in regulation of the trophic functions of the pituitary. Evidence that catecholamines may be involved in the control of the hypothalamic-pituitary-gonads system is given by the results of physiological investigations: on intracerebral injection of 6-hydroxydopamine in 16-day-old fetuses, leading to selective degeneration of noradrenergic terminals, the rise of the testosterone level characteristic of 18-day-old fetuses does not take place [9].

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ULTRASTRUCTURAL MANIFESTATIONS OF FUNCTIONAL PLASTICITY OF THE ENDOTHELIUM OF THE RENAL GLOMERULI IN VERTEBRATES

V. B. Zaitsev, N. T. Raikhlin, and I. N. Sokolova

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The kidney is one of the first biological objects to have undergone thorough submicroscopic investigation in the very earliest stages of creation and development of electron microscopy [5, 7, 8, 10, 11]. In accordance with an empirical rule formulated by Ugolev [4], if a feature discovered in organisms occupying extreme position in the phylogenetic series is constant or varies within certain limits, this feature in intermediate species will correspond to the general rules for that series. The kidney as an organ appears and develops only within the vertebrates, and evolution of renal function has been examined only along the path from fish to mammal [1].

Accordingly, it was decided to undertake a comparative morphological study of the fine structure of the endothelium of the renal glomeruli in fishes and man.

EXPERIMENTAL METHOD

Pieces of tissue from an intact zone of the kidney in patients with Wilms' tumor aged 2, 4, and 6 years (altogether four observations) were studied. The ultrastructural compo-

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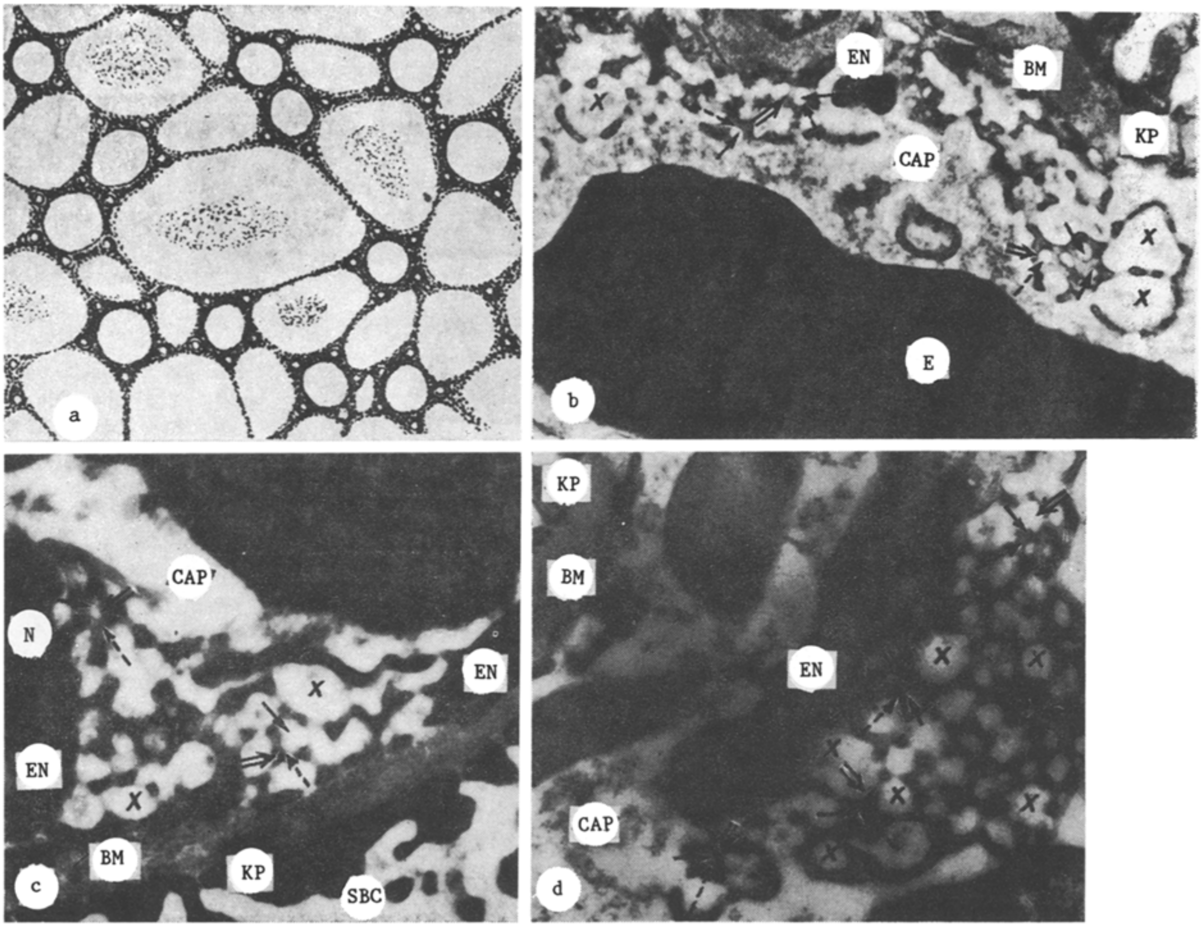

