Table 14-1 Composition of extracellular fluids of representative animals*

	Habitat*	Osmolarity (mosM)	Ionic concentrations (mM)							
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HPO_4^{2-}	Urea
Seawater†		1000	460	10	10	53	540	27		
Coelenterata										
Aurelia (jellyfish)	SW		454	10.2	9.7	51.0	554	14.6		
Echinodermata										
Asterias (starfish)	SW		428	9.5	11.7	49.2	487	26.7		
Annelida										
Arenicola (lugworm)	SW		459	10.1	10.0	52.4	537	24.4		
Lumbricus (earthworm)	Ter.		76	4.0	2.9		43			
Mollusca										
Aplysia (sea slug)	SW		492	9.7	13.3	49	543	28.2		
Liligo (squid)	SW		419	20.6	11.3	51.6	522	6.9		
Anodonta (clam)	FW		15.6	0.49	8.4	0.19	11.7	0.73		
Crustacea										
Cambarus (crayfish)	FW		146	3.9	8.1	4.3	139			
Homarus (lobster)	SW		472	10.0	15.6	6.7	470			
Insecta										
Locusta	Ter.		60	12	17	25				
Periplanta (cockroach)	Ter.		161	7.9	4.0	5.6	144			
Cyclostomata										
Eptatretus (hagfish)	SW	1002	554	6.8	8.8	23.4	532	1.7	2.1	3
Lampetra (lamprey)	FW	248	120	3.2	1.9	2.1	96	2.7		0.4

* The osmolarity and composition of seawater vary, and the values given here are not intended to be absolute. The composition of body fluids of osmoconformers will also vary, depending on the composition of the seawater in which they are tested.

† SW = seawater; FW = freshwater; Ter. = terrestrial.

Sources: Schmidt-Nielsen and Mackay, 1972; Prosser, 1973.

Table 14-1 Composition of extracellular fluids of representative animals*

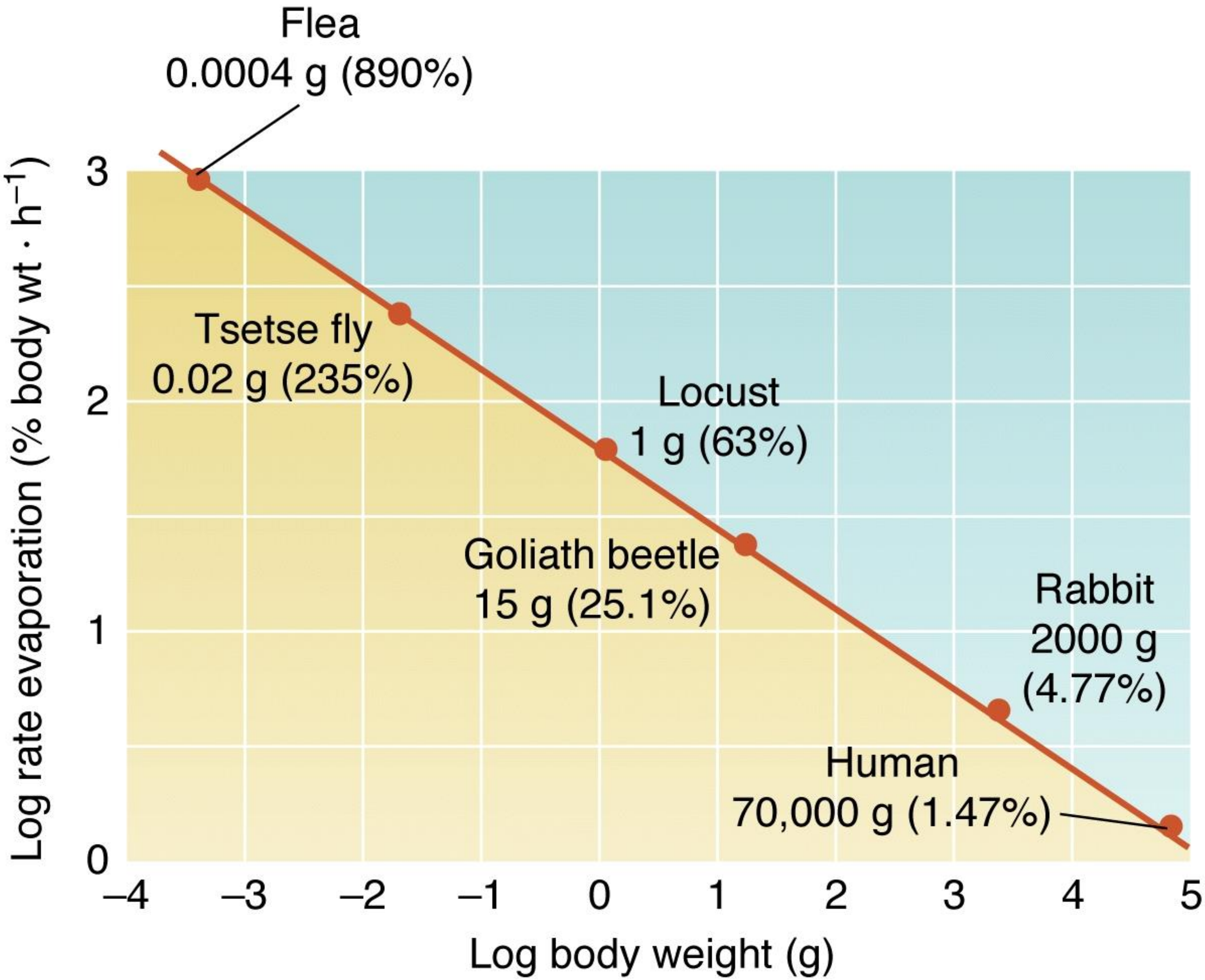
	Habitat*	Osmolarity (mosM)	Ionic concentrations (mM) Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HPO_4^{2-}	Urea
Seawater†		1000	460	10	10	53	540	27		
Chondrichthyes										
Dogfish shark	SW	1075	269	4.3	3.2	1.1	258	1	1.1	376
Carcharhinus	FW		200	8	3	2	180	0.5	4.0	132
Coelacantha										
Latimeria	SW		181	51.3	6.9	28.7	199			355
Teleostei										
Paralichthys (flounder)	SW	337	180	4	3	1	160	0.2		
Carassius (goldfish)	FW	293	142	2	6	3	107			
Amphibia										
Rana esculenta (frog)	FW	210	92	3	2.3	1.6	70			2
Rana cancrivora	FW	290	125	9			98			40
	80% SW	830	252	14			227			350
Reptilia										
Alligator	FW	278	140	3.6	5.1	3.0	111			
Aves										
Anas (duck)	FW	294	138	3.1	2.4		103		1.6	
Mammalia										
Homo sapiens	Ter.		142	4.0	5.0	2.0	104	1	2	
Lab rat	Ter.		145	6.2	3.1	1.6	116			

* The osmolarity and composition of seawater vary, and the values given here are not intended to be absolute.
The composition of body fluids of osmoconformers will also vary, depending on the composition of the seawater in which they are tested.
† SW = seawater; FW = freshwater; Ter. = terrestrial.
Sources: Schmidt-Nielsen and Mackay, 1972; Prosser, 1973.

Table 14-2 **Electrolyte composition of the human body fluids**

Electrolytes	Serum ($meq \cdot kg^{-1}$ H_2O)	Interstitial fluid ($meq \cdot kg^{-1}$ H_2O)	Intracellular fluid (muscle) ($meq \cdot kg^{-1}$ H_2O)
Cations			
Na^+	142	145	10
K^+	4	4	156
Ca^{2+}	5		3
Mg^{2+}	2		26
Totals	153	149	195
Anions			
Cl^-	104	114	2
HCO_3^-	27	31	8
HPO_4^{2-}	2		95
SO_4^{2-}	1		20
Organic acids	6		
Proteins	13		55
Totals	153	145	180

Note: Some of the ions contained within cells are not completely dissolved within the cytosol, but may be partially sequestered within cytoplasmic organelles. Thus, the true free Ca^{2+} concentration in the cytosol is typically below the overall value given in the table for intracellular Ca^{2+}. Failure of anion and cation totals to agree reflects incomplete tabulation.



Flea
0.0004 g (890%)
Tsetse fly
0.02 g (235%)
Locust
1 g (63%)
Goliath beetle
15 g (25.1%)
Rabbit
2000 g
(4.77%)
Human
70,000 g (1.47%)
Log rate evaporation (% body wt · h^{-1})
3
2
1
0
–4
–3
–2
–1
0
1
2
3
4
5
Log body weight (g)

Table 14-3 Evaporative water loss of representative animals under desert conditions

Species	Water loss ($mg \cdot cm^{-2} \cdot h^{-1}$)	Remarks*
Arthropods		
Eleodes armata (beetle)	0.20	30°C; 0% r.h.
Hadrurus arizonensis (scorpion)	0.02	30°C; 0% r.h.
Locusta migratoria (locust)	0.70	30°C; 0% r.h.
Amphibians		
Cyclorana alboguttatus (frog)	4.90	25°C; 100% r.h.
Reptiles		
Gehrydra variegata (gecko)	0.22	30°C; dry air
Uta stansburiana (lizard)	0.10	0°C

* r.h. stands for relative humidity. Where not indicated, relative humidity is not available.

† The cactus mouse and African oryx are desert animals and employ various water-conservation measures. Thus their evaporative water loss is much less than that of humans.

Source: Hadley, 1972.

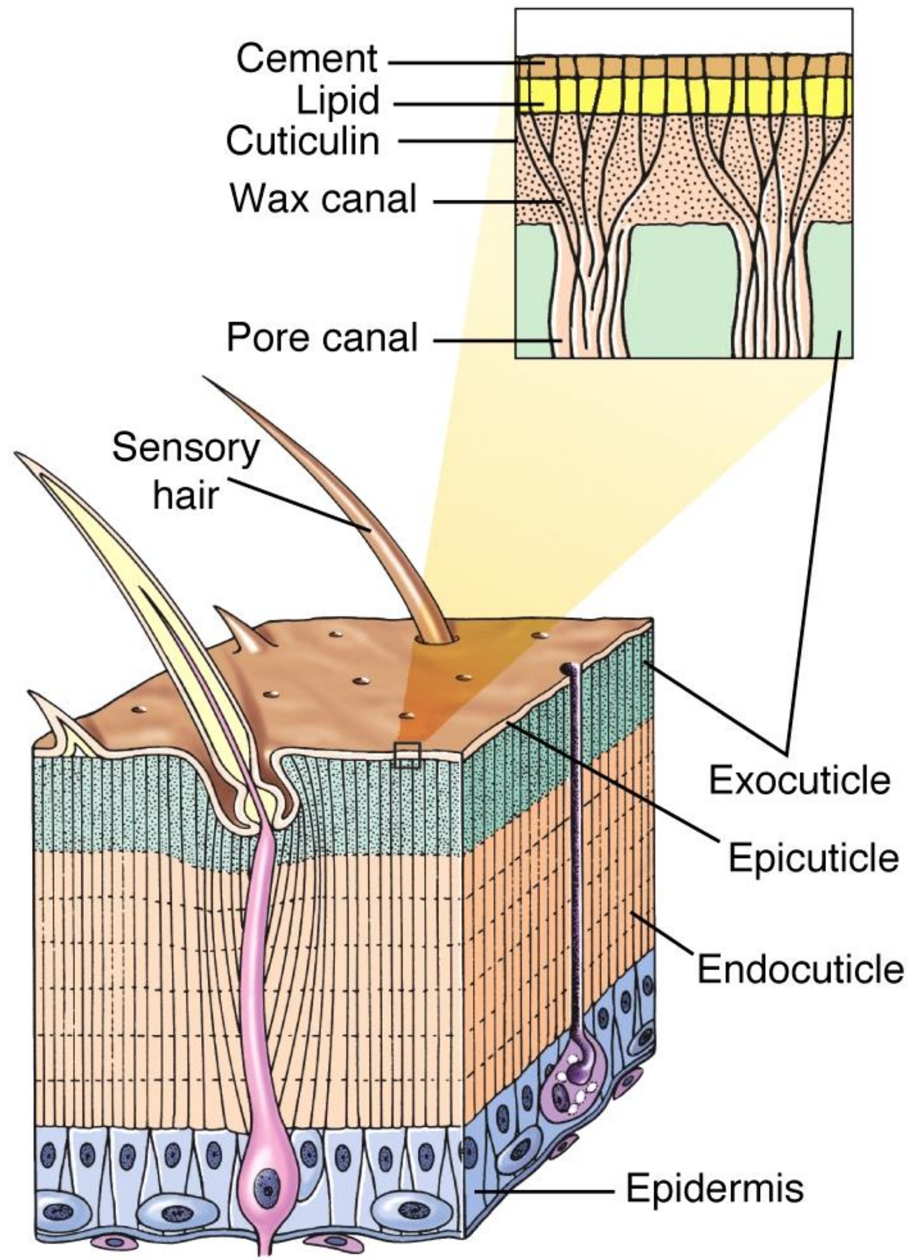
Table 14-3 Evaporative water loss of representative animals under desert conditions

Species	Water loss ($mg \cdot cm^{-2} \cdot h^{-1}$)	Remarks*
Birds		
Amphispiza belli (sparrow)	1.48	30°C
Phalaenpitus nutalllii (poorwill)	0.86	30°C
Mammals†		
Peromyscus eremicus (cactus mouse)	0.66	30°C
Oryx beisa (African oryx)	3.24	22°C
Homo sapiens	22.32	70 kg; nude, sitting in sun; 35°C

* r.h. stands for relative humidity. Where not indicated, relative humidity is not available.

† The cactus mouse and African oryx are desert animals and employ various water-conservation measures. Thus their evaporative water loss is much less than that of humans.

Source: Hadley, 1972.


Cement
Lipid
Cuticulin
Wax canal
Pore canal
Sensory hair
Exocuticle
Epicuticle
Endocuticle
Epidermis

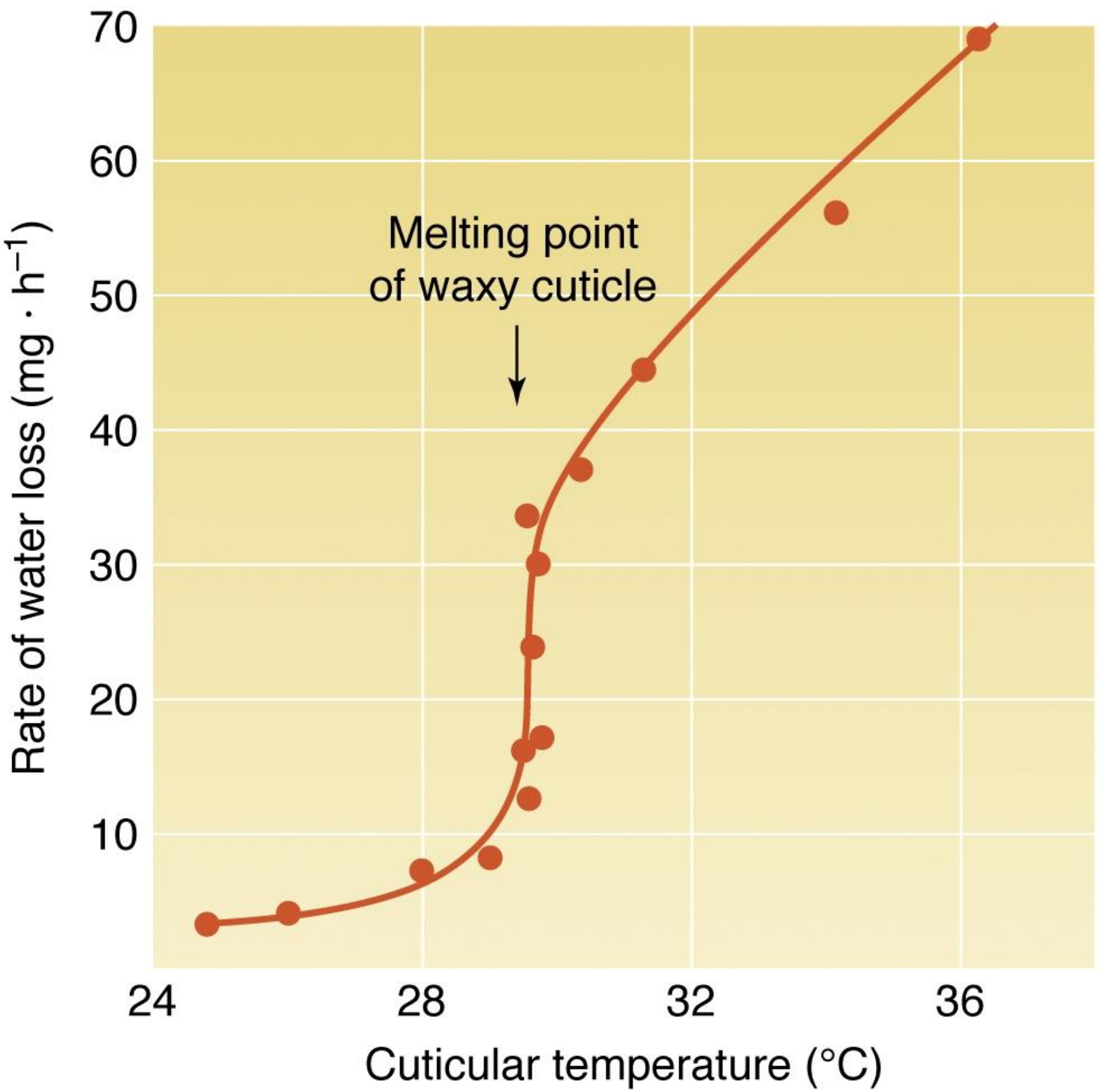
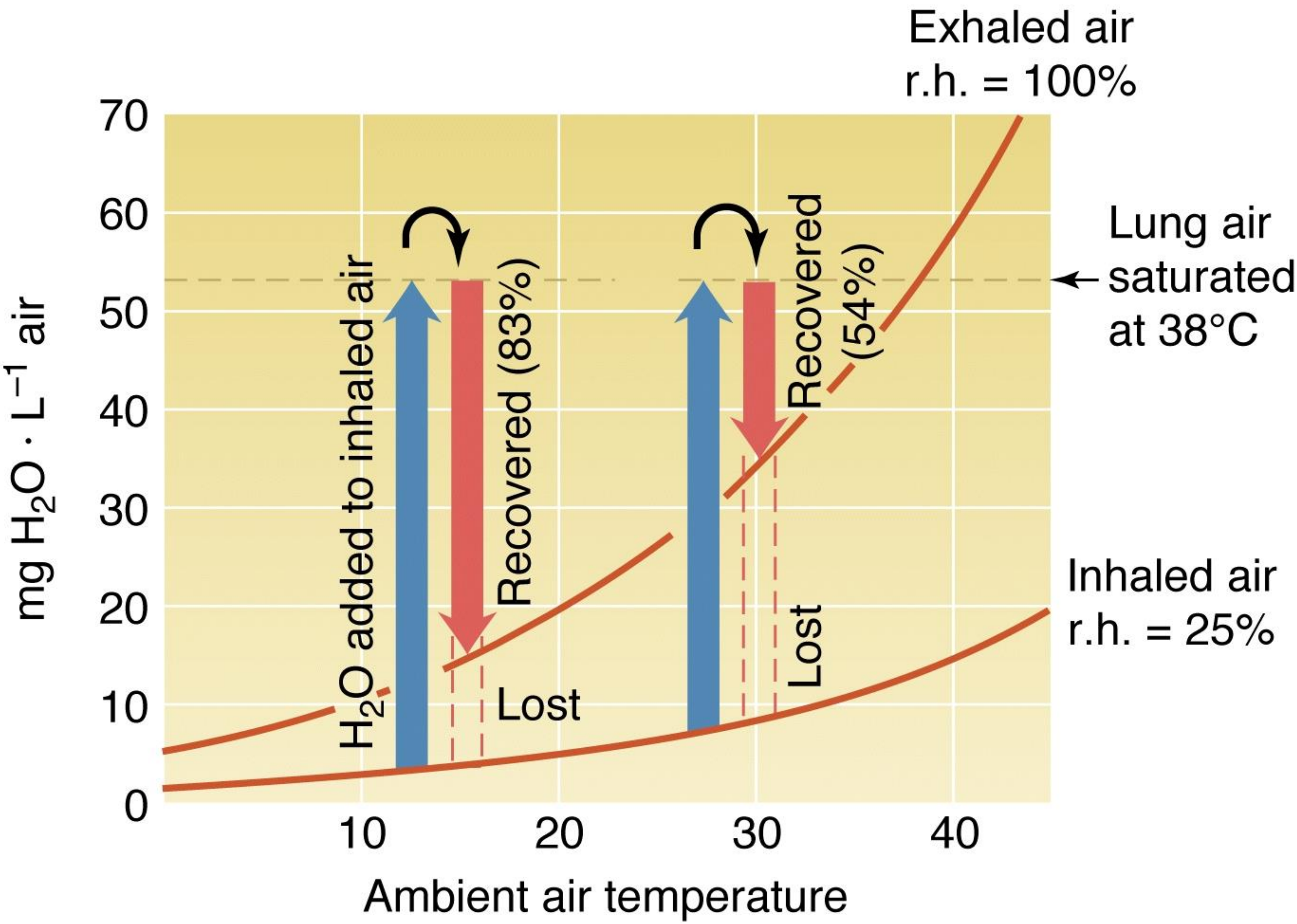
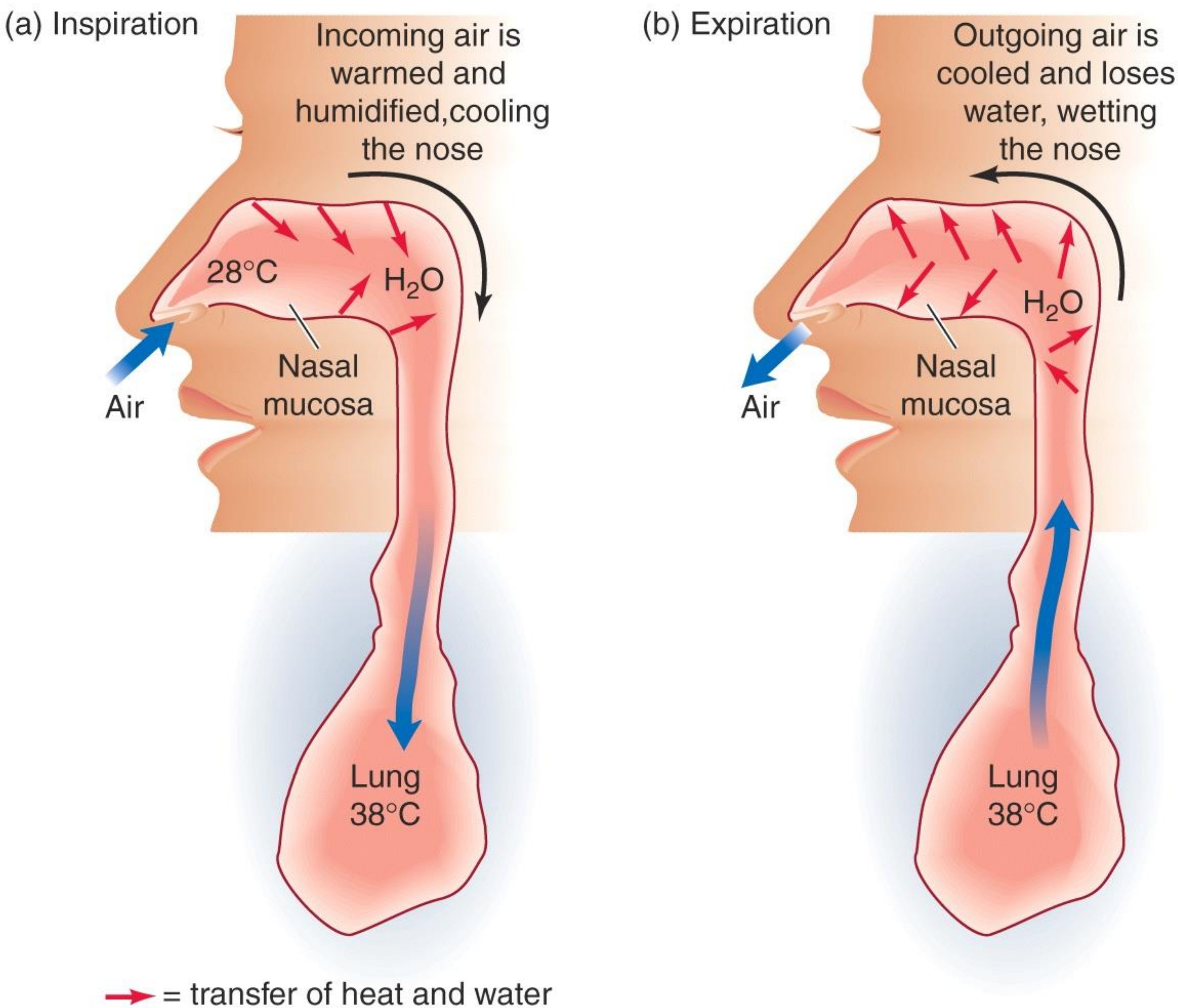

70
60
50
40
30
20
10
Rate of water loss (mg · h⁻¹)
Melting point
of waxy cuticle
24
28
32
36
Cuticular temperature (°C)

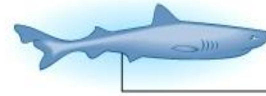
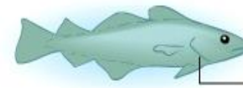
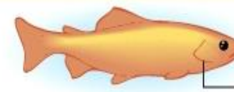
Table 14-4 Production of metabolic water during oxidation of foods

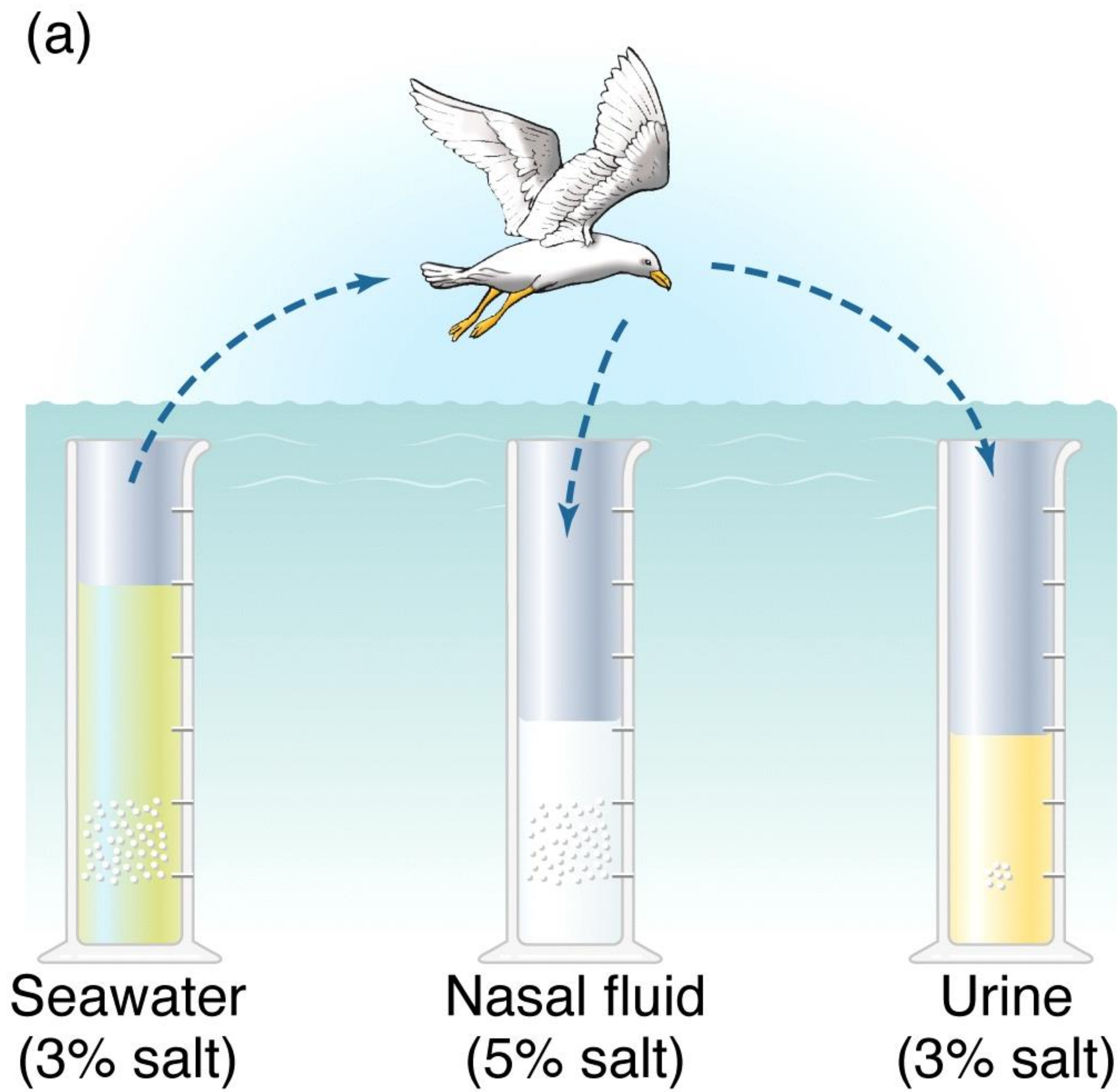
	Food		
	Carbohydrates	Fats	Proteins
Grams of metabolic water per gram of food	0.56	1.07	0.40
Kilojoules expended per gram of food	17.58	39.94	17.54
Grams of metabolic water per kilojoule expended	0.032	0.027	0.023

Source: Edney and Nagy, 1976.


