Chapitre 3
Système urinaire

Système urinaire: finalité et utilité

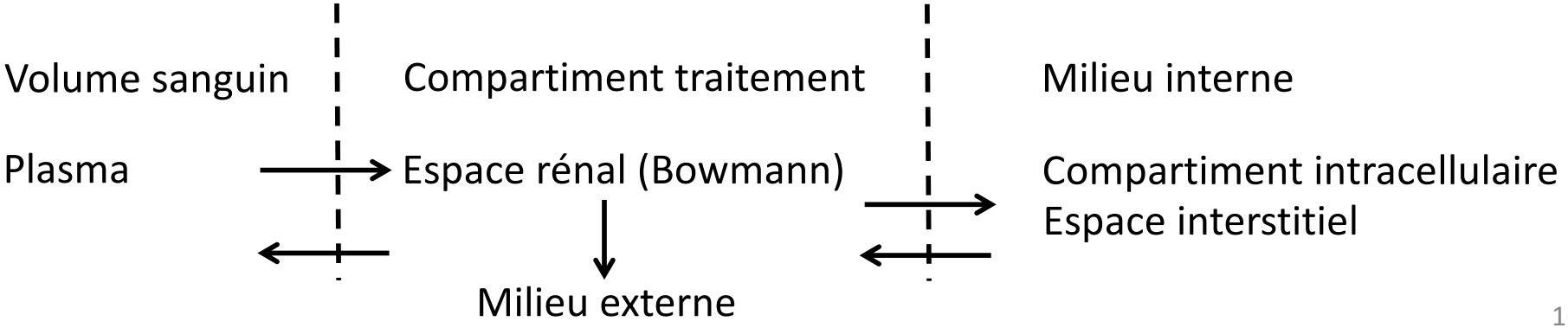
- Homéostasie des fluides et électrolytes
- Gérer l'économie: Na^+, K^+, Cl^-, H^+, HCO_3^-, Ca^{++}, PO_4^{---}
- Gérer volume corporel H_2O
- Contrôle et régulation du pH sanguin (H^+, HCO_3^-)
- Eliminer déchets métabolisme, métabolites hormones, toxines, médicaments
- Equilibre et régulation Osmolarité, pression artérielle, taux d'hématocrite, Vitamine D
- Production messagers: Rénine, Erythropoïétine, Calcitriol
- Transport du glucose

Système urinaire: structure générale

- Gestion liquide faible énergie hydrodynamique: Transfert de matière
  - *Cœur: propulsion matière* *Rein: Echange matière*
- Transport de matière, d'énergie et d'information
- Géométrie de construction: tuyauterie complexe
- Architecture tubulaire et vasculaire
- Organisation spatiale
  - Phénomène d'addition: tubules multiplicateurs
  - Système d'ajustement: tubules stabilisateurs
- Régulation et limites: Boucle fermée ; Plateau (non-linéarité)

Système urinaire: principes généraux

- 2 entités: 1) Production urine primaire
  2) Traitement → élimination de l'urine finale
- 1) et 2) Régulés et limités (valeurs max. de saturation)
- 1) Extraction plasma sanguin → Compartiment traitement
- 2) Echanges solvant ⇌ soluté → Milieux interne ⇄ externe
- 1) et 2) Passage de 2 barrières distinctes



Système urinaire: les débits rénaux

- Reins connectés circulation systémique: 25% débit cardiaque
  - → 1.25 l/min = 1800 l/24h
- Composition sang: ~ 55% liquide (Hct: 45%) → 0.625 l/min = 900 l/24h
- Rendement de filtration = $\frac{\text{Débit sortie}}{\text{Débit entrée}}$ (Fraction de filtration)
- Débit sortie (GFR) = Fraction filtration · Débit plasma sanguin (RPF)
- Glomerular filtration rate (GFR) = 0.2 · Renal plasma flow (RPF)

GFR = 0.2 · 900 l/24h= 180 l/24 h = **125** ml/min

Système urinaire: questions fondamentales

- Problématique:
  - Comment récupérer les 99% d'urine primaire?
  - Comment concentrer les solutés filtrés?
  - Comment réguler l'excrétion rénale?

Système urinaire

- Rappel définitions chimiques:
- 1 mole = 6.02 x 10^{23} particules
- 1 osmole = 6.02 x 10^{23} · Nb particules dissociées dans une solution
  - 1 mole/l glucose = 1 osm/l
  - 1 mole/l NaCl = 2 osm/l
- 1 mOsm = 0.001 osm
- Osmolalité = osmole/kg d'eau Osmolarité = osmole/l d'eau
- 1 Eq = 6.02 x 10^{23} · [charge électrique] = 1 mole · [charge électrique]
  - 1 mmole/l Na^{+}= 1 mEq/l
  - 1 mmole/l Ca^{++}= 2 mEq/l

Système urinaire

Lexique des abréviations utilisées au cours

C_x= clearance d'une substance X [ml/min]

GFR= Glomerular Filtration Rate [ml/min]

$P_{x,a}$= concentration plasmatique d'une substance X dans le compartiment artériel

$P_{x,v}$= concentration plasmatique d'une substance X dans le compartiment veineux

RPF= Renal Plasma Flow [ml/min]

U_x= concentration d'une substance X dans le compartiment urinaire

$\dot{V}$= débit urinaire [ml/min]

K_f = coefficient de filtration au niveau du capillaire glomérulaire

P_G = pression hydrostatique dans le capillaire glomérulaire

P_B = pression hydrostatique dans l'espace de Bowman

π_G = pression colloïdo-osmotique dans le capillaire glomérulaire

π_B = pression colloïdo-osmotique dans l'espace de Bowman

Système urinaire Homéostasie corporelle et bilan hydrique global

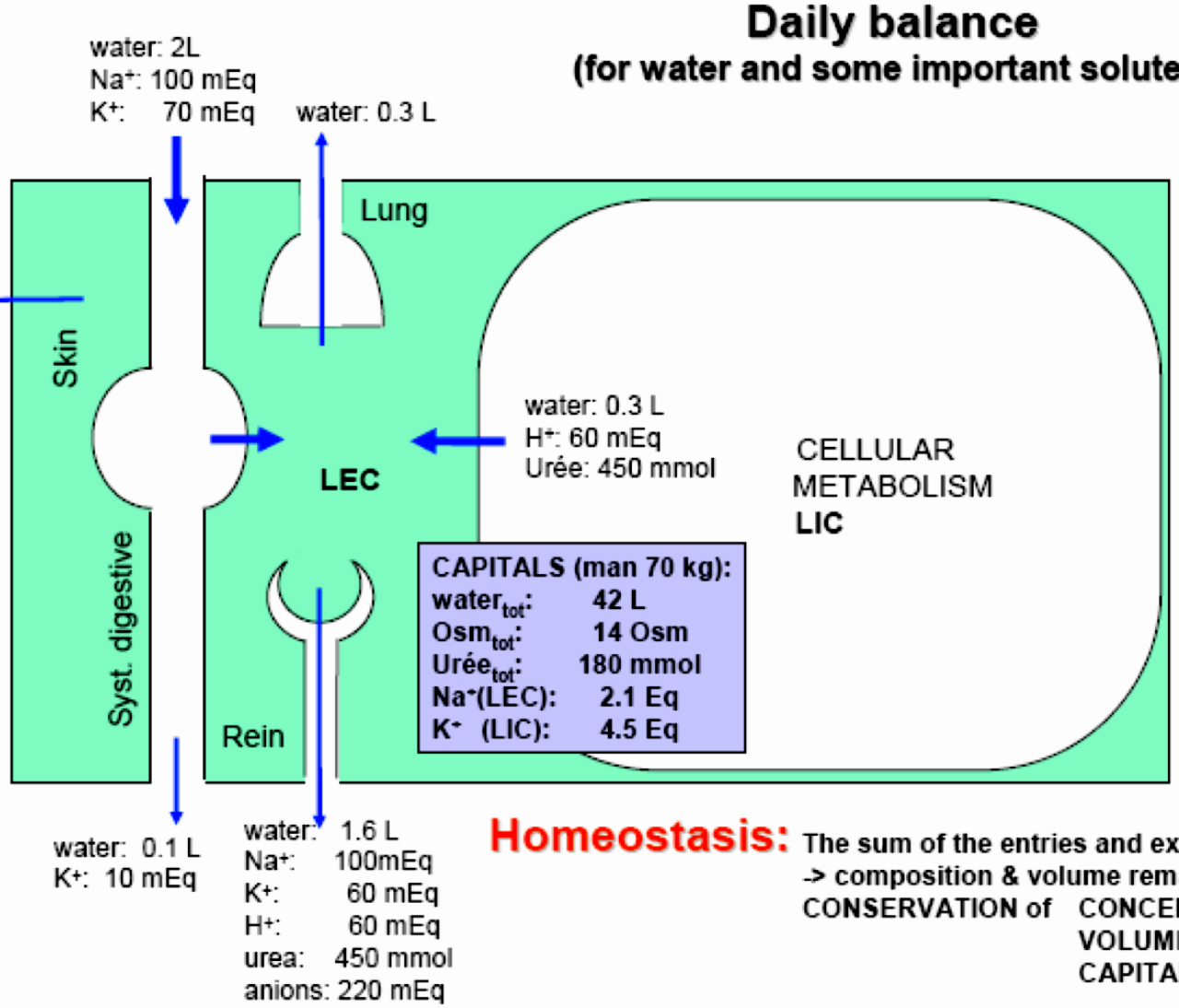
Entrée H_2O:
2 l alimentaire
0.3 l métabolisme