Fig. 1. Formation of stellate structures in peripheral zones of endothelial cells of human renal glomeruli (child aged 4 years). a) Scheme showing region of transformed endothelium; b, c, d) details of formation of stellate structures. Here and in Figs. 2 and 3: EN) endothelium, CAP) capillary lumen, SBC) space of Bowman's capsule; N) nucleus, BM) basement membrane, KP) knife-edge processes, E) erythrocyte; arrows point to fenestrations in central part of stellate structures, double arrows point to fragments of cytoplasm of endothelium, broken arrows – to isthmi connecting fragments of endothelial cytoplasm and fixing stellate structures; crosses indicate lumen of interstellate fenestrations. Explanation in text. Magnification: b) 50,000×; c, d) 60,000×.

nents of cells belonging to different organs and tissues located a considerable distance from areas affected by a tumor, are known to be identical with those of normal organs and tissues both quantitatively and qualitatively. In the representative of the bony fishes, namely the Atlantic salmon Salmo salar L. (10 fish), pieces of the caudal part of the kidneys were investigated. Double fixation of the material with glutaraldehyde and osmic acid was used. A detailed account of the technique of processing of the kidney tissue was given by the writers previously [2]. A JEM-100B electron microscope was used.

EXPERIMENTAL RESULTS

Besides the typical organization of endothelial cells in human renal glomeruli, in which zones of the perikaryon and peripheral zones of fenestrated cytoplasm of reduced thickness, with diaphragmatic or open pores, regions with an unusual architecture of the endothelium also were observed (Figs. 1 and 2). Around the whole perimeter of the luminal surface of the endothelial cells of the renal glomeruli, distinctive cytoplasmic arcades were observed to be formed both on the side of the perikaryon and also on the side of the peripheral zones of the endothelium. The base of the arcades was formed by stellate with a regular pentagonal shape. Working blocks of these stellate constructions consisted of fragments of cytoplasm with round cross-sections 30-40 nm in diameter on tangential sections.