Exhaled air
r.h. = 100%
Lung air
saturated
at 38°C
Inhaled air
r.h. = 25%
H2O added to inhaled air
Recovered (83%)
Lost
Recovered
(54%)
Lost
mg H2O · L−1 air
70
60
50
40
30
20
10
0
10
20
30
40
Ambient air temperature


(a) Inspiration
Incoming air is warmed and humidified,cooling the nose
28°C
H_2O
Air
Nasal mucosa
Lung 38°C
(b) Expiration
Outgoing air is cooled and loses water, wetting the nose
H_2O
Air
Nasal mucosa
Lung 38°C
= transfer of heat and water

Type of animal	Blood concentration relative to environment	Urine concentration relative to blood	Osmoregulatory mechanisms
Marine elasmobranch	Slightly hyperosmotic	Iso-osmotic	 Does not drink seawater; Hyperosmotic NaCl from rectal gland
Marine teleost	Hypo-osmotic	Iso-osmotic	 Drinks seawater; Secretes salt from gills
Freshwater teleost	Hyperosmotic	Hypo-osmotic	 Drinks no water; Absorbs salt with gills
Amphibian	Hyperosmotic	Hypo-osmotic	 Absorbs salt through skin
Marine reptile	Hypo-osmotic	Iso-osmotic	 Drinks seawater; Hyperosmotic salt-gland secretion
Desert mammal	–	Hyperosmotic	 Drinks no water; Depends on metabolic water
Marine mammal	Hypo-osmotic	Hyperosmotic	 Does not drink seawater
Marine bird	–	Hyperosmotic	 Drinks seawater; Hyperosmotic salt-gland secretion
Terrestrial bird	–	Hyperosmotic	 Drinks freshwater


(a)
Seawater
(3% salt)
Nasal fluid
(5% salt)
Urine
(3% salt)

(b)

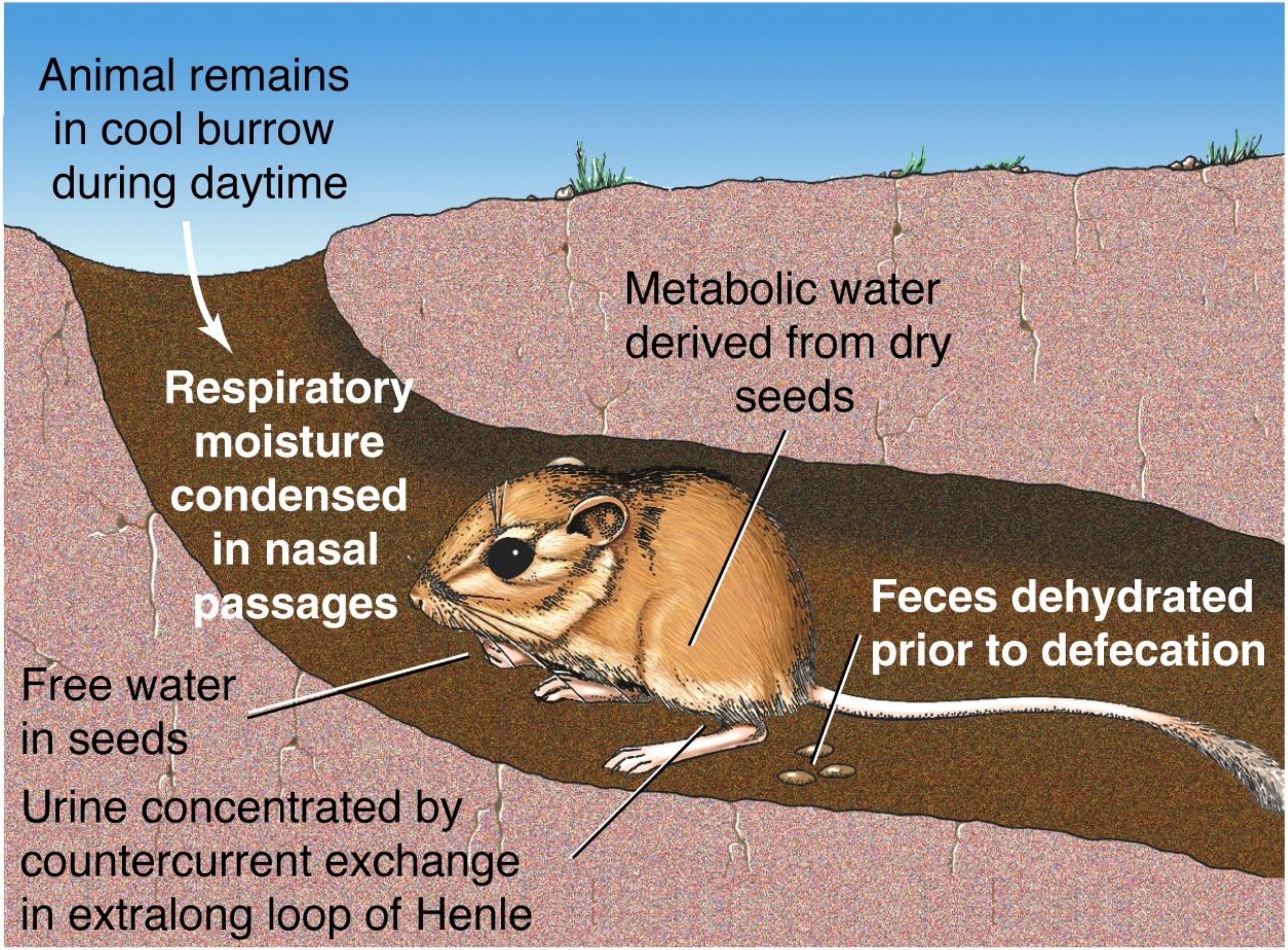
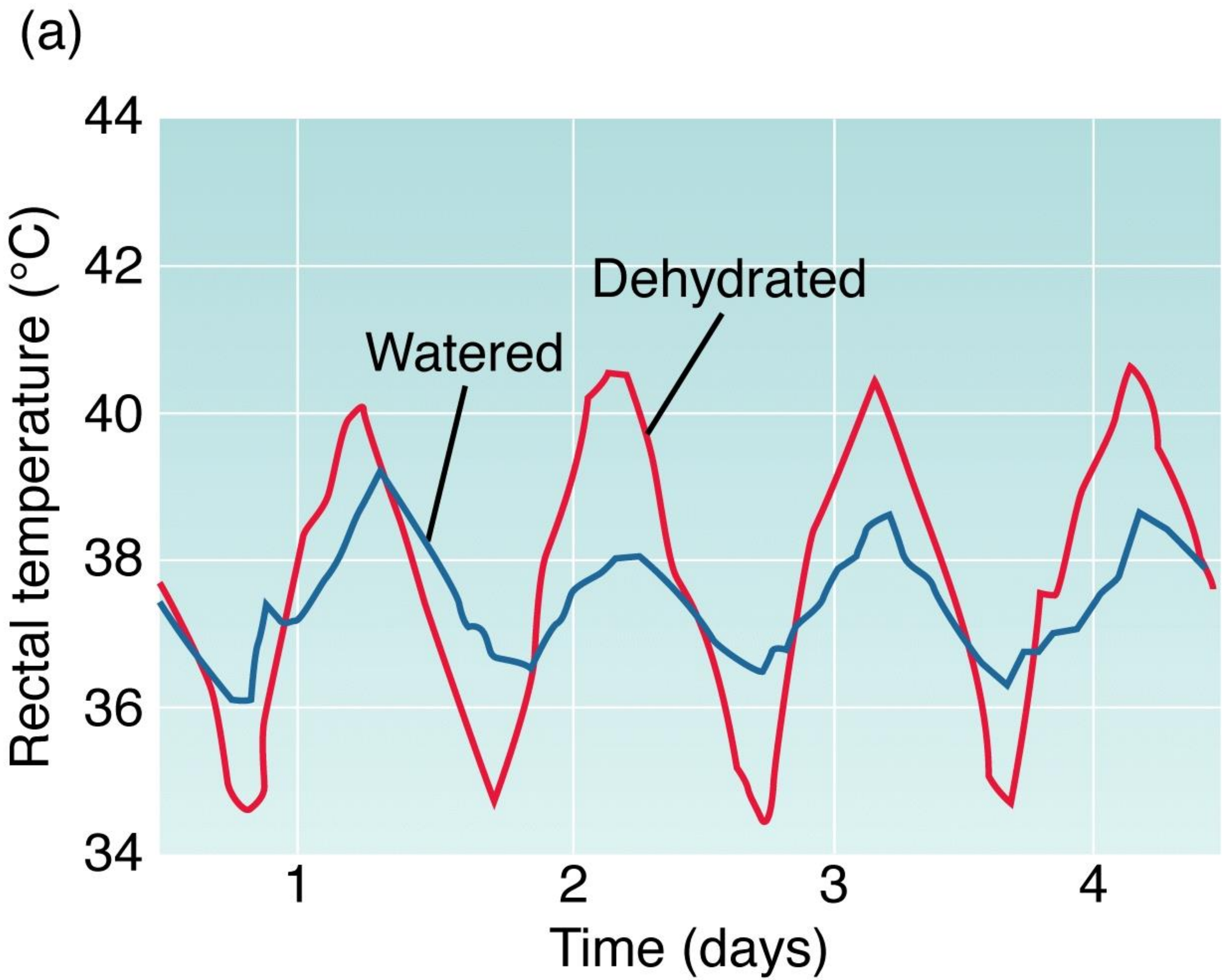
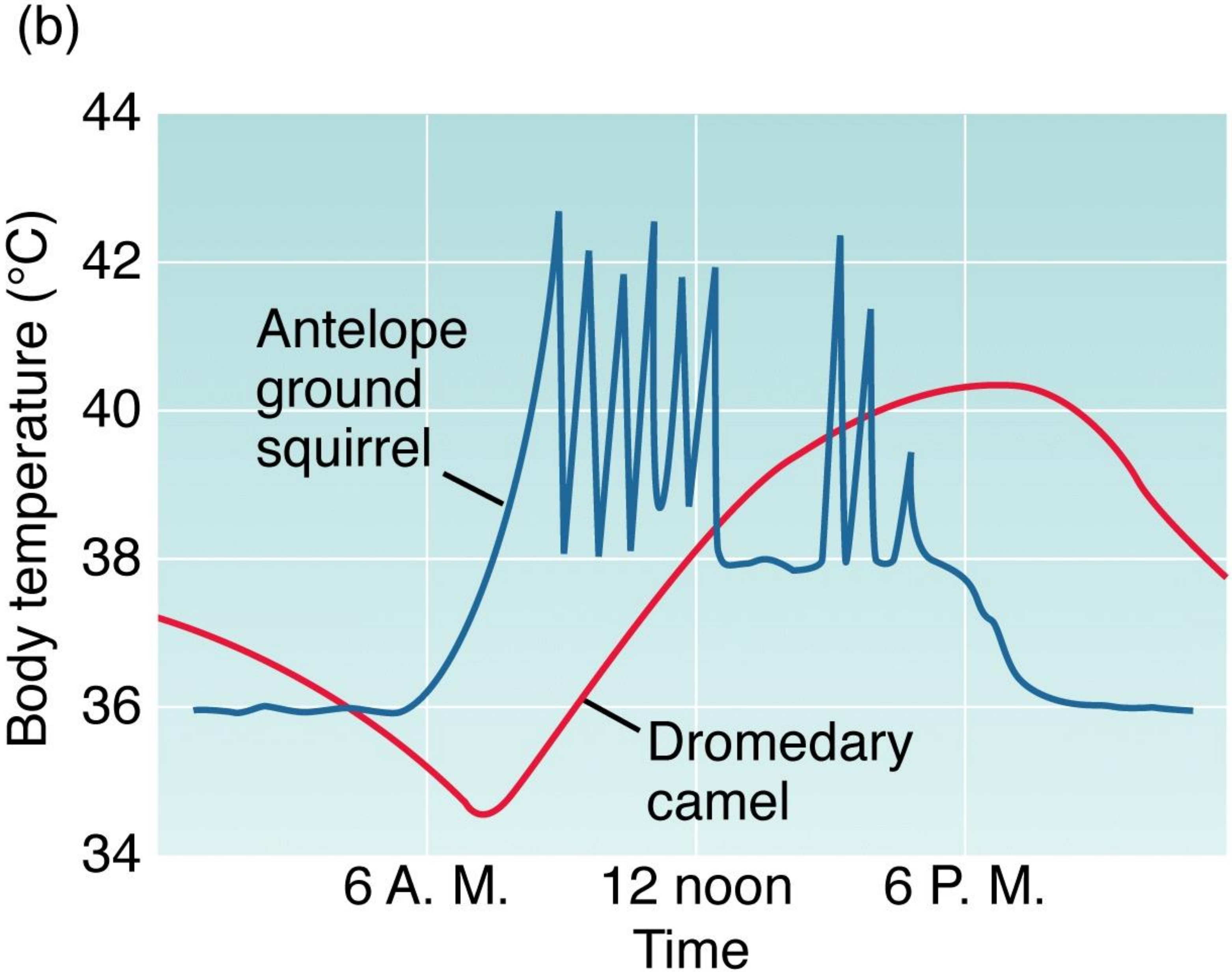

Animal remains in cool burrow during daytime
Respiratory moisture condensed in nasal passages
Metabolic water derived from dry seeds
Feces dehydrated prior to defecation
Free water in seeds
Urine concentrated by countercurrent exchange in extralong loop of Henle

Table 14-5 Sources of water gain and loss by the kangaroo rat

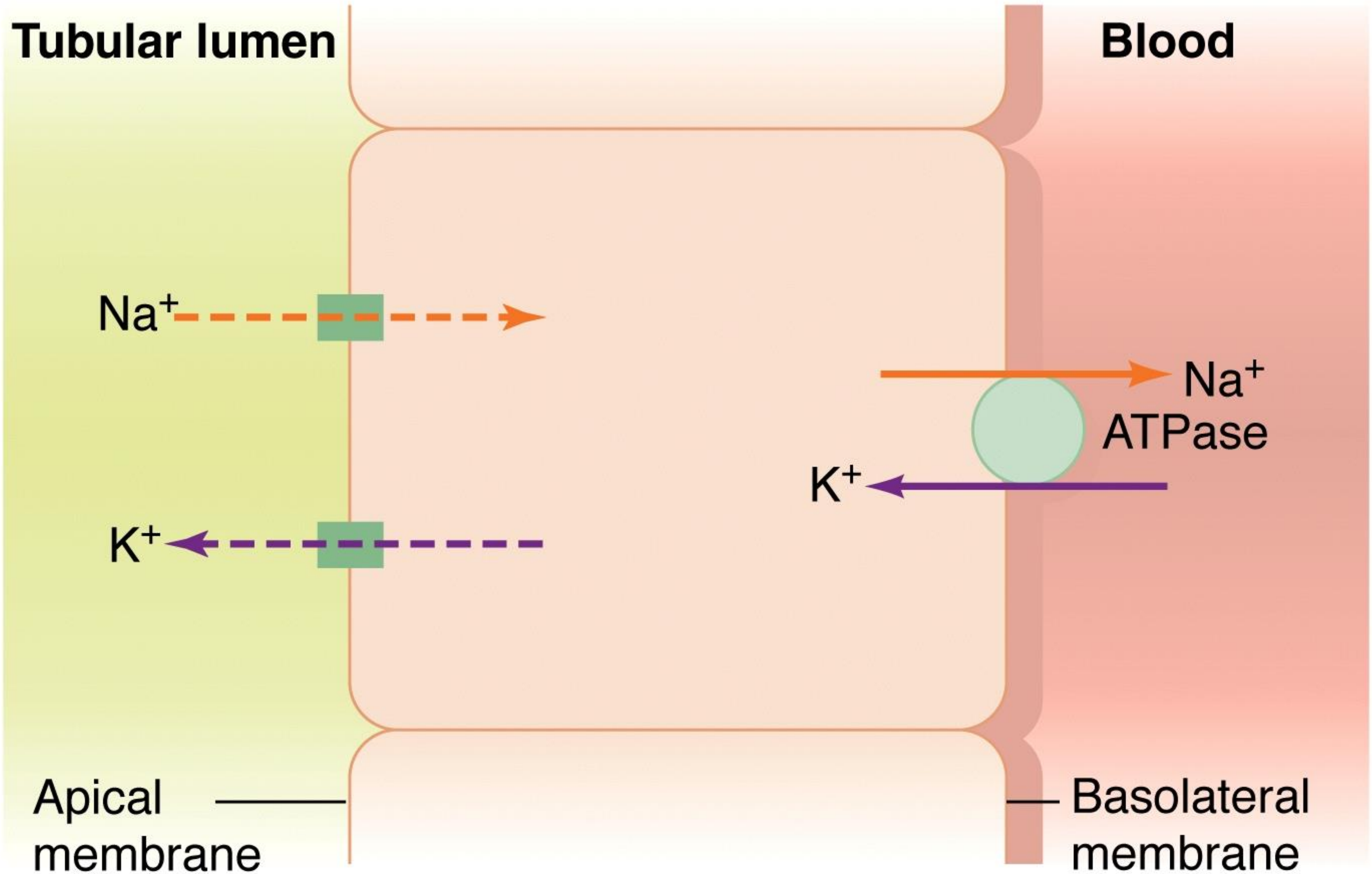
Gains		Losses	
Metabolic water	90%	Evaporation and perspiration	70%
Free water in "dry" food	10%	Urine	25%
Drinking	0%	Feces	5%
	100%		100%

Source: Schmidt-Nielsen, 1972.


(a)
44
42
40
38
36
34
Rectal temperature (°C)
Dehydrated
Watered
1
2
3
4
Time (days)

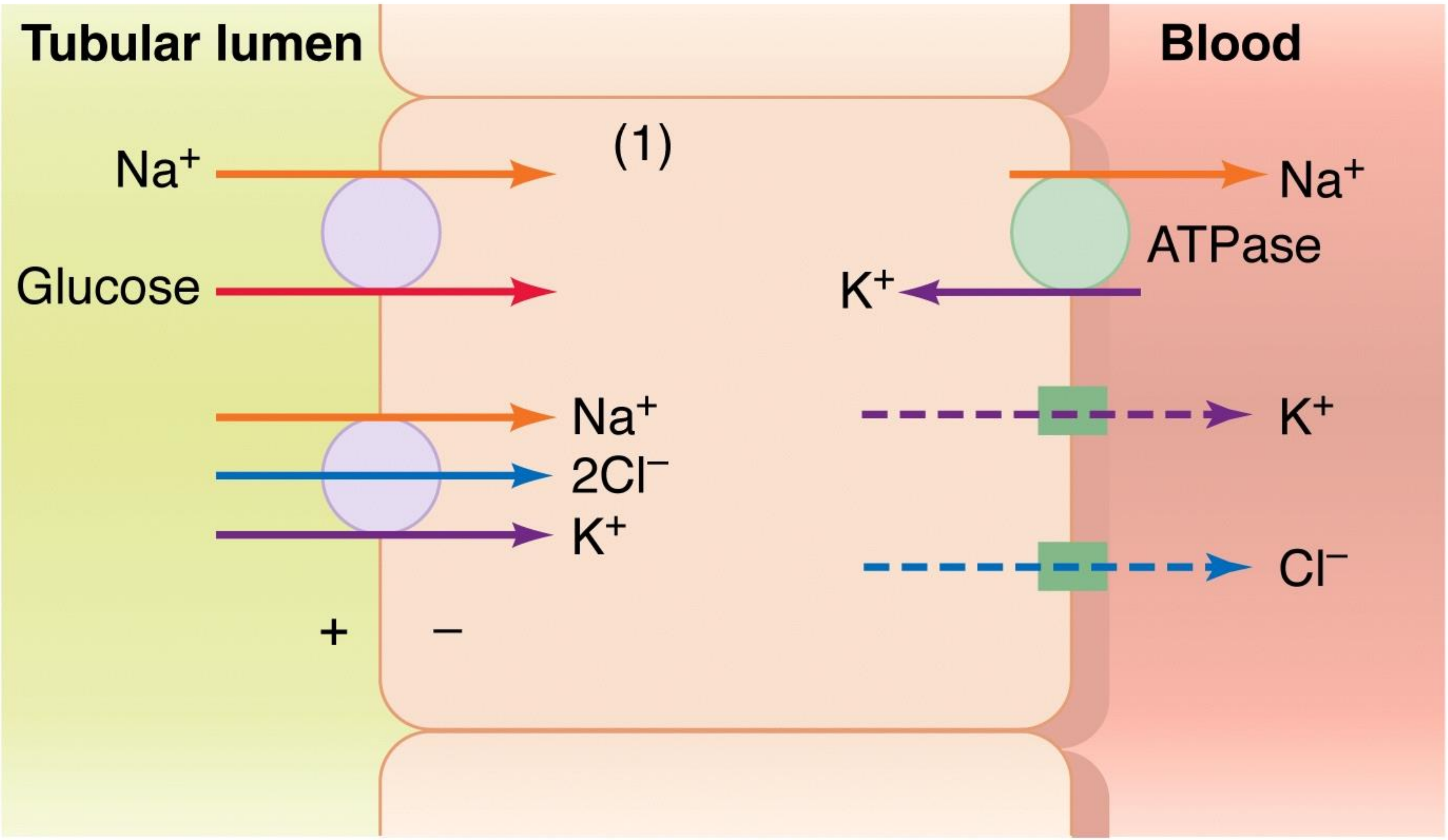


(b)
Body temperature (°C)
44
42
40
38
36
34
Antelope ground squirrel
Dromedary camel
6 A. M.
12 noon
6 P. M.
Time