Sortie H_2O:
0.3 l transpiration

Sortie H_2O:
0.3 l respiration

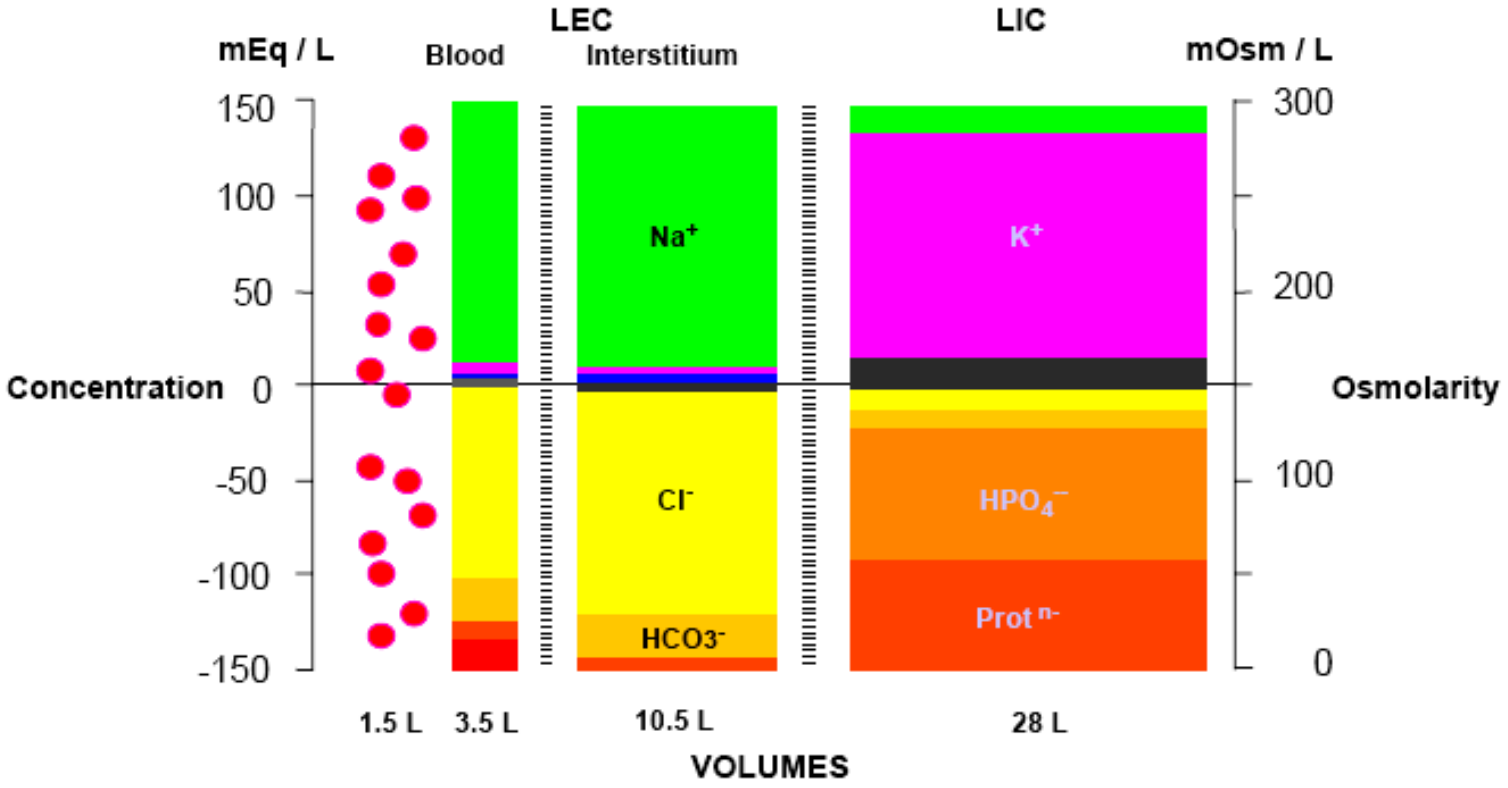
Sortie H_2O:
0.1 l déjections

Sortie H_2O:
1.6 l excrétion urinaire



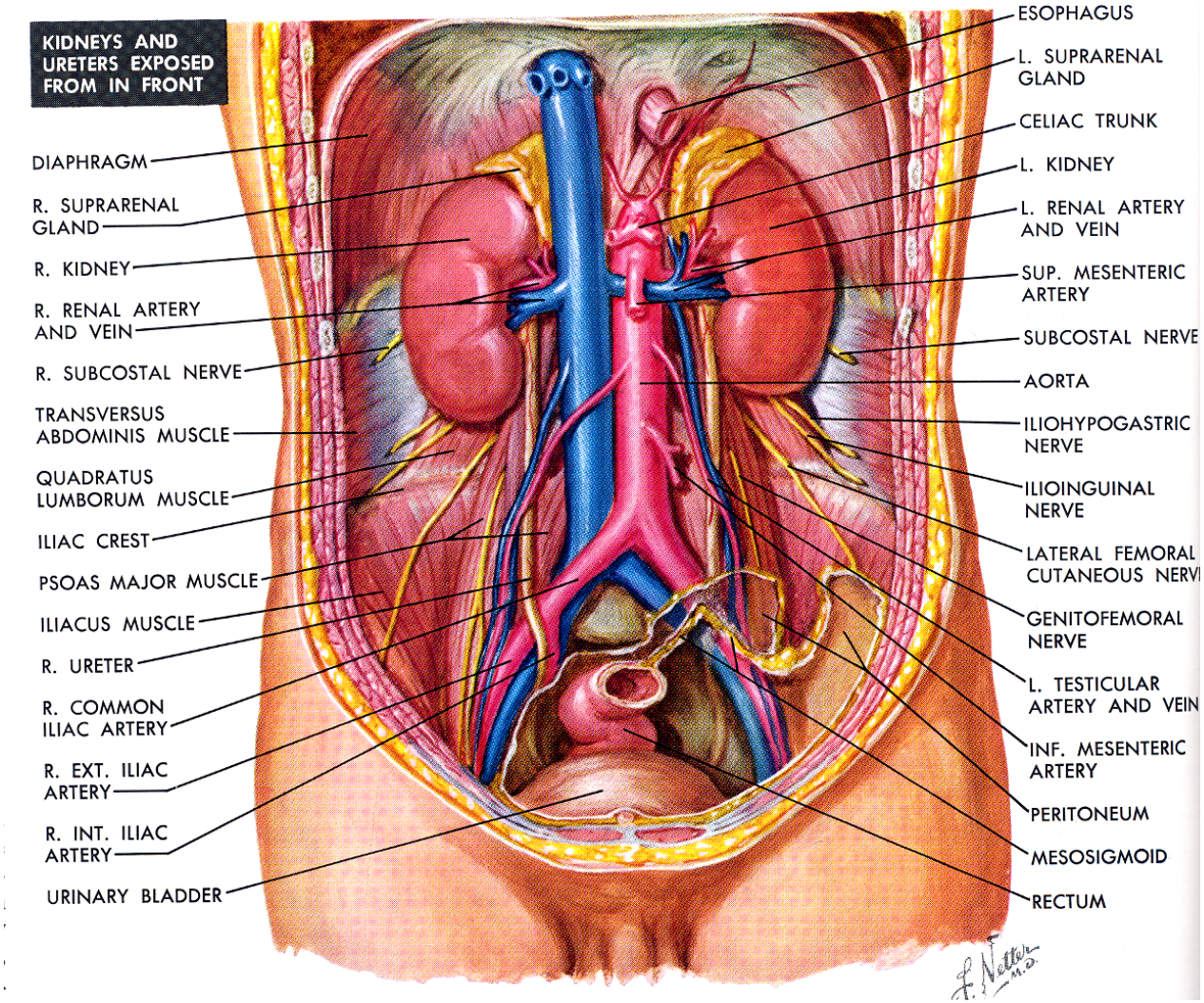
Système urinaire Filtration plasmatique extraction et répartition de solutés

Volumes and compositions of body electrolytic compartments



Concentration x Volume = CAPITAL

Système urinaire Anatomie rénale



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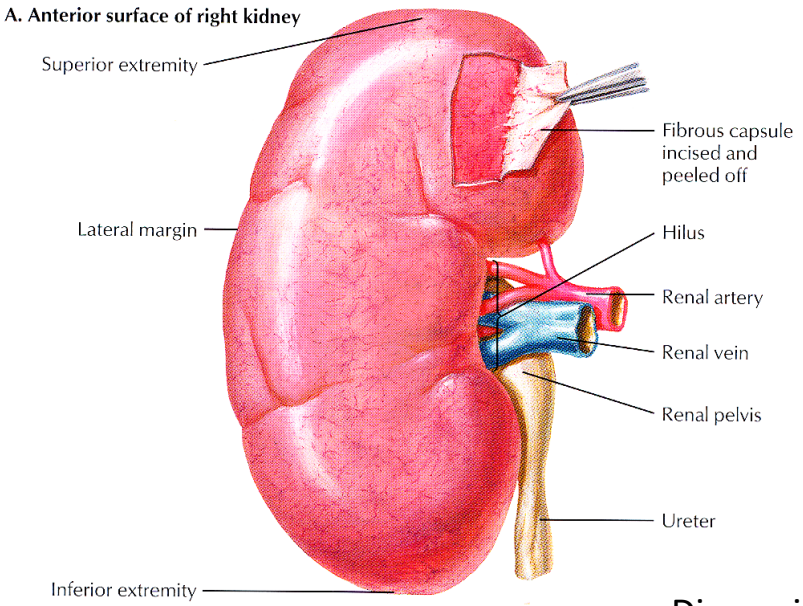
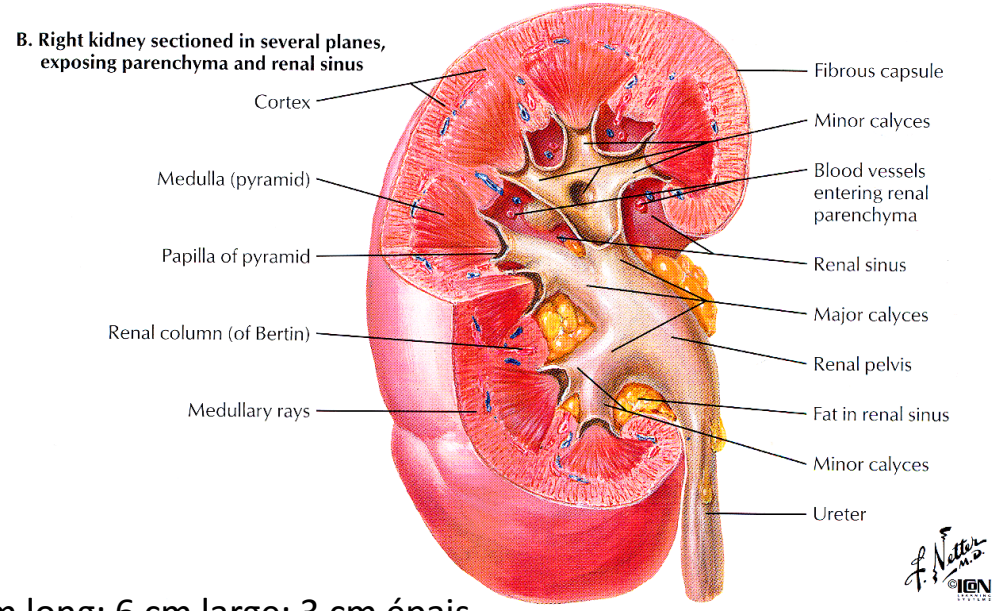
Système urinaire Anatomie rénale





