CILIA IN DIFFERENT SEGMENTS OF THE RAT NEPHRON

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We wish to report here the finding of single cilia in epithelial cells of the parietal layer of Bowman's capsule, of the proximal convoluted tubule, of the distal tubule, and of the collecting tubule of the rat kidney.

Despite the observation by light microscopy, many years ago, of cilia in the tubules of rabbit and human kidneys (16), and despite many electron microscopic studies of kidneys in recent years, only one report of a cilium in a normal mammalian kidney has appeared (5). The present observations of cilia in different parts of the nephron raise interesting questions concerning the significance of cilia in normal and neoplastic renal cells, from the standpoints of physiology, ontogeny, and phylogeny.

MATERIALS AND METHODS

The kidneys of young adult Sprague-Dawley rats were fixed in the living animal (4) and embedded in Araldite (8) or Epon (6). Sections were cut from large blocks which were necessary for various experiments in our laboratories during the past year. Hence, considerable tissue was examined in the process of finding these cilia incidentally.

FIGURE 1

Cilium in epithelial cell of parietal layer of Bowman's capsule. The ciliary membrane is continuous with the plasma membrane. The peripheral filaments continue into the basal body (kinetosome) where a cytoplasmic matrix material condenses around them. The deeper structure (arrow) probably represents an associated centriole. From a rat injected with thorotrast just before fixation. Embedded in Epon. × 25,000.

FIGURE 2

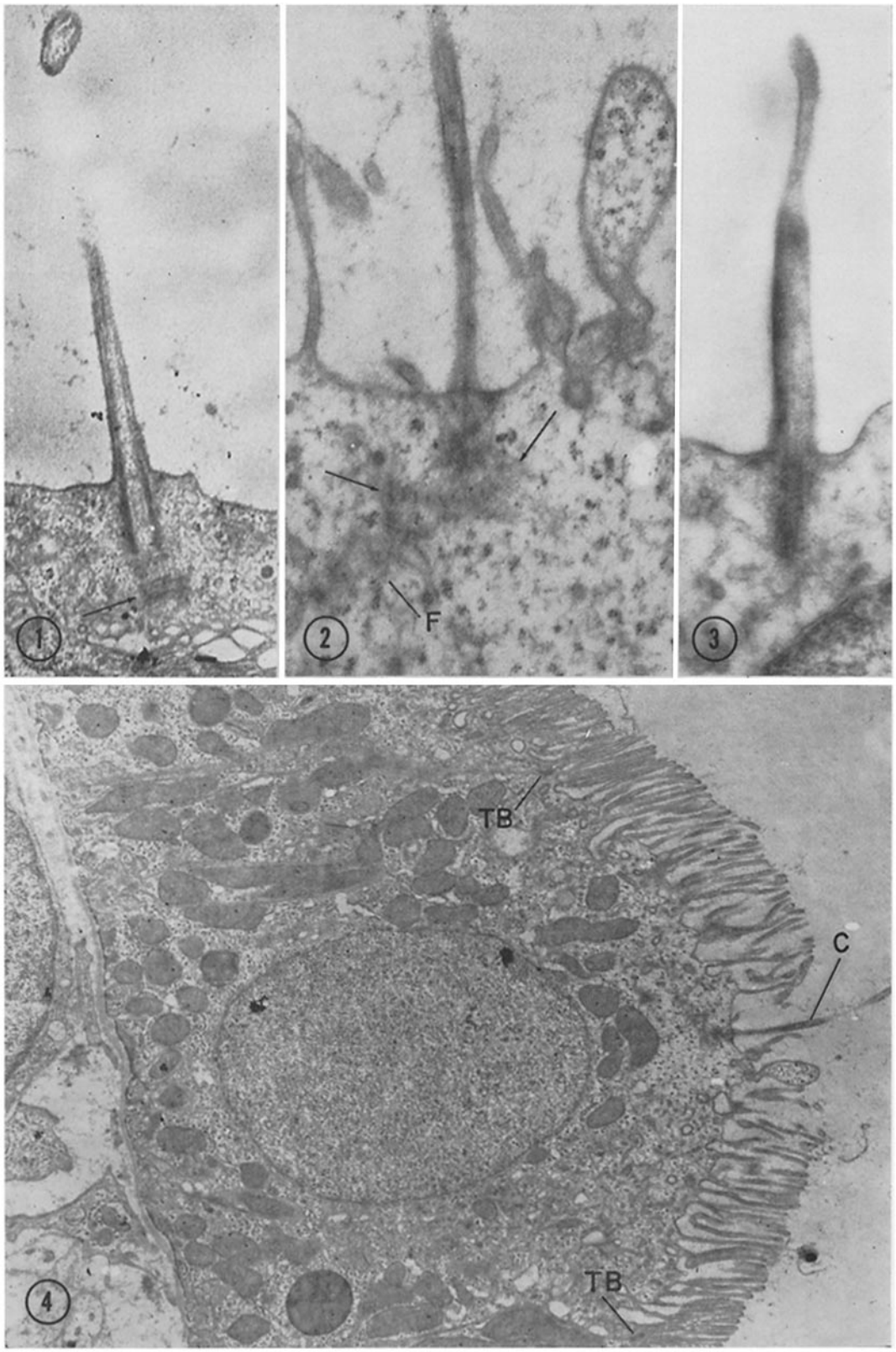
Cilium in proximal convoluted tubule cell. The peripheral filaments are evident. Although a filament appears to extend into the basal body centrally, this could be a tangential cut through a peripheral filament. This would explain why the condensed matrix is apparent, but not the lateral walls of the basal body. The line at the level of the cell membrane is probably not a transverse plate, which is said to be lacking in mammals (3, 12), but a collar of condensation about the neck of the cilium (10). The horizontal structure (between arrows) is possibly periodic and may represent a rootlet. A deeper group of filaments (*F*) may possibly correspond to an infraciliary lattice system (12). The significance of the cytoplasmic projection on the right is unknown. See lower magnification in Fig. 4. From a rat injected with Diamox shortly before fixation. Embedded in Epon. × 32,000.