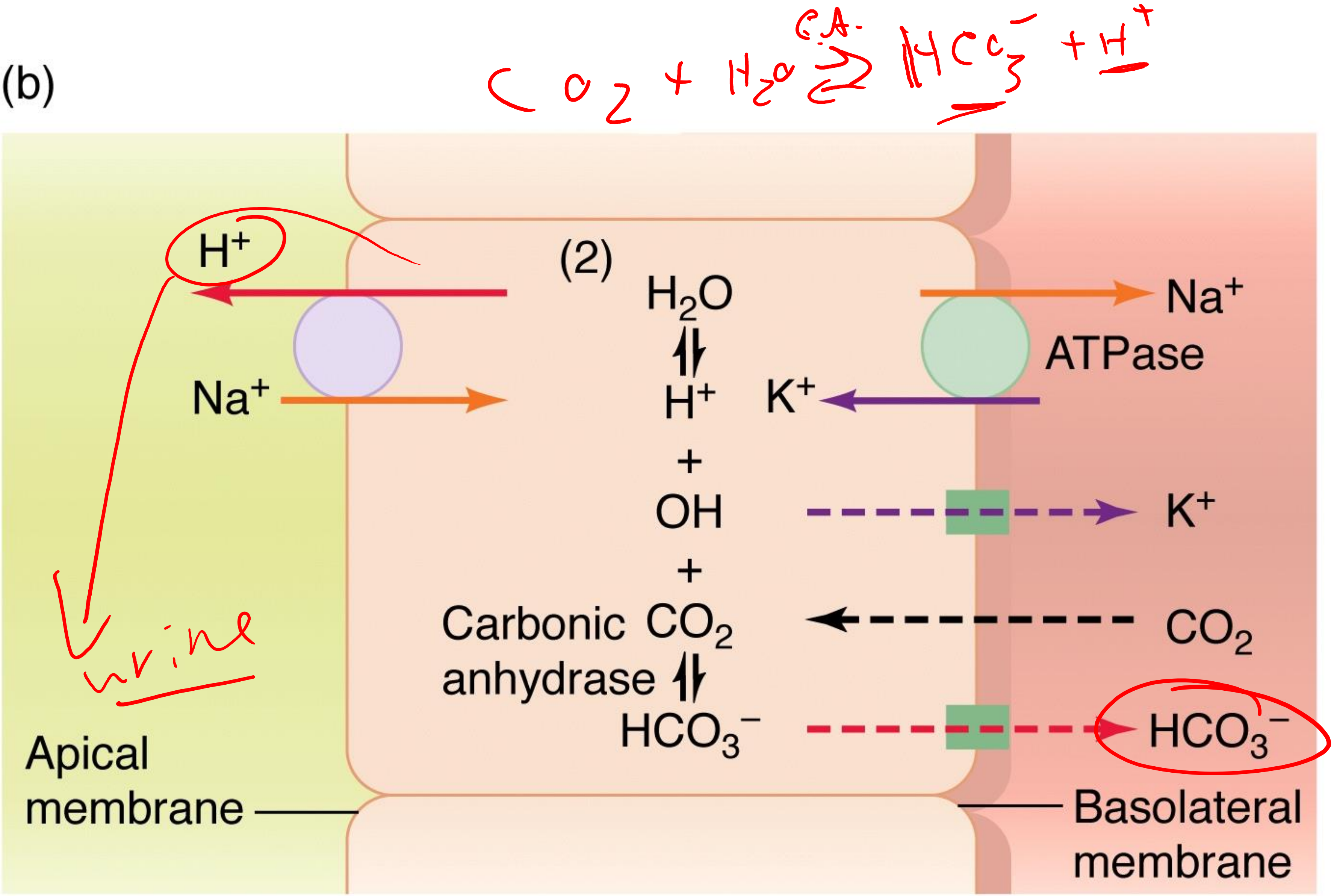


Tubular lumen
Blood
Na+
Na+
ATPase
K+
K+
Apical membrane
Basolateral membrane

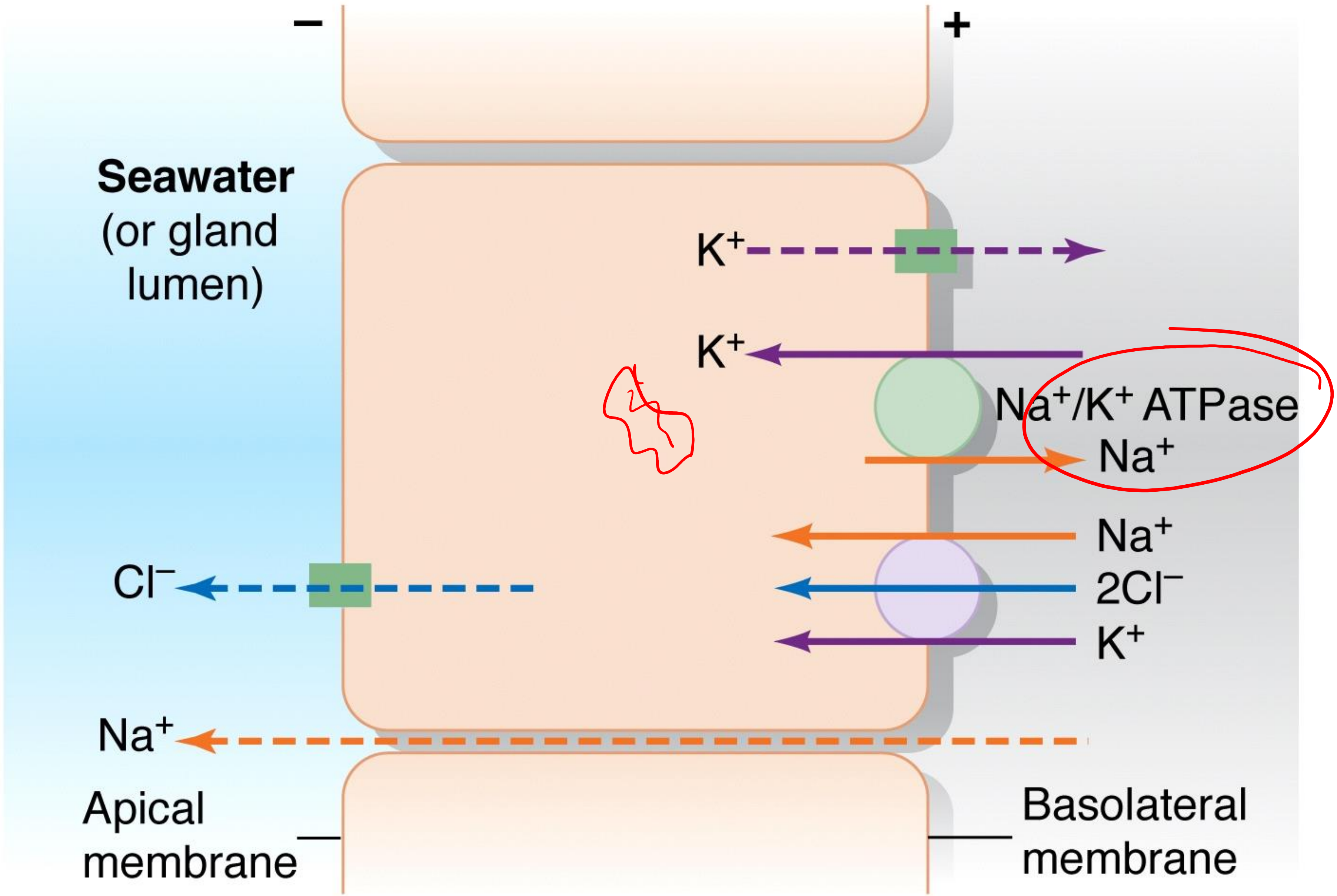
(a)

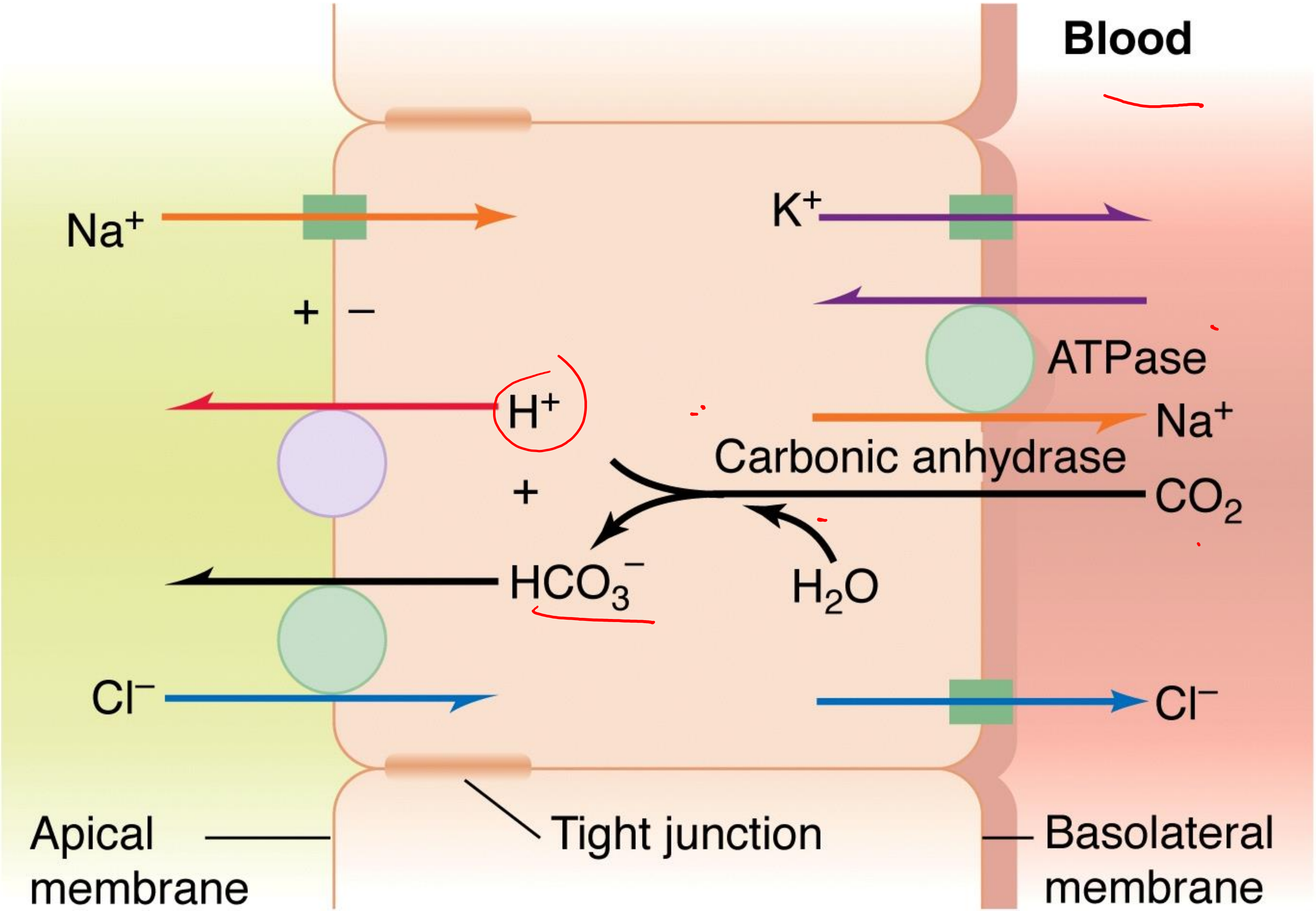


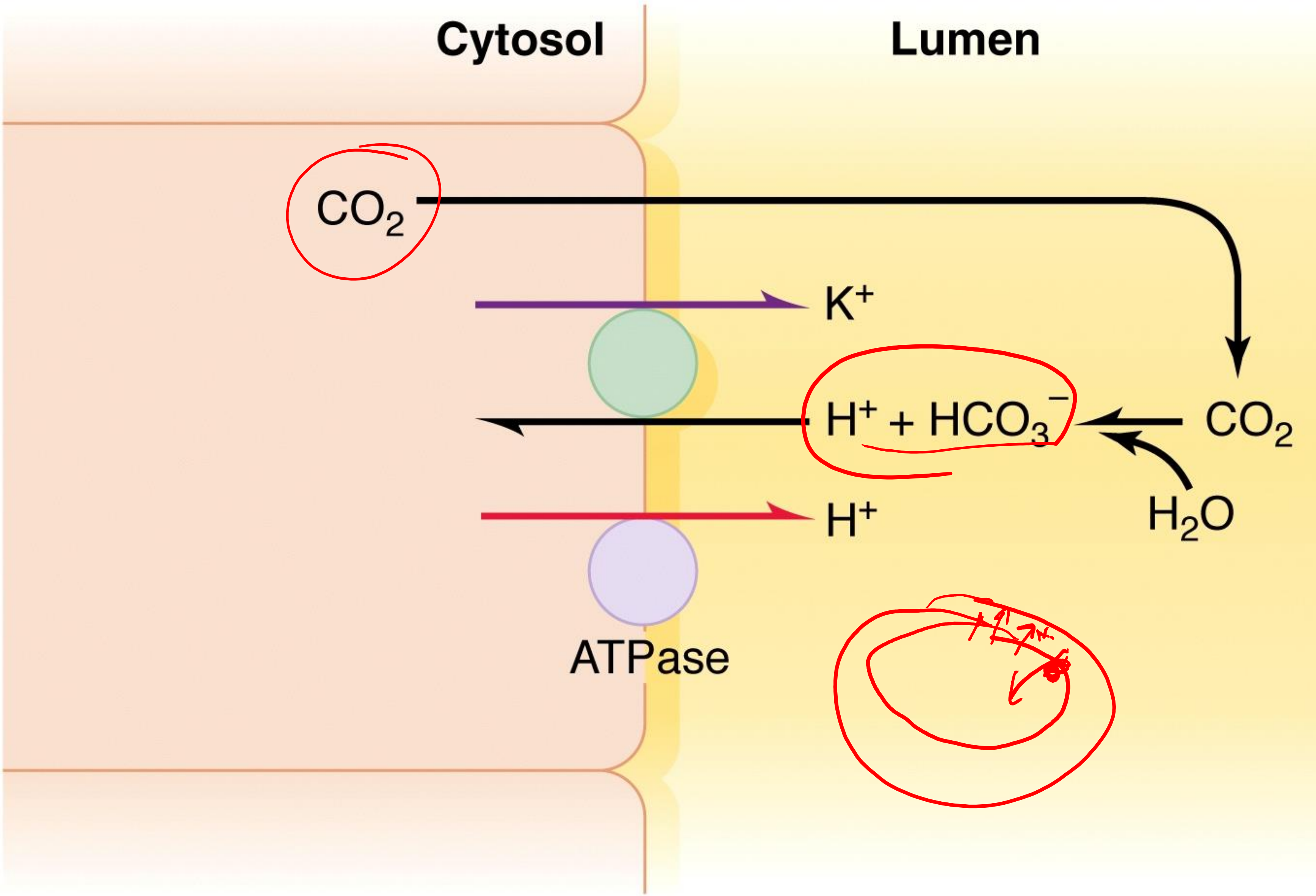
(b)



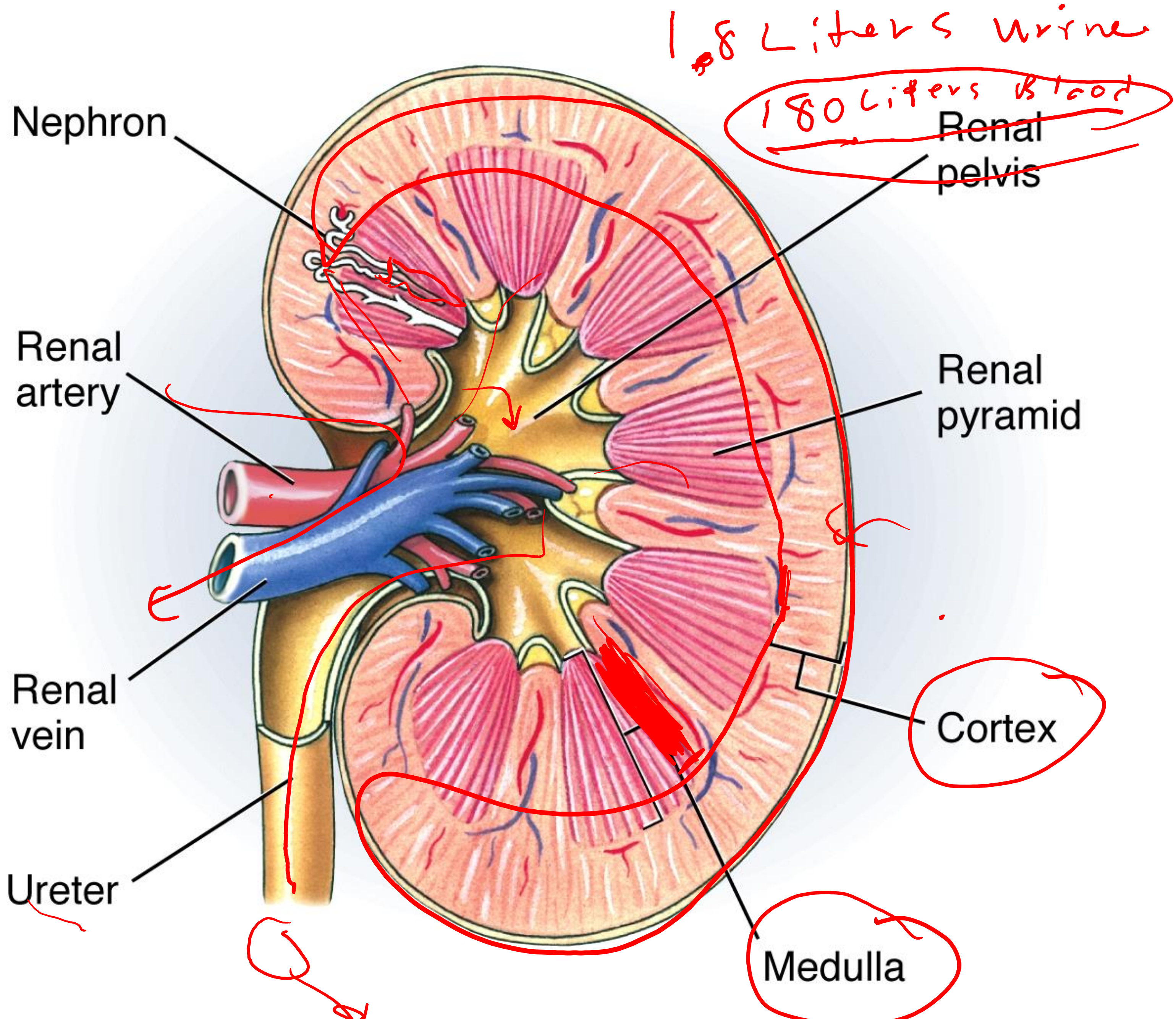
$CO_2 + H_2O \overset{C.A.}{\rightleftharpoons} HCO_3^- + H^+$
(2)
H_2O
H^+
+
OH
+
Carbonic anhydrase
CO_2
HCO_3^-
H^+
Na^+
urine
Na^+
ATPase
K^+
K^+
CO_2
HCO_3^-
Apical membrane
Basolateral membrane

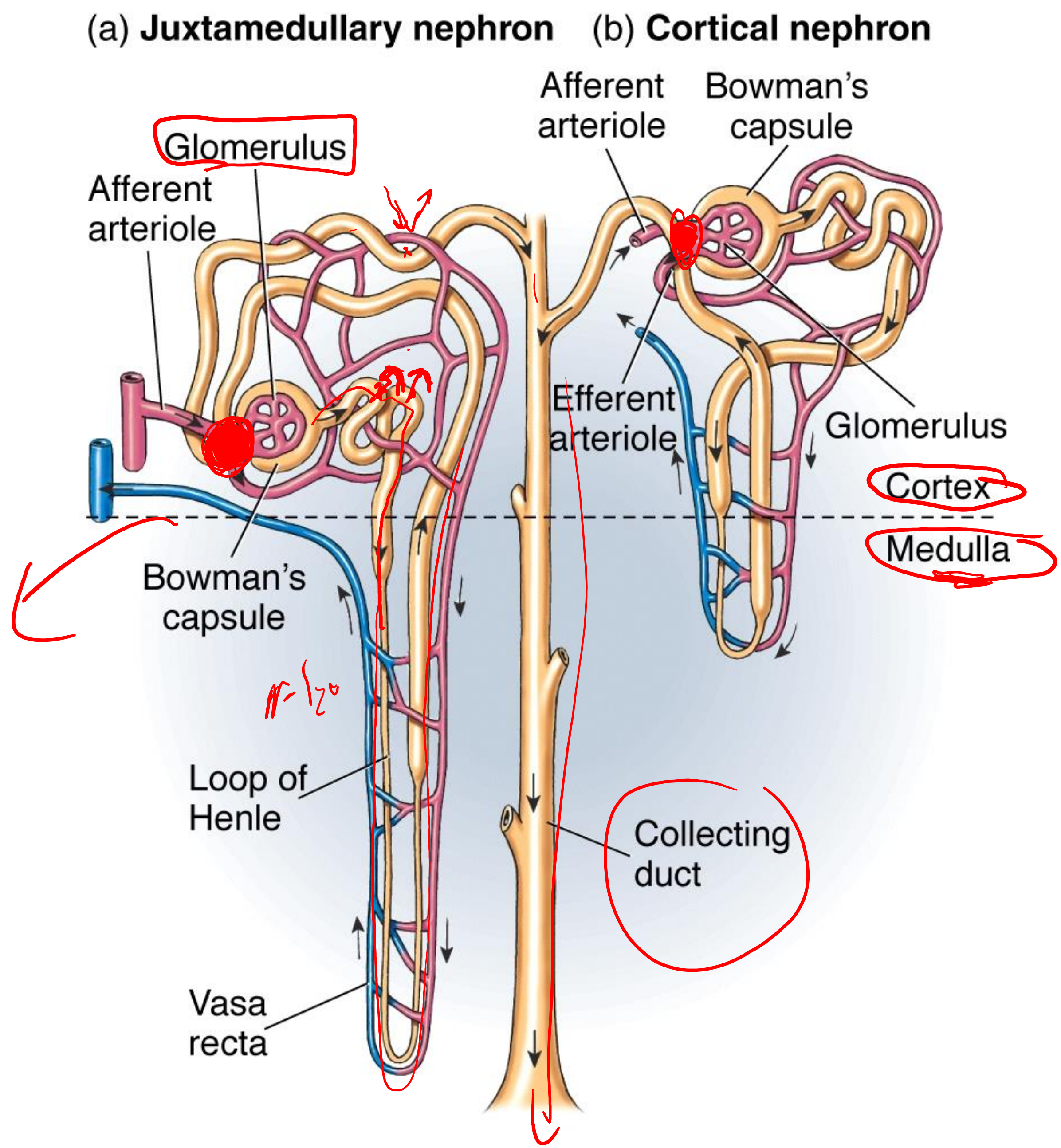

−
+
Seawater
(or gland
lumen)
K+
K+
Na+/K+ ATPase
Na+
Na+
2Cl−
K+
Cl−
Na+
Apical
membrane
Basolateral
membrane


Blood
Na^+
K^+
+ −
ATPase
H^+
Na^+
Carbonic anhydrase
+
CO_2
HCO_3^-
H_2O
Cl^-
Cl^-
Apical membrane
Tight junction
Basolateral membrane