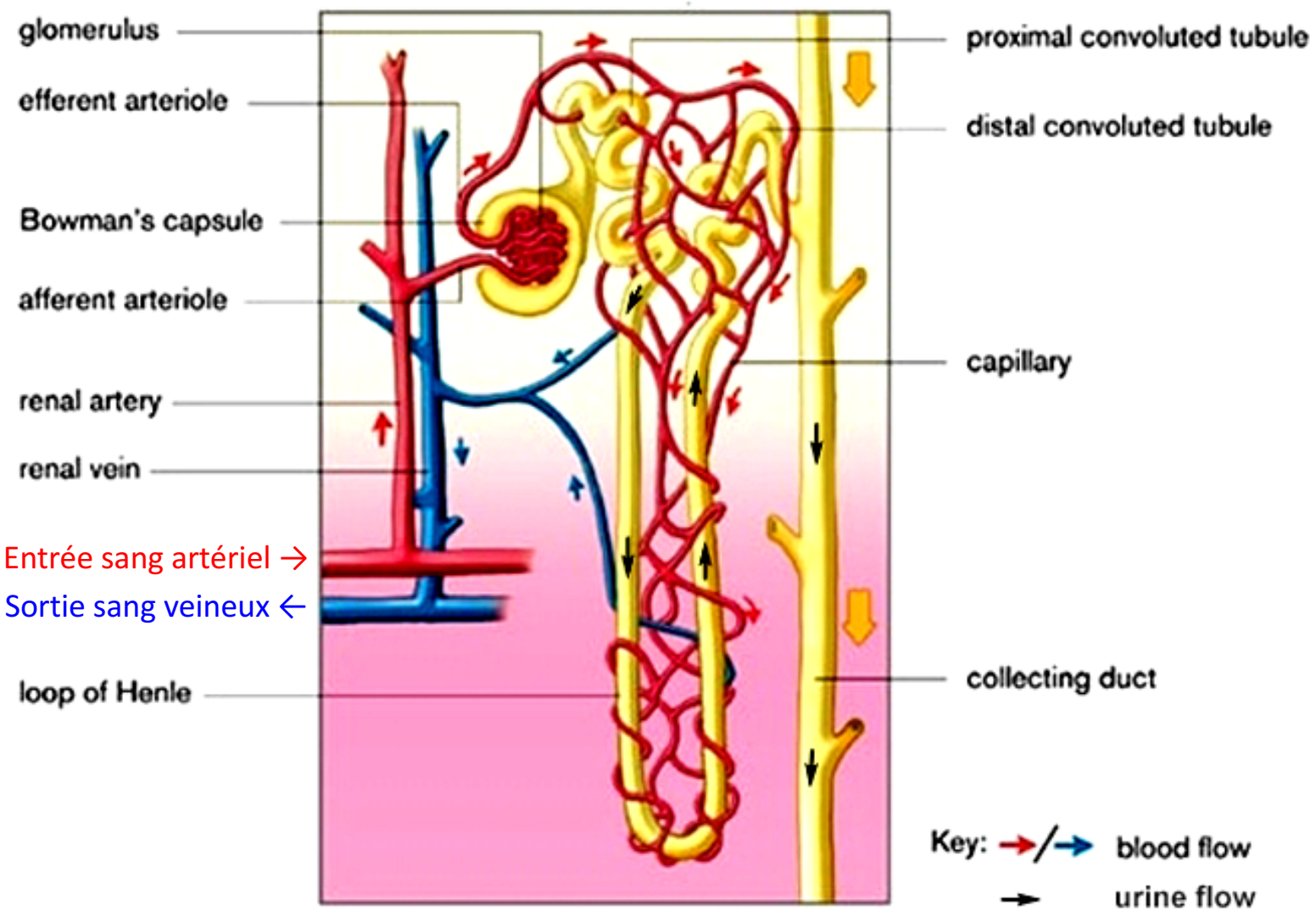
Dimension: 12 cm long; 6 cm large; 3 cm épais
Masse: 120-160 g

ANATOMY OF THE KIDNEY

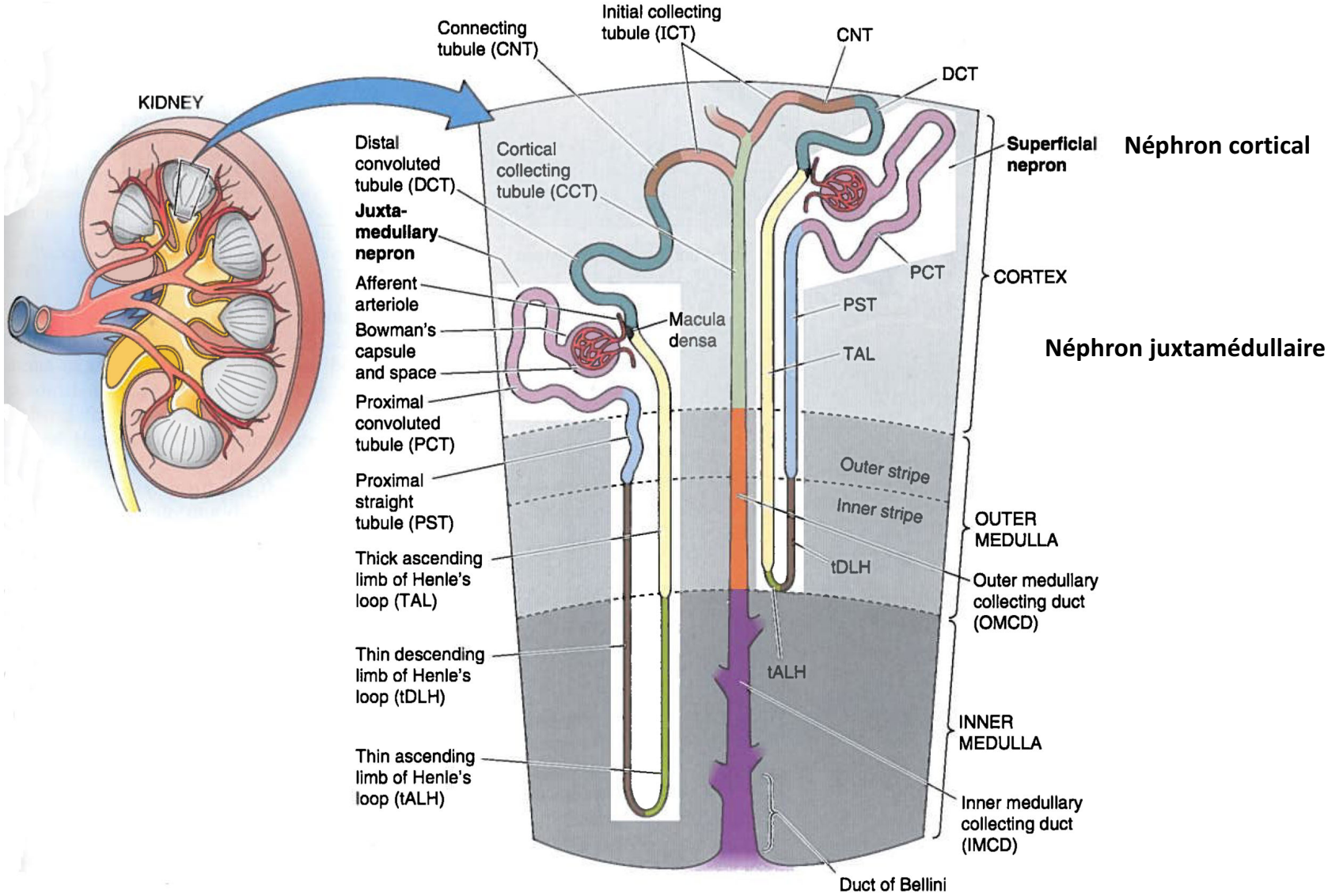
The kidneys are paired retroperitoneal abdominal organs at the level of the T11 to L3 vertebrae. They process the blood and participate in the following general functions: (1) regulating fluid volume and composition, (2) excreting metabolic wastes and removing foreign chemicals (e.g., drugs) and their metabolites from the blood, and (3) functioning as endocrine organs. Internally, the kidney is divided into a cortex and medulla, both of which contain the nephrons (approximately 1.25 million per kidney). The medulla forms 8 to 15 pyramids. Urine exits the papilla of a pyramid and collects in a minor calyx. The minor calyces join to form the major calyces and then the pelvis. The renal columns (of Bertin) consist of cortical nephron segments, whereas the medullary rays contain nephron segments that extend into the medulla.

Nettler Atlas of Anatomy

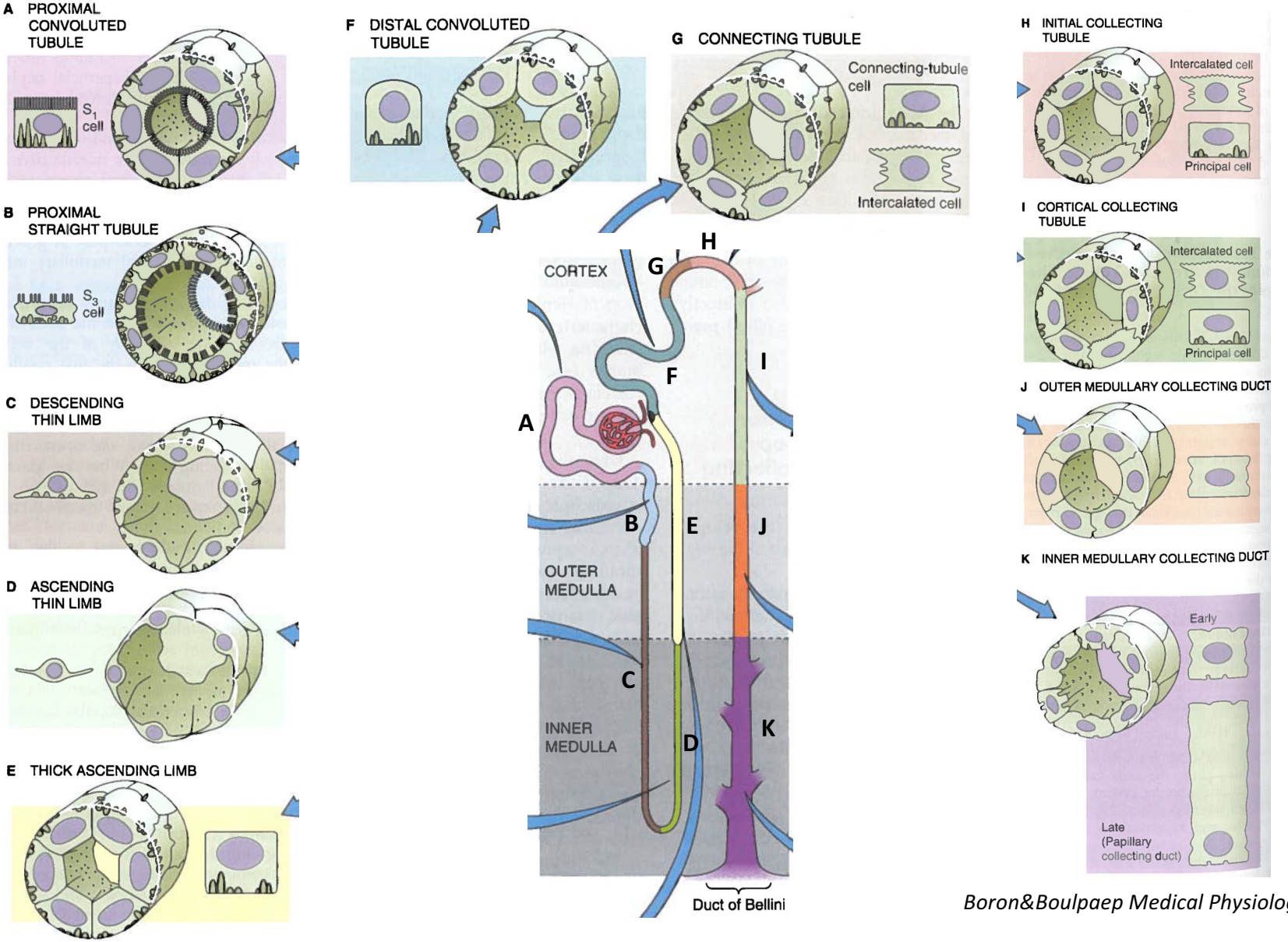
Système urinaire Anatomie et flux du néphron



