EUTECTIC STRUCTURE OF MUSCLE AND CONNECTIVE TISSUES

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Abstract

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P. S. VADILO

EUTECTIC STRUCTURE OF MUSCLE AND CONNECTIVE TISSUES

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We have shown ([1]) that regular crystallization of a given substance on a crystal of a substance epitaxial to it* can occur only in the case where the medium is more or less substantially supercooled with respect to the crystallizing substance (the solution or vapor is supersaturated, the melt or high-temperature crystalline phase is supercooled). The supercooling must be the greater, the smaller the structural planar analogy between the corresponding faces of the crystals of the given substance and of the substance epitaxial to it. As soon as crystallization of the given substance has begun on one of the surface regions of the crystal of the epitaxial substance, a crystal of the former is formed. At the same time, owing to the liberation of the heat of crystallization and the absorption of the crystallizing substance, the supercooling of the medium adjacent to the crystal surface with respect to the given substance decreases. Formation of a new crystal of the given substance on the crystal of the epitaxial substance can occur only at some distance from the first crystal of the given substance. This distance is the greater, the smaller the supercooling of the total mass of the medium with respect to the given substance and the smaller the planar structural analogy between the crystal of the latter and the crystal of the substance epitaxial to it. Crystals of epitaxial substances possess planar structural analogy, not identity. Therefore crystals of the given substance formed on a crystal of the substance epitaxial to it may be either in a crystallographically parallel position or in a twinned position (rotated by 180°).

During the crystallization of melts of eutectic composition, for example Sn—Pb or Cd—Zn, large crystals of the predominant component of the melt are formed, and on each of these there arises

Fig. 1. Structure of metal eutectics. A —single-crystal grain of Sn, grown by the Czochralski method from a melt of Sn—Pb of eutectic composition. Needlelike Pb crystals, grown into the single-crystal Sn grain, are visible. 1.5×. —base of the same single-crystal grain. The tips of very small Pb crystals (dark areas) are visible, situated in crystallographically parallel and twinned positions relative to one another. 20×. —apex of a single-crystal Sn grain grown by the Czochralski method from a melt of Sn—Bi of eutectic composition. In the Sn grain (light) there are needlelike Bi crystals (dark), situated in crystallographically parallel positions relative to one another, as is evident from their

faceted tips (above). 20×

Fig. 2. Eutectic structure of connective and muscle tissues. A –structure of the flight muscle of the insect *Achalarus lyciades*. In large crystals of one protein there are many crystals of another protein, situated in crystallographically parallel positions relative to one another. 215,000×. –transverse section of muscle of the heart of a rabbit. The same phenomena as in Fig. 2A. Small crystals are in crystallographically parallel and twinned positions. 68,500×. –transverse section of connective tissue of the insect *Agallia constricta*. In a large crystal of one protein there are many small (dark areas) crystals of another protein, situated in crystallographically parallel and twinned positions. 40,000×

* Crystals of epitaxial substances have planar structural analogy [with the corresponding faces].

Fig. 1

Fig. 2

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crystals in a crystallographically parallel and twinned position of a multitude of small faceted crystals of the component present in the smaller amount (Pb crystals on an Sn crystal, Zn crystals on a Cd crystal (Fig. 1) [(1)]). Since the crystals of the predominant component and the numerous small crystals of the nonpredominant component that have arisen on it grow simultaneously, the latter grow into it with their bases, while their apices remain on the surface of the crystal. Owing to this, the crystals of the nonpredominant component acquire a threadlike habit and are found inside the crystal (or branch of the dendrite) of the predominant component. These phenomena mean that the substances forming a eutectic are epitaxial (at least, the substances investigated by us).

In the mineralization of the skeleton of a vertebrate animal and of man, there is epitaxial overgrowth of apatite crystals on the crystals of the collagen protein that make up the cartilaginous skeleton of the embryo of the vertebrate animal and of man. In the electron-microscopic photographs, cited in [(2)], of sections of such a skeleton at the initial moment of its mineralization, it is seen that the apatite crystals that have arisen on a large collagen crystal are in crystallographically parallel and twinned positions relative to one another. But an apatite crystal cannot be epitaxial to a collagen crystal, since the macromolecules that make up the collagen crystal are thousands of times larger than the particles composing the apatite crystal. Evidently, the epitaxial pair is the macromolecule of the collagen protein and the apatite crystal, since the ions composing the protein macromolecules scarcely differ in size from the particles composing apatite crystals. In the collagen protein crystal, all its constituent macromolecules are oriented crystallographically identically. Therefore each region of the surface of the collagen protein crystal is epitaxial with respect to apatite.

It is generally known that the calcite skeletons of sea urchins and sea lilies are single crystals (when struck, they cleave like crystals of Iceland spar). There is no doubt that they arose owing to epitaxial overgrowth of calcite on large single crystals of protein that made up the skeleton of these animals before its mineralization.

We have studied electron micrographs of muscular and connective tissues of various animals, kindly made available to us, with permission to publish them, by A. Corsi, F. I. Reger, and K. Maramorosch. In these micrographs it is clearly seen (Fig. 2) that muscular and connective tissues have the same structure as a solid eutectic, for example Sn–Pb (Fig. 1). This means that muscular and connective tissues are large crystals of one protein, in each of which there are many fibrous crystals of another protein, located relative to one another in crystallographically parallel and twinned positions. These tissues are formed as a result of the crystallization of proteins analogous to the crystallization of melts of the eutectic composition of inorganic substances.

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CITED LITERATURE

[1] P. S. Vadilo, *Transactions of the Kursk Pedagogical Institute*, No. 4, 1957, p. 141; *Crystal Growth*, **1**, 1957, p. 138.
[2] M. Gliter, *Contemporary Problems of Biology*, Moscow, 1961, photos 14, 16.

Note: Figure translations are in progress. See original paper for figures.