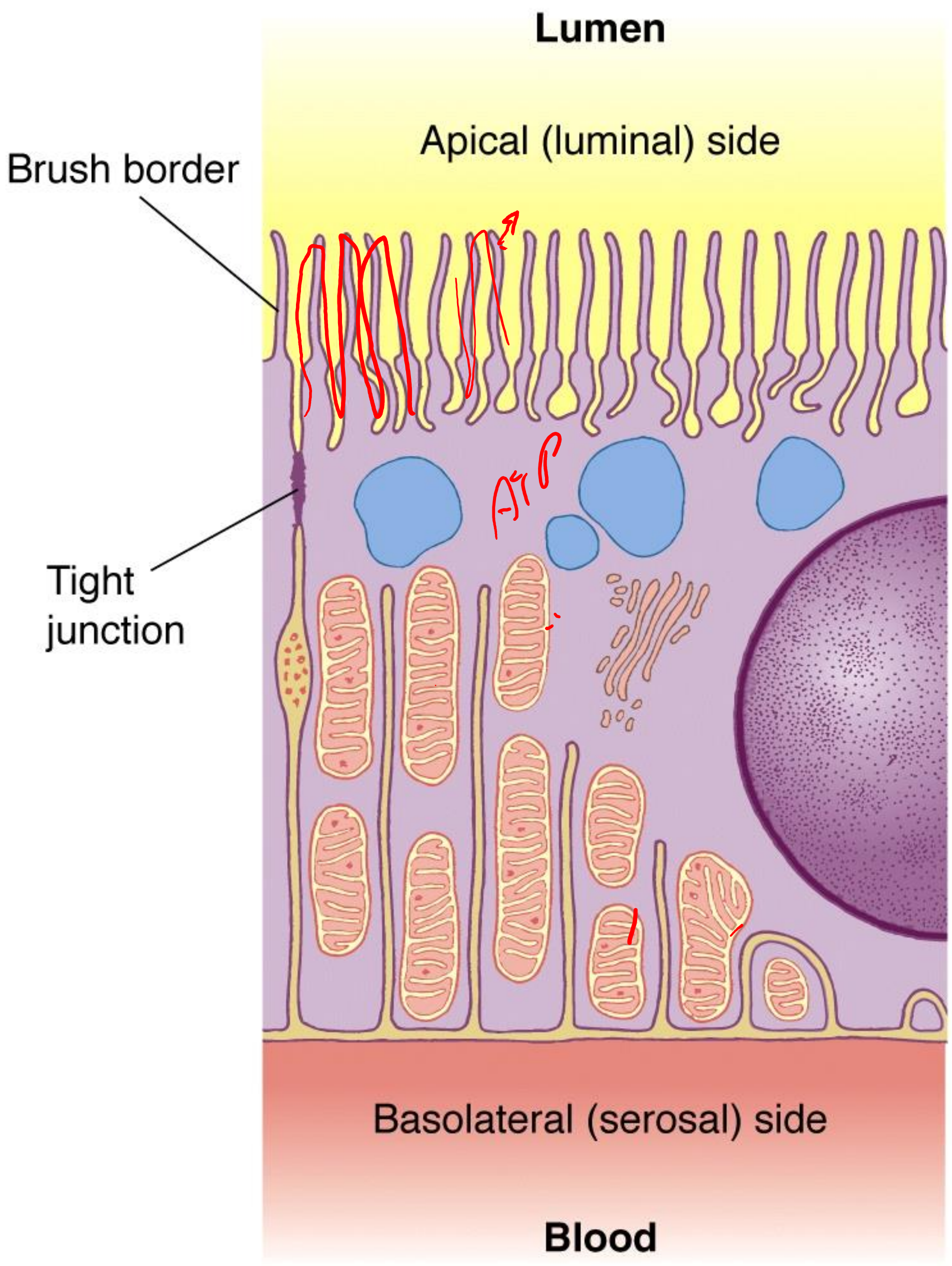


Cytosol
Lumen
CO_2
K^+
$H^+ + HCO_3^-$
CO_2
H_2O
H^+
ATPase

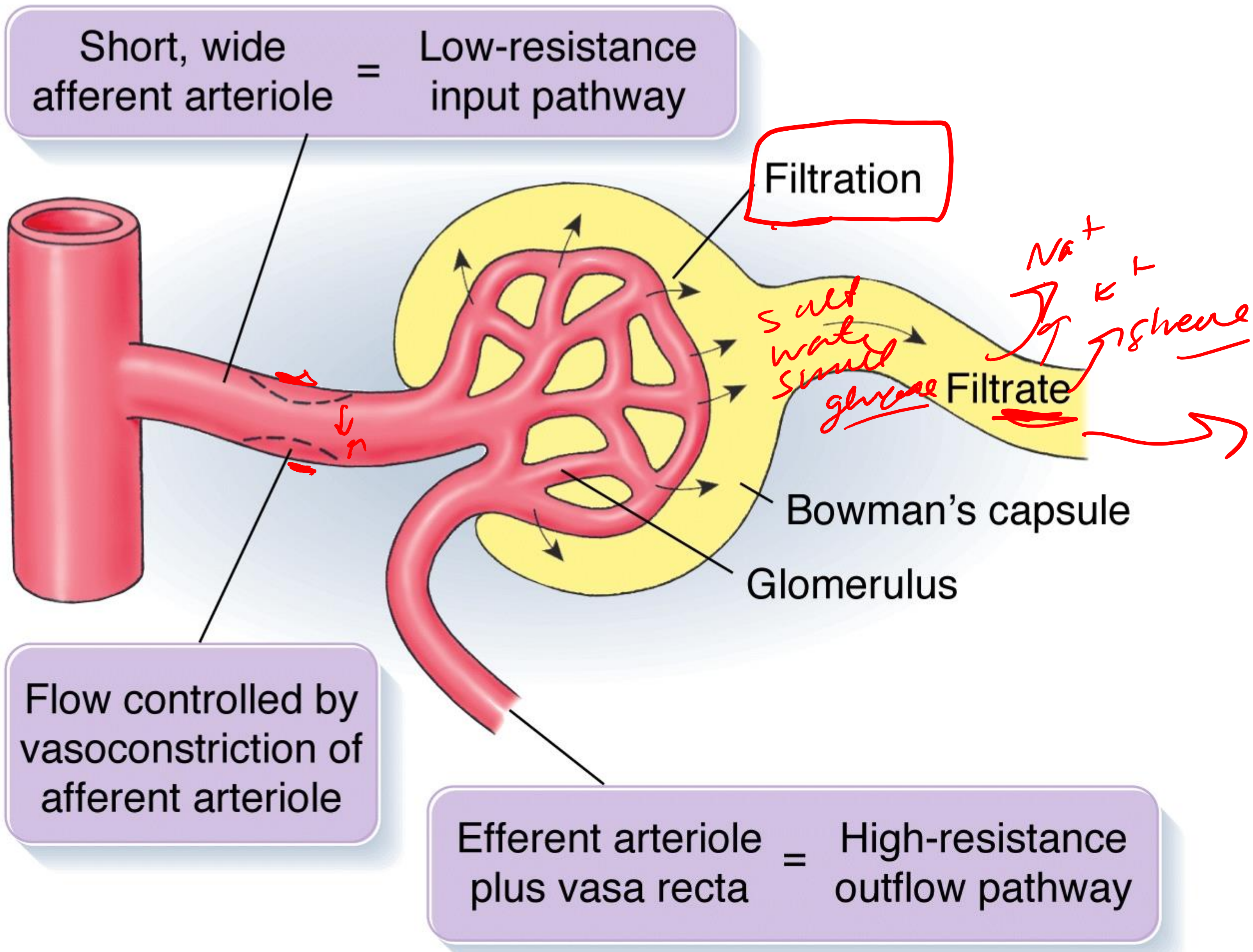

1.8 Liters urine
180 Liters Blood
Nephron
Renal pelvis
Renal artery
Renal pyramid
Renal vein
Cortex
Ureter
Medulla

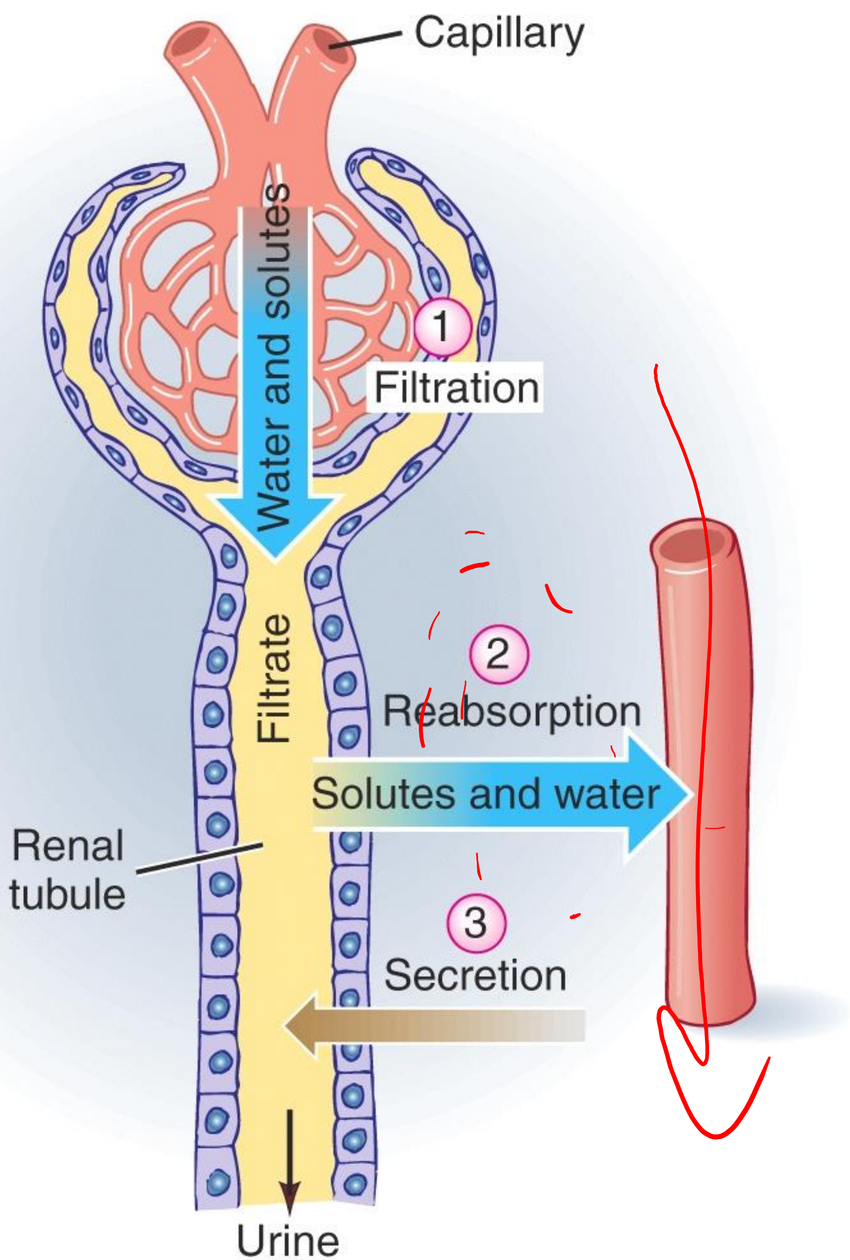


(a) Juxtamedullary nephron
(b) Cortical nephron
Glomerulus
Afferent arteriole
Bowman's capsule
Loop of Henle
Vasa recta
Afferent arteriole
Bowman's capsule
Efferent arteriole
Glomerulus
Cortex
Medulla
Collecting duct



Lumen
Apical (luminal) side
Brush border
Tight junction
ATP
Basolateral (serosal) side
Blood


Short, wide afferent arteriole = Low-resistance input pathway
Filtration
Filtrate
Bowman's capsule
Glomerulus
Flow controlled by vasoconstriction of afferent arteriole
Efferent arteriole plus vasa recta = High-resistance outflow pathway


Capillary
Water and solutes
1
Filtration
Filtrate
2
Reabsorption
Solutes and water
Renal
tubule
3
Secretion
Urine

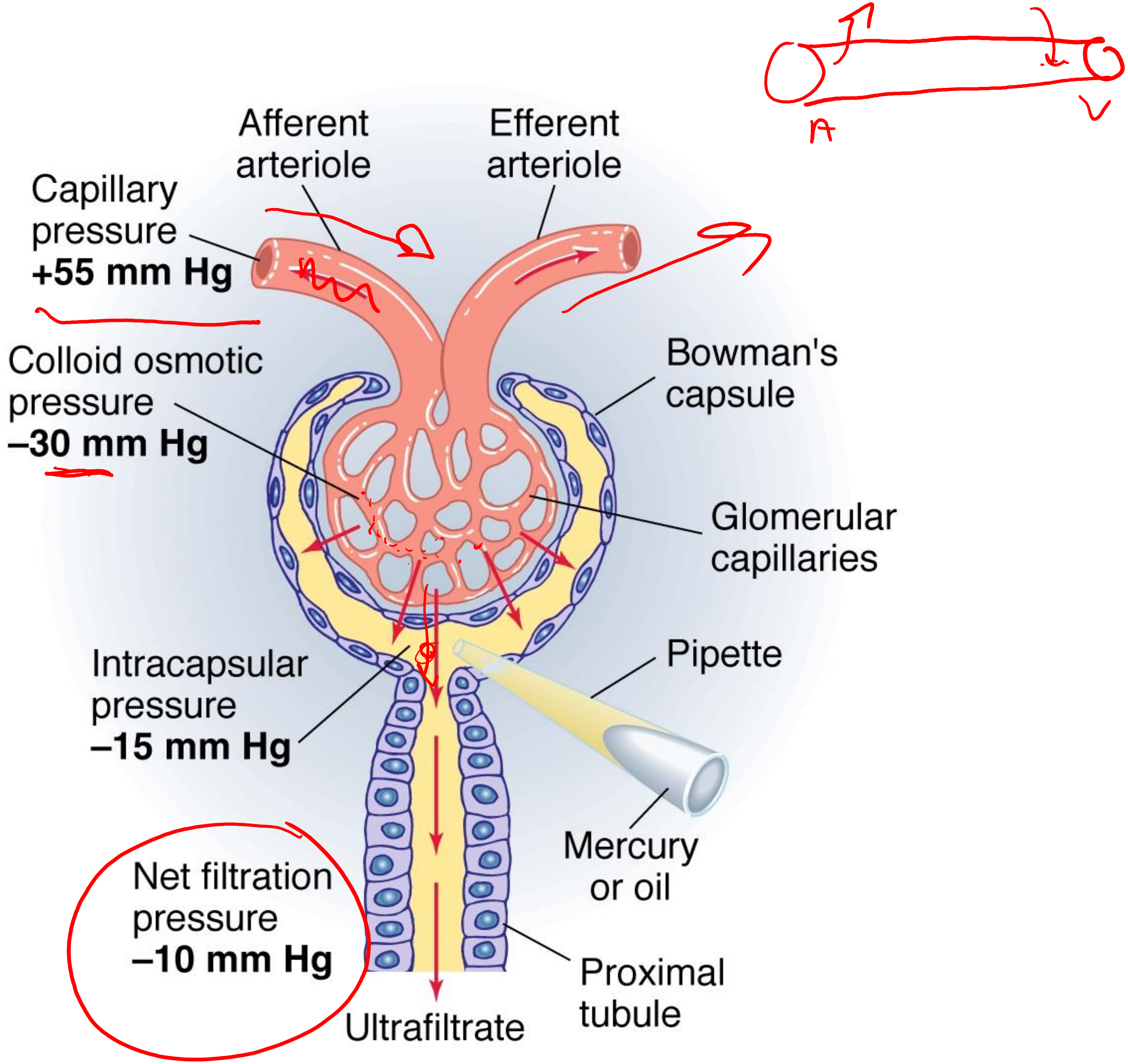
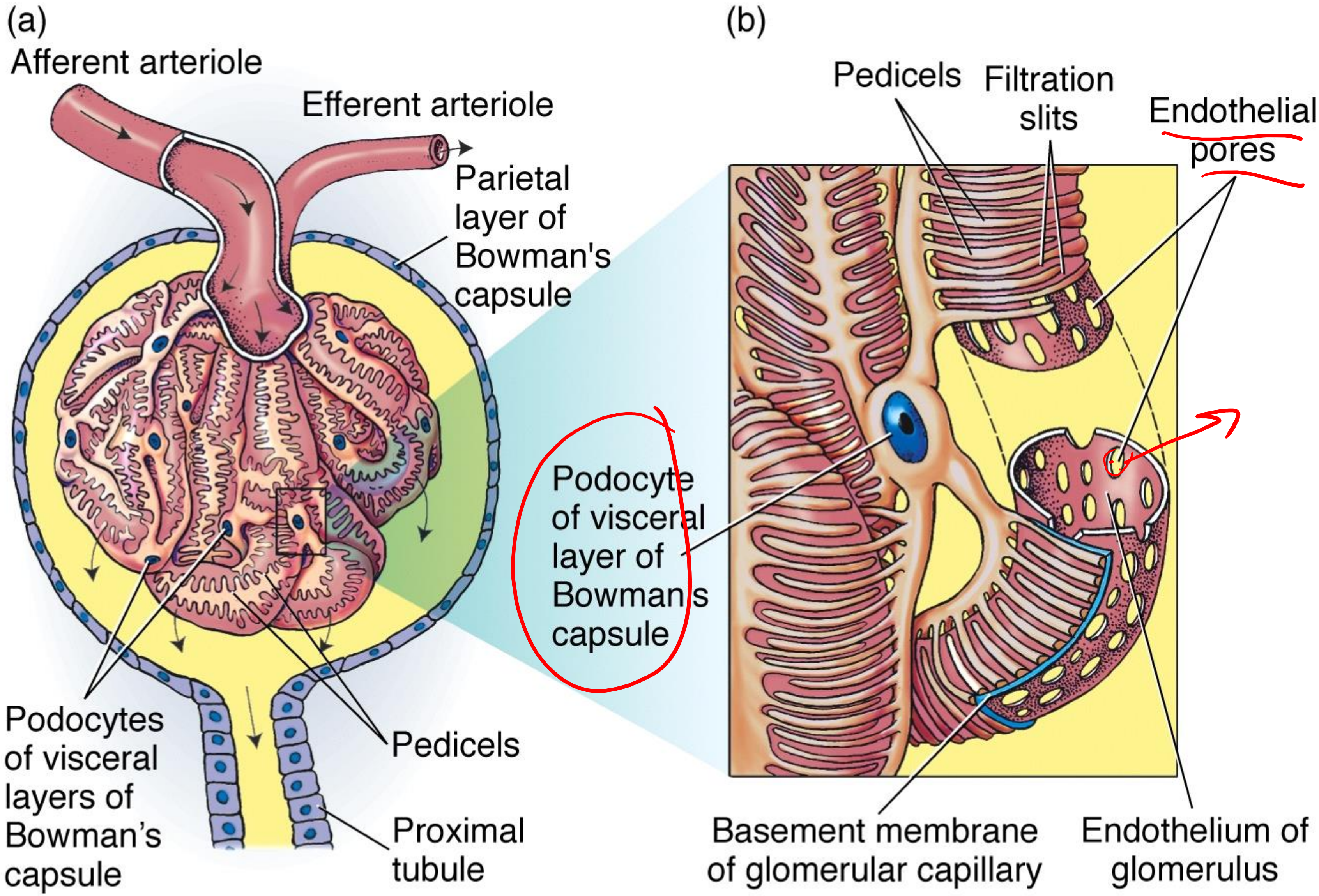

Afferent arteriole
Efferent arteriole
Capillary pressure
+55 mm Hg
Colloid osmotic pressure
–30 mm Hg
Bowman's capsule
Glomerular capillaries
Intracapsular pressure
–15 mm Hg
Pipette
Mercury or oil
Net filtration pressure
–10 mm Hg
Ultrafiltrate
Proximal tubule

Table 14-7 Balance sheet of pressures (in mm Hg) involved in glomerular ultrafiltration

	Salamander	Human
Glomerular capillary pressure	17.7	55
Intracapsular pressure	− 1.5	− 15
Net hydrostatic pressure	16.2	40
Colloid osmotic pressure	− 10.4	− 30
Net filtration pressure	5.8	10

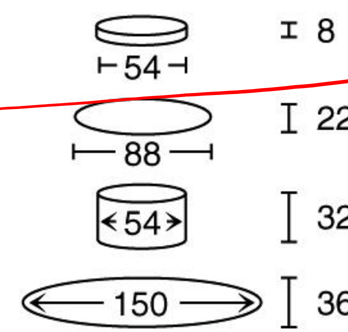
Source: Pitts, 1968; Brenner et al., 1971.



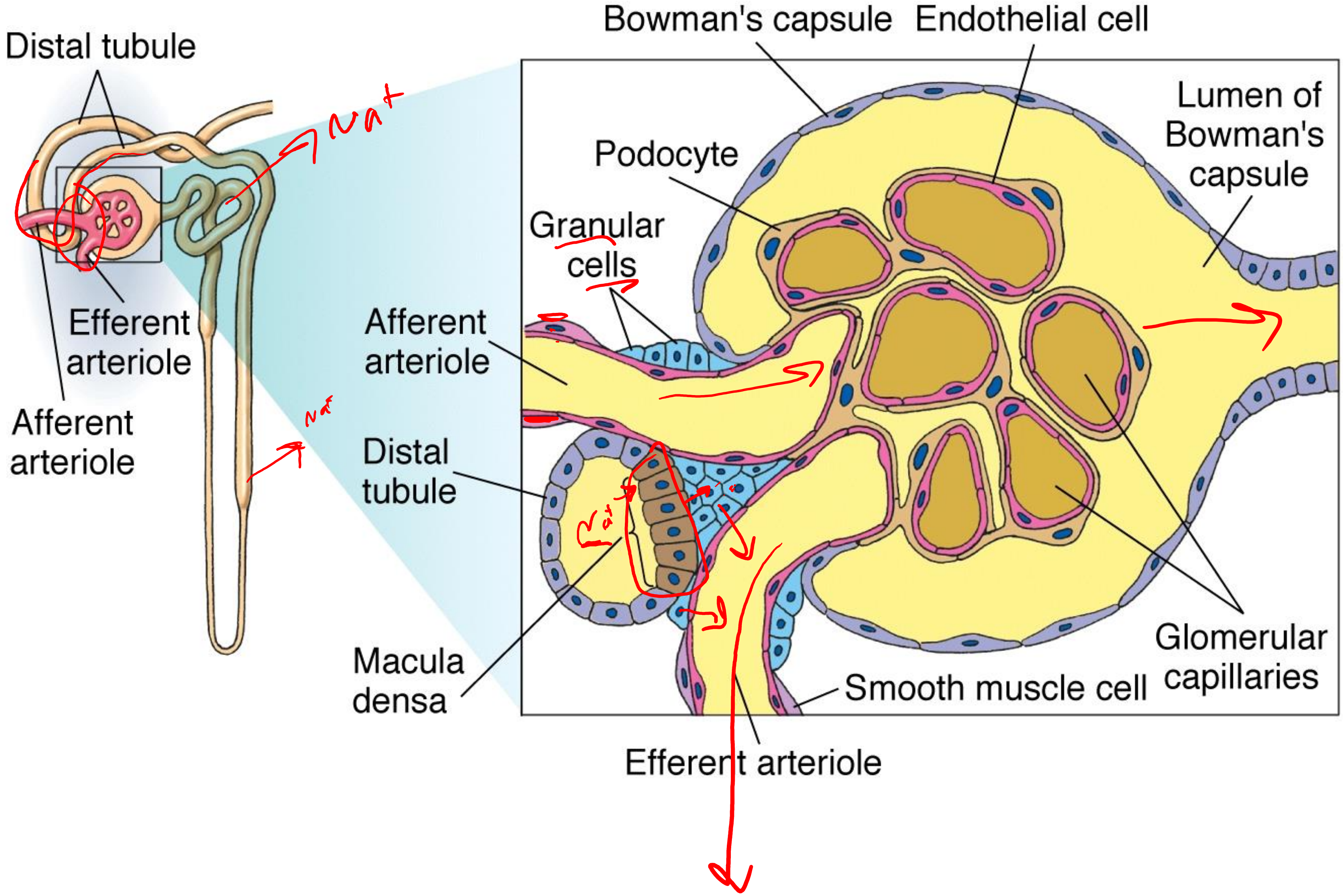
(a)
Afferent arteriole
Efferent arteriole
Parietal layer of Bowman's capsule
Podocytes of visceral layers of Bowman's capsule
Pedicels
Proximal tubule
(b)
Pedicels
Filtration slits
Endothelial pores
Podocyte of visceral layer of Bowman's capsule
Basement membrane of glomerular capillary
Endothelium of glomerulus

Table 14-8 Relation between the molecular size of a substance and the ratio of its concentration in the filtrate appearing in Bowman's capsule to its concentration in the plasma [filtrate]/[filtrand]

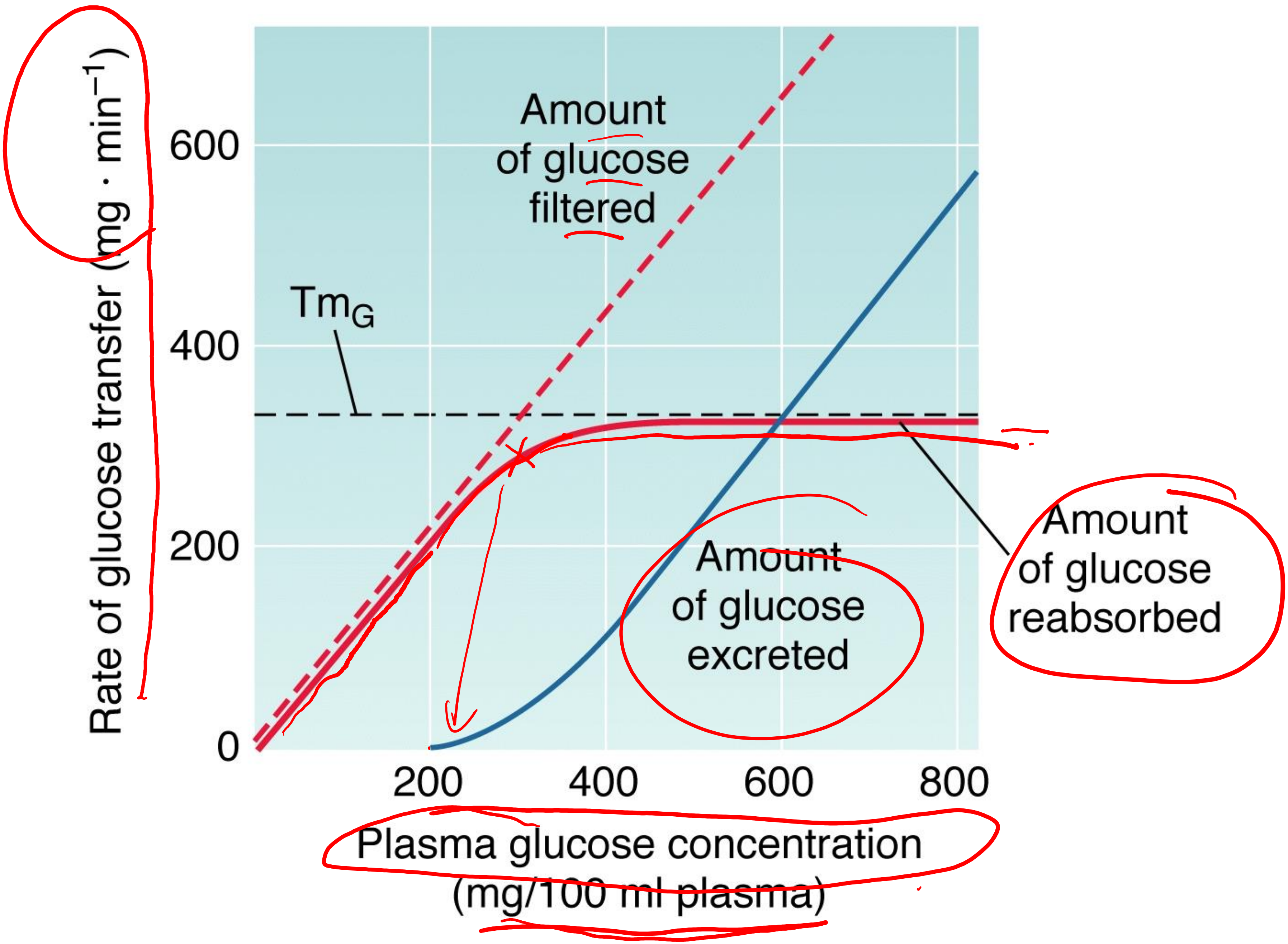
Substance	Mol. wt.	Radius from diffusion coefficient (nm)	Dimensions from X-ray diffraction (nm)	[filtrate]/[filtrand]
Water	18	0.11		1.0
Urea	62	0.16		1.0
Glucose	180	0.36		1.0
Sucrose	342	0.44		1.0
Insulin	5500	1.48		0.98
Myoglobin	17,000	1.95		0.75
Egg albumin	43,500	2.85		0.22
Hemoglobin	68,000	3.25		0.03
Serum albumin	69,000	3.55		<0.01



Source: Pitts, 1968.