Système urinaire Structure générale d'un néphron



Système urinaire Structure générale d'un néphron et des tubules



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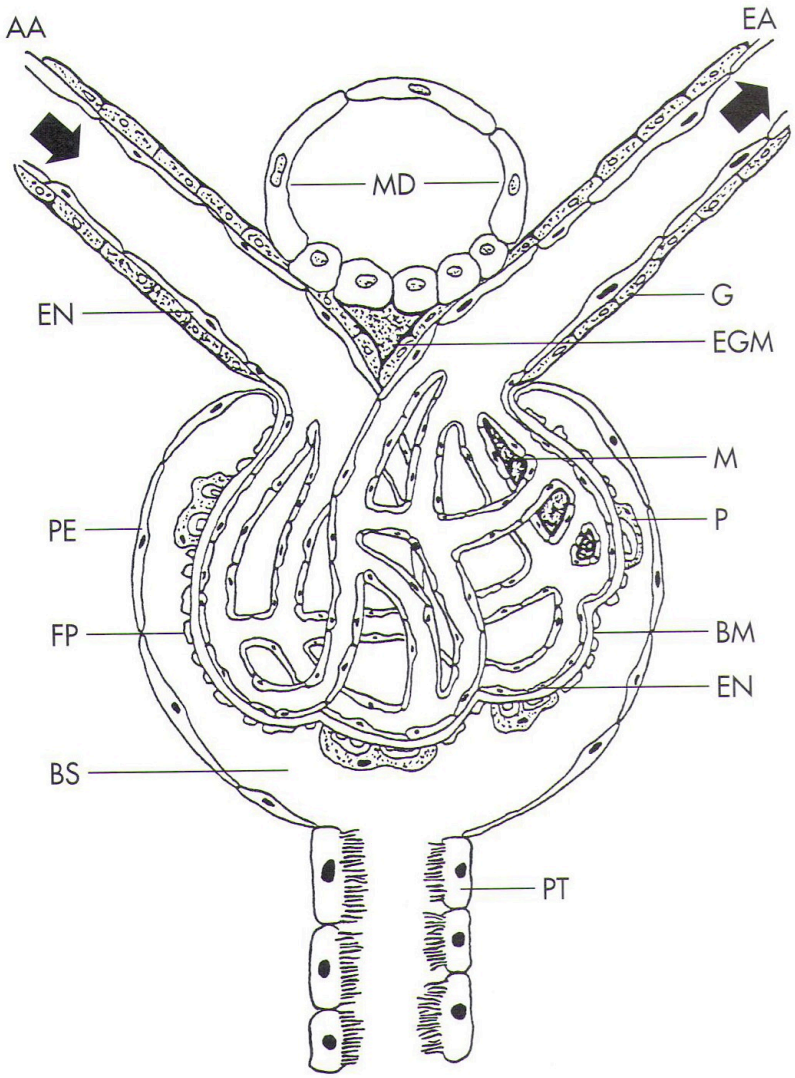
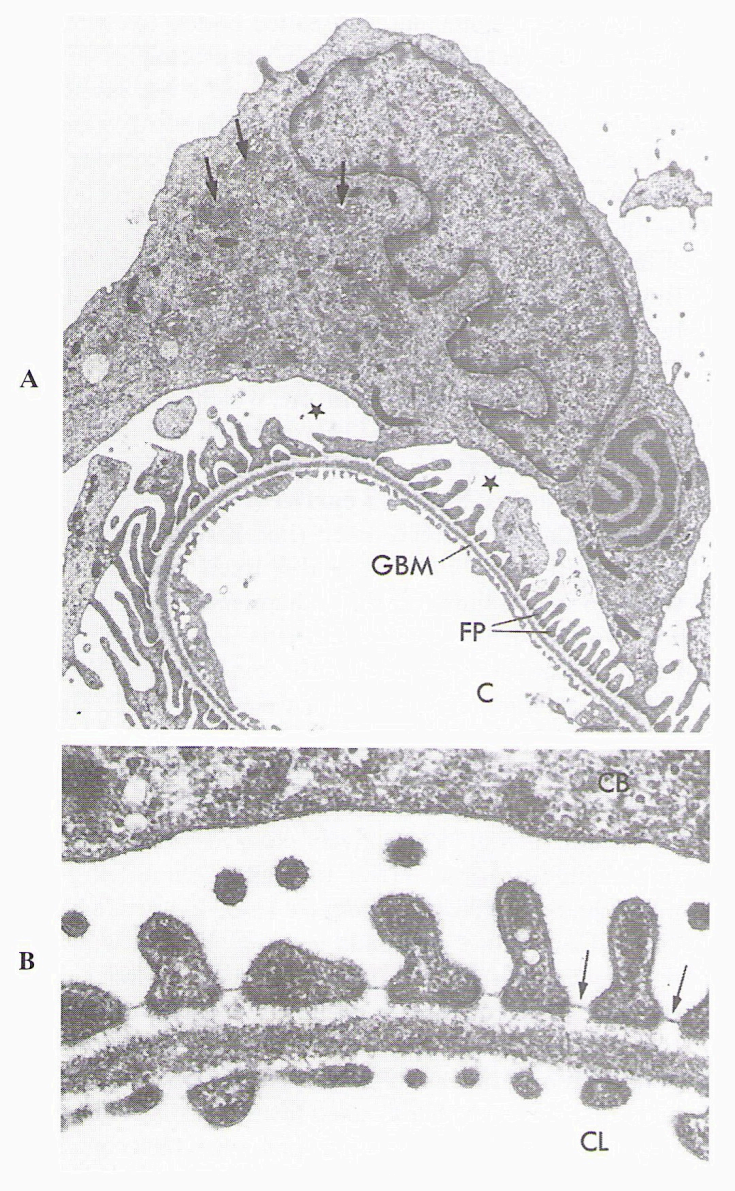
Système urinaire Anatomie d'un corpuscule rénal et appareil juxtaglomérulaire



■ **Fig. 40-4** Anatomy of the renal corpuscle and the juxtaglomerular apparatus. The latter is composed of the (1) macula densa of the thick ascending limb, (2) extraglomerular mesangial cells, and (3) renin-producing granular cells of the afferent and efferent arterioles. *AA*, Afferent arteriole, *EA*, efferent arteriole; *G*, granular cell of the afferent and efferent arterioles; *MD*, macula densa; *BM*, basement membrane; *FP*, foot processes of the podocyte; *P*, podocyte cell body (visceral cell layer); *M*, mesangial cells between capillaries; *EGM*, extraglomerular mesangial cells between the afferent and efferent arterioles; *EN*, endothelial cell; *PT*, proximal tubule cell; *BS*, Bowman's space; *PE*, parietal epithelium. (Modified from Koushanpour E, Kriz W: *Renal physiology: principles, structure, and function*, ed 2, New York, 1986, Springer-Verlag.)

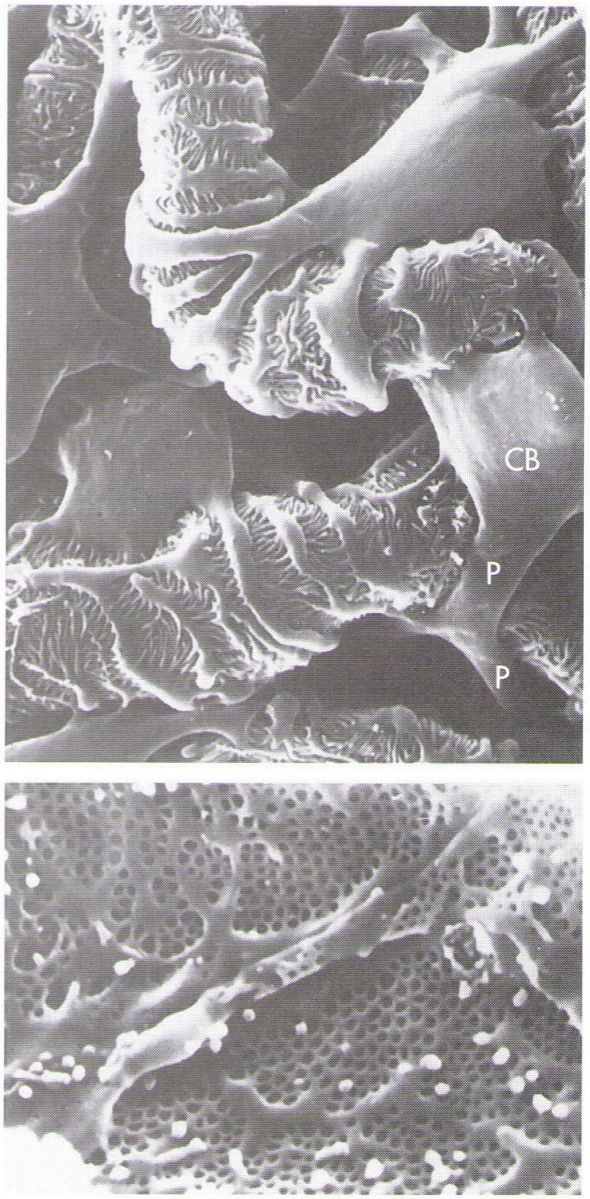
Macula densa distal tubule)
Extraglomerular Mesangial cells) JuxtaGlomerular Apparatus JGA
Granular cells afferent arterioles) ↳ Renine