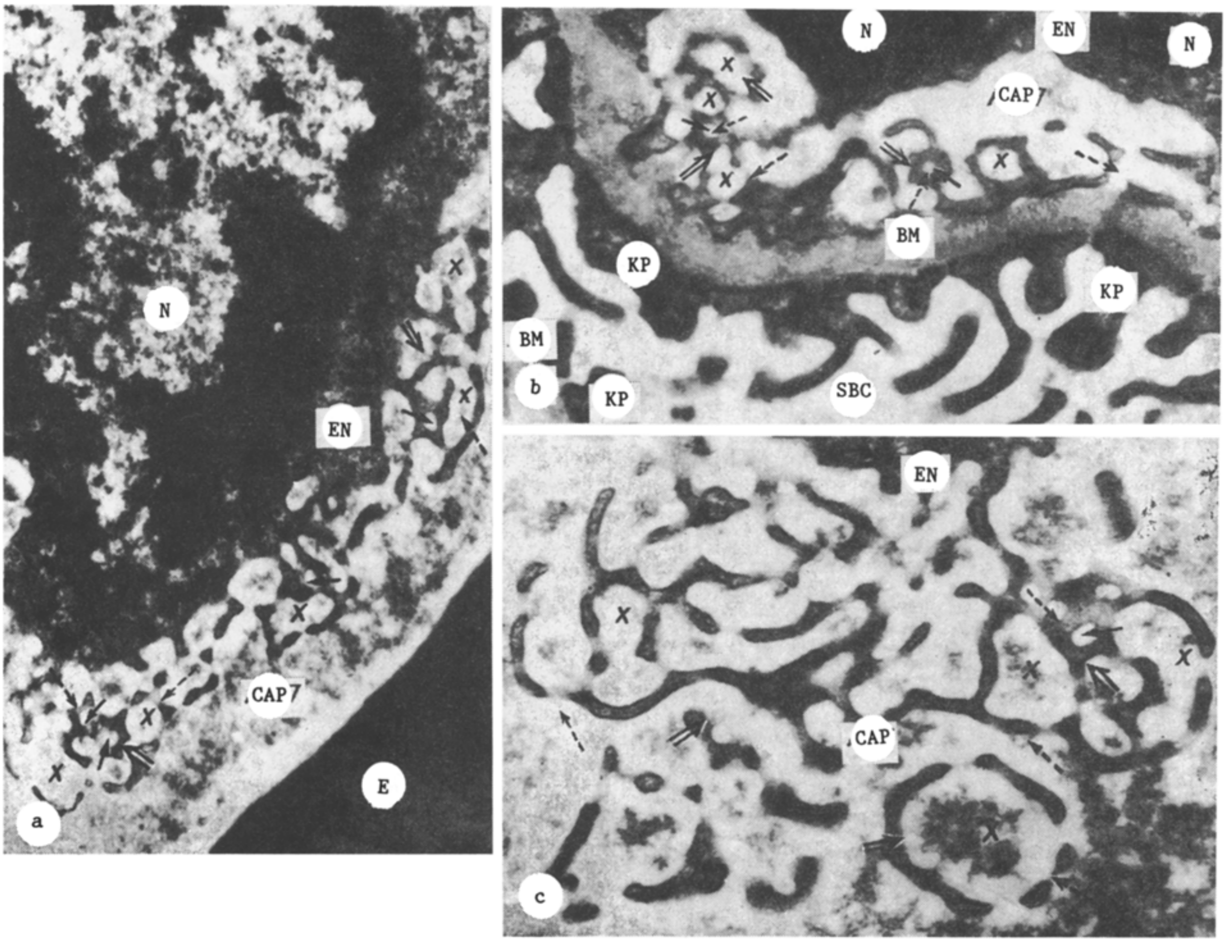

Fig. 2. Formation of stellate structures in region of perikaryon of endothelial cells of human renal glomeruli (child aged 4 years). a, b, c) Details of formation of stellate structures. Explanation in text. Magnification: a) 50,000, b) 60,000, c) 80,000×.

