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EDITORIAL REVIEW

A standard nomenclature for structures of the kidney

THE RENAL COMMISSION OF THE INTERNATIONAL UNION OF PHYSIOLOGICAL SCIENCES (IUPS)

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The Editors have chosen, deliberately, to duplicate publication of this document in the above three journals, to insure the widest possible dissemination of this terminology, which has been adopted simultaneously by each of the three journals.

JAMES A. SCHAFER, Ph.D., Editor, *American Journal of Physiology: Renal, Fluid and Electrolyte Physiology*
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Preamble

The kidney is an organ of complex structure and function, a fact that is increasingly revealed as our investigations proceed. We have witnessed a progression from recognition of a single nephron to three types of nephrons, of four main tubular parts (proximal tubule, intermediate tubule, distal tubule, collecting duct) to several subdivisions of those parts, and of homogeneity of cells within a given part to identification of several types of cells within a part or subdivision. With our heightened ability to dissect the many components of the kidney, both anatomically and functionally, there is an increasing need to convey to our colleagues precisely which structure we were working with. The following standard nomenclature is disseminated to help meet that need.

The project was undertaken at the request of the Renal Commission of the International Union of Physiological Sciences (IUPS). It is the hope of the Commission that the nomenclature proposed herein may be widely adopted. We recommend that when disagreement arises—as is bound to happen—the author(s) may indicate that the name which he or she applies to a given structure is synonymous with one of the elements designated in Table 1 or Figures 1 and 2 of the present report. Discoveries which alter the schema should be called to the attention of one of the co-chairs, W. Kriz, or L. Bankir.

References have been deliberately omitted because it would have been cumbersome to include the many sources that served as a basis for the recommendations. Those needing particulars on the sources should contact one of the co-chairs.

Heinz Valtin, Chair
Renal Commission of IUPS (1980–86)

