

nantly with peripheral zone of endotheliocyte (most effective transport zone) was relatively stable both in intact and desympathized rats. This feature of the BCC architectonics complies with the principle of biological utility with respect to optimization of JCC-transporting processes.

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Ultrastructural and Stereological Analysis of the Gastric Epithelium in Wild Muridae from Regions Exposed to Anthropogenic Pollution

G. I. Nepomnyashchikh, S. V. Aidagulova, and L. M. Nepomnyashchikh

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Ultrastructural analysis of epitheliocytes in the gastric mucosa of wild Muridae captured in three regions of the Altai with various levels of ecological pollution reveals predominance of dystrophic and atrophic changes in the surface and glandular epithelium. Stereological analysis demonstrates a universal character of structural response to a complex of anthropogenic factors.

Key Words: radiation and anthropogenic pollution; wild rodents; gastric epithelium; ultrastructure; stereology

An attempt has been recently made to determine threshold parameters for radiation and technogenic toxicants and to substantiate biological criteria of ecological stress [2-4,7,10]. It has been emphasized that the permissible doses of adverse eco-

logical factors should be established on the basis of ultrastructural changes [11] with proper consideration of the role of the borderline tissues [6,8]. In this context, gastric mucosa represents a convenient model. As an entry for various xenobiotics, promptly renewing gastric epithelium may serve as an indicator of the mobility of adaptive-compensatory reactions developing at the basis of regeneration processes.

Laboratory of Ultrastructural Pathology, Institute of Regional Pathology and Pathomorphology, Siberian Division of the Russian Academy of Medical Sciences, Novosibirsk

In the present study, electron microscopy and stereological methods were used to analyze ultrastructural reactions of the gastric mucosa epithelial cells from wild Muridae captured in three regions of the Altai with different ecological conditions.

MATERIALS AND METHODS

The study was carried out on common voles (*Microtus arvalis*). By virtue of peculiar vital activity, trophic relations, and behavioral characteristics [1,5] common voles most closely contact with the soil, which is known to accumulate technogenic pollutants. A total of 60 adult rodents weighing 17 ± 2 g were studied. Group 1 comprised animals captured in the Uglovskoe region which was maximally affected by atmospheric nuclear explosions in the Semipalatinsk testing ground in 1949-1962 [1]. The animals of group 2 were captured in the Lokot' region. This zone was exposed to both moderate radioactive pollution and contamination by heavy metals due to intense development of mining industry [12]. The animals of group 3 were captured in the Tyumentsevo region which is a little contaminated with radionuclides, while the concentrations of pesticides in the soil are high due to intense irrigation agriculture [12].

Specimens of gastric mucosa from the fundal region were fixed in 4% paraformaldehyde and post-fixed in 1% osmium tetroxide, dehydrated, and embedded in Epon-Araldite. Ultrathin sections were examined under a JEM-100B electron microscope.

Stereological parameters of the surface epithelium, parietal and chief cells were determined using electron micrographs at a final magnification of 12,000. The volume and surface density of the nucleus and ultrastructure of epitheliocytes were measured using the multipurpose test system consisting of short lines ($n=21$, $P_t=42$, $L_t=35 \mu$), and the secondary stereological parameters for organelles (surface/volume ratios) were then calculated [9].

RESULTS

In animals of group 1, the height of the surface epitheliocytes varied in different parts of gastric pits, cuboid, flat, and sometimes rhomboid cells prevailing (Fig. 1, a). Numerous complex interdigitations — extensive contacts of lateral surfaces with narrow intercellular spaces — were observed. The luminal surface was flattened due to reduction of the microvilli, while the basement membrane was swollen and lacked fibers. In the majority of cells, the number of heterochromatin condensates along dilated nuclear membrane and over the nucleus was increased. The nucleolus was often blot-shaped.

Collapse and segregation of the nucleoli were sometimes observed.

The cytoplasm of some surface and pit epitheliocytes was characterized by high electron density with solitary secretory granules in the apical part, small immature polymorphic granules of varied density predominating. Chaotically directed narrow profiles of the cytoplasmic reticulum, solitary mitochondria with electron-dense matrix and sparse cristae, elements of the Golgi complex, and polymorphic lisosomes were seen in the perinuclear zone.

