CUTICULAR ULTRASTRUCTURE OF EPITHELIAL CELLS OF THE MUCOUS MEMBRANE OF THE SMALL INTESTINE IN DOGS, RATS, AND MAN

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An electron-microscopic investigation of the cuticle of the epithelial cells of the mucous membrane of the small intestine of dogs, rats, and man has shown that the general scheme of ultrastructure of the brush border of the intestinal epithelium is similar, differences being found only in the length, diameter, number, and arrangement of the microvilli. These are longest in man. Because of the microvilli, the absorbing surface of the epithelial cells of the small intestine is increased 20-77 times.

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A major factor determining the rate of absorption of food substances is the large absorbing surface of the small intestine and the characteristic structure of the epithelial cell cuticle. Results of electron-microscopic investigations have shown that the cuticle of the intestinal epithelium is very complex in structure, and consists of a very large number of extremely thin cytoplasmic fibrillary microvilli, covered externally by a typical cell membrane [1-6, 10-12, 14-17]. According to some observations [4, 8, 9, 13], many enzyme systems concerned with the active transport of substances and also with the completion of contact digestion are located in the zone of the microvilli.

So far the electron-microscopic structure of the epithelial cell cuticle of the intestinal mucous membrane has been studied in sheep and some laboratory animals (frogs, mice, and rats).

We have made a comparative study of the cuticular ultrastructure of epithelial tissue of the small intestine in dogs, rats, and man.

EXPERIMENTAL METHOD

In chronic experiments on dogs the mucous membrane was removed from an isolated loop of small intestine by the method previously developed by the authors [7]. The mucous membrane of the small intestine of rats was excised in an acute experiment, and in man during operations on the gastrointestinal tract. The material was fixed by Palade's method in 2% osmium tetroxide. Ultrathin sections were cut with glass knives on a type UMD-5 ultramicrotome and investigated with the UÉMV-100B electron microscope at a voltage of 75 kV.

EXPERIMENTAL RESULTS

The free surface of the epithelial cells of the mucous membrane of the small intestine in dogs is covered with a cross-striated cuticle up to 2 μ in height. At the apical pole of the cytoplasm many mitochondria of different shapes and 0.6-1.9 μ in length (0.1-0.7 μ in diameter) are found. Goblet-shaped cells with a clearly defined surface, also with a cuticle on their free surface, are distributed singly between the groups of cells. The cuticle is formed of numerous microvilli, lying vertically or at an angle, and not always uniformly. On all sides the microvilli are bounded by a line which is the continuation of the cell membrane (Fig. 1). The distance between them rarely exceeds 200 A. The height of the microvilli varies from 1.2 to 2 μ (diameter 0.08-0.12 μ), and the surface area of the one microvillus is 0.5 μ^2. The density of microvilli is 40-70 μ^2 of the cell.

The epithelial cells of the mucous membrane of the rat's small intestine also are covered with a cross-striated cuticle (Fig. 2). The winding membrane is clearly visible between the cells. The height of

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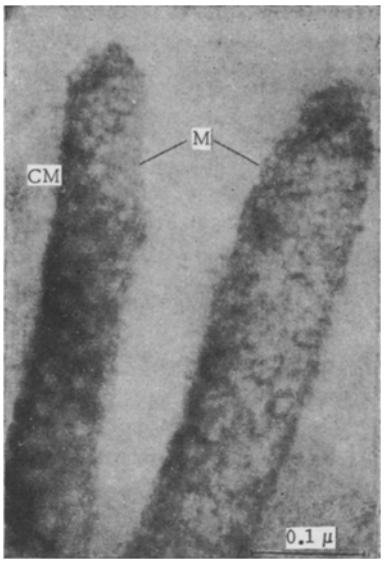

Fig. 1. Electron micrograph of longitudinal section through two microvilli of an epithelial cell of the mucous membrane of a dog's small intestine. The surface of the microvillus (M) is covered by a cell membrane (CM). Fixation with 2% osmium tetroxide. 180,000 ×.