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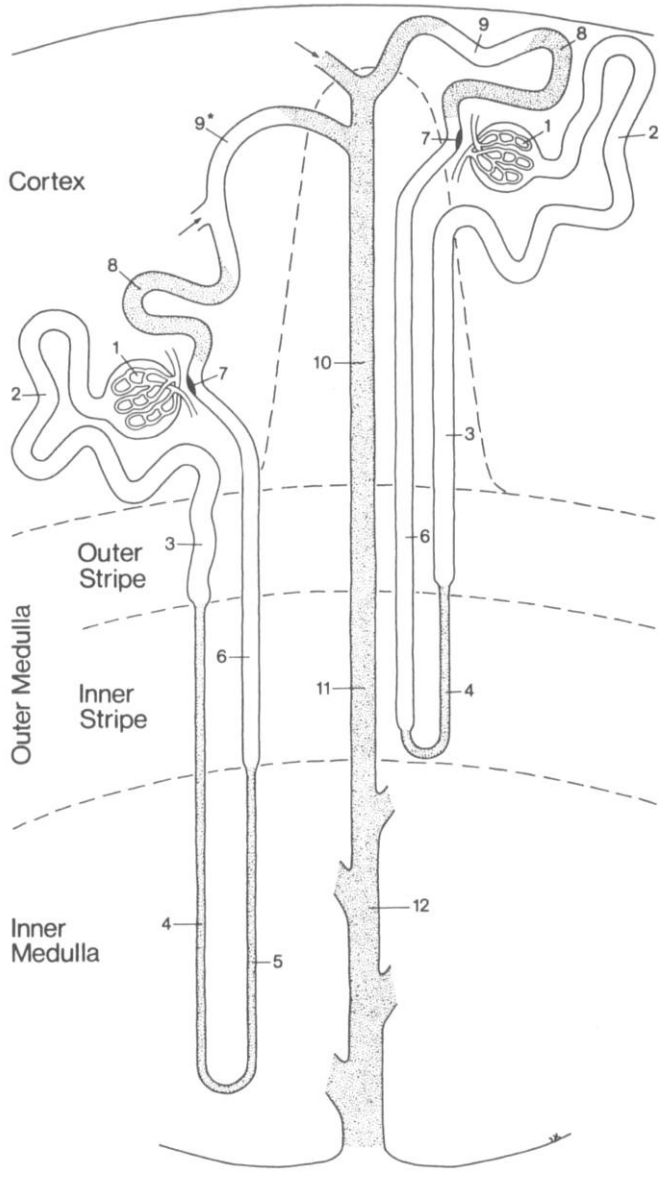
Kidney structure	Explanation
Main Divisions	
Cortex (C)[a]	
Cortical labyrinth	
Cortex corticis	
Medullary rays	
Medulla	
Outer medulla (OM)	
Outer stripe (OS)	
Inner stripe (IS)	
Vascular bundles	
Interbundle region	
Inner medulla (IM)	
Papilla	The papilla is that part of the inner medulla which projects into the pelvis. In many kidneys a crest is developed instead of a papilla.
Crest	
Renal pelvis	
Pelvic cavity	
Pelvic extension	Extensions of the pelvic cavity along the blood vessels.
Secondary pouches	Extensions of the pelvic cavity around the edges of the pelvic septa.
Renal sinus	
Renal hilum	
For *multilobar, multipapillary kidneys* the following additional terms are necessary:	
Renal column (Column of Bertin)	
Major calices, minor calices	
Renal artery, anterior and posterior divisions	
Segmental artery	
Vessels, nerves, and interstitium	
Renal vasculature	
Renal artery (vein)	
Interlobar artery (vein)	
Arcuate artery (vein)	
Cortical radial artery (vein)	This term is much more appropriate in describing the course of these vessels; it replaces the term interlobular artery.
Perforating radial artery	
Stellate vein	
Afferent arteriole	
Efferent arteriole	
Welling point	
Glomerular capillaries	
Peritubular capillaries	
Descending vasa recta	
Ascending vasa recta	
Vascular bundles	
Primary bundles	
Secondary bundles	Fusion of two primary bundles.
Giant bundles	Fusion of several bundles.
Simple type	The simple type contains only descending and ascending vasa recta; the complex type includes the descending thin limbs of short loops of Henle.
Complex type	
Interbundle capillary plexus	Only for the inner stripe capillary plexus.
Renal lymphatics	
Renal nerves	
Renal interstitium	
Lipid laden interstitial cells	
Nephrons	
Nephron—Types	
Superficial nephrons	Those originating from a superficial, midcortical, or juxtamedullary glomerulus (see later). A less strict definition for a superficial nephron says that it touches the renal surface.
Midcortical nephrons	
Juxtamedullary nephrons	
Short-looped nephrons	Henle's loop turning back in the outer medulla (or cortex).
Cortical nephrons	Henle's loop turning back in the cortex.
Long-looped nephrons	Henle's loop turning back in the inner medulla.
	N.B.: The two divisions in nephron types do not always coincide: for example, juxtamedullary nephron is not necessarily synonymous with long-looped nephron. Superficial as well as juxtamedullary nephrons may have long or short loops.
Nephron—Main divisions	
Renal corpuscle	
Bowman's capsule	
Glomerulus	
Glomerular lobule	The term "glomerulus" (plural: glomeruli) is widely used to designate the entire renal corpuscle. In the present system the glomerulus is more precisely termed "glomerular tuft."
Urinary space	Often called Bowman's space.
Tubular portions of the nephron	
Proximal tubule	
Intermediate tubule	The term "Intermediate tubule" has formerly been used. It is regarded as a very appropriate term and is therefore reintroduced to designate the entire thin limb.
Distal tubule	

[a] Abbreviations are in parenthesis.

