fairly irregular course and to a varying extent are split apart by vacuolar spaces of more or less irregular form.

In addition to the GOLGI membranes, *granules* are found in the GOLGI ground substance. These granules show intimate topographic relationship to the GOLGI membranes. Their size, form and opacity varies considerably. The biggest granules are zymogen granules, exhibiting all the characteristic morphological features of such granules. There are found all kinds of transmission stages from small sized granules to these zymogen granules. Topographic relationships produce the impression of a transition of GOLGI membrane material into granules which, when moving away from the membrane zone, are gradually transformed into zymogen granules. Further studies which take the time factor into account seem necessary for a sound interpretation of such relationships.

Our experiments using starving and fed animals, and injections of pilocarpine hydrochloride, in order to vary the functional conditions of the exocrine pancreas cells, have failed to present sufficiently well-defined states of activity for a more critical analysis of the functional significance of the GOLGI apparatus.

One great difficulty in accepting the GOLGI apparatus as a preformed cell component has been the lack of a specific method for demonstration. The high degree of organization observed in EMG's of the GOLGI apparatus, make it now stand out as a morphologically well-defined and characteristic cell component which is easily recognized in the cell. It certainly impresses us as a structure that is preformed in the living cell.

A cell component similar to the one described here as the GOLGI apparatus has been observed in the columnar epithelial cells, in the GOBLET cells of the intestines (SJÖSTRAND and ZETTERQUIST[1]) and in the tubular cells of the mouse kidney (RHODIN[2]).

A more detailed report on this study will be presented in Experimental Cell Research.

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Zusammenfassung

In den exokrinen Pankreaszellen der Maus wurde der Golgiapparat im Elektronenmikroskop mit hoher Auflösung auf ultradünnen Schnitten studiert. Der Golgiapparat zeichnet sich durch ein deutlich abgegrenztes, unregelmässiges Zytoplasmagebiet mit eigenartiger Struktur aus, wobei man drei verschiedene Komponenten unterscheiden kann: 1. eine fast homogene Grundsubstanz; 2. Gruppen von 3 bis 5 dicht gepackten Golgimembranpaaren, von unregelmässigen Vakuolbildungen getrennt; 3. Golgigranula von verschiedener Form, Grösse und Dichte. Die grössten sind typische Zymogengranula.

[1] F. S. SJÖSTRAND and H. ZETTERQUIST, in preparation.

[2] J. RHODIN, *Correlation of Ultrastructural Organization and Function in Normal and Experimentally Changed Proximal Convoluted Tubule Cells of the Mouse Kidney* (Stockholm, 1954).

Electron Microscopy of the Intercalated Discs of Cardiac Muscle Tissue

The interpretation from light microscopic observations of the significance of the intercalated discs of heart muscle has been very controversial. A very extensive light microscopic study was presented by AURELL[1] in a monograph in which the literature was carefully reviewed up till 1945. Even earlier electron microscopic studies[2] have failed to give a conclusive answer. The intercalated discs have recently been subject to a histochemical study by BOURNE[3] who found a high enzyme concentration in the discs indicating their interest from a biochemical point of view.

The present study, which will be reported on in more detail elsewhere, has revealed that the intercalated discs of cardiac muscle tissue represent cell boundaries of a special kind. This type of cell boundary is, however, far from unique as far as pure morphology is concerned.

Heart muscle from frog, mouse and guinea pig has been studied after fixation in buffered isotonic osmium tetroxide solution (modified Palade solution[4]) embedded in methacrylate and sectioned with the ultra-microtome designed by SJÖSTRAND[5]. The about 200 Å thick sections have been studied in an RCA EMU 2 c electron microscope without dissolving or subliming the embedding medium.

Figure 1 shows a longitudinal section through a myofibril from guinea pig heart muscle. The myofibril consists of two fibril components similar to those described by HUXLEY[6] (not clearly shown in this picture). At the end of the sarcomere seen in the picture a very opaque zone runs across the whole diameter of the myofibril. In the middle of this dark zone a bright line is observed. At higher magnification, as in Figure 2 (which is from a section in series with that presented in Fig. 1), it is seen that the bright, less opaque line has a sharp boundary against the opaque material; and in very thin sections a well defined thin dark line is observed at this boundary. This thin line is continuous with the sarcolemma facing the interstitial connective tissue spaces.