Parietal cells of the top and middle glandular compartments (Fig. 2, a, b) were heterogeneous in their functional activity. The most abundant cells were glandulocytes with heterochromatin-enriched nuclei and signs of tubulovesicular hypoplasia and profiles of intracellular secretory channels, focal decomposition of cristae in few mitochondria, and numerous myelin figures.

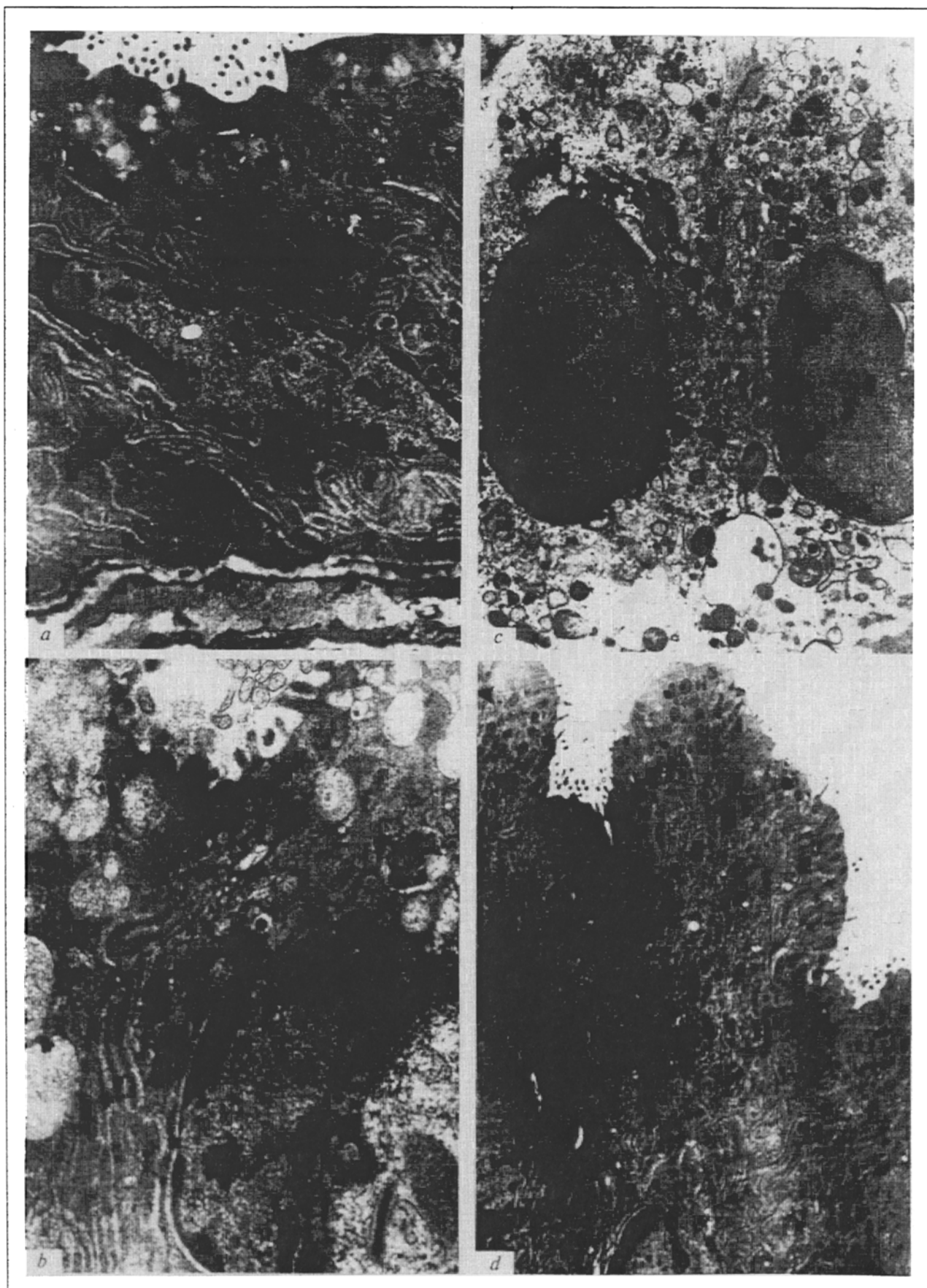
Chief cells showed a higher level of heterogeneity, different stages of the secretory cycle, and accumulations of secretory granules heterogeneous in electron density. The cytoplasm was empty and electron-transparent; vacuolization, fragmentation of dilated cisternae of the rough endoplasmic reticulum containing a floccular material, and formation of multivesicular bodies were observed.