Kidney structure	Explanation
Proximal convolution	N.B. This micro-anatomical subdivision of the nephron tubule is independent from the above one. The distal convolution does not comprise the same segments as the distal tubule (Table 1). The term "loop of Henle" comprises the straight part of the proximal tubule (thick descending limb), the intermediate tubule (thin descending and ascending limbs) and the straight part of the distal tubule (thick ascending limb).
Loop of Henle	
Long loop, short loop, cortical loop	
Distal convolution	
Nephron—Details	
a. Renal corpuscle	
Types	
Superficial renal corpuscles (superficial glomeruli)	Those giving rise to an efferent arteriole which touches the renal surface. A less strict definition comprises all glomeruli establishing the most superficial layer of glomeruli.
Midcortical renal corpuscles (midcortical glomeruli)	The term comprises all glomeruli which are neither superficial nor juxtamedullary.
Juxtamedullary renal corpuscles (juxtamedullary glomeruli)	Those giving rise to an efferent arteriole which turns towards the medulla and splits into descending vasa recta.
Components	
Parietal cells of Bowman's capsule	
Peripolar cells	These cells are modified cells of Bowman's capsule which contain granules.
Podocytes	Synonymous with visceral cells of Bowman's capsule or glomerular epithelial cells.
Filtration slit	
Slit diaphragm	
Endothelial cells	
Mesangium	
Mesangial cells	
Mesangial matrix	
Glomerular basement membrane (GBM)	
Lamina rara interna	
Lamina densa	
Lamina rara externa	
b. Juxtaglomerular apparatus (JGA)	
Granular cells	Synonymous with epithelioid cells. They are modified vascular smooth muscle cells.
Extraglomerular mesagium	
Extraglomerular mesangial cells	Synonymous with Goormaghtigh cells, lacis cells.
Macula densa	
Macula densa cells	

Kidney structure	Explanation
c. Proximal tubule	
• *Neck segment*	Only present in some species; it may be considered as a tubular elongation of Bowman's capsule.
• *Convoluted part* (pars convoluta) or *Proximal convoluted tubule* (PCT)	Situated in the cortical labyrinth.
• *Straight part* (pars recta) or *Proximal straight tubule* (PST)	Situated in the medullary ray of cortex and in the outer stripe of the outer medulla. Note that the straight parts of the juxtamedullary nephrons are not straight, but descend tortuously through the outer stripe. They are defined as "straight parts" by their location in the outer stripe.
Subdivisions: (defined ultrastructurally)	
S1 (segment) (or P1) S1 cells	Comprises the beginning and middle portions of the convoluted part. Transition to S2 is gradual.
S2 (segment) (or P2) S2 cells	Comprises the end portions of the convoluted part and the beginning portions of the straight part. Transition to S3 is abrupt in some species (rat, dog), gradual in others (rabbit).
S3 (segment) (or P3) S3 cells	Comprises the remaining portions of the straight part. Generally, all proximal tubules lying in the outer stripe are S3 segments.
	Instead of S1, S2, and S3 the abbreviations P1, P2, and P3 are widely used. The "S" refers to "segment" and "P" to "proximal."
d. Intermediate tubule	
Descending thin limb of Henle's loop (pars descendens) (DTL)	
Descending thin limb of a short loop	
DTL type 1 cells	
Descending thin limb of a long loop	
Upper part	
DTL type 2 cells	Defined by the appearance of the epithelium. The limit between upper and lower part occurs at different levels and does not correspond to the border between inner stripe and inner medulla.
Lower part	
DTL type 3 cells	