The elementary fibrils of the myofibrils do not bridge over the gap formed by the less opaque area of the intercalated disc.

The width of this bright zone is 150–200 Å. The adjacent opaque areas show a finely granular appearance. Its boundary towards the sarcomere is somewhat irregularly outlined and not sharply demarcated as it is towards the bright central zone.

The analysis of a great number of EMG's indicate that the cardiac muscle tissue is completely subdivided into units representing cell territories without any anastomoses. This conclusion is further supported by the very careful light microscopic study of AURELL[7] with three dimensional reconstruction of the arrangement of the intercalated discs. The rod-like structure frequently observed at the intercalated discs when studied by means of light microscopy corresponds to a wavy arrangement of the cell boundary at the site of the disc. When the amplitude of these waves is pronounced

[1] G. AURELL, *Die Glanzscheiben des Herzmuskelgewebes und ihre Verbindungen* (Stockholm, 1945).

[2] V. L. VAN BREEMEN, Anat. Rec. *117*, 49 (1953).

[3] G. H. BOURNE, Nature *172*, 588 (1933).

[4] G. PALADE, J. exptl. Med. *95*, 285 (1952).

[5] F. S. SJÖSTRAND, Exper. *9*, 114 (1953).

[6] H. E. HUXLEY, Biochim. biophys. Acta *12*, 387 (1953).

[7] G. AURELL, *Die Glanzscheiben des Herzmuskelgewebes und ihre Verbindungen* (Stockholm, 1945).