In group 2 voles, the surface and pit epitheliocytes of the gastric mucosa retained their cylindrical shape (Fig. 2, b, c), the areas of contact between lateral membranes were considerably smaller than in group 1, and reduction of the apical microvilli was minimal. The nuclei usually had large nucleoli, the number of cytoplasmic protein-synthesizing organelles was reduced, few large mucoid granules and non-secreting cells were seen.

Morphological differences between parietal cells of group 1 and group 2 voles were insignificant: the myelin figures were less abundant and nuclear polychromia was noted. Chief cells varied considerably in size and electron density of secretory granules, light granules with dense core predominating.

Another pattern of the ultrastructural alterations in epitheliocytes of gastric mucosa was observed in group 3 voles. The nuclei of the surface and pit epitheliocytes (Fig. 1, d) contained crude chromatin clumps. The cytoplasm was characterized by ex-

Fig. 1. Ultramicroscopic characteristics of surface and pit epitheliocytes of gastric mucosa from voles captured in different regions. a) flat cells with immature secretory granules, $\times 4000$; b) numerous profiles of rough cytoplasmic reticulum, $\times 4000$; c) small polymorphic lisosomes and solitary secretory granules, $\times 5000$; d) large fluctuation of cell height, poorly structured cytoplasm with small dense granules, $\times 5000$. Uglovskoe (a), Lokot' (b, c), and Tyumentsevo (d) regions of the Altai.