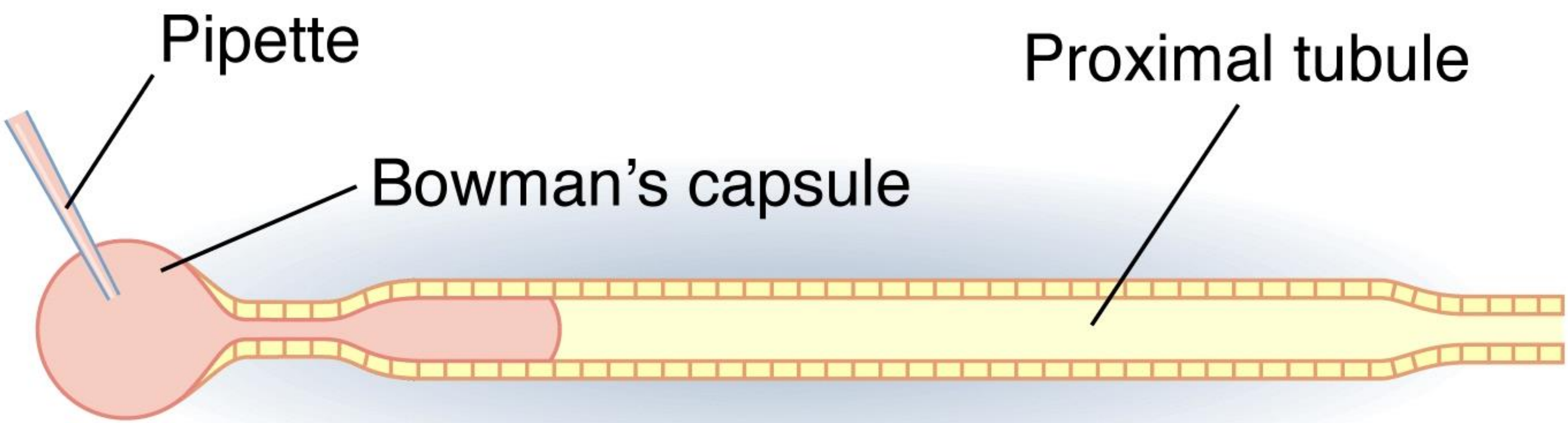
Distal tubule
Efferent arteriole
Afferent arteriole
Bowman's capsule
Endothelial cell
Lumen of Bowman's capsule
Podocyte
Granular cells
Afferent arteriole
Distal tubule
Macula densa
Glomerular capillaries
Smooth muscle cell
Efferent arteriole



Rate of glucose transfer (mg · min⁻¹)
600
400
200
0
Amount of glucose filtered
Tm$_G$
Amount of glucose excreted
Amount of glucose reabsorbed
200
400
600
800
Plasma glucose concentration (mg/100 ml plasma)

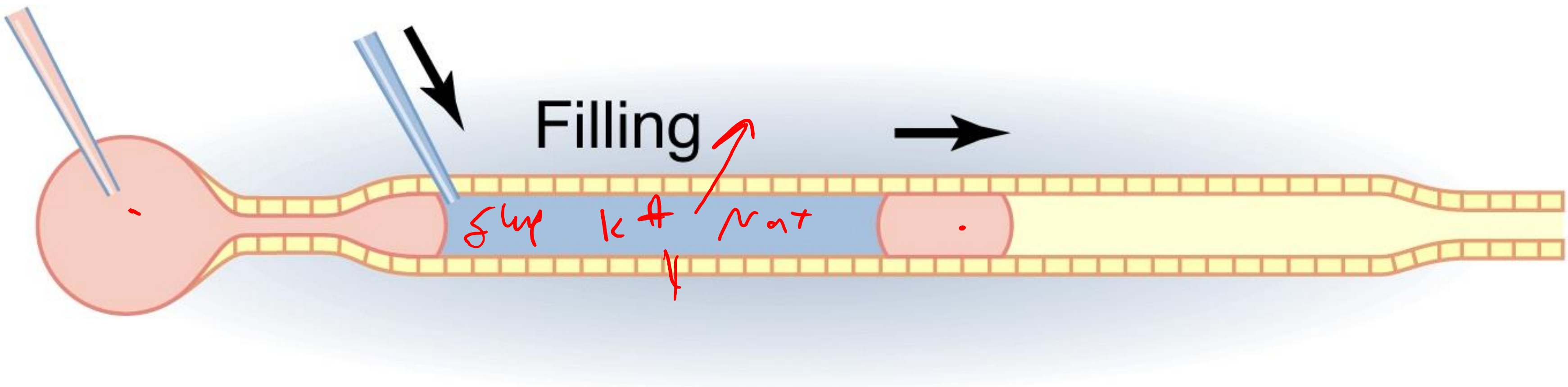
1

Micropipette is inserted and oil is injected until it enters proximal tubule.



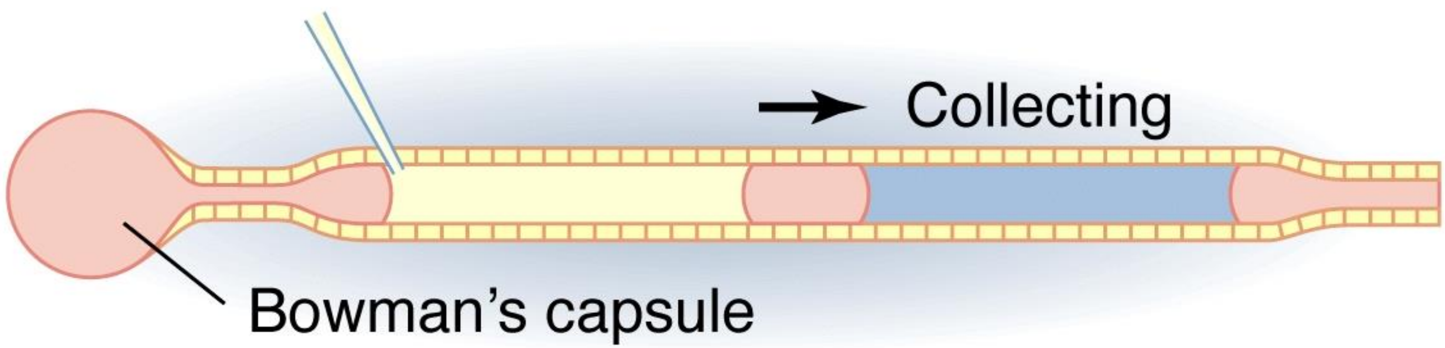
2

Perfusion fluid is injected in oil column, forcing oil droplet forward to end of tubule.



3

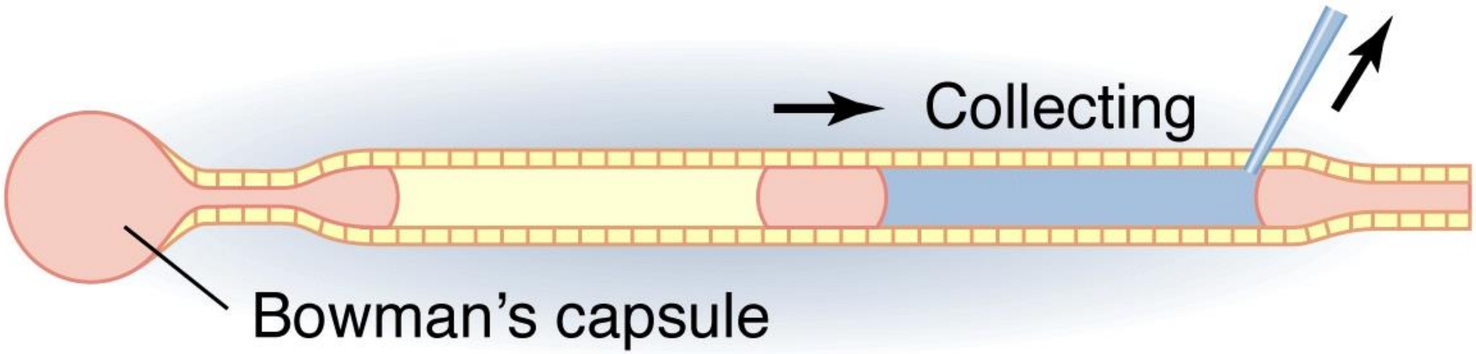
After 20 minutes, second fluid forces a second oil droplet forward, driving perfusion fluid forward.



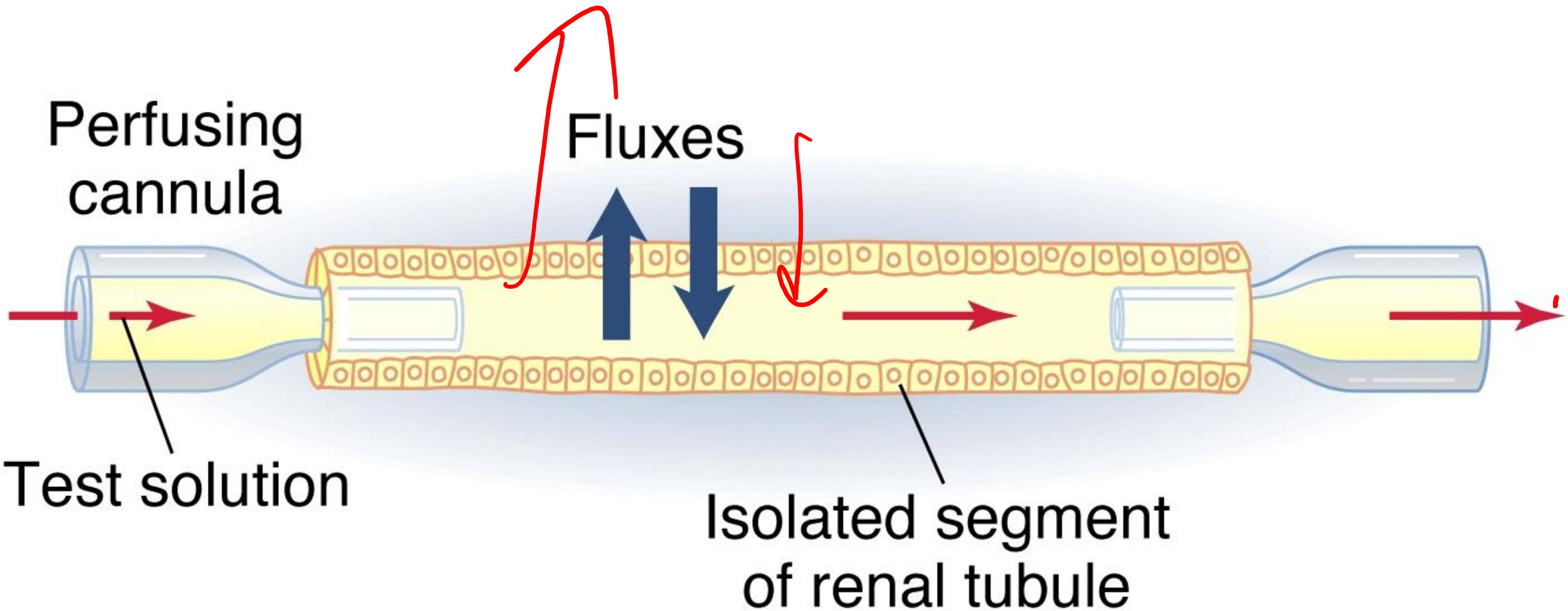
Ability of the tubule segment to reabsorb or secrete substances is determined by comparing composition of perfusate before and after injection.

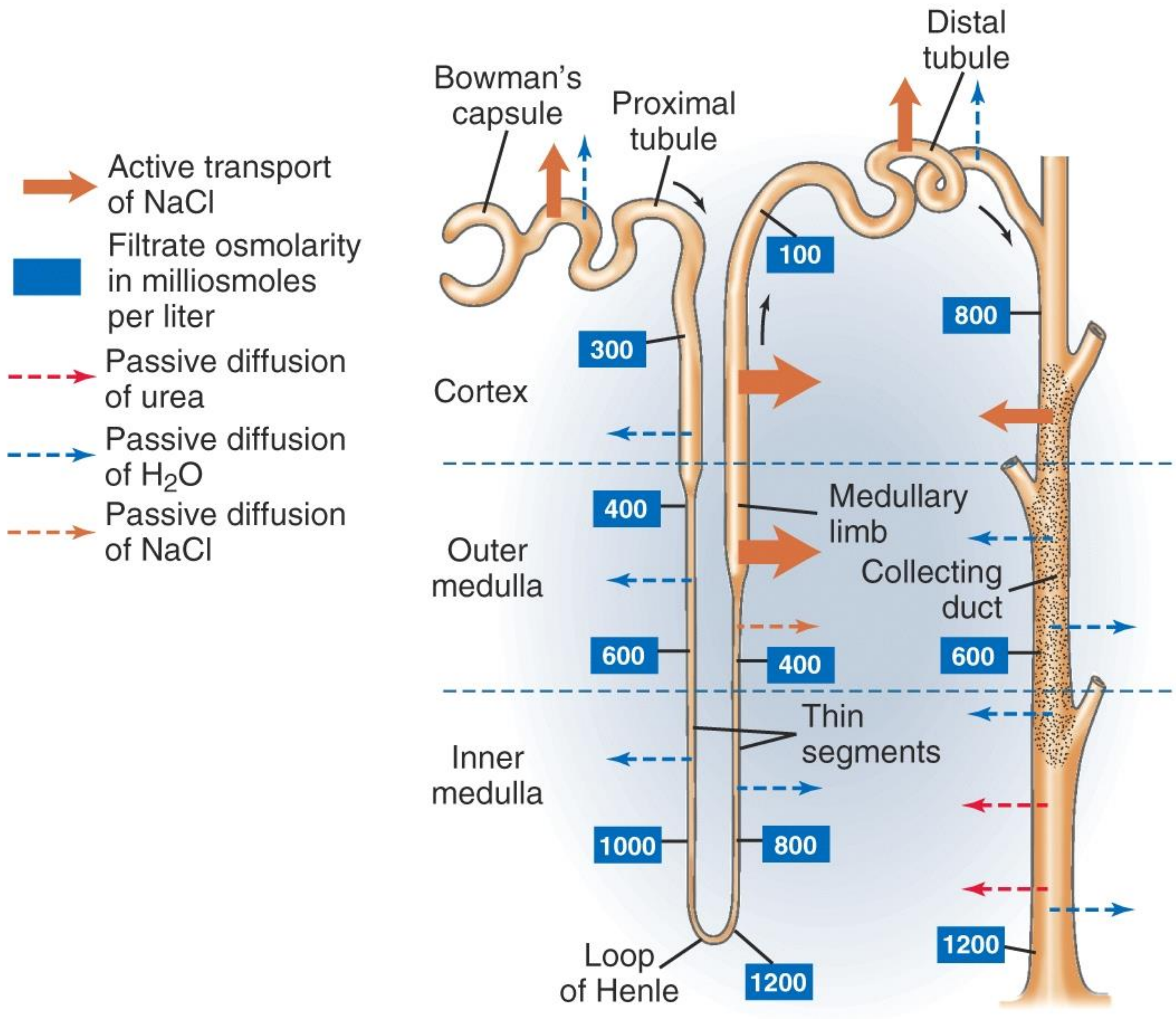
4

Perfusion fluid is collected.



Ability of the tubule segment to reabsorb or secrete substances is determined by comparing composition of perfusate before and after injection.


Perfusing
cannula
Fluxes
Test solution
Isolated segment
of renal tubule



Active transport of NaCl
Filtrate osmolarity in milliosmoles per liter
Passive diffusion of urea
Passive diffusion of H_2O
Passive diffusion of NaCl
Bowman's capsule
Proximal tubule
Distal tubule
Cortex
Outer medulla
Inner medulla
Medullary limb
Collecting duct
Thin segments
Loop of Henle
300
400
600
1000
100
400
800
1200
800
600
1200

GFR
And eGFR - Estimated glomerular filtration rate

Good resource: https://www.kidney.org/atoz/content/gfr

Inulin clearance using a constant-infusion urinary clearance approach has long been regarded as the gold standard measure of GFR.
Only filtered and not secreted and without being reabsorbed by the renal tubules.

http://www.experimentalphysiology.gr/UserFiles/IntCollabor/Sullivan/Renal%20Physiol%20III.pdf

MEASUREMENT OF FILTRATION

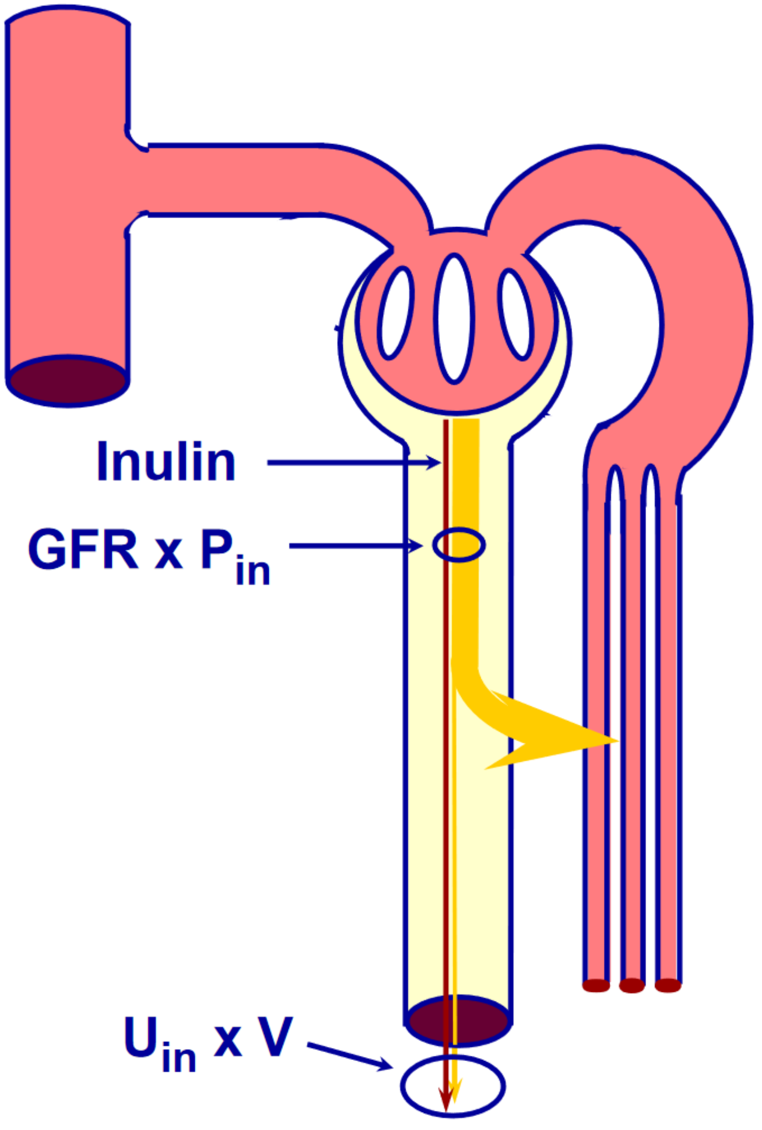
The rate of fluid filtration, GFR, can be measured with the use of inulin.

The rate at which inulin is filtered, GFR x P_{in}, equals the rate it is excreted, U_{in} x V.

$$GFR \times P_{in} = U_{in} \times V$$

$$GFR = U_{in}V / P_{in}$$

Units are volume / time: ml / min, L / day.



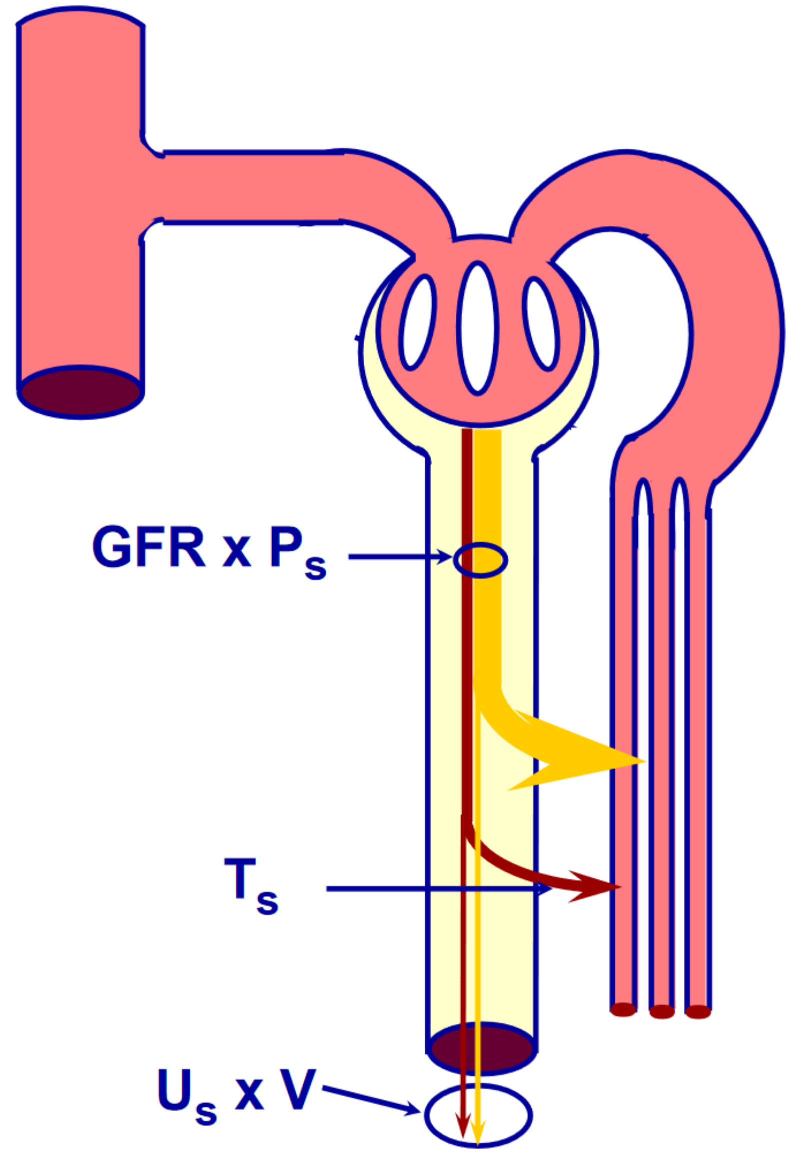
MEASUREMENT OF REABSORPTION

The rate of reabsorption of a solute, T_s, is the difference between the rate of its filtration, GFR x P_s, and the rate of its excretion, U_s x V.

$$T_s = (GFR \times P_s) - (U_s \times V)$$

Units are mass / time:

mg / min, mMoles / min.



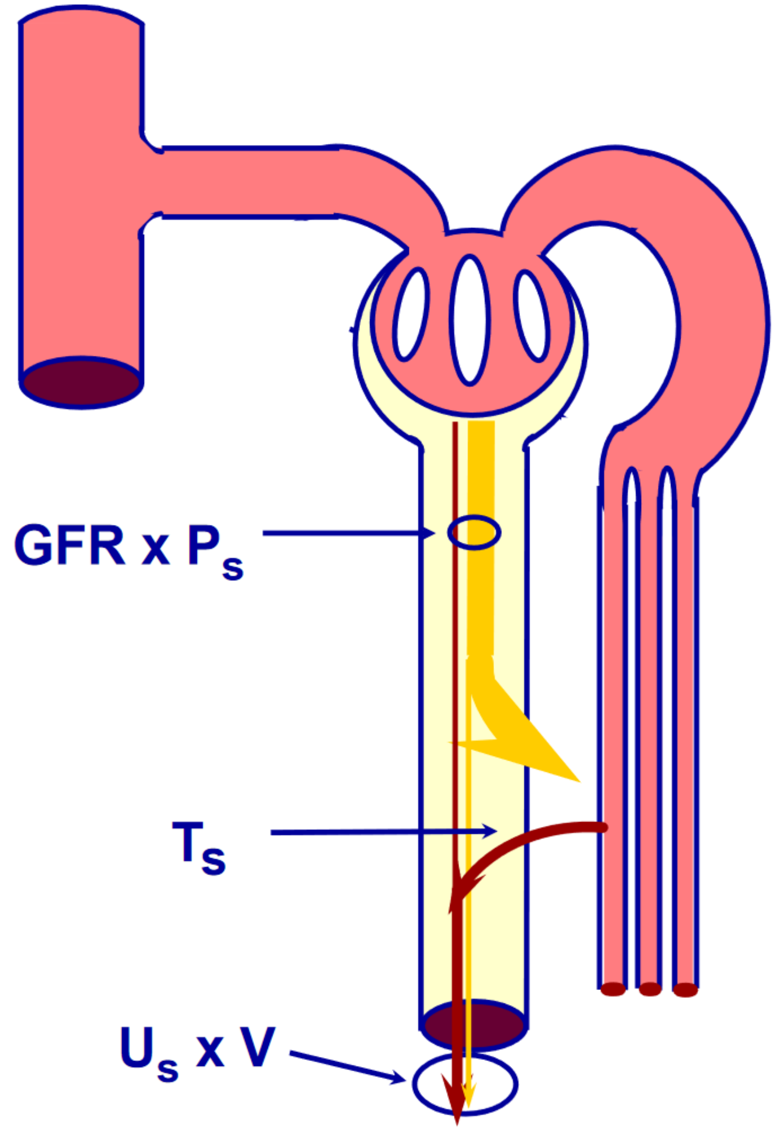
MEASUREMENT OF SECRETION

The rate of secretion of a solute, Ts, is the difference between the rate of excretion, U_s x V, and the rate of filtration, GFR x P_s.

$$T_s = (U_s \times V) - (GFR \times P_s)$$

Units are mass / time:

mg / min, mMoles / min.



MEASUREMENT OF RENAL FUNCTION

- **CLEARANCE is a term used to describe the rate of removal or ‘clearing’ of a substance from the blood. It is often used to measure the efficiency of the kidney in removing a substance from the blood.**
- **DEFINITION: <u>Volume</u> of plasma cleared of a substance per <u>unit time.</u>**
- **Clearance = excretion rate / plasma concentration.**

$$C_s = U_s V / P_s$$

- **UNITS: (µmoles/min) / (µmoles/ml) = ml/min**

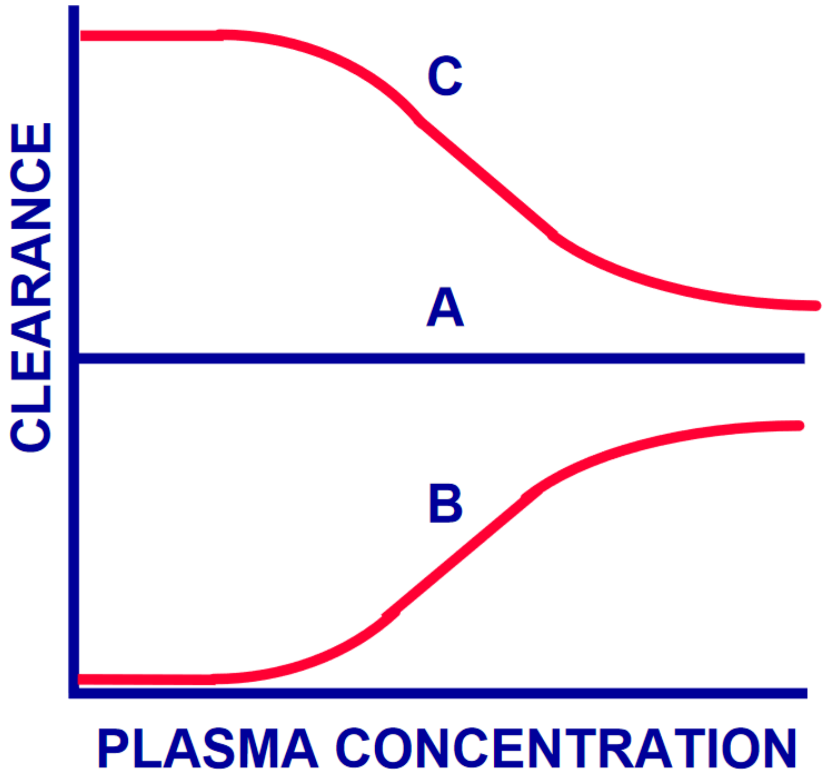
CLEARANCE RATES

Clearance rates of substances may or may not vary with changes in their plasma concentration.

A. The clearance of a substance that is neither reabsorbed or secreted does not change when the plasma concentration changes.