Kidney structure	Explanation
Pre-bend segment (already ATL cells)	Short portion before the loop bend, already outlined by the same type of epithelium that lines the ascending limb.
Ascending thin limb of Henle's loop (pars ascendens) (ATL)	Instead of the abbreviation ATL, TAL has also been used. However, TAL is now widely used to designate the *thick* ascending limb.
ATL cells (type 4 cells)	
e. Distal tubule	
Straight part (pars recta), or *Distal straight tubule*, or *Thick ascending limb* (DST or TAL)	
Distal straight tubular cells, DST cells, or TAL cells	
Medullary straight part or medullary thick ascending limb (MTAL)	The transition between MTAL and CTAL is gradual; the most noticeable changes, however, occur close to the border between IS and OS (known from rat and rabbit).
Cortical straight part or cortical thick ascending limb (CTAL)	
Macula densa (MD) MD cells	The macula densa is a cell plaque within the end portion of the thick ascending limb.
Post-macular segment	Part of the cortical thick ascending limb between the macula densa and the transition to the convoluted part.
Convoluted part (pars convoluta) or *Distal convoluted tubule* (DCT)	Transition to the subsequent connecting tubule (see below) may be abrupt (rabbit) or gradual (most other species)
DCT cells	in the sense that the characteristic cells for the two tubular portions (DCT-cells and CNT-cells) are found intermingled with each other over a certain distance. In those cases, the connecting tubule may be considered to start with the first occurrence of CNT-cells, even if DCT-cells are still present.
f. Collecting system	The different segments of the collecting system in the cortex are defined here according to the cell types they comprise (which gives each segment its functional properties) and not by their position with regard to the first junction with another nephron.
Connecting tubule (CNT)	The "connecting tubule" connects the distal convoluted tubule to the collecting
Two cell types:	
Connecting tubule cells = CNT cells	duct and is functionally different from both. The embryonic origin of this segment is not considered here. It is characterized by the presence of a typical cell type, the CNT cell. In many species, connecting tubule epithelium is observed before the first junction with another nephron.
Intercalated cells = IC cells	
	Transition to the collecting duct (arbitrarily defined by the first appearance of its typical cell, the CD cell or principal cell, see below) is gradual in most species; that is, the characteristic cells of both segments (CNT and CD cells) are intermingled over a certain distance. In the rabbit, this transition is abrupt.
Arcade	This structure is defined anatomically, not by the cell types it comprises. Arcade is not synonymous with connected tubule.
	An arcade is an ascending tubule found in the cortical labyrinth and joining deep and midcortical nephrons to a cortical collecting duct. Arcades are found in many species to different degrees. Ultrastructurally, they generally comprise CNT and CD cells (plus interspersed IC cells) in proportions varying along the arcade (such as, rat). In the rabbit, they are lined by CNT cells only (plus interspersed IC cells).
Cortical collecting duct (CCD)	Collecting tubule is often used instead of collecting duct. Collecting duct seems more appropriate since this part of the uriniferous system emerges from the confluence of many nephrons.
	Defined ultrastructurally by the beginning of the occurrence of CD cells. Located mostly in the medullary rays of the cortex. The distinction between cortical collecting duct and outer medullary collecting duct is arbitrarily based on their location within the kidney. No abrupt limit is recognizable ultrastructurally.
	The term "cortical collecting duct" comprises two por-



1 = Renal corpuscle including Bowman's capsule and the glomerulus (glomerular tuft)
2 = Proximal convoluted tubule
3 = Proximal straight tubule
4 = Descending thin limb
5 = Ascending thin limb
6 = Distal straight tubule (thick ascending limb)
7 = Macula densa located within the final portion of the thick ascending limb
8 = Distal convoluted tubule
9 = Connecting tubule
9* = Connecting tubule of the juxtamedullary nephron that forms an arcade
10 = Cortical collecting duct
11 = Outer medullary collecting duct
12 = Inner medullary collecting duct

Fig. 1. *Schema of nephron.* This scheme depicts a short-looped and a long-looped nephron together with the collecting system. Not drawn to scale. Within the cortex a medullary ray is delineated by a dashed line.

