بسم الله الرحمن الرحيم

1

Physiology of the Kidney and Urological system

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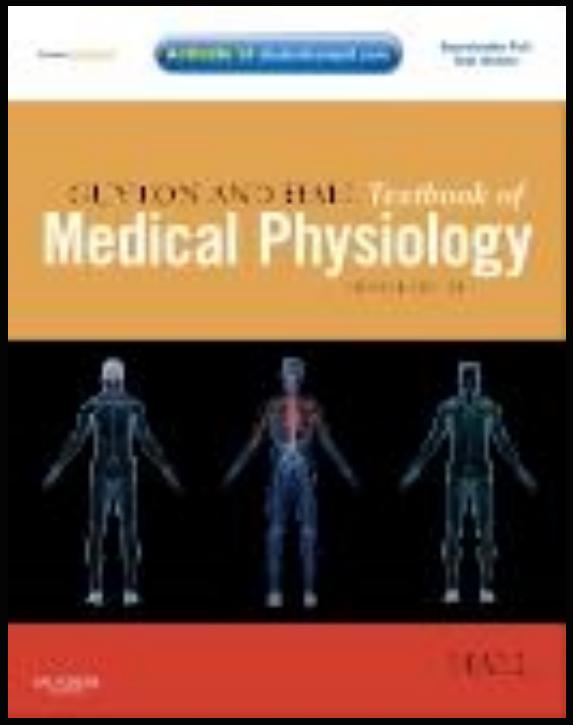
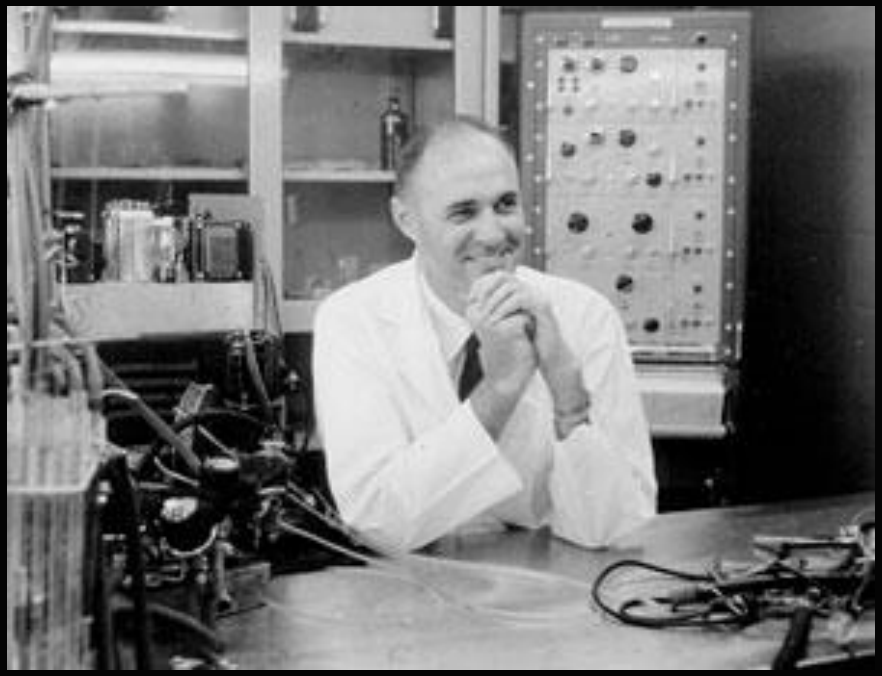
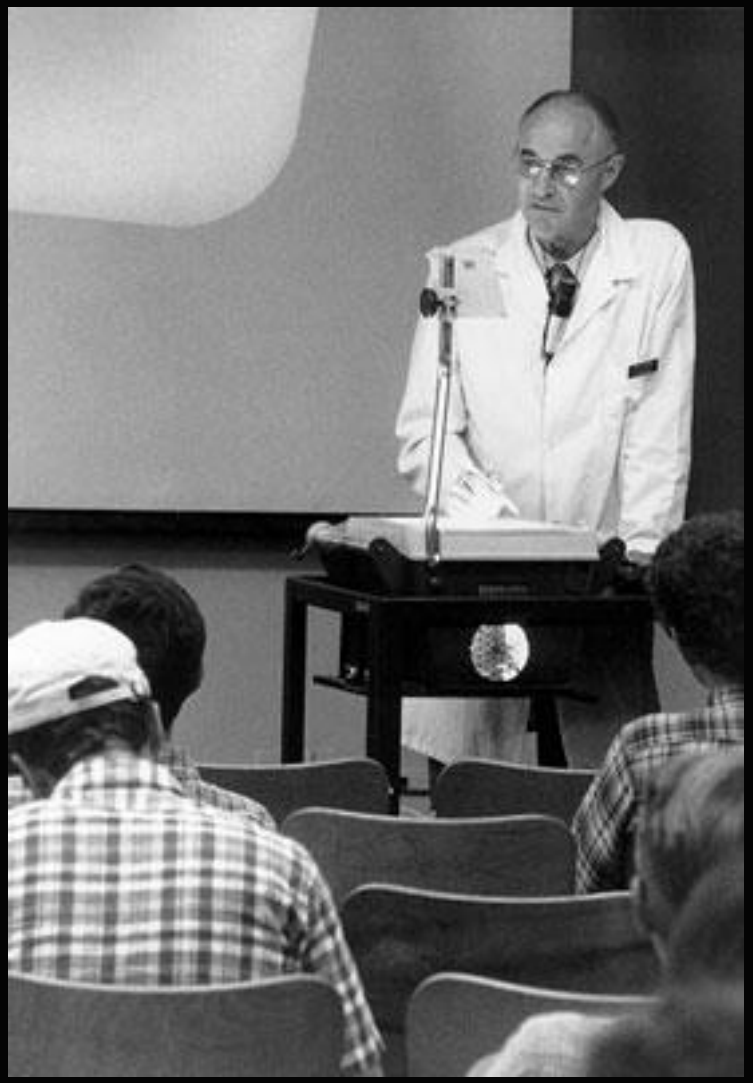


Frank H. Netter, MD
(1906-1991)
"Medicine's Michelangelo"

Arthur Guyton
(1919-2003)





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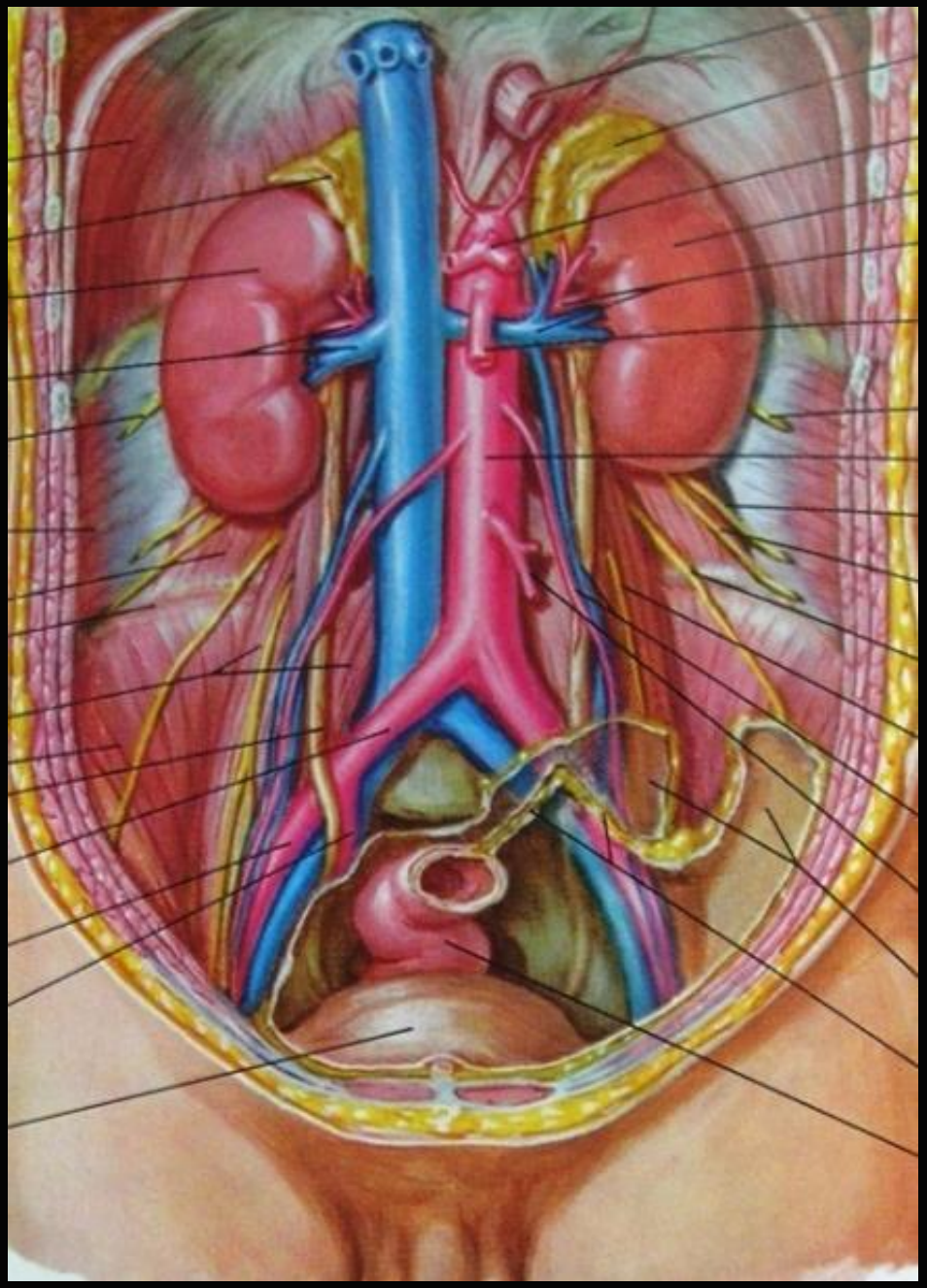
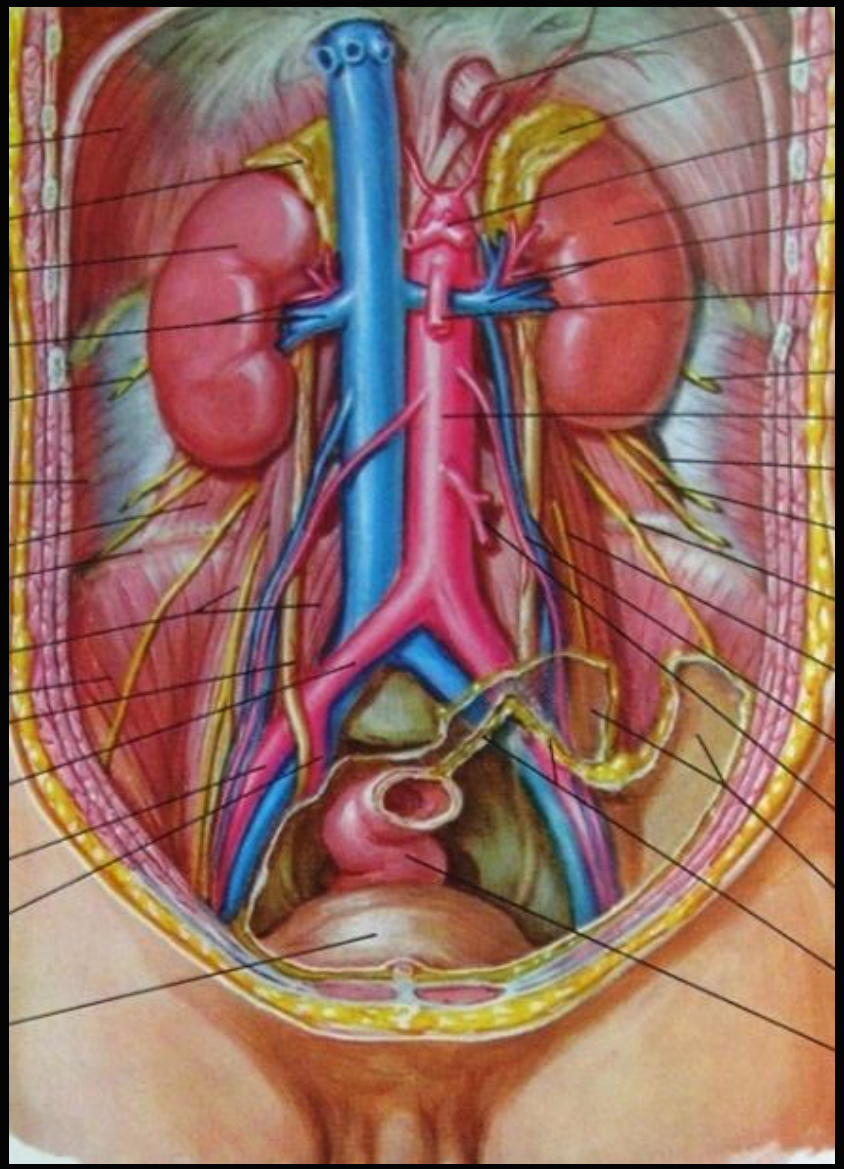
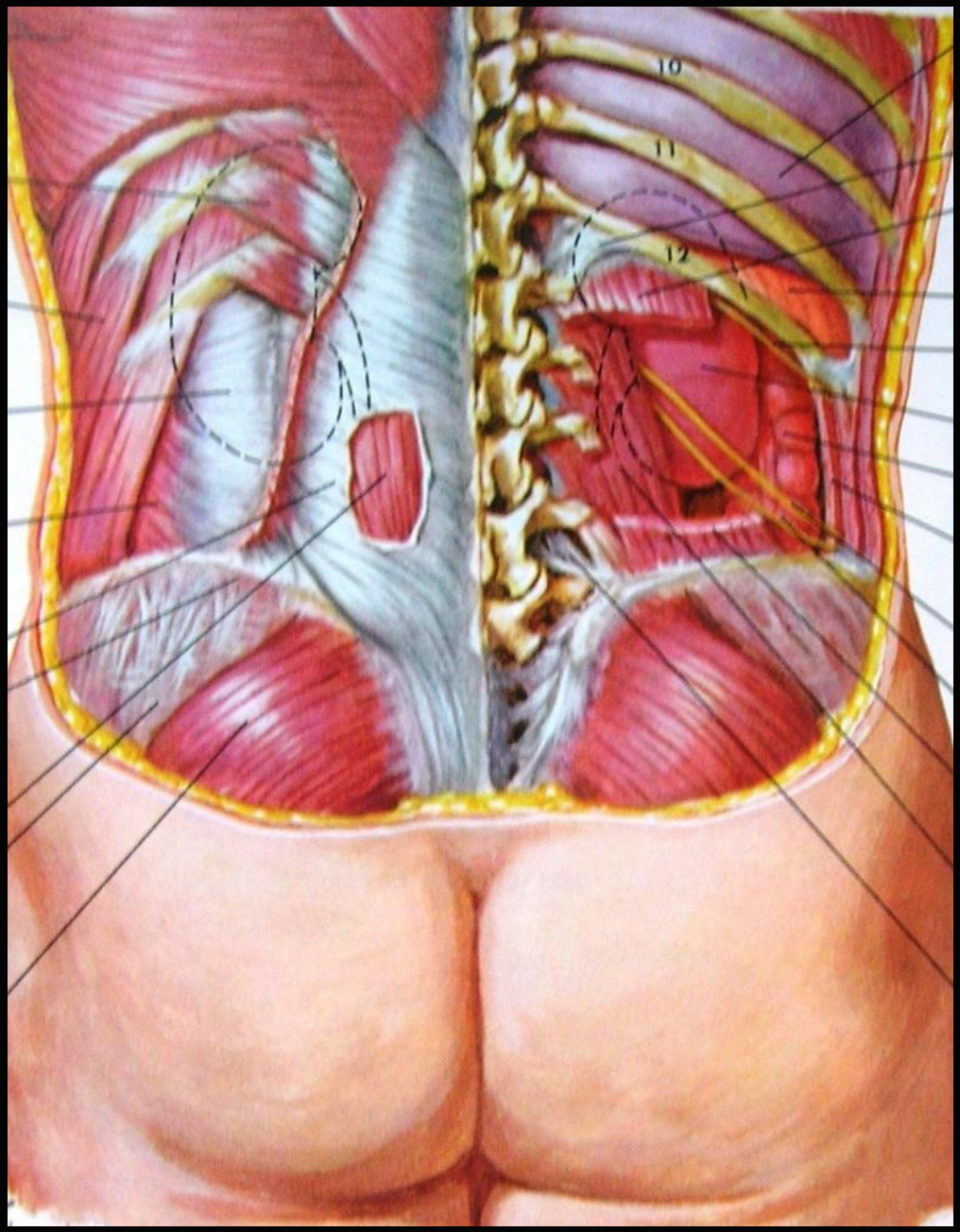


Kidneys

- Paire, Retroperitoneal
- Partially protected by the 11th and 12th ribs
- Right slightly lower due to liver
- Surrounded by renal capsule
- Adipose capsule
- Renal fascia

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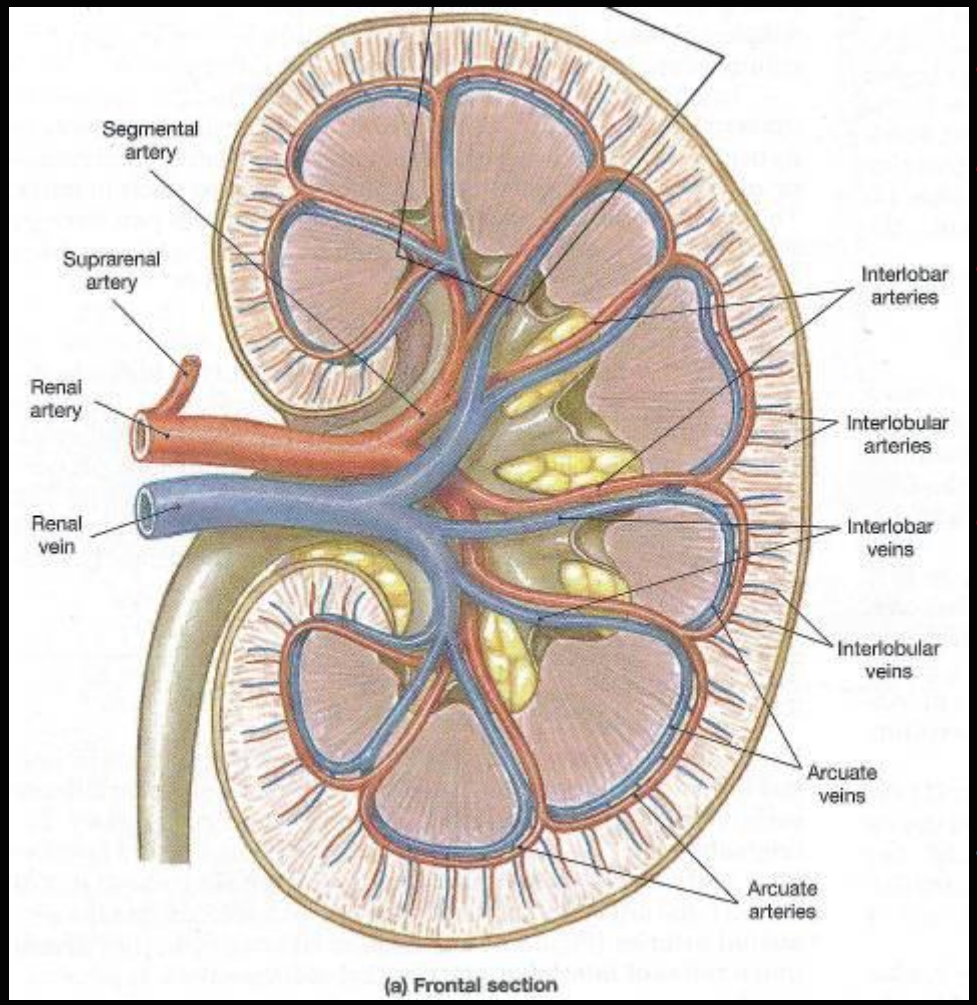
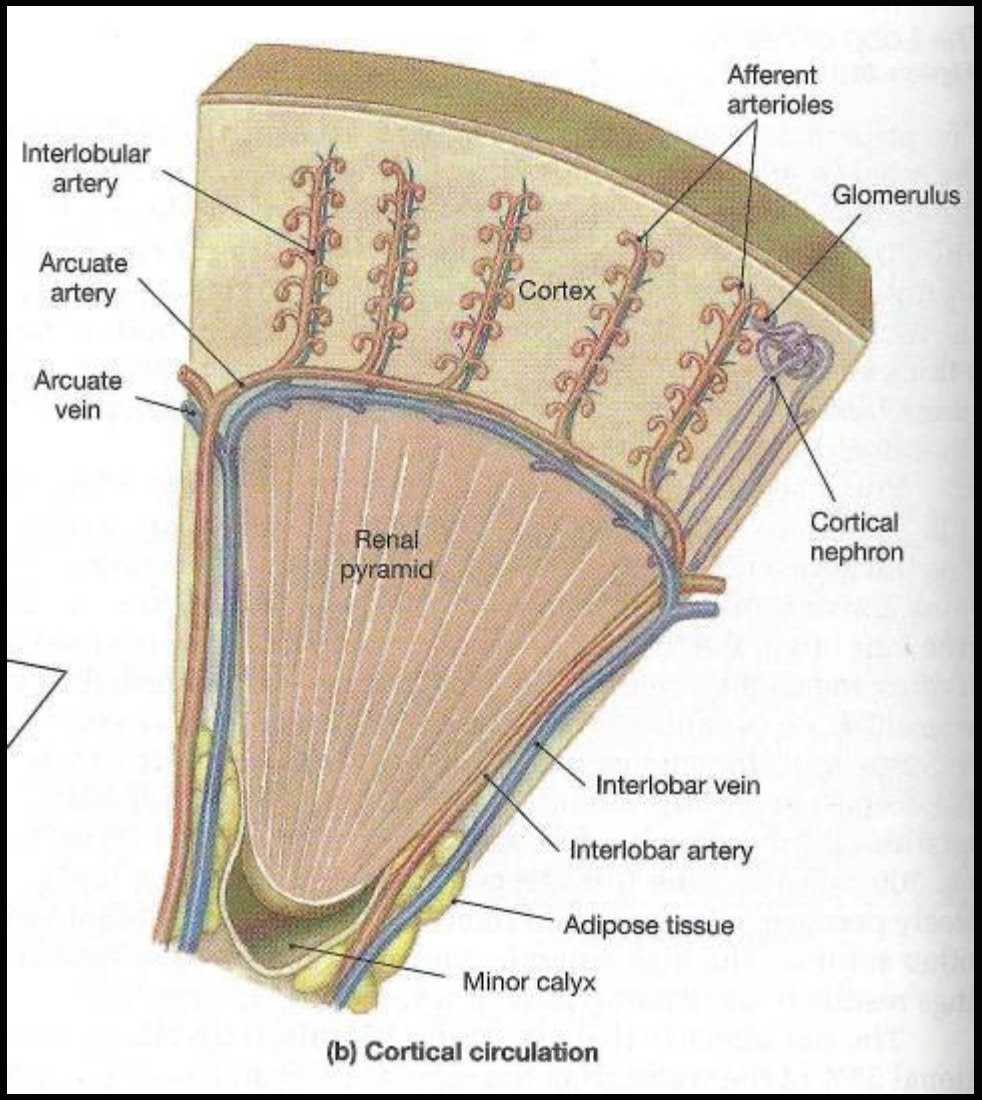
Blood Supply to the Kidney



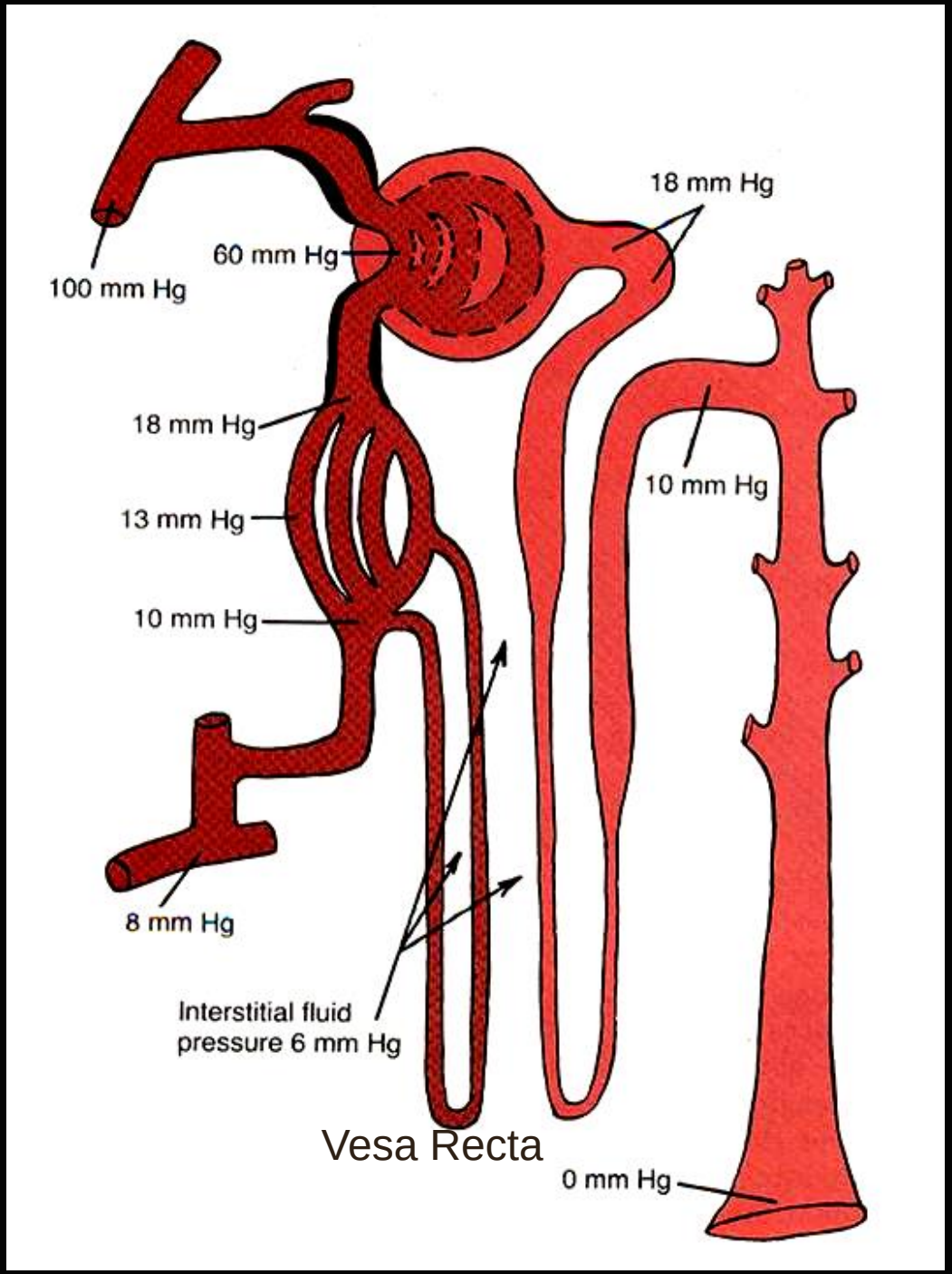
- The renal artery
- segmental arteries
- interlobar arteries that communicate with one another via arcuate arteries.
- The arcuate arteries give off branches called interlobular arteries that extend into the cortex.
- Venous return of blood is via similarly named veins.

Blood Supply to the Kidney



(b) Cortical circulation

- The interlobular arteries
- afferent arteriole
- Glomerulus
- efferent arterioles
- capillary network surrounding the tubule system of the nephron.
- The interlobular veins are then the collecting vessel of the nephron capillary system.



Characteristics of the renal blood flow:

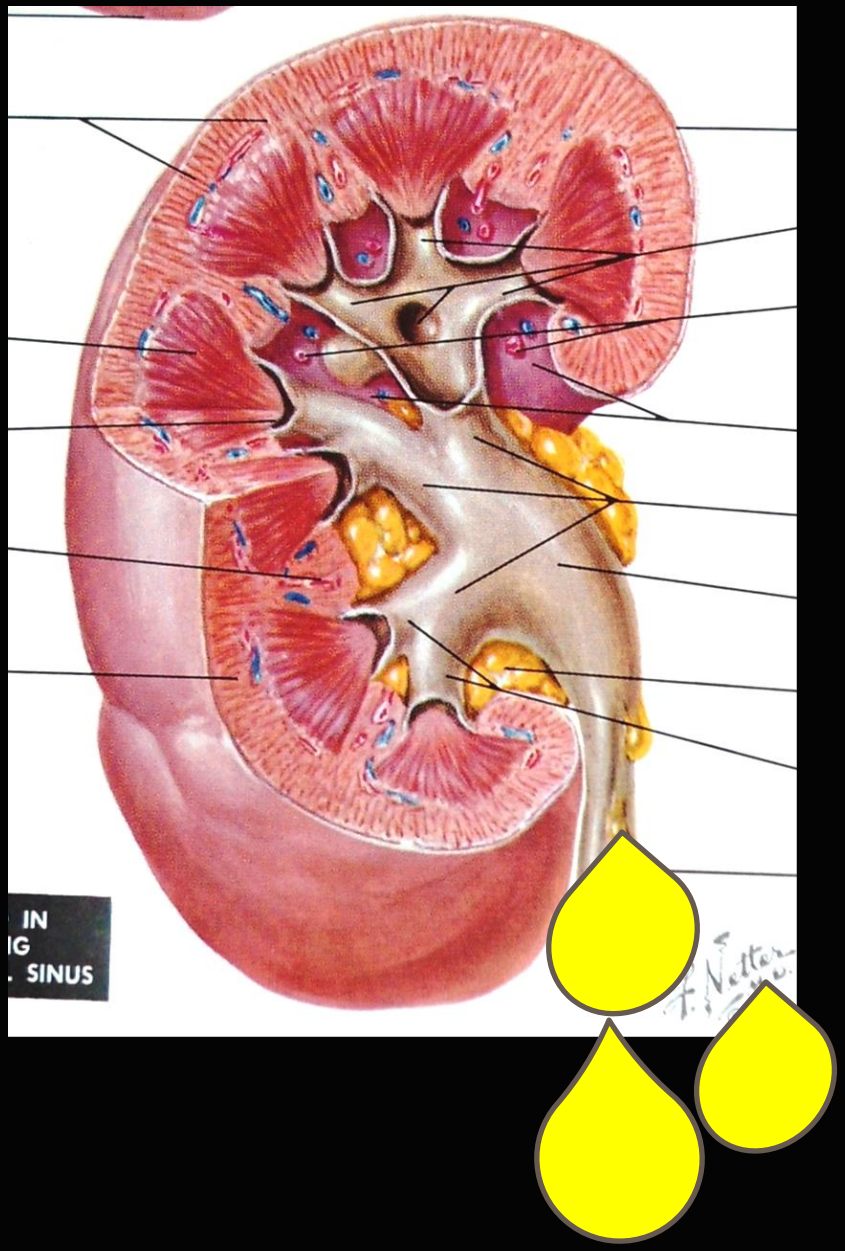
1, **high blood flow**

1200 ml/min, or 21 percent of the cardiac output. 94% to the cortex

2, **Two capillary beds**

High hydrostatic pressure in glomerular capillary (about 60 mmHg) and low hydrostatic pressure in peritubular capillaries (about 13 mmHg)

Kidneys

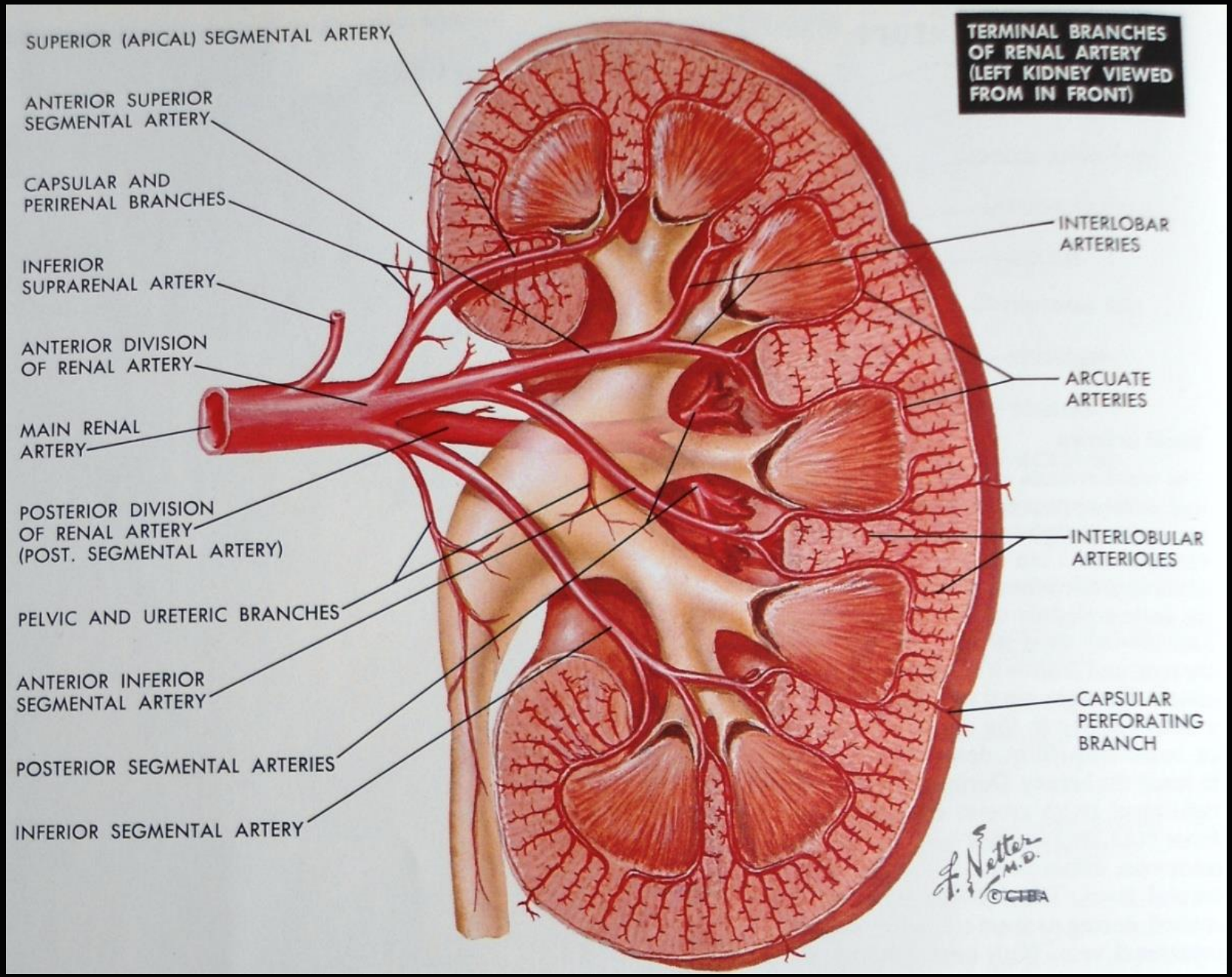


- Kidneys make up 1 % of body mass, but receive about 25% of cardiac output.
- Kidney has two major functions:

1. Filtration of blood
    - Removes metabolic wastes from the body, esp. those containing nitrogen **(Urine formation)**
2. Regulation:
    - Blood volume and composition
    - Electrolytes
    - Blood pH
    - Blood pressure

Blood flow in kidneys and other organs

Organ	**Approx. blood flow** (mg/min/g of tissue)	**A-V O_2 difference** (ml/L)
Kidney	4.00	12-15 (depends on reabsorption of Na^+)
Heart	0.80	96
Brain	0.50	48
Skeletal muscle (rest)	0.05	-
Skeletal muscle (max. exercise)	1.00	-


TERMINAL BRANCHES OF RENAL ARTERY (LEFT KIDNEY VIEWED FROM IN FRONT)
SUPERIOR (APICAL) SEGMENTAL ARTERY
ANTERIOR SUPERIOR SEGMENTAL ARTERY
CAPSULAR AND PERIRENAL BRANCHES
INFERIOR SUPRARENAL ARTERY
ANTERIOR DIVISION OF RENAL ARTERY
MAIN RENAL ARTERY
POSTERIOR DIVISION OF RENAL ARTERY (POST. SEGMENTAL ARTERY)
PELVIC AND URETERIC BRANCHES
ANTERIOR INFERIOR SEGMENTAL ARTERY
POSTERIOR SEGMENTAL ARTERIES
INFERIOR SEGMENTAL ARTERY
INTERLOBAR ARTERIES
ARCUATE ARTERIES
INTERLOBULAR ARTERIOLES
CAPSULAR PERFORATING BRANCH
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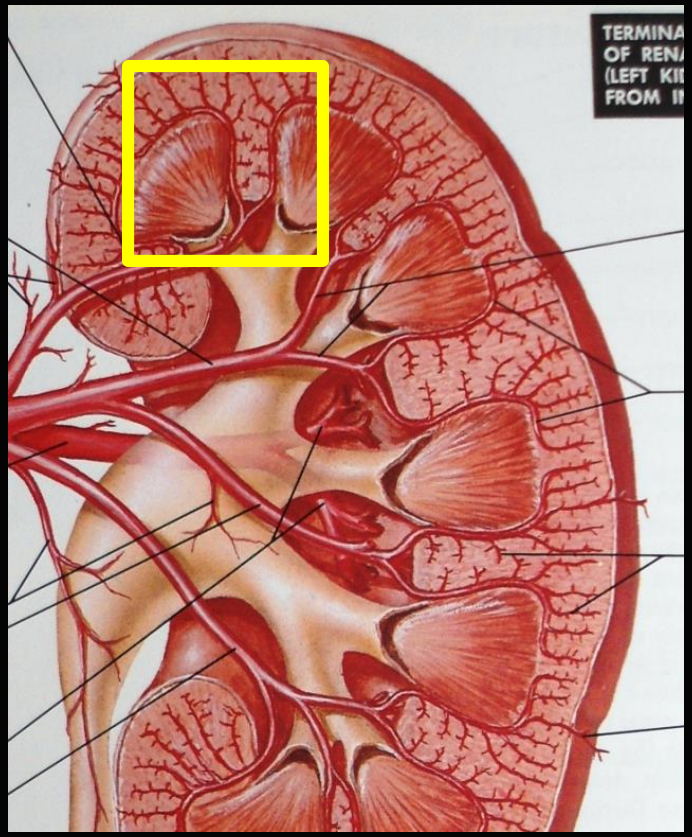
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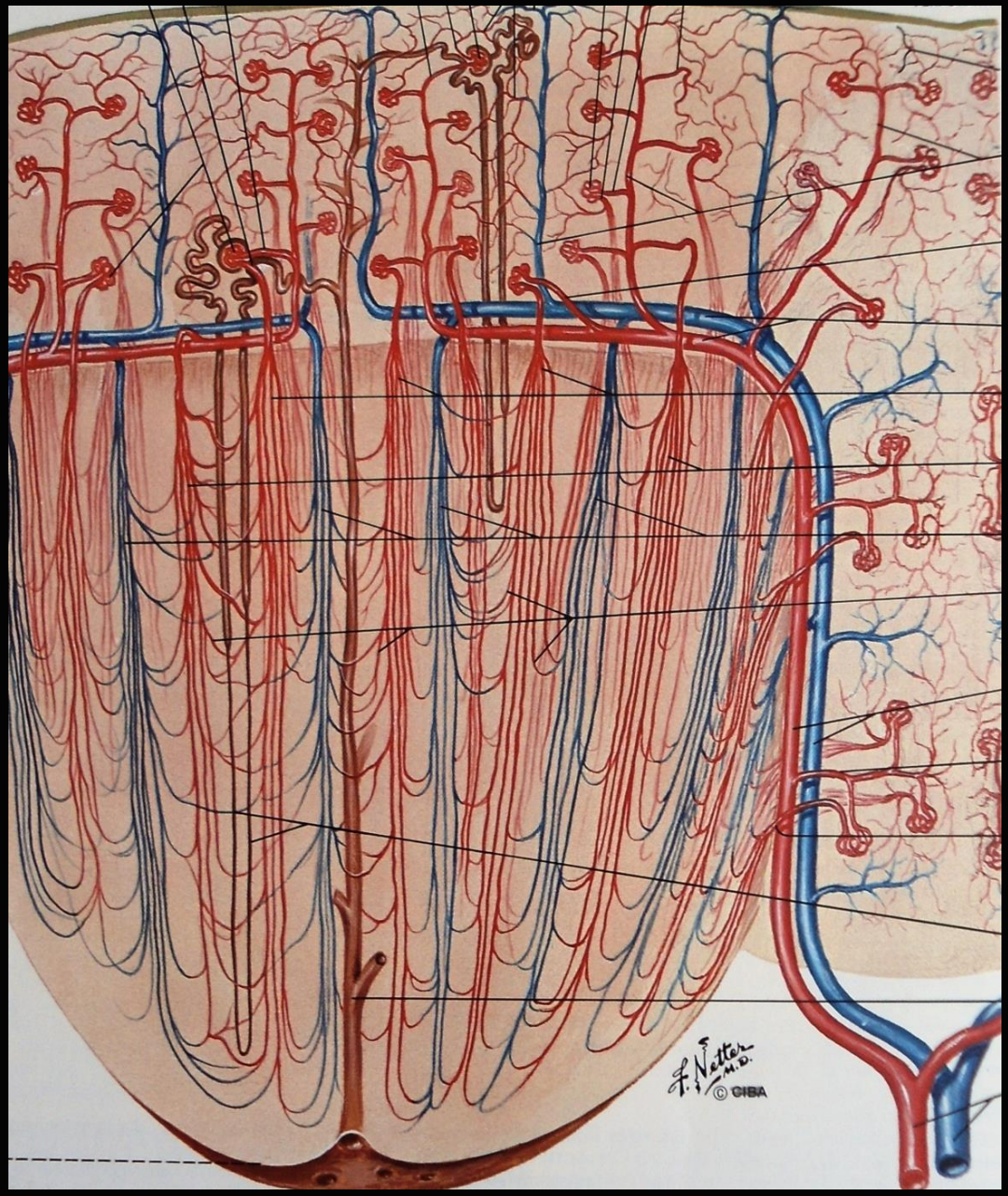
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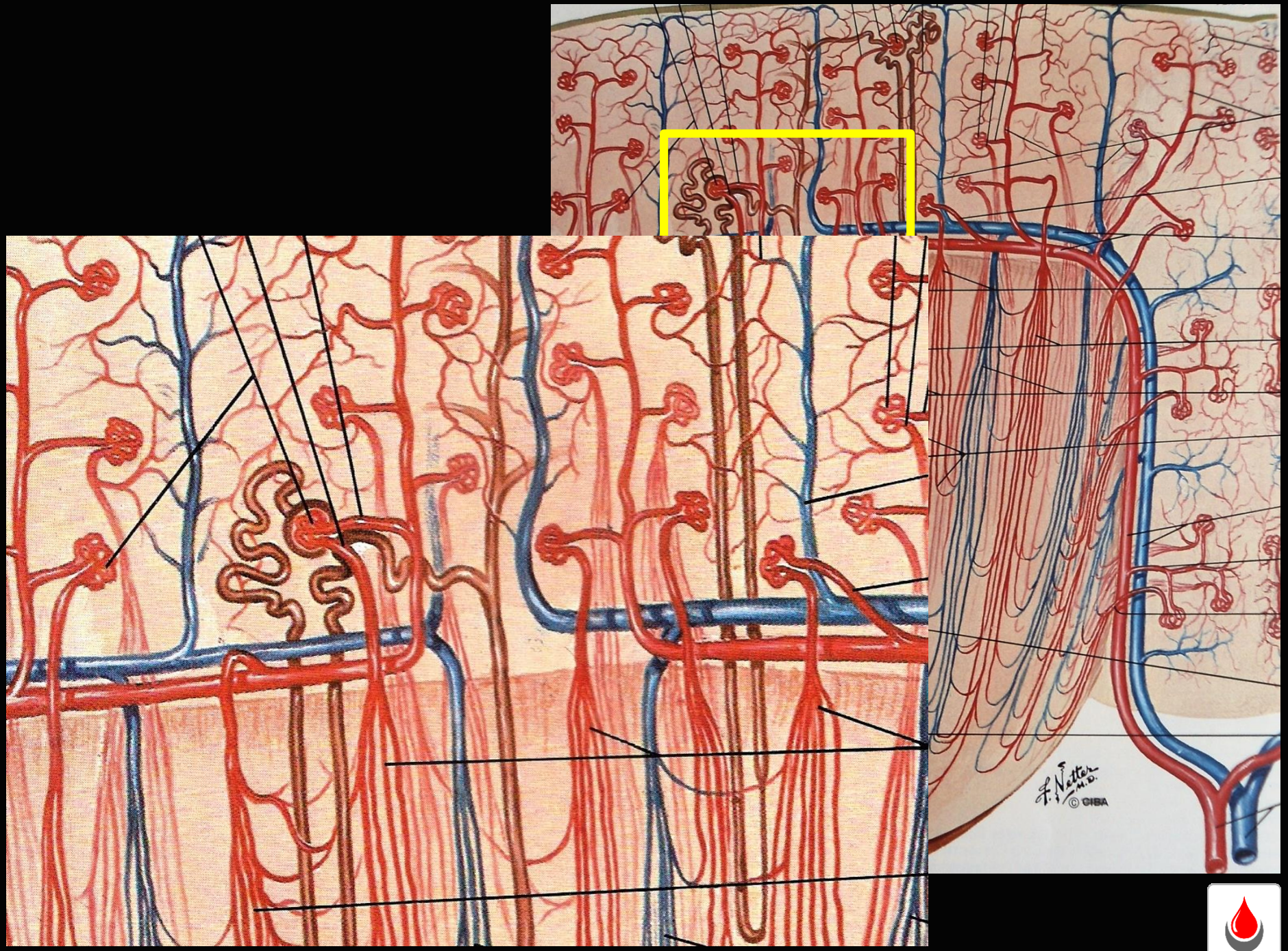
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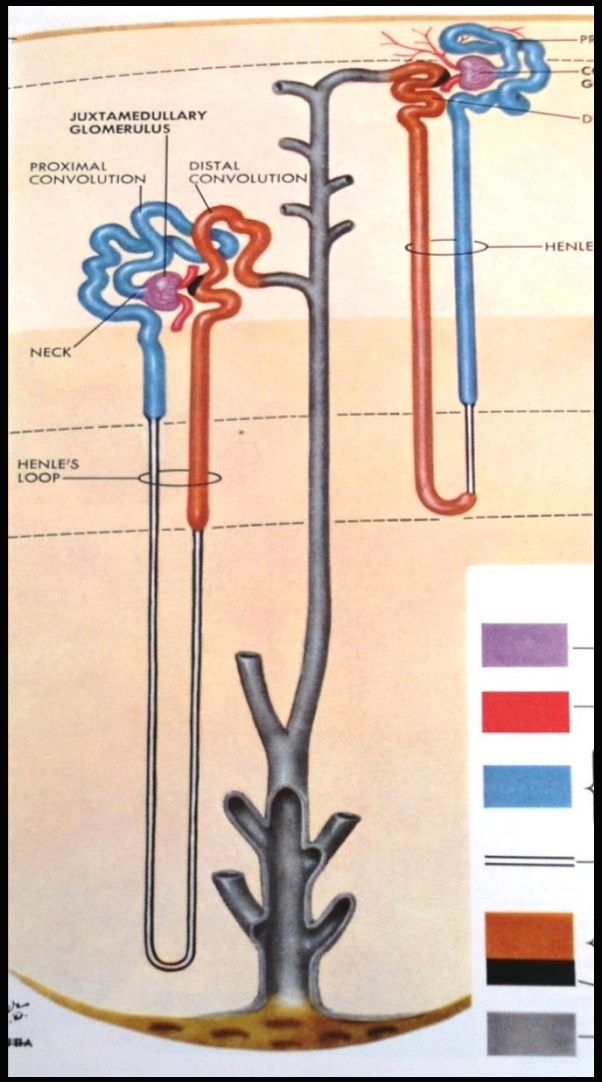
Nephron

- Functional unit of the kidney
- Filtration, tubular reabsorption, tubular secretion
- Renal corpuscle:
  - Glomerulus – capillaries
  - Glomerular or Bowman's capsule



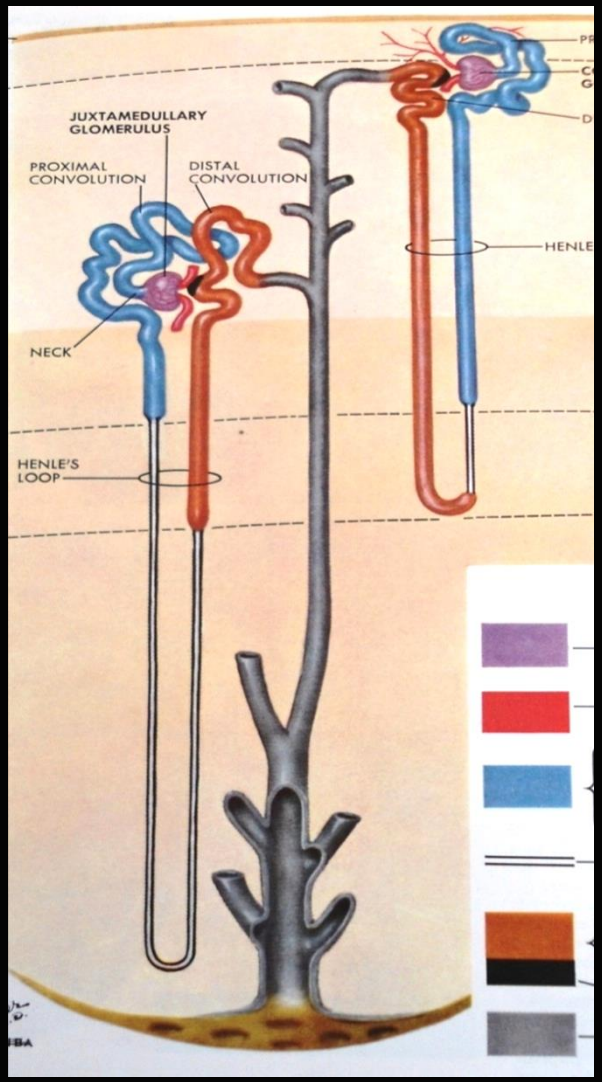
The Nephron

1. glomerulus
2. proximal convoluted tubule
3. loop of Henle
    - descending limb
    - ascending limb
4. distal convoluted tubule

many nephrons connect to collecting duct

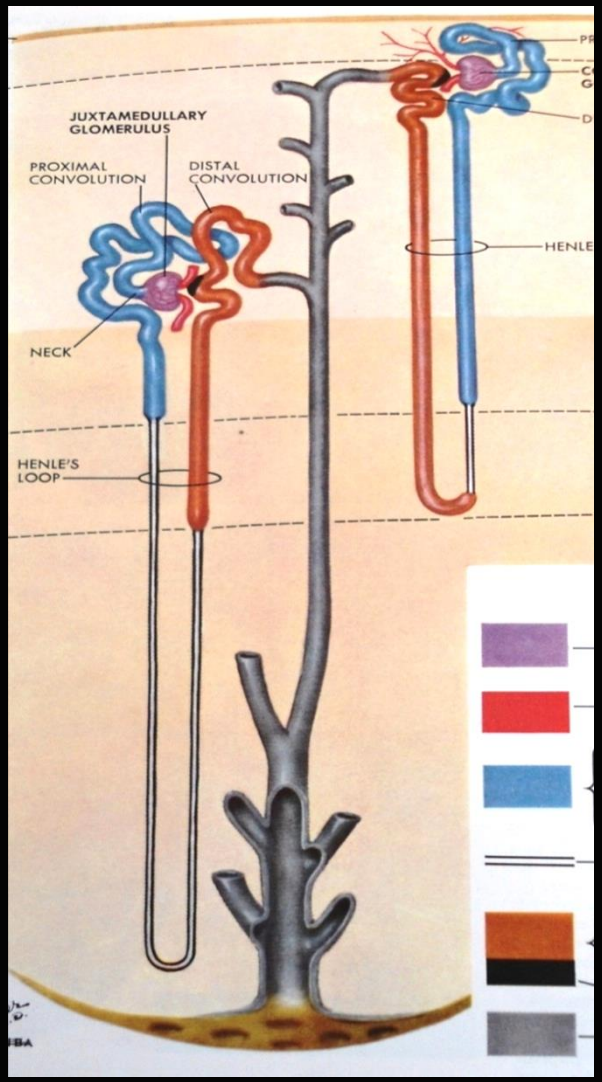
Blood flow:

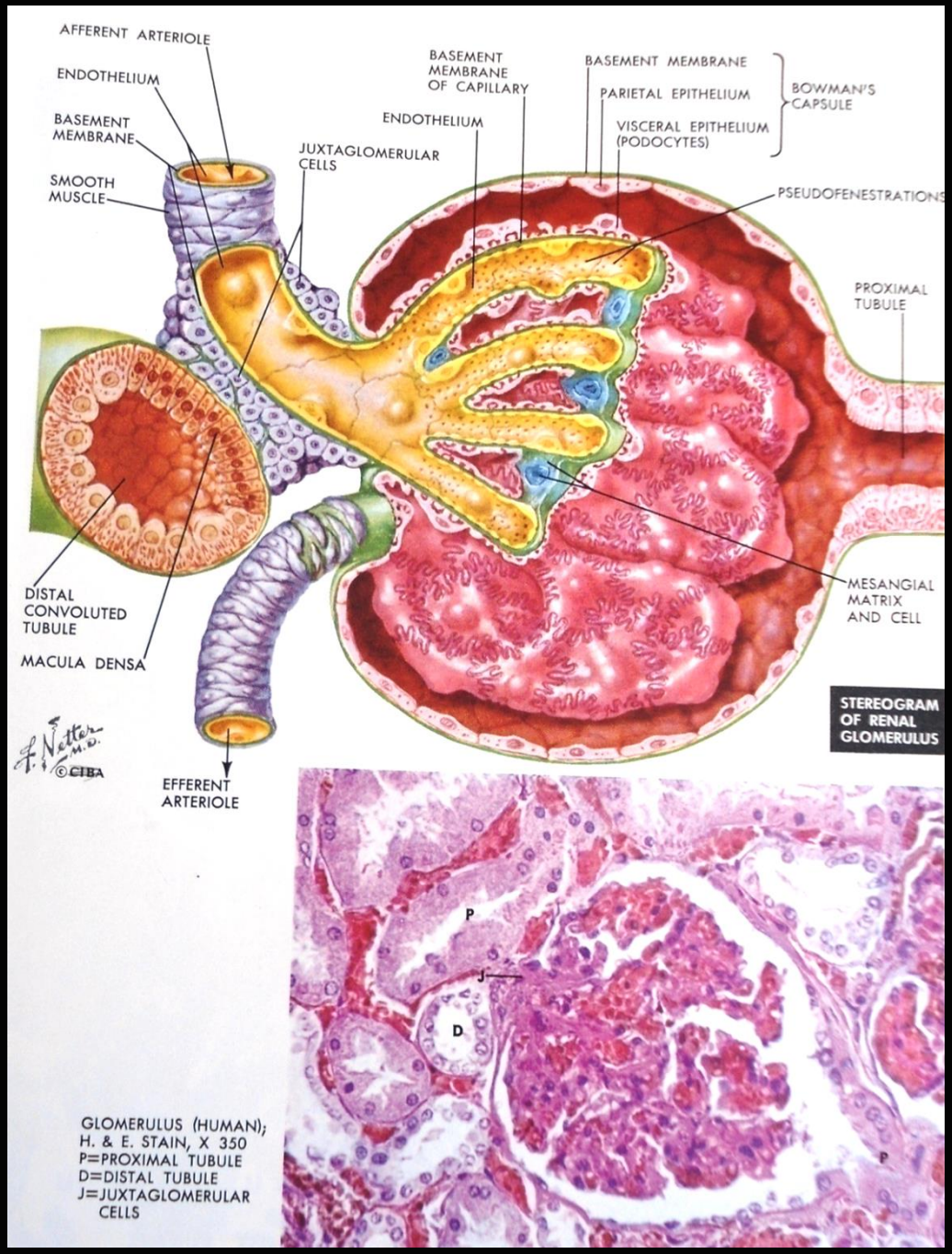
- afferent arteriole
- efferent arteriole
- Peritubular capillaries
- vasa recta

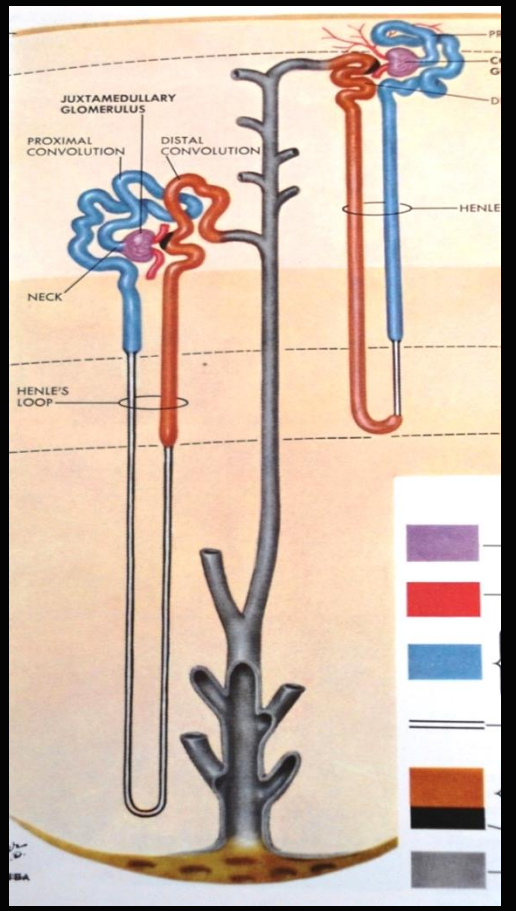


Cortical nephron – glomeruli in outer cortex & short loops of Henle that extend only short distance into medulla-- blood flow through cortex is rapid – majority of nephrons are cortical.