These were distributed at different distances from one another and joined together by membranous isthmi, similar in structure to the diaphragms of endothelial pores. In the center of the stellate formations (pentahedra) large perforations or pores, 100-150 nm in diameter, were formed, their walls consisting of fragments of cytoplasm of the endothelium and the membranous isthmi connecting them. No diaphragms could be seen in the region of the pores. Stellate structures in turn also were connected together by isthmi. As a result, free surfaces, round in shape and 250-350 nm in diameter, were formed between the outer sides of their surfaces. It will be noted that the diameter of these spaces, as analysis of the electron micrographs showed, was determined by the number of stellate structures between which they appeared. With an increase in their number, the diameter of the interstellate spaces also increased. Unlike the electron-translucent pores of the stellate structures, the spaces between them were usually filled with delicate floccules of electron-dense material. This material was evidently high-molecular-weight plasma proteins, for a similar substance was often found to be lying freely in the lumen of a capillary. Thus the endothelium was strongly perforated in two zones: the central part of the stellate structures and the spaces between them.

Local areas of endothelium with the geometric characteristics described above also were found in the renal glomeruli of yearling Atlantic salmon (Fig. 3). Their only distinguishing features were the somewhat smaller size of the stellate formations and the larger number of interstellate intervals.

The endothelium of the renal glomeruli of vertebrates is of the fenestrated type. The fenestrations may be open (i.e., true pores) or closed by diaphragms. In the latter case permeability of the transendothelial channels is determined by the transport properties of the diaphragms which cover the fenestrations [3]. In our observations, stellate structures