Système urinaire Anatomie d'un glomérule capillaire et podocyte



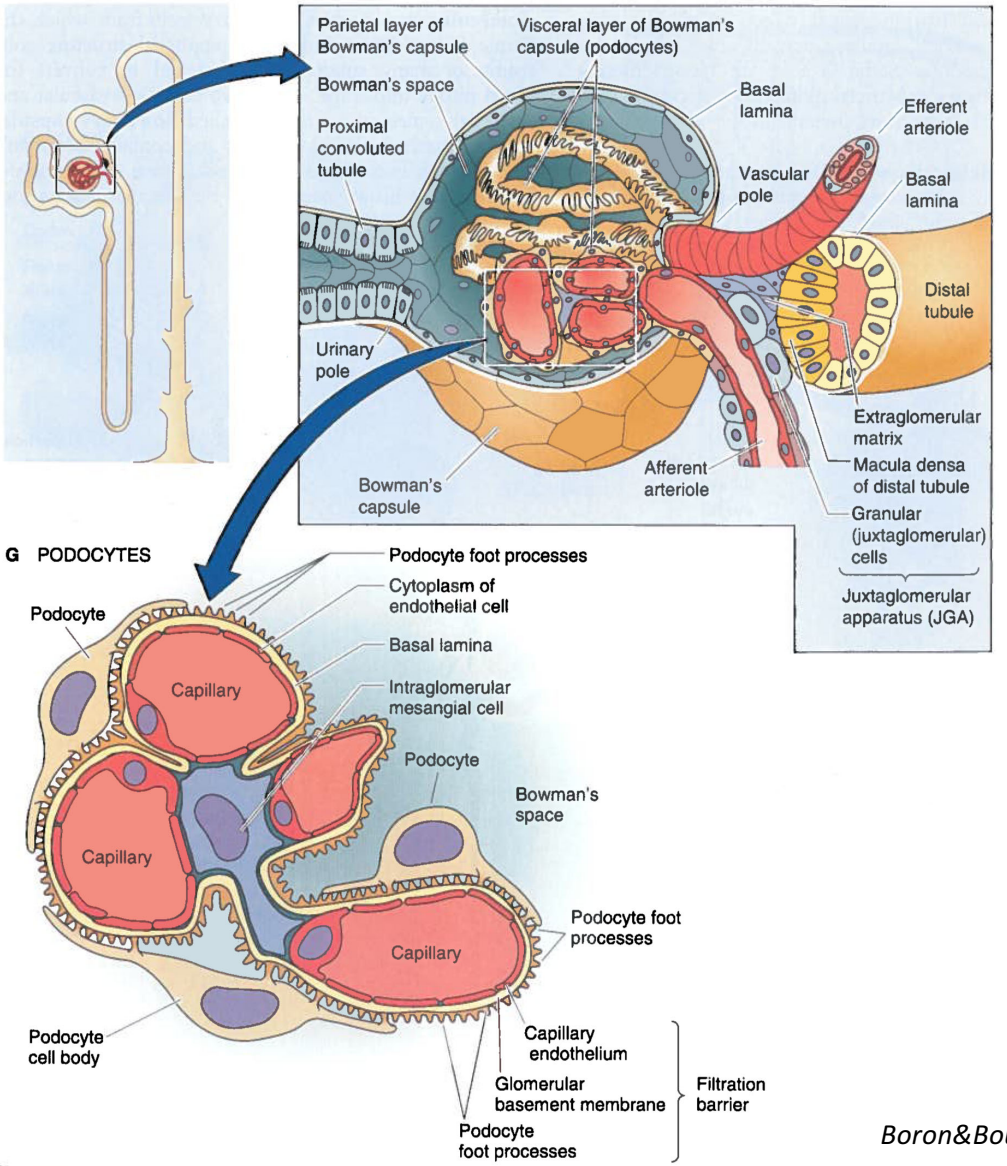
■ **Fig. 40-6** **A,** Electron micrograph of a podocyte surrounding a glomerular capillary. The cell body of the podocyte contains a large nucleus with three indentations. Cell processes of the podocyte form the interdigitating foot processes *(FP)*. The arrows in the cytoplasm of the podocyte indicate the well-developed Golgi apparatus. *C,* Capillary lumen; *GBM,* glomerular basement membrane. Stars indicate Bowman's space. (Magnification ~5700 ×.) **B,** Electron micrograph of the filtration barrier of a glomerular capillary. *CL,* Capillary lumen; *CB,* cell body of a podocyte. The filtration barrier is composed of three layers: the endothelium, the basement membrane, and the foot processes of the podocytes. Note the diaphragm bridging the floor of the filtration slits *(arrows)*. (Magnification ~42,700 ×.) (Courtesy of Kriz W, Kaissling B: *Structural organization of the mammalian kidney.* In Seldin DW, Giebisch G, editors: *The kidney: physiology and pathophysiology,* ed 2, New York, 1992, Raven Press.)

Système urinaire Anatomie d'un glomérule capillaire et endothélium



■ **Fig. 40-7** **A,** Scanning electron micrograph showing the outer surface of glomerular capillaries. This is the view that would be seen from Bowman's space. Processes *(P)* of podocytes run from the cell body *(CB)* toward the capillaries where they ultimately split into foot processes. Interdigitation of the foot processes creates the filtration slits. (Magnification ~2,500 ×.) **B,** Scanning electron micrograph of the inner surface (blood side) of a glomerular capillary. This view would be seen from the lumen of the capillary. The fenestrations of the endothelial cells are seen as small 700-Å holes. (Magnification ~12,000 ×.) (Courtesy of Kriz W, Kaissling B: *Structural organization of the mammalian kidney.* In Seldin DW, Giebisch G, editors: *The kidney: physiology and pathophysiology,* ed 2, New York, 1992, Raven Press.)

Système urinaire Glomérule capillaire



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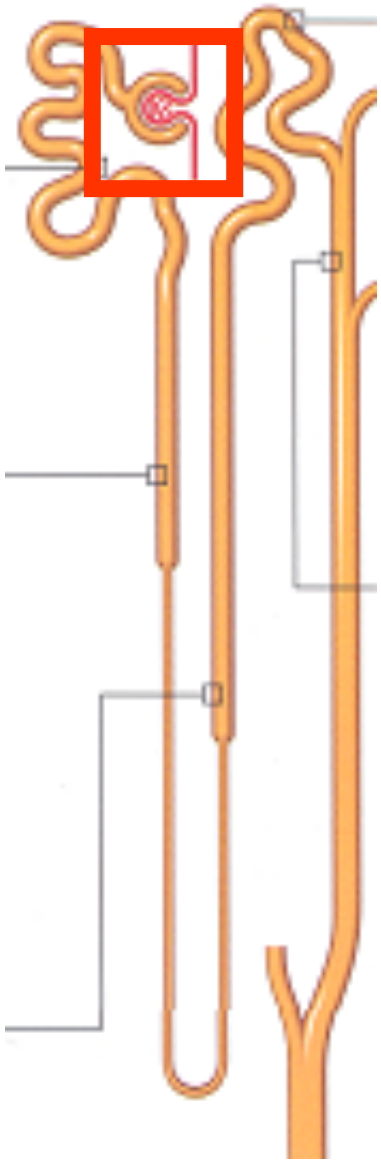
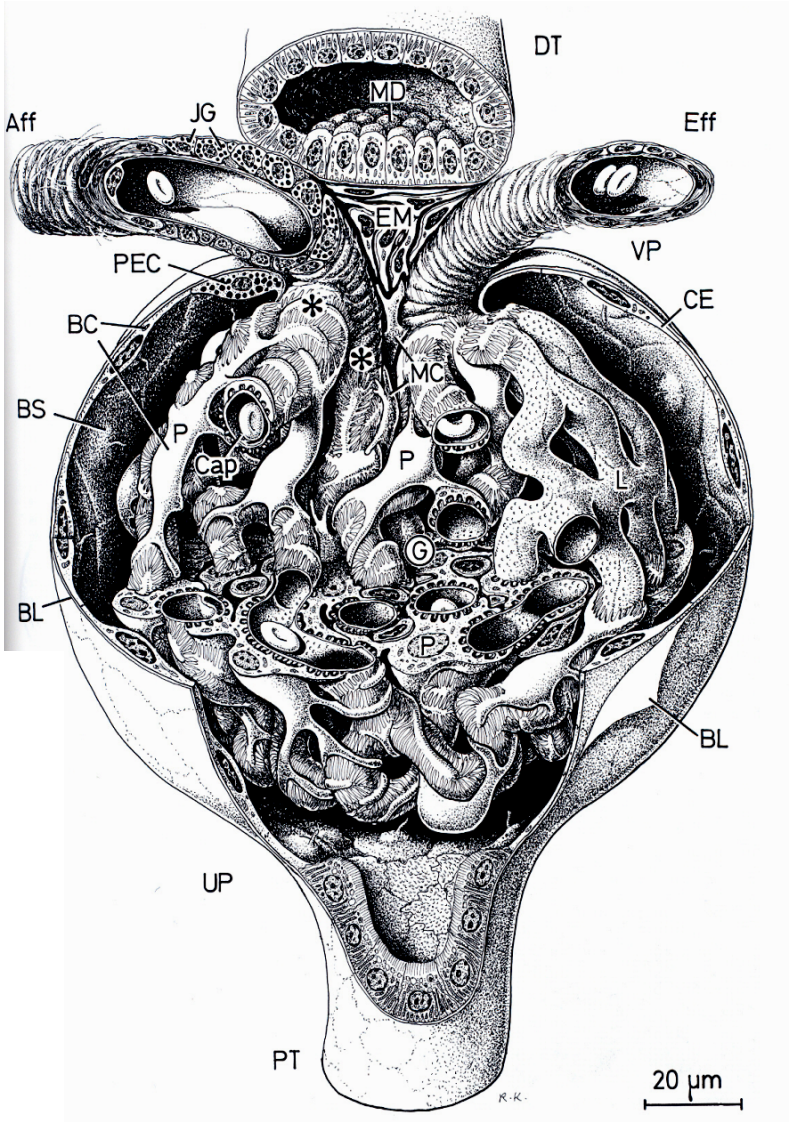
Système urinaire Glomérule capillaire



Aff= afferent arteriole
Eff= efferent arteriole
BC= Bowman capsule
BS= Bowman space
BL= basal lamina
CE= capilar epithelium
G = glomerulus
JG= juxtaglomerular cells
PEC= peripolar epithelial cell
P= podocyte
PT=proximal convoluted tubule
DT= distal tubule
VP= vascular pole