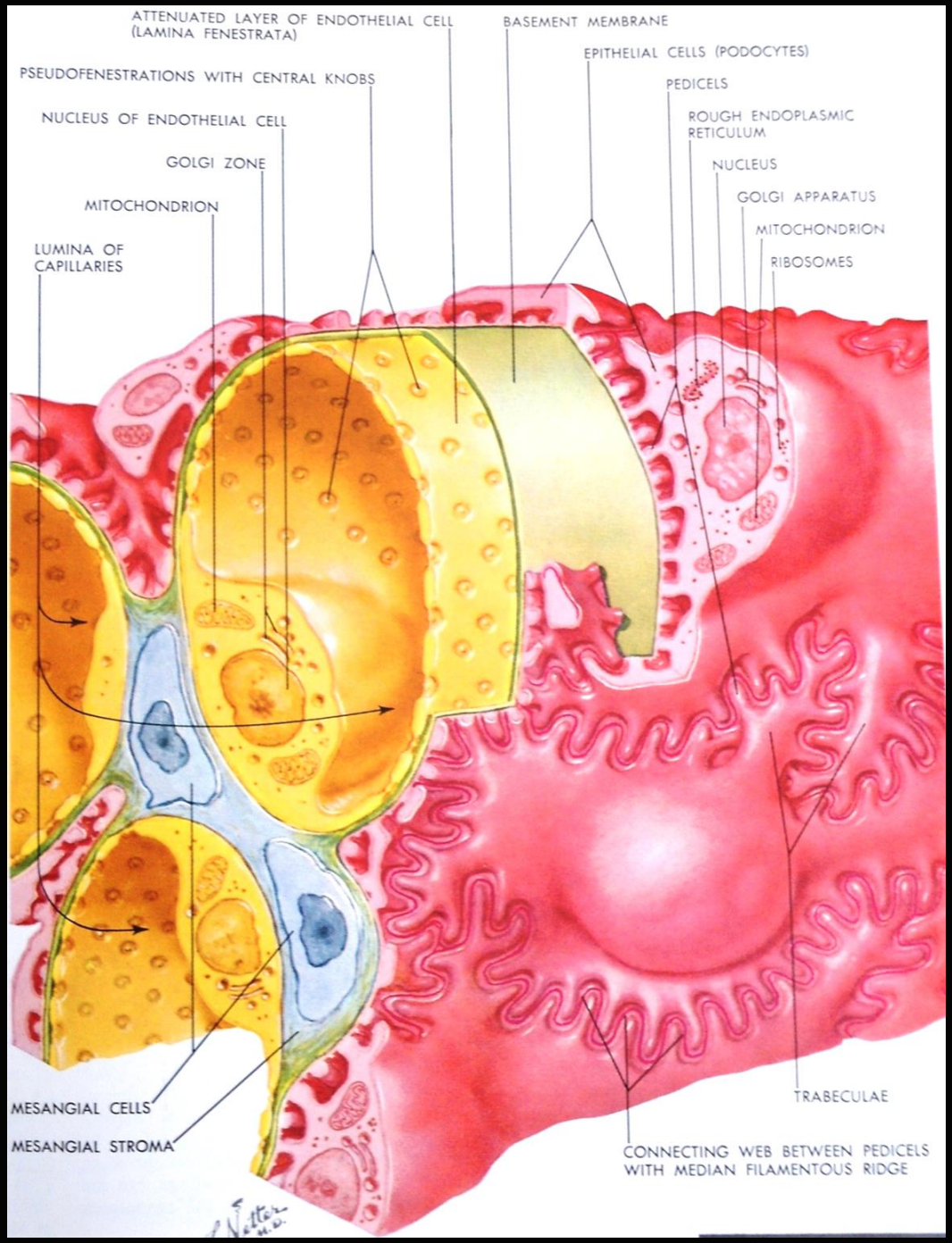
Juxtamedullary nephron – glomeruli in inner part of cortex & long loops of Henle which extend deeply into medulla.– blood flow through vasa recta in medulla is slow.

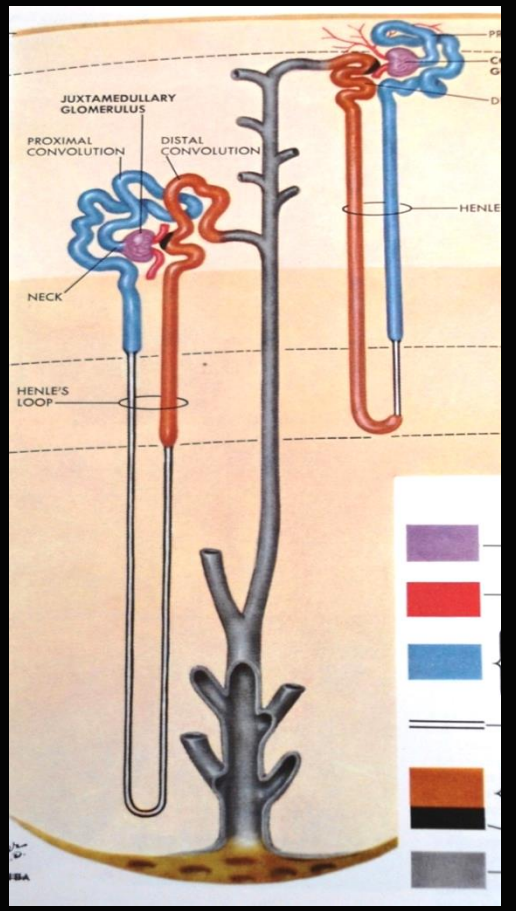




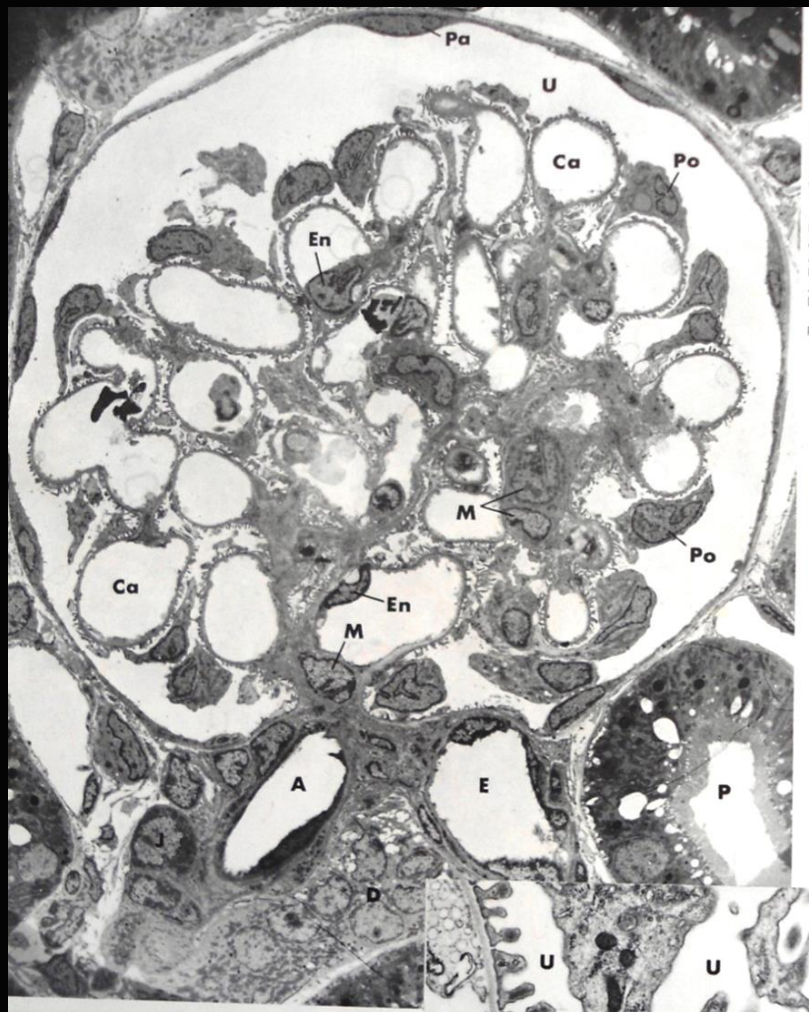


Bowman's capsule
200 mcm
Receives filtrate

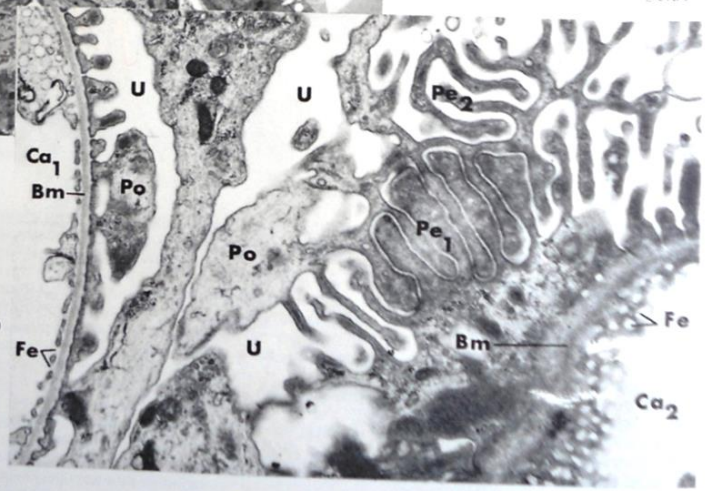

ATTENUATED LAYER OF ENDOTHELIAL CELL (LAMINA FENESTRATA)
BASEMENT MEMBRANE
EPITHELIAL CELLS (PODOCYTES)
PSEUDOFENESTRATIONS WITH CENTRAL KNOBS
PEDICELS
NUCLEUS OF ENDOTHELIAL CELL
ROUGH ENDOPLASMIC RETICULUM
GOLGI ZONE
NUCLEUS
MITOCHONDRION
GOLGI APPARATUS
LUMINA OF CAPILLARIES
MITOCHONDRION
RIBOSOMES
MESANGIAL CELLS
TRABECULAE
MESANGIAL STROMA
CONNECTING WEB BETWEEN PEDICELS WITH MEDIAN FILAMENTOUS RIDGE


JUXTAMEDULLARY GLOMERULUS
PROXIMAL CONVOLUTION
DISTAL CONVOLUTION
NECK
HENLE'S LOOP

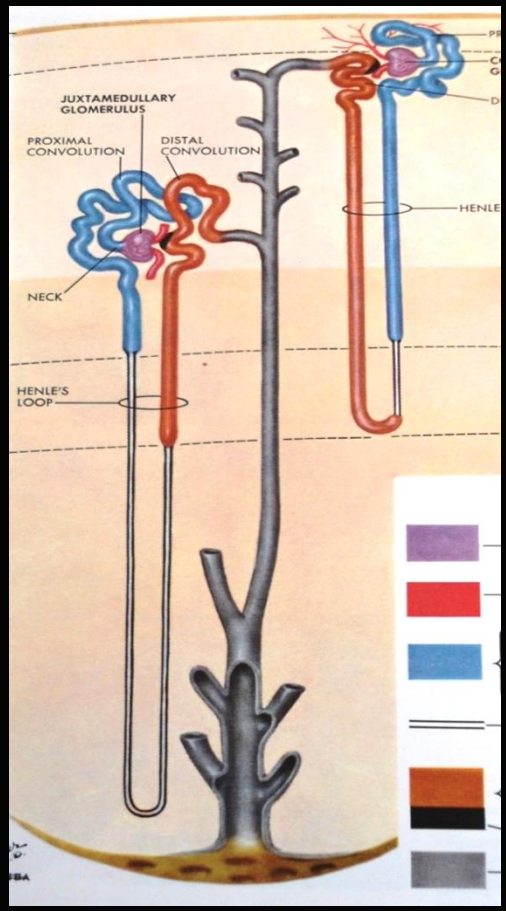
0.4 mm2



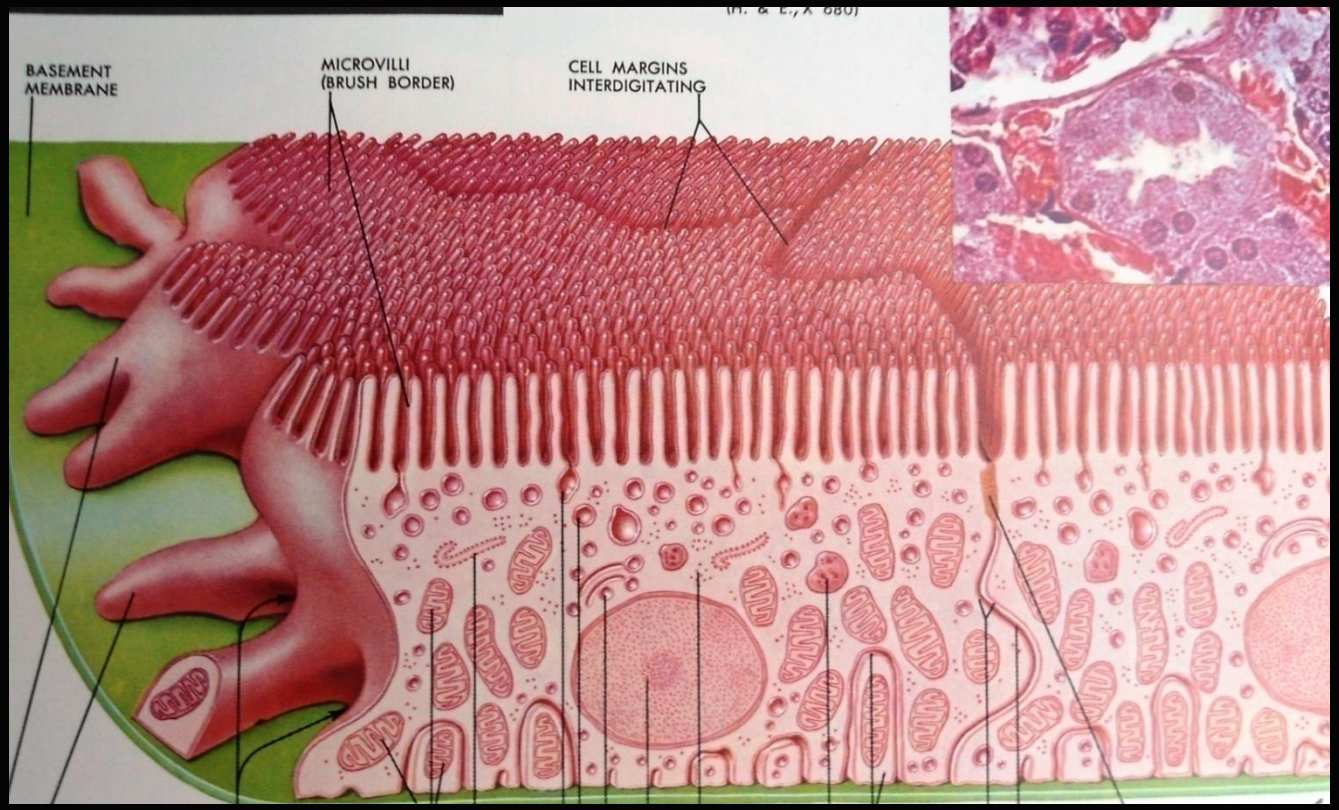
ELECTRON PHOTOMICROGRAPH OF RENAL CORPUSCLE, X 1100
Pa=PARIETAL EPITHELIUM NUCLEUS
U=URINARY SPACE
Ca=CAPILLARY
Po=PODOCYTE (VISCERAL EPITHELIUM) NUCLEUS
En=ENDOTHELIUM NUCLEUS
M=MESANGIAL CELL NUCLEUS
A=AFFERENT ARTERIOLE
E=EFFERENT ARTERIOLE
J=JUXTAGLOMERULAR CELL
D=MACULA DENSA OF DISTAL TUBULE (TANGENTIALLY CUT)
P=PROXIMAL TUBULE

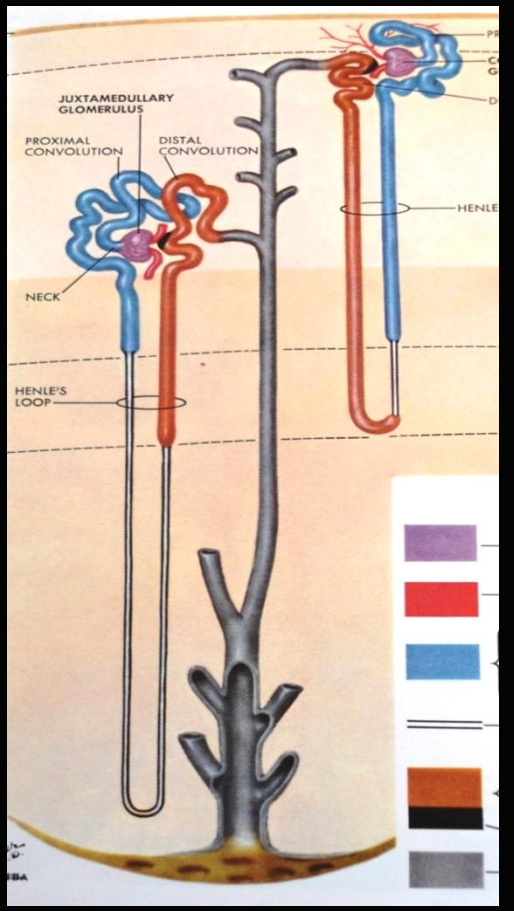


ELECTRON PHOTOMICROGRAPH, DETAIL OF GLOMERULAR FILTRATION MEMBRANES, X 15,000
Ca_1=CAPILLARY, CROSS SECTIONED
Ca_2=CAPILLARY, TANGENTIALLY SECTIONED
Bm=BASEMENT MEMBRANE
Fe=FENESTRATED ENDOTHELIUM
Po=PODOCYTE
U=URINARY SPACE
Pe_1=PEDICELS NEAR BASEMENT MEMBRANE
Pe_2=PEDICELS SECTIONED FURTHER FROM BASEMENT MEMBRANE

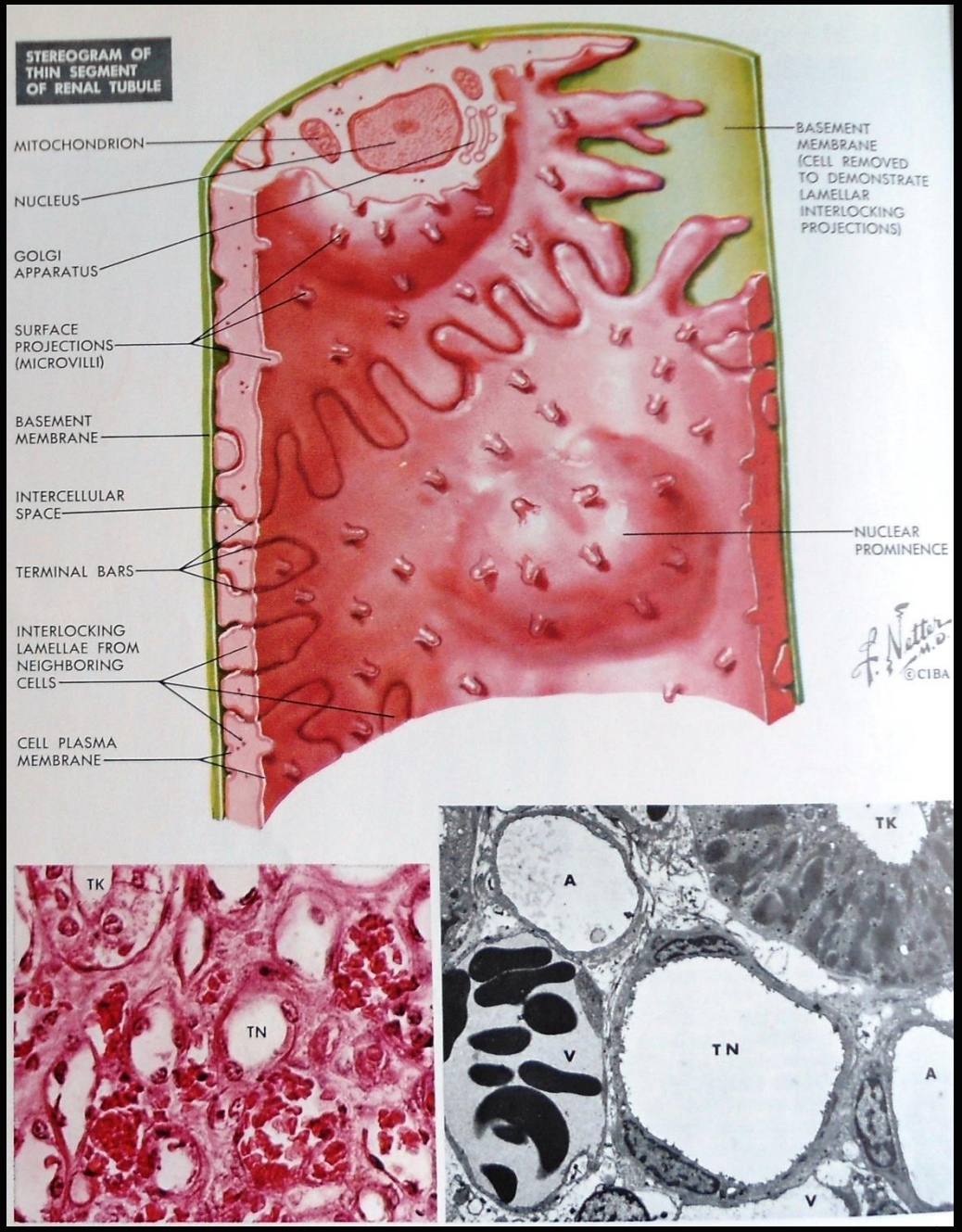


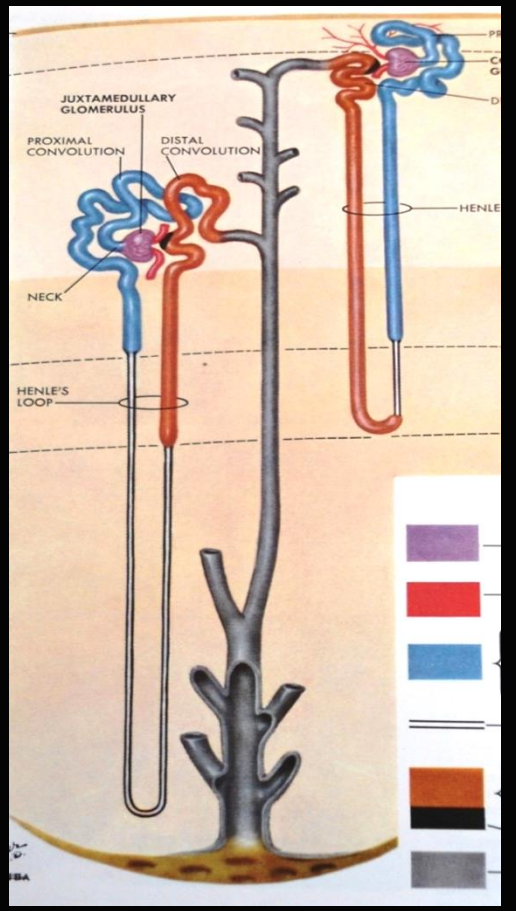
Proximal convoluted tubule
Reabsorption of water and solutes





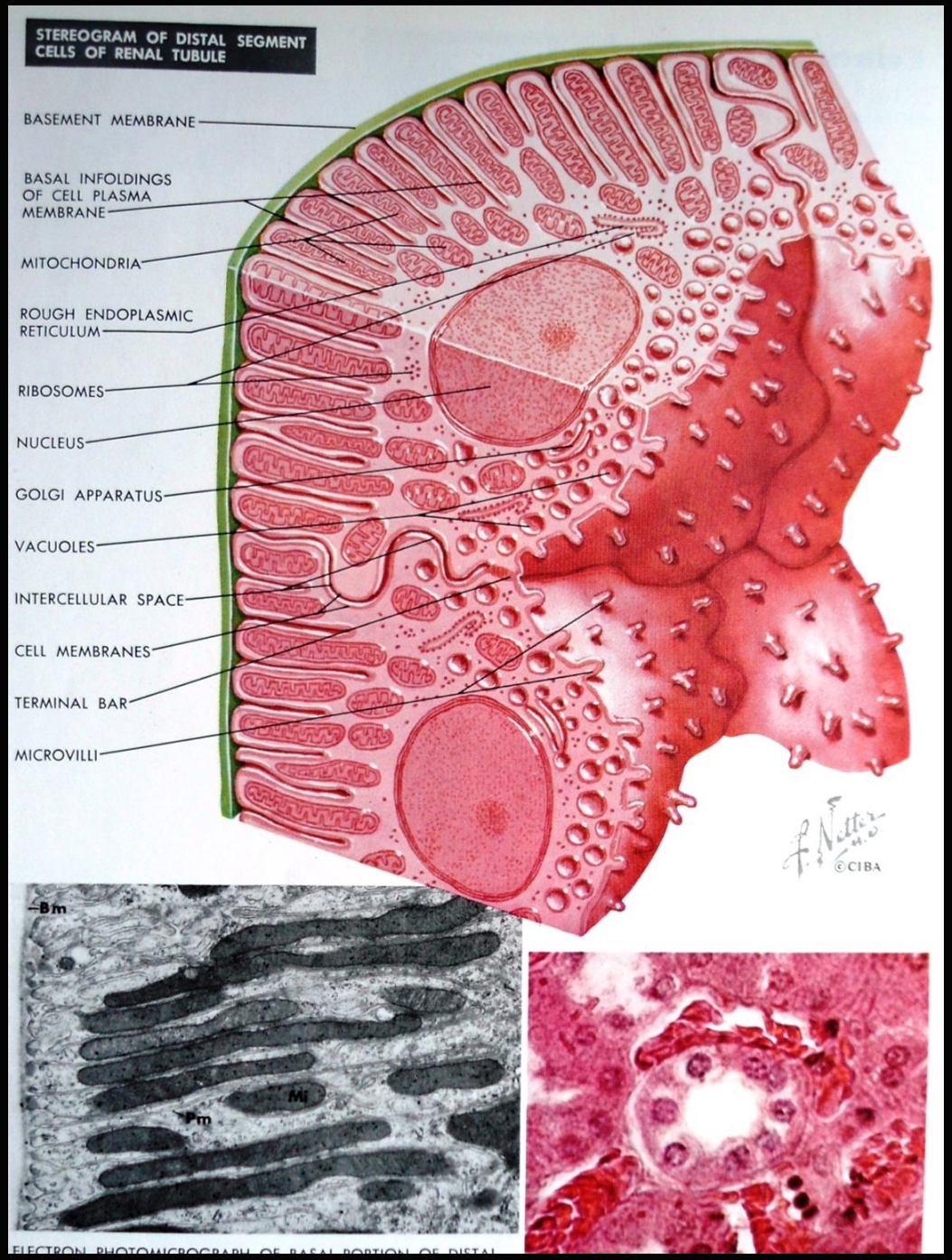
15 mm

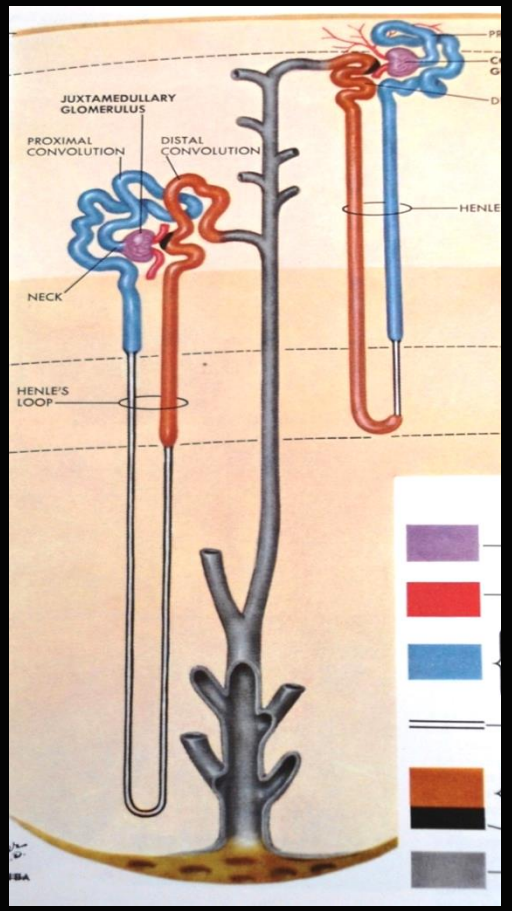




Nephron loop or Loop of Henle
Regulates concentration of urine

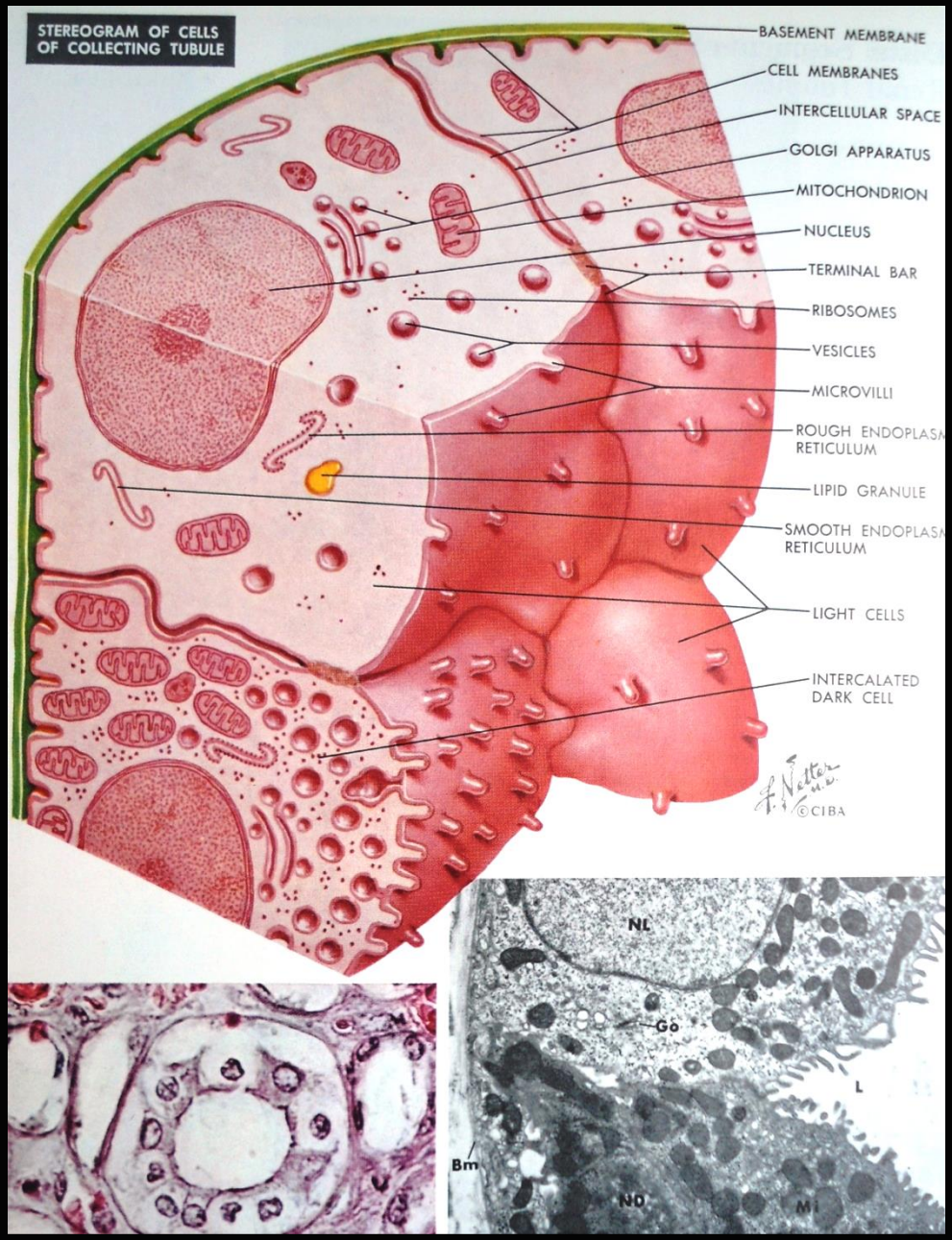
10mm , 15 mm





Distal convoluted tubule and Collecting duct
Reabsorption of water and electrolytes
ADH, aldosterone, ANP
Tubular secretion

5 mm


STEREOGRAM OF CELLS OF COLLECTING TUBULE
BASEMENT MEMBRANE
CELL MEMBRANES
INTERCELLULAR SPACE
GOLGI APPARATUS
MITOCHONDRION
NUCLEUS
TERMINAL BAR
RIBOSOMES
VESICLES
MICROVILLI
ROUGH ENDOPLASM RETICULUM
LIPID GRANULE
SMOOTH ENDOPLASM RETICULUM
LIGHT CELLS
INTERCALATED DARK CELL
F. Netter M.D.
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Go
L
Bm
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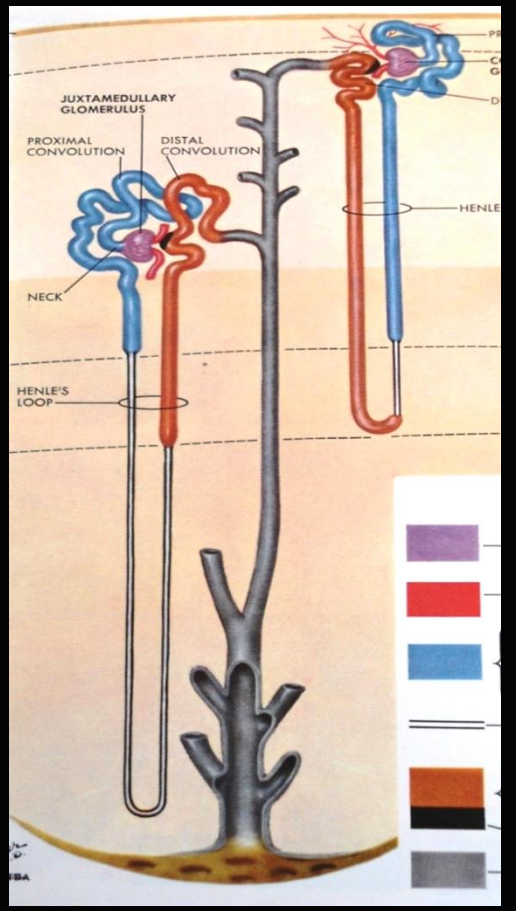
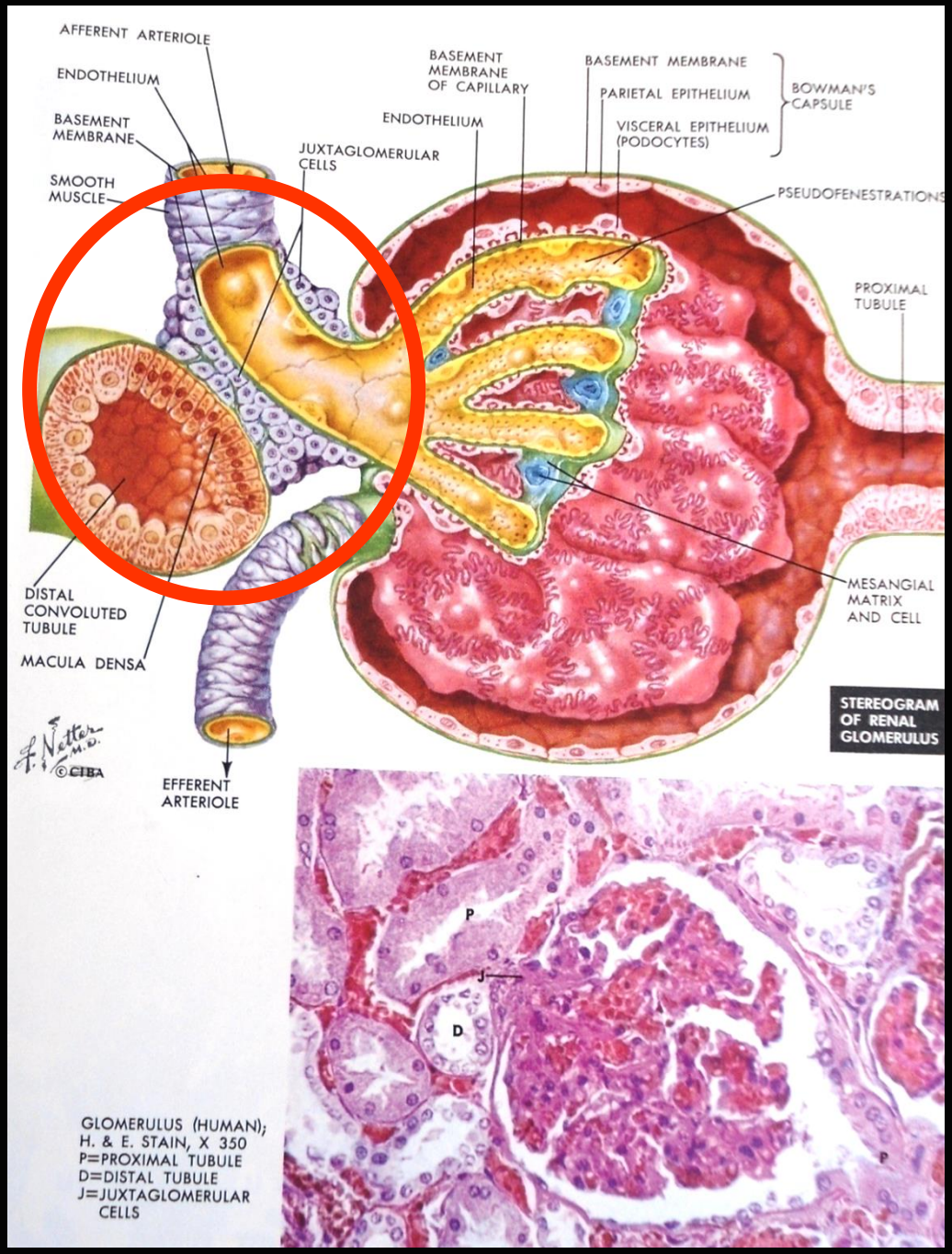

JUXTAMEDULLARY GLOMERULUS
PROXIMAL CONVOLUTION
DISTAL CONVOLUTION
HENLE
NECK
HENLE'S LOOP


AFFERENT ARTERIOLE
ENDOTHELIUM
BASEMENT MEMBRANE
SMOOTH MUSCLE
JUXTAGLOMERULAR CELLS
BASEMENT MEMBRANE OF CAPILLARY
ENDOTHELIUM
BASEMENT MEMBRANE
PARIETAL EPITHELIUM
VISCERAL EPITHELIUM (PODOCYTES)
BOWMAN'S CAPSULE
PSEUDOFENESTRATIONS
PROXIMAL TUBULE
MESANGIAL MATRIX AND CELL
DISTAL CONVOLUTED TUBULE
MACULA DENSA
EFFERENT ARTERIOLE
F. Netter M.D.
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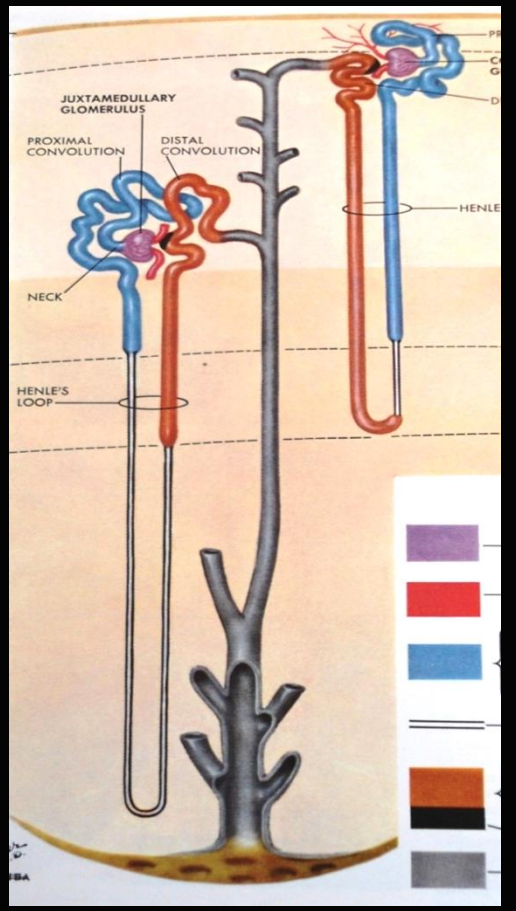
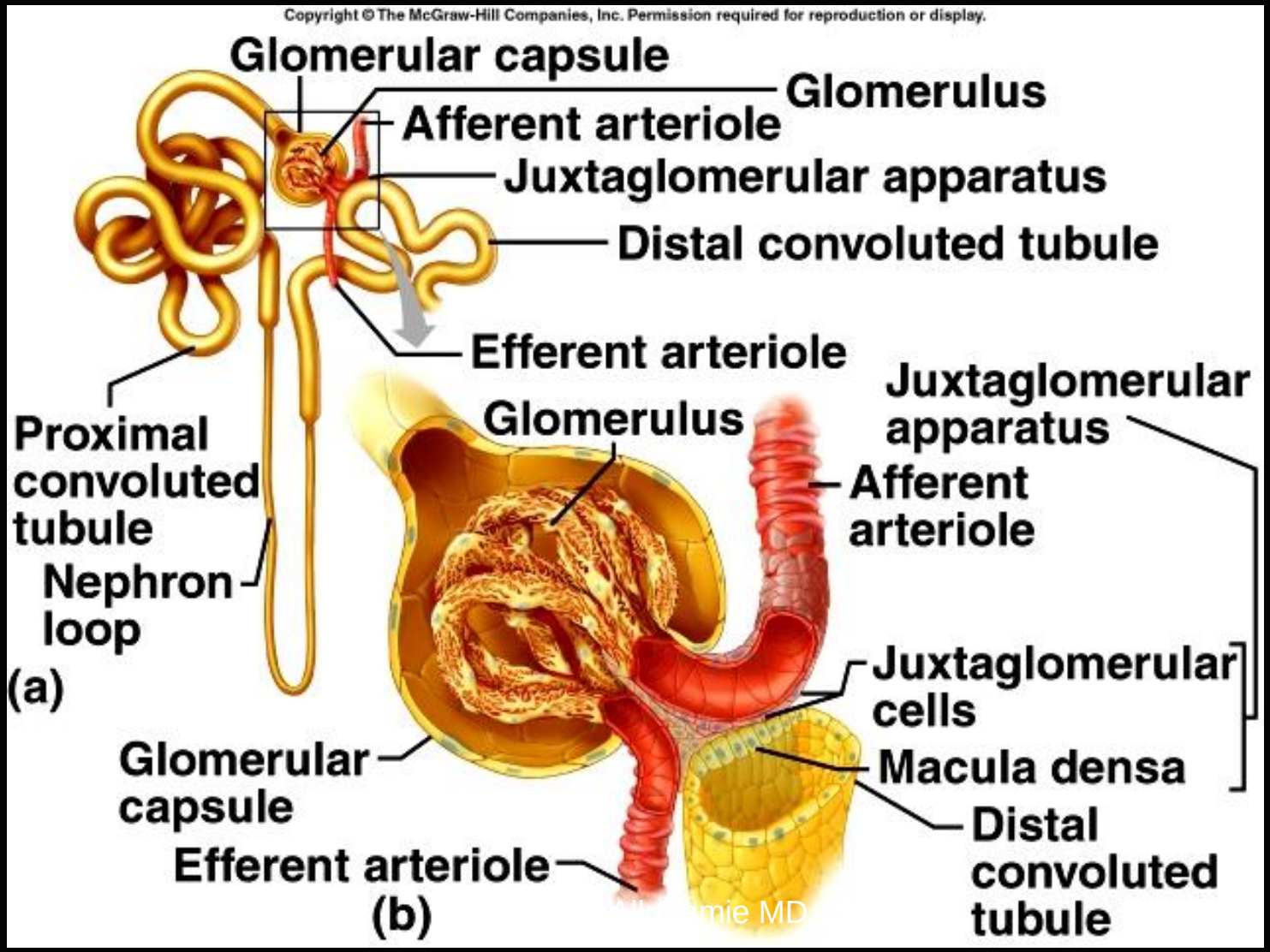
STEREOGRAM OF RENAL GLOMERULUS
P
J
D
P
GLOMERULUS (HUMAN); H. & E. STAIN, X 350
P=PROXIMAL TUBULE
D=DISTAL TUBULE
J=JUXTAGLOMERULAR CELLS

