n, One fibre and part of another of a Purkinje type.
Fig. o, A muscle syncytium, the fibrils of which are cross-striated.
Fig. p, The upper part is found in the sino-auricular node of Keith and Flack; it shows the manner in which this tissue is connected with the main part of the auricular muscle fibre.

endocardium in relation with the superior vena cava is sharp, except at one point where in the heart figured there is a free cord of thickened endocardium coming downwards to meet and join a tongue of thickened endocardium stretching anteriorly from the region of the foramen ovale. Where the auricular wall becomes trabeculated owing to the formation of the auricular appendix the thickened endocardium is well seen on the convexity of the trabeculae gradually fading away as they stretch towards the more dilated parts of the appendix. The pattern here described is by no means uniform in all hearts, but in young persons some such pattern can usually be found. In older persons the endocardium is most often uniformly covered with a whitish layer, but the parts which show the greatest thickening in the young adult are as a rule also thicker in the old person. The endocardium of the left auricle is for the most part uniform, and of a yellowish-grey tint; in no places in normal hearts is it usual to see the reddish-brown of the muscular fibres through the endocardium except in the auricular appendix.

This thickened endocardium has been examined histologically in a number of regions, and has been found to consist largely of fibrous tissue staining red by Van Gieson's stain. In its substance, or immediately in relation with it, are large numbers of muscular fibres, occurring singly or in bundles, mostly of the smooth or unstriated type (Plate, Fig. a). In the greater number of sections examined this is the only type seen, but in others the type is different, and may be traced through a very

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definite series of changes which it will be well to describe before going further into their distribution.

DESCRIPTION OF THE DIFFERENT TYPES OF FIBRES.

In the plate will be seen drawings of certain types of fibres met with in the sections examined. These must be taken as specimens of their classes, for amongst them very few are exactly alike. Fig. *a* is a drawing of the whole of one and part of another smooth muscular fibre as met with commonly in the endocardium. Figs. *b* and *c* are smooth fibres, but slightly shorter and thicker than the normal type. Fig. *d* is still thicker, and shows on either side near the nucleus two longitudinal bands which by careful focussing can be seen to be cross-striated; this is seen also near one pole of the cell. Fig. *e* shows a fibre markedly thickened at one end directly continuous with a long tail-like process indistinguishable from a smooth muscle fibre. Fig. *f* has a similar but shorter tail-like process, attached to which is a smooth muscle fibre; the cell contains two nuclei, and shows only the faintest evidence in one spot of cross-striation. Fig. *i* is a similar but much broader cell, with only the faintest evidence of striation. Fig. *g* shows a large irregular muscle syncytium in which only at one point could any cross-striation be detected. Fig. *h* shows a nearly normal auricular muscle fibre with a non-striated process side by side with a fibre which for the greater part of its length shows no striation. Fig. *l* is a fairly common type, and seems to be a bundle of non-striated fibres becoming thicker, the next stage being seen in Fig. *m*, which is a muscle syncytium showing irregular cavities containing nuclei; the substance of the fibre appears to be an interlacement of fibrils, stretching for the most part longitudinally. The fibre here depicted, though non-striated in the section from which the figure was drawn, showed some striation in a neighbouring section. This type is very nearly allied to one figured by Tawara (Table V, Fig. 1). Fig. *o* is another syncytium which is very similar in appearance to Fig. *m*, except that it is striated and the bundles which compose it are more longitudinally arranged. Fig. *k* is a fibre met with occasionally in association with the fibres depicted in Figs. *c* to *j*. Fig. *n* is an extremely common fibre, and is of the type of certain Purkinje fibres; for the most part it is striated, though, as shown, many portions have no striation. Fig. *p* shows a reticular type of fibre and its junction towards more normal auricular muscle fibre.

These fibres may be roughly classified into three groups: first, those more nearly related to smooth muscle tissue (Figs. *b*, *c*, *d*, *e*, *f*, *h*, and *i*); secondly, those having a syncytial arrangement (Figs. *l*, *m*, *n*, *o*); and thirdly, those of a reticular structure (Figs. *g* and *p*).

THEIR DISTRIBUTION.

It is too early as yet to do more than indicate the positions in which some of these fibres may be found, but there

are certain regions in which more of one type may be found than the other. It may be said at once that no mere cursory examination would be sufficient to discover even a few types, not only numbers of sites have to be examined, but numbers of sections in various parts. Speaking generally, the greater number of the first type, those which can be traced from smooth muscle tissue, are to be found in the region of the foramen ovale and in the valve of Vieussens.

The fibres of the second class are found most frequently in relation to the superior vena cava and the parts immediately related thereto. Fig. *m* was drawn from a section including part of the superior vena cava and the auricle; Fig. *n* was found in the valve of Vieussens, but is a very common type in the superior vena cava; Fig. *o* was found immediately under the endocardium of a trabecula of the right auricular appendix, where many other such fibres can be found.

The third class, the reticular fibres, constitute the tissue described by Keith and Flack as the sino-auricular node, found in relation to the vessel which encircles the greater part of the circumference of the superior vena cava. Fig. *k*, however, was found in the valve of Vieussens. All the types of muscle fibres mentioned lie either embedded in the fibrous tissue of the endocardium or very closely in relation with it.

THEIR SIGNIFICANCE.

The presence of the forms mentioned in the first class is probably to be explained from the consideration of the heart as a tube originally developed from elongated cells which showed no striation, the striation only gradually developing it when the organ became rhythmically contractile; those parts which show such fibres in the adult being the remains of the unfinished part of the cardiac musculature, that zone between the highly differentiated tissue of the auricles and the undifferentiated muscular tissue of the veins. Certain neoplasms, too, in the heart and elsewhere show a similar series of changes.

The syncytial fibres may have some function originating the beat of the heart; this would be borne out by their being found largely in the neighbourhood of the superior vena cava, where experiment suggests that the beat usually starts, and their presence in other parts would also be confirmed by the experiments of Erlanger and Blackman,⁴ who find that the beat may arise in a large number of different places in the auricle. These speculations are suggested by the type, arrangement, and site of fibres, and must not be taken as anything more than hypotheses for future work which is being undertaken.

REFERENCES.

- ¹ Tawara: *Das Reizleitungssystem des Säugetierherzens*, Jena, 1906.
- ² Wenckebach: *Arch. f. Anat. u. Physiol., Physiol. Abt.*, Leipzig, 1907, p. 1.
- ³ Keith and Flack: *Journal of Anatomy and Physiology*, Edinburgh, 1906, xli, p. 172.
- ⁴ Erlanger and Blackman: *American Journal of Physiology*, 1907, xix, p. 125.

Fig. 1.—The right auricle of a normal young adult opened by joining the opening of the inferior vena with that of the superior vena cava and making a cut from the inferior vena cava down towards the ventricle. *s v c*, superior vena cava; *i v c*, inferior vena cava; *t*, tricuspid valve; the valve of Vieussens is marked by the figure 7, the Eustachian valve by the figure 8. Those portions where the muscular tissue of the auricle can be seen easily through a transparent endocardium are dotted; the undotted parts have a greyish colour which in the region of the foramen ovale is yellowish. The other numbers are for convenience in referring to particular portions in the histological examination and do not concern the description.