Kidney structure	Explanation
	tions generally distinguished in microperfusion experiments: the segment from the end of the CNT to the first confluence with another CCD (ICT = initial collecting tubule) and the unbranched portion in the medullary ray (CCT = cortical collecting tubule).
Two cell types: collecting duct cells = CD cells; also called principal cells = P cells	In analogy with the denomination of cell types in the other segments, which also may have heterogeneous cell populations, it seems preferable to use "collecting duct cell" or "CD cell" instead of "principal cell."
Intercalated cells = IC cells	
Outer medullary collecting duct (OMCD) *Inner medullary collecting duct* (IMCD)	The distinction between the outer and inner medullary collecting ducts is arbitrarily based on their location within the kidney. No abrupt transition is noticed ultrastructurally. IC cells may be found in the early IMCD in some species.
Papillary ducts	The fused ducts within the tip of the papilla are sometimes called "papillary ducts" (Ducts of Bellini), but a clear definition and separation from the inner medullary collecting ducts has never been done.

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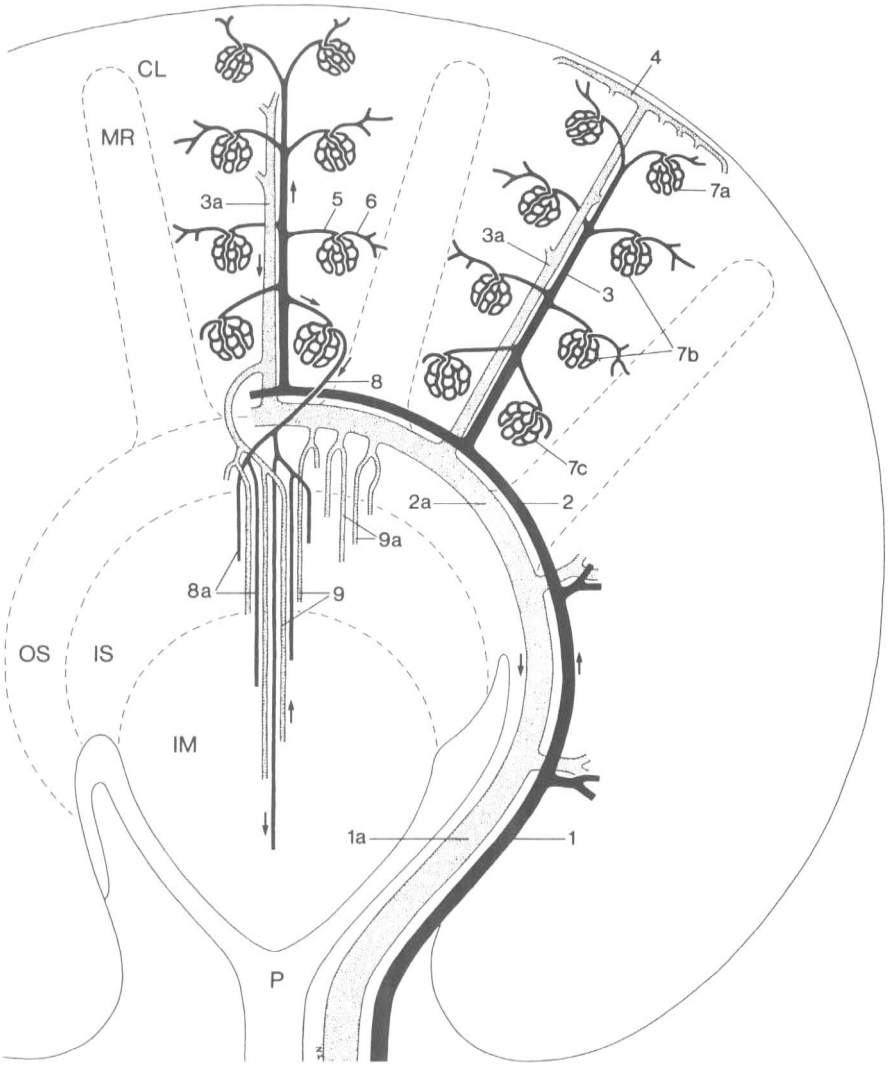