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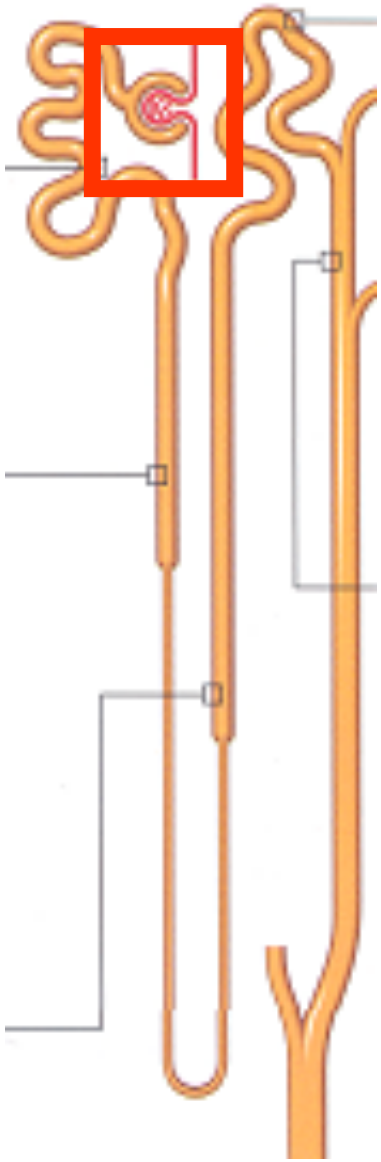
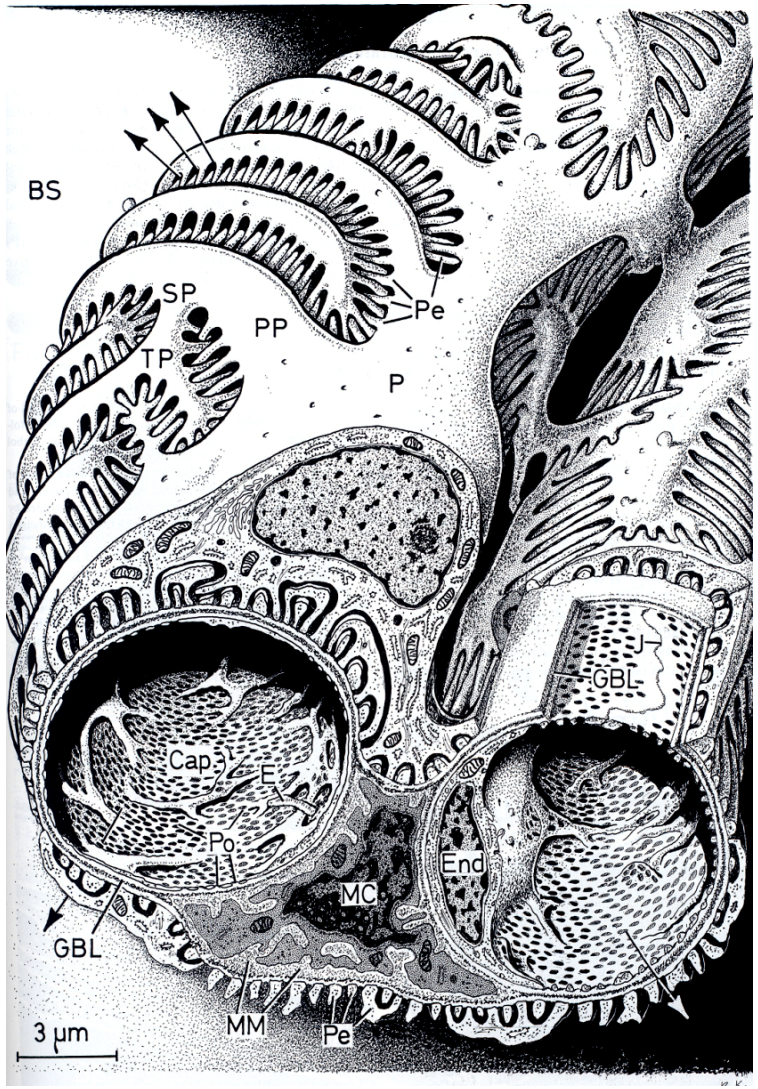
Système urinaire Glomérule capillaire et podocyte



BS= Bowman space
Cap= capillar
End= endothelial cell
GBL= glomerular basal lamina
MC= mesengial cell
MM= mesangial matrix
P= podocyte
Pe= pedicels
Po= pores (60-100 nm diameter)
PP= primary processes
SC= secondary processes
TP= tertiary processes



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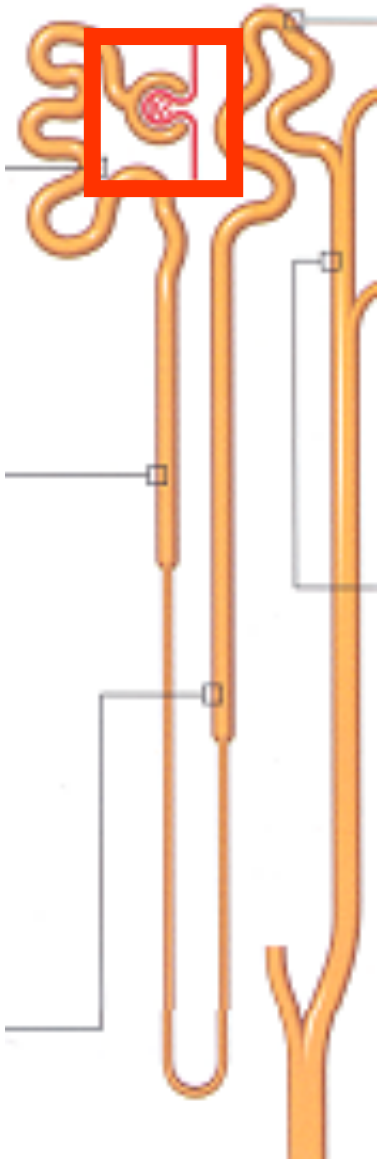
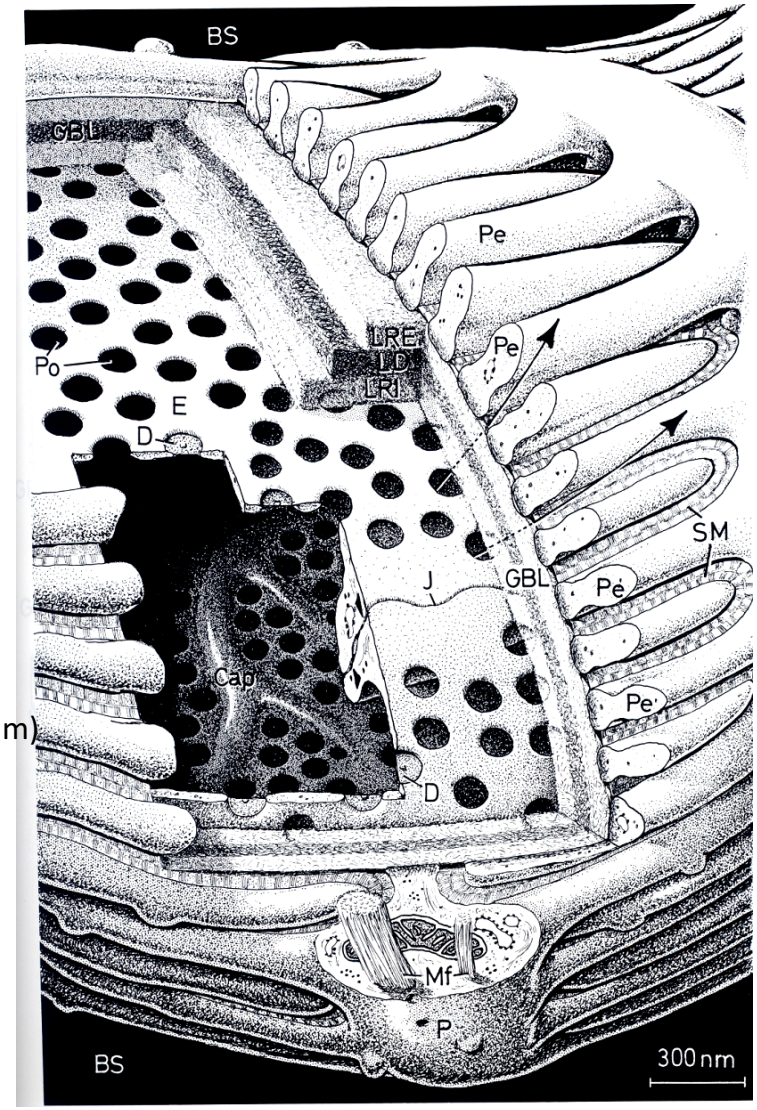
Système urinaire Glomérule capillaire et endothélium fenestré



BS= Bowman space
Cap= capilar
D= diaphragm
End= endothelial cell
GBL= glomerular basal lamina (250-450nm)
J= junctional line
LRI= lamina rara interna
LD= lamina densa
LRE= lamina rara externa
Mf= microfilament bundles
P= podocyte
Pe= pedicels
Po= pores (60-100 nm diameter)
SM= glomerular slit membrane
TP= tertiary processes



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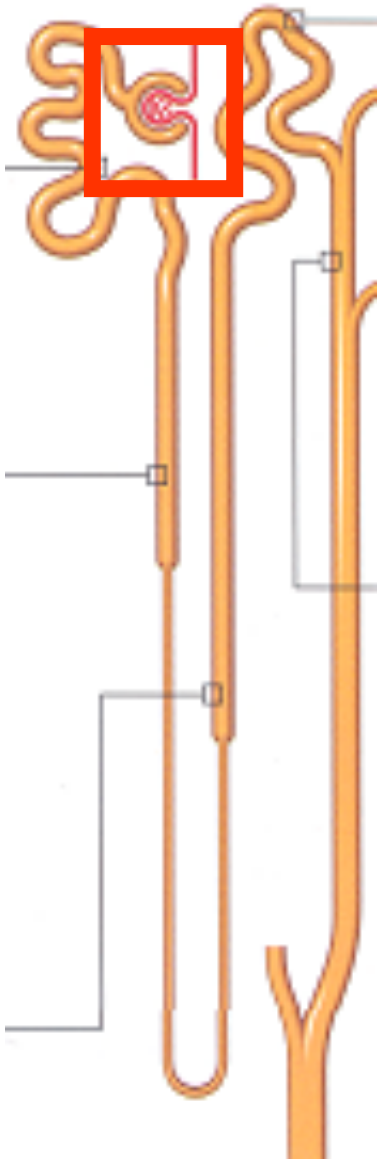
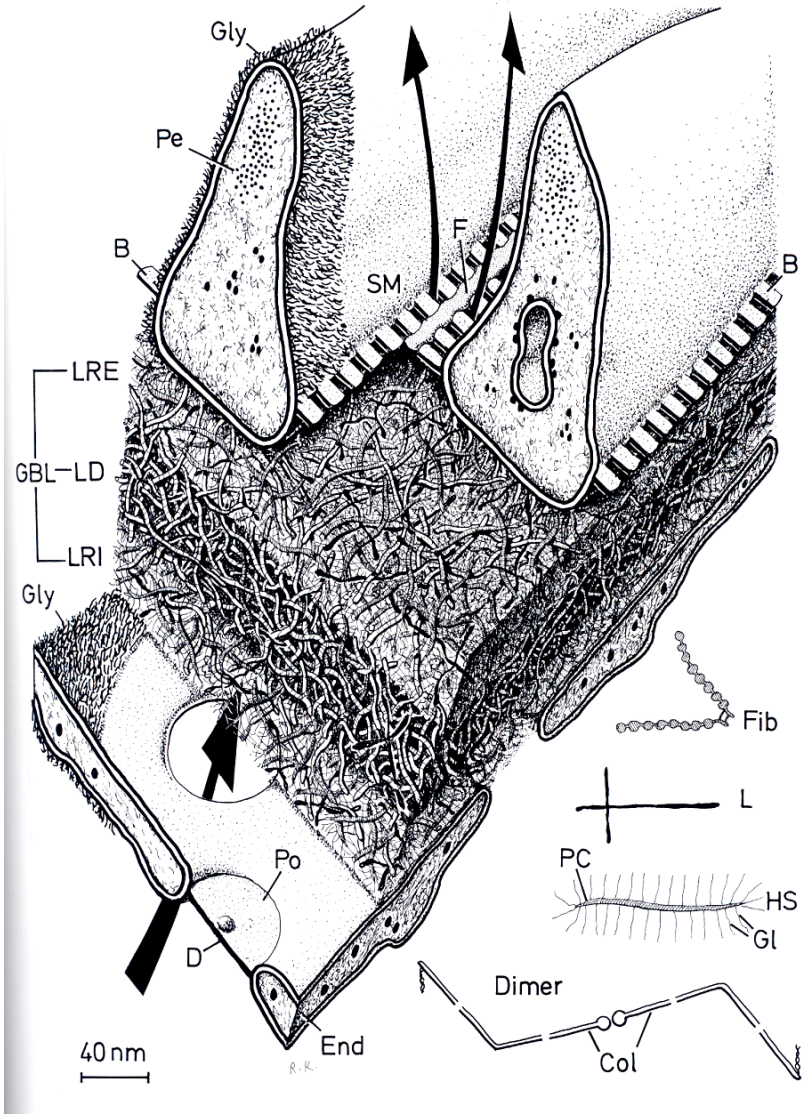
Système urinaire Glomérule capillaire et endothélium fenestré