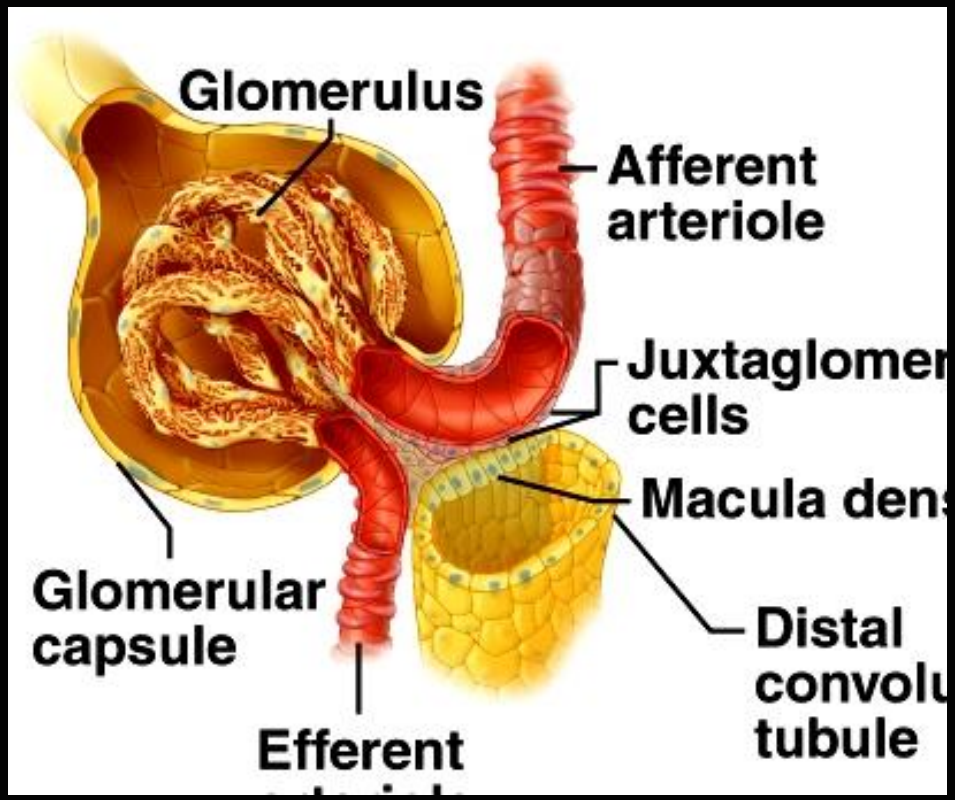

JUXTAMEDULLARY GLOMERULUS
PROXIMAL CONVOLUTION
DISTAL CONVOLUTION
HENLE
NECK
HENLE'S LOOP

Juxtaglomerular apparatus



Juxtaglomerular apparatus

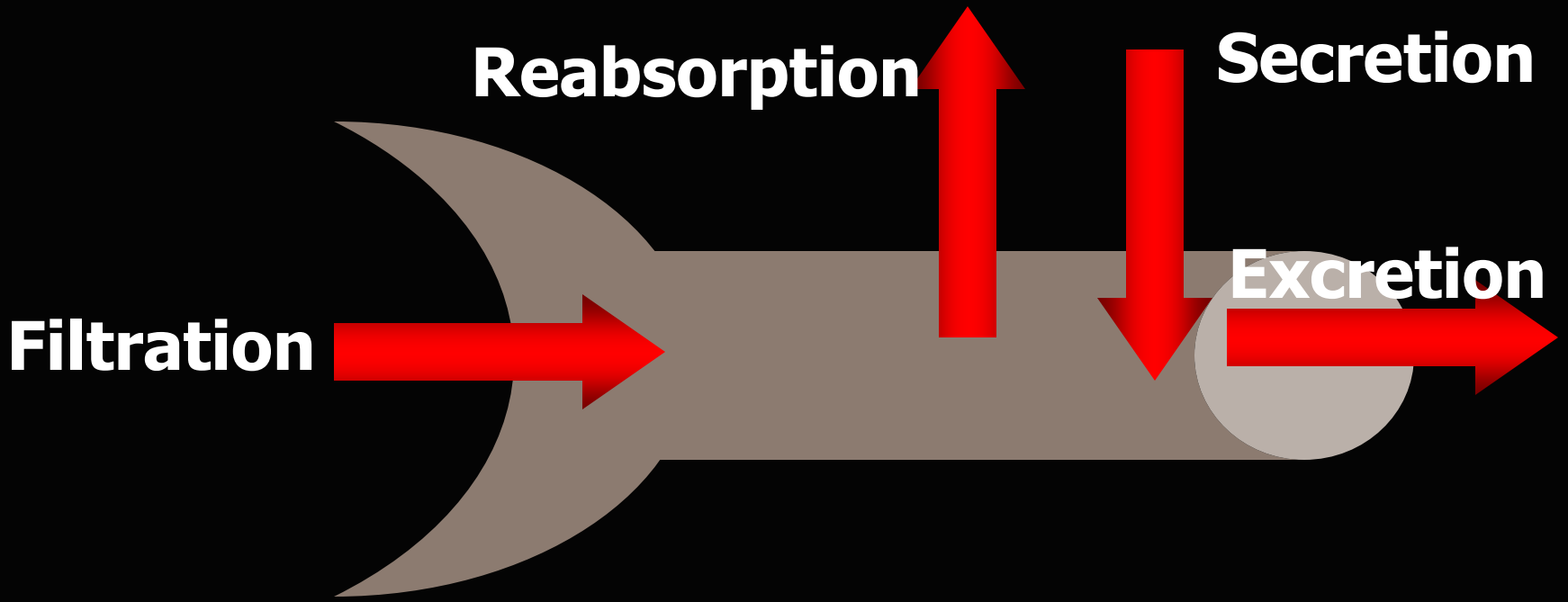
- Juxtaglomerular cells lie in the wall of afferent arteriole
- Macula densa in final portion of loop of Henle – monitor **Na^+ and Cl^-** conc. and **water**
- Control blood flow into the glomerulus
- Control glomerular filtration

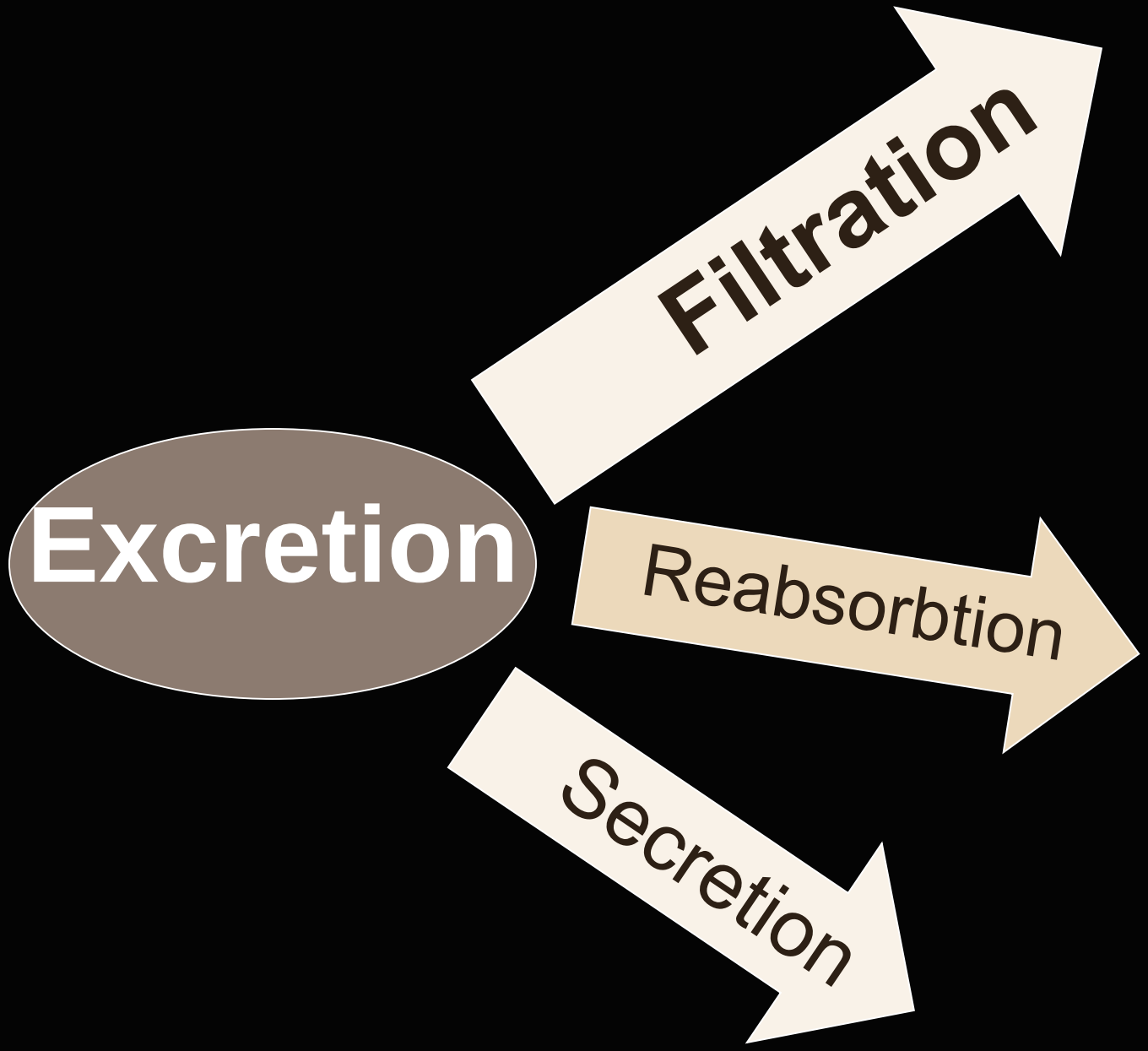


HUMAN RENAL PHYSIOLOGY

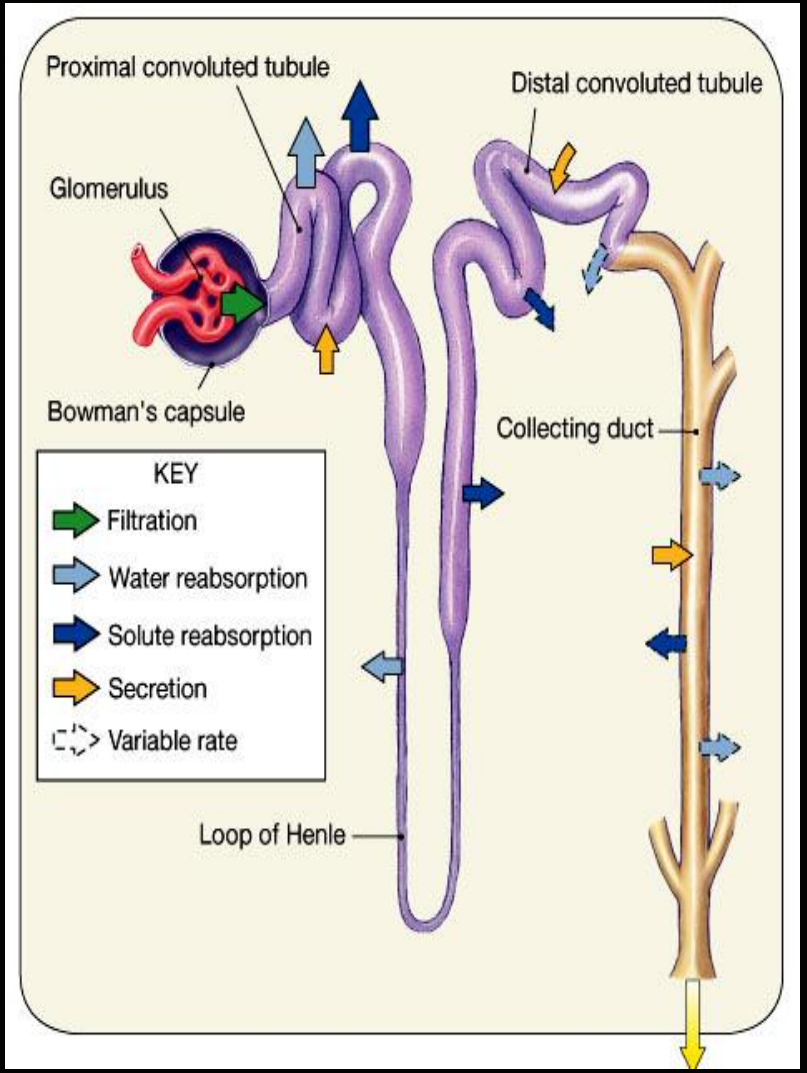
- Four Main Processes:
  - Filtration
  - Reabsorbtion
  - Secretion
  - Excretion

Functions of the Nephron



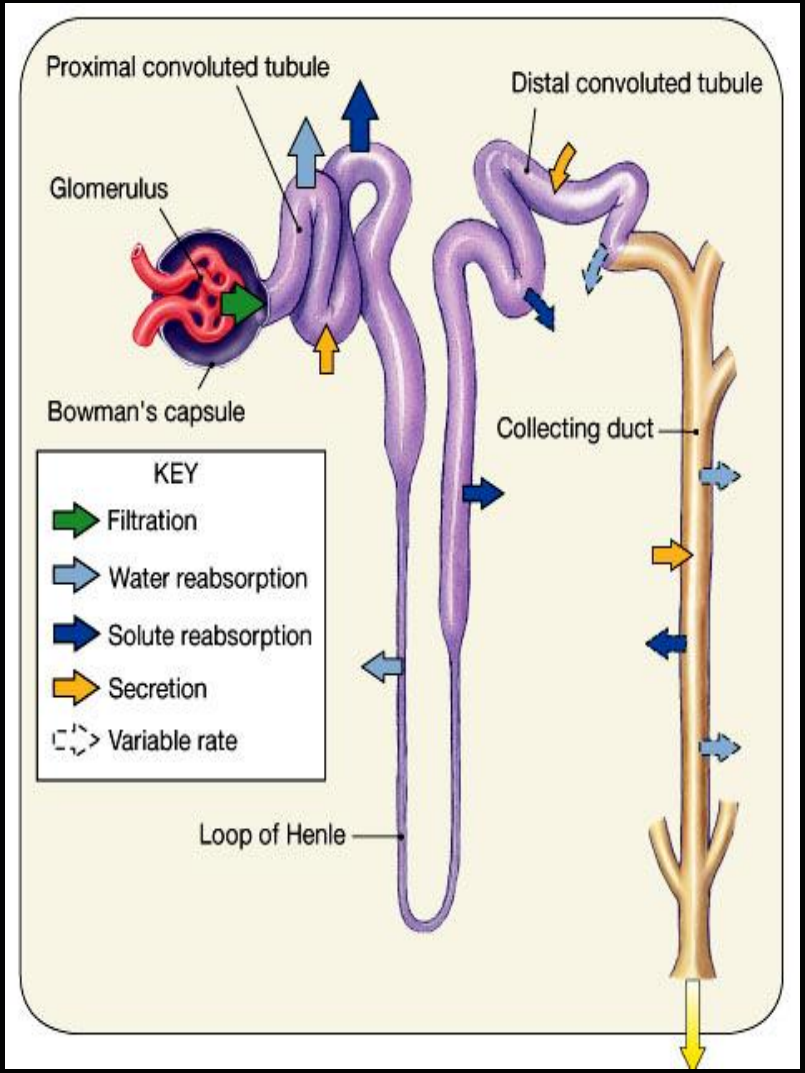

Filtration
Excretion
Reabsorbtion
Secretion

HUMAN RENAL PHYSIOLOGY



HUMAN RENAL PHYSIOLOGY

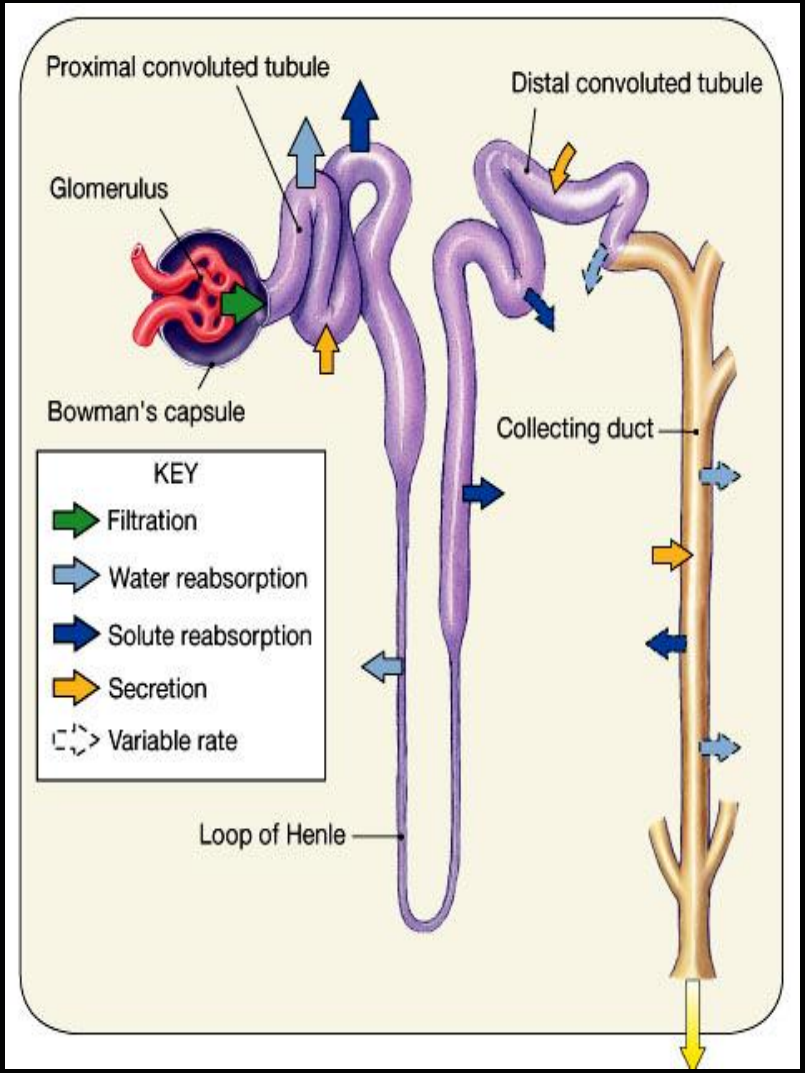
- **Filtration:**
  - First step in urine formation
  - Bulk transport of fluid from blood to kidney tubule
    - » Isosmotic filtrate
    - » Blood cells and proteins don't filter
  - Result of hydraulic pressure
  - GFR = 180 L/day



HUMAN RENAL PHYSIOLOGY

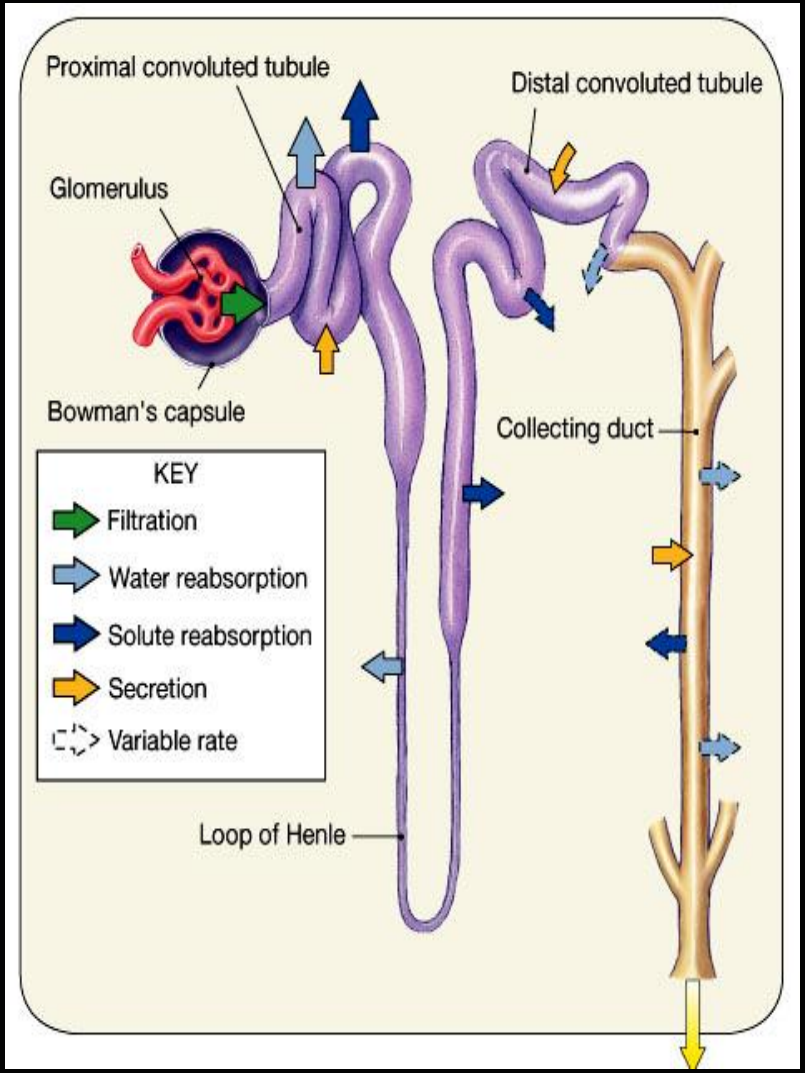
– **Reabsorbtion:**

- Process of returning filtered material to bloodstream
- 99% of what is filtered
- May involve transport protein(s)
- Normally **glucose** is totally reabsorbed



HUMAN RENAL PHYSIOLOGY

- **Secretion:**
  - Material added to lumen of kidney from blood
  - Active transport (usually) of toxins and foreign substances
    - » Saccharine
    - » Penicillin



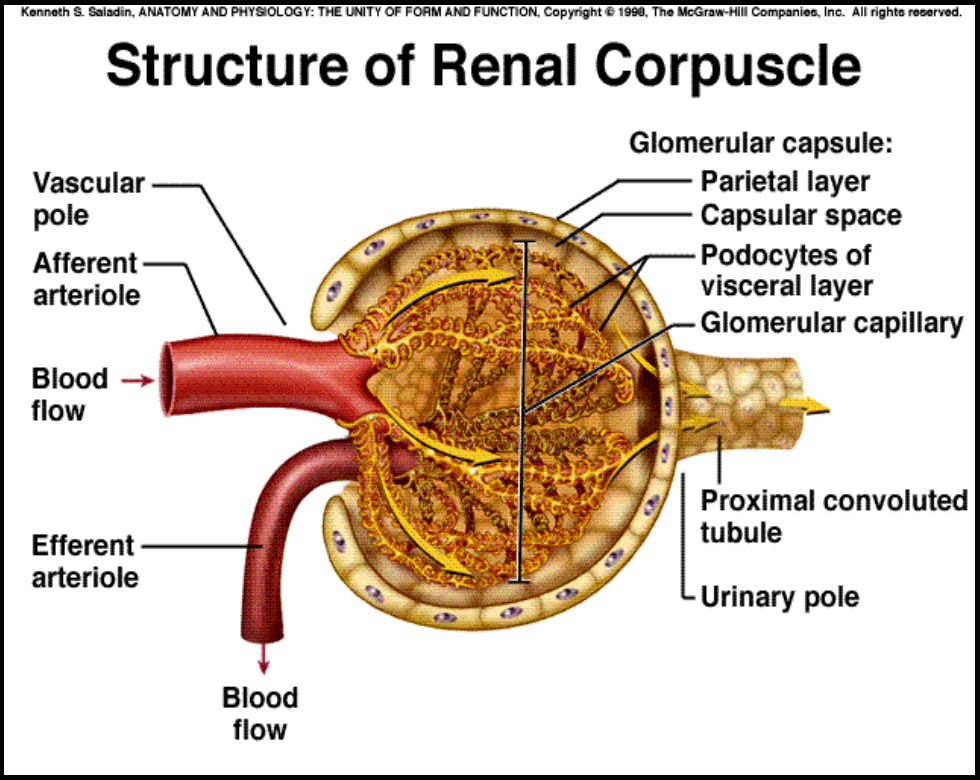
HUMAN RENAL PHYSIOLOGY

- Functions of the Kidney:
  - **Excretion:**
    - Loss of fluid from body in form of urine

$$\left(\begin{array}{l}\text{Amount}\\ \text{of Solute}\\ \text{Excreted}\end{array}\right) = \left(\begin{array}{l}\text{Amount}\\ \text{Filtered}\end{array}\right) + \left(\begin{array}{l}\text{Amount}\\ \text{Secreted}\end{array}\right) -- \left(\begin{array}{l}\text{Amount}\\ \text{Reabsorbed}\end{array}\right)$$

Glomerular filtration

Occurs as fluids move across the glomerular capillary in response to glomerular hydrostatic pressure



- blood enters glomerular capillary
- filters out of renal corpuscle
  - large proteins and cells stay behind
  - everything else is filtered into nephron
  - glomerular filtrate
    - plasma like fluid in glomerulus

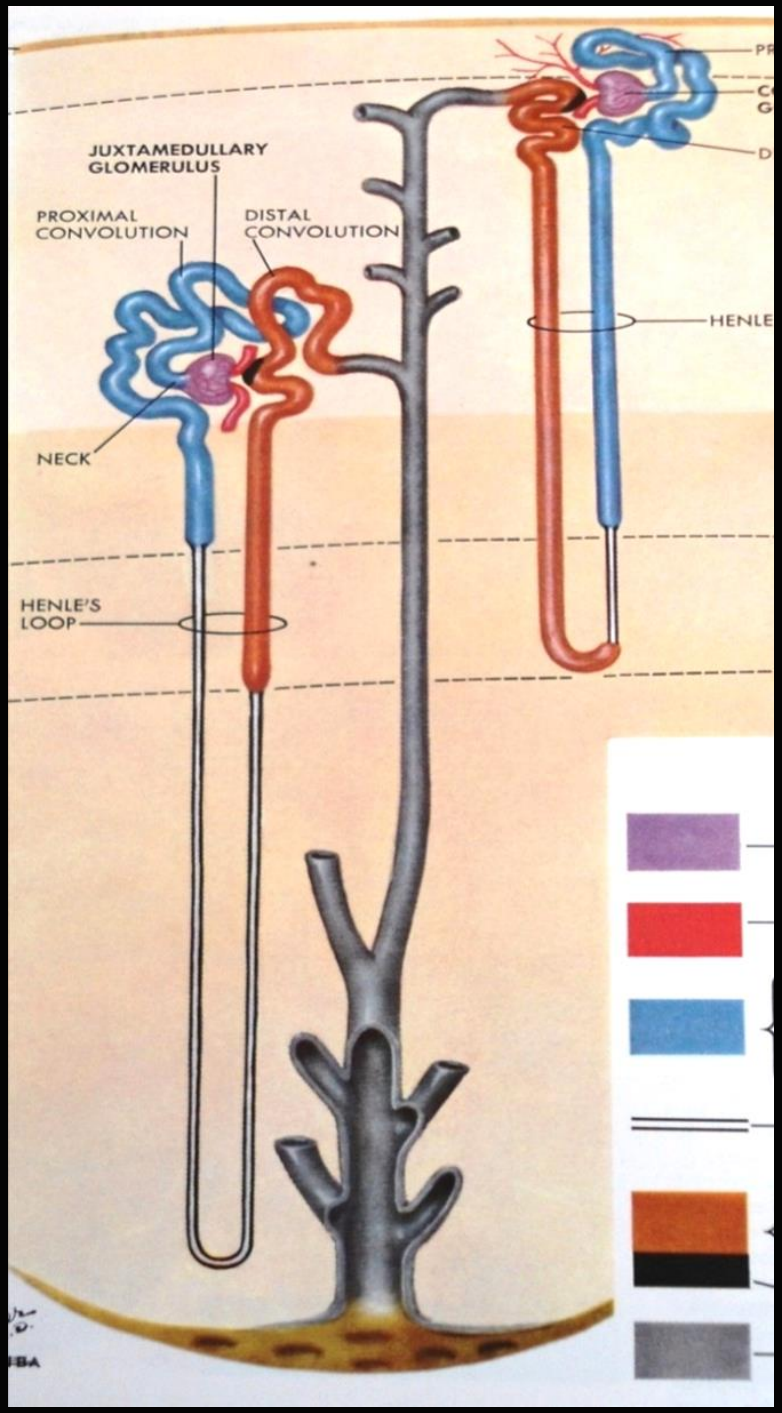
Factors that determining the glumerular filterability

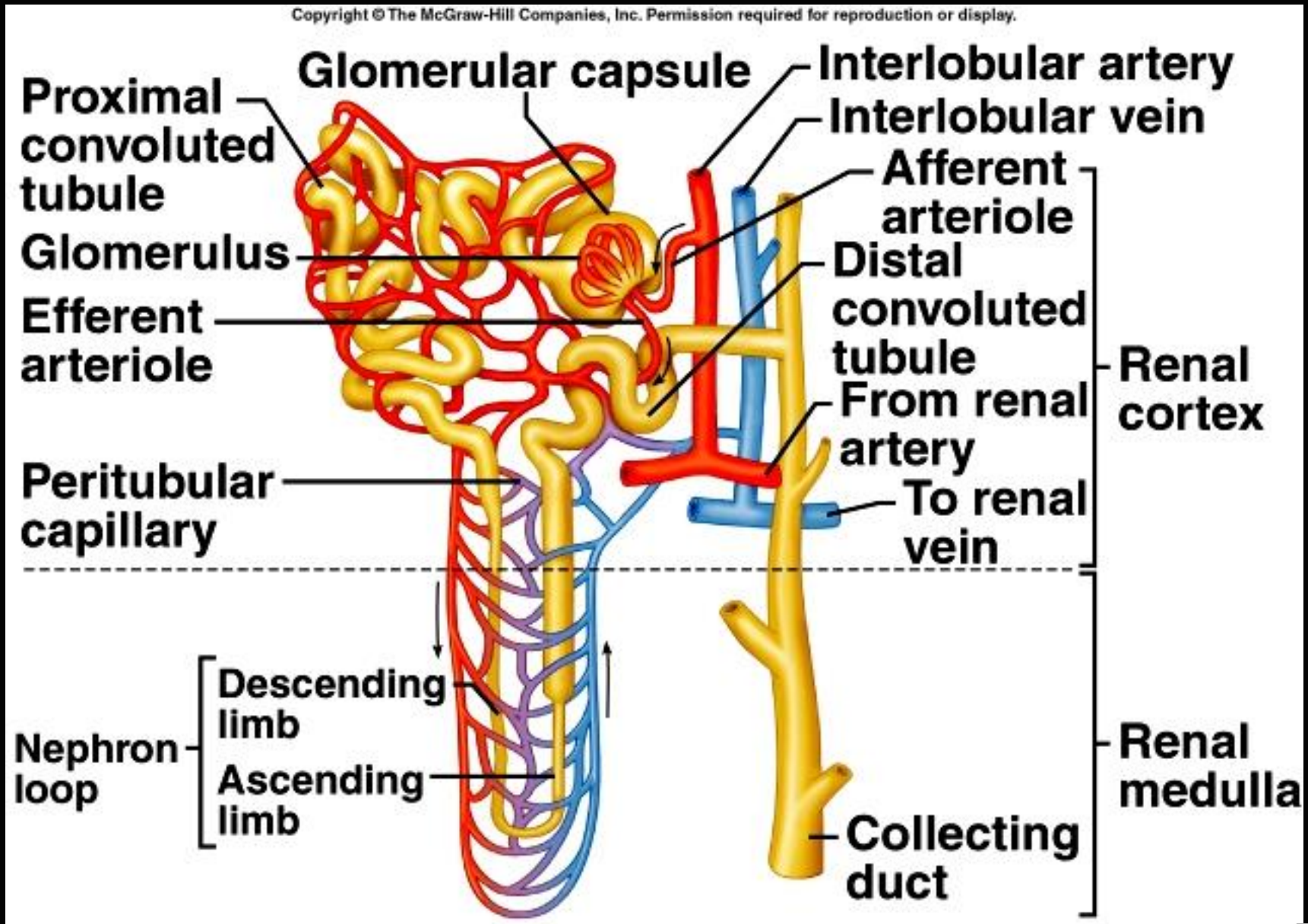
1. Molecular weight
2. Charges of the molecule

بسم الله الرحمن الرحيم

2

Nephron


JUXTAMEDULLARY GLOMERULUS
PROXIMAL CONVOLUTION
DISTAL CONVOLUTION
NECK
HENLE'S LOOP
HENLE



Function of the Kidney

١- المحافظة على حجم وتركيب سوائل الدم

٢-تزيل الفضلات والسموم من الدم (عن طريق البول) .

٣- طرح الكمية الزائدة من الهيدروجين للمحافظة على (pH 7.4).

٤- المحافظة على سوائل الجسم والضغط الأسمولي (٣٠٠ ملي ازمول/لتر)

٥- تنظم الكلية ضغط الدم عن طريق افراز انزيم الرينين كما تنظم افراز هرمون مضاد ادار البول من الفص الخلفي للغدة النخامية وهرمون الألدوستيرون من الغدة الكظرية كما انها تتحكم في معدل تصنيع الهرمون المولد للكريات الحمراء والمعروف بالأريثروبيوتين كما تنظم بعض الهرمونات كالبروستاغلاندين .

كما تشارك الكلية في تصنيع الشكل الفعال لفيتامين د (D) الكلسيتيرول (Calcitiriol) والذي يساعد في امتصاص الكالسيوم من الغذاء الى الدم.

Measuring GFR

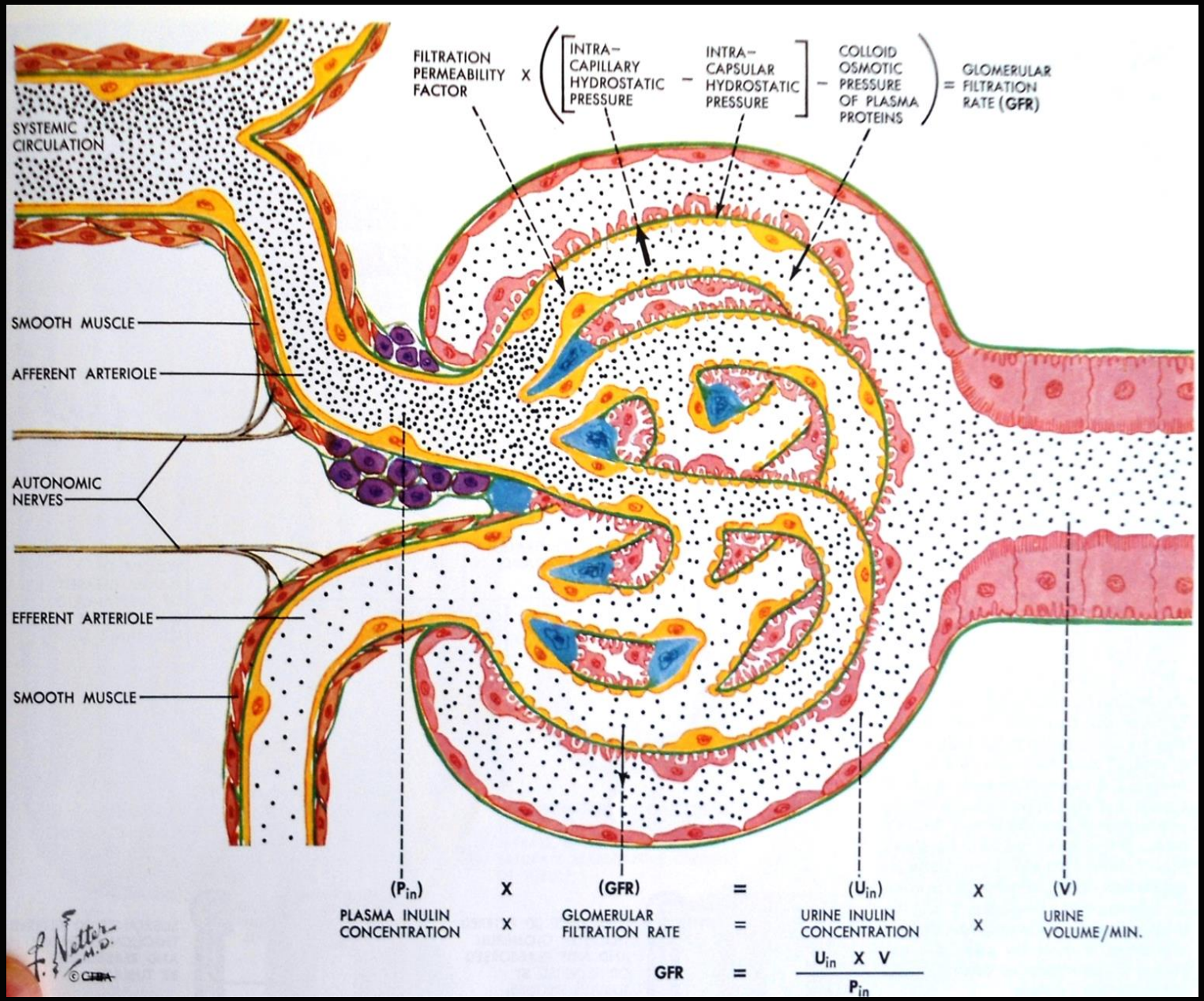
- **125 ml/min** of plasma is cleared in glomerulus(or 180L/day)
- If a substance is filtered but neither reabsorbed nor secreted, then the amount present in urine is its plasma clearance(amount in plasma cleared/min by glomerulus)
- If plasma conc. Is 3mg/L then

3	X	180/day	=	540mg/day
(known)		(unknown)		(known)

Qualities of agents to measure GFR

Inulin: (Polysaccharide from Dahalia plant)

- Freely filterable at glomerulus
- Does not bind to plasma proteins
- Biologically inert
- Non-toxic, neither synthesized nor metabolized in kidney
- Neither absorbed nor secreted
- Does not alter renal function
- Can be accurately quantified
- Low concentrations are enough (10-20 mg/100 ml plasma)


FILTRATION PERMEABILITY FACTOR
X
INTRA-CAPILLARY HYDROSTATIC PRESSURE
–
INTRA-CAPSULAR HYDROSTATIC PRESSURE
–
COLLOID OSMOTIC PRESSURE OF PLASMA PROTEINS
= GLOMERULAR FILTRATION RATE (GFR)
SYSTEMIC CIRCULATION
SMOOTH MUSCLE
AFFERENT ARTERIOLE
AUTONOMIC NERVES
EFFERENT ARTERIOLE
SMOOTH MUSCLE
(Pin) X (GFR) = (Uin) X (V)
PLASMA INULIN CONCENTRATION X GLOMERULAR FILTRATION RATE = URINE INULIN CONCENTRATION X URINE VOLUME/MIN.
GFR = Uin X V / Pin
F. Netter M.D.
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Inulin

GFR

Qualities of agents to measure GFR

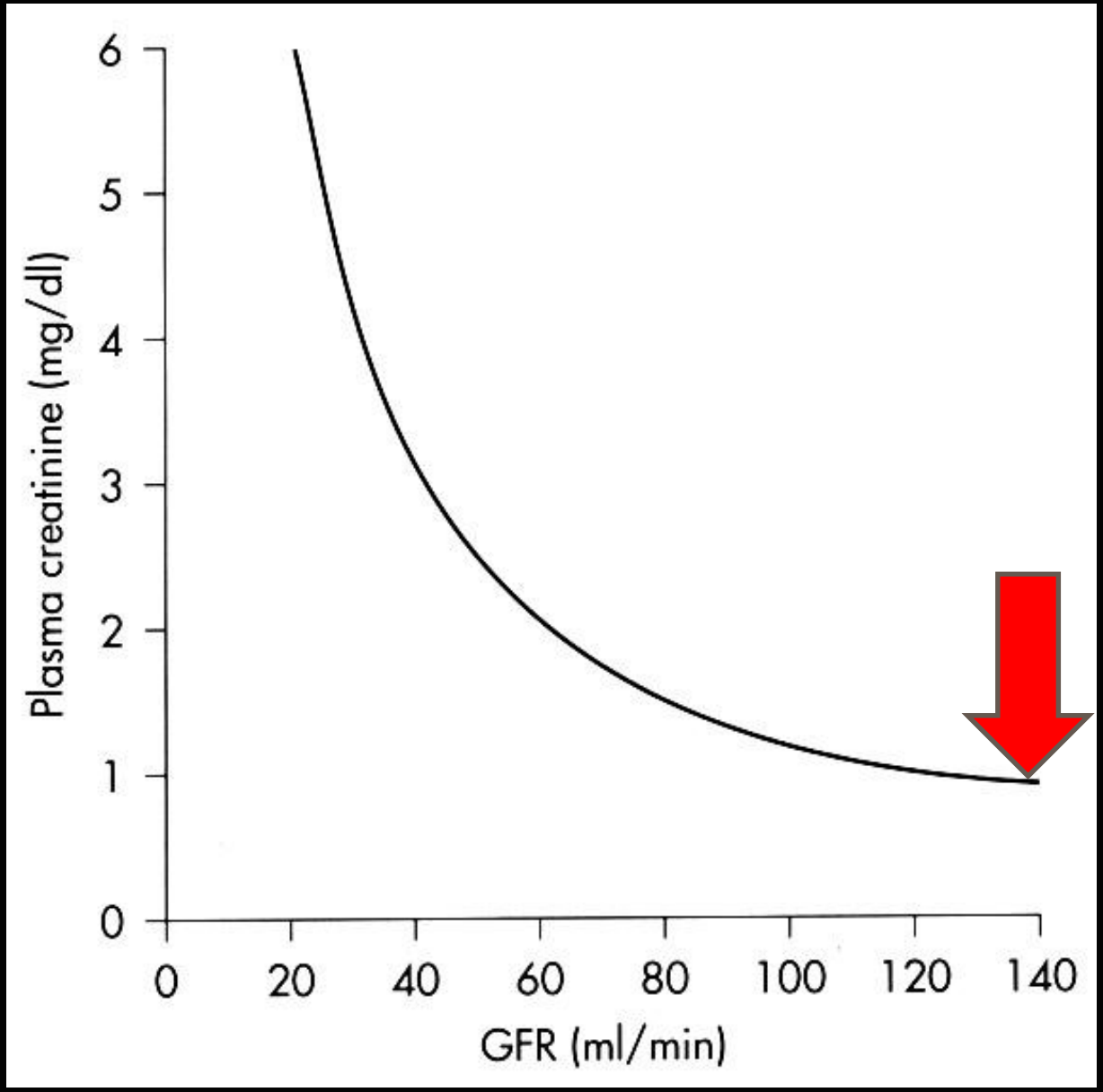
Creatinine:

End product of muscle creatine metabolism

Used in clinical setting to measure GFR but less accurate than inulin method

Small amount secrete from the tubule

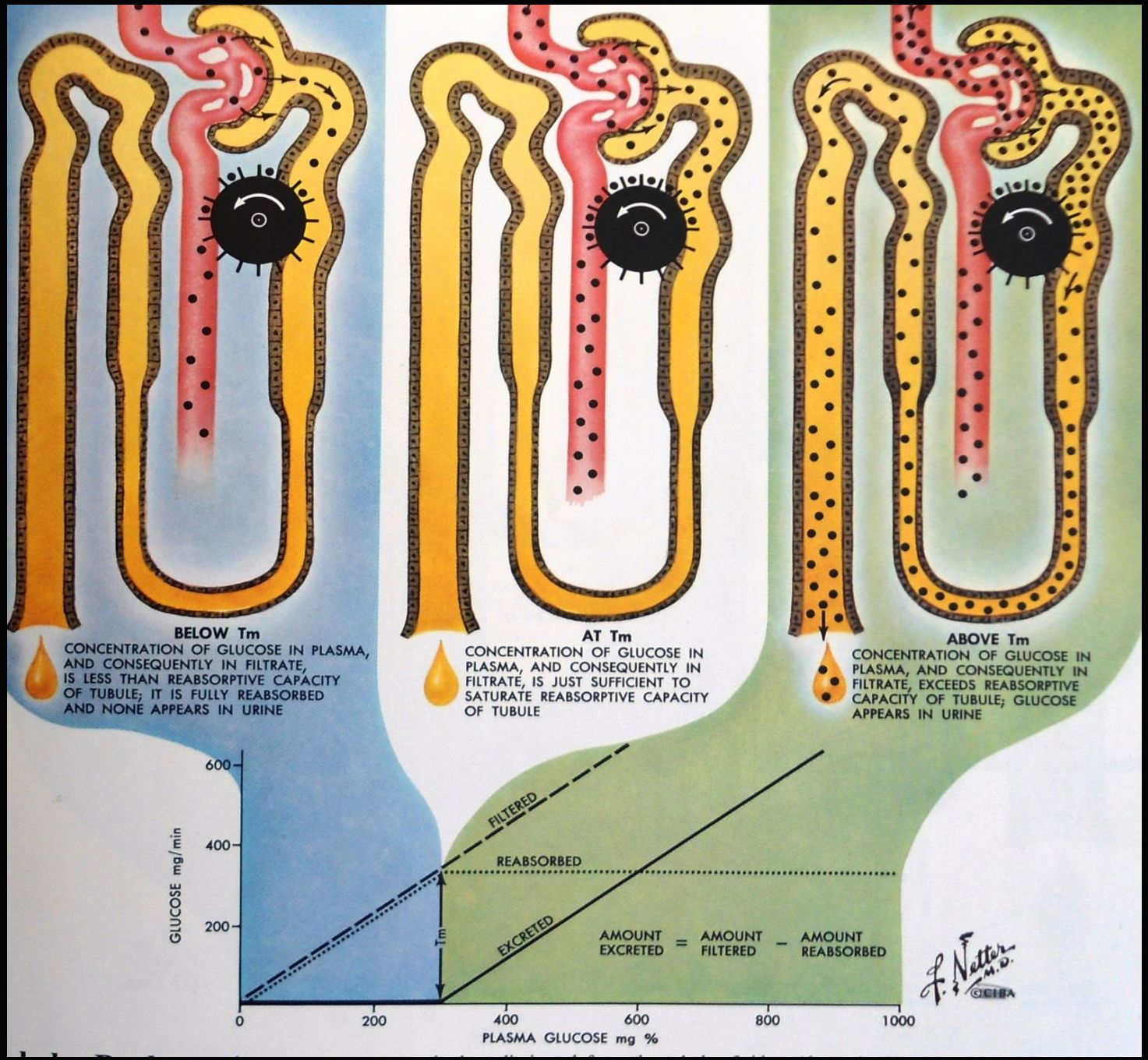
Plasma creatinine level vs. GFR



Filterablility of plasma constituents vs. water

Constituent	Mol. Wt.	Filteration ratio
Urea	60	1.00
Glucose	180	1.00
Inulin	5,500	1.00
Myoglobin	17,000	0.75
Hemoglobin	64,000	0.03
Albumin	69,000	0.01

Glucose


BELOW Tm
CONCENTRATION OF GLUCOSE IN PLASMA, AND CONSEQUENTLY IN FILTRATE, IS LESS THAN REABSORPTIVE CAPACITY OF TUBULE; IT IS FULLY REABSORBED AND NONE APPEARS IN URINE
AT Tm
CONCENTRATION OF GLUCOSE IN PLASMA, AND CONSEQUENTLY IN FILTRATE, IS JUST SUFFICIENT TO SATURATE REABSORPTIVE CAPACITY OF TUBULE
ABOVE Tm
CONCENTRATION OF GLUCOSE IN PLASMA, AND CONSEQUENTLY IN FILTRATE, EXCEEDS REABSORPTIVE CAPACITY OF TUBULE; GLUCOSE APPEARS IN URINE
600
400
200
GLUCOSE mg/min
FILTERED
REABSORBED
EXCRETED
TM
AMOUNT EXCRETED = AMOUNT FILTERED – AMOUNT REABSORBED
0
200
400
600
800
1000
PLASMA GLUCOSE mg %
F. H. Netter, M.D.
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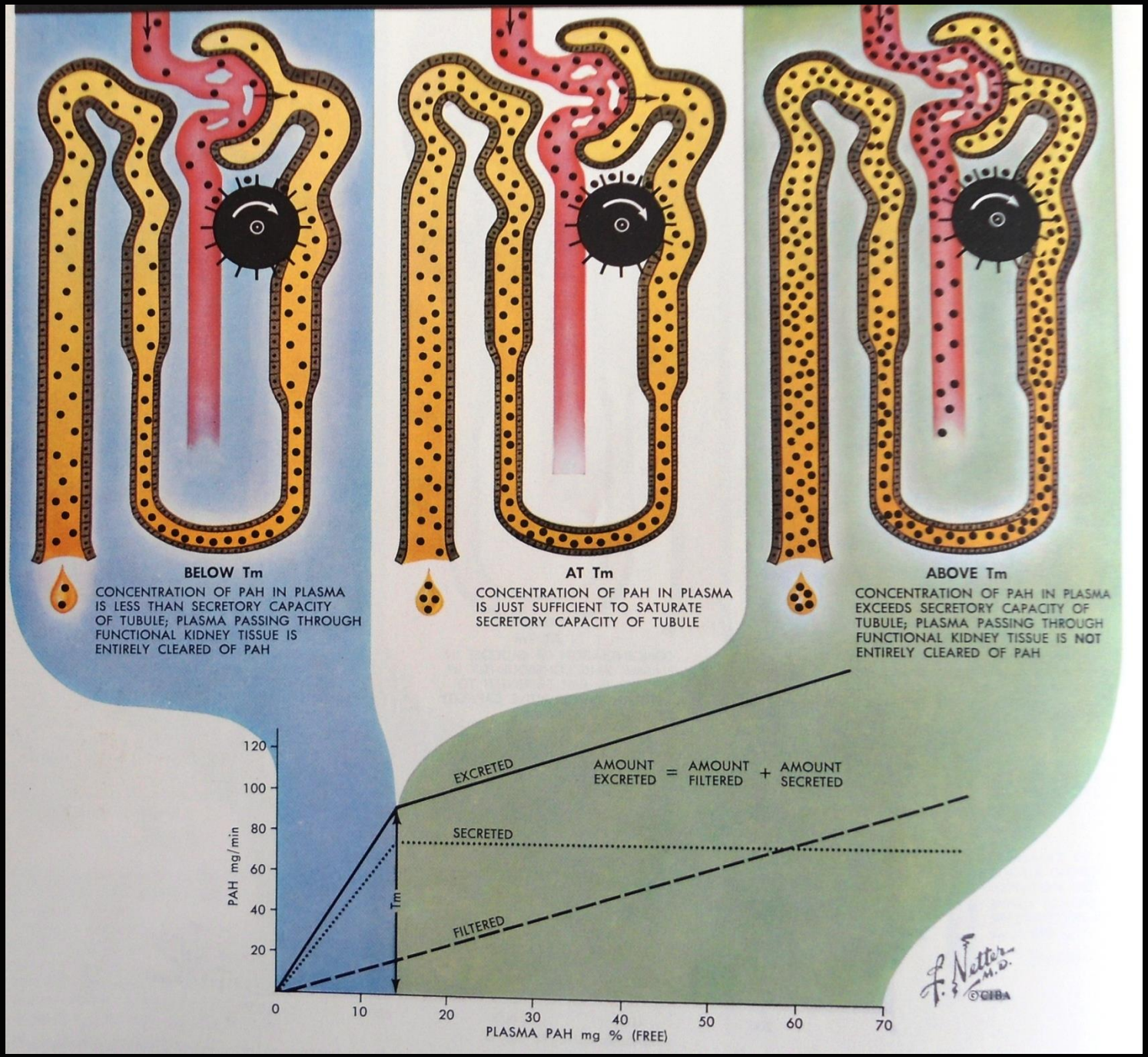
BELOW Tm
CONCENTRATION OF PAH IN PLASMA IS LESS THAN SECRETORY CAPACITY OF TUBULE; PLASMA PASSING THROUGH FUNCTIONAL KIDNEY TISSUE IS ENTIRELY CLEARED OF PAH
AT Tm
CONCENTRATION OF PAH IN PLASMA IS JUST SUFFICIENT TO SATURATE SECRETORY CAPACITY OF TUBULE
ABOVE Tm
CONCENTRATION OF PAH IN PLASMA EXCEEDS SECRETORY CAPACITY OF TUBULE; PLASMA PASSING THROUGH FUNCTIONAL KIDNEY TISSUE IS NOT ENTIRELY CLEARED OF PAH
EXCRETED
SECRETED
FILTERED
AMOUNT EXCRETED = AMOUNT FILTERED + AMOUNT SECRETED
Tm
PAH mg/min
120
100
80
60
40
20
0
10
20
30
40
50
60
70
PLASMA PAH mg % (FREE)
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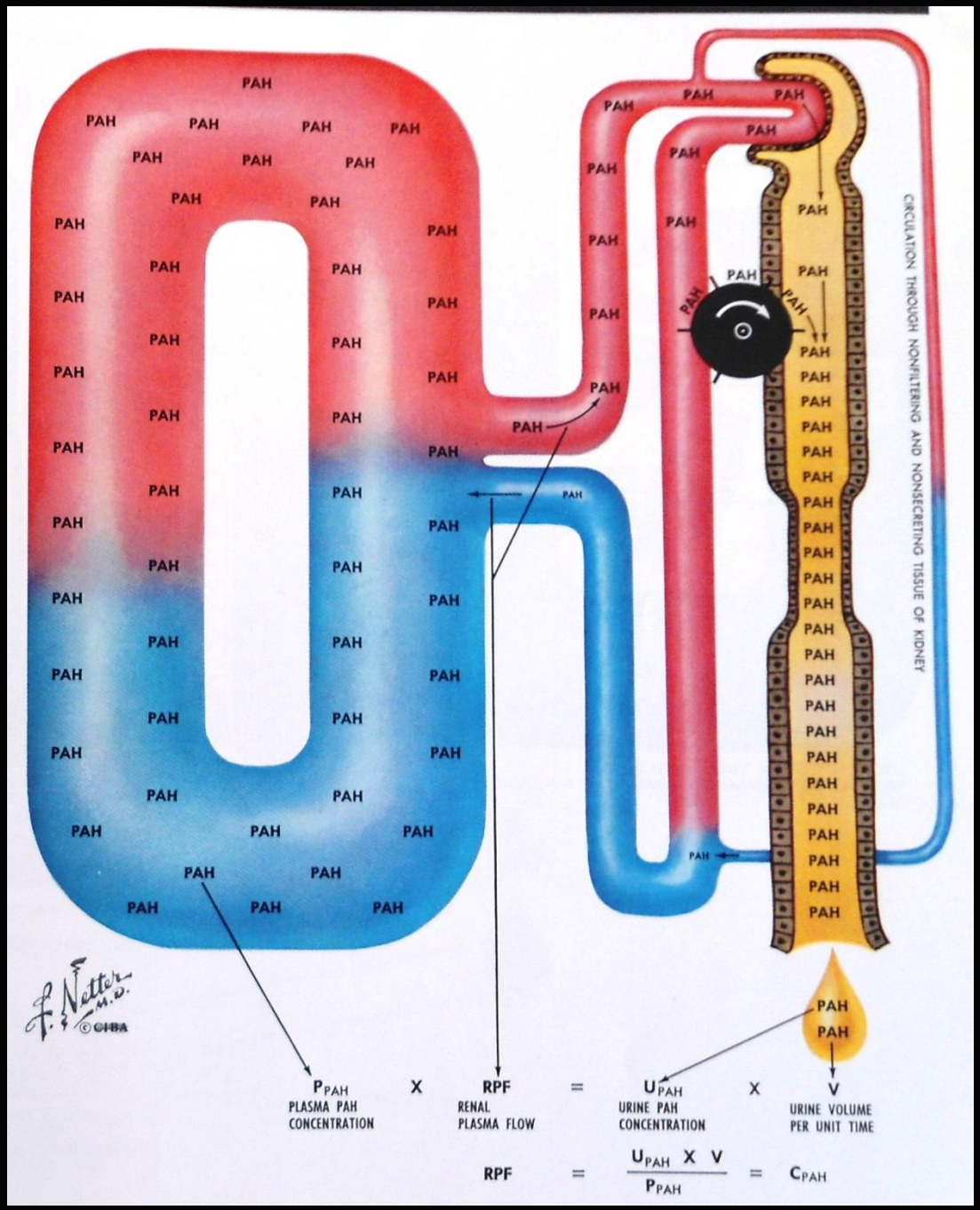
PAH