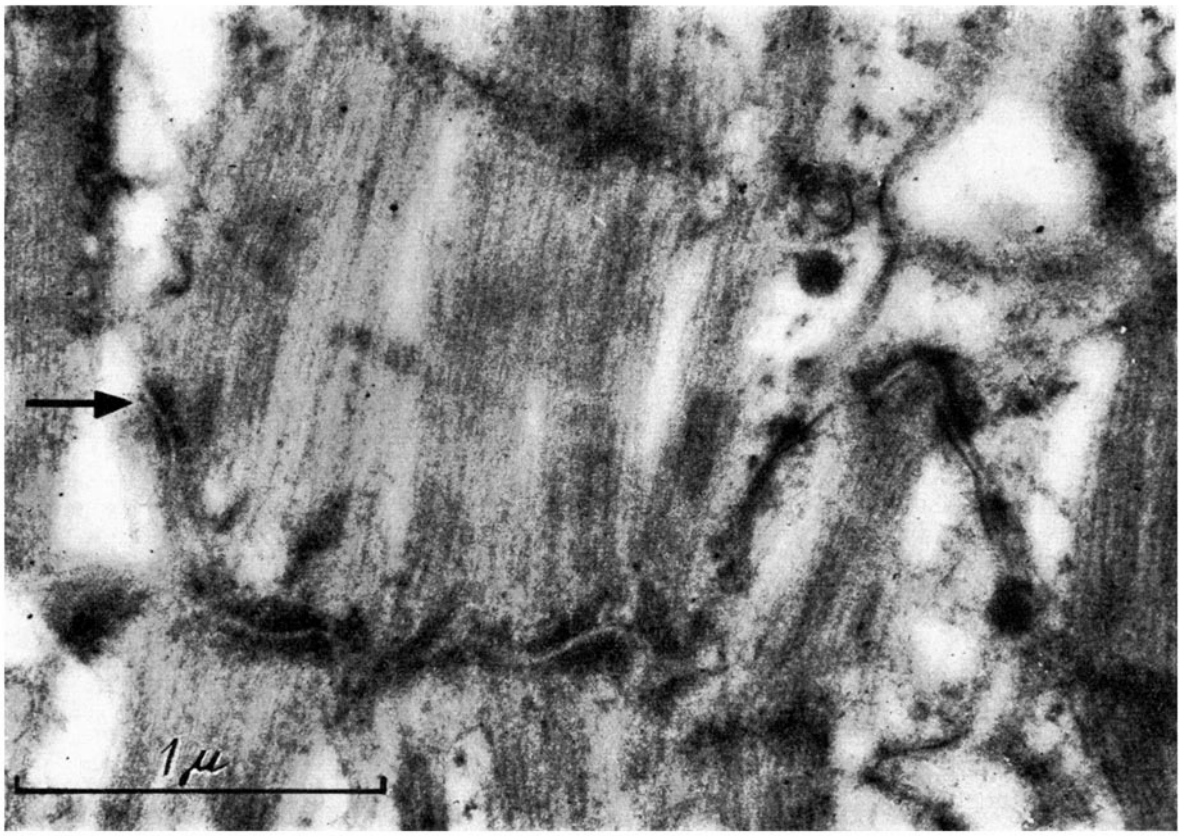

Fig. 1.—Longitudinal section through a cardiac muscle myofibril. In the lower part an intercalated disc extending across the myofibril. Magnification 48,000 ×.

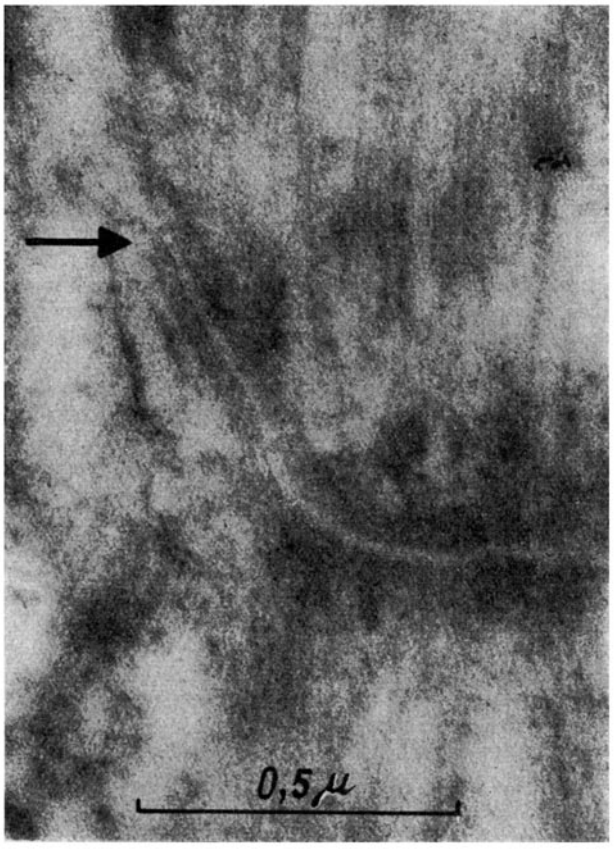

Fig. 2.—The left part of the same intercalated disc as shown in Figure 1 but from a section in series with that shown in Figure 1. The relation between the sarcolemma and the intercalated disc is shown. Magnification 84,000 ×.

they will appear as rods at the resolution of the light microscope.

The cardiac muscle tissue, as composed of well defined individual heart muscle cells, is important to consider when discussing the spreading of the excitatory state through the cardiac muscle. The observations of BOURNE regarding the occurrence of succinic dehydrogenase and non-specific alkaline phosphatase in the intercalated discs point to their possessing considerable metabolic activity. BOURNE assumed that they might act as boosters of the contraction wave spreading through the cardiac muscle tissue at the heart beat.

A similar appearance of cell boundaries has been observed in several other tissues, for instance, the epidermis of frog skin[1], the so-called external limiting membrane of the retina of the guinea pig eye[2] and the exocrine cells of the pancreas[3].

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Zusammenfassung

Eine elektronenmikroskopische Analyse ultradünner Schnitte durch Herzmuskelgewebe hat ergeben, dass die sogenannten Glanzscheiben speziell organisierte Zellgrenzen sind. Das Herzmuskelgewebe ist folglich in Herzmuskelzellen eingeteilt und bildet kein Synzytium. Die Elementarfibrillen der Muskelfasern erreichen die Zellgrenzen an den Glanzscheiben, überbrücken aber nicht die 150–200 Å breite Zone zwischen den opaken Partien der benachbarten Zellgrenzen.

[1] D. OTTOSSON, F. S. SJÖSTRAND, S. STENSTRÖM, and G. SVAETICHIN, Acta physiol. Scand. *106*, 611 (1953).

[2] F. S. SJÖSTRAND, J. Cell. and. Comp. Physiol. *42*, 45 (1953).

[3] F. S. SJÖSTRAND and V. HANZON, Exptl. Cell. Res. (in press).