and ventricles then beat simultaneously. The application of a third clamp at the junction of the inferior vena cava and auricle was followed by reversal of the mechanism which persisted until the animal was killed.

The occurrence of reversal but once in a series of seven experiments has occasioned no surprise. We had surmised that after destruction of the usual pacemaker it would be quite fortuitous should the next most irritable focus lie below the auricles.

Before definite conclusions can be drawn regarding any relation which may be thought to exist between the clinical and experimental conditions it will be necessary to determine whether this is the only lesion which can give rise to a permanent reversal of the cardiac mechanism.

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The intercalated discs of atrophied heart muscle.

By H. E. JORDAN.

[*From the Anatomical Laboratory, University of Virginia.*]

In two earlier papers[1] I presented evidence in support of my interpretation of intercalated discs as irreversible contraction bands. In a more recent paper the idea was tested by appearances in a natural experiment, namely, extremely hypertrophied heart muscle.[2] The conditions here obtaining were in perfect accord with, and confirmed the plausibility of, my previous interpretation. Since then I have had opportunity to study lesser degrees of hypertrophy, as well as an excellent specimen of atrophy[3] (weight of heart 180 grams). It is the purpose of this note to complete my report of observations on intercalated discs by a record of my findings in atrophied heart muscle, and to reëmphasize the point that all the evidence, including ontogenetic, com-

[1] Jordan, H. E., (1911) "The Structure of Heart Muscle of the Humming Bird, with Special Reference to the Intercalated Discs," *Anat. Rec.*, 5: 11; (1912; with Mr. K. B. Steele) "A Comparative Microscopic Study of the Intercalated Discs of Vertebrate Heart Muscle," *Am. Journ. Anat.*, 13: 2.

[2] Jordan, H. E. (1912), "The Intercalated Discs of Hypertrophied Heart Muscle," *Anat. Rec.*, 6: 9.

[3] For this material I am indebted to Dr. W. H. F. Addison, of the University of Pennsylvania.

parative anatomical and pathological (experimental—including the phenomena of fragmentation and segmentation) data points to the same conclusion, namely, that the so-called "discs" are aggregations of irreversible contraction foci on the myofibrillæ in the form of bands variously modified by a variety of normal mechanical and pathological, both chemical and mechanical, factors.

The first step, and central fact, in the chain of observations leading to the above conclusion respecting the origin and nature of the discs is the close similarity, amounting practically to an identity, between the normal contraction band in contracted muscle fibers and the simplest type of disc. This correspondence of appearance is very striking in the humming-bird's heart. In the relaxed fiber the *Z*-line is very conspicuous but delicate.[1] The *Q*-disc is wide and pale. In the contracted fibers the appearance is one of an alternation of robust dark (*Q*) and light (*J*) bands of approximately equal thickness. These are the same conditions that obtain in striped muscle generally in relaxed and contracted states respectively. In contraction the *Z*-line appears to become thickened by accumulation about it of dark (*Q*) substance. Of course the changes take place in the myofibrillæ. We need simply postulate local inability (due to strain, whether an instant or cumulative effect) on the part of a contraction band to reverse (or relax) to pass to the first step in the formation of a disc. The similarity between such "bands" and "discs," as also their peripheral and frequently supernuclear position, renders the assumption almost a certainty. Further support to this interpretation is derived from the following ontogenetic facts: (*a*) the discs begin to make their appearance coincidently with the cross striations; (*b*) they are at first exclusively of the simple homogeneous band type; (*c*) they increase in number (and complexity) at least to the time of full growth of the heart; (*d*) they are permanent structures throughout life. Further confirmative data are these: (*a*) step-forms are rare in birds, and absent in lower forms, the prevailing disc being of a type corresponding to the earlier ontogenetic forms in mammals; (*b*) in hypertrophied hearts the discs are exactly of a form expected from a modification of a simple

[1] Prepared according to Zimmermann's technique.

"comb-type" under the influence of longitudinal and transverse gross enlargement, and multiplication of myofibrillæ, *i. e.*, irregular zig-zag form; (*c*) mechanical ruptures in normal hearts are not localized along the discs, while in pathological fragmentation and segmentation the lines of fracture are largely limited to these levels. Of further significance is the fact that the presence of step-forms coincides with the condition of more profuse branching, hence absent in forms below birds. Step-forms would seem to be due to tension at various angles to the main longitudinal axis of the fibers.

The predominant type of disc in atrophied heart muscle is the comb-type. Fractures again occur almost exclusively at these levels. The discs in pathological heart muscle appear to be regions of weakness, probably in part at least due to chemical change. The main steps in the formation of the discs are conceived as follows: (1) irreversible contraction band (apparently homogeneous); (2) comb-discs, the length of the "teeth" varying according to the total amount, or degree, of traction on the modified regions of the included fibrils; and (3) zig-zag discs, due to a combination of the factors of longitudinal and transverse tension, and increase in number of fibrils by longitudinal splitting, *e. g.*, in hypertrophied cardiac fibers. Under the condition of general compaction which prevails in atrophied cardiac fibers, we should expect to find exactly the type of disc actually present, namely, a comb-type. Comb-discs according to the above interpretation of their origin are obviously regions of relative weakness, of relatively greater degree in pathological hearts where there is operating very probably an additional chemical factor. Hence in atrophied hearts fragmentation when present is limited to these levels. The discs once formed are permanent structures undergoing various modifications according to physiological conditions. Direct observation reveals a close similarity between the contraction band and the simplest type of disc. Hence the evidence for the origin of the various types of discs from irreversible contraction bands is practically complete.