RP Flow

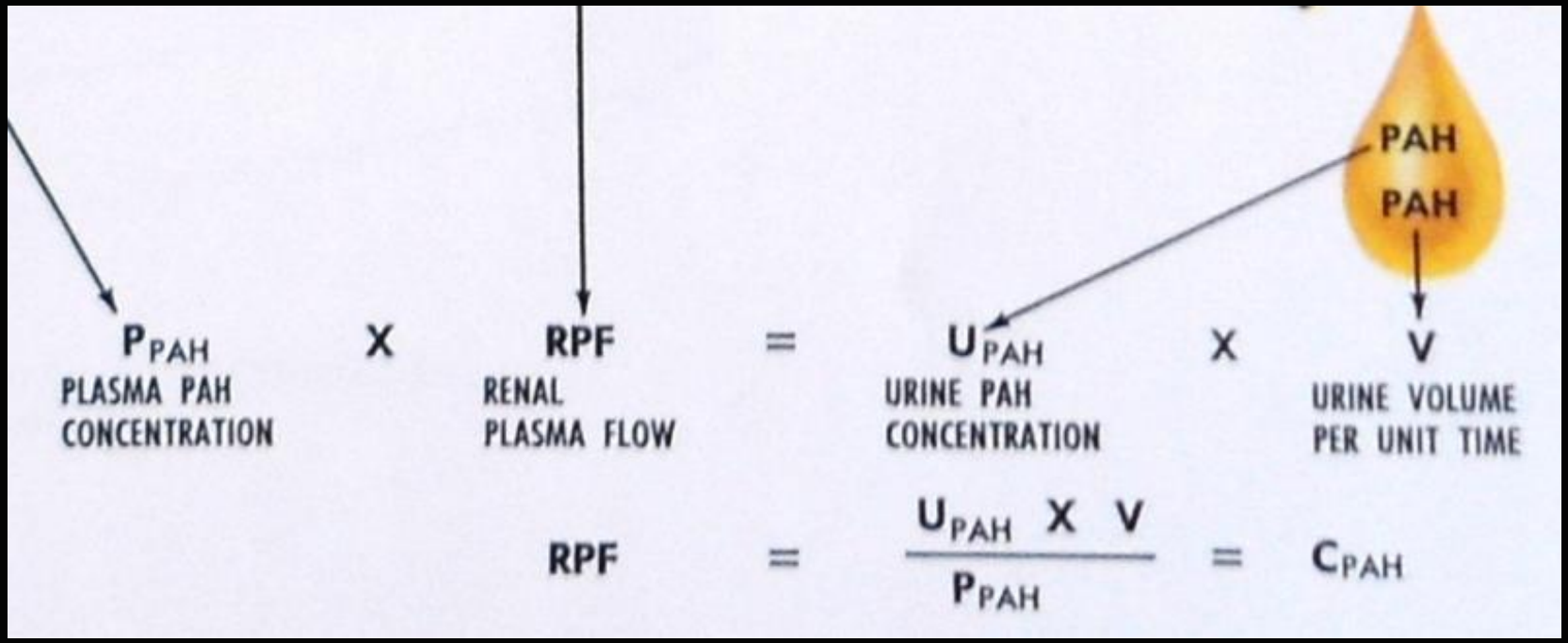

PAH
CIRCULATION THROUGH NONFILTERING AND NONSECRETING TISSUE OF KIDNEY
F. Netter M.D.
©CIBA
P_{PAH} PLASMA PAH CONCENTRATION
X
RPF RENAL PLASMA FLOW
=
U_{PAH} URINE PAH CONCENTRATION
X
V URINE VOLUME PER UNIT TIME
$RPF = \frac{U_{PAH} \times V}{P_{PAH}} = C_{PAH}$

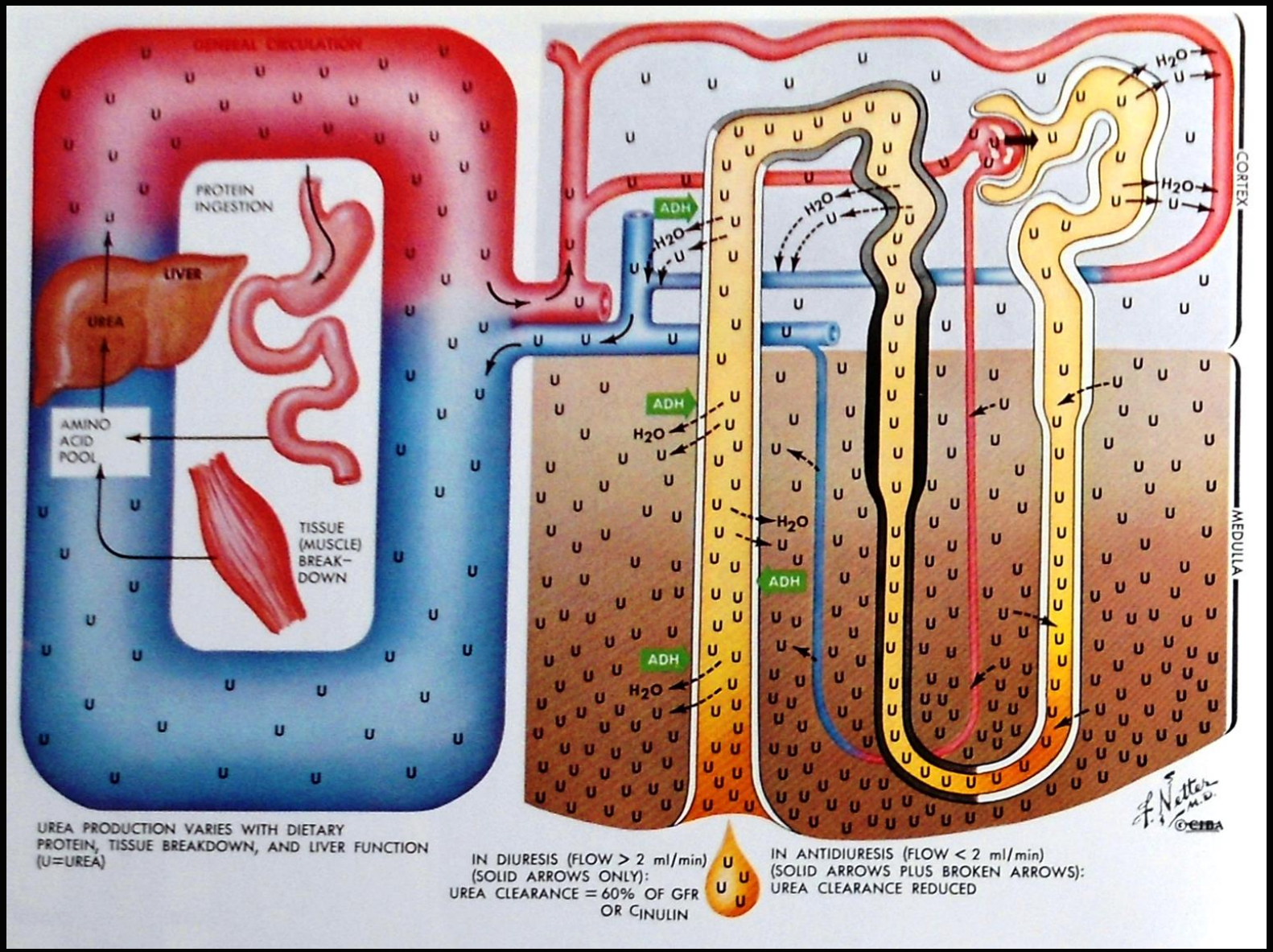
PAH

RPF

PAH

RPF

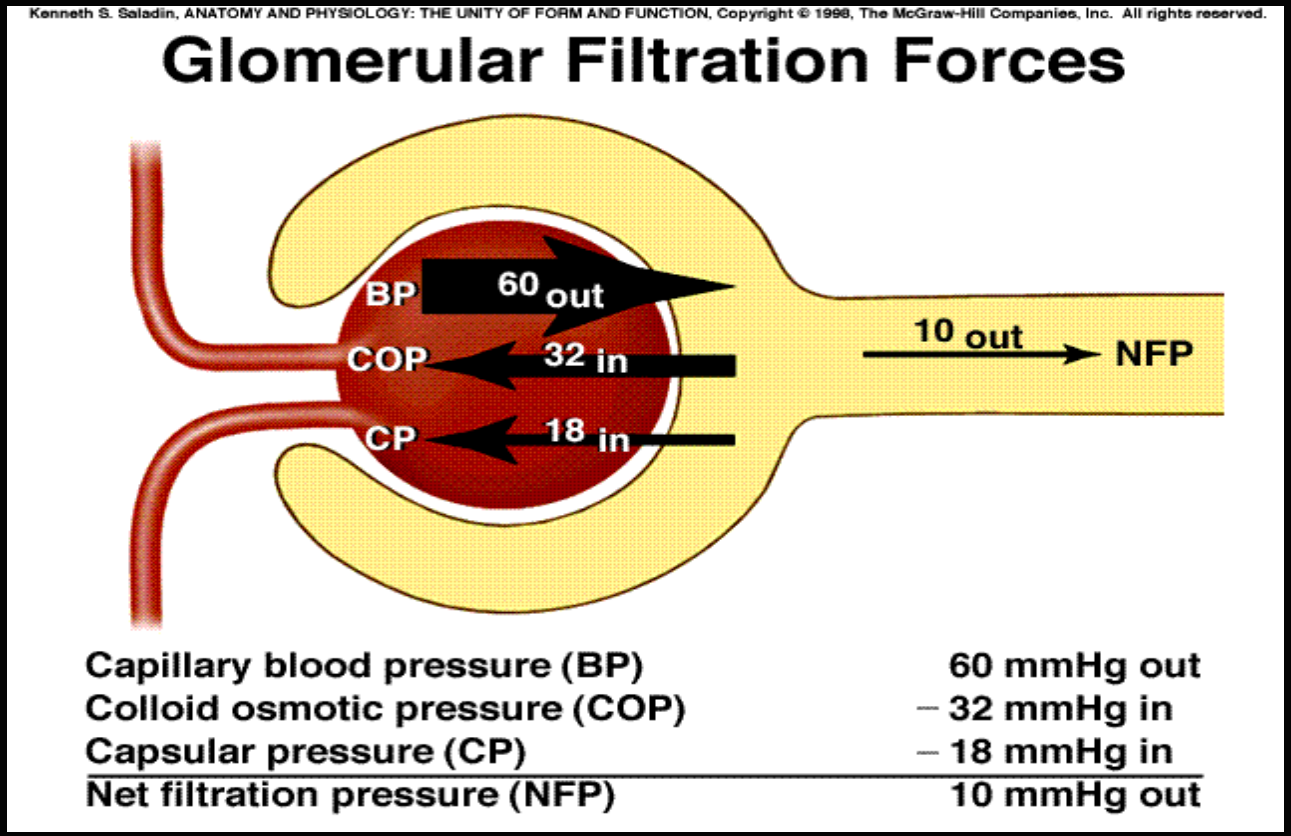

PAH
PAH
P_{PAH}
PLASMA PAH CONCENTRATION
X
RPF
RENAL PLASMA FLOW
=
U_{PAH}
URINE PAH CONCENTRATION
X
V
URINE VOLUME PER UNIT TIME
RPF = $\frac{U_{PAH} \times V}{P_{PAH}}$ = C_{PAH}


GENERAL CIRCULATION
PROTEIN INGESTION
LIVER
UREA
AMINO ACID POOL
TISSUE (MUSCLE) BREAK-DOWN
ADH
H_2O
U
CORTEX
MEDULLA
UREA PRODUCTION VARIES WITH DIETARY PROTEIN, TISSUE BREAKDOWN, AND LIVER FUNCTION (U=UREA)
IN DIURESIS (FLOW > 2 ml/min) (SOLID ARROWS ONLY): UREA CLEARANCE = 60% OF GFR OR C_{INULIN}
IN ANTIDIURESIS (FLOW < 2 ml/min) (SOLID ARROWS PLUS BROKEN ARROWS): UREA CLEARANCE REDUCED
F. Netter M.D.
CIBA

URIA

Forces that influence filtration

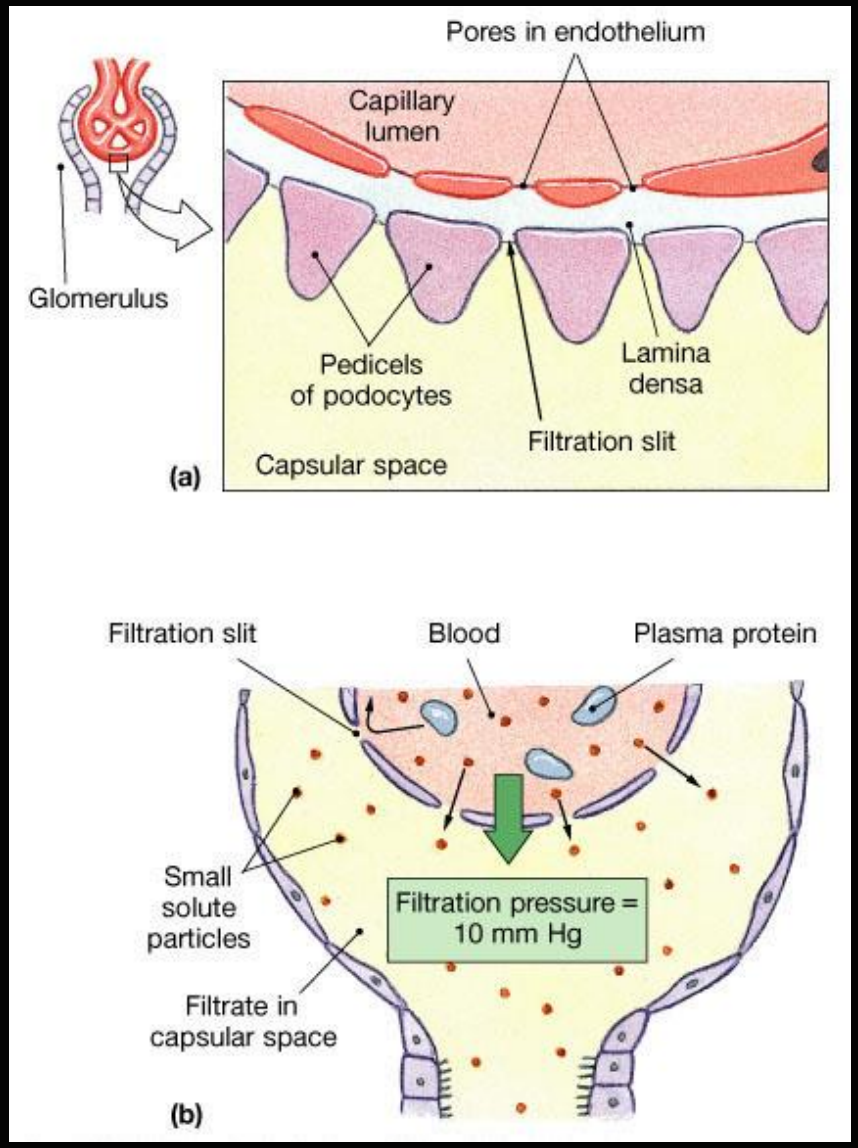
- Glomerular blood hydrostatic pressure 60
- Opposing forces:
  - Plasma colloid osmotic pressure 32
  - Capsular hydrostatic pressure 18



Filtration

- Renal corpuscle
- Filtration membrane
  - Fenestrated endothelium of capillaries
  - Basement membrane of glomerulus
  - Slit membrane between pedicels of podocytes

Glomerular Filtration



Glomerular filtration rate (GFR)

- Amount of filtrate produced in the kidneys each minute. 125mL/min = 180L/day
- Factors that alter filtration pressure change GFR. These include:
  - Increased renal blood flow -- Increased GFR
  - Decreased plasma protein -- Increased GFR. Causes edema.
  - Hemorrhage -- Decreased capillary BP -- Decreased GFR

GFR regulation : Adjusting blood flow

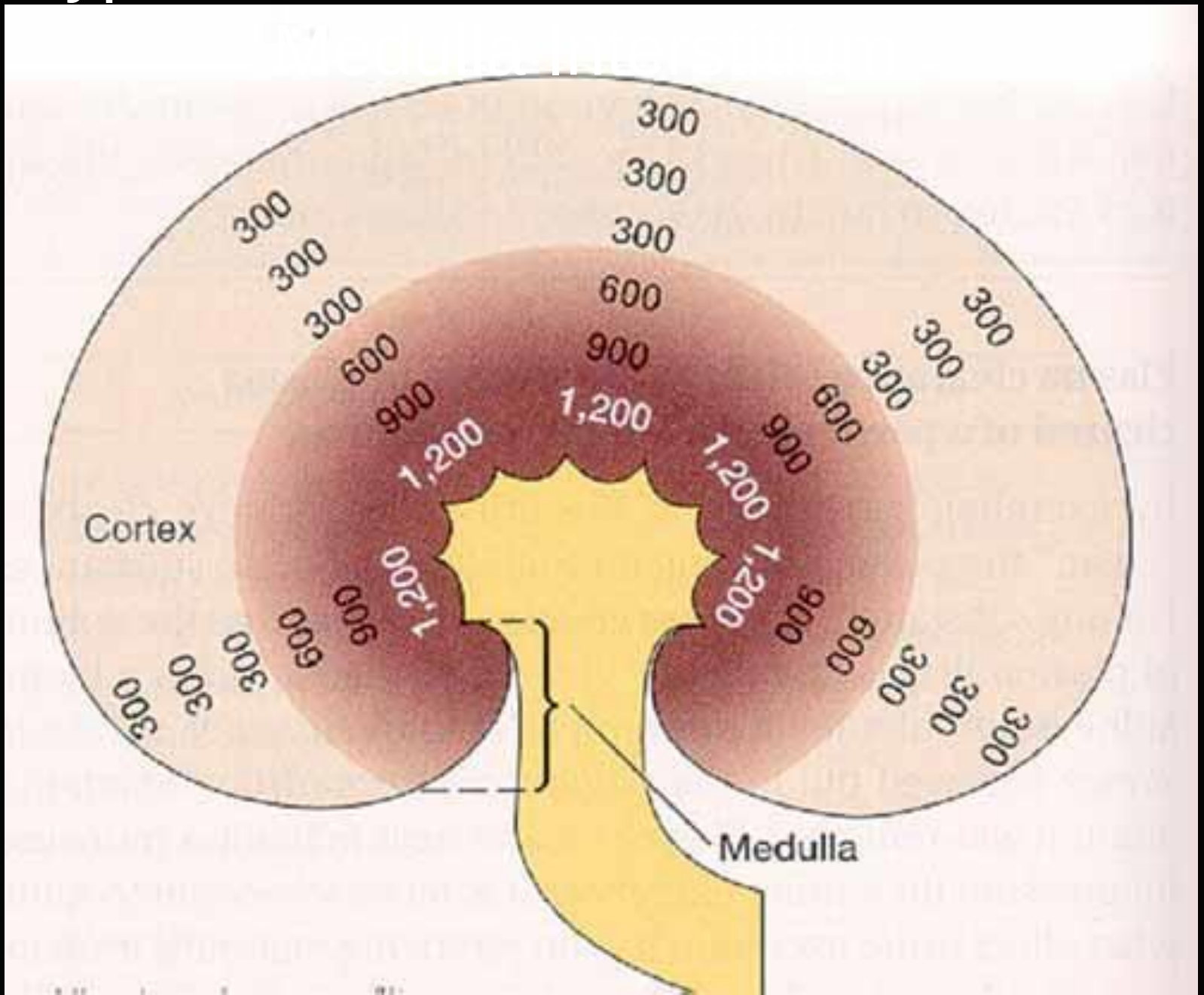
- GFR is regulated using three mechanisms

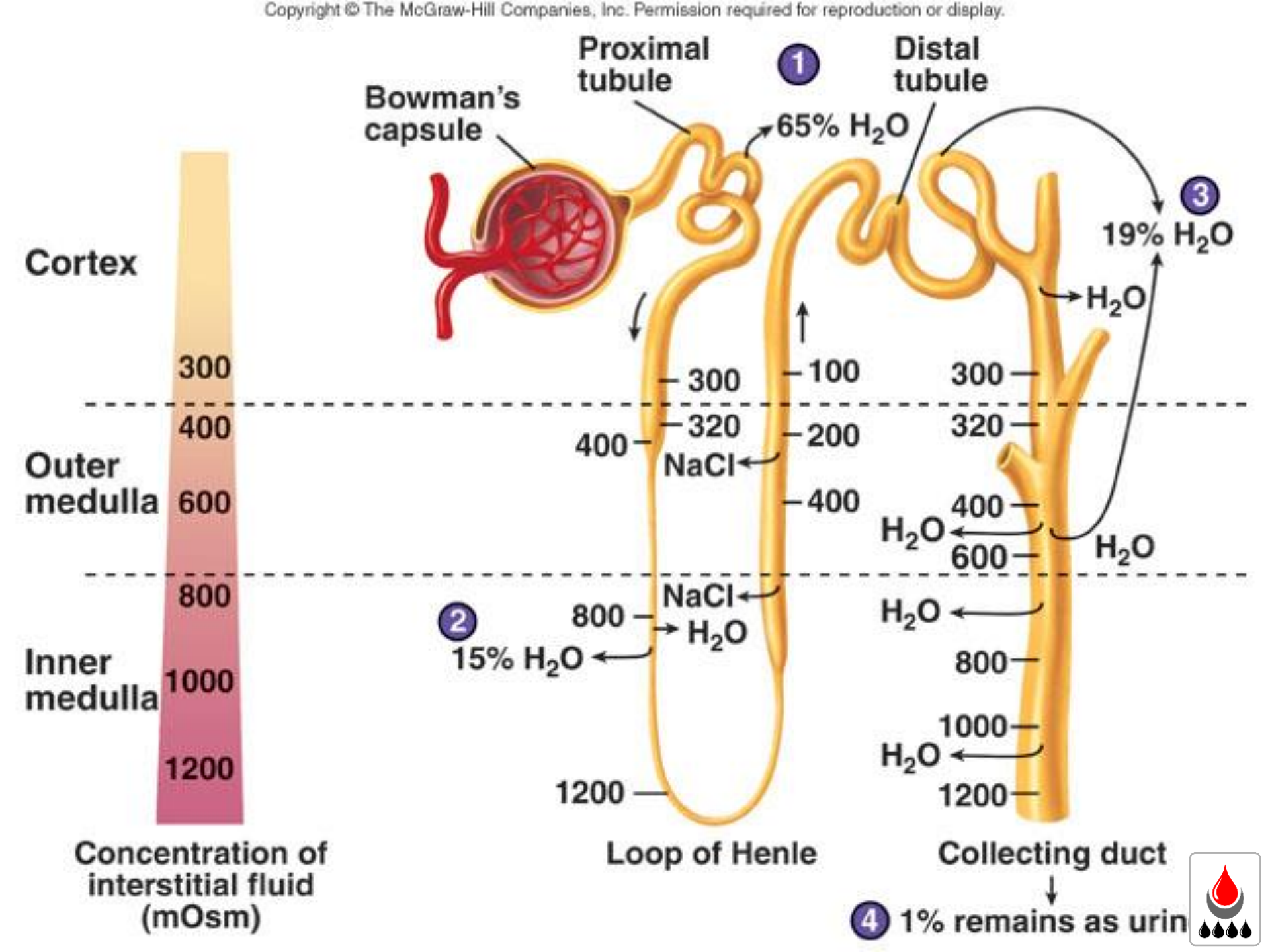
1. Renal Autoregulation
2. Neural regulation
3. Hormonal regulation

All three mechanism adjust renal blood pressure and resulting blood flow

1. Renal autoregulation

Hyperosmotic Gradient in the Renal





GFR influenced by:

- Blood pressure and blood flow
- Obstruction to urine outflow
- Loss of protein-free fluid
- Hormonal regulation
  - Renin – angiotensin
  - Aldosterone
  - ADH
  - ANP

2. Neural regulation

INNERVATION OF THE KIDNEY

Nerves from the renal plexus (sympathetic nerve) of the autonomic nervous system enter kidney at the hilus→innervate smooth muscle of afferent & efferent arterioles→regulates blood pressure & distribution throughout kidney

Effect:

(1) Reduce the GPF and GFR and through contracting the afferent and efferent artery (α receptor)

(2) Increase the Na^+ reabsorption in the proximal tubules (β receptor)

(3) Increase the release of renin (β receptor)

Nerve reflex:

1. Cardiopulmonary reflex and Baroreceptor Reflex

2. Renorenal reflex

Sensory nerves located in the renal pelvic wall are activated by stretch of the renal pelvic wall, which may occur during diuresis or ureteral spasm/occlusion.

Activation of these nerves leads to an increase in afferent renal nerve activity, which causes a decrease in efferent renal nerve activity and an increase in urine flow rate and urinary sodium excretion.

This is called a renorenal reflex response.

The series of mechanisms leading to activation of renal mechanosensory nerves include:

Increased renal pelvic pressure increases the release of bradykinin which activates protein kinase C which in turn results in renal pelvic release of PGE_2 via activation of COX-2.

PGE_2 increases the release of substance P via activation of N-type calcium channels in the renal pelvic wall.

2. Neural regulation of GFR

- Sympathetic nerve fibers innervate afferent and efferent arteriole
- Normally sympathetic stimulation is low but can increase during hemorrhage and exercise
- Vasoconstriction occurs as a result which conserves blood volume (hemorrhage) and permits greater blood flow to other body parts (exercise)

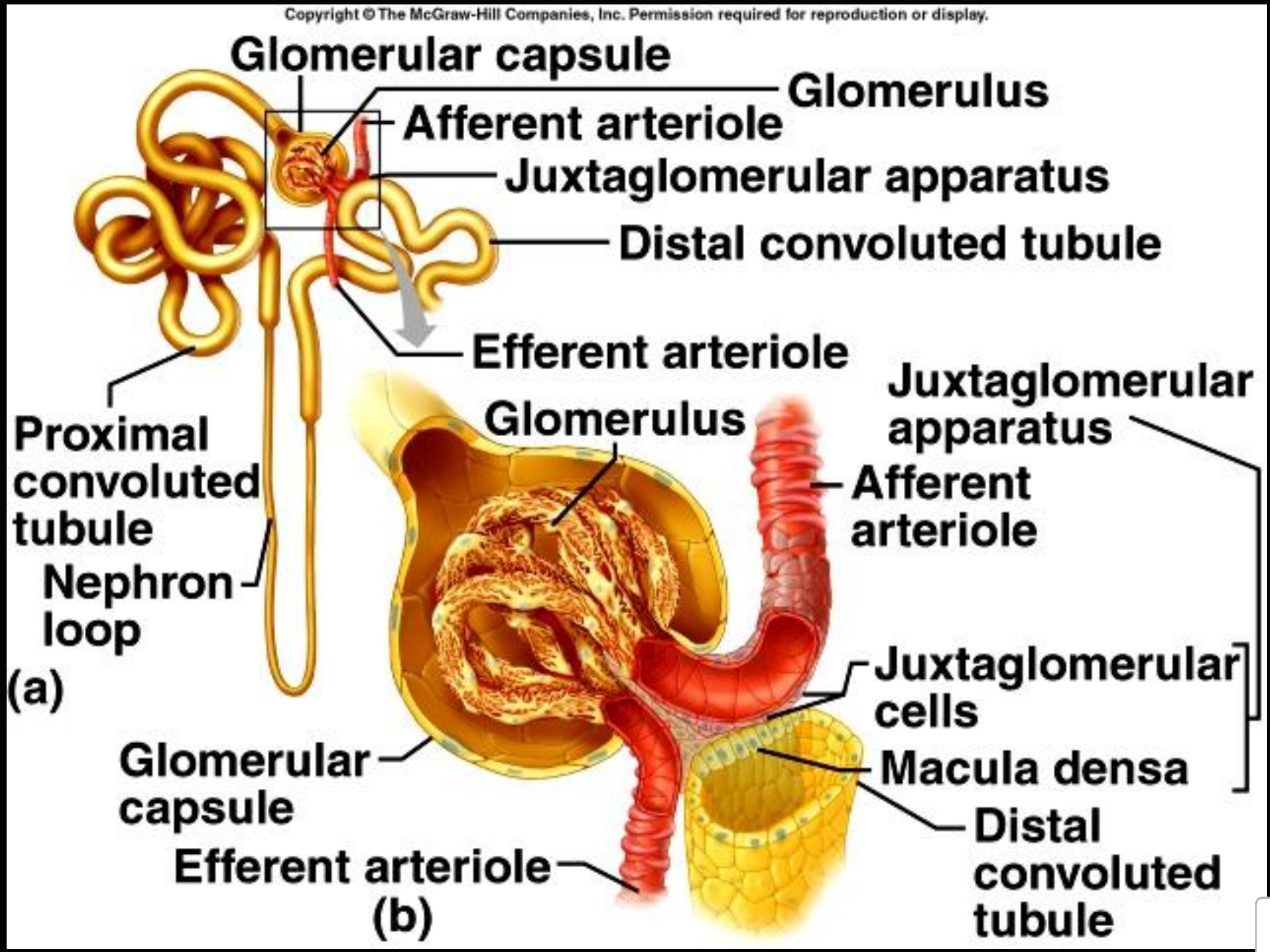
3. Hormonal regulation

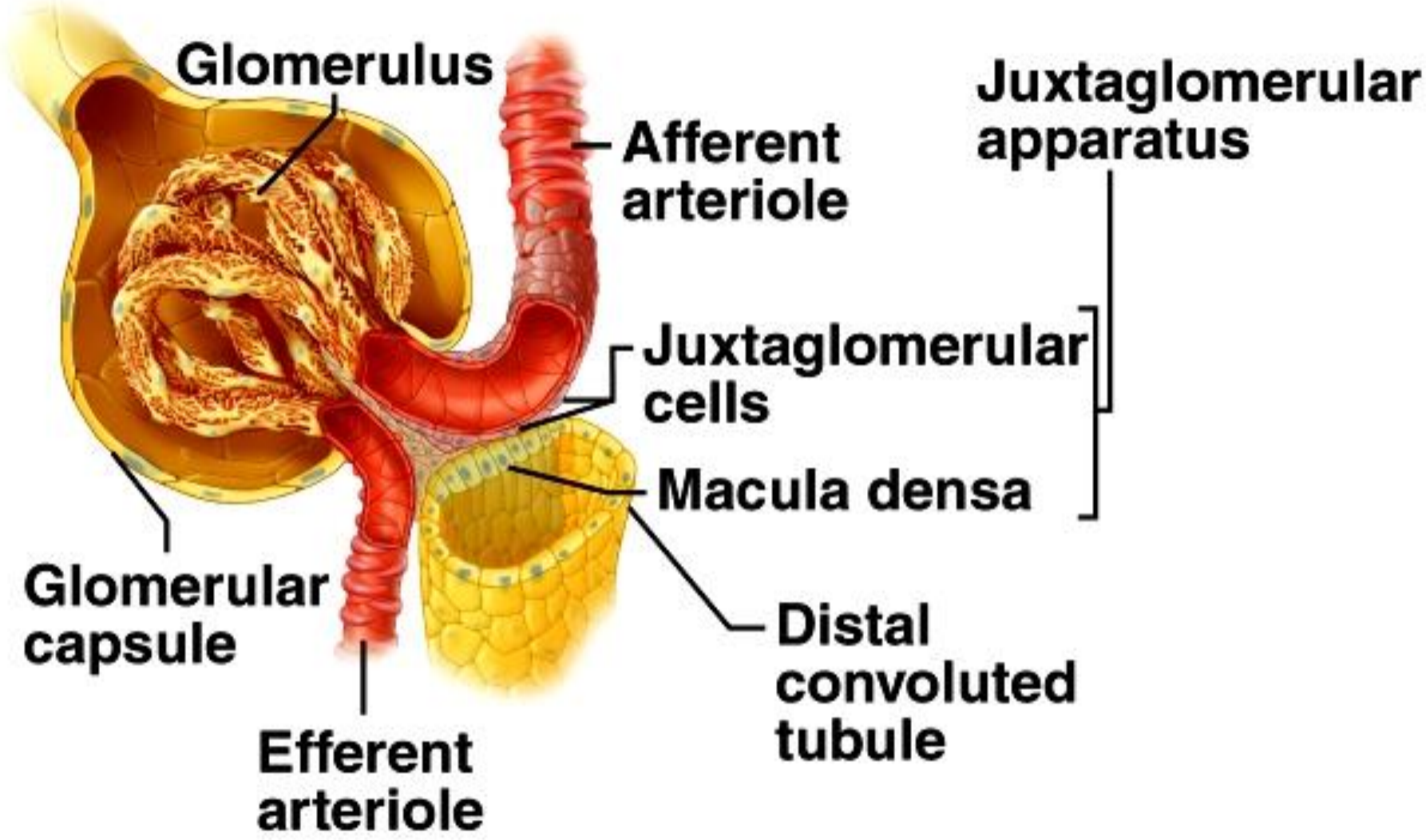
3. Hormonal regulation of GFR

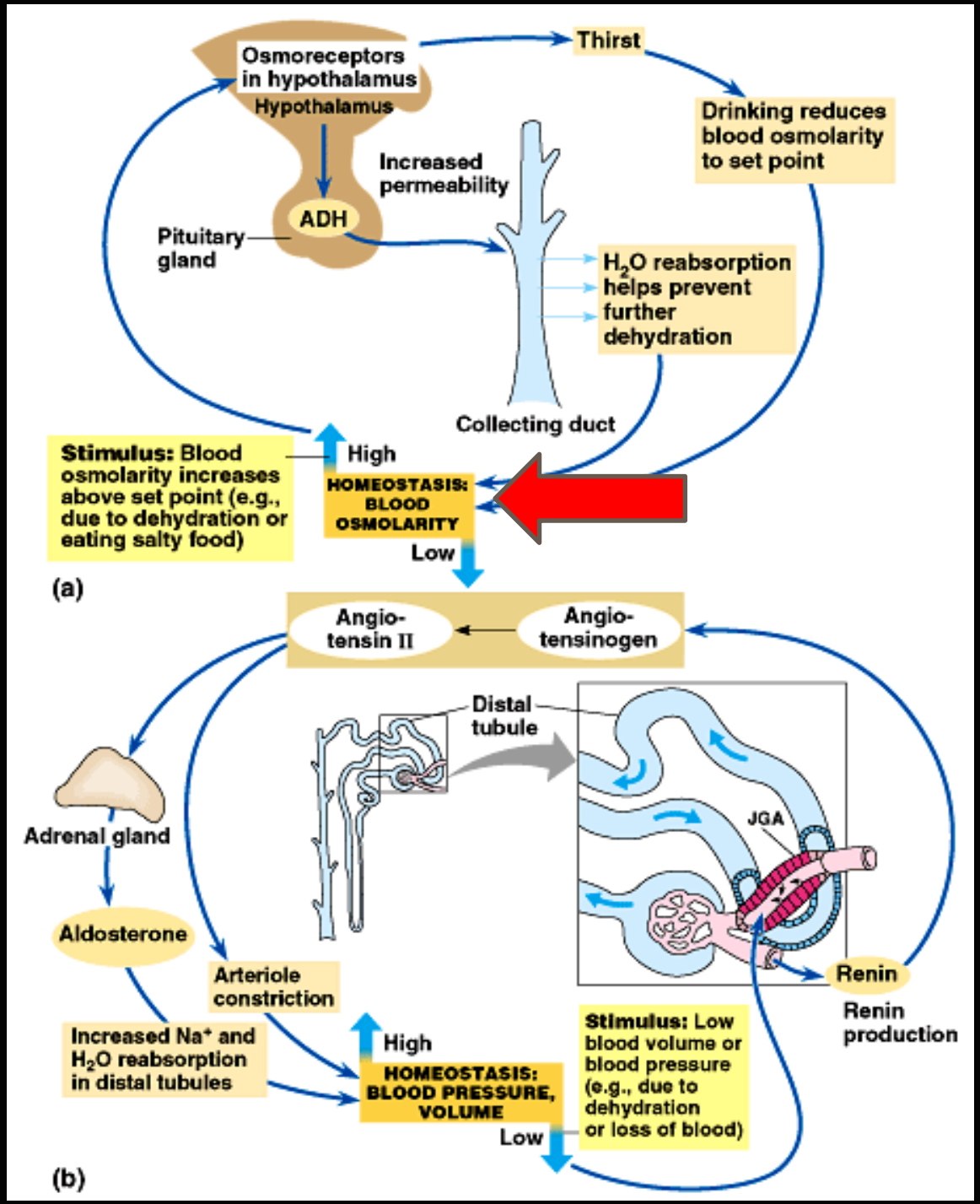
- Several hormones contribute to GFR regulation
- Angiotensin II. Produced by Renin, released by JGA cells is a potent vasoconstrictor. Reduces GFR
- ANP atrial natriuretic peptide (released by atria when stretched) increases GFR by increasing capillary surface area available for filtration
- NO
- Endothelin
- Prostaglandin E2

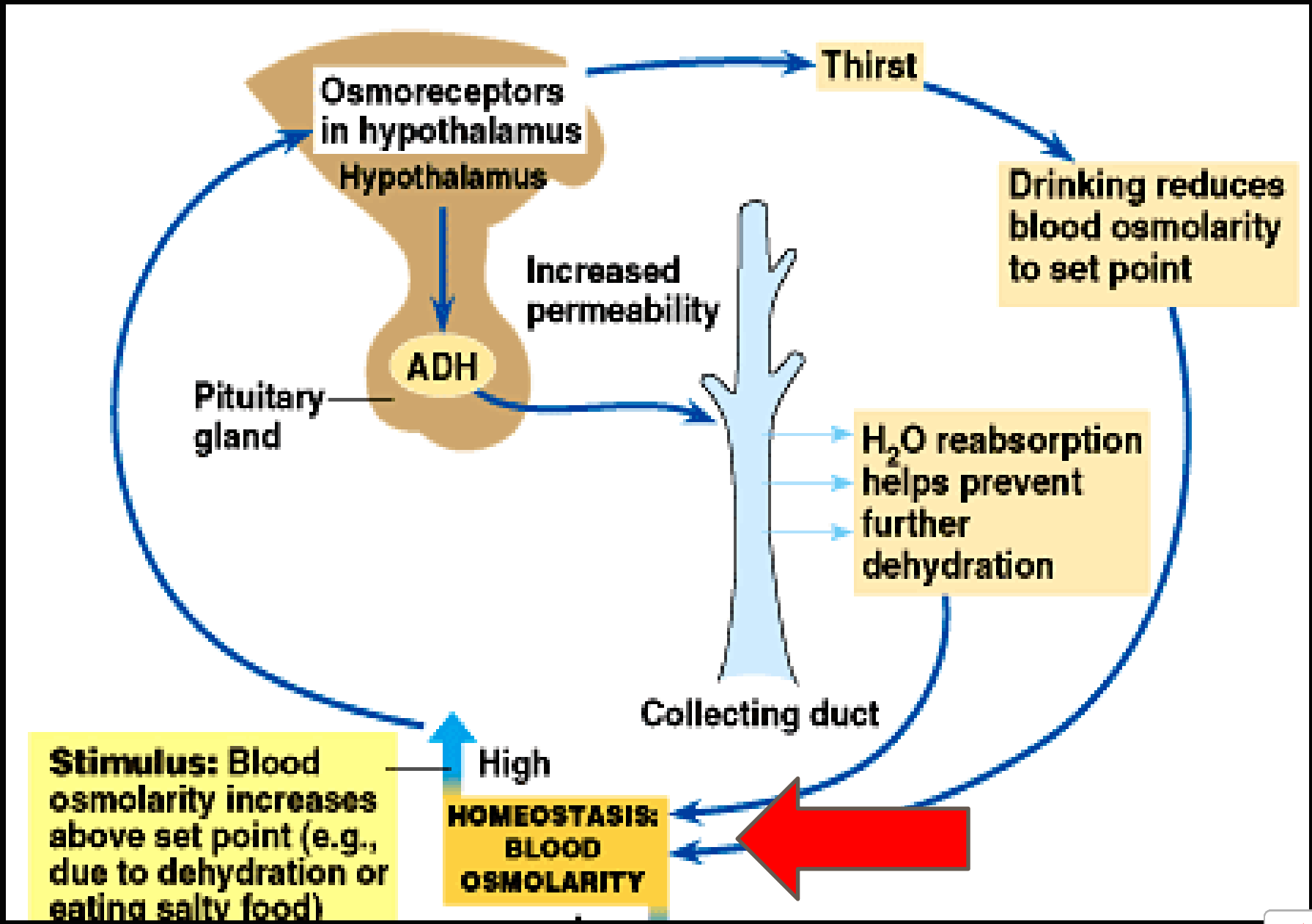
Juxtaglomerular apparatus

- Juxtaglomerular cells lie in the wall of afferent arteriole
- Macula densa in final portion of loop of Henle – monitor Na^+ and Cl^- conc. and water
- Control blood flow into the glomerulus
- Control glomerular filtration