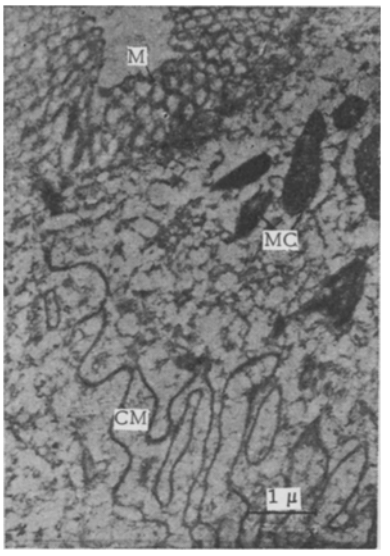

Fig. 2. Electron micrograph of transverse section through the apical part of epithelial cells of the mucous membrane of a rat's small intestine. Microvilli (M) cut across transversely, mitochondria (MC), and the winding cell membrane (CM) can be seen. Fixation with 2% osmium tetroxide. 11,000 ×.

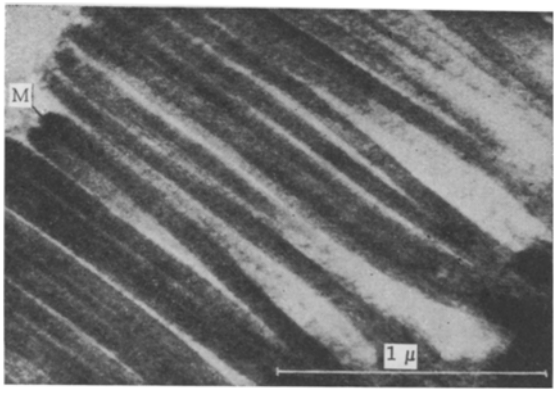

Fig. 3. Electron micrograph of longitudinal section through cuticle of epithelial cells of mucous membrane of human small intestine. Long, thin microvilli (M), in close contact with each other, can be seen. Fixation with 2% osmium tetroxide. 430,100 ×.

the microvilli in rats is much smaller than in dogs, namely 0.4–1 μ (diameter 0.08–0.1 μ). The distance between them is 150–200 A. The mean surface area of one microvillus is 0.2 μ^2. The density of microvilli is 80–120 μ^2 of cell.

The brush border of the epithelial cells of the human small intestine shows certain distinguishing features from that in the rat and dog (Fig. 3). The microvilli of the cuticle are very long (1.8–2.2 μ; diameter 0.08–0.13 μ). They are arranged uniformly or in tufts, and are covered externally by a membrane. Their contents are homogeneous. Similar processes are present on the goblet cells. The surface area of one microvillus is 0.7 μ^2 and the density of microvilli is 80–150 μ^2 of cell surface. Round or rod-shaped mitochondria are found mainly in the apical part of the cell cytoplasm. None are present in the goblet cells. Complex, winding protrusions of membranes are present between the lateral surfaces of the cell, and may act as a reserve for the cell enabling it to increase its volume during absorption of food substances.

It may be concluded from the results of these investigations that the general scheme of ultrastructure of the cuticle is similar, and that differences are found only in the length, number, and arrangement of the microvilli. Depending on the level of development of the animal, an increasingly complex structure of its brush border is observed. The microvilli reach their highest development in man, rather less in dogs, and

less still in rats. Because of the microvilli, the absorbing surface of the epithelial cells of the small intestine is increased 20 times in rats, 27 in dogs, and 77 times in man. The particularly great increase in cell surface in man is the result of the large number of microvilli and of their length.

The uniform or tufted distribution of cytoplasmic fibrils (vertical or sloping) is evidence of their great mobility and their active participation in absorption processes. The closeness of the individual microvilli (150-200 A apart) suggests that only substances with molecules smaller than 200 A in diameter can penetrate into the brush border of the epithelial cells of the small intestine.

Hence, the presence of microvilli, considerably increasing the free cell surface, is a morphological adaptation providing for high rates of enzymic hydrolysis and absorption of food substances.

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