B= cross bridge
Col= type IV collagen
D= diaphragm
End= endothelial cell
F= central filament
Fib= fibronectin
GBL= glom. basal lamina (250-450nm)
GI= glycoprotein branches
Gly= glycocalyx
HS=Heparan sulfate
PC= protein core
LRI= lamina rara interna
LD= lamina densa
LRE= lamina rara externa
Pe= pedicels
Po= pores (60-100 nm diameter)
SM= glomerular slit membrane



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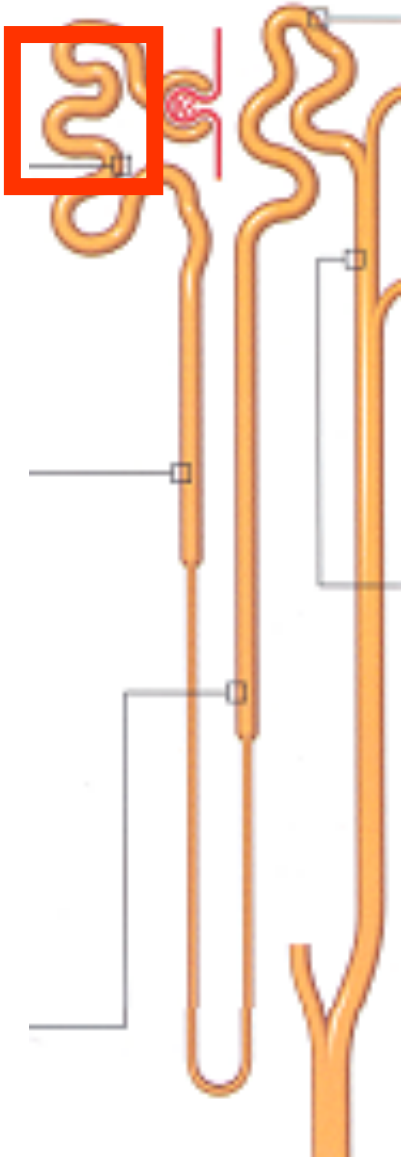
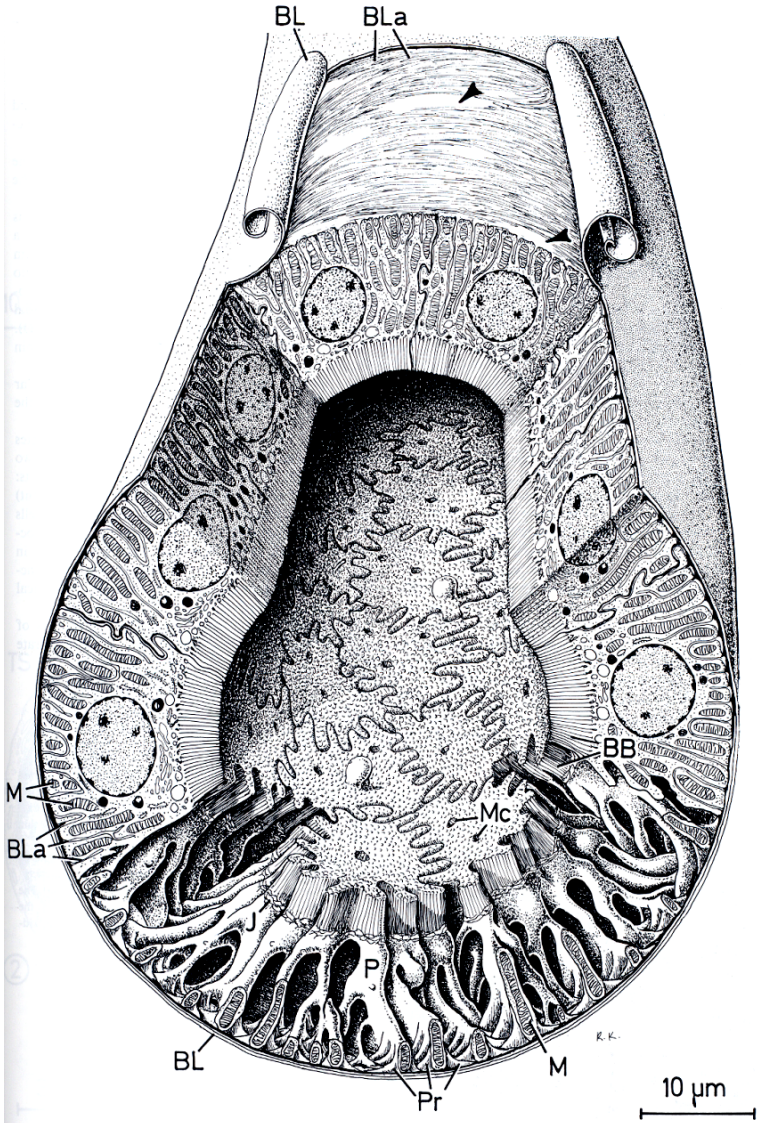
Système urinaire Tubule proximal



BL= basal lamina
BLa= basal laminar adhesion
BB= border brush
M= mitochondria
Mc= membrane chanel
P= podocyte
Pr= podocyte ramification



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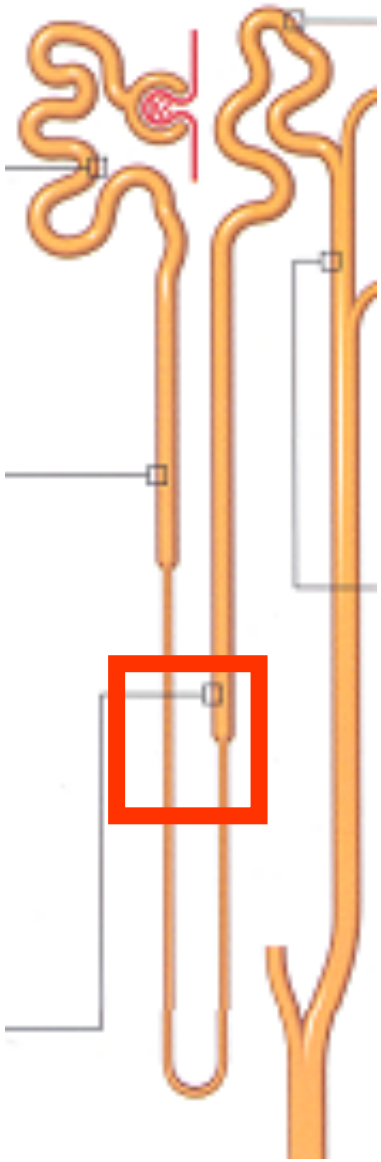
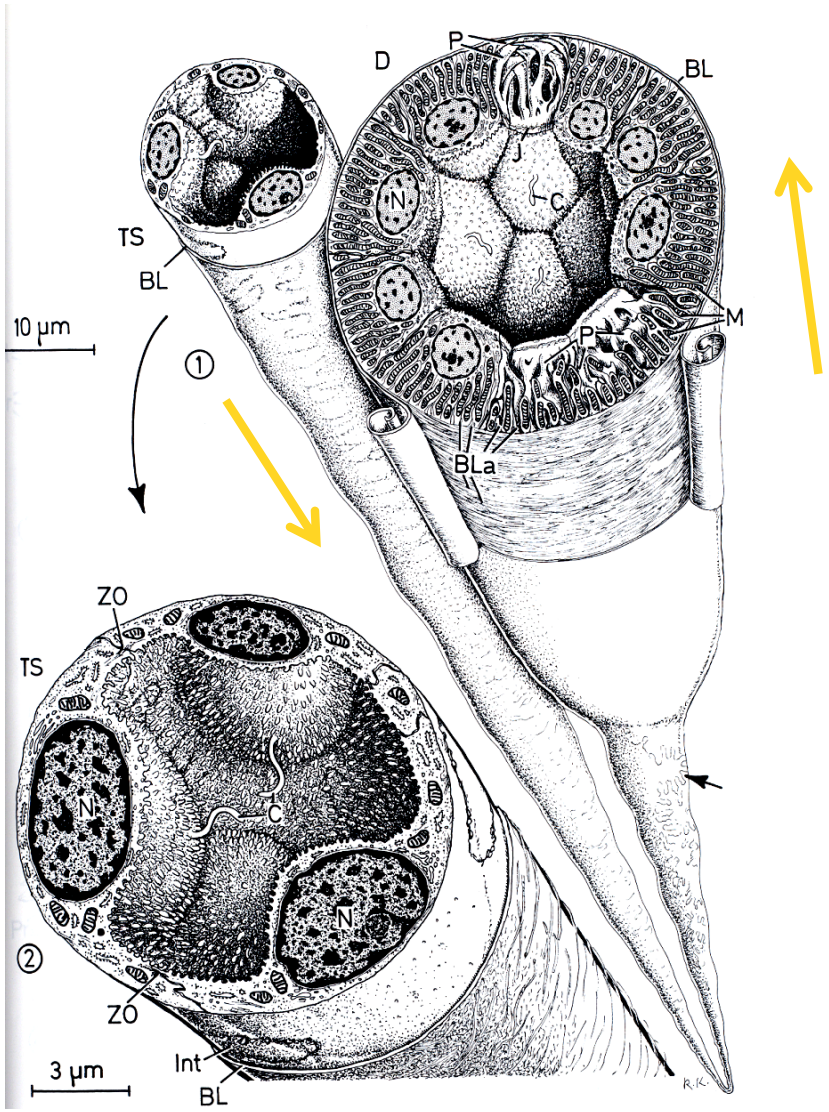
Système urinaire Tubule droit distal et branche descendante fine de Henle