Osmoreceptors in hypothalamus
Hypothalamus
Thirst
Drinking reduces blood osmolarity to set point
Increased permeability
ADH
Pituitary gland
H_2O reabsorption helps prevent further dehydration
Collecting duct
Stimulus: Blood osmolarity increases above set point (e.g., due to dehydration or eating salty food)
High
HOMEOSTASIS: BLOOD OSMOLARITY
Low
(a)
Angio-tensin II
Angio-tensinogen
Distal tubule
JGA
Adrenal gland
Aldosterone
Arteriole constriction
Renin
Renin production
Increased Na^+ and H_2O reabsorption in distal tubules
High
HOMEOSTASIS: BLOOD PRESSURE, VOLUME
Stimulus: Low blood volume or blood pressure (e.g., due to dehydration or loss of blood)
Low
(b)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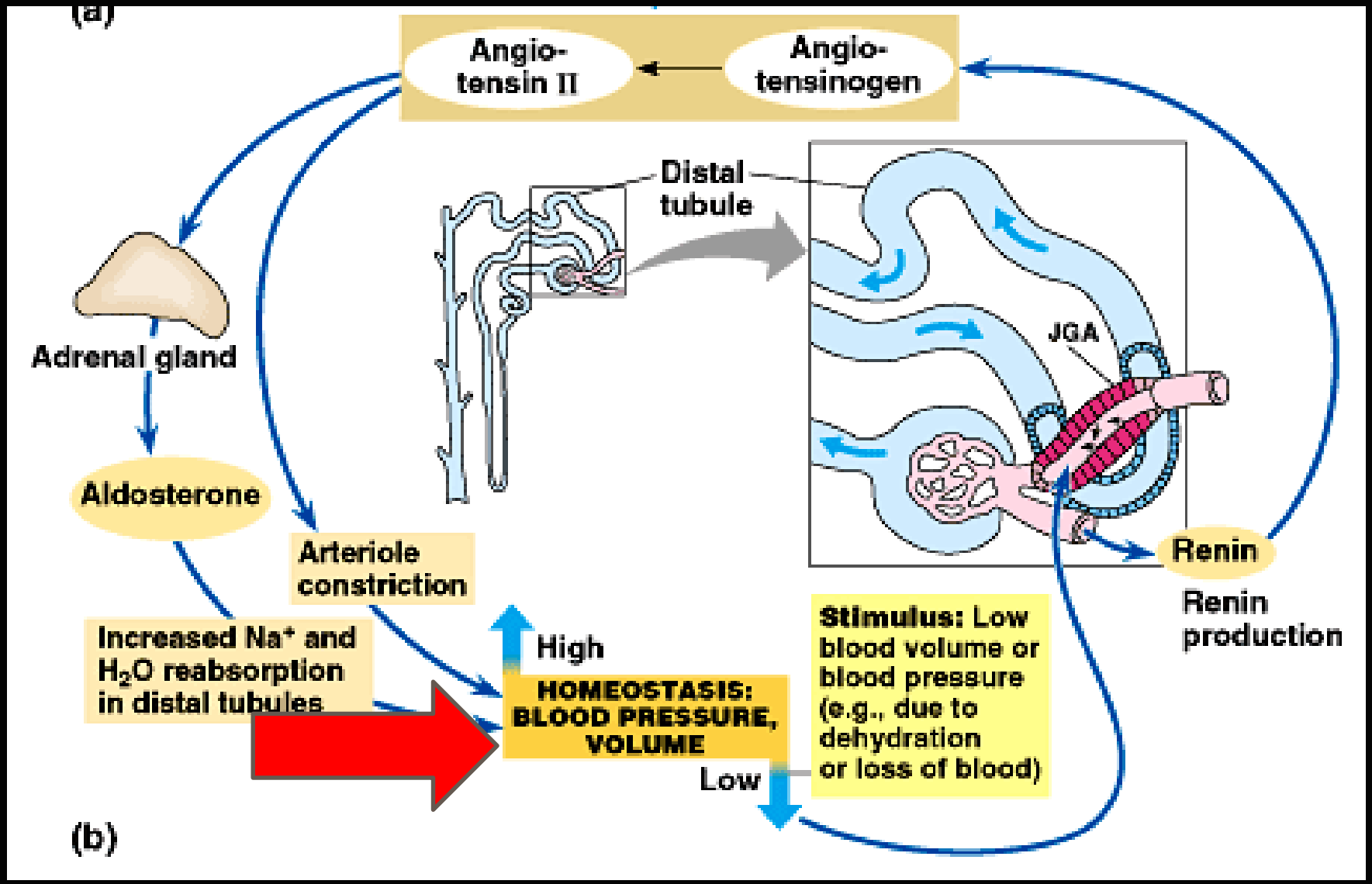
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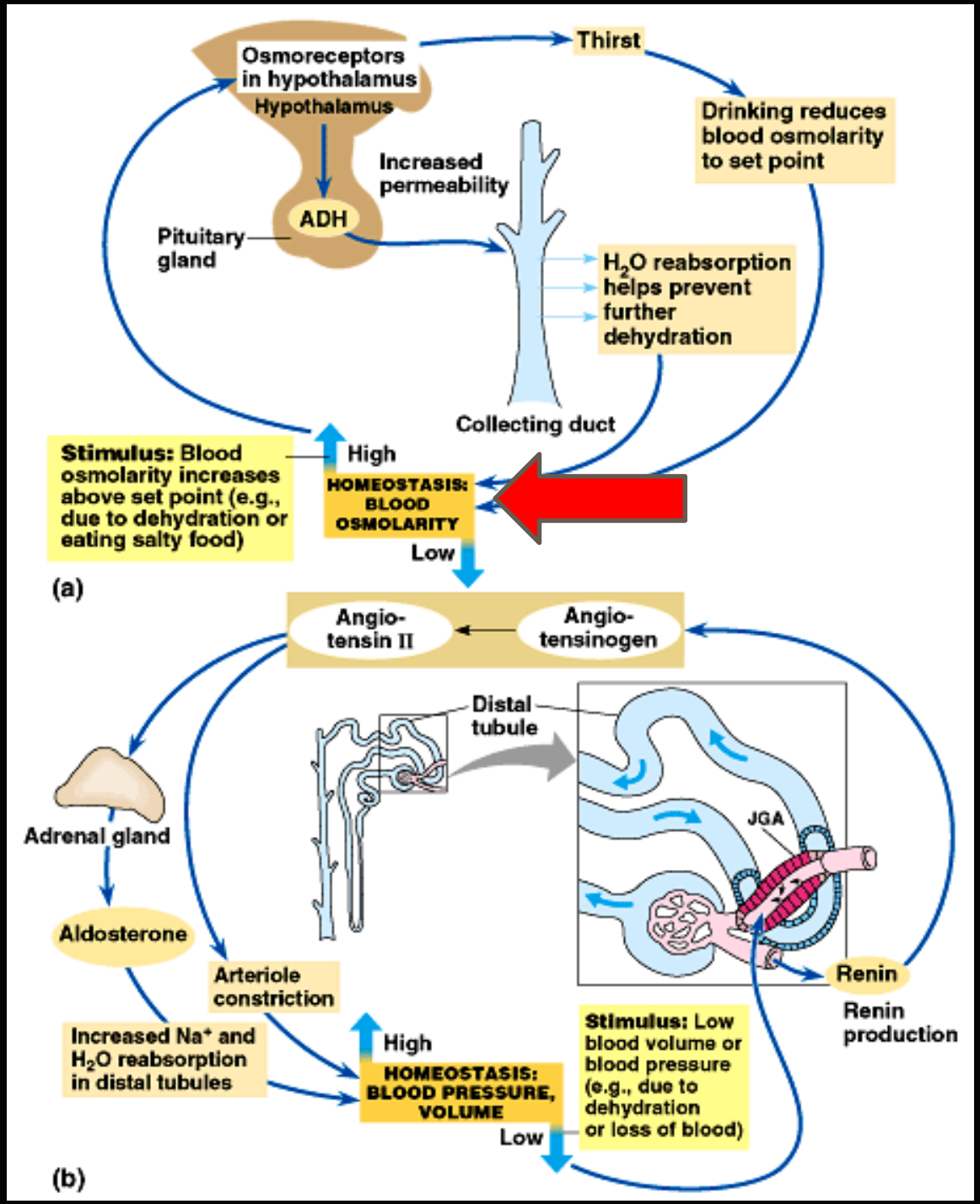
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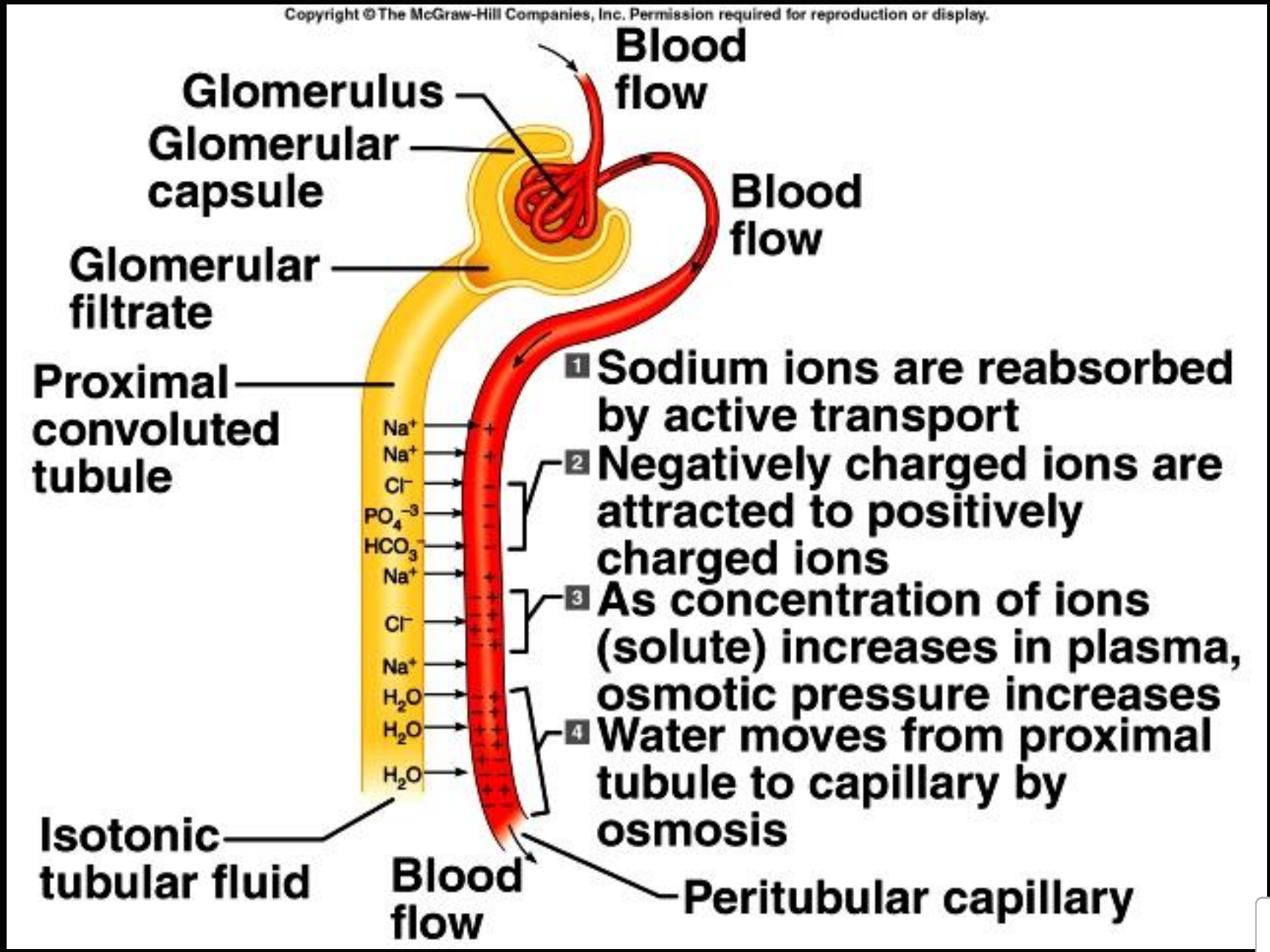
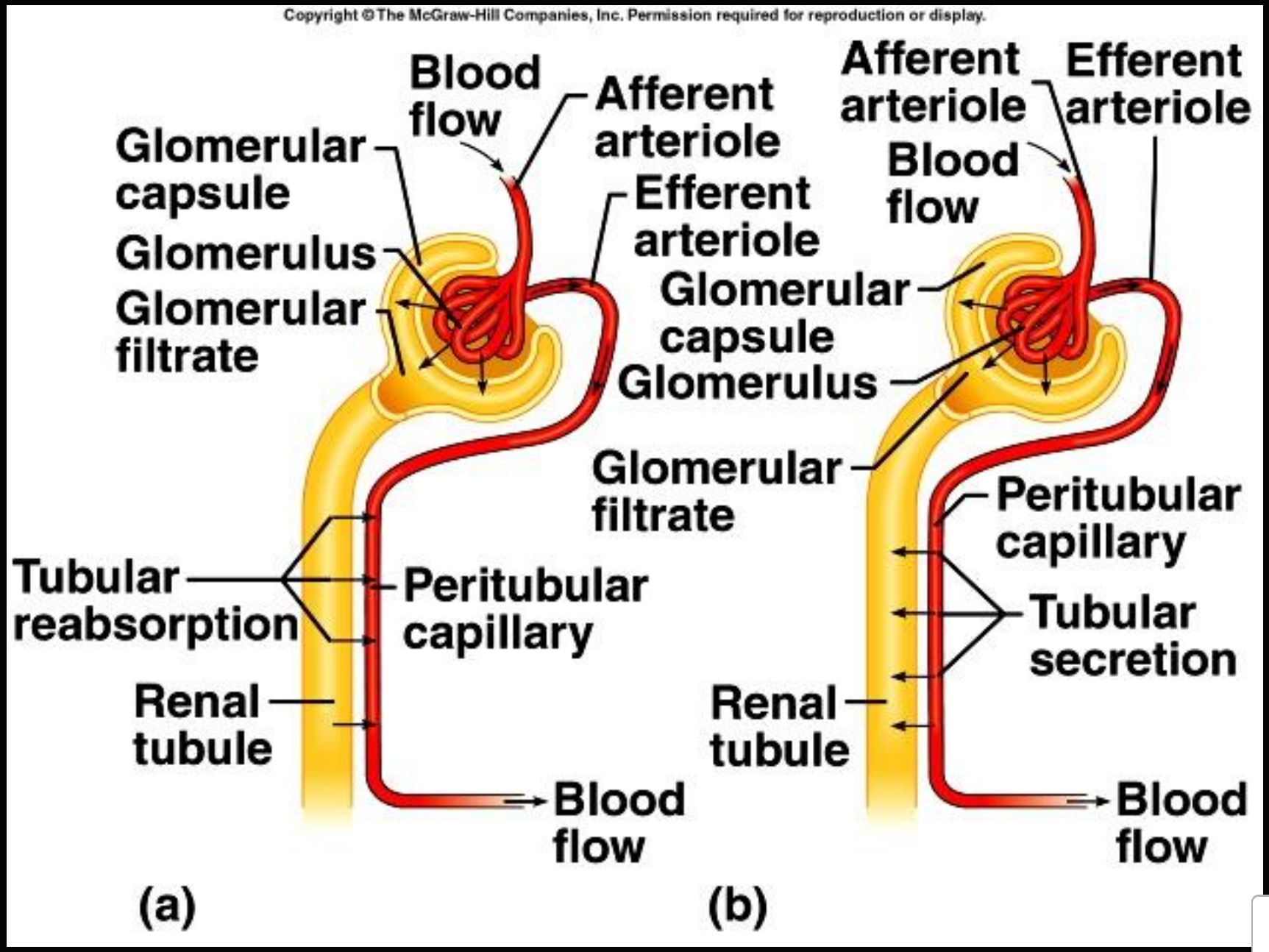
Stimulus: Low blood volume or blood pressure (e.g., due to dehydration or loss of blood)
Low
(b)

Tubular reabsorption

- Water, glucose, amino acids, urea, ions
- Sodium diffuses into cell; actively pumped out – drawing water with it



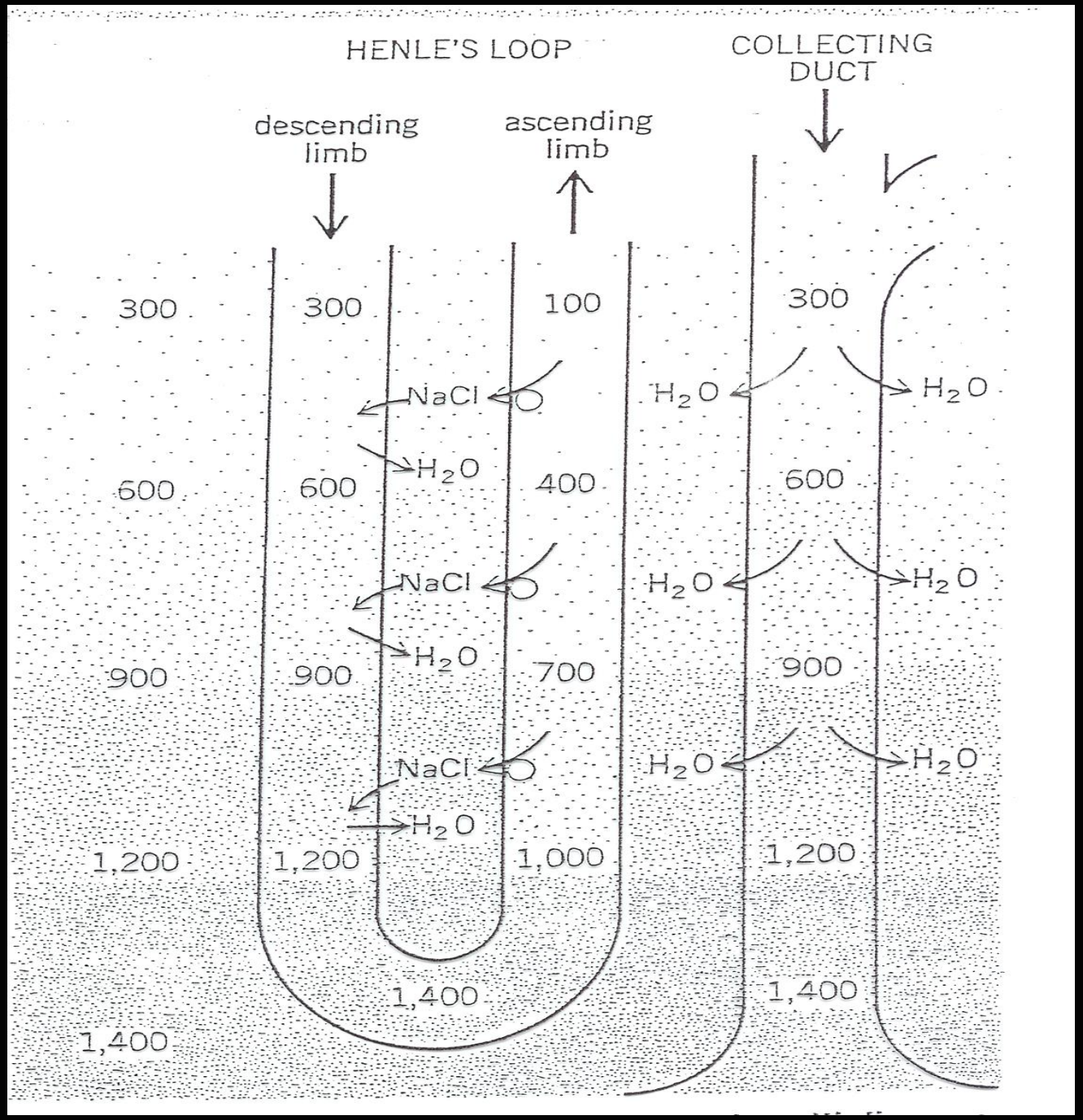
- In addition to reabsorption, also have tubular secretion – substances move from peritubular capillaries into tubules – a second chance to remove substances from blood.



- By end of proximal tubule have reabsorbed:
- 60- 70% of water and sodium
- about 100% of glucose and amino acids
- 90 % of K+, bicarb, Ca++, uric acid
- **Transport maximum** – maximum amount of a substance that can be absorbed per unit time
- **Renal threshold** – plasma conc. of a substance at which it exceeds Tm.

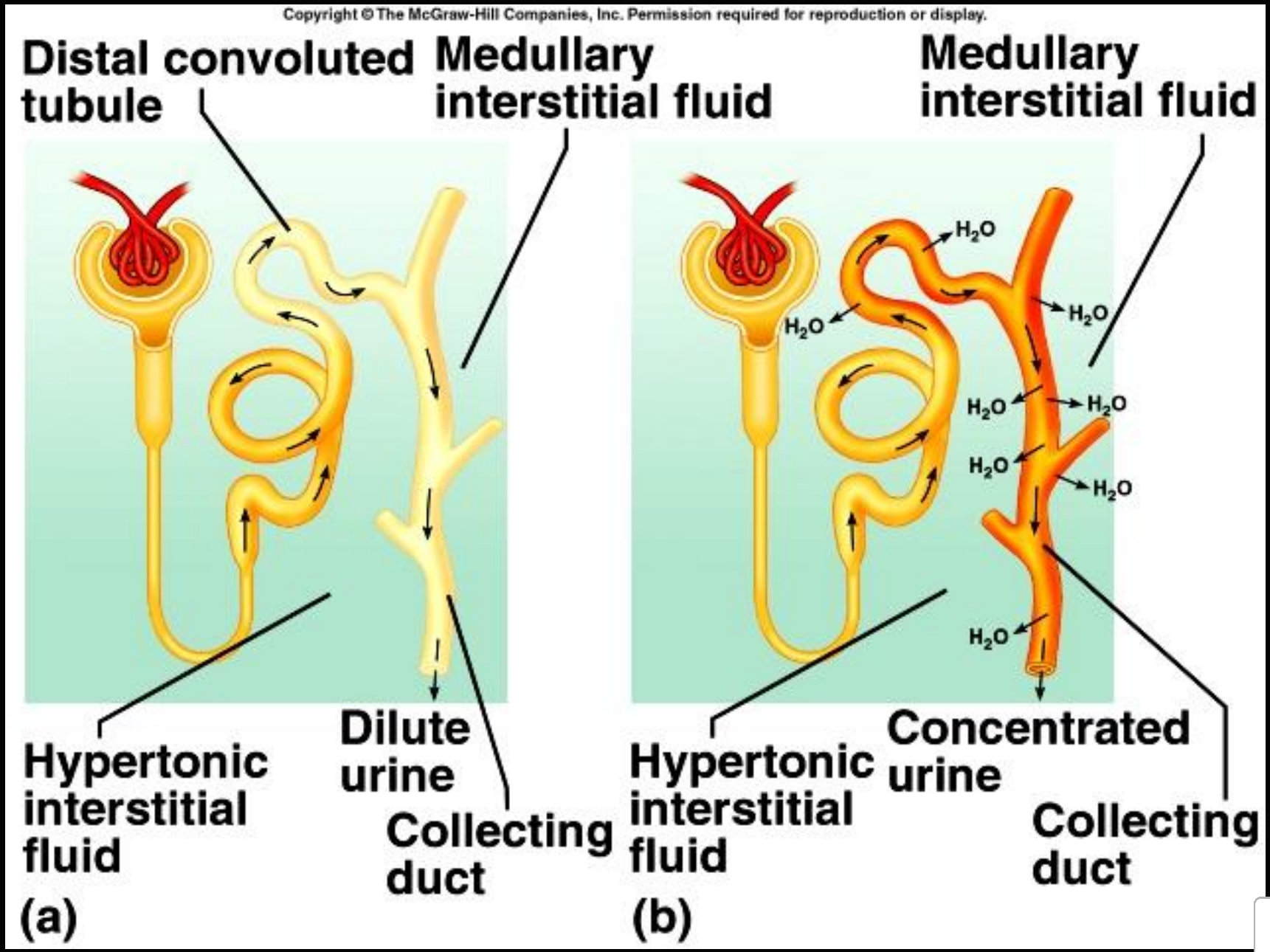
Loop of Henle

- Responsible for producing a concentrated urine by forming a concentration gradient within the medulla of kidney.
- When ADH is present, water is reabsorbed and urine is concentrated.
- Counter-current multiplier


HENLE'S LOOP
COLLECTING DUCT
descending limb
ascending limb
300
300
100
300
NaCl
H_2O
H_2O
H_2O
600
600
400
600
NaCl
H_2O
H_2O
H_2O
900
900
700
900
NaCl
H_2O
H_2O
H_2O
1,200
1,200
1,000
1,200
1,400
1,400
1,400

Distal convoluted tubule and collecting ducts

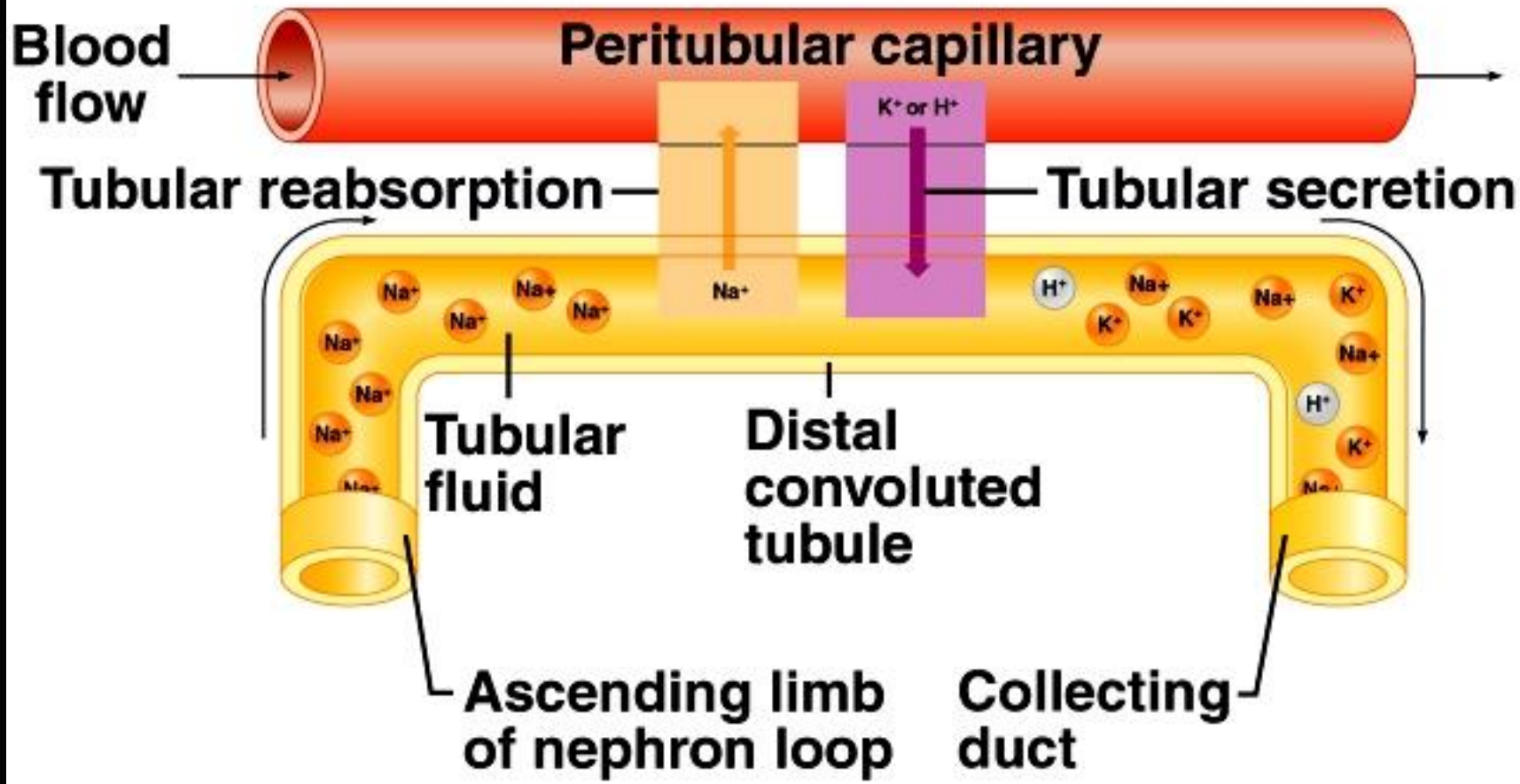
- What happens here depends on ADH
- Aldosterone affects Na+ and K+
- ADH – facultative water reabsorption
- Parathyroid hormone – increases Ca++ reabsorption



Distal convoluted tubule and collecting ducts

- Tubular secretion to rid body of substances: K+, H+, urea, ammonia, creatinine and certain drugs
- Secretion of H+ helps maintain blood pH

  (can also reabsorb bicarb and generate new bicarb)



Atrial natriuretic peptide(ANP)

- ANP is released by atrium in response to atrial stretching due to increased blood volume

- ANP inhibits Na^+ and water reabsorption, also inhibits ADH secretion

- Thus promotes increased sodium excretion (natriuresis) and water excretion (diuresis) in urine

- 1) APs generated by stretch receptors
- 2) reflex arc generates APs that
- 3) stimulate smooth muscle lining bladder
- 4) relax internal urethral sphincter (IUS)
- 5) stretch receptors also send APs to Pons
- 6) if it is o.k. to urinate
  - –APs from Pons excite smooth muscle of bladder and relax IUS
  - –relax external urethral sphincter
- 7) if not o.k.
  - –APs from Pons keep
    - EUS contracted

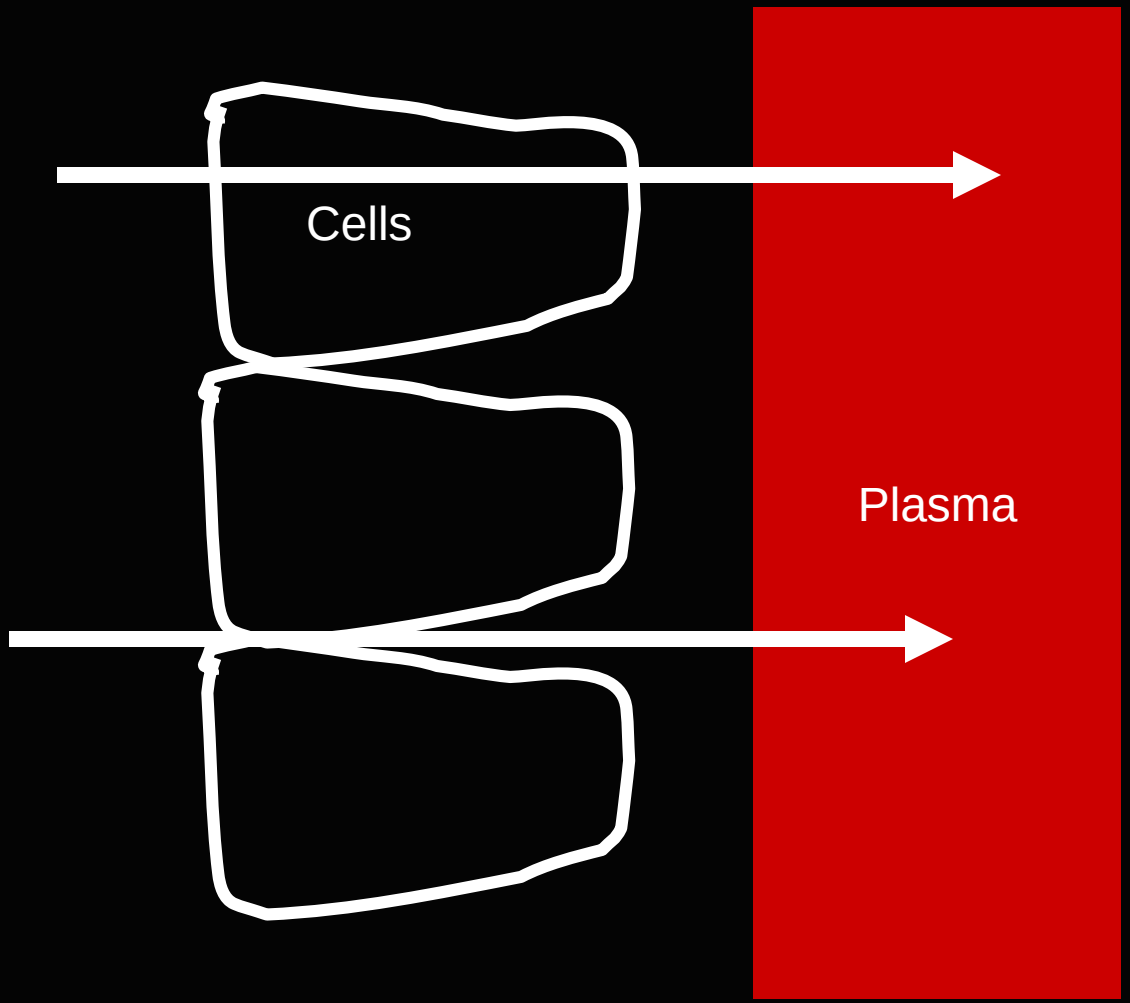
Reabsorption and Secretion

Concept of Reabsorption and Secretion

Filtration, reabsoption, and excretion rates of substances by the kidneys

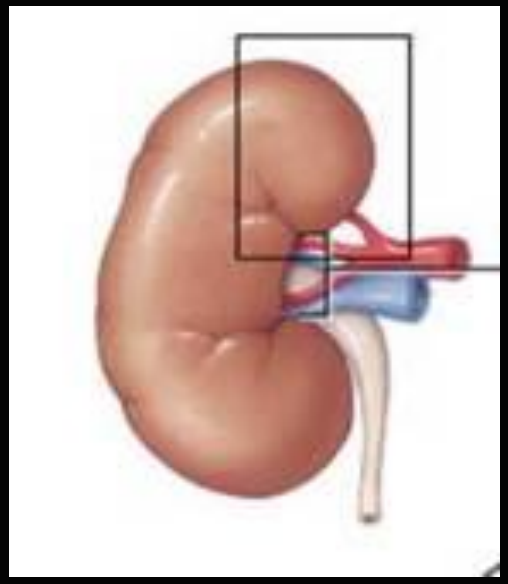
		Filtered (meq/24h)	Reabsorbed (meq/24h)	Excreted (meq/24h)	Reabsorbed (%)
Glucose	(g/day)	180	180	0	100
Bicarbonate	(meq/day)	4,320	4,318	2	> 99.9
Sodium	(meq/day)	25,560	25,410	150	99.4
Chloride	(meq/day)	19,440	19,260	180	99.1
Water	(l/day)	169	167.5	1.5	99.1
Urea	(g/day)	48	24	24	50
Creatinine	(g/day)	1.8	0	1.8	0

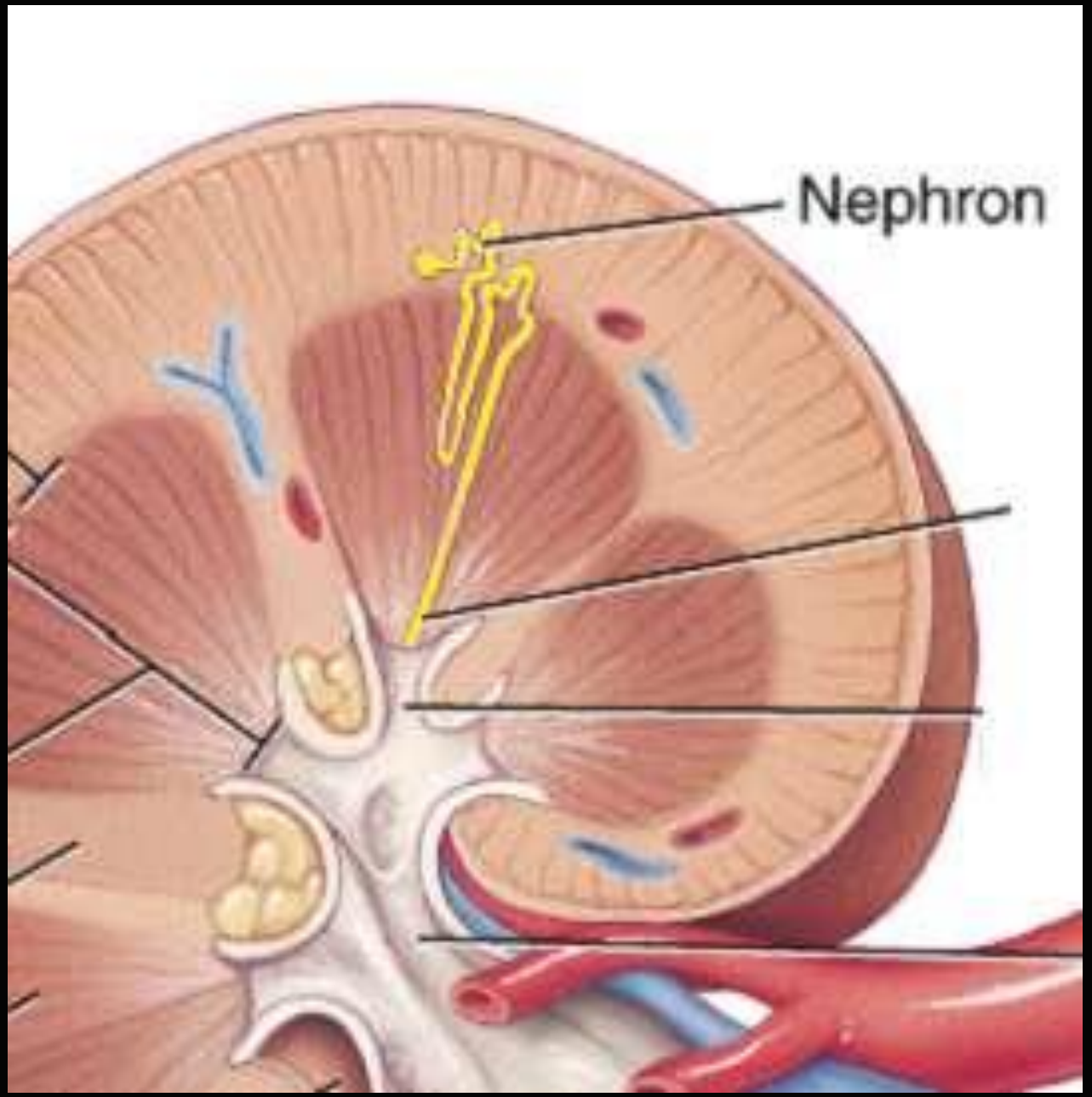
Two pathways of the absorption:



بسم الله الرحمن الرحيم

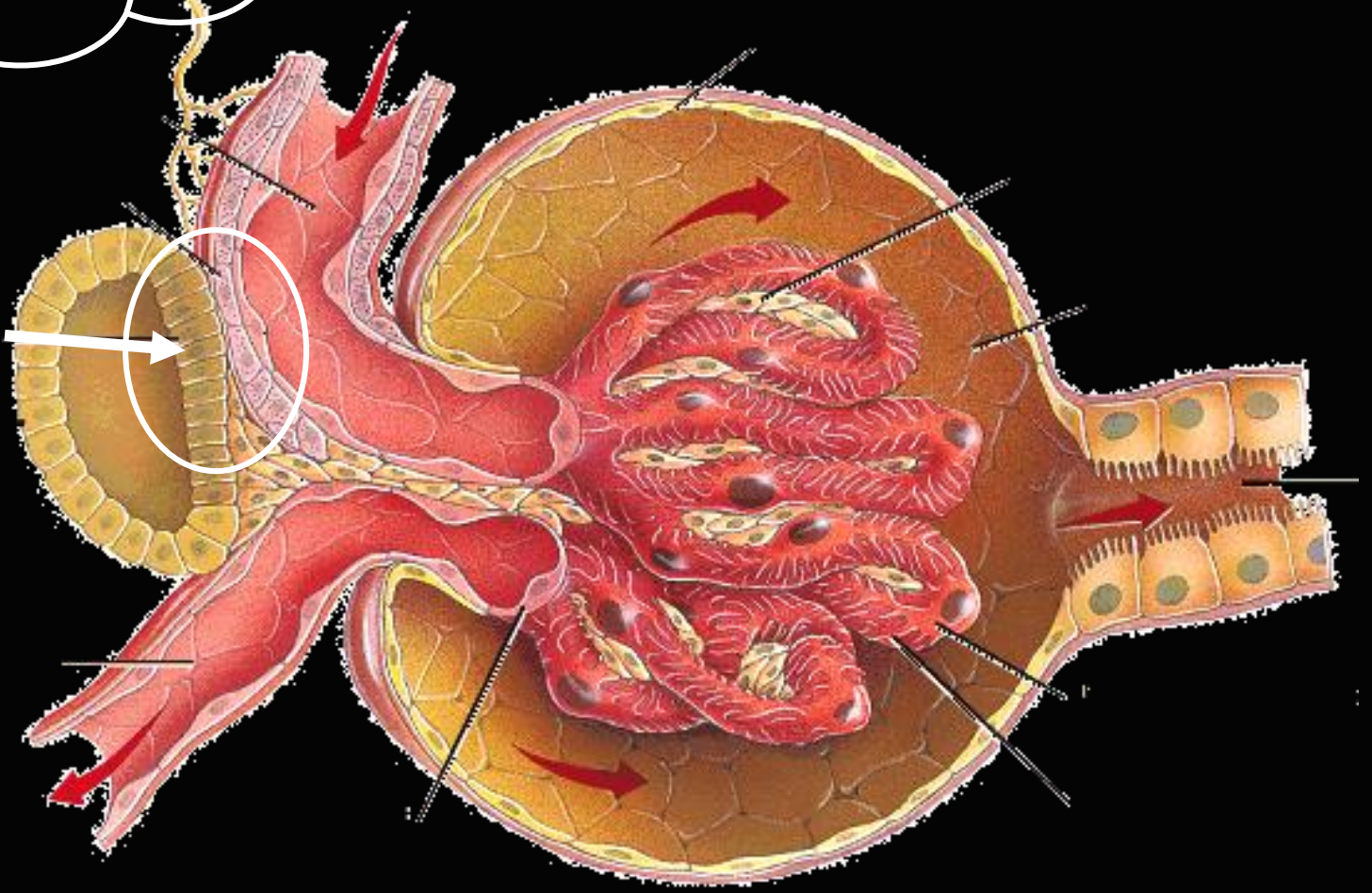
3



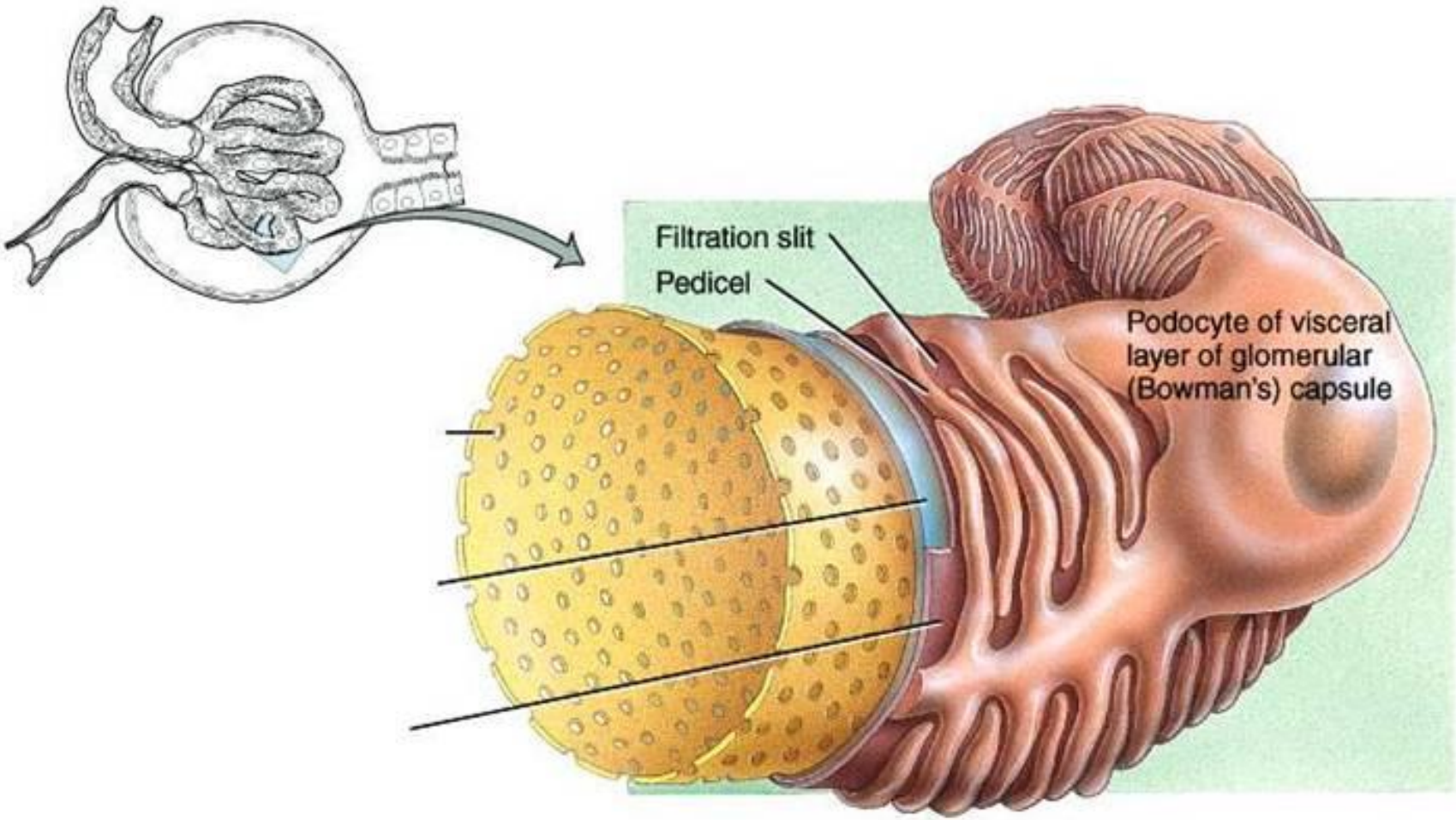

Nephron

GFR → Renin
→Angiotensin
Blood Pressure

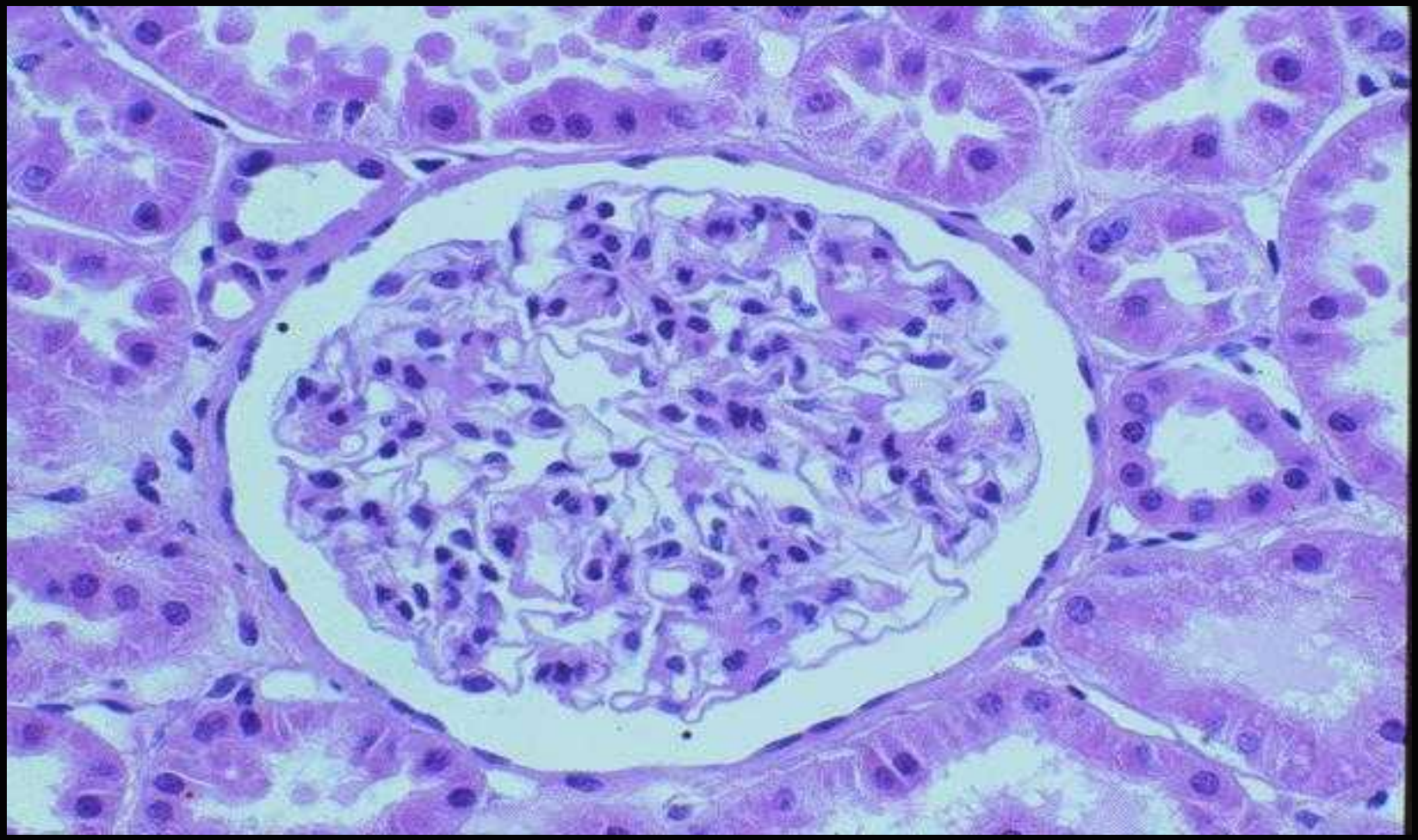
JGA



Filtration Membrane:



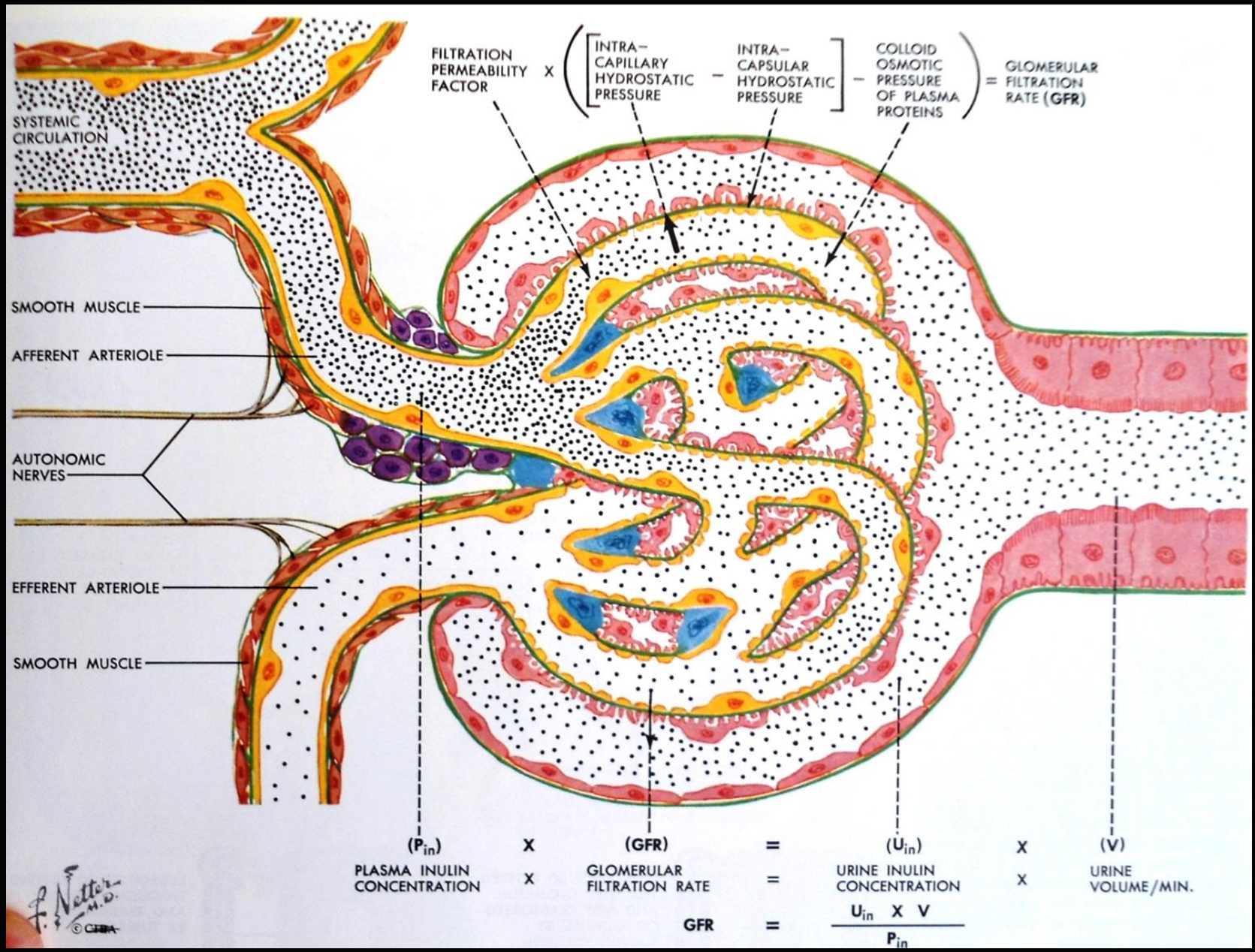
Normal Kidney:



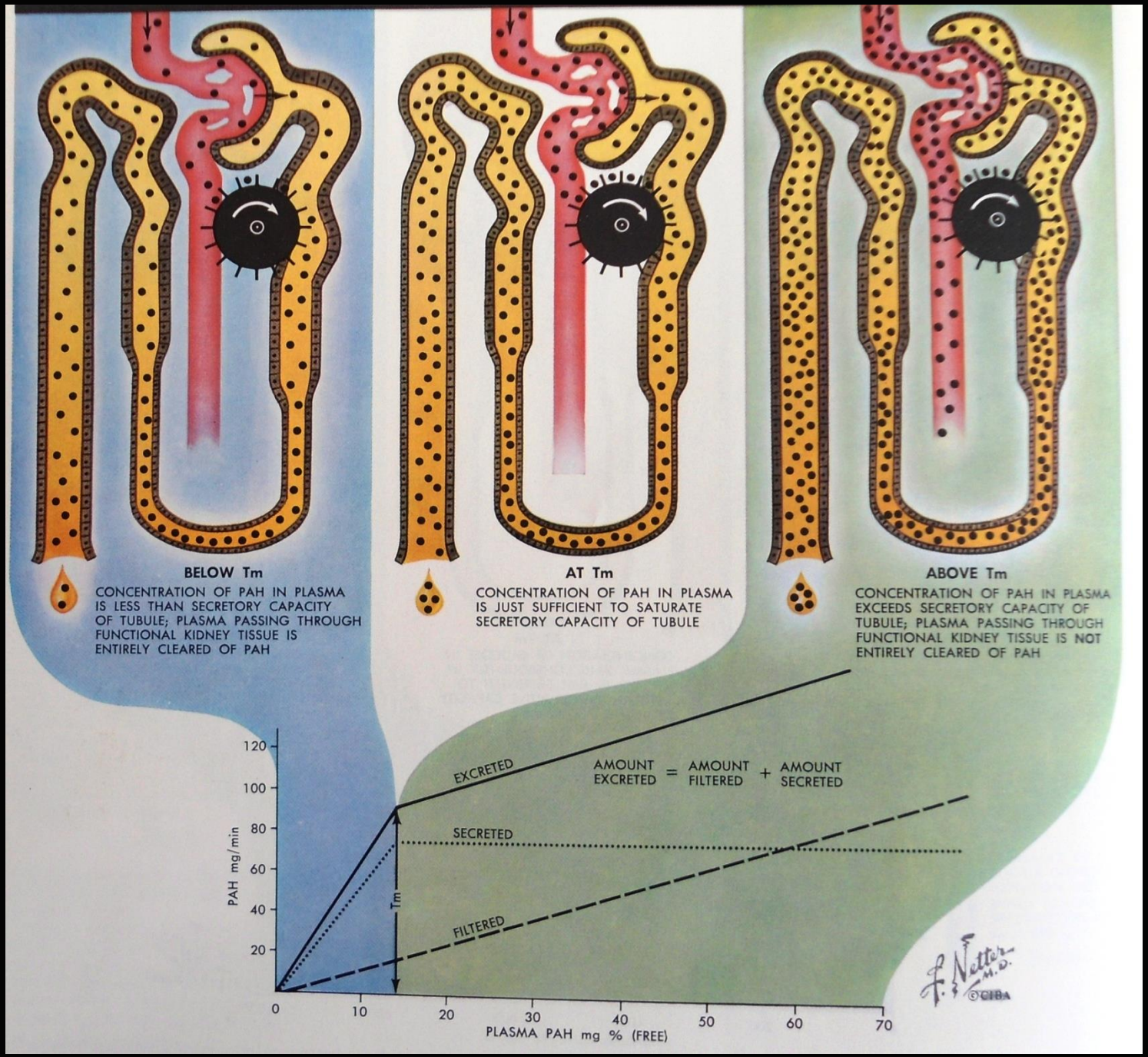
Diagnostic testing

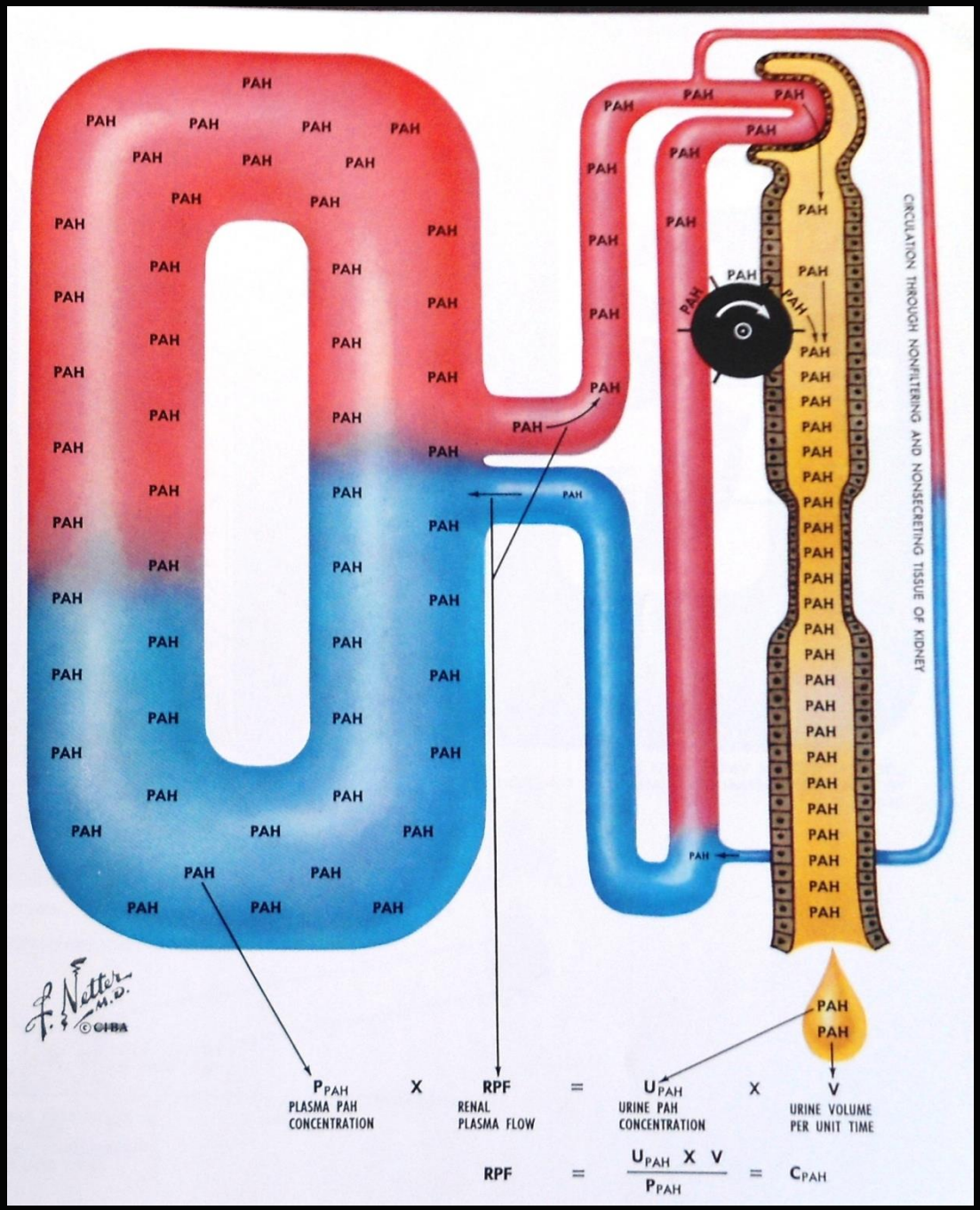
- Inulin clearance not absorbed or secreted = GFR