B. The clearance of a substance that is reabsorbed tends to increase when the plasma concentration rises.

C. The clearance of a substance that is secreted tends to fall when the plasma concentration rises.



GLUCOSE CLEARANCE

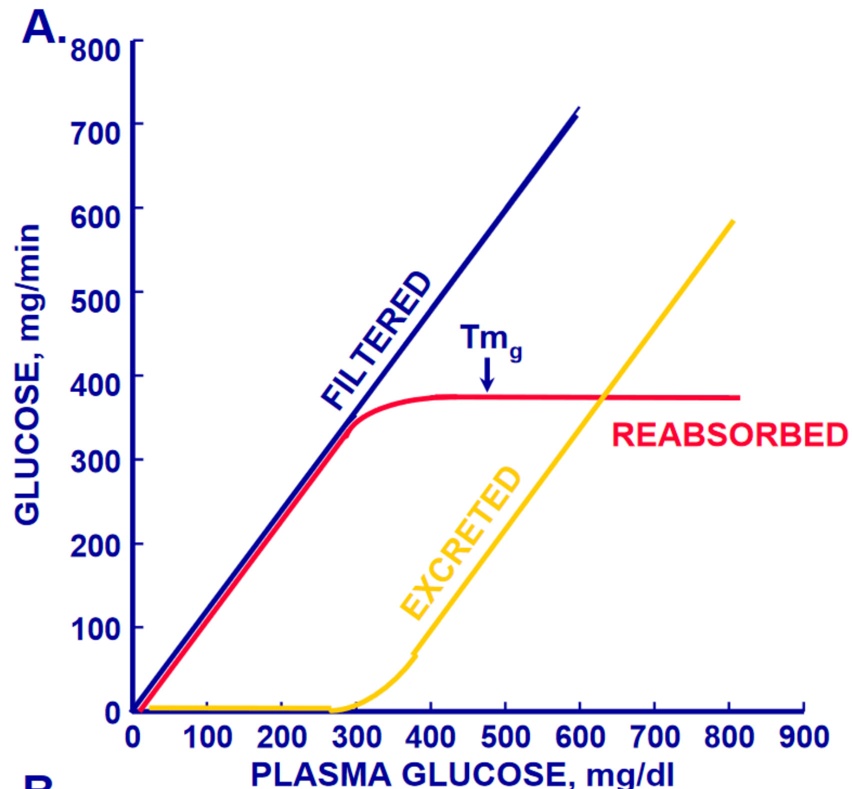
A. All filtered glucose is reabsorbed at plasma concentrations below 250 mg/dl.

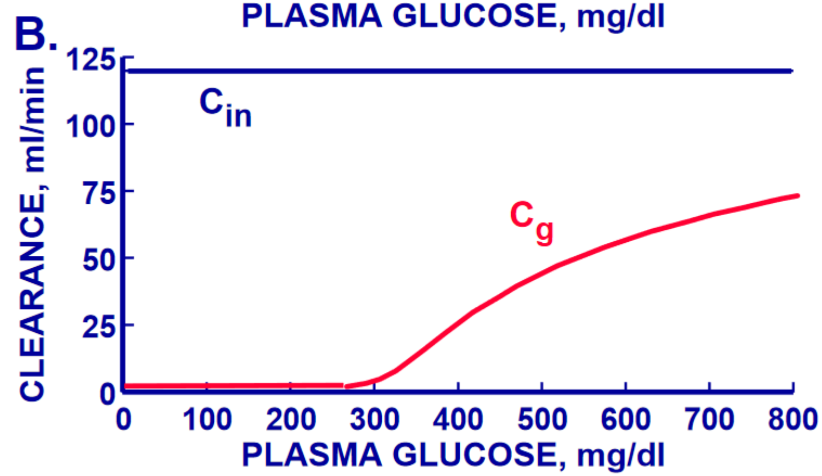
The reabsorptive mechanism becomes saturated at plasma concentrations above 350 mg/dl. The maximum transport rate (Tm_g) is about 375 mg/min.

Glucose begins to appear in the urine at about 250 mg/min.

B. The clearance of glucose (C_g) is 0 when the plasma concentration is below 250mg/dl because no glucose is excreted.

Above that concentration C_g rises and begins to approach the clearance of inulin (C_{in}).





USE OF CREATININE TO MEASURE GFR

Major Advantage: An endogenous substance present in body fluids at concentrations that normally vary little. Thus does not require an IV infusion as inulin does.

Most of the excreted creatinine has been filtered and none is reabsorbed.

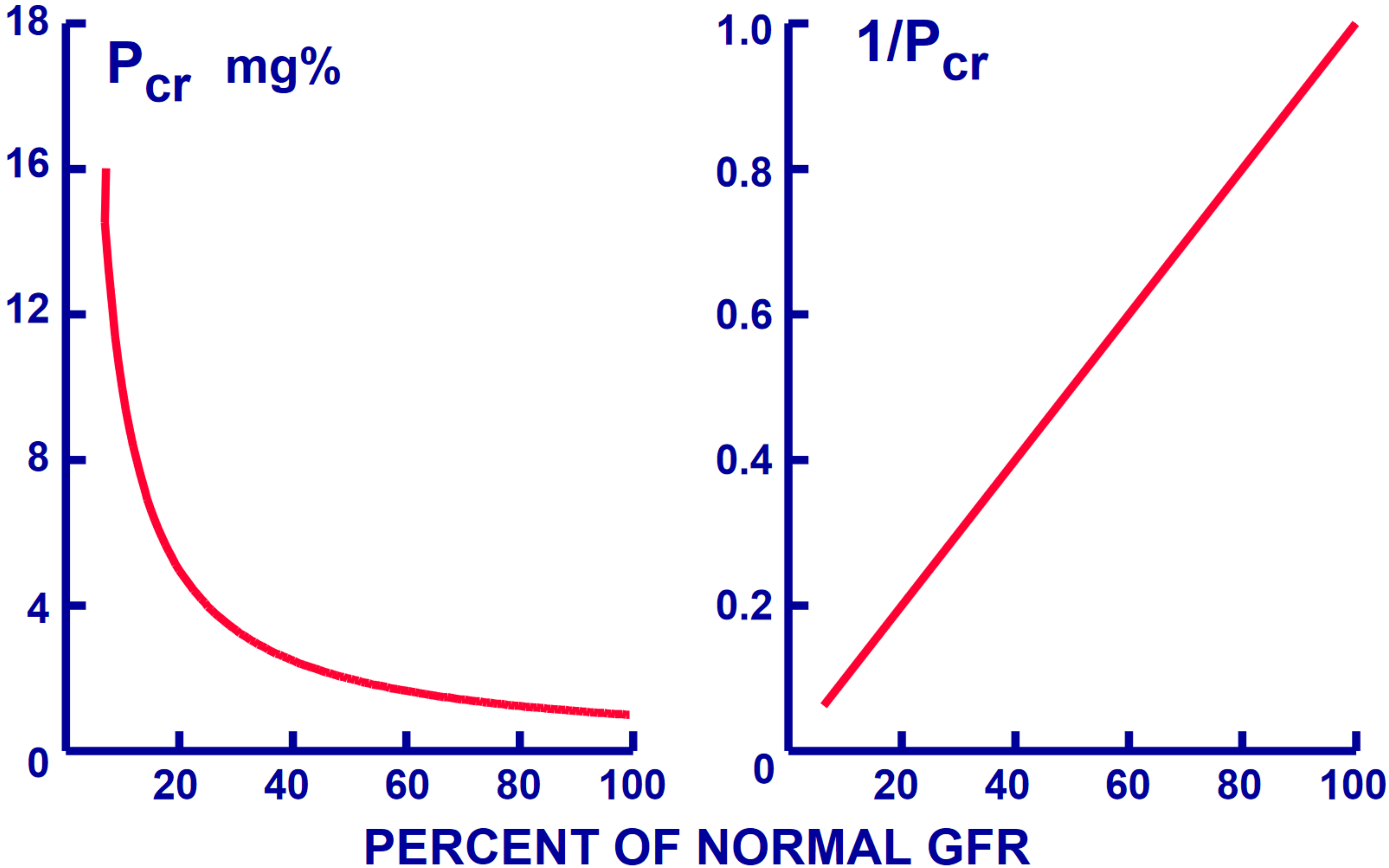
Major Disadvantage: Creatinine is secreted by the proximal tubule to a slight extent. Thus the creatinine clearance may exceed the GFR.

When glomerular function is reduced, the fraction of the creatinine clearance due to secretion increases, raising the error in GFR determination.

Certain drugs affect the secretion of creatinine.

Problems in quantitative collection of all urine produced during a clearance period complicate determination of clearance.

UTILITY OF PLASMA CREATININE MEASUREMENT



CLINICAL METHODS FOR ESTIMATING GFR

MDRD Formula:

Measurements needed: S_{cr}, BUN, Alb.

GFR (ml/min/1.73 m^2) = 170 $Scr^{-0.999}$ x $Age^{-0.176}$ x $BUN^{-0.17}$ x $Alb^{0.318}$

Multiply by 0.762 if female; 1.18 if African-American

If BUN and Alb are not available:

GFR (ml/min) = 186 $Scr^{-1.154}$ x $Age^{-0.203}$

Multiply by 0.742 if female; 1.21 if African-American

Cockroft-Gault formula:

Measurements needed: S_{cr}

C_{cr} (ml/min) = ((140-Age) x kg bw)/(72 S_{cr}(mg/dl))

blood urea nitrogen (**BUN**) test measures the amount of nitrogen in your blood that comes from the waste product urea.

The Cockcroft and Gault formula (1973)

$C_{Cr}=\{((140–age) \times weight)/(72 \times S_{Cr})\} \times 0.85$ (if female)

Abbreviations/ Units

C_{Cr} (creatinine clearance) = mL/minute

Age = years

Weight = kg

SCr (serum creatinine) = mg/dL

Why isn't the Cockcroft-Gault formula recommended for clinical use?

•The Cockcroft-Gault (CG) formula has not been expressed using standardized creatinine values. This means it will give inaccurate results. It is not recommended for clinical use.

https://www.niddk.nih.gov/health-information/professionals/clinical-tools-patient-management/kidney-disease/laboratory-evaluation/glomerular-filtration-rate/creatinine-standardization/recommendations

isotope dilution mass spectrometry (IDMS)

chromium-51–labeled ethylenediaminetetraacetic acid

IDMS-traceable MDRD Study Equation

Conventional Units (creatinine as mg/dL; age in years):

GFR ($mL/min/1.73\ m^2$) = **175** × $(S_{cr})^{-1.154}$ × $(Age)^{-0.203}$ × (0.742 if female) × (1.212 if African American)

SI Units (creatinine as μmol/L; age in years):

GFR ($mL/min/1.73\ m^2$) = **175** × $(S_{cr}/88.4)^{-1.154}$ × $(Age)^{-0.203}$ × (0.742 if female) × (1.212 if African American)

Modification of Diet in Renal Disease (MDRD) https://academic.oup.com/ndt/article/24/10/3055/1815967

See the reasons not good to use BSA

Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI)

CKD-EPI Equation

Note: the CKD-EPI equation can also be expressed as a series of equations applicable to specific creatinine and race combinations. View the CKD-EPI equation as a series of equations.

Conventional Units (creatinine as mg/dL; age in years):

GFR = 141 × min $(S_{cr}/\kappa, 1)^{\alpha}$ × max$(S_{cr}/\kappa, 1)^{-1.209}$ × 0.993^{Age} × 1.018 [if female] × 1.159 [if black]

where:

S_{cr} is serum creatinine in mg/dL,

κ is 0.7 for females and 0.9 for males,

α is -0.329 for females and -0.411 for males,

min indicates the minimum of S_{cr}/κ or 1, and

max indicates the maximum of S_{cr}/κ or 1.

SI Units (creatinine as μmol/L; age in years):

GFR = 141 × min $(S_{cr}/\kappa, 1)^{\alpha}$ × max$(S_{cr}/\kappa, 1)^{-1.209}$ × 0.993^{Age} × 1.018 [if female] × 1.159 [if black]

where:

S_{cr} is serum creatinine in μmol/L,

κ is 61.9 for females and 79.6 for males,

α is -0.329 for females and -0.411 for males,

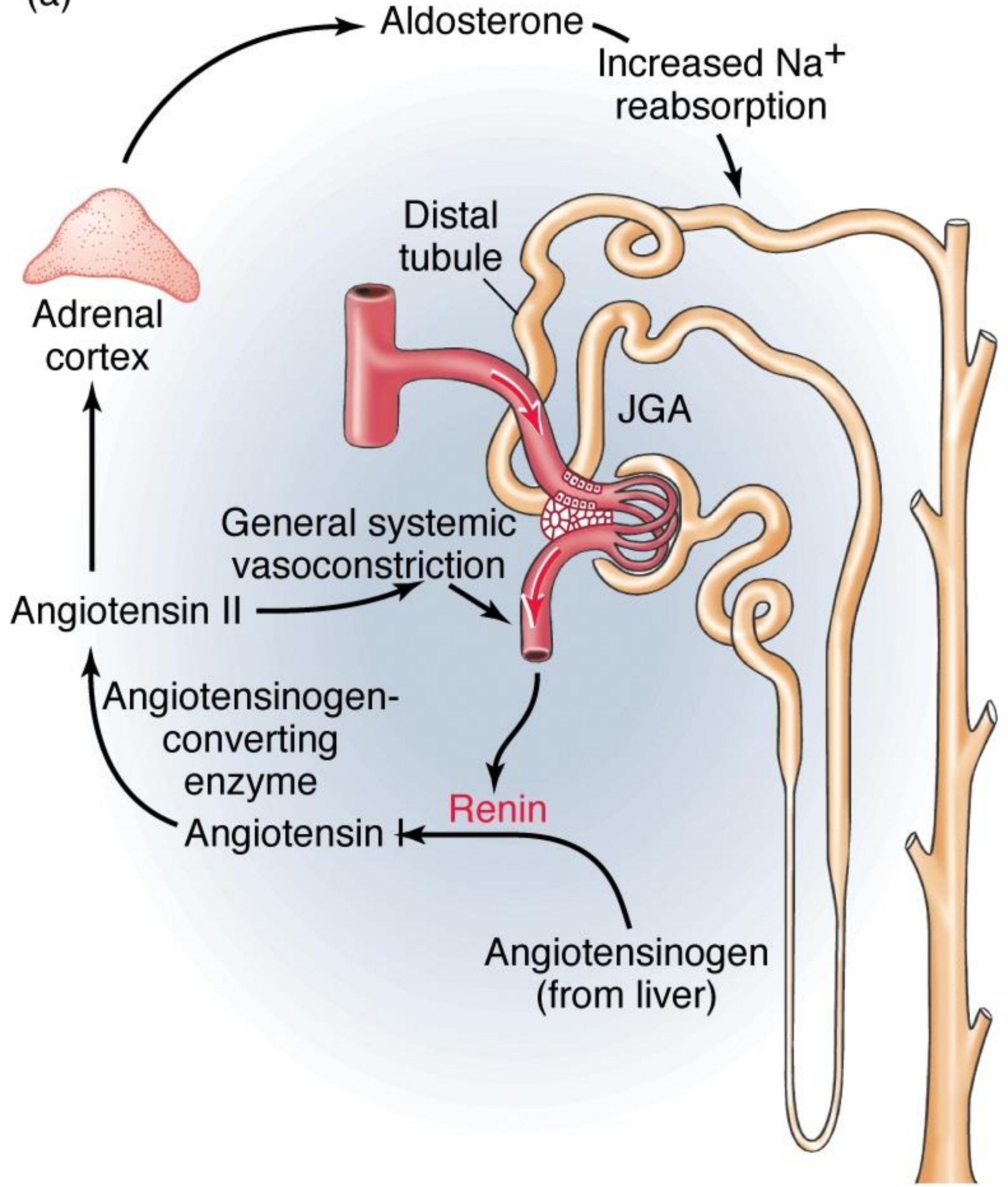
min indicates the minimum of S_{cr}/κ or 1,

and max indicates the maximum of S_{cr}/κ or 1.

Para-aminohippurate (*PAH*) clearance.
Only secreted not filtered. Has to be injected iv.
Can examine if kidney is not secreting well.

We conclude that postischemic injury to the renal allograft results in profound impairment of E_{PAH} that persists for at least 7 days, even after the onset of recovery. An ensuing reduction in urinary PAH clearance results in a gross underestimate of renal plasma flow, which is close to the normal range in the initiation, maintenance, and recovery stages of this injury…..
https://journals.physiology.org/doi/full/10.1152/ajprenal.1999.277.2.F312?rfr_dat=cr_pub++0pubmed&url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org

(a)


Aldosterone
Increased Na+ reabsorption
Distal tubule
Adrenal cortex
JGA
General systemic vasoconstriction
Angiotensin II
Angiotensinogen-converting enzyme
Renin
Angiotensin I
Angiotensinogen (from liver)

(b)

Angiotensinogen (Renin substrate)

Asp-Arg-Val-Tyr-Ile-His-Pro-Phe-His-Leu-Leu-Val-Tyr-Ser-Protein

↓ Renin

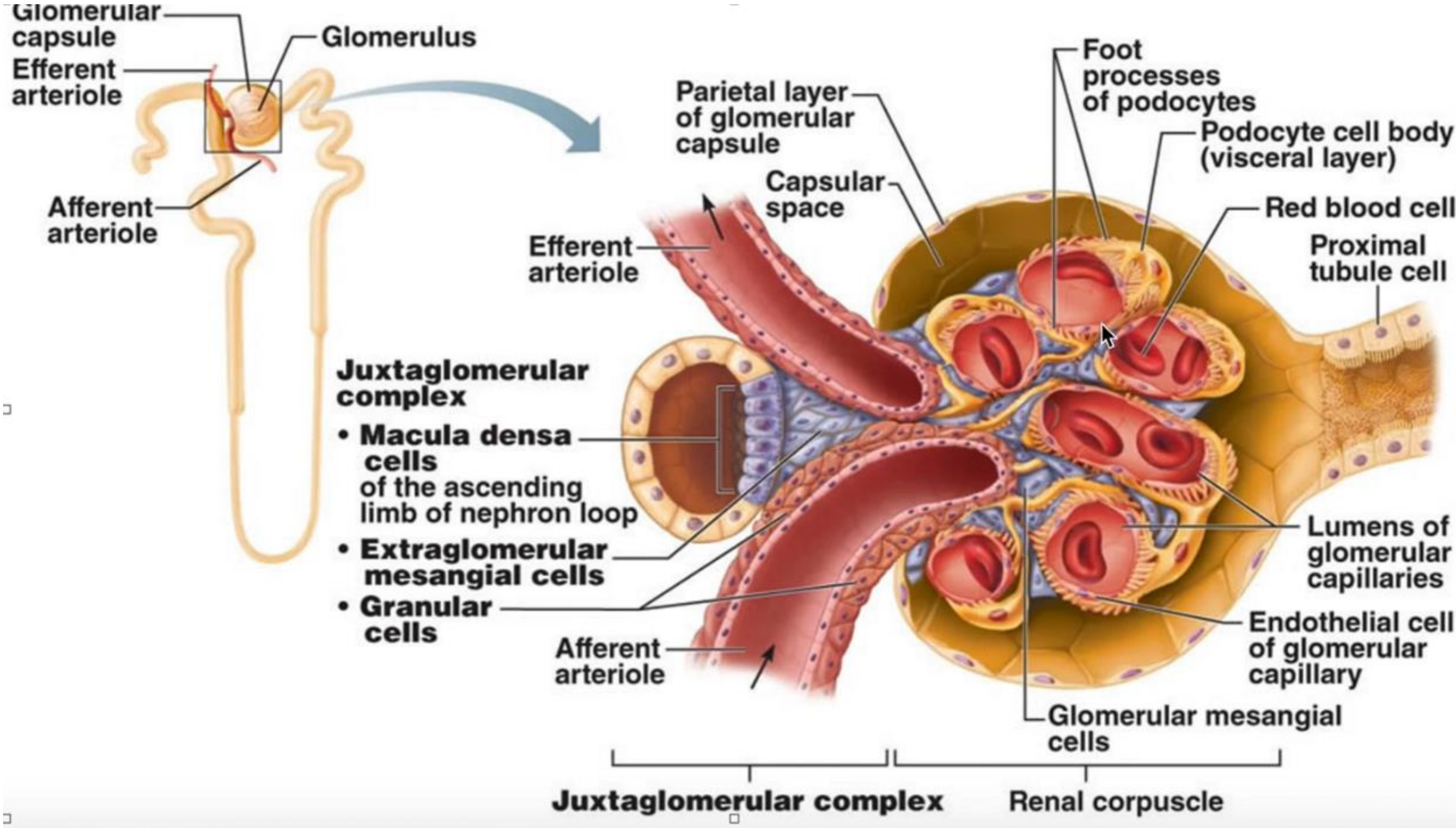
Angiotensin I

Asp-Arg-Val-Tyr-Ile-His-Pro-Phe-His-Leu

↓ Angiotensinogen-converting enzyme

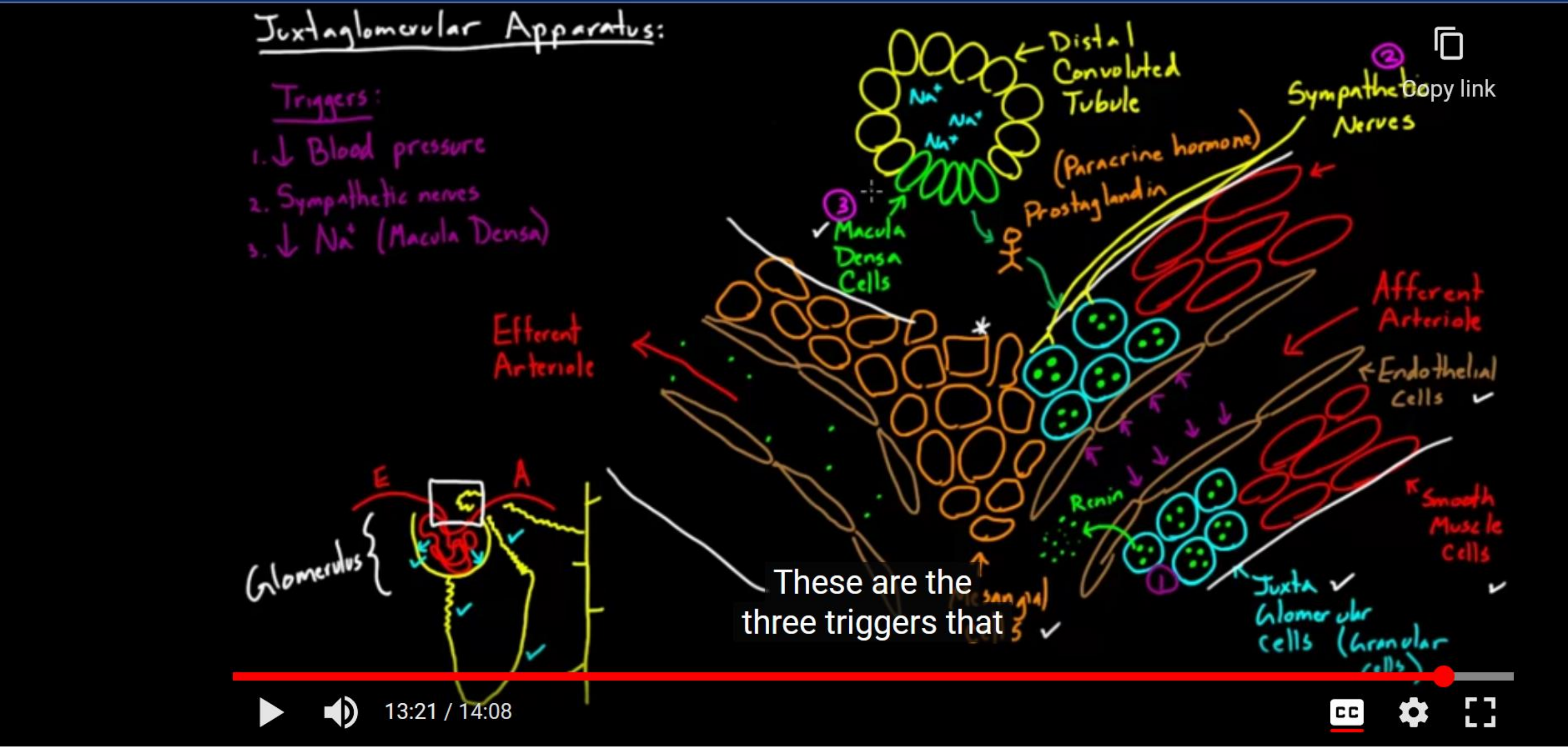
Angiotensin II

Asp-Arg-Val-Tyr-Ile-His-Pro-Phe


Glomerular capsule
Glomerulus
Efferent arteriole
Afferent arteriole
Parietal layer of glomerular capsule
Capsular space
Foot processes of podocytes
Podocyte cell body (visceral layer)
Red blood cell
Proximal tubule cell
Efferent arteriole
Juxtaglomerular complex
• Macula densa cells of the ascending limb of nephron loop
• Extraglomerular mesangial cells
• Granular cells
Afferent arteriole
Lumens of glomerular capillaries
Endothelial cell of glomerular capillary
Glomerular mesangial cells
Juxtaglomerular complex
Renal corpuscle

https://www.khanacademy.org/test-prep/mcat/organ-systems/renal-regulation-of-blood-pressure/v/renin-production-in-the-kidneys

Need to watch…. 3 triggers to increase Renin. How is the negative feedback accomplished with renin?