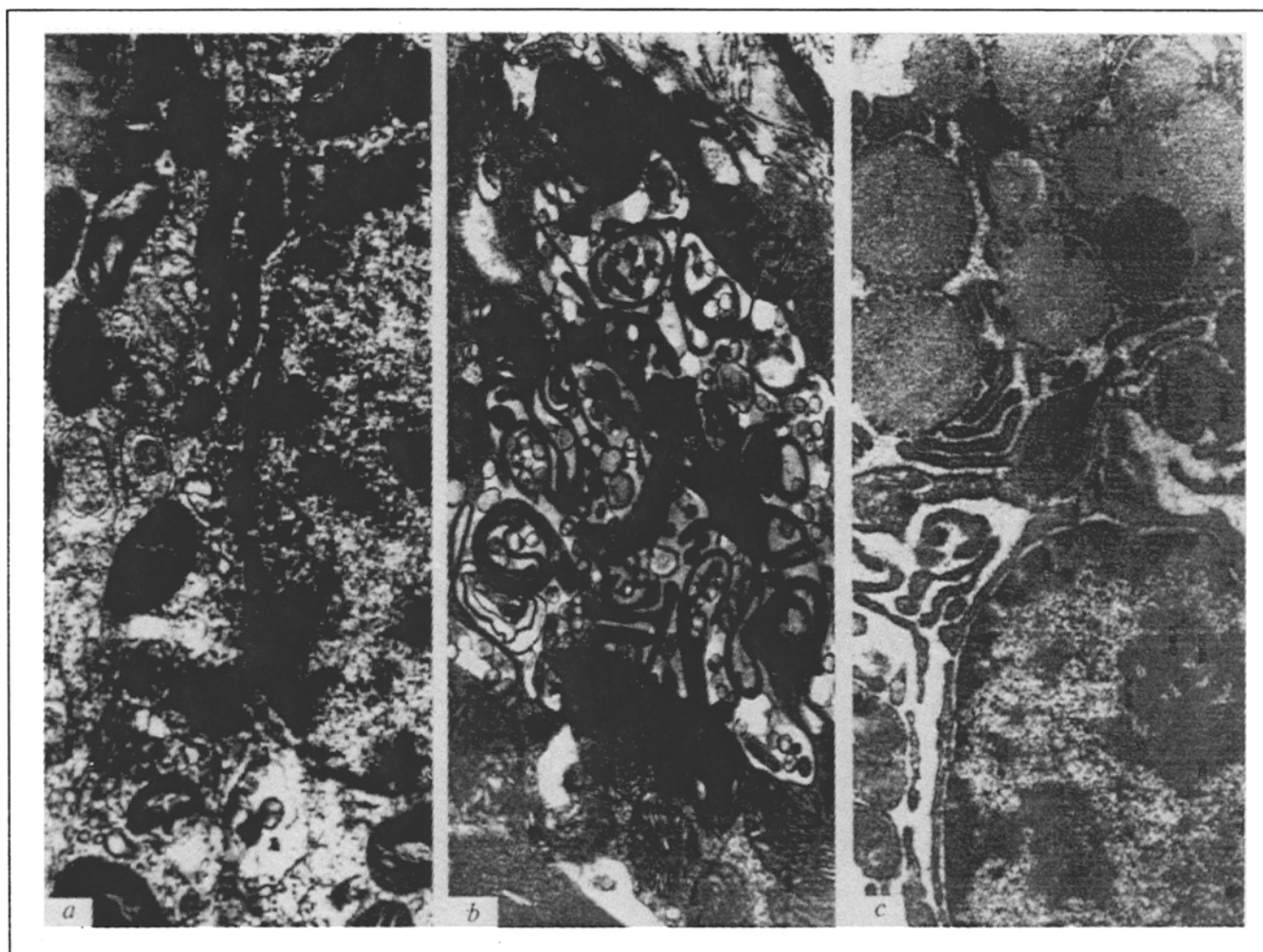


Fig. 2. Ultrastructure of parietal and chief glandulocytes of gastric mucosa from voles captured in different regions. a) decomposition of mitochondrial cristae, reduction of secretory tubules of a parietal cell. $\times 8000$; b) accumulation of myelin structures and lipid droplets in a parietal cell, $\times 10,000$; c) chief cell with polymorphic secretory granules and dilated cisternae of cytoplasmic reticulum, $\times 6000$. Uglovskoe (a, b) and Tyumentsevo (c) regions of the Altai.

tremely high electron density, abundant randomly oriented filamentous profiles of the cytoplasmic reticulum, numerous lysosomes, and mitochondria with densely packed cristae. The high electron-dense secretory granules varied considerably in size and shape.

Functional activity of glandulocytes also varied in a wide range. The degree of chromatin condensation in the nuclei and the number of tubulovesicles and profiles of secretory tubules in the cytoplasm were different in parietal cells at the neck and base of the gland. The mitochondrial cristae were parallel or randomly oriented and exhibited the signs of focal decomposition. Parietal cells with enhanced functional activity predominated. In the chief cells, partial edema of the cytoplasm, focal fragmentation, and vacuolization of the cytoplasmic reticulum cisternae were observed in line with different stages of granule formation.

Stereological analysis of the ultrastructure of surface and pit epitheliocytes from group 1 and group

3 voles revealed a significant difference between the surface/volume ratios of the nuclei. In group 1, the mean cell area was significantly smaller, indicating epithelial atrophy. Bearing in mind light microscopy data on the architectonics of gastric pits in group 1 animals, it can be suggested that in this case adaptation consists in the maintenance of the primary barrier role of these cells. In group 3, we found epitheliocyte hyperplasia. It should be noted that there were no statistically significant intergroup differences between stereological parameters of the granules.

In group 1 voles, a significant increase in the volume density of the nuclei reflected an increase in the number of binuclear parietal cells. The surface density and the surface/volume ratio of secretory tubules differed significantly in all the studied groups, the difference being maximal in group 2 and minimal in group 1. This may be associated with accelerated involution of the neck of gastric glands (judging from

numerous myelin figures) and with differences in the stages of acid secretion.

Ultrastructural stereological analysis of chief cells revealed slight intergroup differences. This indicates that the secretory function of glandulocyte is preserved at an approximately equal level; some fluctuations of these parameters indicate a mosaic pattern of granule-formation processes.

Thus, analysis of the ultrastructural organization of the gastric mucosa epitheliocytes of voles captured in the regions with a high level of anthropogenic pollution showed that these changes are based on dystrophic processes reducing the functional activity of the surface and glandular cells. This is a universal structural response of the borderline tissues [8] to adverse environmental conditions

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