FUNCTIONAL AND MORPHOLOGICAL FEATURES OF THE MUCOUS MEMBRANE OF THE GUINEA PIG SMALL INTESTINE

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Many studies have been made of the change in weight, volume, and length of the different parts of the intestine in relation to the food required [1, 3, 4]. The secretion of intestinal juice is related to the kind of food [6, 7]. However, insufficient attention has been paid to the physiological features.

In our investigations we have paid principal attention to the mucous membrane, because it is here that secretion and absorption take place and there is close contact between this part and the food mass, and the mucosa is adapted to the quality of the food. Besides the structural features of the intestinal mucous membrane we have also studied in guinea pigs the process of desquamation of the epithelial cells [2, 5, 8, 9], which appears to depend upon the characteristics of the food.

EXPERIMENTAL METHOI

The guinea pigs were fed on cabbage, beetroot, hay, oats, milk, and grass. The experiments were carried out on 43 adult guinea pigs, on three newborn animals, and on four fetuses. In the adult and the newborn guinea pigs we studied the duodenum, and the anterior, middle and posterior divisions of the small intestine. To follow possible changes in the time taken for digestion, the animals were killed at various times after they had fed; four after 5-7 min, three after 40 min, three after 1½ h, three after 3 h, three after 4 h, three after 7 h, two after 16 h, and four after 26 h. In 15 animals the time which had elapsed after the last meal was not determined. They were killed by decapitation and immediately dissected. The material was fixed in two ways. In the first group (45 guinea pigs) after the abdominal cavity had been opened the different parts of the intestine were removed and immersed in various fixatives (formalin, Bouin, Zenker, or Carnoy), in order that artefacts might be excluded through the use of several methods. We embedded the material in paraffin or in celloidin. Some of it was sectioned on a freezing microtone. In the other method of fixing the mucous membrane (five guinea pigs) of the intestine of the dead animal was first washed in physiological saline, and then the fluid fixative (formalin or Bouin's fluid) was introduced into the lumen. Sections were stained in hematoxylin-cosin or in thionine; the following chemical tests were carried out: polysaccharides – Van Duin; RNA – Brachet; DNA – Feulgen; phospholipids – acid hematin; Lipofuchsin – Shmorl' with control reactions for ferrous salts by the method of Perls; the test for iron was by McCallum's method; Vitamin C – Zhir and Le Blanc.

EXPERIMENTAL RESULTS

In the wall of the guinea pig's small intestine small Peyers patches (0.2 to 0.4 cm in diameter) could well be seen by the naked eye from the outer side. There were only three or four of them and they were evenly divided along the length of the intestine. At the upper end, the first patch lay 18-20 cm from the pylorus.

The cecum takes origin 1-1.5 cm below the junction of the small and large intestines; it somewhat resembles that of the rabbit, though it is much smaller (about 11-14 cm). In the guinea pig there is no well-marked lymphatic sac at the point at which the cecum arises. A further difference from the rabbit is that there is no vermiform appendix to the cecum.

Fig. 1. Separation into the lumen intestine of the epithelial cells from the villus vertex of the guinea pig No. 12. The staining according to Van Duin. Enlargement 400.

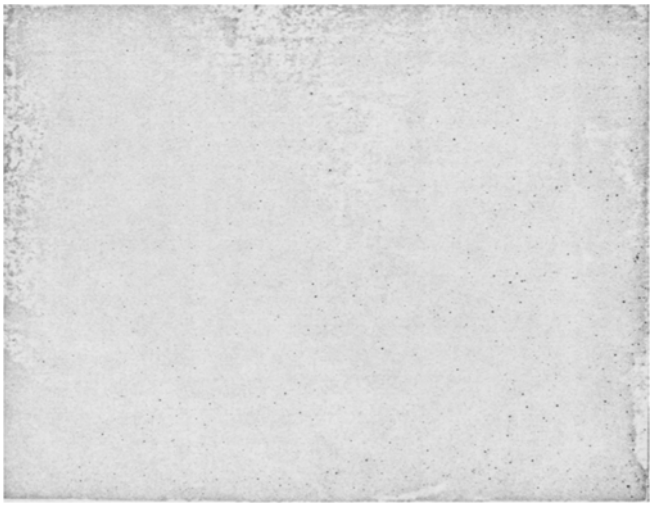

Fig. 2. Fixator's administration into the lumen intestine of the guinea pig No. 40. Reticular stroma of the villus vertex is deprived of nutrient tegment. The straining with hema - toxylin eosin. Enlargement 200.

Histological studies show that in the meshes of the reticular syncytium of the basement membrane of the mucosa, besides lymphocytes, plasma cells, cells with an eosinophil granularity in the cytoplasms, and macrophages, in the stroma of the mucosa of the different portions of the intestine various stages of disintegration of plasma cells into cells with an eosinophilic granularity could be seen. The breakdown product of these cells could be seen in the meshes of the reticular stroma. Feulgen's and Brachet's reactions revealed nucleic acid in the form of droplets or granules. The disintegration products of the cells were present in the cytoplasm of the macrophages – large cells with a rounded cytoplasmic outline. The nuclei of the macrophages were large, rounded or oval, and showed occasional chromatin granules. Sometimes macrophages as well as a large number of inclusions and pigment granules were present in their cytoplasm.

The qualitative study of the pigment granules shows that the pigment dissolved in neither 25% HCl nor 25% NaOH but it gave no red stain in the reaction with concentrated H_2SO_4, and that it gave a positive reaction for iron oxide salts and bound iron. The reaction for bound iron was better shown in material taken from adult animals. In

the macrophage cytoplasm large amounts of polysaccharides, phospholipid inclusions and vitamin C were present. The pigment granules or a considerable proportion of them must consist of hemosiderin formed as a result of transformation of the phagocytosed elements.