FIGURE 3

Cilium in collecting tubule cell. Peripheral filaments extend into the basal body. From a rat injected with Diamox shortly before fixation. × 42,000.

FIGURE 4

Proximal convoluted tubule with cilium (*C*). This is a lower magnification of the cell shown in Fig. 2. The luminal edge of the cell is rounded and the single cilium is placed at the apex. The microvilli of the brush border are more loosely arranged than is usual in proximal convoluted tubules, as shown here in the adjacent cells lateral to the terminal bars (*TB*). Other details shown by the cell are similar to those ordinarily found in cells of the proximal convoluted tubule. × 8,000.



OBSERVATIONS

Characteristic cilia with a ciliary membrane, peripheral filaments, and a kinetosome or basal body are found in epithelial cells in the different segments of cortical portions of nephrons in rat kidneys (Figs. 1 to 6). Although the sections are somewhat thick because they are cut from large blocks prepared for other studies, some additional detail can be discerned. There is a condensation of cytoplasmic matrix on the peripheral filaments as they pass into the basal body (Figs. 1, 3, 5). Two cilia have structures close to the basal body (Figs. 1 and 2). One structure probably represents an associated centriole (13). One cilium shows a bundle of fibers that may correspond to an infraciliary lattice system (Fig. 2) (12). Only a single cilium has been observed in any one cell. In the proximal tubule cell the microvilli next to the cilium are more loosely arranged than usual and a cytoplasmic protrusion is noted (Figs. 2 and 4). Otherwise the ciliated cells of the various tubular segments seem to possess a normal structure.

DISCUSSION

The observation of various characteristic components of kinocilia (11) (rather than stereocilia (9)) leaves no doubt as to their identity. It also confirms their being found in mammalian kidney by light microscopy and their being described as solitary and centrally placed in the renal cells (16). The basal body and associated structures vary among species, with mammalian cilia appearing to form a separate group (3, 12).

The infrequency of cilia in the mammalian metanephric kidney is further attested by the fact that they are rarely found with light (16) or electron (5) microscopy. It was necessary to study a very large number of sections in this laboratory in the past year to collect the observations reported here.

It is difficult to suggest a function for such rare cilia in the mammalian kidney. Perhaps they serve to create turbulence and prevent laminar flow of tubular fluid, thereby facilitating the resorption of solutes. They may also be viewed as an evolutionary remnant because they are found much more frequently in the excretory ducts of lower animals (15). Cilia are numerous in the frog kidney and have been reported in electron microscopic studies (1, 3). Although they may develop considerable pressure in the frog kidney (3), the cilia of the mammalian kidney could hardly propel much fluid.

The present observations offer more evidence in support of a common embryologic origin of cells in different tubular segments. However, cilia have not yet been found in embryologic studies of rat kidneys (2, 14). The observation of large groups of cilia in a renal carcinoma of hamsters (but not in normal hamster kidney) (7) is remarkable. This suggests that if dedifferentiation is associated with neoplasia it can still evoke highly differentiated structures from an early evolutionary period.