- PAH not absorbed ; actively secreted = renal plasma flow (RPF)


FILTRATION PERMEABILITY FACTOR
X
INTRA-CAPILLARY HYDROSTATIC PRESSURE
–
INTRA-CAPSULAR HYDROSTATIC PRESSURE
–
COLLOID OSMOTIC PRESSURE OF PLASMA PROTEINS
= GLOMERULAR FILTRATION RATE (GFR)
SYSTEMIC CIRCULATION
SMOOTH MUSCLE
AFFERENT ARTERIOLE
AUTONOMIC NERVES
EFFERENT ARTERIOLE
SMOOTH MUSCLE
(Pin) X (GFR) = (Uin) X (V)
PLASMA INULIN CONCENTRATION X GLOMERULAR FILTRATION RATE = URINE INULIN CONCENTRATION X URINE VOLUME/MIN.
GFR = Uin X V / Pin
F. Netter M.D.
© CIBA

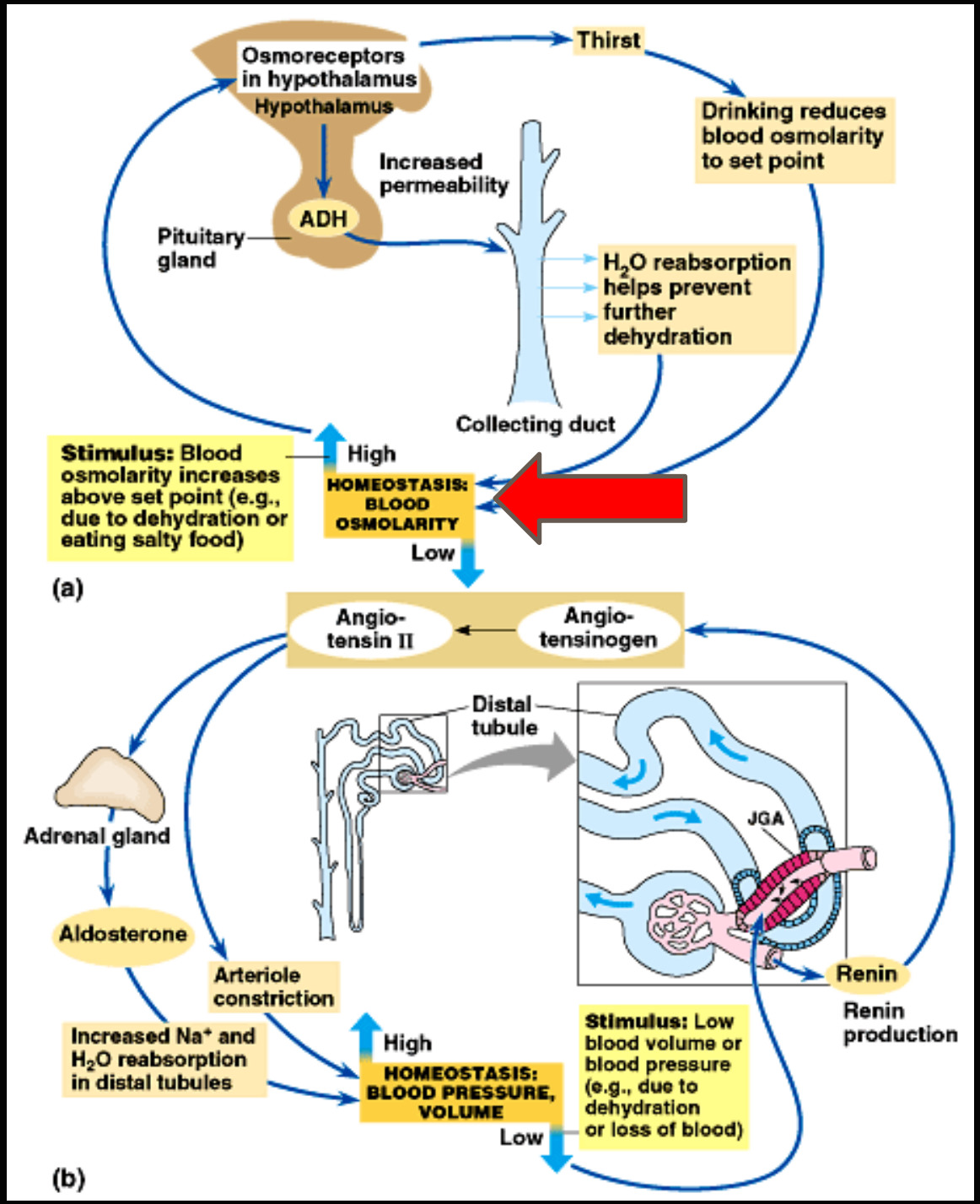
PAH

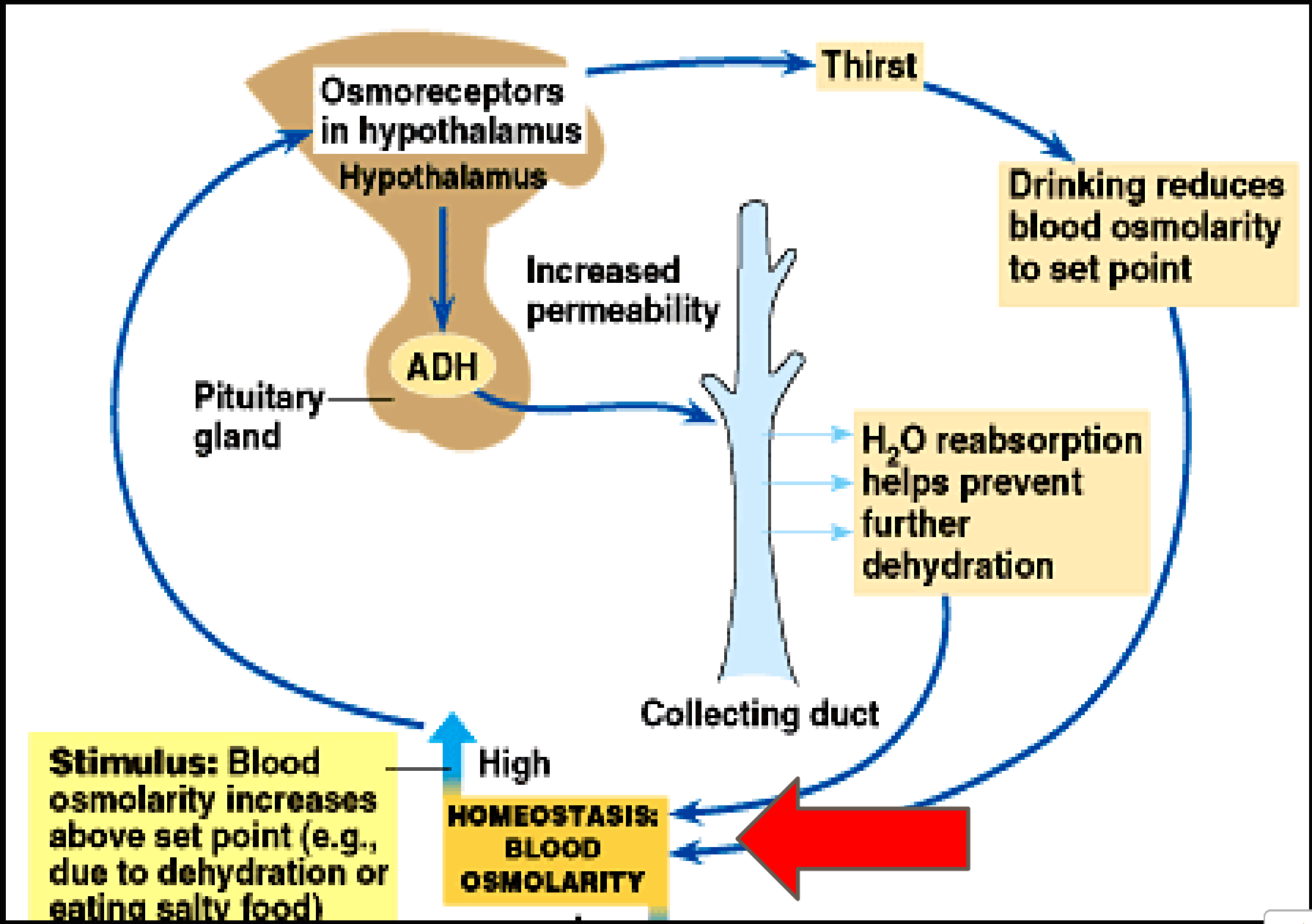

BELOW Tm
CONCENTRATION OF PAH IN PLASMA IS LESS THAN SECRETORY CAPACITY OF TUBULE; PLASMA PASSING THROUGH FUNCTIONAL KIDNEY TISSUE IS ENTIRELY CLEARED OF PAH
AT Tm
CONCENTRATION OF PAH IN PLASMA IS JUST SUFFICIENT TO SATURATE SECRETORY CAPACITY OF TUBULE
ABOVE Tm
CONCENTRATION OF PAH IN PLASMA EXCEEDS SECRETORY CAPACITY OF TUBULE; PLASMA PASSING THROUGH FUNCTIONAL KIDNEY TISSUE IS NOT ENTIRELY CLEARED OF PAH
EXCRETED
SECRETED
FILTERED
AMOUNT EXCRETED = AMOUNT FILTERED + AMOUNT SECRETED
Tm
PAH mg/min
120
100
80
60
40
20
0
10
20
30
40
50
60
70
PLASMA PAH mg % (FREE)
F. Netter M.D.
©CIBA


PAH
CIRCULATION THROUGH NONFILTERING AND NONSECRETING TISSUE OF KIDNEY
F. Netter M.D.
©CIBA
P_{PAH} PLASMA PAH CONCENTRATION
X
RPF RENAL PLASMA FLOW
=
U_{PAH} URINE PAH CONCENTRATION
X
V URINE VOLUME PER UNIT TIME
$RPF = \frac{U_{PAH} \times V}{P_{PAH}} = C_{PAH}$

PAH

RPF


Osmoreceptors in hypothalamus
Hypothalamus
Thirst
Drinking reduces blood osmolarity to set point
Increased permeability
ADH
Pituitary gland
H_2O reabsorption helps prevent further dehydration
Collecting duct
Stimulus: Blood osmolarity increases above set point (e.g., due to dehydration or eating salty food)
High
HOMEOSTASIS: BLOOD OSMOLARITY
Low
(a)
Angio-tensin II
Angio-tensinogen
Distal tubule
JGA
Adrenal gland
Aldosterone
Arteriole constriction
Renin
Renin production
Increased Na^+ and H_2O reabsorption in distal tubules
High
HOMEOSTASIS: BLOOD PRESSURE, VOLUME
Stimulus: Low blood volume or blood pressure (e.g., due to dehydration or loss of blood)
Low
(b)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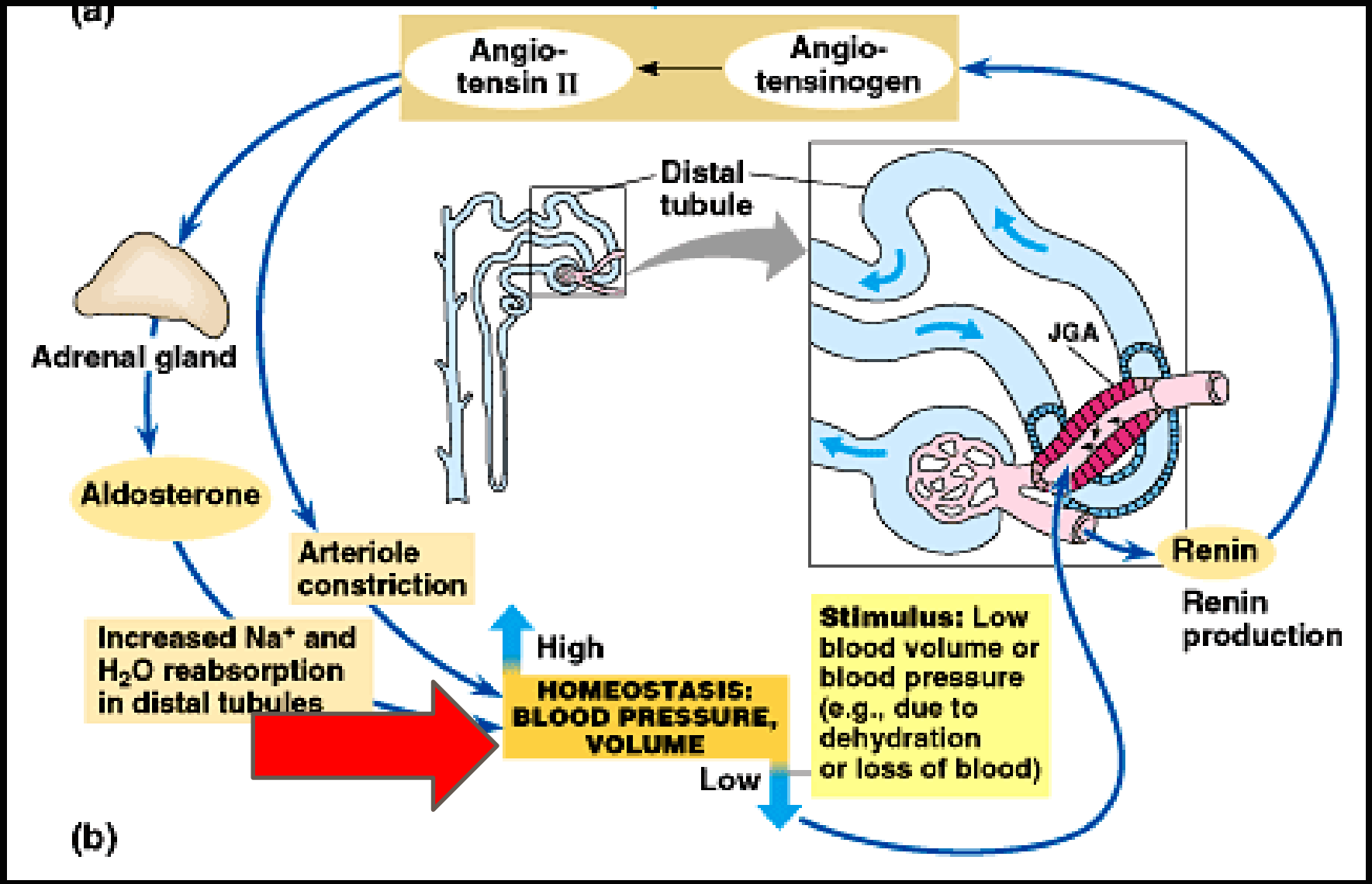
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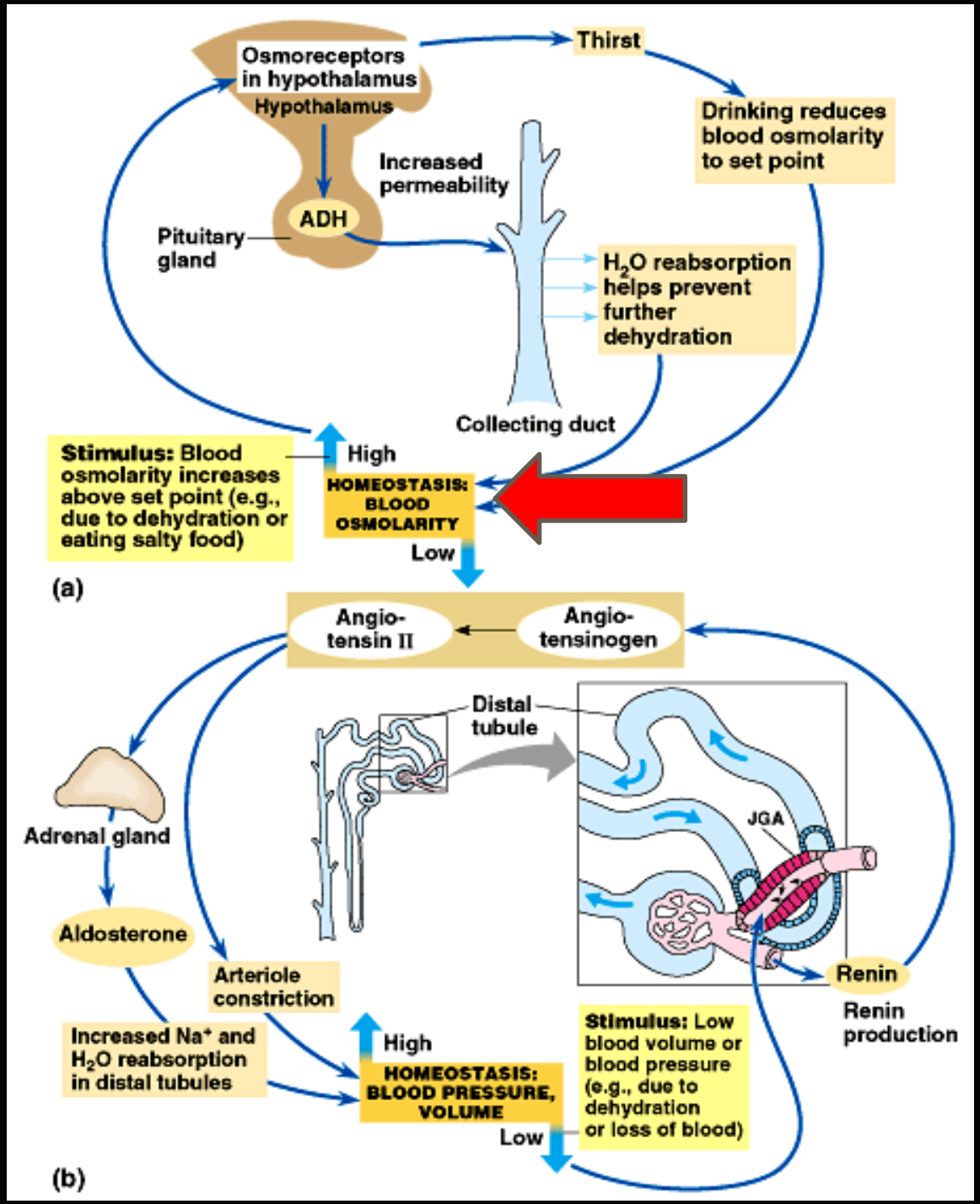
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Stimulus: Low blood volume or blood pressure (e.g., due to dehydration or loss of blood)
Low
(b)

Mechanism of Transport

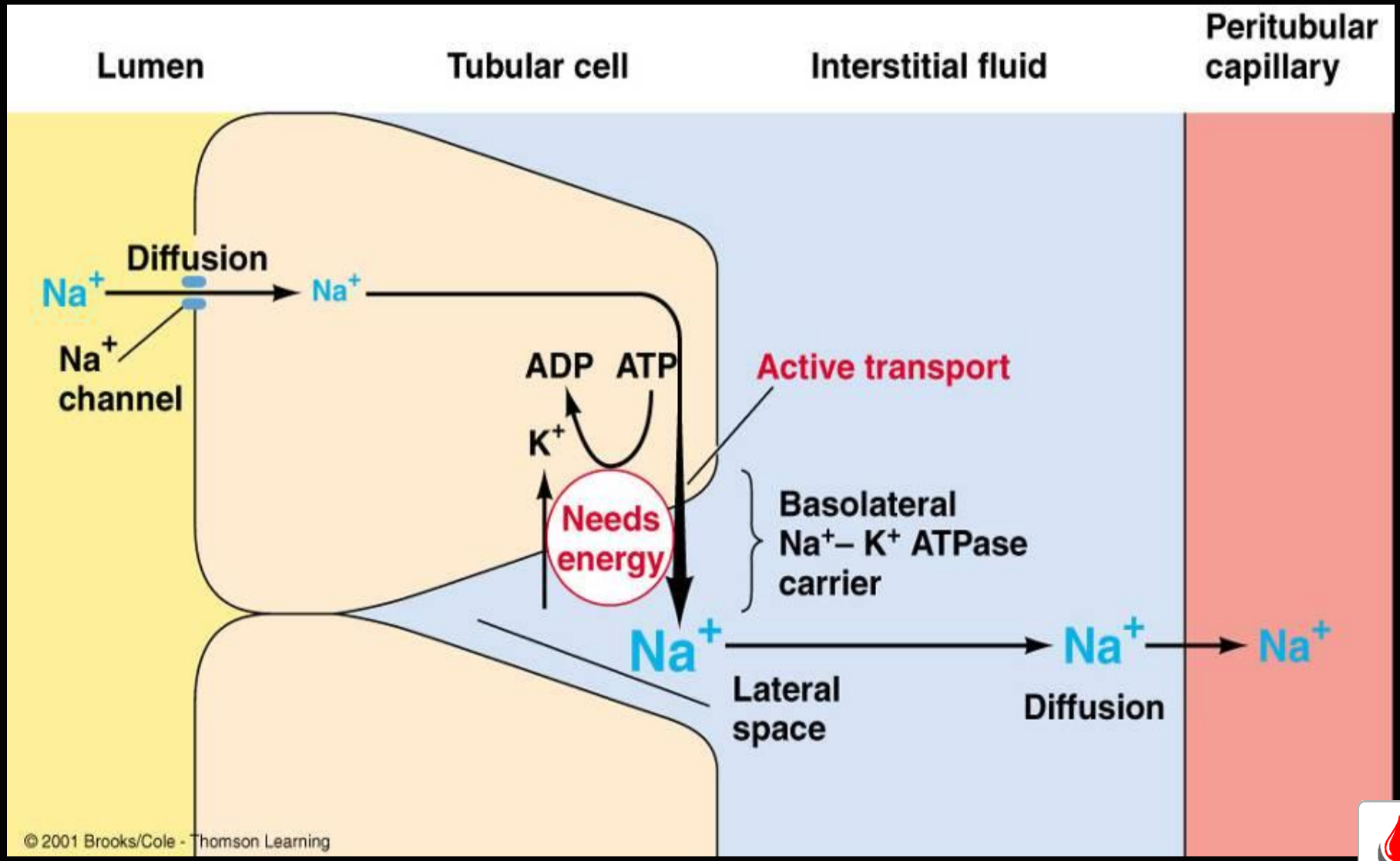
1, Primary Active Transport

2, Secondary Active Transport

3, Pinocytosis

4, Passive Transport

Primary Active Transport



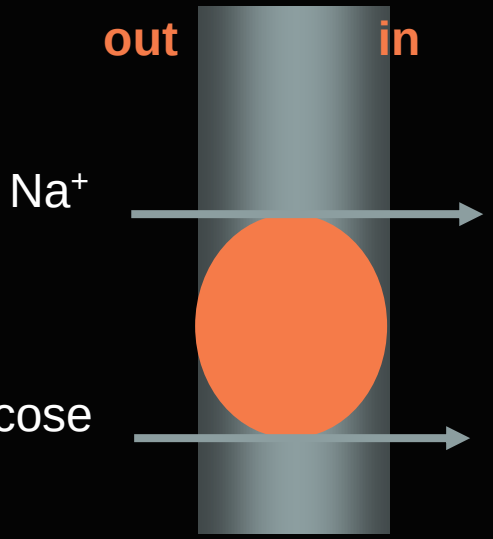
Secondary active transport

Tubular lumen

Tubular Cell

Interstitial Fluid

co-transport (symport)



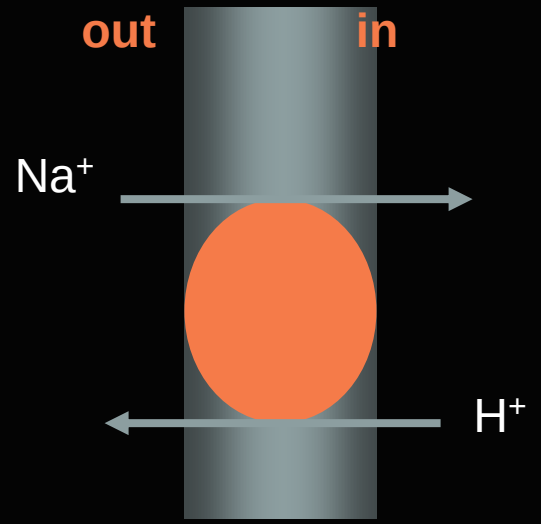
Co-transporters will move one moiety, e.g. glucose, in the same direction as the Na^+.

Tubular lumen

Tubular Cell

Interstitial Fluid

counter-transport (antiport)



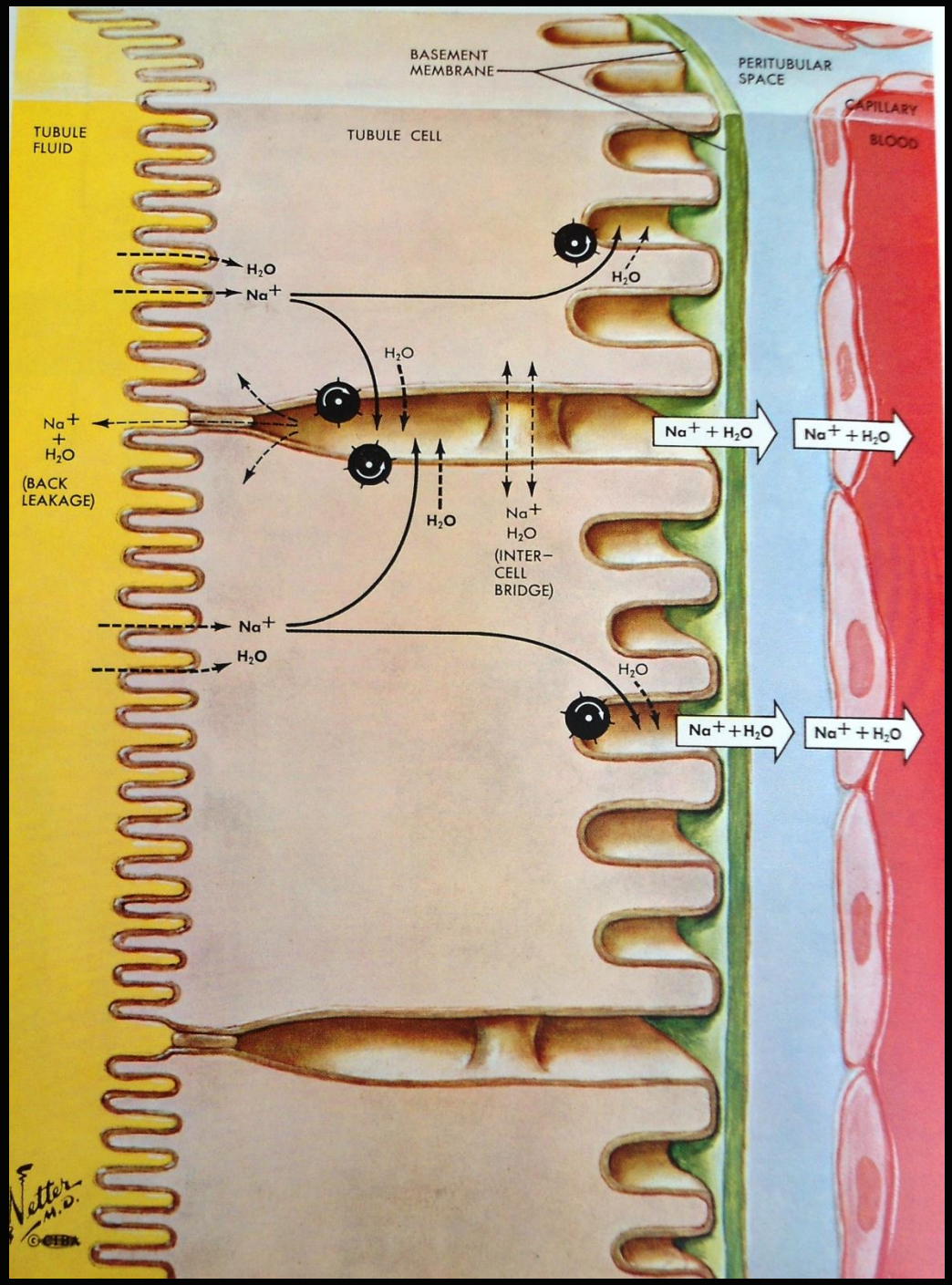
Counter-transporters will move one moiety, e.g. H^+, in the opposite direction to the Na^+.

Glucose Reabsorption

Glucose is reabsorbed along with Na^+ in the early portion of the proximal tubule.

Glucose is typical of substances removed from the urine by secondary active transport.

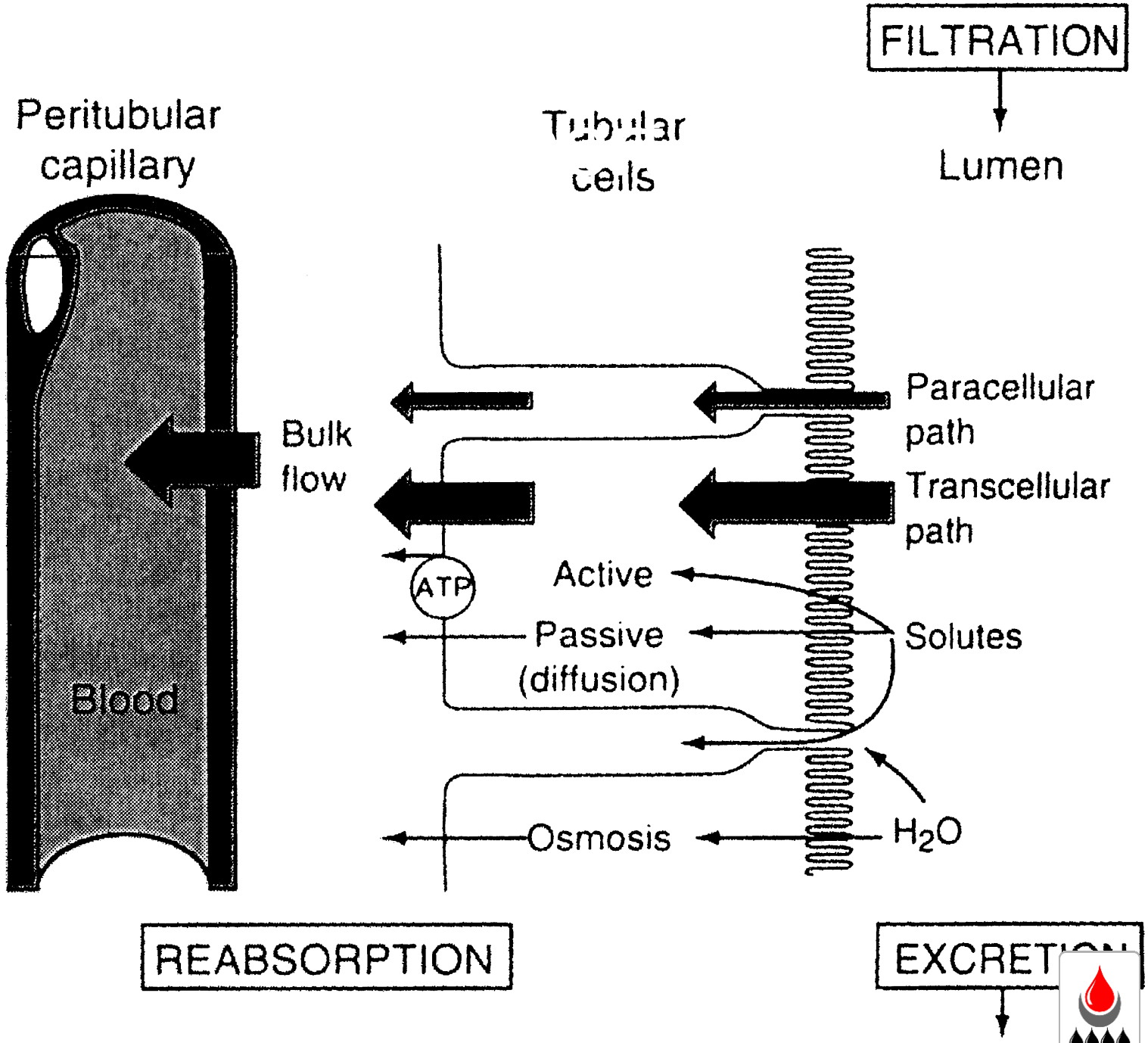
Essentially all of the glucose is reabsorbed, and no more than a few milligrams appear in the urine per 24 hours.


BASEMENT MEMBRANE
PERITUBULAR SPACE
CAPILLARY BLOOD
TUBULE FLUID
TUBULE CELL
H_2O
Na^+
$Na^+ + H_2O$
(BACK LEAKAGE)
(INTER–CELL BRIDGE)
Netter M.D.
©CIBA

Pinocytosis:

Some parts of the tubule, especially the proximal tubule, reabsorb large molecules such as proteins by pinocytosis.

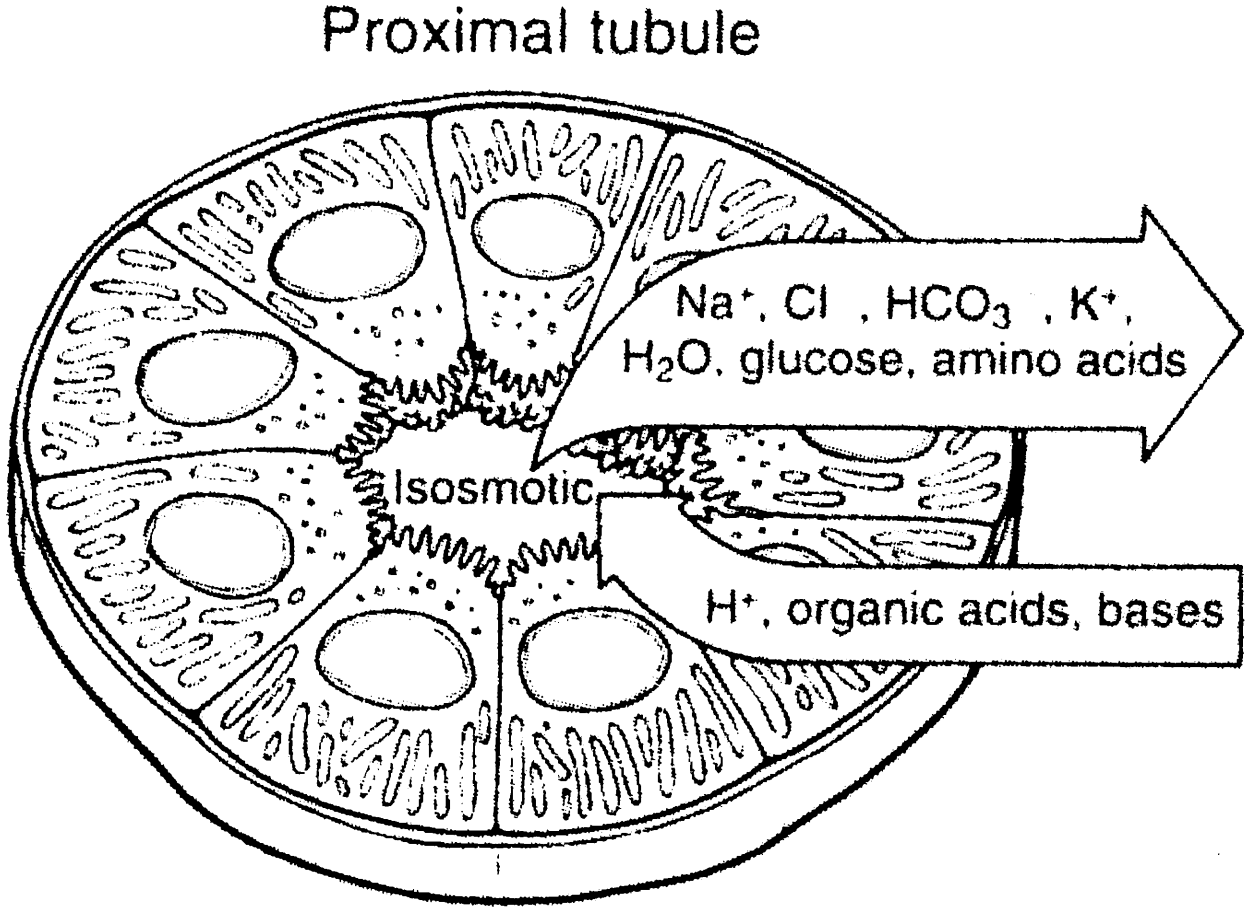
Diffusion


FILTRATION
Peritubular capillary
Tubular cells
Lumen
Bulk flow
Blood
Paracellular path
Transcellular path
ATP
Active
Passive (diffusion)
Solutes
Osmosis
H_2O
REABSORPTION
EXCRETION

1. Transportation of Sodium, Water and Chloride

(1)Sodium, water and chloride reabsorption in proximal tubule

Proximal tubule, including the proximal convoluted tubule and thick descending segment of the loop



Reabsorb about 65 percent of the filtered sodium, chloride, bicarbonate, and potassium and essentially al the filtered glucose and amino acids.

Secrete organic acids, bases, and hydrogen ions into the tubular lumen.

Sodium, water and chloride reabsorption in proximal tubule

The sodium-potassium ATPase: major force for reabsorption of sodium, chloride and water

In the first half of the proximal tubule, sodium is reabsorbed by co-transport along with glucose, amino acids, and other solutes.

In the second half of the proximal tubule, sodium reabsorbed mainly with chloride ions.

Sodium, water and chloride reabsorption in proximal tubule

The second half of the proximal tubule has a relatively high concentration of chloride (around 140mEq/L) compared with the early proximal tubule (about 105 mEq/L)

In the second half of the proximal tubule, the higher chloride concentration favors the diffusion of this ion from the tubule lumen through the intercellular junctions into the renal interstitial fluid.

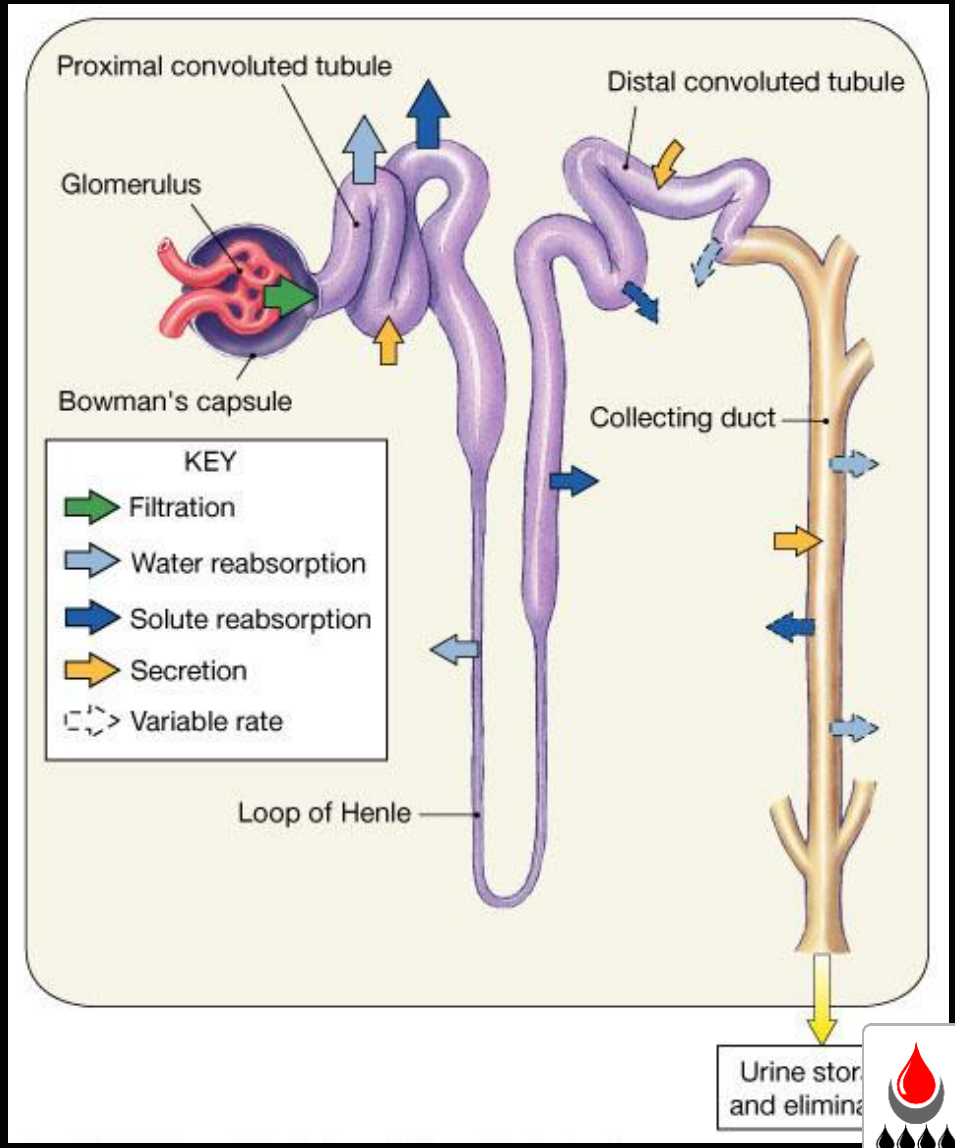
(2) Sodium and water transport in the loop of Henle

The loop of Henle consists of three functionally distinct segments:

the thin descending segment,

the thin ascending segment,

and the thick ascending segment.



Control of Calcium Excretion

(1) Calcium is both filtered and reabsorbed in the kidneys but not secreted

(2) Only about 50% of the plasma calcium is ionized, the remainder being bound to the plasma proteins.

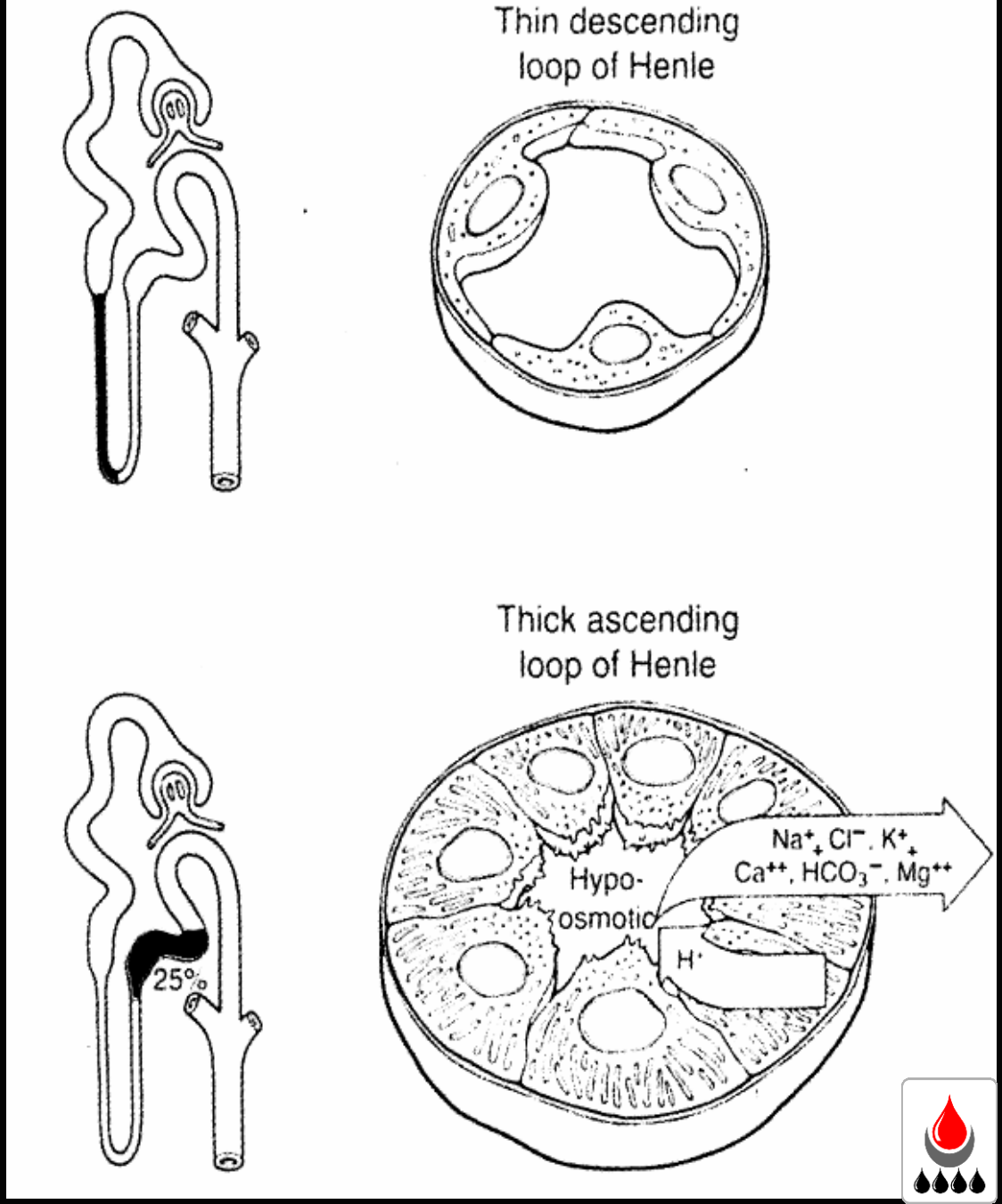
(3) Calcium excretion is adjusted to meet the body's needs.

(4) Parathyroid hormone (PTH) increases calcium reabsorption in the thick ascending lops of Henle and distal tubules, and reduces urinary excretion of calcium

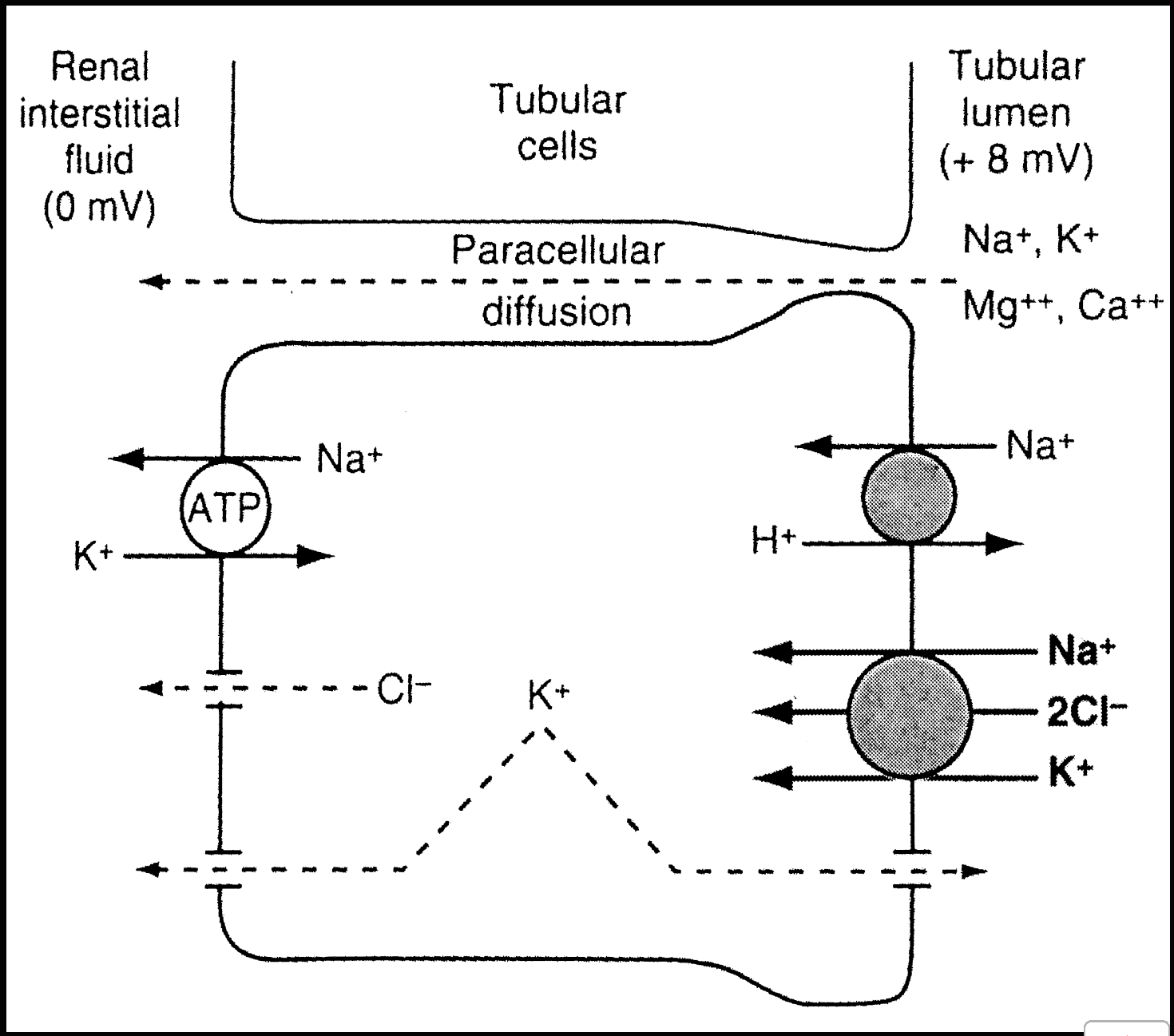
(5) little or no active reabsorption.