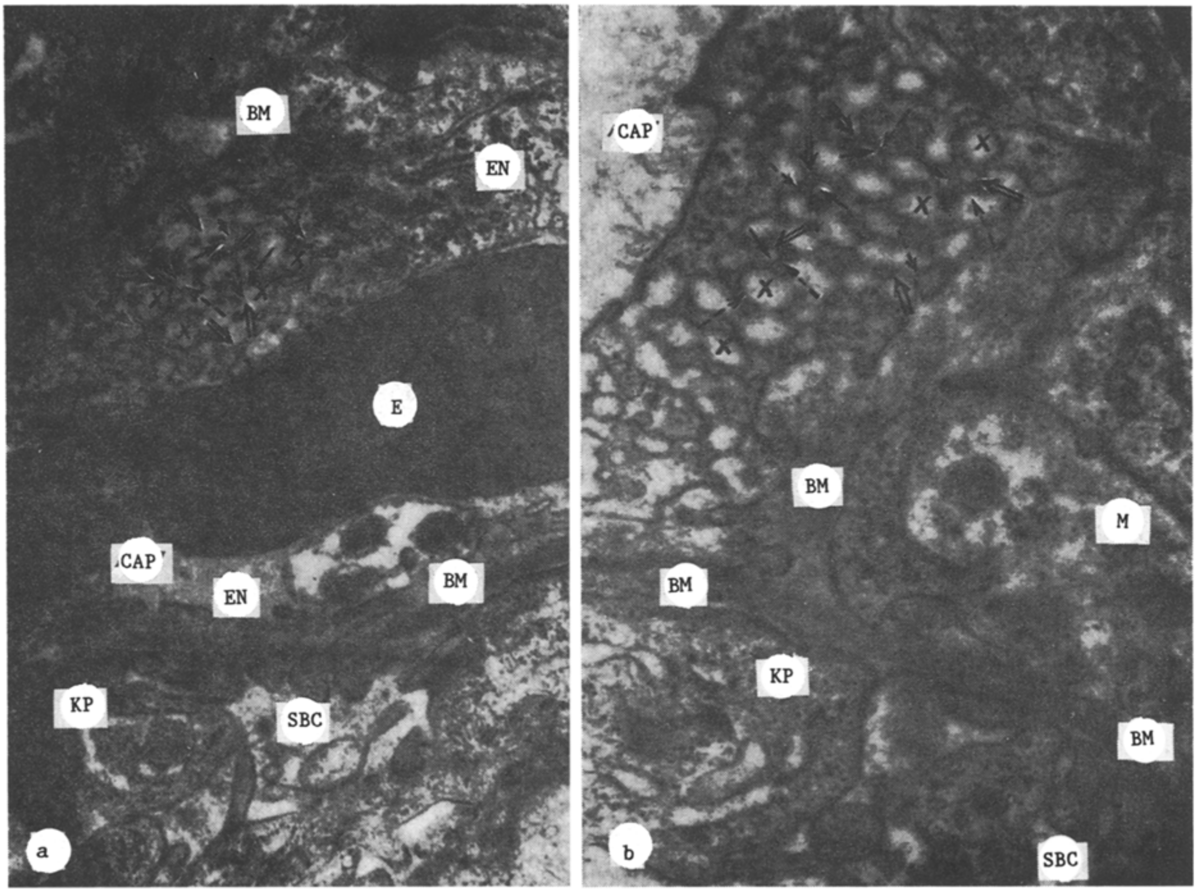

Fig. 3. Formation of stellate structures in endothelial cells of renal glomeruli in yearling Atlantic salmon. a, b) Details of formation of stellate structures. M) Mesangium. Explanation in text. Magnification: a) 45,000, b) 68,000×.

whose cental part consists of large pores, while between these structures numerous free spaces are formed, are created by means of diaphragm-like isthmi. These free spaces are actually intercellular clefts which, for example, in relation to the endothelium of the sinusoid type, are often called intercellular fenestrations [9]. Consequently, the structural changes which we found in the endothelium lead to the appearance of two different types of open fenestrations in it, with a diameter of 100-350 nm. This particular structural feature undoubtedly can lead to a sharp increase in permeability of the endothelium. According to some workers [12], the appearance of powerfully developed cytoplasmic arcades in the renal capillaries of the human glomeruli reflects hyperfunction, not pathology, of the endothelial cells. In our observations intensification of ultrafiltration in the glomeruli of the intact zone of the human kidneys is probably due to the need to compensate for the work of glomeruli excluded from the renal blood flow by growth of the tumor.

The diadromous Atlantic salmon has a complex biological developmental cycle, in which a freshwater period of life alternates with a period in the sea. For each period of life of the salmon there is a corresponding, strictly determined program of working of the kidneys. In the freshwater period of life the kidneys of the salmon have a hypertonic type of function, in the sea period, a hypotonic type. Yearling salmon live in fresh water, and their kidneys have to extract from it the essential ions, but at the same time, to avoid an excess of water in order to maintain constancy of the water and electrolyte composition of their internal medium, which is hyperosmotic relative to the medium in which they live. This process requires highly intensive renal ultrafiltration and, correspondingly, it throws a heavy load on all components of the filtration barrier of the glomeruli, leading in turn to the conformational changes of the endothelial cells described above. Such changes in the endotheliocytes in the glomerular capillaries of the salmon kidneys are evidently caused by the physiological requirements of diadromous fish in the freshwater period of their life. During migration of the salmon into the sea, when ultrafiltration in the kidneys is reduced to a minimum, the glomerular endothelium has its ordinary fenestrated type of structure.

The temporary and functionally determined structural transformation of the endothelial cells, which we found, cannot be identified with the so-called stellate (reticular) type of endotheliocytes, which can be detected only by scanning microscopy, and only in capillaries of lymphoid organs [6].

The results of electron-microscopic investigations of the endothelium of the renal glomeruli in representatives of higher and lower vertebrates, which have different historically-evolved types of definitive kidney (the metanephros in man, the mesonephros in fishes) indicate that the transformation of the endothelium which we discovered can be most probably regarded as a sign of intensive functional activity of the filtration apparatus of the vertebrate kidney. The heterogeneous character of the factors contributing to structural transformation of the endothelium (compensatory hyperfunction in man and the influence of the external environment in fishes), must be particularly emphasized, while at the same time, the architecture of the stellate structures of the endothelium is identical in kidneys of both man and fishes, reflecting the universal and nonspecific nature of these reactions. Thus the data described above can probably be taken as evidence of high morphological and functional plasticity of the endothelium of the renal glomerular capillaries of vertebrates, realized at the ultrastructural level.

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