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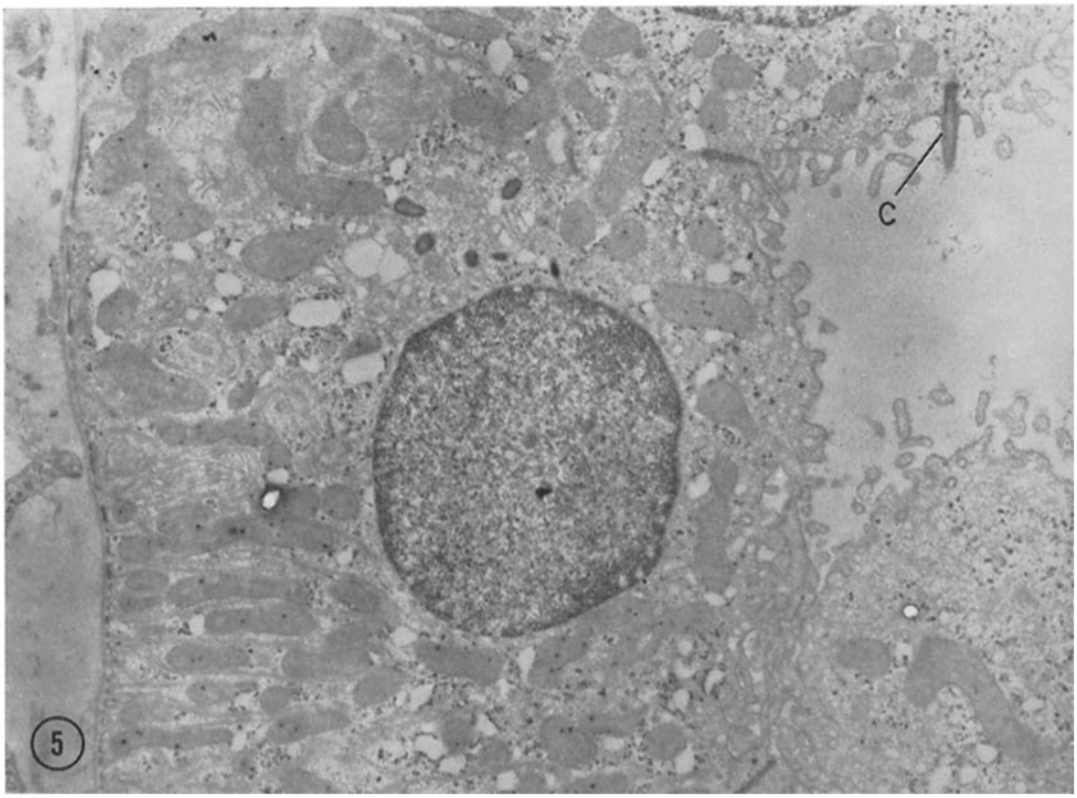
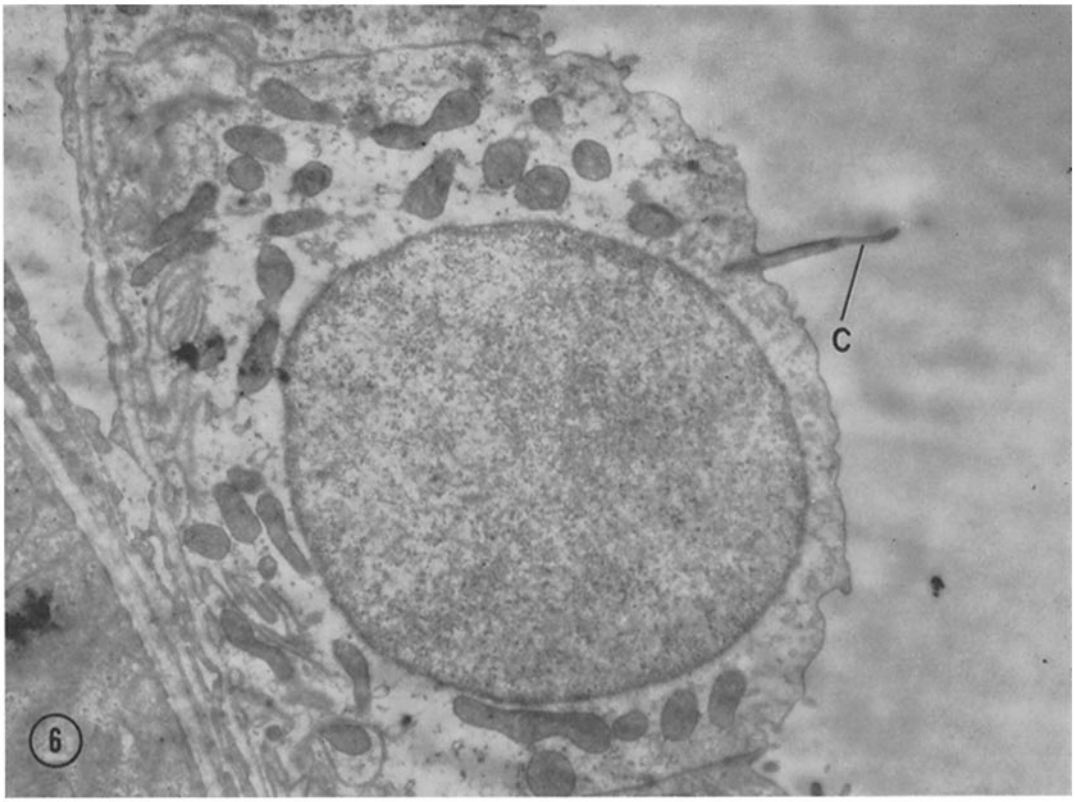
FIGURE 5

Distal convoluted tubule cell with cilium (*C*). Peripheral filaments extend into the kinetosome. Normal rat. Embedded in Araldite. Unstained. × 11,000.

FIGURE 6

Collecting tubule cell with cilium (*C*). This is a lower magnification of the cell shown in Fig. 3. Except for the cilium this cell resembles most other cells of the light type found in the collecting tubules of the cortex. From a rat injected with Diamox shortly before fixation. × 11,000.





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