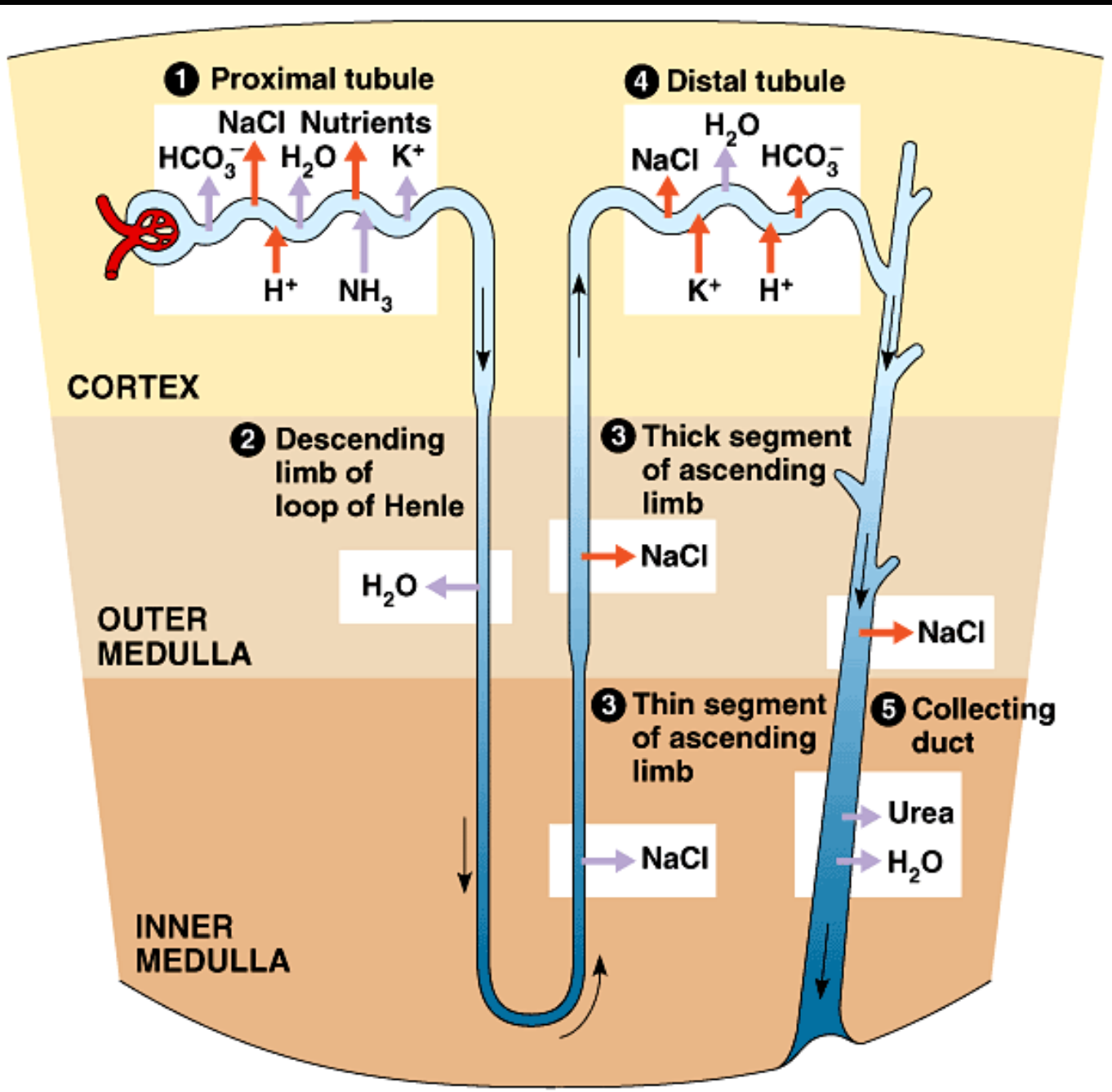
High permeable to water and moderately permeable to most solutes but has few mitochondria and little or no active reabsorption.

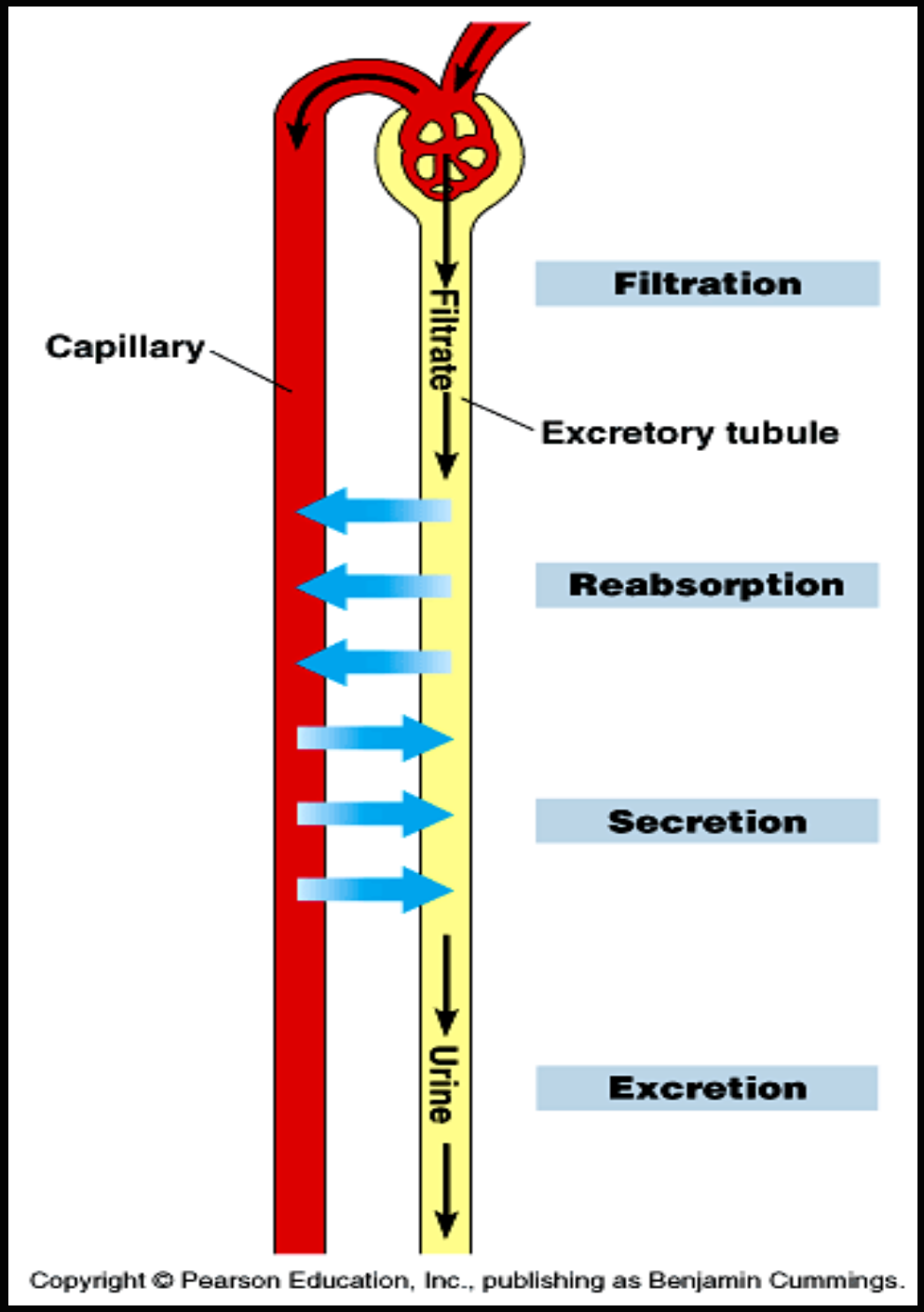
Reabsorbs about 25% of the filtered loads of sodium, chloride, and potassium, as well as large amounts of **calcium**, bicarbonate, and magnesium.
This segment also secretes hydrogen ions into the tubule

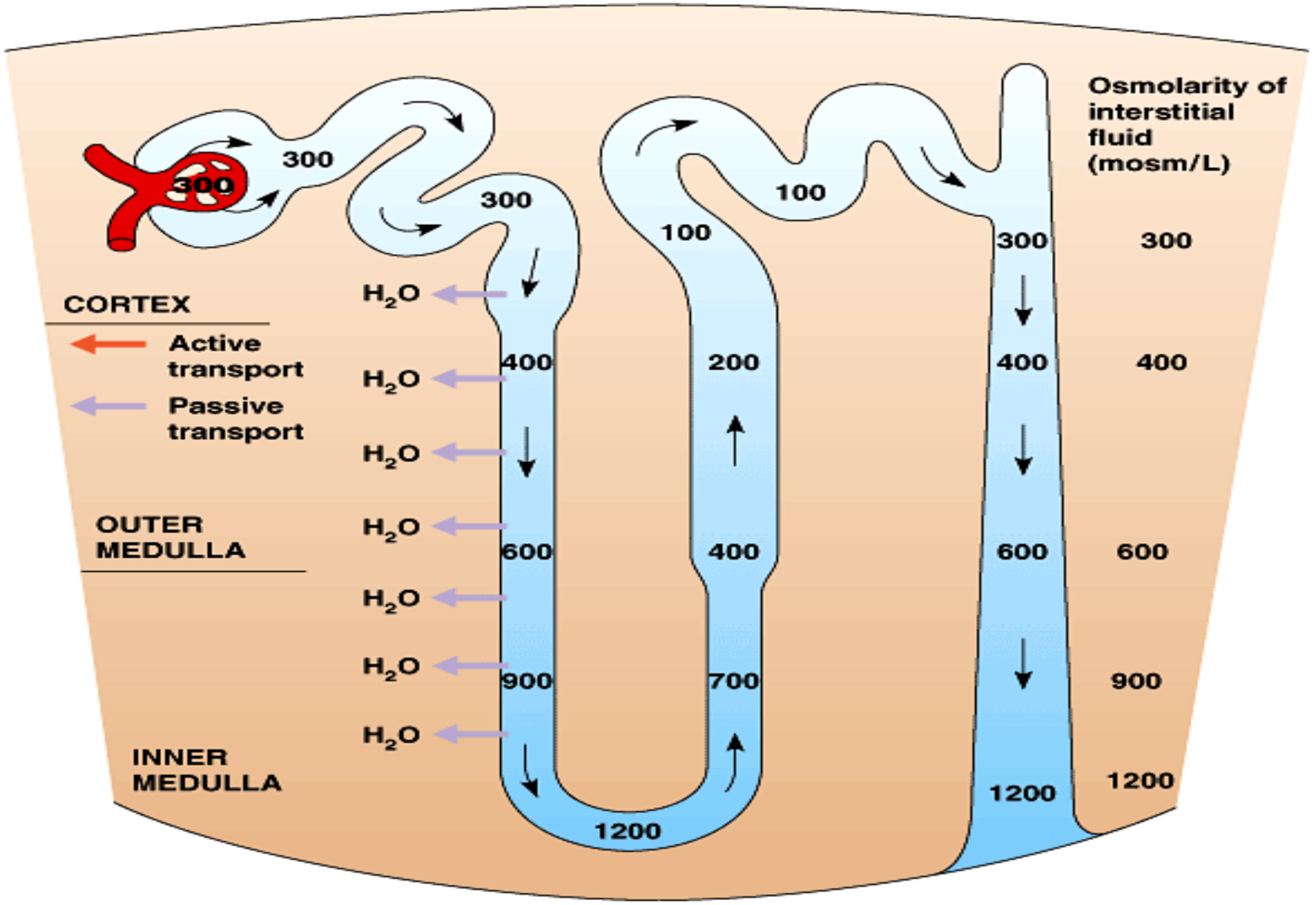


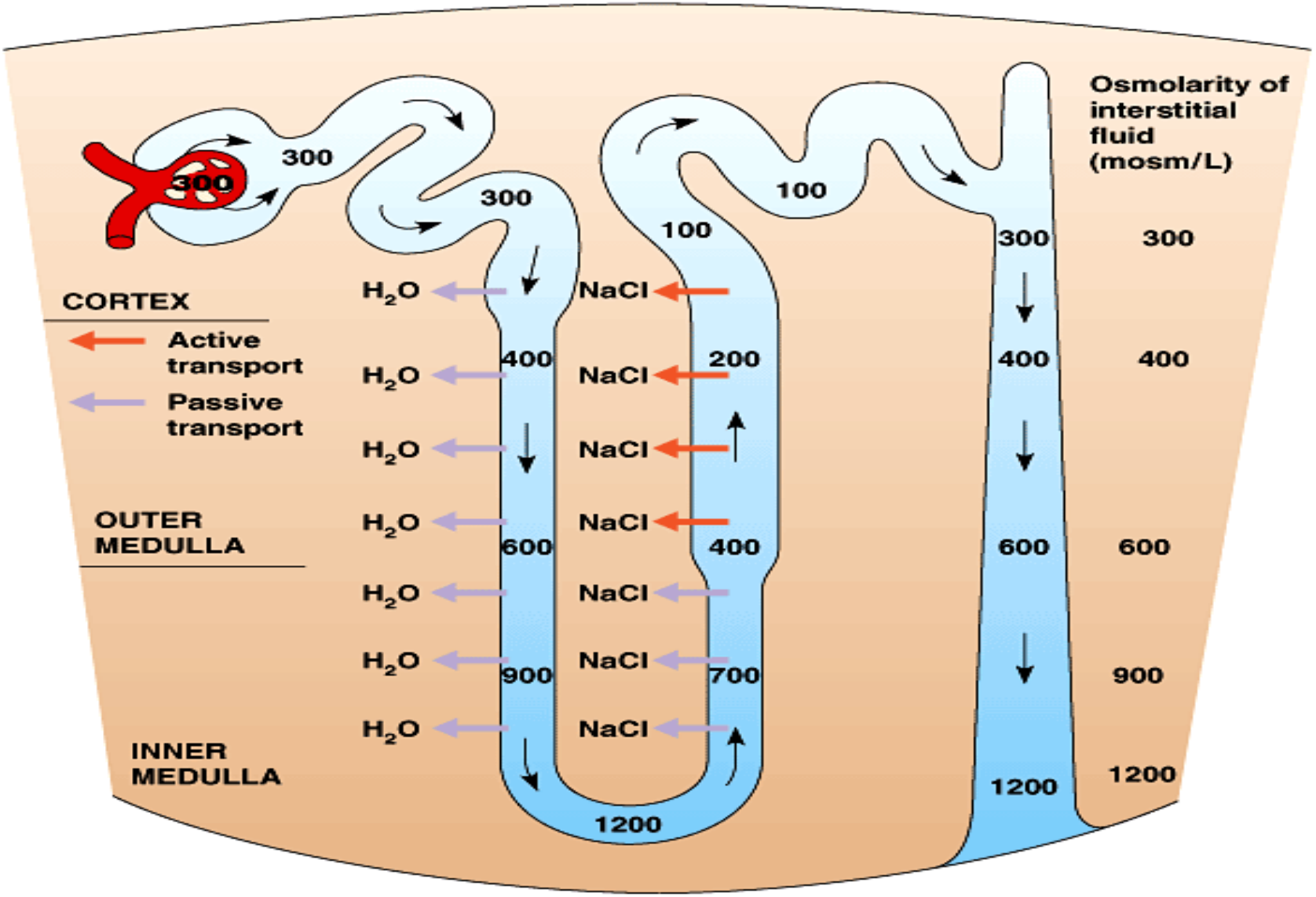
Mechanism of sodium, chloride, and potassium transport in the thick ascending loop of Henle

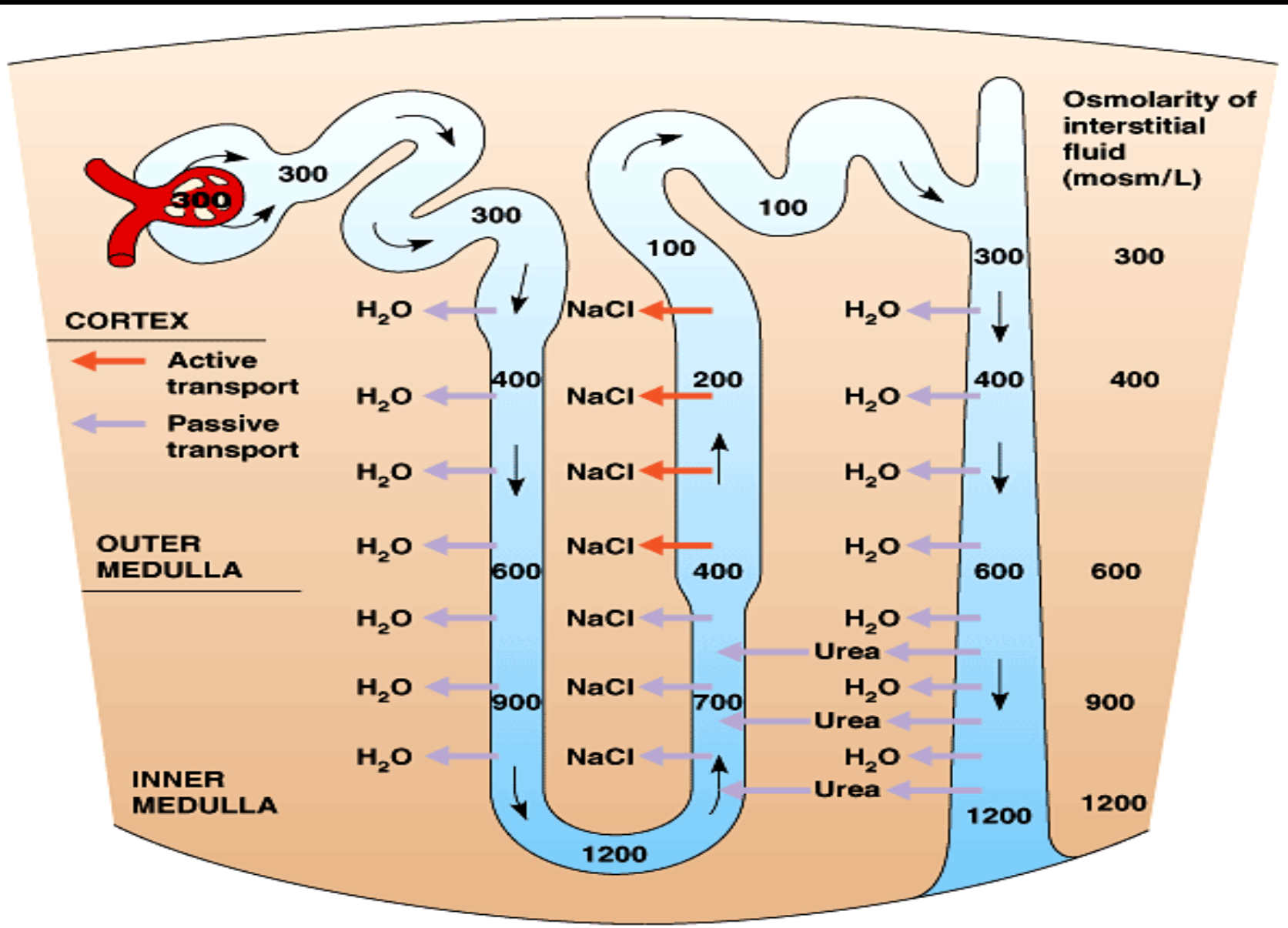




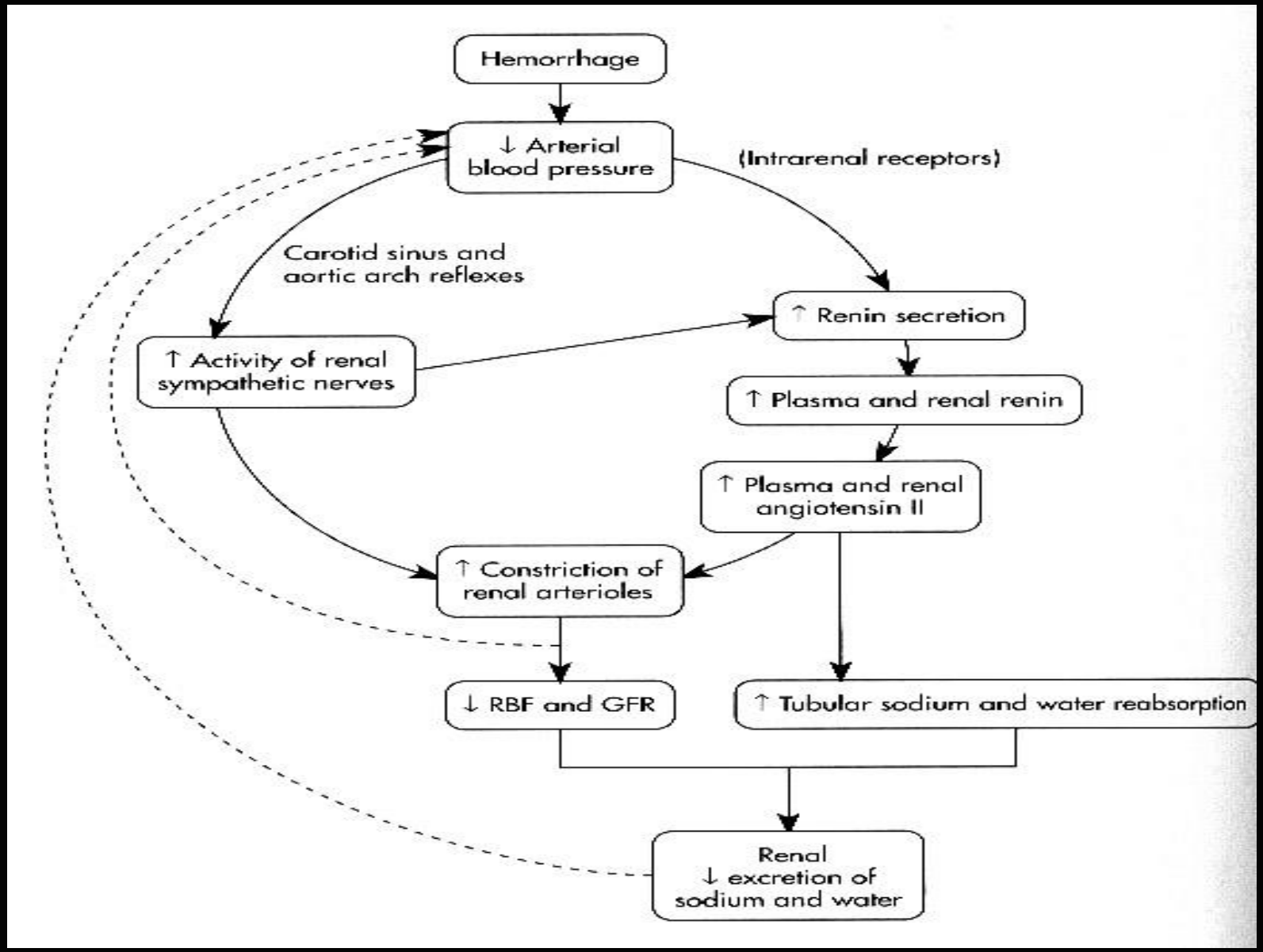

Filtration
Capillary
Filtrate
Excretory tubule
Reabsorption
Secretion
Urine
Excretion
Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.





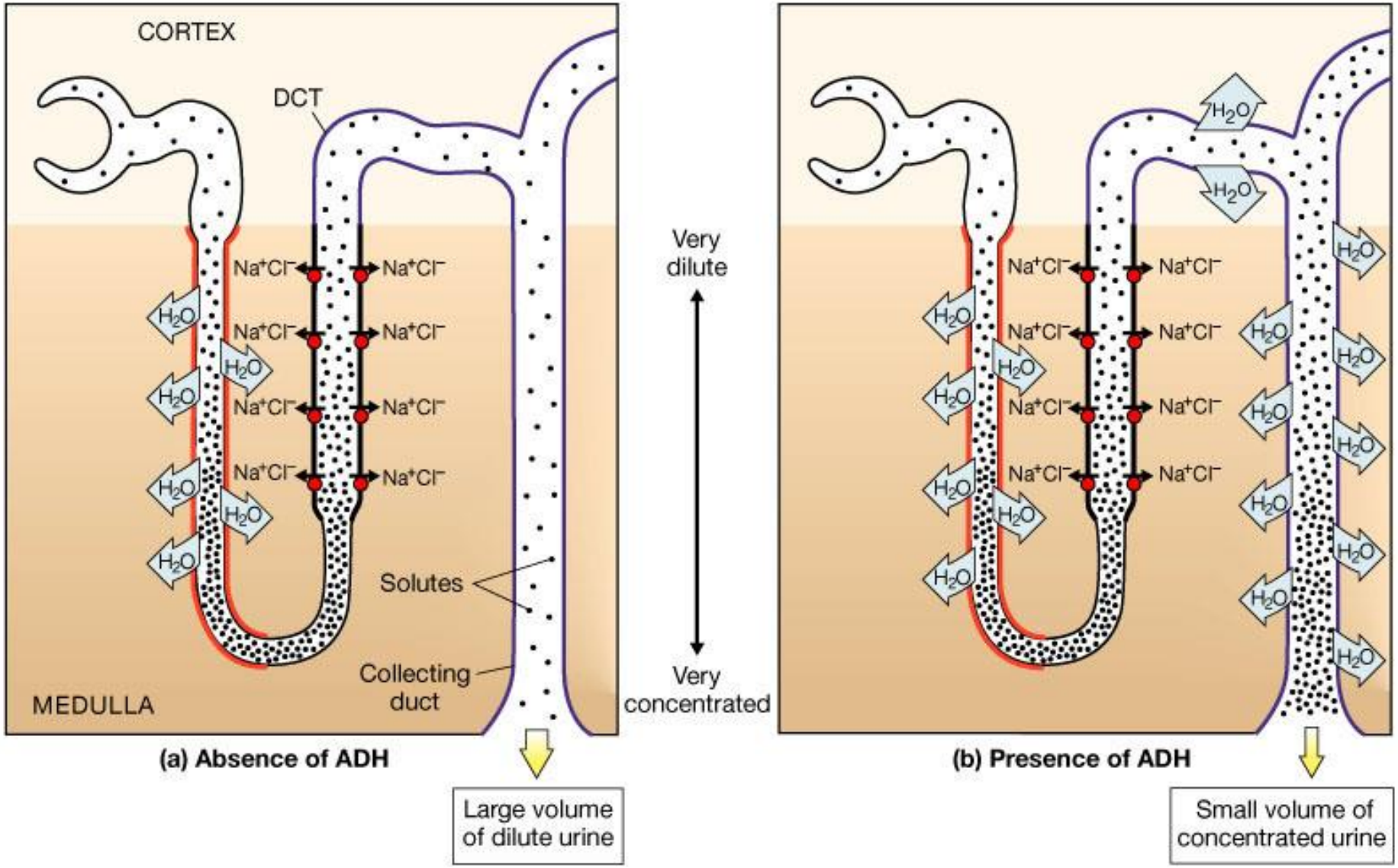


Renal Response to Hemorrhage

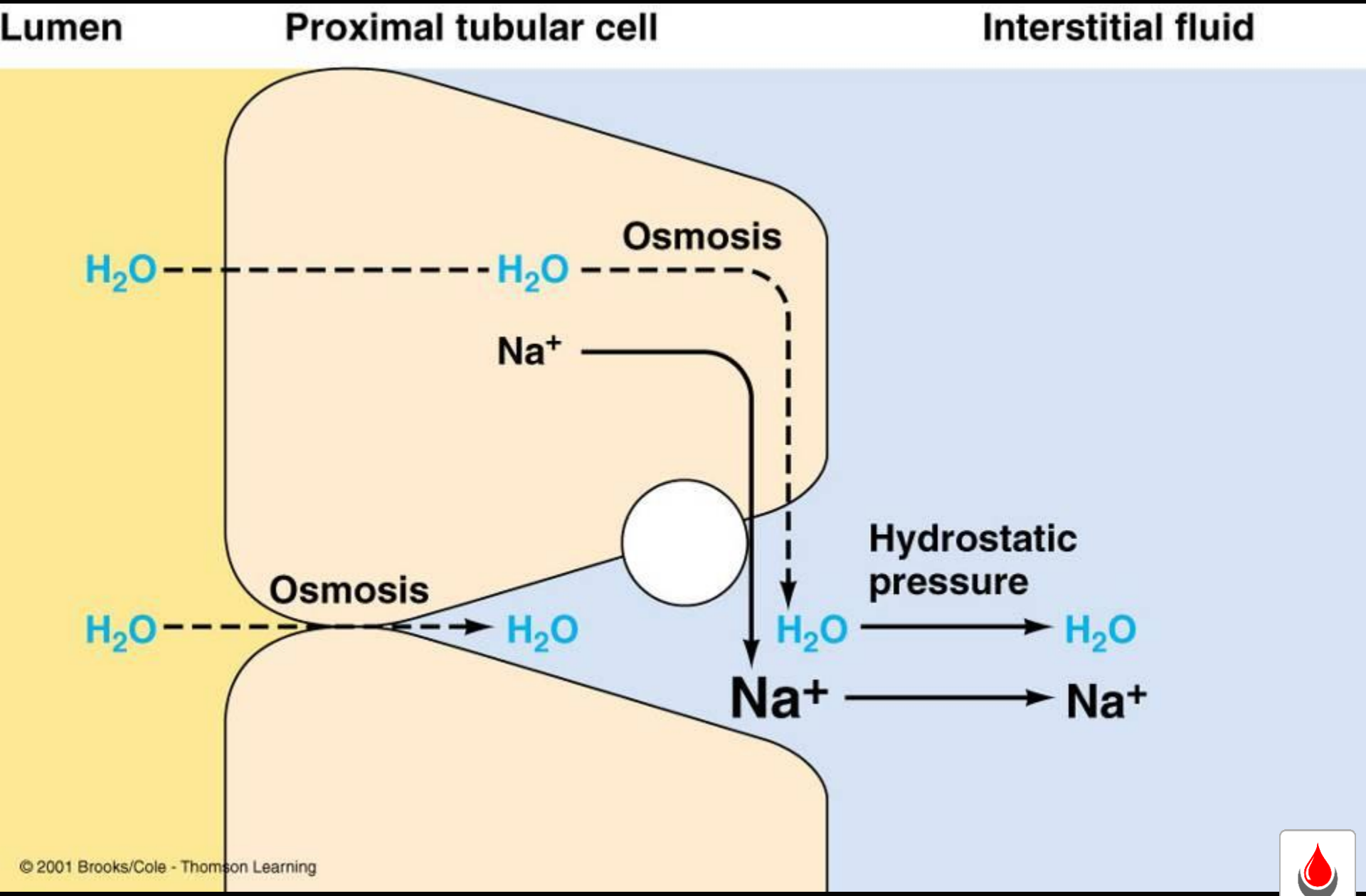


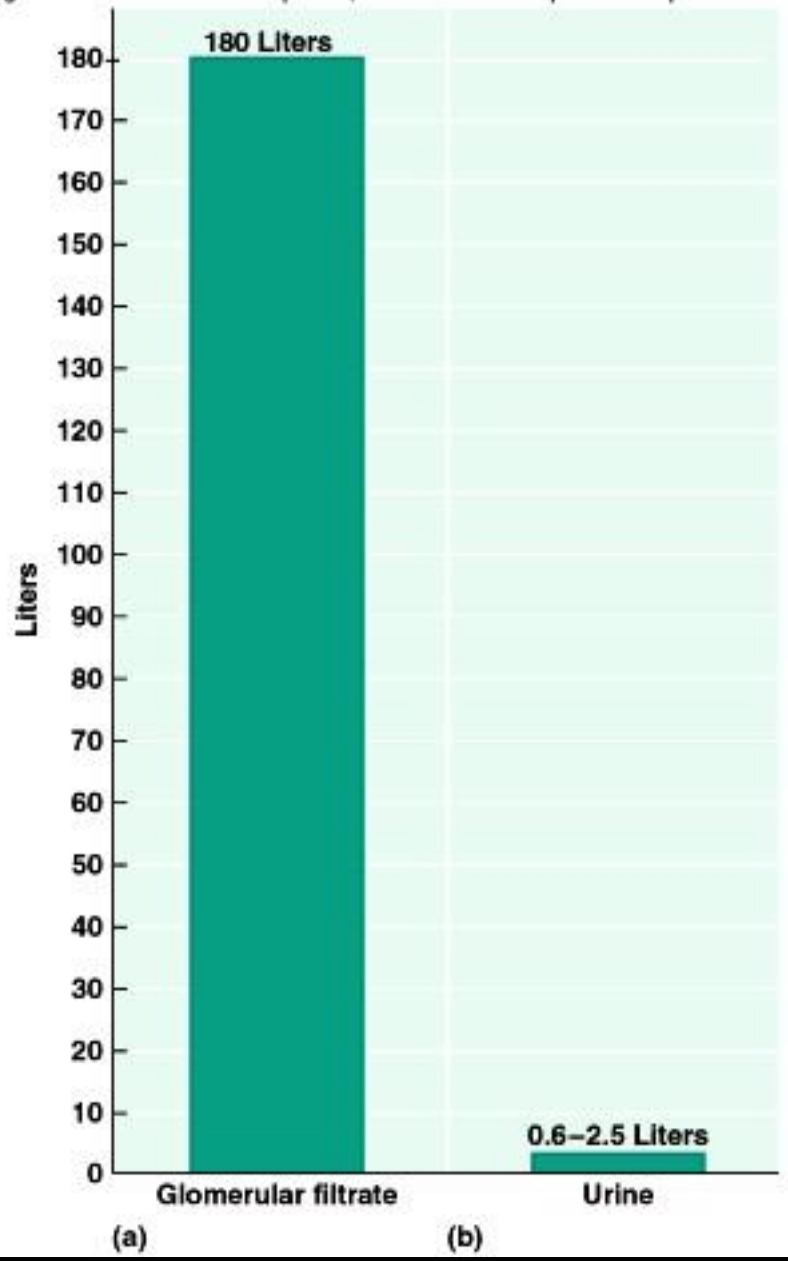
Role of the Distal Tubule and Collecting Ducts in Forming Concentrated or Diluted urine

The Effects of ADH on the distal collecting duct and Collecting Ducts

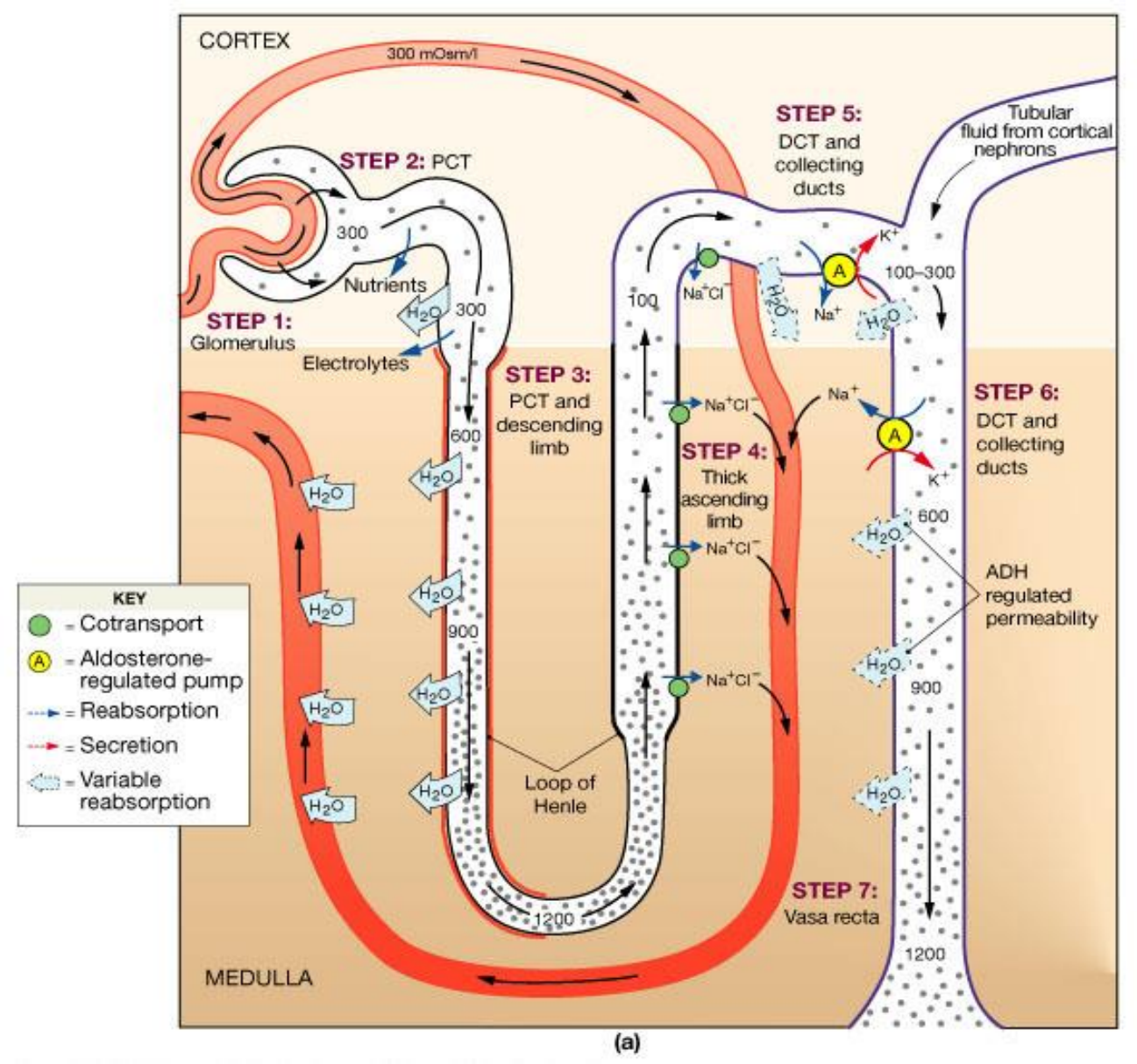


Obligatory water reabsorption





A Summary of Renal Function



Changes with aging include:

- Decline in the number of functional nephrons
- Reduction of GFR
- Reduced sensitivity to ADH
- Problems with the micturition reflex

مكونات البول Urine composition

- لون البول الطبيعي اصفر قشائيا
- يكون الماء ٩٥% من البول اما ٥% من المواد المذابة فيه وتشمل :
- ١- نواتج ايض او هدم المواد البروتينية في الخلايا من المواد النيتروجينية الضارة بالجسم مثل البولينا وحمض البولينا والامونيا والكريتانين.
- ٢- الإلكتروليتات (Electrolytes) وتشمل أيونات الصوديوم والبوتاسيوم والامونيوم والكلوريد والبيكربونات والفوسفات والكبريتات
- ٣- المواد السامة التي تنتجها البكتيريا الممرضة التي تصيب الجسم عن طريق البول.
- ٤- الأصباغ وخاصة اصباغ اليوروكروم (Urochromes) اصباغ مصفرة تشتق من تكسر خلايا الدم الحمراء في الكبد ، يضاف إليها اصباغ بعض الأطعمة والعقاقير احيانا توجد في البول
- ٦- الهرمونات تستخلص الزائدة منها عن طريق البول
- المكونات غير العادية مثل الدم والجلكوز والألبيومين (بروتين البلازما) والمواد المخاطية التي تتصلب داخل المجاري البولية ومن ثم تغسل او تطرد مع البول او الحصوات الصغري التي تترسب ثم تخرج مع البول .

pH

- Normally 4.8 – 8.0
- Higher in alkalosis, lower in acidosis
- Diabetes and starvation ↓ pH
- Urinary infections ↑ pH
  - Proteus and pseudomonas are urea splitters

Specific gravity

- Normal values 1.025 -1.032
- High specific gravity can cause precipitation of solutes and formation of kidney stones
- When tubules are damaged, urine specific gravity approaches that of glomerular filtrate – 1.010 – remains fixed = 2/3 of nephron mass has been lost

- Diabetes insipidus = 1.003
- Diabetes mellitus = 1. 030
- Emesis or fever = 1.040

Microscopic analysis

- Red blood cells – should be few or none
  - Hematuria – large numbers of rbc's in urine
  - Catheterization
  - Menstruation
  - Inflamed prostate gland
  - Cystitis or bladder stones
- Crystals –
  - Infection
  - Inflammation
  - Stones
- White blood cells
  - Pyuria
  - Urinary tract infection
- Bacteria

Urine analysis

الاسم :

التاريخ: الثلاثاء 2004/02/10 الرقم: 6827

URINE

URINALYSIS تحليل البول

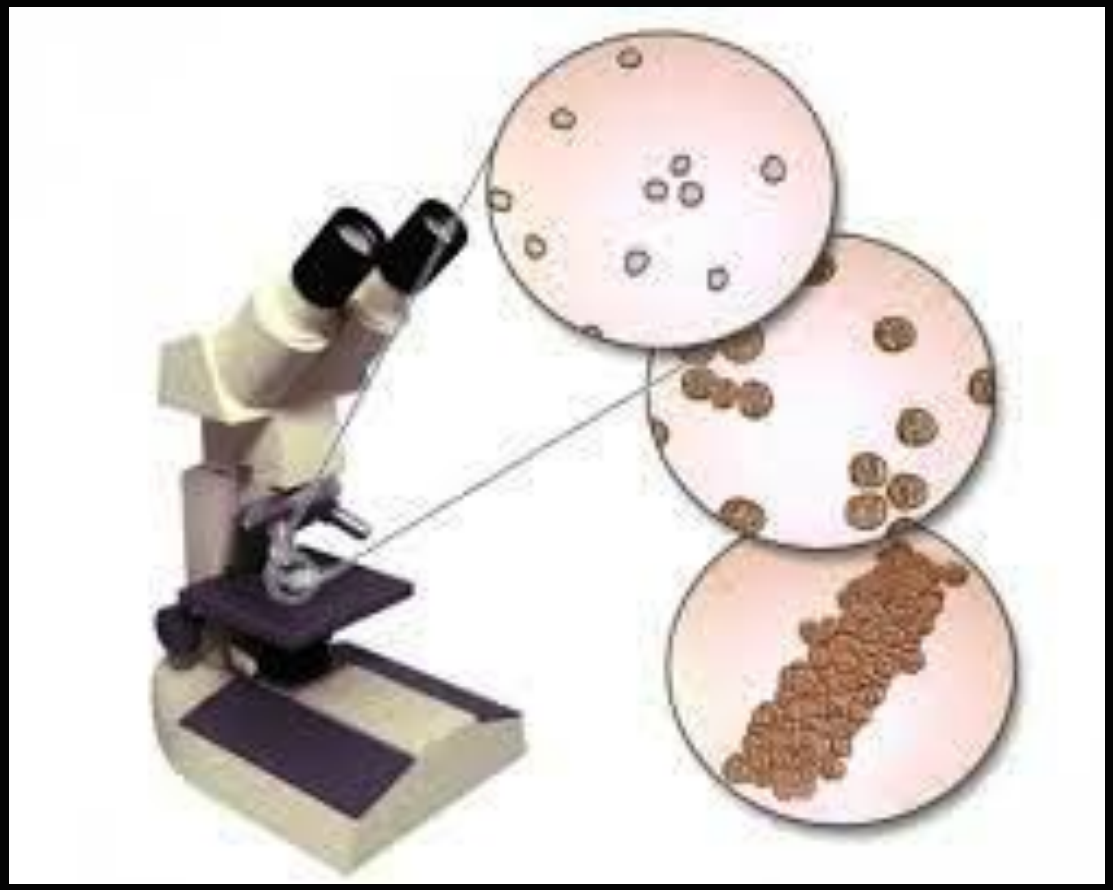
اللون		الغلوكوز		مولد اليوروبيلين	
	Yellow	Glucose	Neg.	Urobilinogen	Normal
المظهر		البروتين		البليروبين	
Appearence	Turbid	Protein	28 mg/dl	Bilirubin	Neg.
الثقل النوعي		الخضاب		النتريت	
Specific Gravity	1.015	Hemoglobin	Neg.	Nitrite	Pos.(++)
الحموضة				الكيتون	
pH	5			Ketone	Neg.

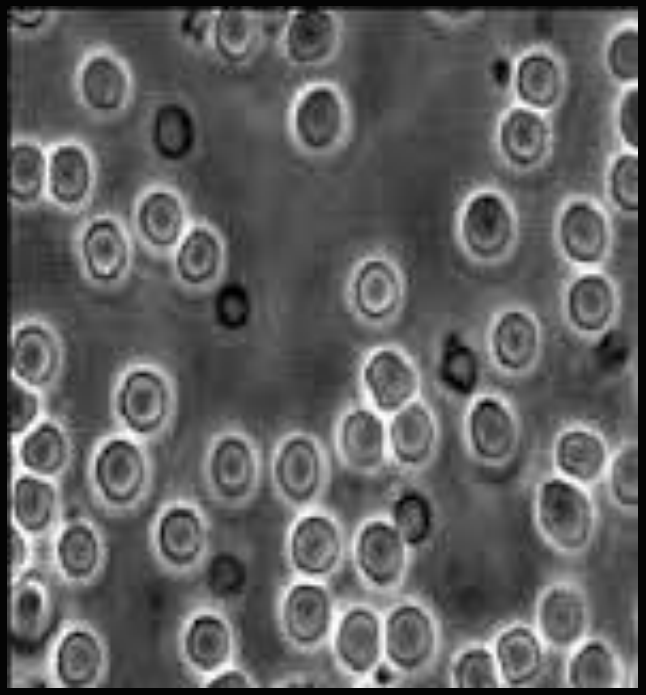
Microscopic Examination الفحص المجهري

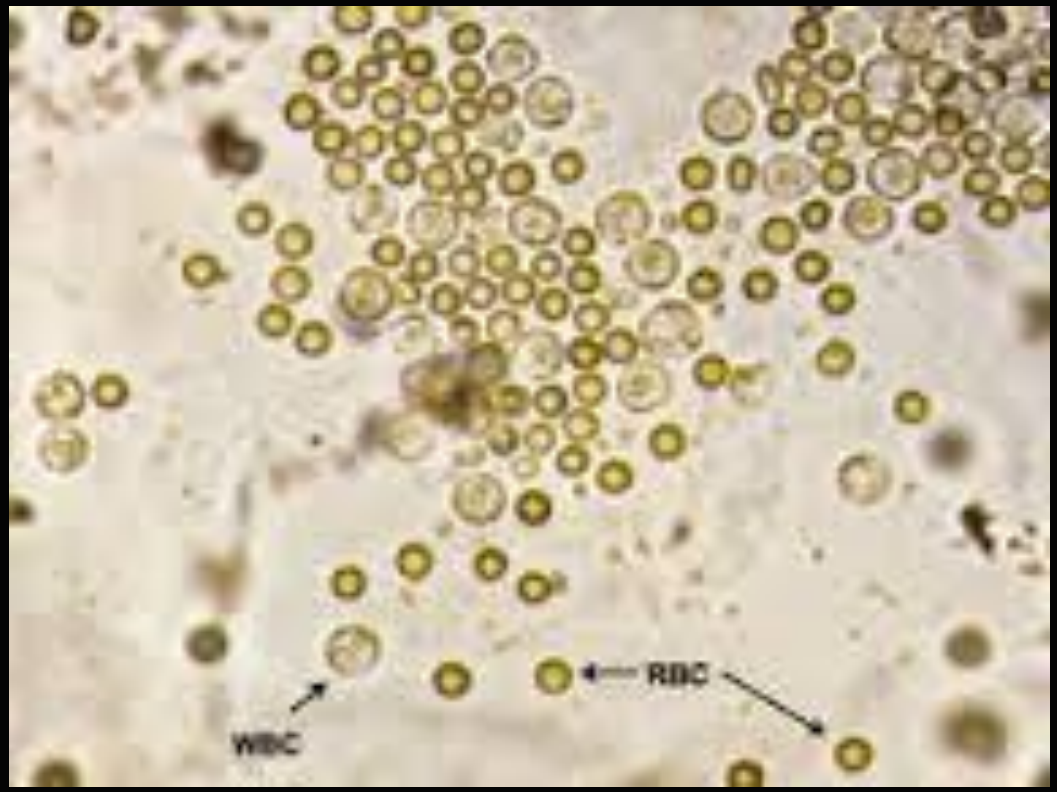
الكريات البيض		اكسالات الكالسيوم			
Leucocytes	14-16 /field	Ca. Oxalate	(-)	Bacteria	(++)
الكريات الحمر		اليورات			
Erythrocytes	3-4 /field	Urate	(-)	Funji	(++)
الخلايا الظهارية		اليوريك اسيد			
Epithelial Cells	5-6 /field	Uric Acid	(-)		
الاسطوانات		الفوسفات			
Cylinders	0 /field	Phosphate	(-)		