Macrophages were found in the basement membrane of the mucosa of all parts of the intestine of fetuses, or newborn or adult guinea pigs. They were found in various parts of the mucosa and formed large accumulations in the stroma of the apex of the villi greatly extending the meshwork of the reticular syncitium in these regions. Occasional macrophages penetrate into the epithelium, chiefly the epithelium of the apices of the villi.

The remainder of the reticular stroma of the mucosa of the guinea pig small intestine differed little from that of the rabbit. As in rabbits in the central portion of many of the villi there was a formed lymphatic duct. The endothelium of the wall of the duct could be seen well in several preparations. In the lumen of the expanded ducts sometimes fine protein grains were present.

On the surface of the reticular stroma of the villi and crypts there was a layer of secretory epithelium. The cells of the epithelium had a well-marked cuticular border which in parts showed a rod-like structure. The cuticle is rich in polysaccharides and in Vitamin C. The tissue of the epithelium is infiltrated with wandering cells, chiefly lymphocytes (10-20, or more seldom 60-80) cells in a section through the epithelium of a single villus. Sometimes in the epithelium cells with an eosinophil granularity in the cytoplasm could be seen.

There is a variation in the connection of the epithelium with the reticular stroma in the different regions of the duodenum and small intestines and in the different villi. In most villi the epithelium is firmly joined with the reticular stroma and in parts covers its surface. However, in many villi the epithelial layer at the apex is separated from the reticular stroma. In these villi the epithelium is, as it were, raised up above the reticular stroma of the apex, forming small tubes or "covers" in these regions. Beneath the layer of epithelium which has been raised up and pushed aside from the stroma, in the lumens of the tubes albumen and occasional wandering cells are to be found. At the apex of a villus, tubes consisting of epithelium seldom reach one-quarter of the length of the villus.

In the intestine just as in other animals we found epithelial cells shed into the intestinal lumen. The epithelium desquamates along the whole length of the small intestine, the process being somewhat more marked in the duodenum and in the upper end of the small intestine. But in these parts the rate of desquamation is quite low. At the apex of the villi 5-10 cells are torn away. Such cells can be seen in the intestinal lumen in the neighborhood of the apices of the villi, and in the mass of intestinal chyme (Fig. 1).

The cells which have been shared differ from other epithelial cells of the villi. The cytoplasm is looser, it frequently stains less strongly with eosin than does the cytoplasm of the cell of the lateral surfaces of the villi. The cells which have been shed are also distinguished by the distribution of phospholipids in the cytoplasm. In the epithelium of the sides of the villi, acid hematin reveals phospholipids throughout the whole cytoplasm of the cell; it takes the form of brightly stained clumps. No such intrusions are present in the desquamated cells. Their cytoplasm is less strongly stained with hematin but it also gives quite a uniform reaction. In certain preparations we observed the disintegration of the desquamated cells.

The desquamation of the epithelial cells in the small intestine can be followed by use of various fixatives, dilutions, embedding materials, and by various methods of fixation, either by immersing pieces of intestine into the fixative or by irrigating the intestine with it. When the second method is used, many of the villi show bare portions of stroma which has been exposed through desquamation of epithelial cells (Fig. 2). Such cells are seen in sections made from the residue obtained by centrifugation of the washing fluid and fixative. It is important to note that the second method of fixation leads to undesired consequences. Even the most careful washing of the intestine and introduction of fixative into the lumen leads to a distension of the intestinal cells rendering the mucosa thinner. The general appearance of the mucosa is then altered; the villi becomes smaller, shortened, and separate from each other by a considerable distance.

By killing the animals at various times after they had fed we attempted to determine the influence of feeding on the structure of the mucosa, principally during the process of desquamation of epithelial cells. However, we were unable to make out any relationship between desquamation of epithelial cells and the time between the amount of the last feed and the moment of death.

Our investigations show that on the one hand the intestinal mucosas of the guinea pig and rabbit have many common features, and on the other that they differ in many respects. In both, lymphoid tissue is sparse. In the guinea pig Peyers patches are few, and the cecum has no lymphatic sac or vermiform appendex. In the guinea pig, which differs in this respect from other animals, macrophages are present in the stroma of the mucosa. Their presence is related neither to age nor to any transient reaction in response to a local or generalized stimulus.

At present nothing is known of the significance of the macrophages in the guinea pig mucosa. The large amount of polysaccharides, and the presence of phospholipids and Vitamin C in their cytoplasm indicate a high metabolic activity. Possibly they are in some way concerned with protein metabolism.

Guinea pigs show a characteristic desquamation of epithelial cells. In the number of cells which are shared the guinea pig resembles the rabbit. As in the latter a small number of epithelial cells are shed into the lumen. However, in the guinea pig, at the apices of the villi short epithelial tubes are formed but they are not found in rabbits.

As in rabbits we attribute the small number of desquamating epithelial cells in the intestine to an adaptation of these animals to vegetable food which is comparatively poor in protein. This viewpoint is entirely in line with experiments where it has been shown that the influence of protein in the diet on the amount of the thick portion of the juice in the canine intestine.

SUMMARY

As has been shown, the guinea pig is not rich in lymphoid tissue. Peyer's patches are not numerous, there is no appendix and no lymphoid sac. Guinea pigs differ from other animals which have been studied in having macrophages in the stroma of the mucosa. These macrophages are confined to the intracellular space of the reticular syncitium and are present in the fetuses, newborn animals, and adults. Desquamation of the cellular epithelium is a characteristic of guinea pigs. The epithelium forms short tubes on the apices of the villi. Only a few cells are detached from the apices of the villi into the intestinal lumen.

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