1/1a = Interlobar artery and vein
2/2a = Arcuate artery and vein
3/3a = Cortical radial artery and vein
4 = Stellate vein
5 = Afferent arteriole
6 = Efferent arteriole
7a/7b/7c = Superficial, midcortical, and juxtamedullary glomerulus
8/8a = Juxtamedullary efferent arteriole, descending vasa recta
9/9a = Ascending vasa recta (those ascending within a vascular bundle and those independent from a bundle)

Fig. 2. *Schema of renal vessels.* This scheme depicts the course and distribution of the intrarenal blood vessels; peritubular capillaries are not shown. Not drawn to scale. Within the cortex the medullary rays of the cortex (MR) are delineated from the cortical labyrinth (CL) by a dashed line. OS = outer stripe; IS = inner stripe; IM = inner medulla; P = renal pelvis.

Table 1. Nomenclature

Micro-anatomical terms	Main divisions	Subdivisions	Segmentation	Abbreviation	Cell types	Other frequently used denominations		
Proximal convolution	Proximal tubule	Pars convoluta or convoluted part	Proximal convoluted tubule: S 1 segment, S 2 segment	PCT	S 1 cells S 2 cells	P 1 segment PT P 2 segment		
		Pars recta or straight part	Proximal straight tubule: S 3 segment	PST	S 3 cells	P 3 segment PR		
Loop of Henle	Intermediate tubule	Pars decendens or descending part	Descending thin limb: of short loops; of long loops (upper part, lower part); pre-bend segment	DTL	DTL cells: Type 1; Type 2; Type 3	Short descending thin limb of Henle's loop (SDL) Long descending thin limb, upper part (LDL_u) Long descending thin limb, lower part (LDL_l)		
		Pars ascendens or ascending part	Ascending thin limb	ATL	ATL cells: Type 4	TAL	Thin ascending limb (of long loops only)	
	Distal tubule	Pars recta or straight part	Distal straight tuble or Thick ascending limb: Medullary straight part; Cortical straight part; Macula densa; postmacular segment	MTAL; CTAL; MD (DST or TAL)	DST or TAL cells; MD cells	MAL mTALH; CAL cTALH; MD	Thick ascending limb of Henle's loop: Medullary thick limb; Cortical thick limb (incl. Macula densa)	
						DCT a*	early distal tubule	
Distal convolution		Pars convoluta or convoluted part	Distal convoluted tubule	DCT	DCT cells (+ IC cells)	DCTb*		Distal tubule
	Collecting system		Connecting tubule	CNT	CNT cells + IC cells	DCTg*; CCTg*	late distal tuble	Connecting segment
Collecting duct		Collecting duct	Cortical collecting duct	CCD	CD cells = principal cells = light cells + IC cells = intercalated cells = mitochondria-rich cells = carboanhydrase-rich cells = dark cells	DCTl*; CCTl*	late distal tuble	Initial collecting tubule Cortical collecting tubule (CCT)
			Outer medullary collecting duct	OMCD		Outer medullary collecting tubule (OMCT)		
			Inner medullary collecting duct	IMCD	CD cells = principal cells	Inner medullary collecting tubule (IMCT) Papillary collecting duct (PCD) of ducts or Bellini		

This table summarizes the nomenclature of segments and cells of the renal tubule. A continuous serpentine arrow (⇝) means that the transition between the two structures is gradual. An interrupted serpentine arrow (⇝//⇝) means that the transition is gradual in some species, abrupt in others. Abbreviations marked by a star were introduced by Morel and coworkers (*Kidney Int* 9, 264, 1976). They mean: DCTa, distal convoluted tubule, initial portion; DCTb, Distal convoluted tubule, bright portion; DCTg, distal convoluted tubule, granular portions; DCTl, distal convoluted tubule, light portion; CCTg, cortical collecting tubule, granular portion; CCTe, cortical collecting tubule, light portion.