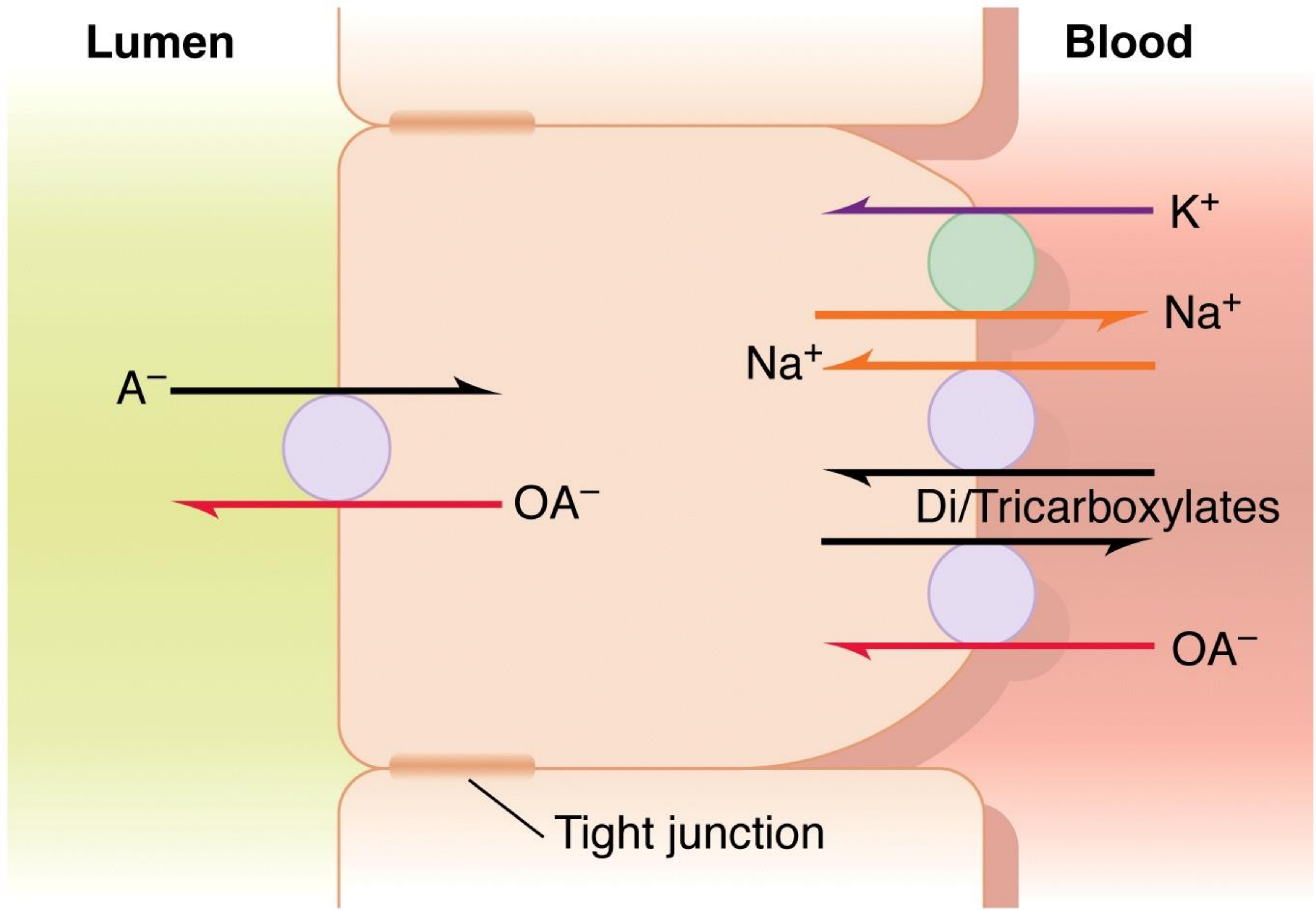

Lumen
Blood
K+
Na+
Na+
A−
OA−
Di/Tricarboxylates
OA−
Tight junction

Table 14-9 Some organic ions secreted by the proximal tubule

Anions	Cations
Endogenous	*Endogenous*
Urates	Dopamine
Hippurates	Epinephrine
Oxalate	Norepinephrine
Prostaglandins	Creatinine
cAMP	
Exogenous	*Exogenous*
Furosemide	Morphine
Bumetanide	Amiloride
Penicillin	Quinine
Aspirin	Atropine
Chlorothiazides	Isoproterenol

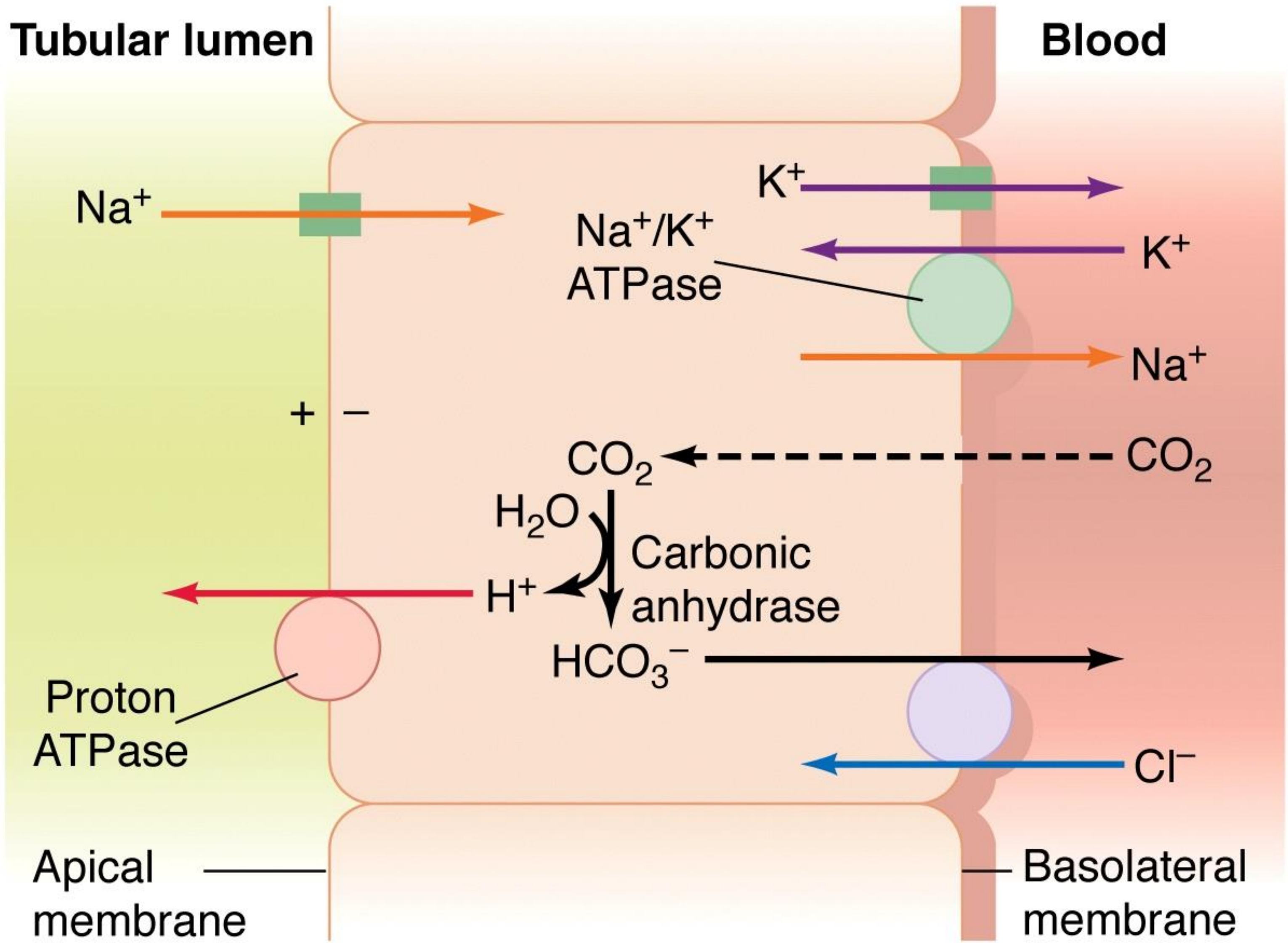
Probenecid was developed in the 1940s and used during World War II to prolong the life of penicillin and is now used to treat gout.

https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/flemingpenicillin.html

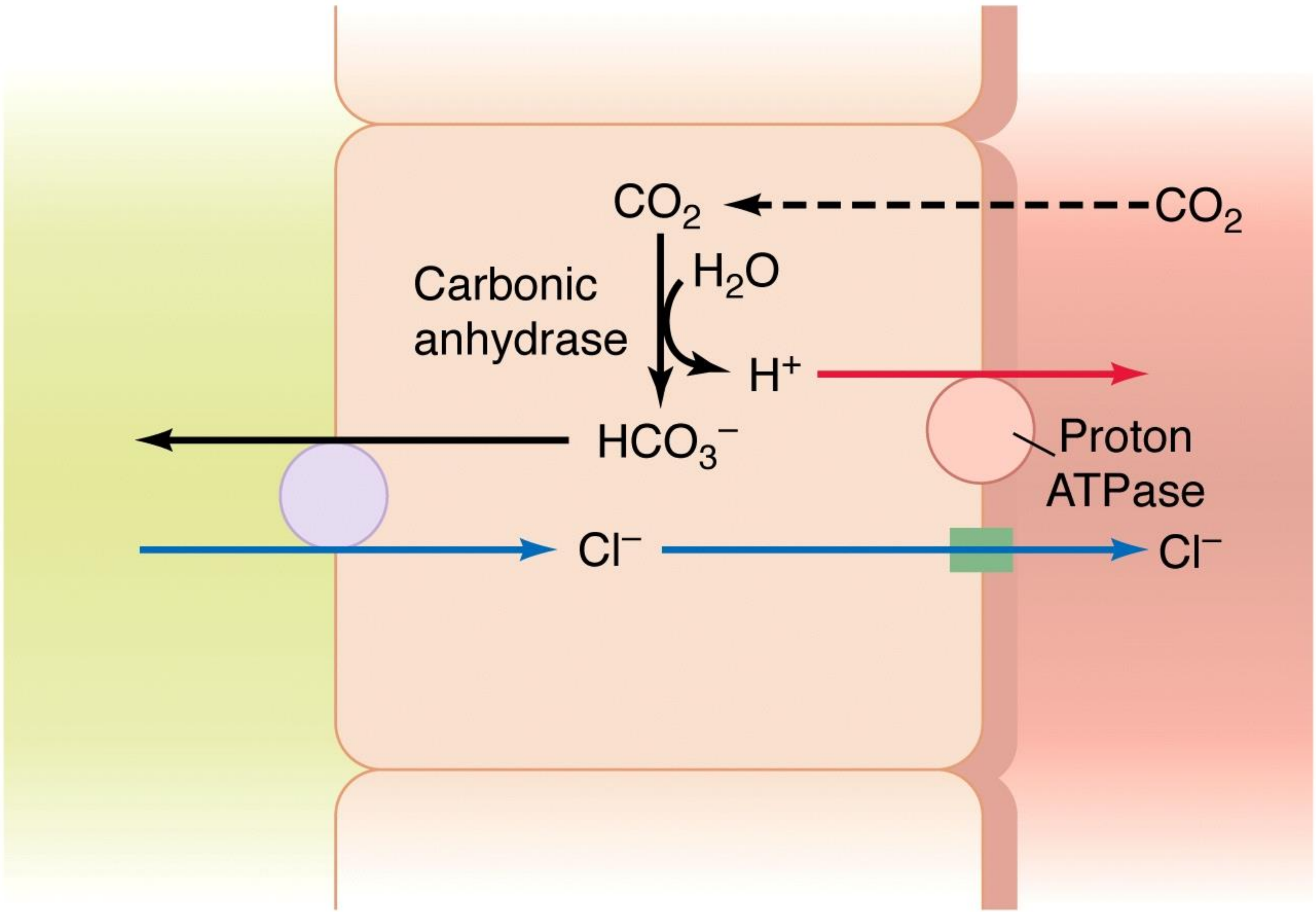
…..the War Production Board (WPB) in 1943 to take responsibility for increased production of the drug (Penicillin).

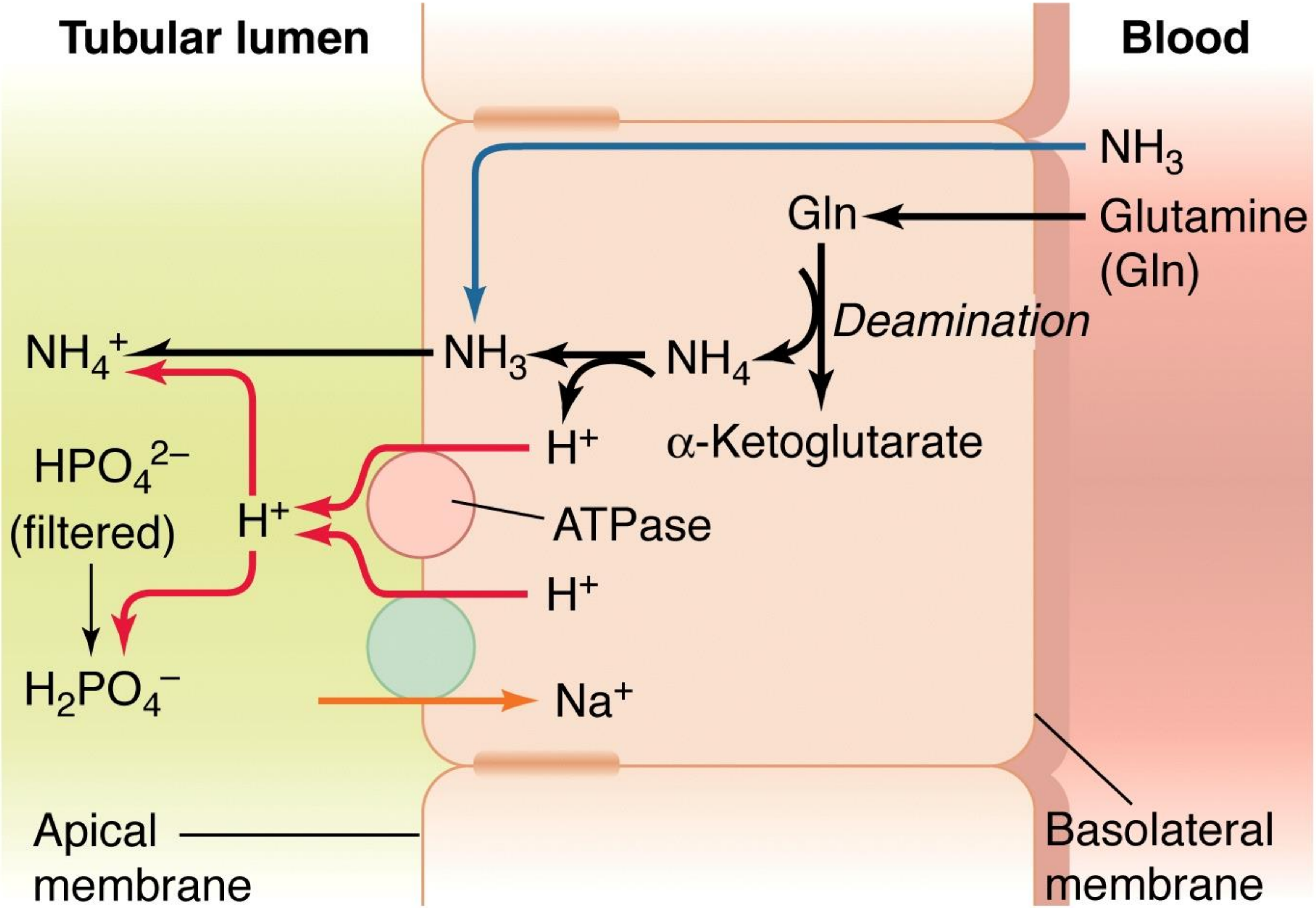
Similarities with the war production act to produce COVID vaccine
https://www.npr.org/sections/health-shots/2021/03/13/976531488/defense-production-act-speeds-up-vaccine-production

(a) A-type cells of kidney

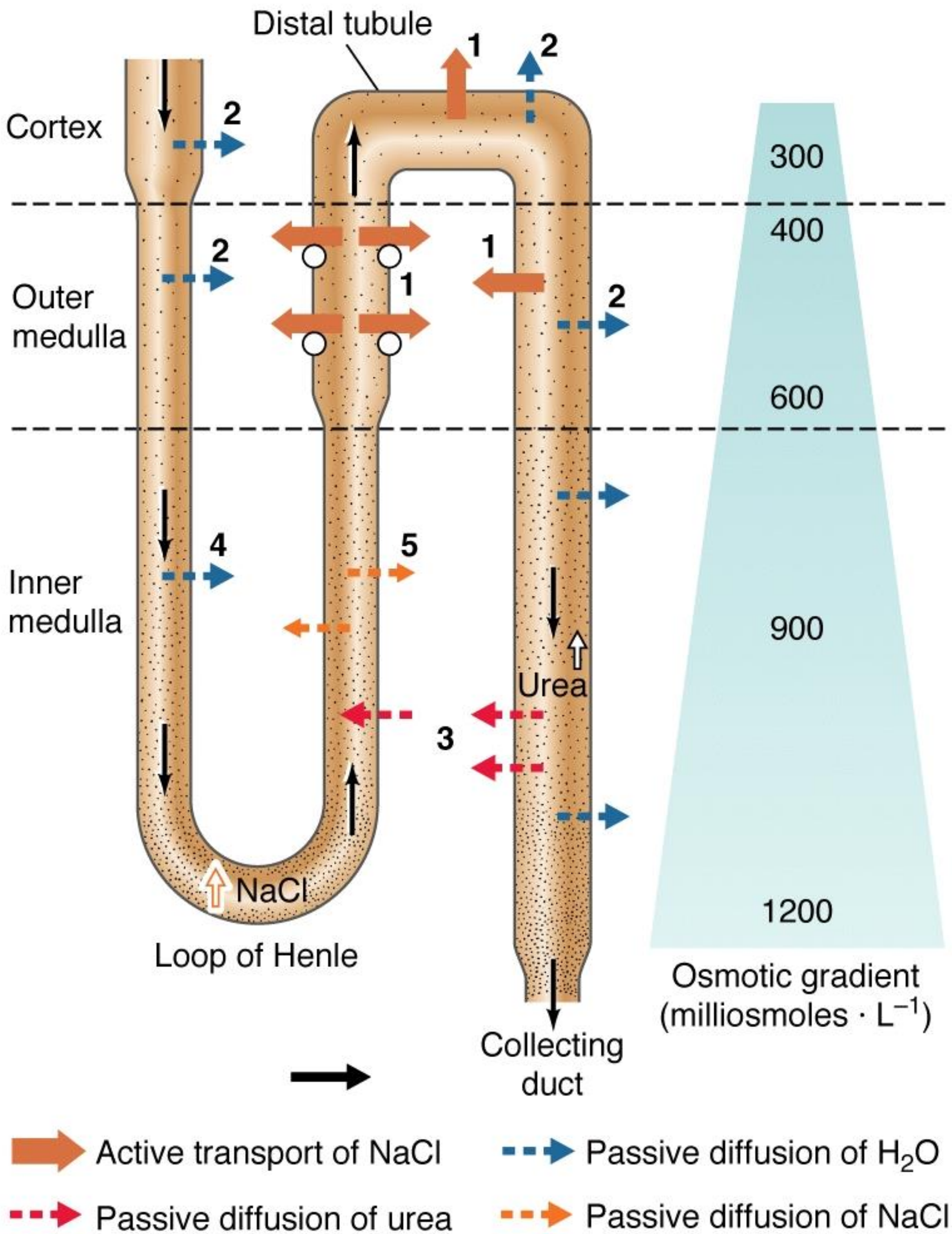


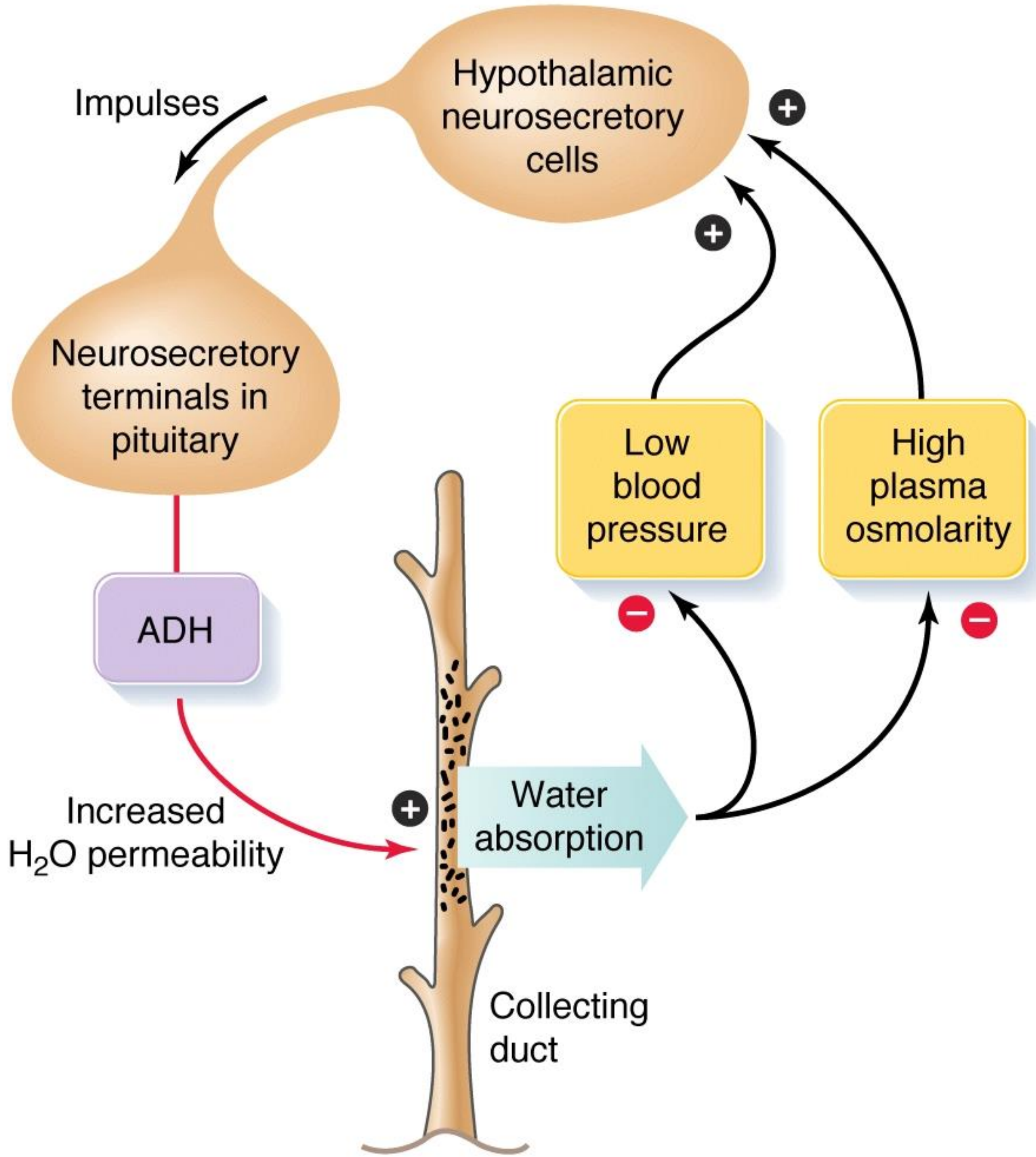
(b) B-type cells of kidney



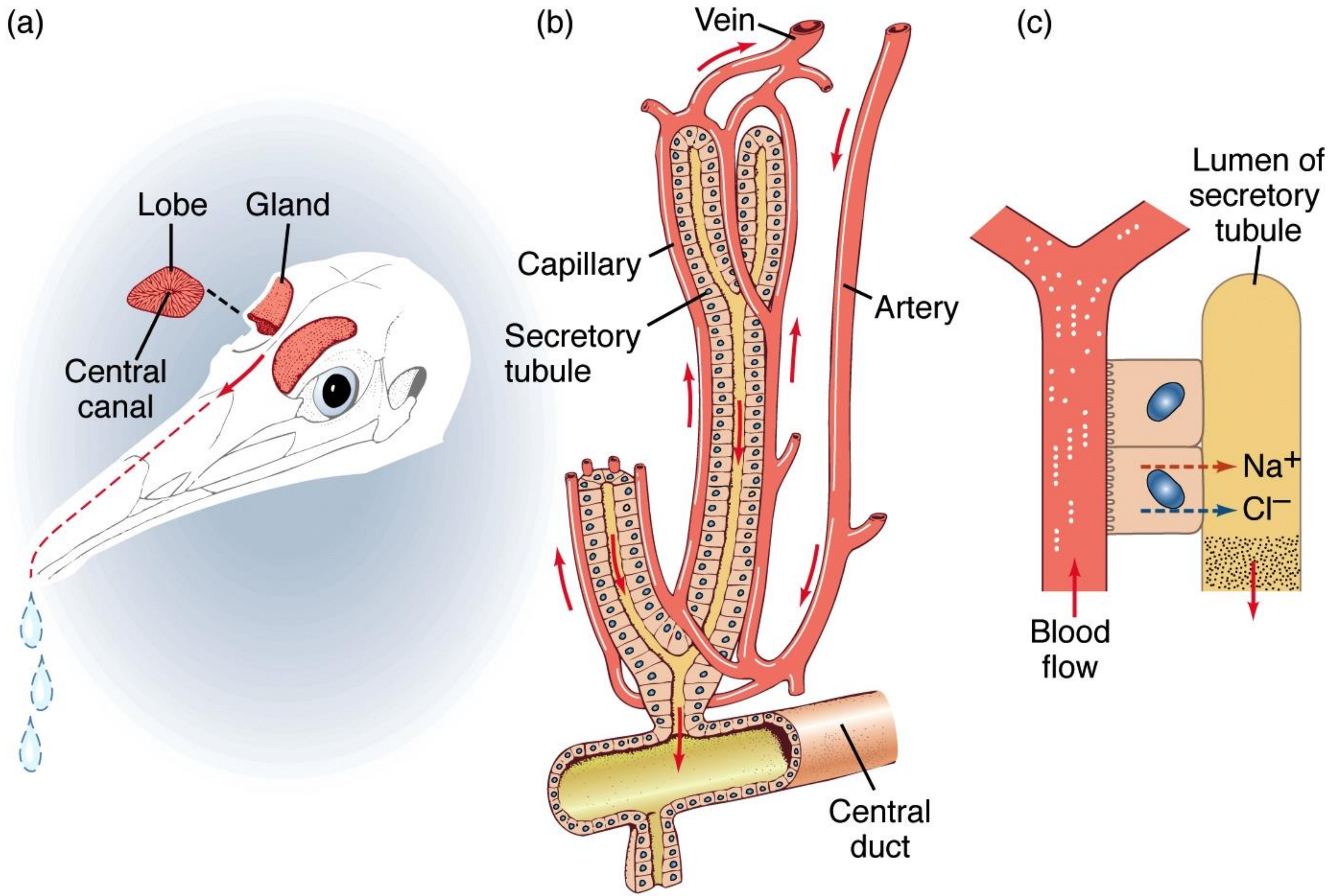


Tubular lumen
Blood
NH3
Gln
Glutamine
(Gln)
Deamination
NH4+
NH3
NH4
H+
α-Ketoglutarate
HPO4 2–
(filtered)
H+
ATPase
H+
H2PO4–
Na+
Apical
membrane
Basolateral
membrane

