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THE NEPHRON OF THE SKATE, Raja erinacea

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The kidney of the common skate is a circumscribed anatomical structure which, unlike that of the spiny dogfish, is readily exposed in its entirety by a small dorsal incision. This characteristic makes it particularly suitable for micropuncture studies since both glomeruli and proximal portions of the nephron lie close to its dorsal surface. The following description of the skate nephron is made in anticipation of future micropuncture experiments by ourselves and others.

These observations were made on 20 male and female skates weighing 0.7 to 1.4 kg. anaesthetized with nembutal (0.2 mg Kg^{-1}) and curare (0.3 mg Kg^{-1} x BW). The fish were placed dorsal side uppermost on a board, the spiracles being perfused with aerated sea water, thermostated at 10° C.

The right kidney, exposed through a dorsal para-midline incision, was partially immobilized with moist gauze packs and its surface visualized by incident light microscopy. For micropuncture we used pulled glass pipettes ground to a tip diameter of about 10 μ and positioned with a Leitz micromanipulator. Lissamine green (2% in Forster's dogfish solution) was injected into a punctured glomerulus and its timed passage along the nephron observed. Frequent sketches were made of the surface convolutions. Other superficial nephrons were injected with colored latex to determine the course of their deeper segments. These kidneys were then fixed in formalin for later maceration and microdissection. To delineate the renal vascular structures injections of colored microfil were made via caudal artery or portal vein.

The renal arterial blood supply of the skate is not, as in Squalus, segmental in distribution but comprises one main renal artery. This arises as a terminal branch of the divided dorsal aorta, enters the kidney substance and courses cephalad immediately below the dorsal surface, sending branches to each of the imperfectly formed lobules. These branches bifurcate and give rise to glomeruli which generally lie within 1 mm of the kidney surface. A single portal vein upon entering the kidney divides profusely into large branches which anastomose to form a spongy network. This fills the interstitial spaces between tubules and appears to constitute their main supply. Portal blood is collected together with that from post glomerular vessels into a common renal vein which leaves cephalad along the ventral surface.

In these preliminary studies we have divided the skate nephron into 8 segments, based on their configuration and location. The designation is arbitrary and will be improved by later histological evidence.

From Bowman's capsule (see Figure 1) a short, thin-walled segment (I) arises and runs away from the glomerulus close to the dorsal surface in a straight line. After a distance of a few hundred micra, it turns and begins to form a loop upon itself (II), the adjacent portions of the tubule being in close apposition. Segment (III) begins at the completion of this loop; the lumen widens and is lined by large cells having a brush border. Convolutions of this segment are closely packed as it descends to the deeper portion of the kidney. The nephron now forms a loose bundle of parallel tubules (IV) which in the aggregate make up most of the ventral surface of the kidney. Rising again in a series of open convolutions (V) the nephron reappears at the dorsal surface in close proximity to its glomerulus of origin. Segment VI now forms loose coils around