BL= basal lamina
BLa= basal laminar adhesion
D= distal tube
M= mitochondria
Mc= membrane chanel
P= podocyte
TS= thin descending loop
ZO= zonula occludens



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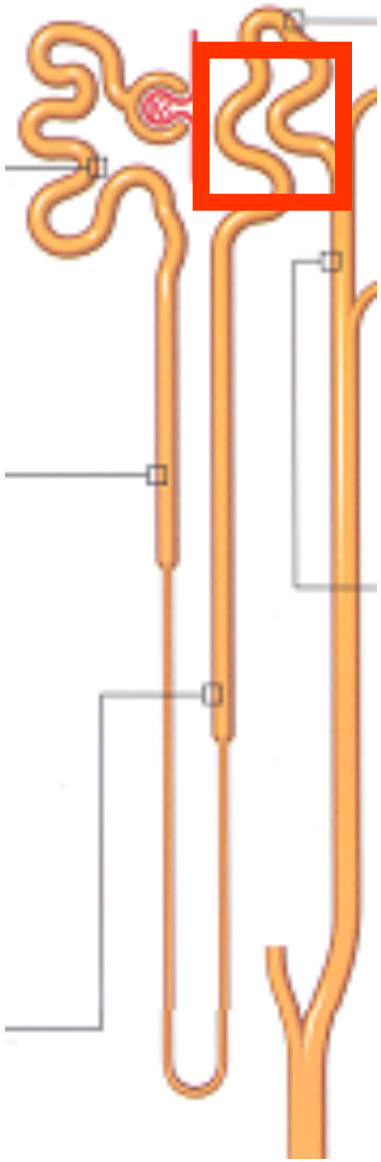
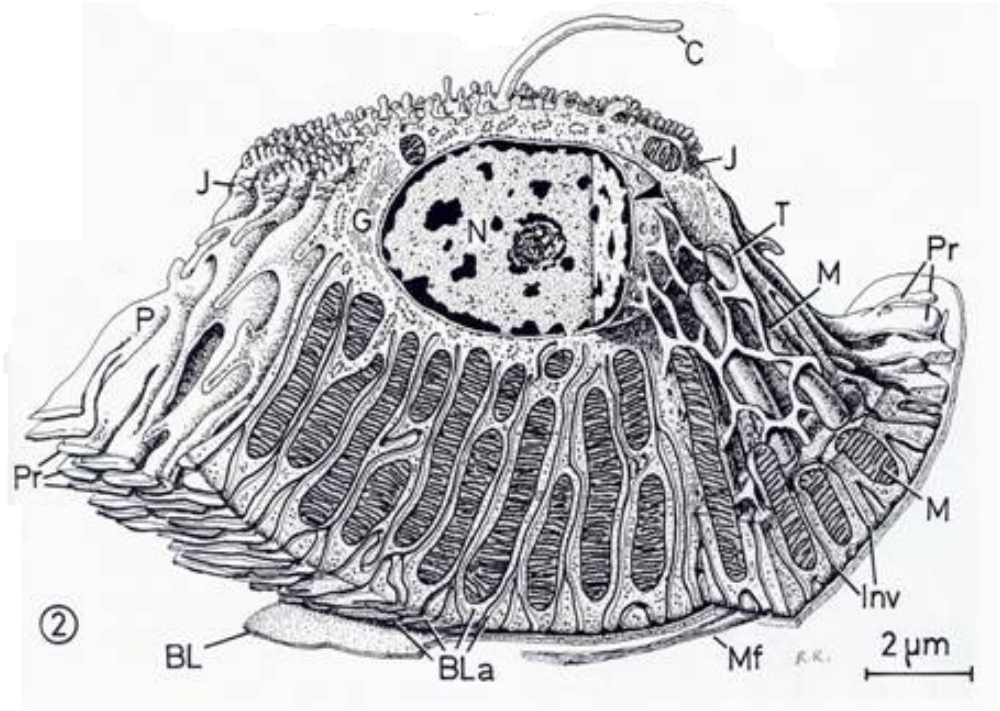
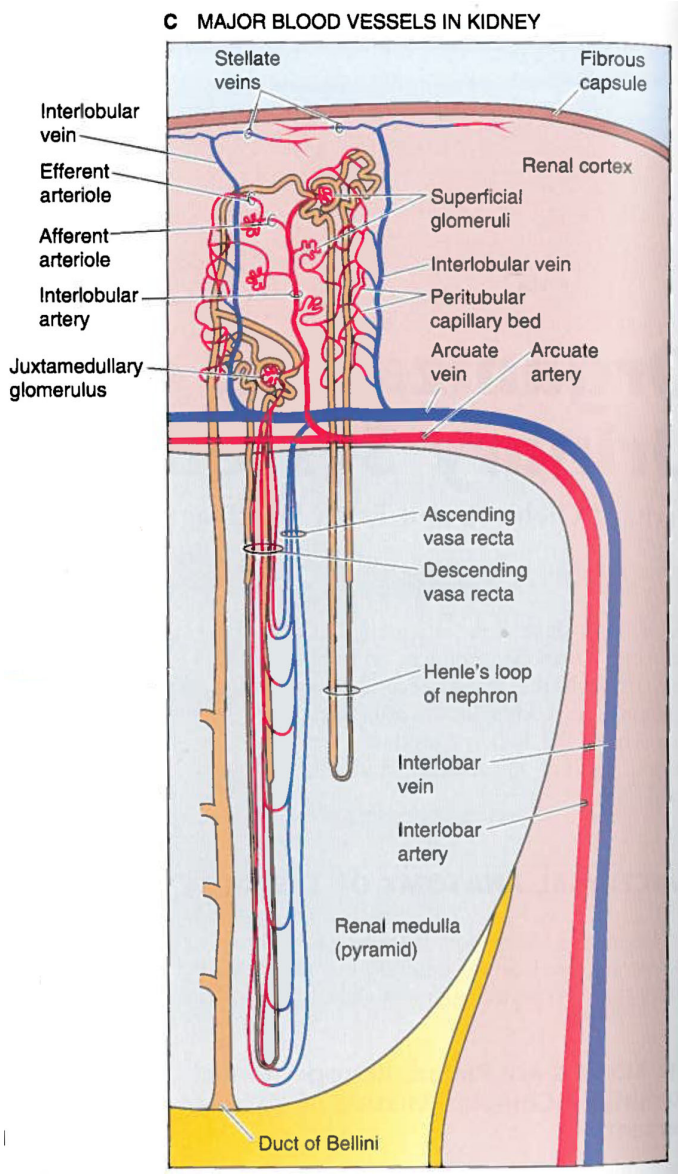
Système urinaire Tubule contourné distal

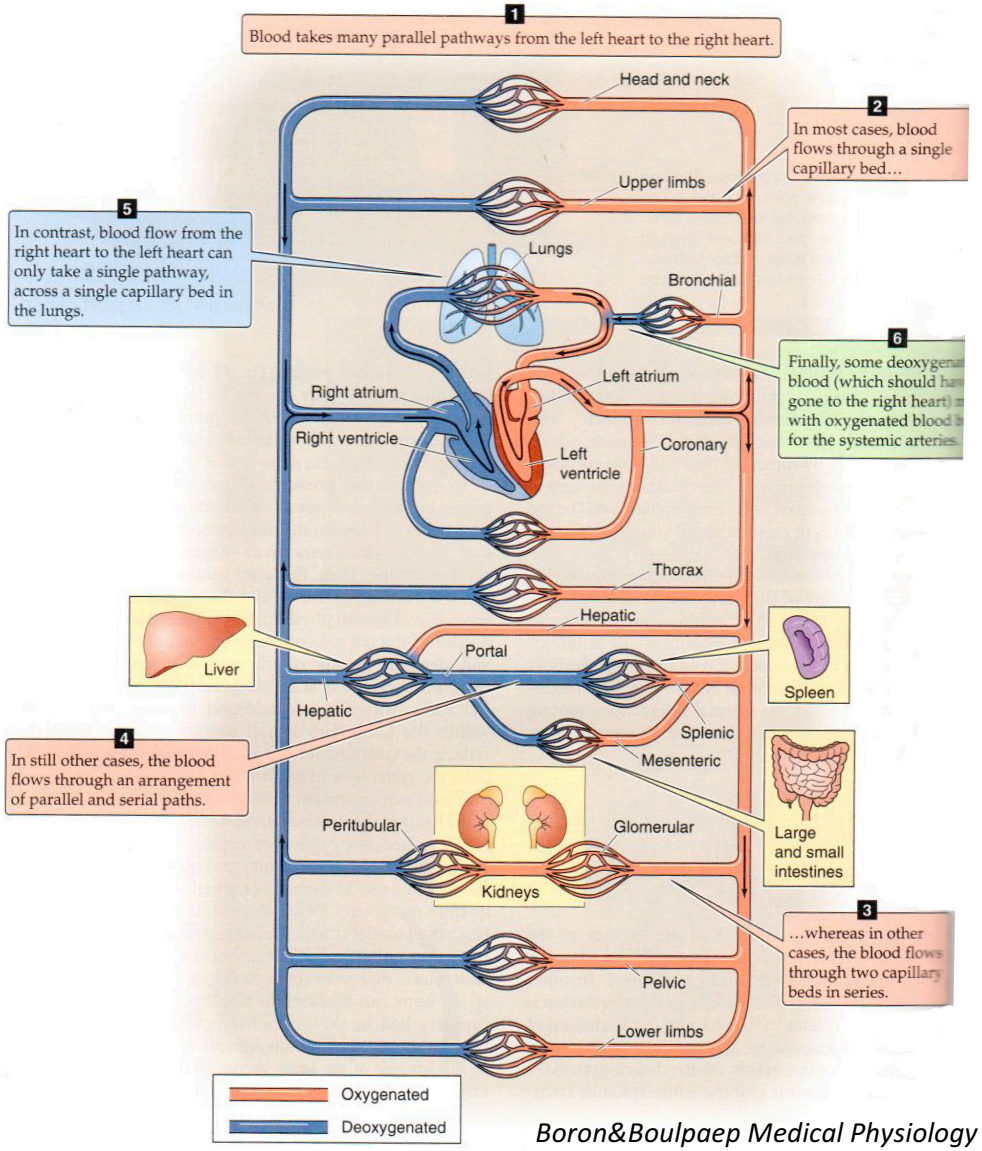




BL= basal lamina
BLa= basal laminar adhesion
C= cilia
D= distal tube
Inv= invagination
J= junction
M= mitochondria
Mf= membrane folds
N= nucleus
Pr= podocyteramification
T= tubule
ZO= zonula occludens

Système urinaire Vascularisation rénale et circulation générale





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