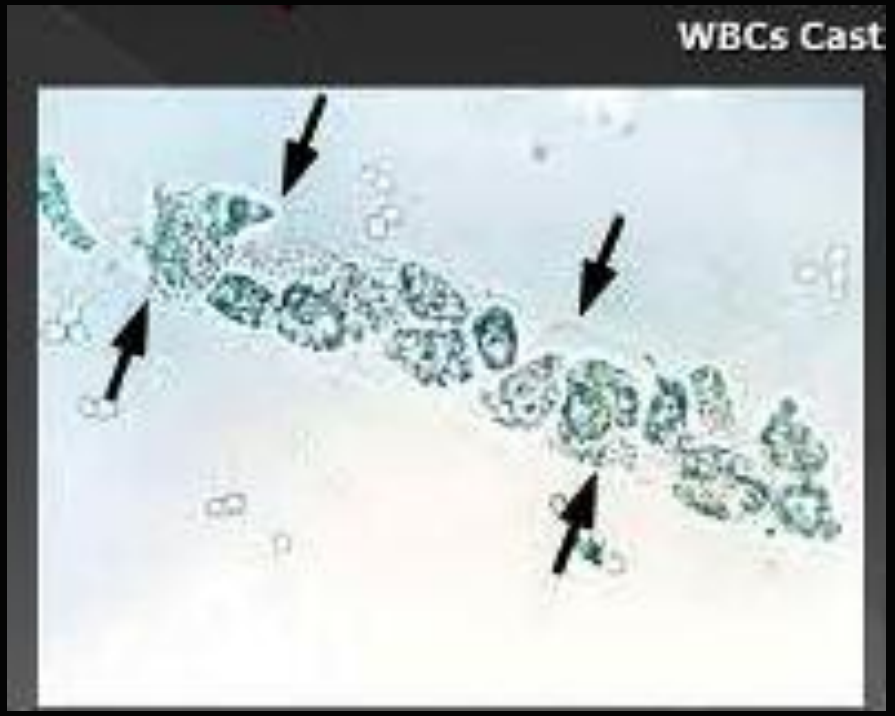

Good
Good
Fair
Dehydrated
Dehydrated
Very Dehydrated
Severe Dehydration

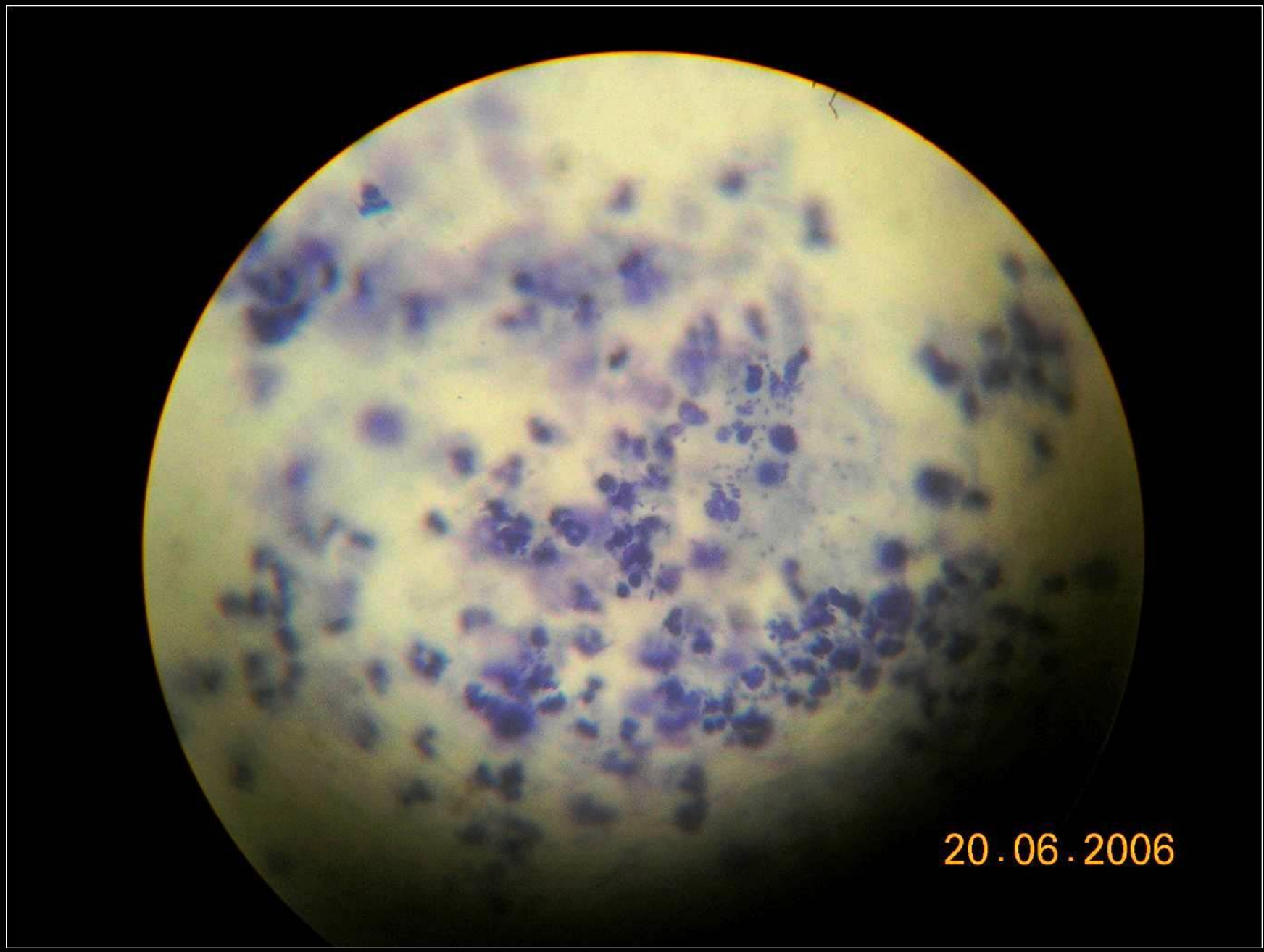

Ph 3

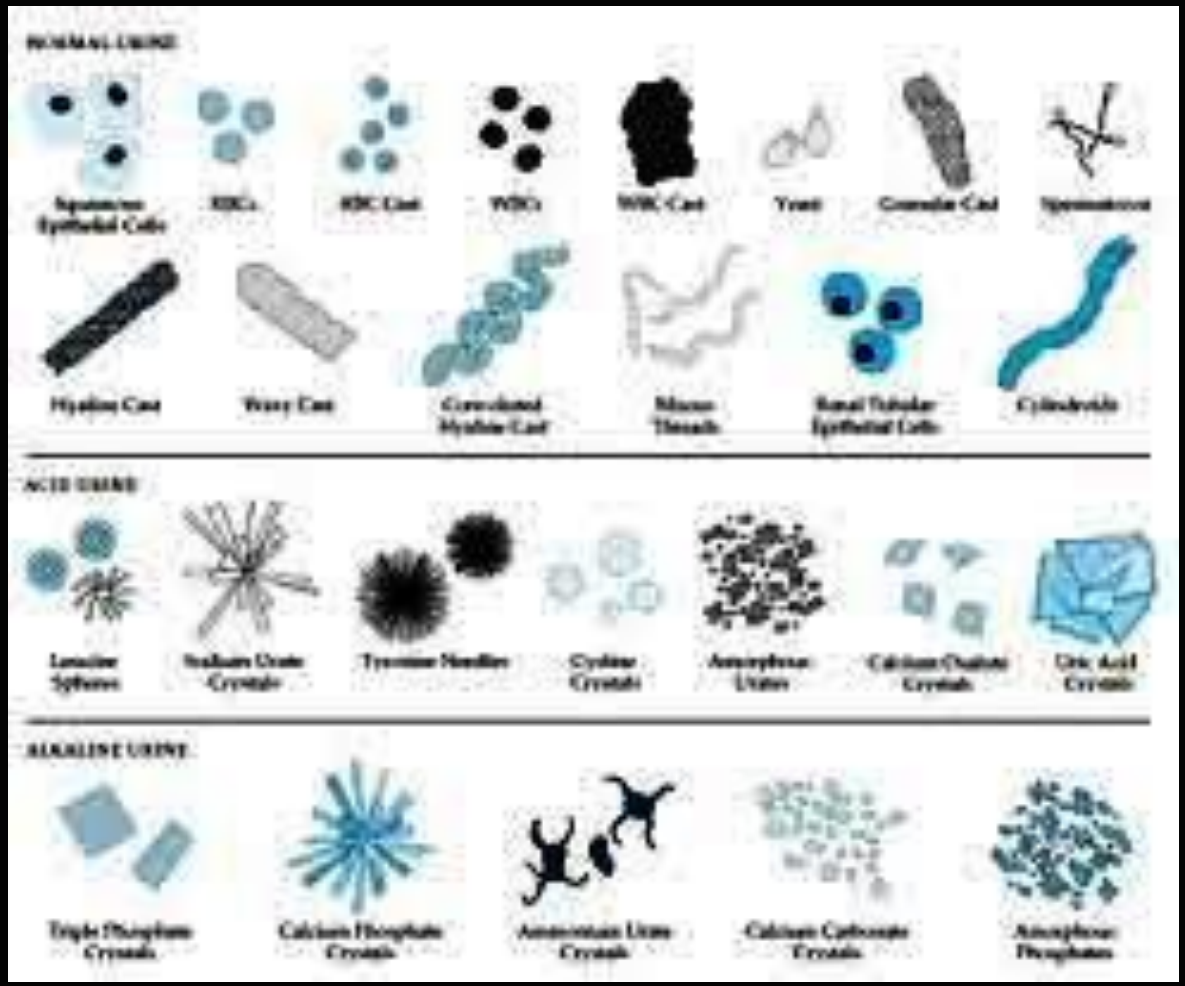




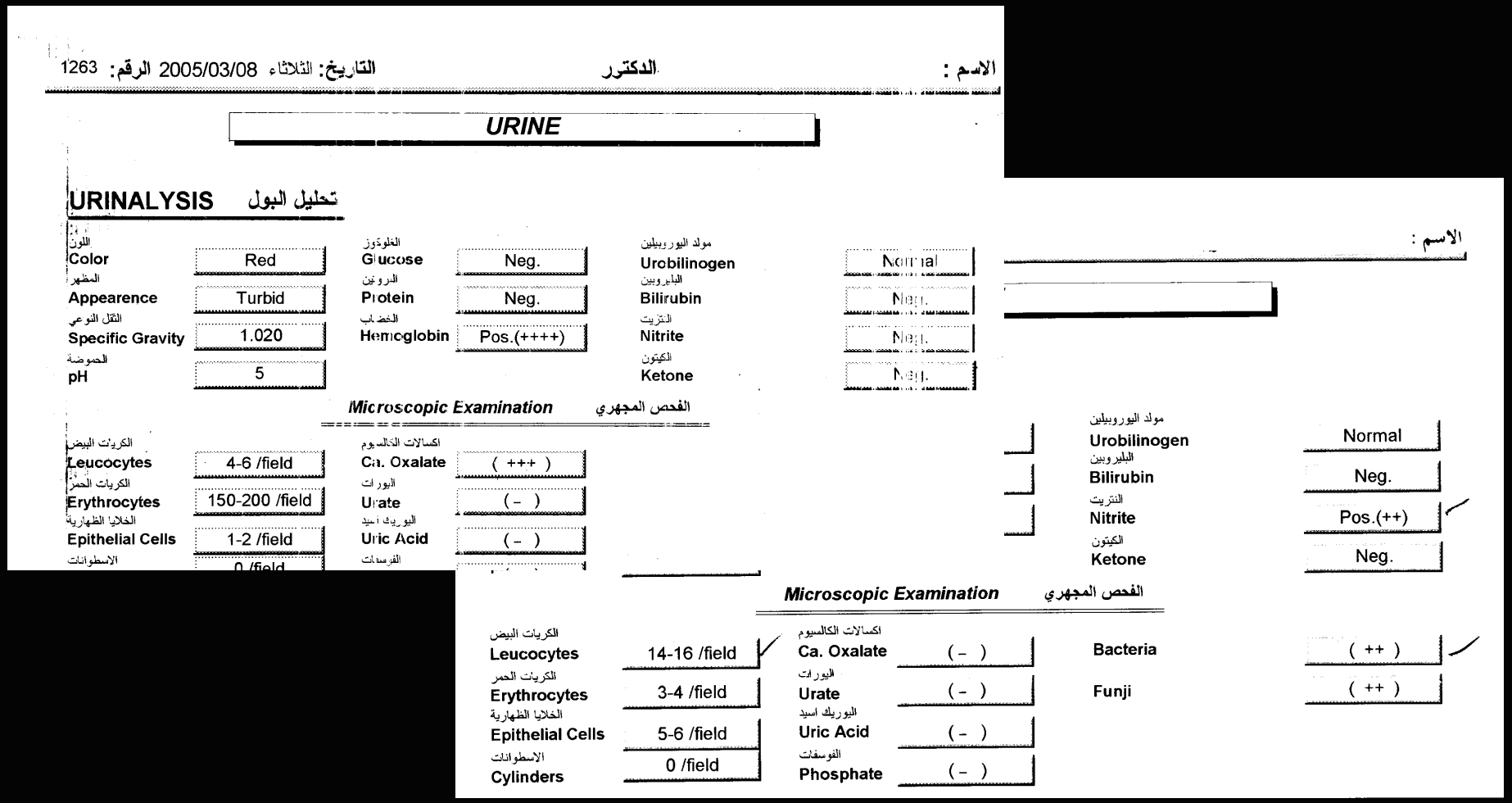

RBC
WBC


WBCs Cast


20.06.2006


Hyaline Cast
Waxy Cast
Leucine Spheres
Cystine Crystals
Triple Phosphate Crystals
Calcium Phosphate Crystals
Calcium Carbonate Crystals

Urine analysis



الاسم : الدكتور التاريخ: الثلاثاء 2005/03/08 الرقم: 1263

URINE

URINALYSIS تحليل البول

اللون Color	Red	الغلوكوز Glucose	Neg.	مولد اليوروبيلين Urobilinogen	Normal
المظهر Appearence	Turbid	البروتين Protein	Neg.	البايروبين Bilirubin	Neg.
الثقل النوعي Specific Gravity	1.020	الخضاب Hemoglobin	Pos.(++++)	النتريت Nitrite	Neg.
الحموضة pH	5			الكيتون Ketone	Neg.

Microscopic Examination الفحص المجهري

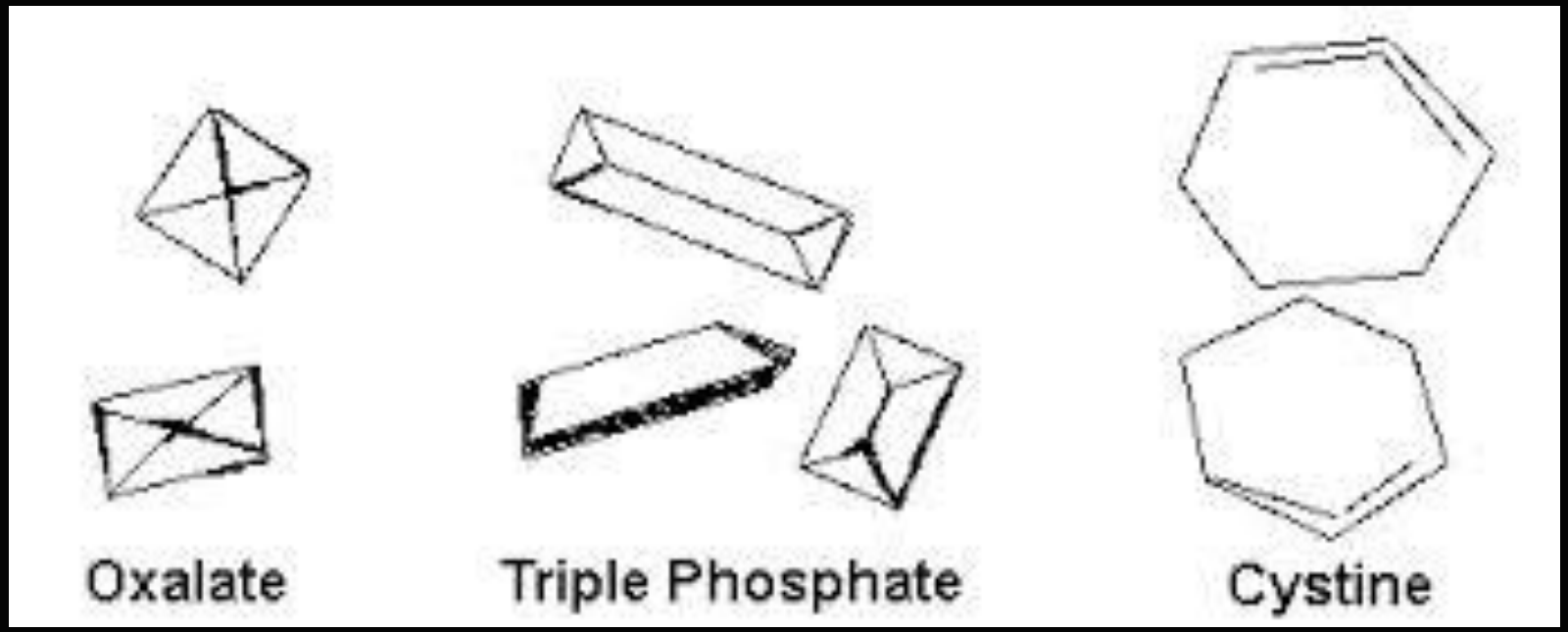
الكريات البيض Leucocytes	4-6 /field	اكسالات الكالسيوم Ca. Oxalate	(+++)		
الكريات الحمر Erythrocytes	150-200 /field	اليورات Urate	(-)		
الخلايا الظهارية Epithelial Cells	1-2 /field	اليوريك اسيد Uric Acid	(-)		
الاسطوانات	0 /field	الفوسفات			

الاسم :

				مولد اليوروبيلين Urobilinogen	Normal
				البليروبين Bilirubin	Neg.
				النتريت Nitrite	Pos.(++)
				الكيتون Ketone	Neg.

Microscopic Examination الفحص المجهري

الكريات البيض Leucocytes	14-16 /field	اكسالات الكالسيوم Ca. Oxalate	(-)	Bacteria	(++)
الكريات الحمر Erythrocytes	3-4 /field	اليورات Urate	(-)	Funji	(++)
الخلايا الظهارية Epithelial Cells	5-6 /field	اليوريك اسيد Uric Acid	(-)		
الاسطوانات Cylinders	0 /field	الفوسفات Phosphate	(-)		

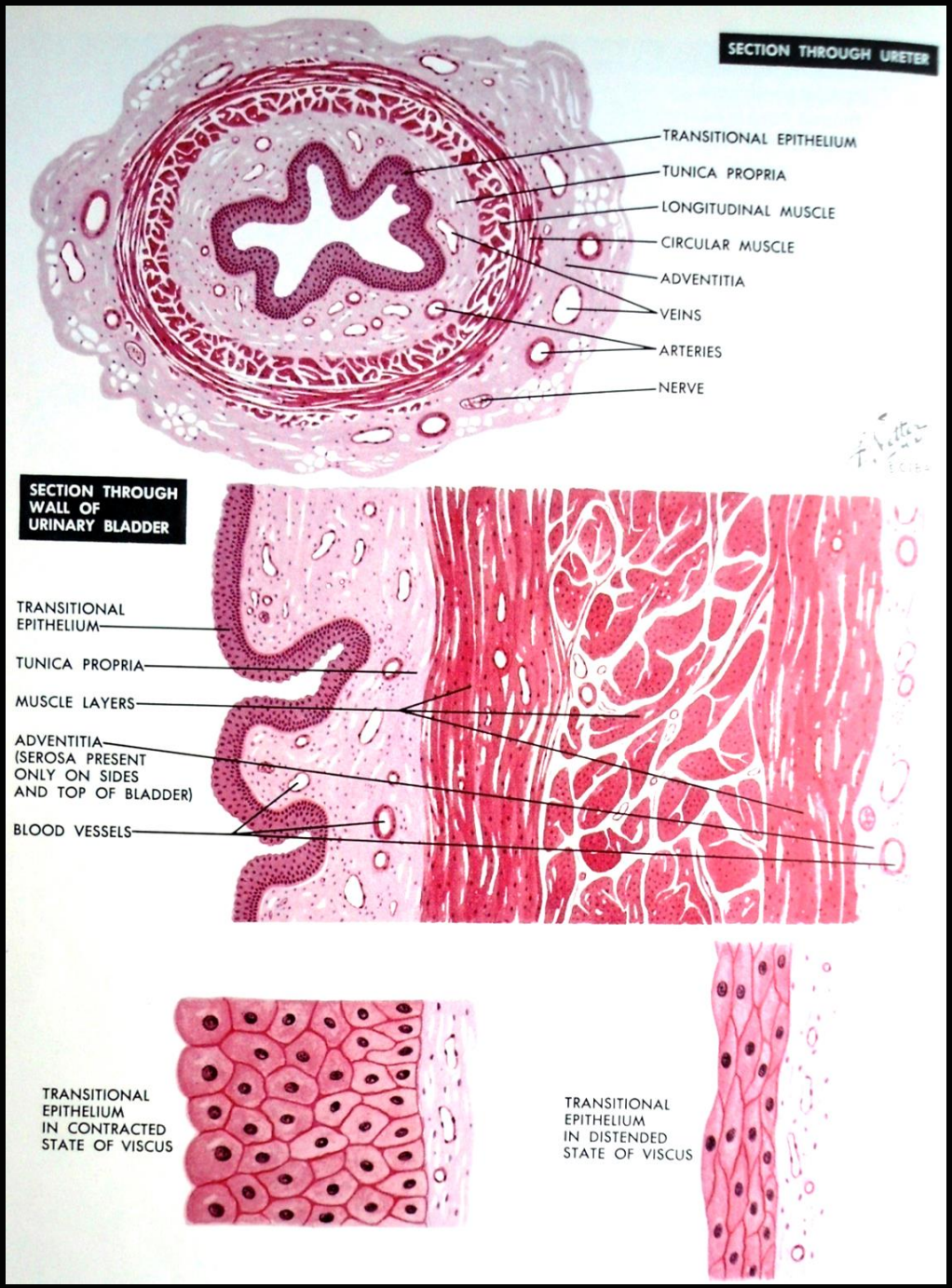

Oxalate
Triple Phosphate
Cystine

Substances **not** normally present in urine

- Acetone
- Bile, bilirubin
- Glucose
- Protein – albumin
  - Renal disease involving glomerulus

Ureters

- هما انبوبان طويلان يمتدان من الحوض الكلوي للكلية الى ان يصبا في المثانة البولية (Urinary bladder).
- يتراوح طول الحالب ٢٥-٣٠سم وجداراه يزدادان سمكا بإتجاه المثانة وقطرة ١,٧سم
- تساعد الحركات التموجية لجدران الحالب على جريان البول الى المثانة حيث يتجمع ثم عند امتلاء المثانه يطرح البول خارج الجسم عن طريق الاحليل .
- يتركب جدار الحالب من ثلاث طبقات :
- ١-الطبقة الداخلية المخاطية (Mucosa) وهي طلائية انتقالية تقوم بإفراز مادة المخاط لحماية جدار الحالب والحيلولة من تاثره بحموضية البول والمواد المذابة فيه .
- ٢- الطبقة الوسطى او الطبقة العضلية تتكون من عضلات طولية ملساء او ناعمة للداخل ودائرية للخارج تقوم بالحركات التموجية لدفع البول الى المثانة.
- ٣- الطبقة الخارجية : وهي طبقة ليفية تساعد على ربط الحالبين بأنسجة الجسم لبقائهما في مكانهما .
- لا توجد اى صمامات تحرس الفتحة بين الحالبين والمثانه البولية


SECTION THROUGH URETER
TRANSITIONAL EPITHELIUM
TUNICA PROPRIA
LONGITUDINAL MUSCLE
CIRCULAR MUSCLE
ADVENTITIA
VEINS
ARTERIES
NERVE
SECTION THROUGH WALL OF URINARY BLADDER
TRANSITIONAL EPITHELIUM
TUNICA PROPRIA
MUSCLE LAYERS
ADVENTITIA (SEROSA PRESENT ONLY ON SIDES AND TOP OF BLADDER)
BLOOD VESSELS
TRANSITIONAL EPITHELIUM IN CONTRACTED STATE OF VISCUS
TRANSITIONAL EPITHELIUM IN DISTENDED STATE OF VISCUS

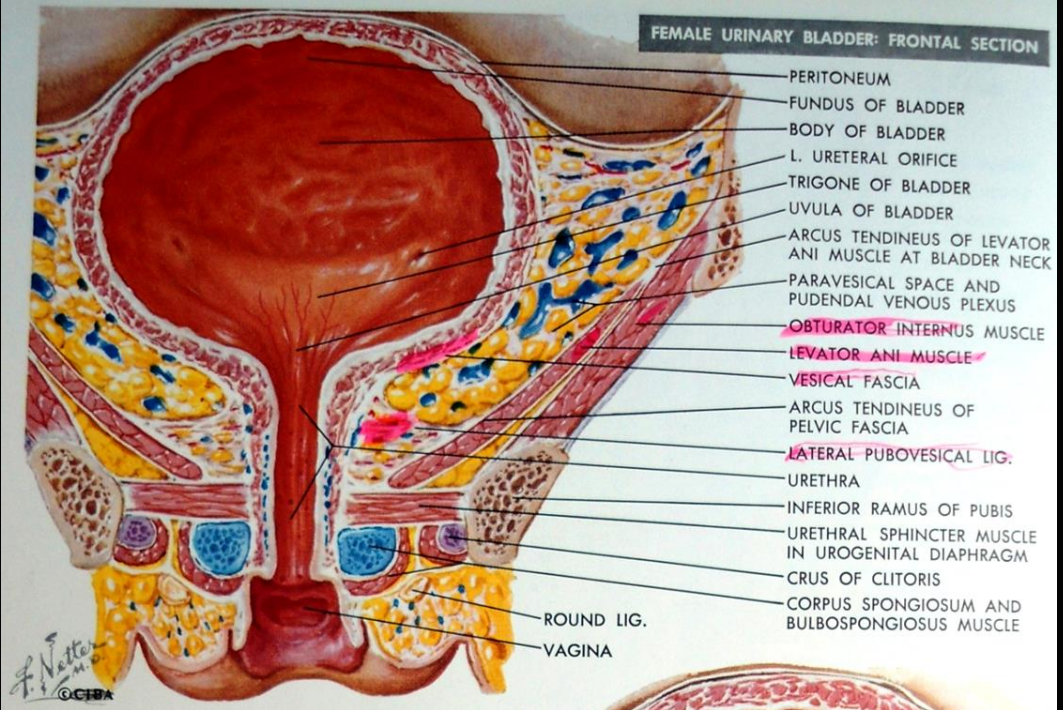
Urinary Bladder

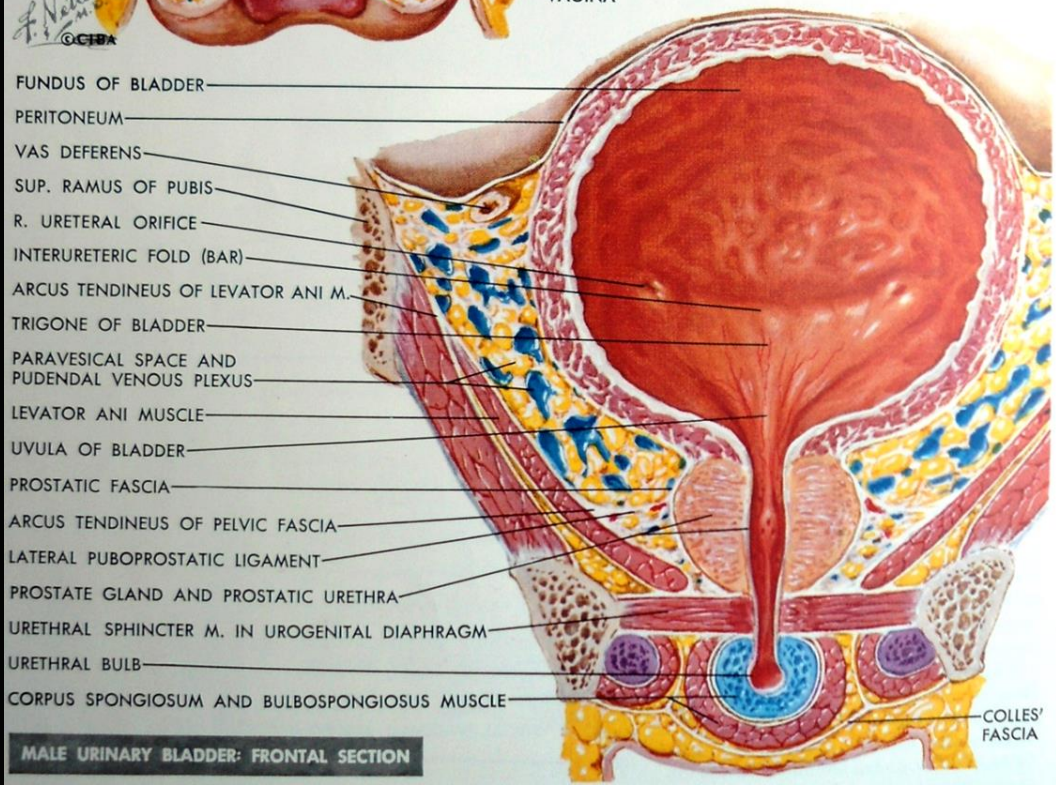
- المثانة البولية عبارة عن كيس عضلي مطاطي ، تعمل كمخزن للبول قبل طرح للخارج.
- توجد في داخل الحوض وعندما تمتلئ تصل الى اسفل البطن اما عند الطفل فهى عند اسفل البطن حتى وهب فارغة.
- فهي ذات جدار سميك تبدو على هيئة مثلثة ولكن عندما وصول البول تبدو كروية الشكل ثم كمثرية الشكل عند امتلائها .
- يتركب جدار المثانه من اربع طبقات :
- ١- الطبقة المخاطية (الداخلية) وهي خلايا طلائية انتقالية قادرة على التمدد وتفرز مادة المخاط للحماية
- ٢-الطبقة تحت المخاطية : عبارة عن انسجة ضامه تصل ما بين الطبقة المخاطية والطبقة الثالثة العضلية
- ٣- الطبقة العضلية وتتكون من عضلات طولية للداخل ودائرية في الوسط وطولية في الخارج .وعند المجرى البولي تكون الالياف الدائرية ما يعرف بالعاصرة الداخلية (Internal sphinchtor) وتحت هذه العاصرة توجد العاصرة الخارجية والتي تتكون من عضلات هيكلية
- ٤- الطبقة المصلية تتكون من امتداد غشاء البريتونيوم الذي يغطي السطح العلوي للمثانة .

Urethra

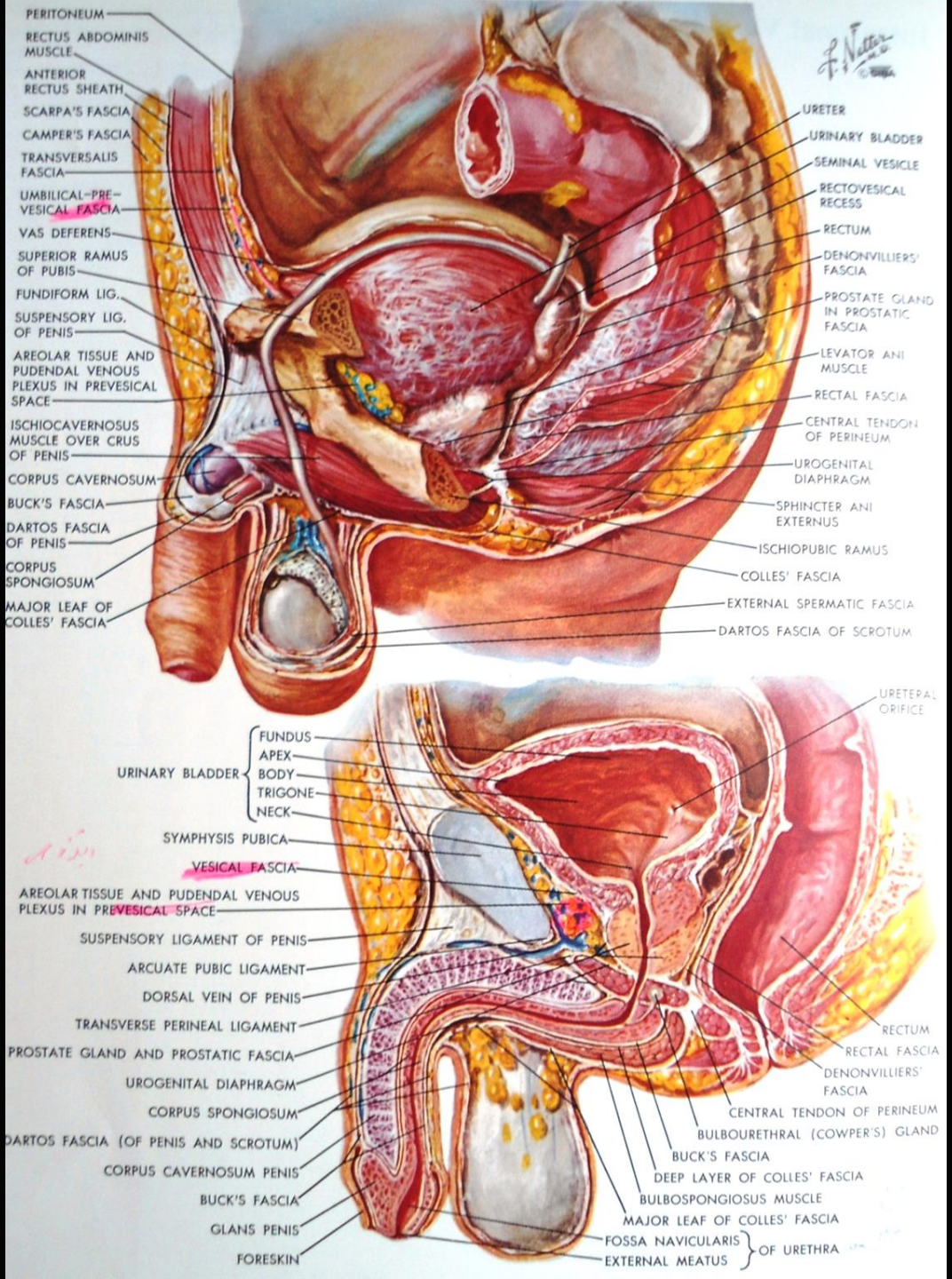
- الإحليل عبارة عن قناة طولية تصل قاع المثانه البولية بخارج الجسم
- طولها في الرجل ٢٠ سم وفي المرأة ٤ سم وقطره ٦ مم من عنق المثانة الى فتحة الإحليل الأمامية او الخارجية .
- عند الرجل يكون هو القناة البولية التناسلية تمر وسط القضيب للرجل وتحاط بالأنسجة الأسفنجية، وقبل ذلك يمر الاحليل في غدة البروستاتا ، بينما في المرأة تفتح قناة الإحليل بفتح مستقلة اعلى الفرج للمرأة.
- يتركب جدار الإحليل من ثلاث طبقات :
- ١- الطبقة المخاطية للداخل ثم
- ٢ - طبقة اسفنجية رقيقة غنية بالشعيرات الدموية في الوسط ثم
- ٣- الطبقة العضلية للخارج وهي امتداد لتلك الطبقات العضلية الملساء في المثانة

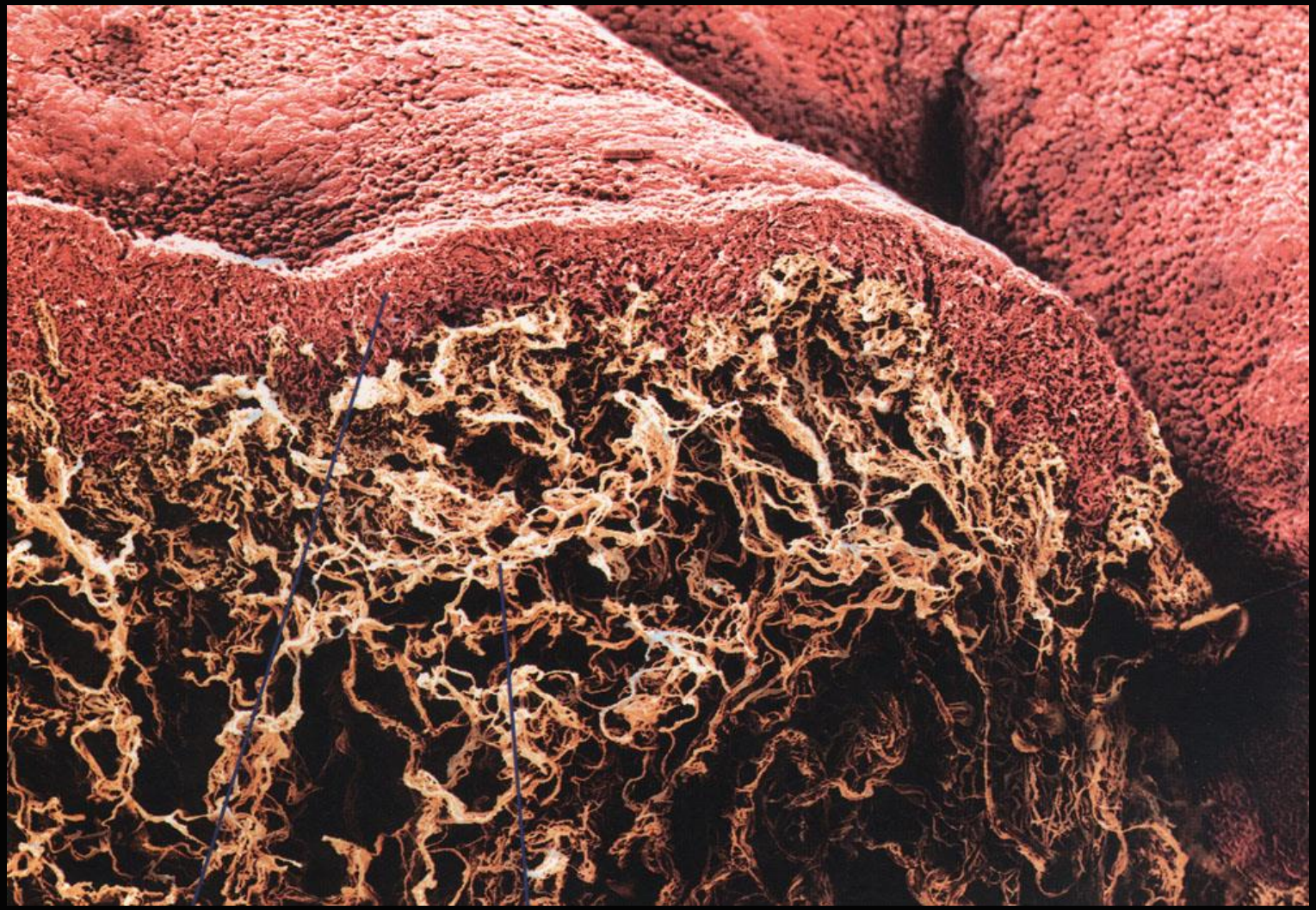
FEMALE URINARY BLADDER: FRONTAL SECTION





MALE URINARY BLADDER: FRONTAL SECTION

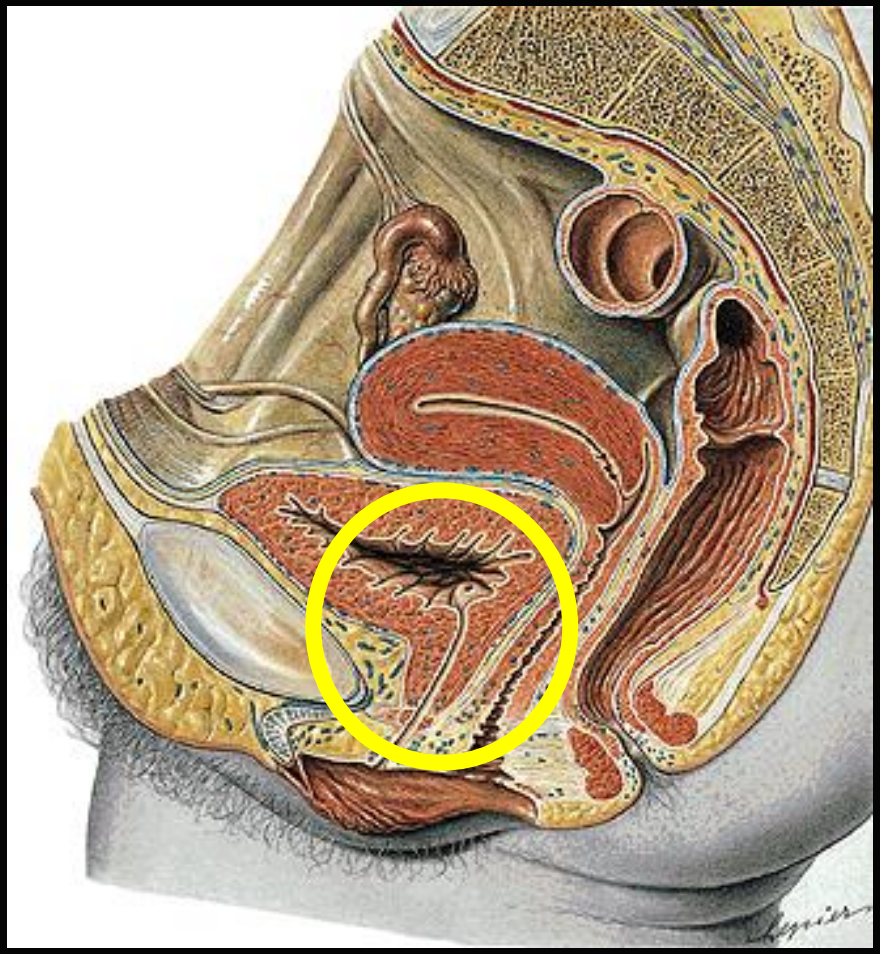

PERITONEUM
RECTUS ABDOMINIS MUSCLE
ANTERIOR RECTUS SHEATH
SCARPA'S FASCIA
CAMPER'S FASCIA
TRANSVERSALIS FASCIA
UMBILICAL-PREVESICAL FASCIA
VAS DEFERENS
SUPERIOR RAMUS OF PUBIS
FUNDIFORM LIG.
SUSPENSORY LIG. OF PENIS
AREOLAR TISSUE AND PUDENDAL VENOUS PLEXUS IN PREVESICAL SPACE
ISCHIOCAVERNOSUS MUSCLE OVER CRUS OF PENIS
CORPUS CAVERNOSUM
BUCK'S FASCIA
DARTOS FASCIA OF PENIS
CORPUS SPONGIOSUM
MAJOR LEAF OF COLLES' FASCIA
URETER
URINARY BLADDER
SEMINAL VESICLE
RECTOVESICAL RECESS
RECTUM
DENONVILLIERS' FASCIA
PROSTATE GLAND IN PROSTATIC FASCIA
LEVATOR ANI MUSCLE
RECTAL FASCIA
CENTRAL TENDON OF PERINEUM
UROGENITAL DIAPHRAGM
SPHINCTER ANI EXTERNUS
ISCHIOPUBIC RAMUS
COLLES' FASCIA
EXTERNAL SPERMATIC FASCIA
DARTOS FASCIA OF SCROTUM
URETERAL ORIFICE
URINARY BLADDER
FUNDUS
APEX
BODY
TRIGONE
NECK
SYMPHYSIS PUBICA
VESICAL FASCIA
AREOLAR TISSUE AND PUDENDAL VENOUS PLEXUS IN PREVESICAL SPACE
SUSPENSORY LIGAMENT OF PENIS
ARCUATE PUBIC LIGAMENT
DORSAL VEIN OF PENIS
TRANSVERSE PERINEAL LIGAMENT
PROSTATE GLAND AND PROSTATIC FASCIA
UROGENITAL DIAPHRAGM
CORPUS SPONGIOSUM
DARTOS FASCIA (OF PENIS AND SCROTUM)
CORPUS CAVERNOSUM PENIS
BUCK'S FASCIA
GLANS PENIS
FORESKIN
RECTUM
RECTAL FASCIA
DENONVILLIERS' FASCIA
CENTRAL TENDON OF PERINEUM
BULBOURETHRAL (COWPER'S) GLAND
BUCK'S FASCIA
DEEP LAYER OF COLLES' FASCIA
BULBOSPONGIOSUS MUSCLE
MAJOR LEAF OF COLLES' FASCIA
FOSSA NAVICULARIS
EXTERNAL MEATUS
OF URETHRA

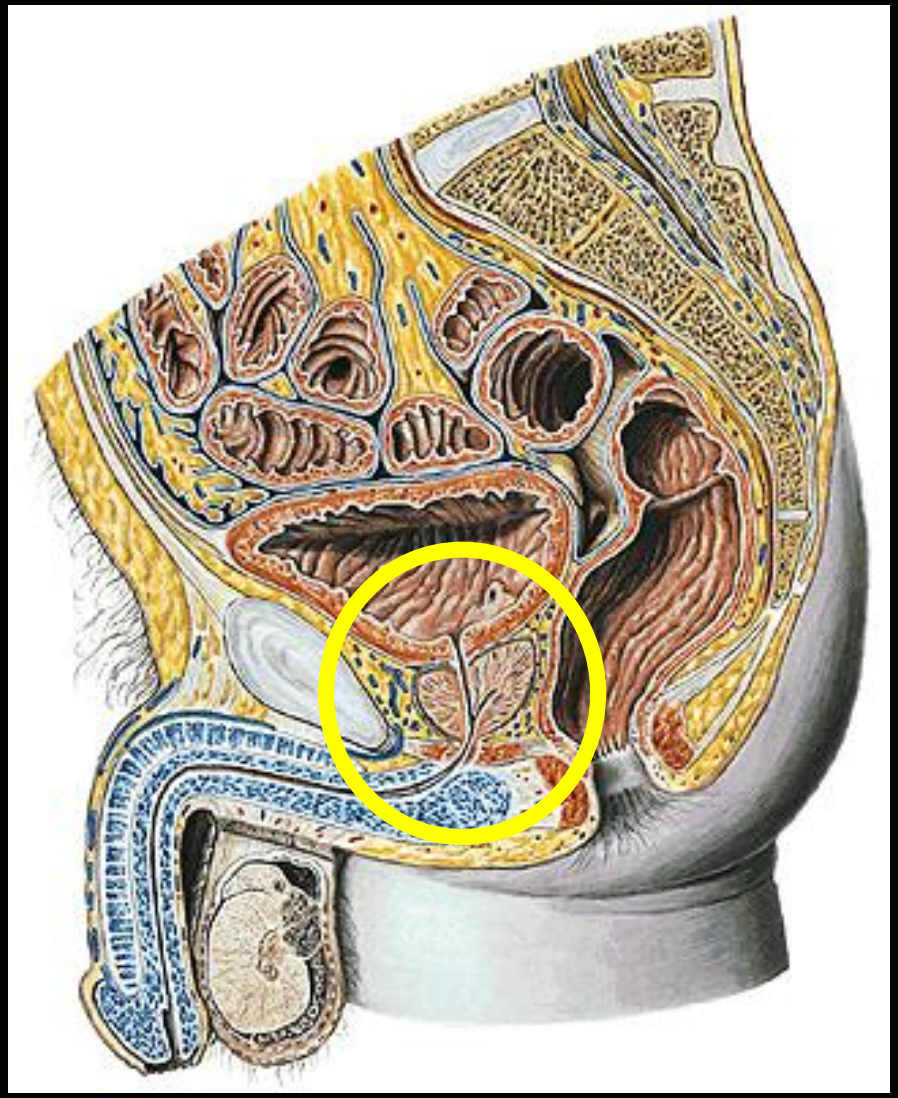


التحكم في خروج البول من المثانة (التبـوّل)

- يفتح الحالبان عند قاعدة المثانة من الناحية العلوية العريضة بينما فتحة الإحليل توجد في قمة مثلث المثانة من الناحية السفلية .
- يتم طرد البول عن طريق التبول (urination) عن طريق تحفيزات عصبية حركية ودية وذاتية (Voluntary and involentary)
- تبلغ سعة المثانة حوالي ٧٠٠-٨٠٠ مل وعندما تبلغ ٣٥٠-٤٠٠ مل تبدأ مستقبلات التمدد في جدار المثانه بنقل التحفيزات الى الجزء السفلي للحبل الشوكي ليرسل اشارة للمخ والذي بدورة يرسل الاعصاب الحركية لكي تنبه العضلات في جدار المثانة ثم للعاصرة لترتخي ومن ثم يندف البول الى المجري البولي او الإحليل.

Micturation





Micturition

Once urine enters the renal pelvis, it flows through the ureters and enters the bladder, where urine is stored.

Micturition is the process of emptying the urinary bladder.

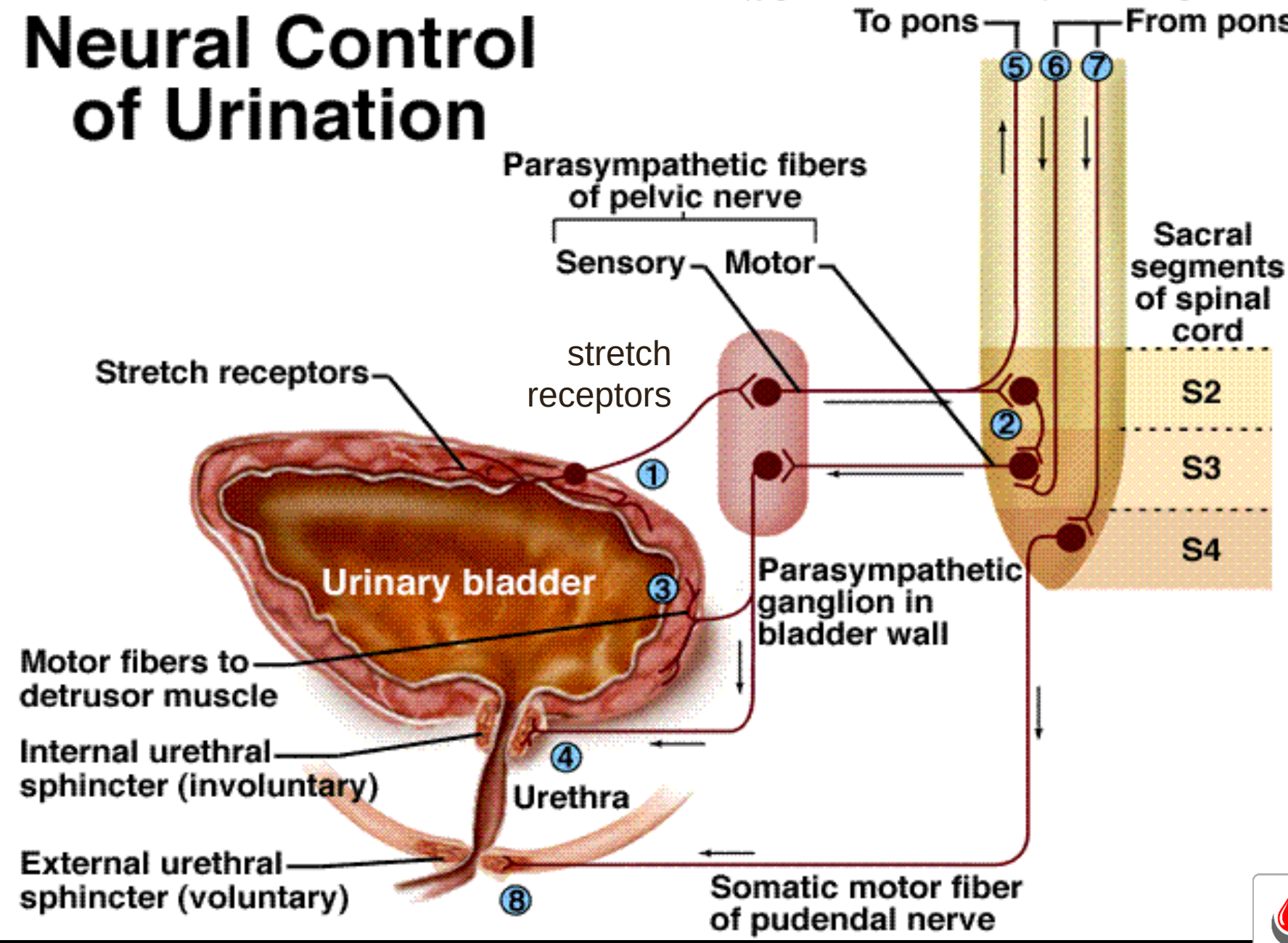
Two processes are involved:

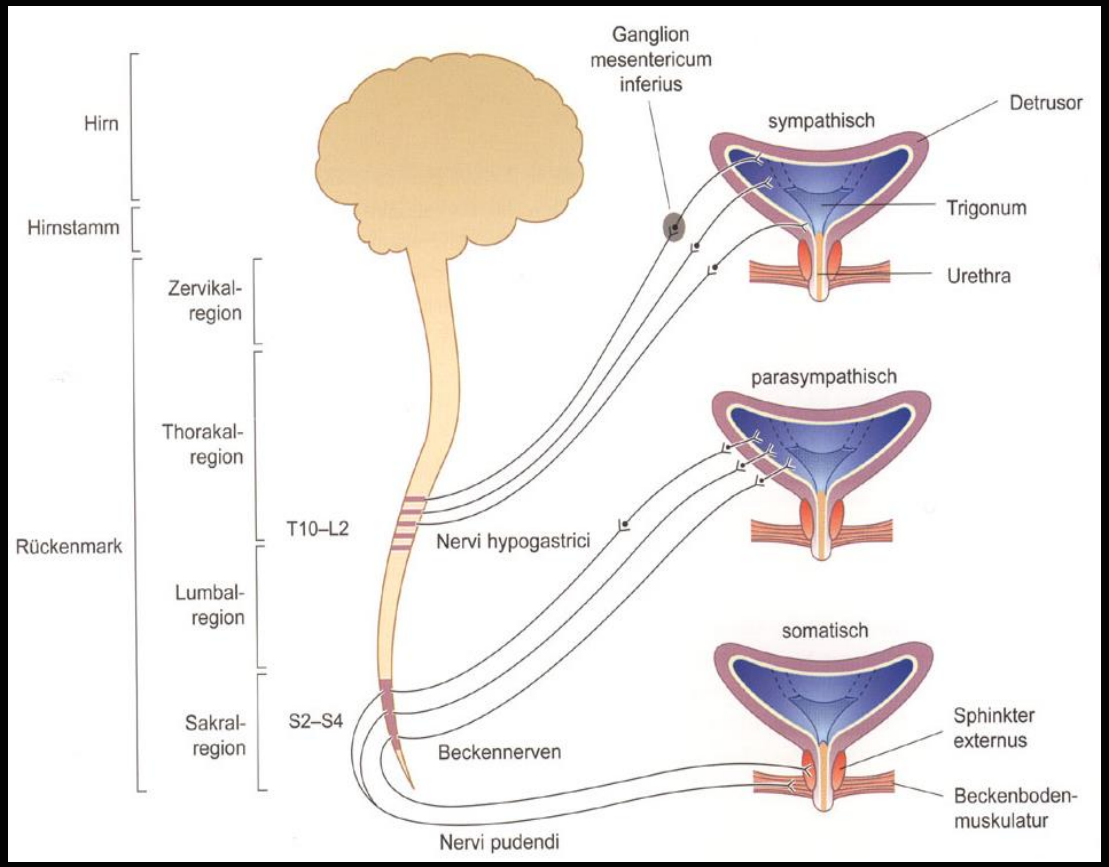
(1) The bladder fills progressively until the tension in its wall reses above a threshold level, and then

(2) A nervous reflex called the micturition reflex occurs that empties the bladder.

The micturition reflex is an automatic spinal cord reflex; however, it can be inhibited or facilitated by centers in the brainstem and cerebral cortex.

Neural Control of Urination





- Parasympathic S2-4
  Plexus pelvicus
  (detrusor contractility)
- Sympathic Th10-L2
  Nn.Hypogastrici
  (Bladder neck relaxant)
- Somatic S2-4
  N.Pudendus
  (external sphincter)