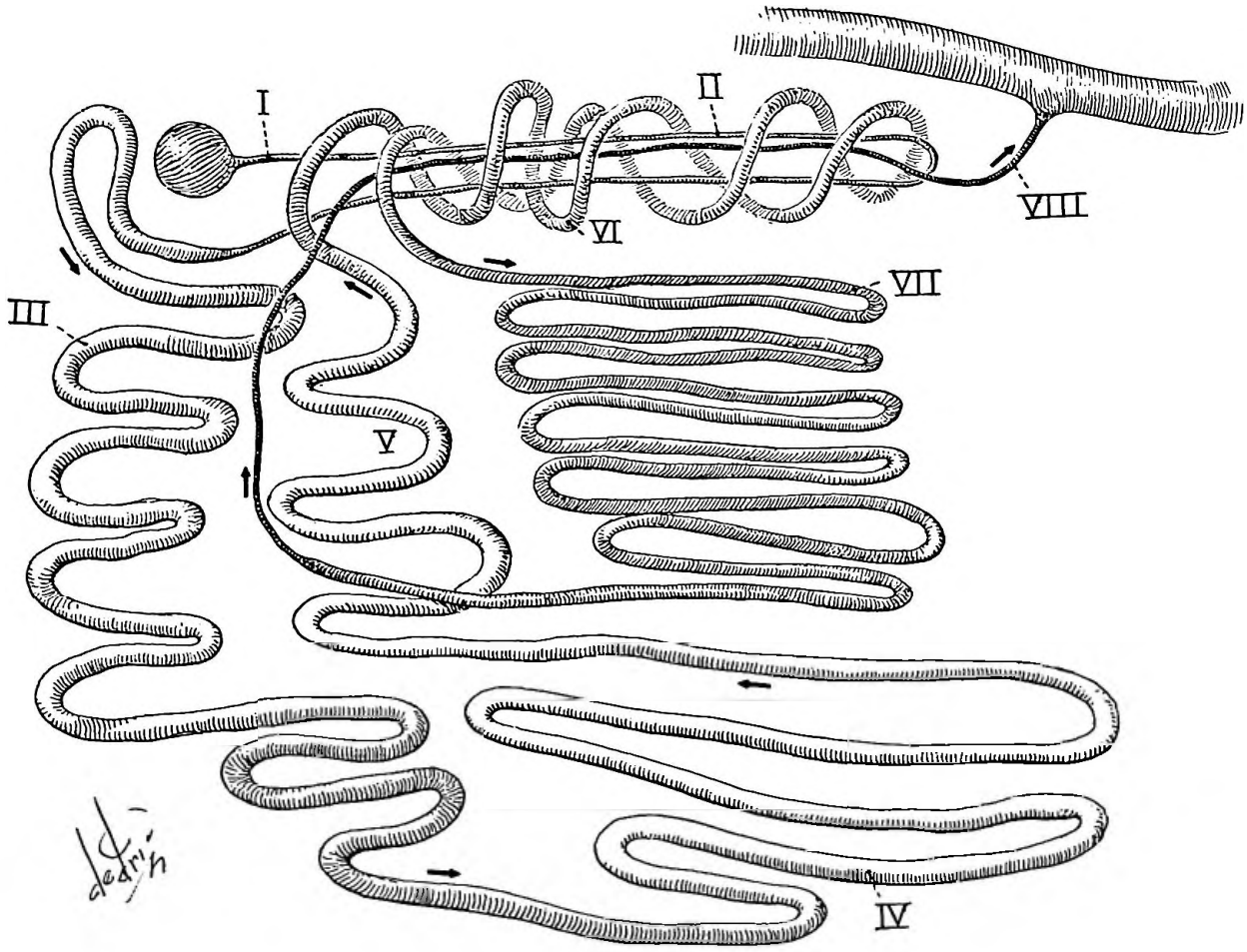

Figure 1. Schematic drawing of skate nephron, reconstructed from surface microscopy and microdissected segments. Numerals identify segments.

and along the loop of segment II passing first away from and then toward the glomerulus, completely investing the loop. Descending again the nephron then forms in the central portion of the kidney substance a tightly coiled bundle (VII) which rests in close apposition to surrounding elements of all other segments and fills the space between them. The nephron returns to the ventral surface, again near its glomerulus and now becomes a thin-walled structure (VIII) which follows in intimate association with the loops of segments II and VI. The close adherence of this final segment to the loop of segment II is quite striking and leaves little doubt that it constitutes, structurally at least, a counter-current system. Segment VIII terminates in a collecting duct (Figure 1).

The collecting ducts course in straight lines on the surface of each lobule and join at the dorsal aspect of the kidney near the midline to form the ureter which leads directly to the cloaca.

Figure 2 represents the dorsal aspect of the kidney as the surface loops are sequentially visualized following the injection of Lissamine green into a glomerulus. The transit times to

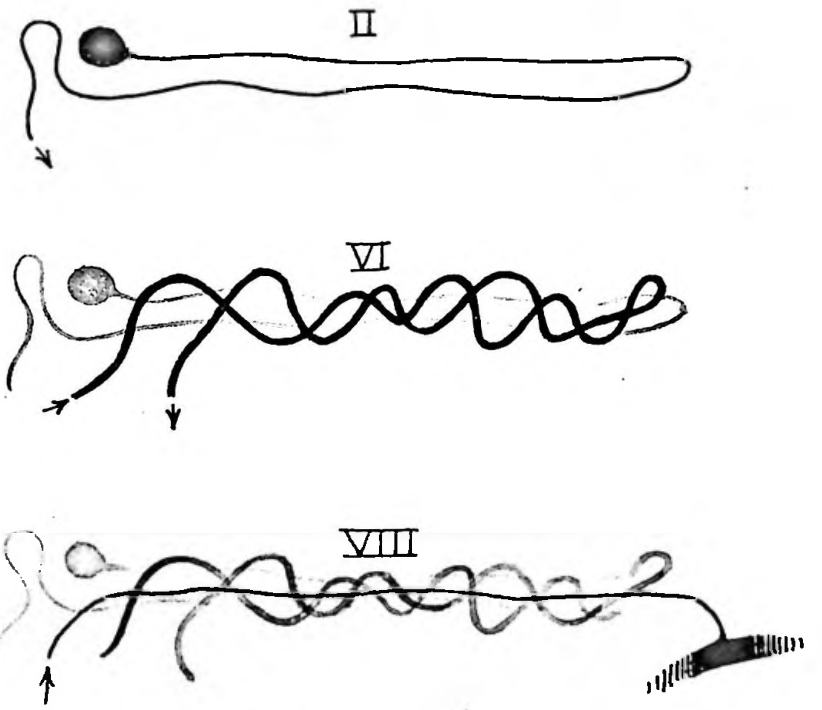

Figure 2. Timed sequence drawings of surface tubules showing relationships between the segments indicated. Compare Table 1.

Table 1

LENGTHS AND TUBULE FLUID PASSAGE TIMES OF DIFFERENT SEGMENTS IN SKATE NEPHRON

Segment	Length mm	Passage time sec	Linear flow velocity μ/sec
I	.5		
II	1.7	30 (I & II)	73
III	4.2		
IV	10.0	935 (III, IV & V)	23
V	7.4		
VI	2.2	100	22
VII	22.0	1050	21
VIII	2.2	110	20
I - VIII	50.2	2225	

successively appearing segments are given in Table 1.

Table 1 presents the lengths of dissected segments. Together they describe a nephron averaging about 50 mm total length. Observed passage times to the distances indicated are given as well as derived linear velocity of flow in several segments.

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