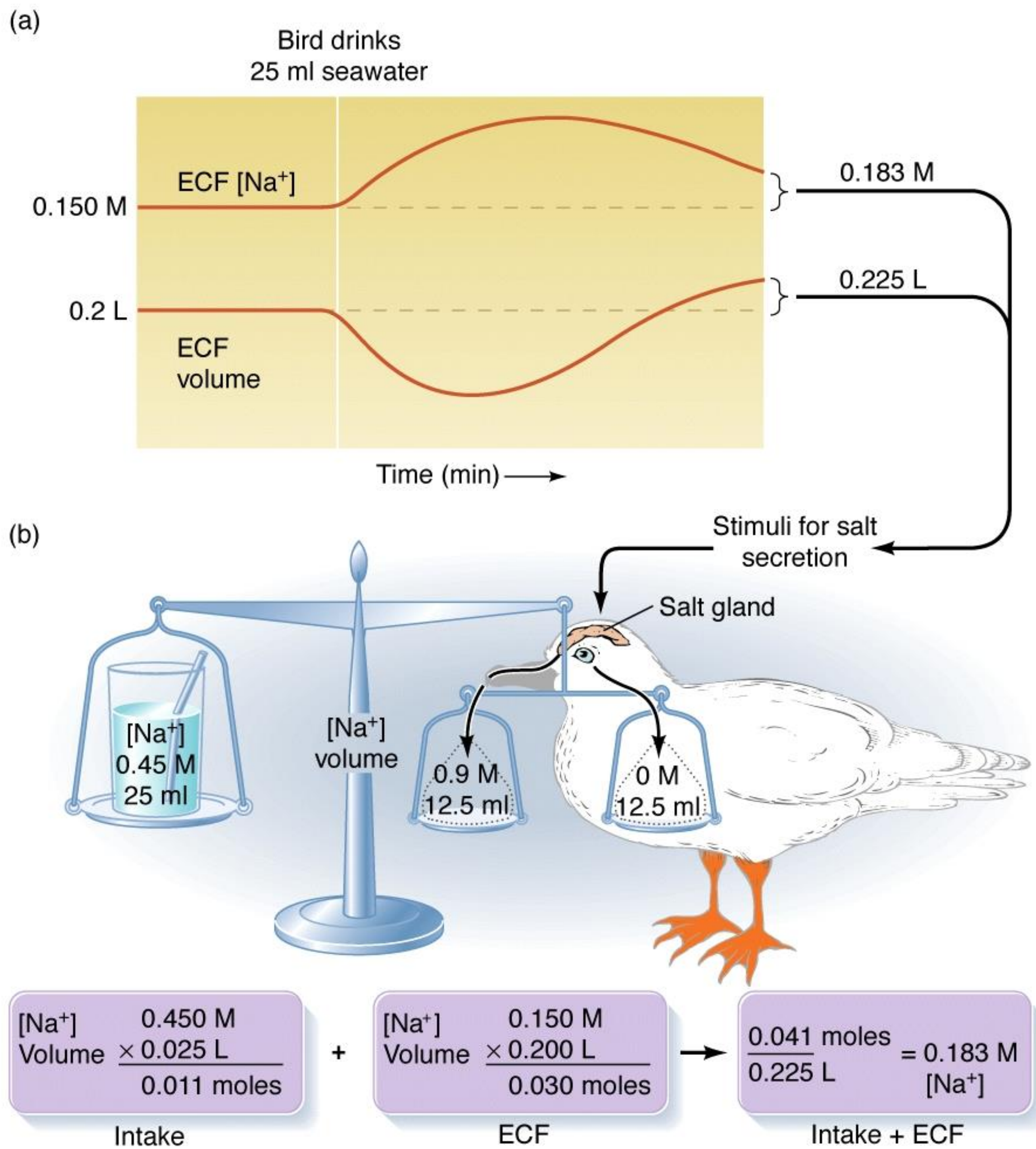

Distal tubule
1
2
Cortex
2
300
400
2
1
1
2
Outer
medulla
600
4
5
Inner
medulla
900
Urea
3
NaCl
1200
Loop of Henle
Osmotic gradient
(milliosmoles · L^{-1})
Collecting
duct
Active transport of NaCl
Passive diffusion of H_2O
Passive diffusion of urea
Passive diffusion of NaCl



Hypothalamic neurosecretory cells
Impulses
Neurosecretory terminals in pituitary
ADH
Increased H_2O permeability
Water absorption
Low blood pressure
High plasma osmolarity
Collecting duct

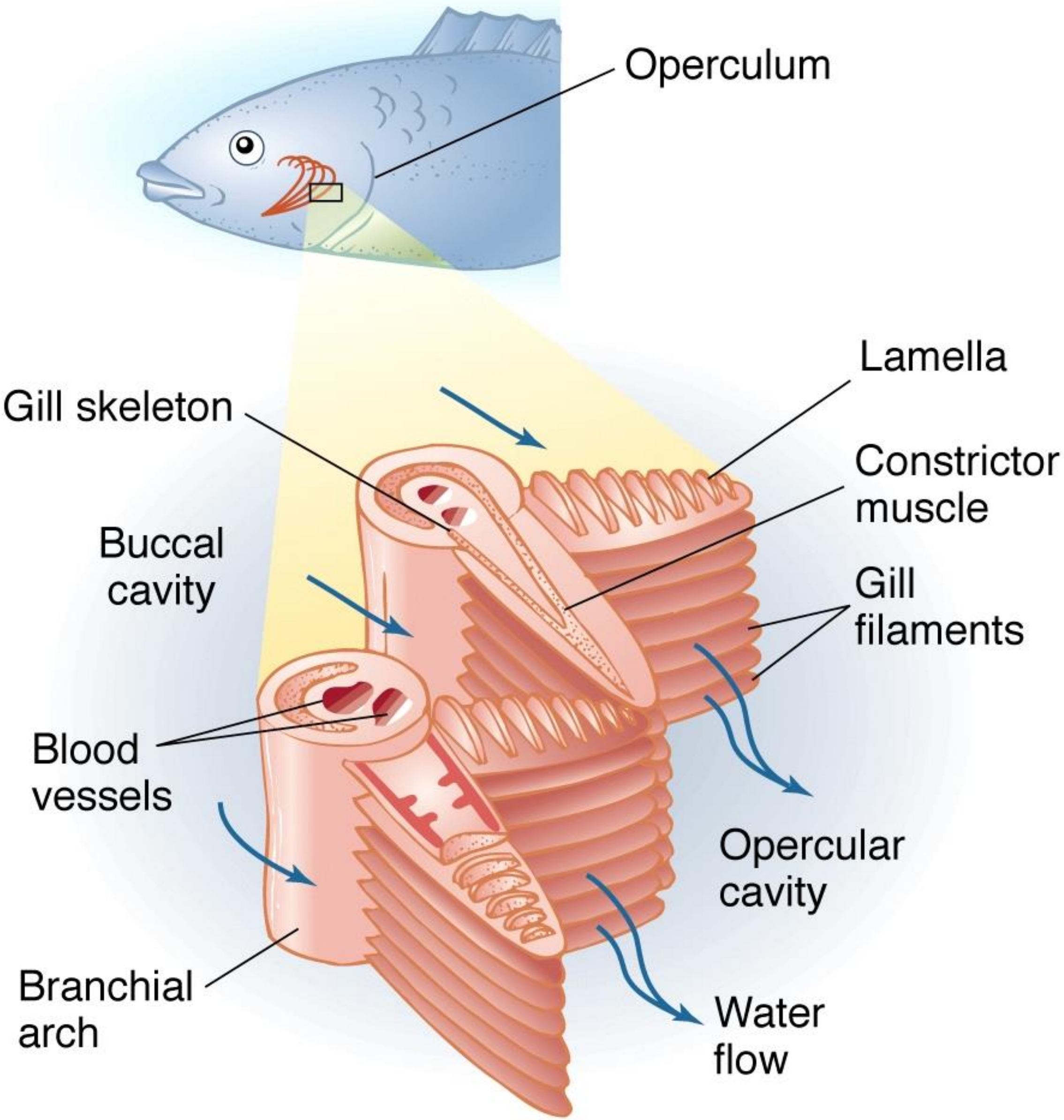


(a)
Lobe
Gland
Central canal
(b)
Vein
Capillary
Secretory tubule
Artery
Central duct
(c)
Lumen of secretory tubule
Na+
Cl−
Blood flow

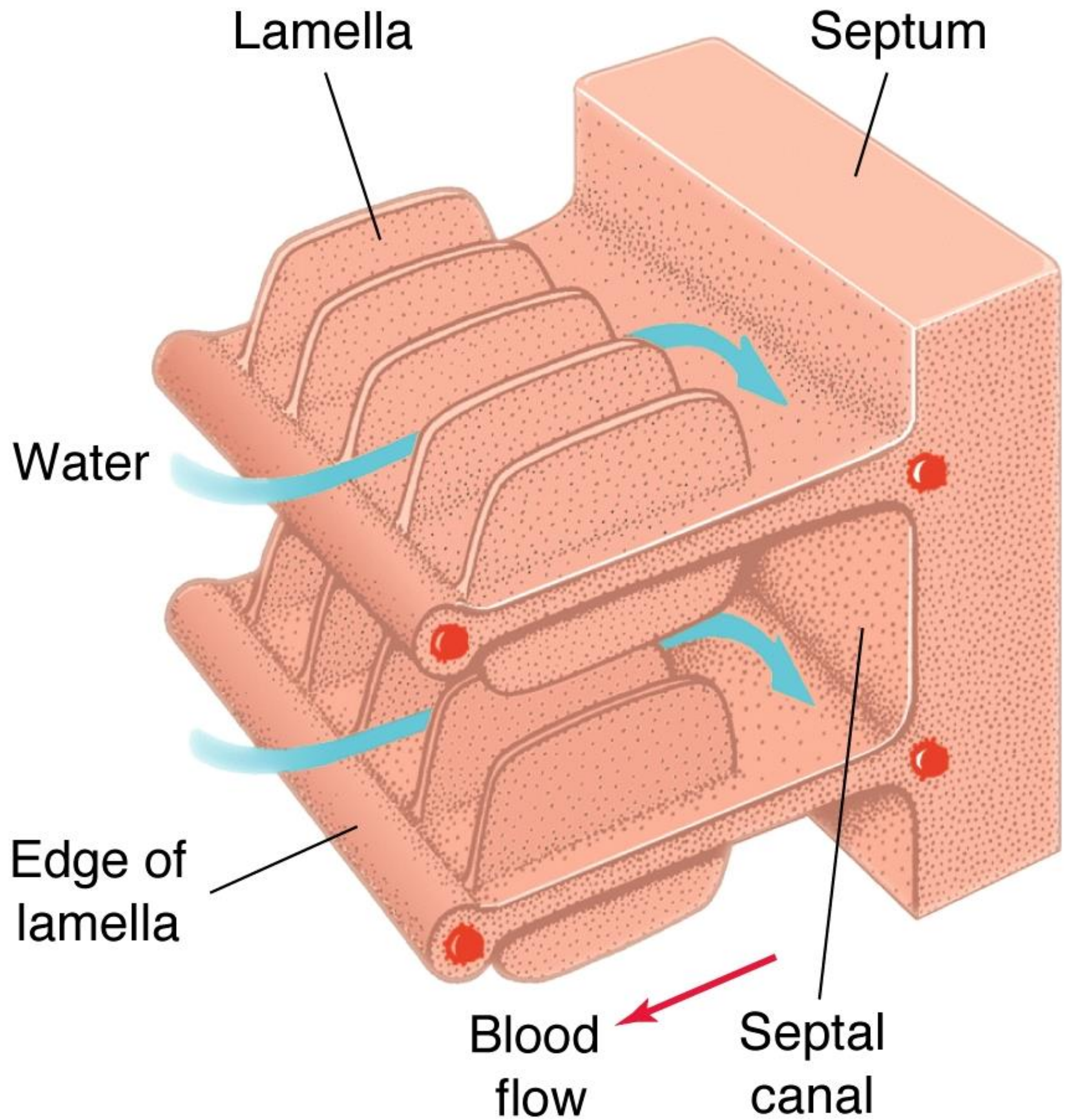


(a)
Bird drinks
25 ml seawater
ECF [Na+]
0.150 M
0.2 L
ECF
volume
0.183 M
0.225 L
Time (min)
(b)
Stimuli for salt
secretion
Salt gland
[Na+]
0.45 M
25 ml
[Na+]
volume
0.9 M
12.5 ml
0 M
12.5 ml
[Na+] 0.450 M
Volume × 0.025 L
0.011 moles
Intake
+
[Na+] 0.150 M
Volume × 0.200 L
0.030 moles
ECF
0.041 moles
0.225 L
= 0.183 M
[Na+]
Intake + ECF

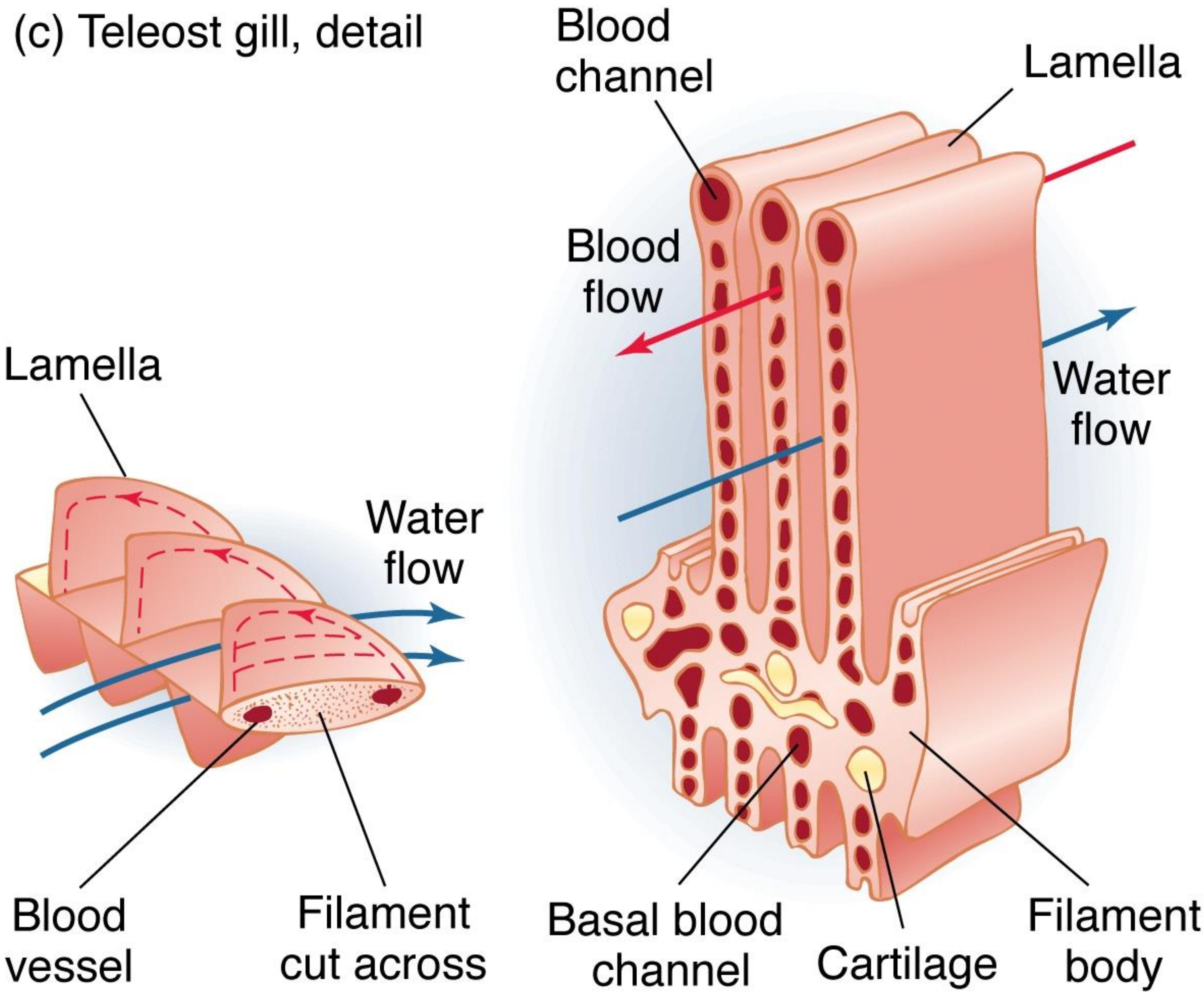
(a) Teleost gill



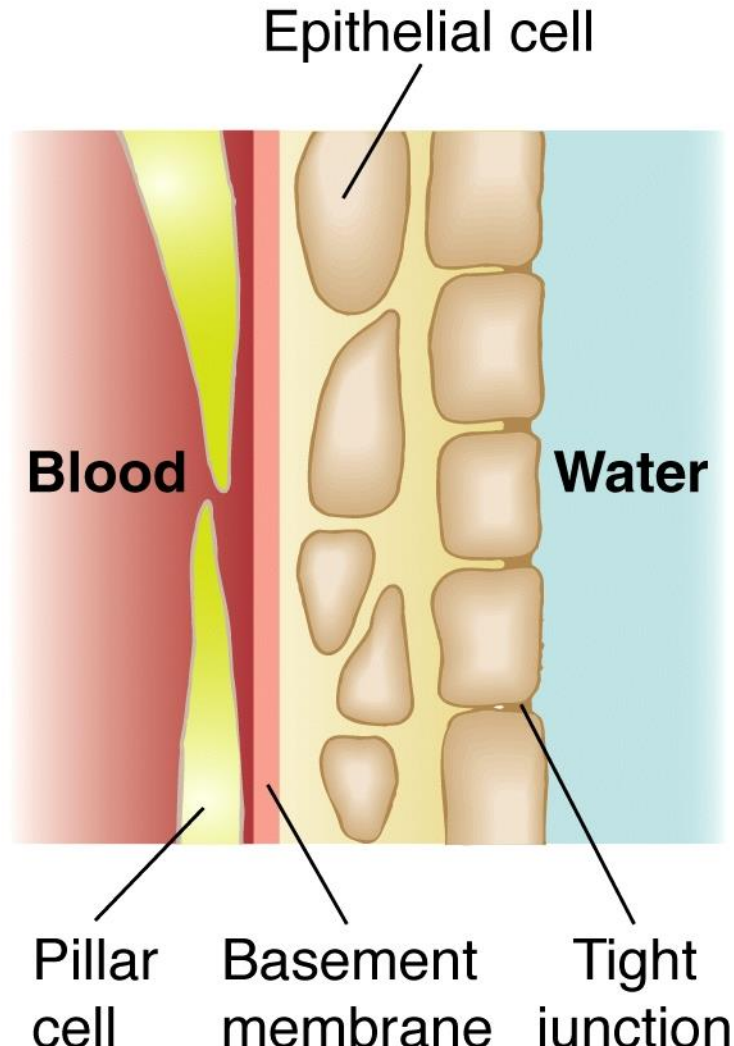
(b) Elasmobranch gill, detail (dogfish)



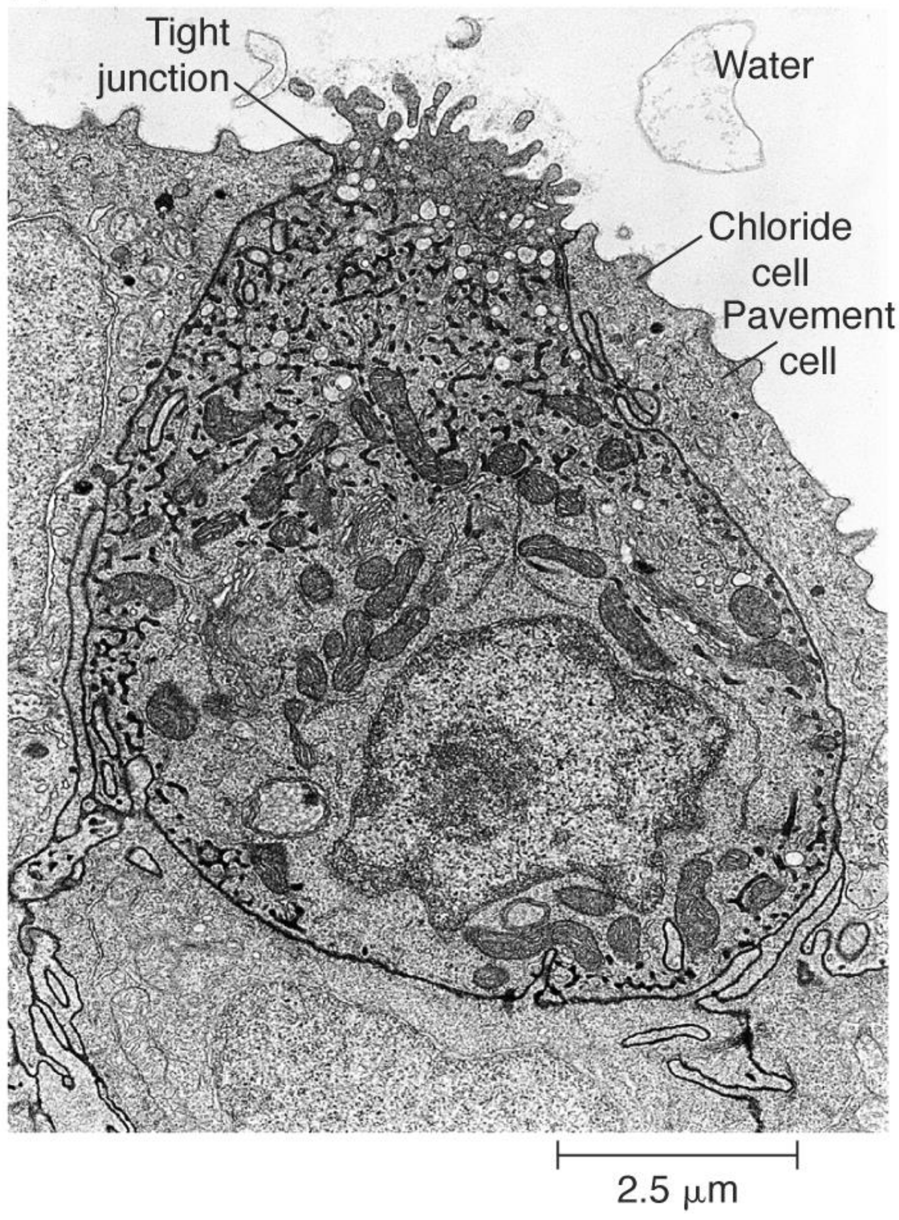
(c) Teleost gill, detail

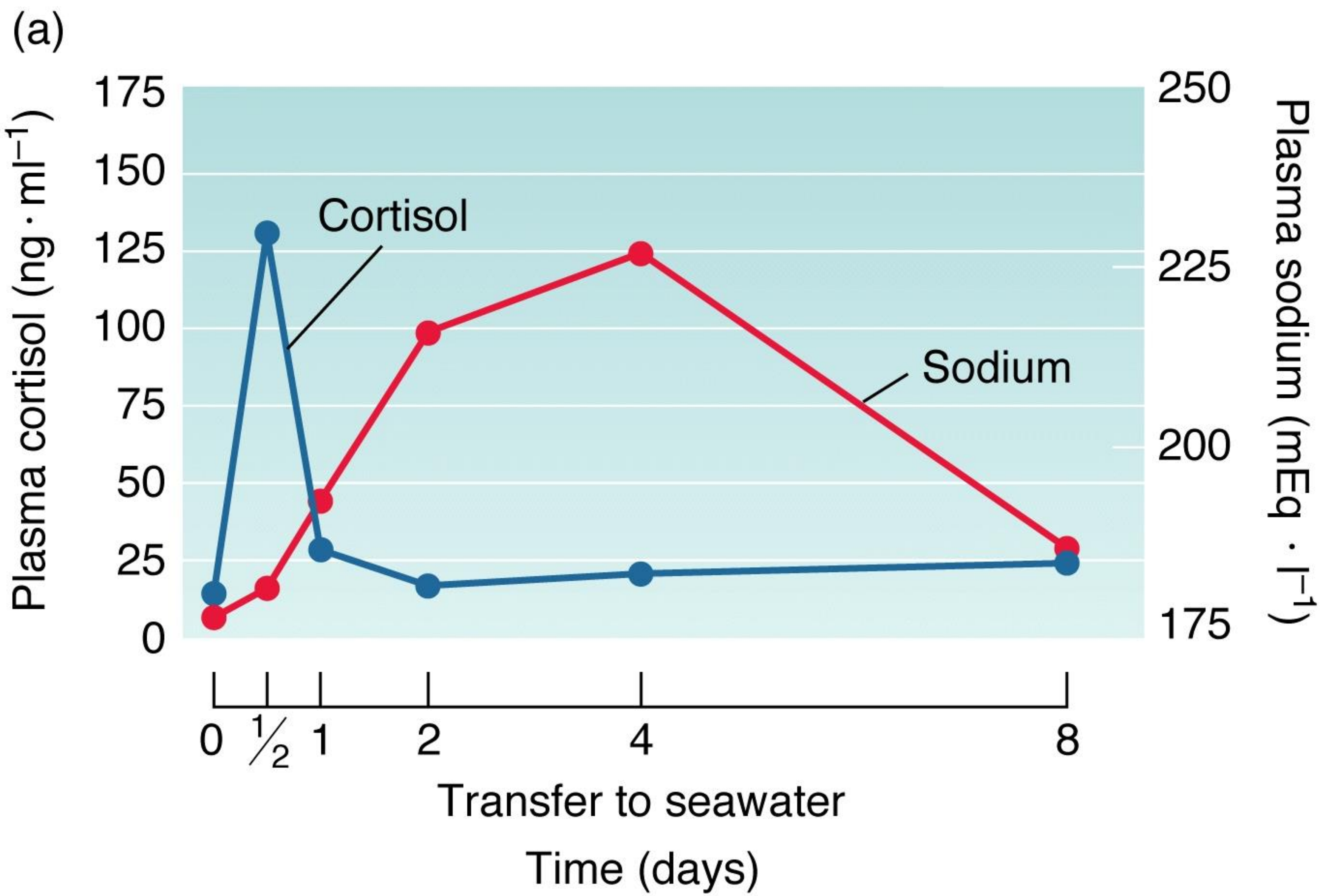


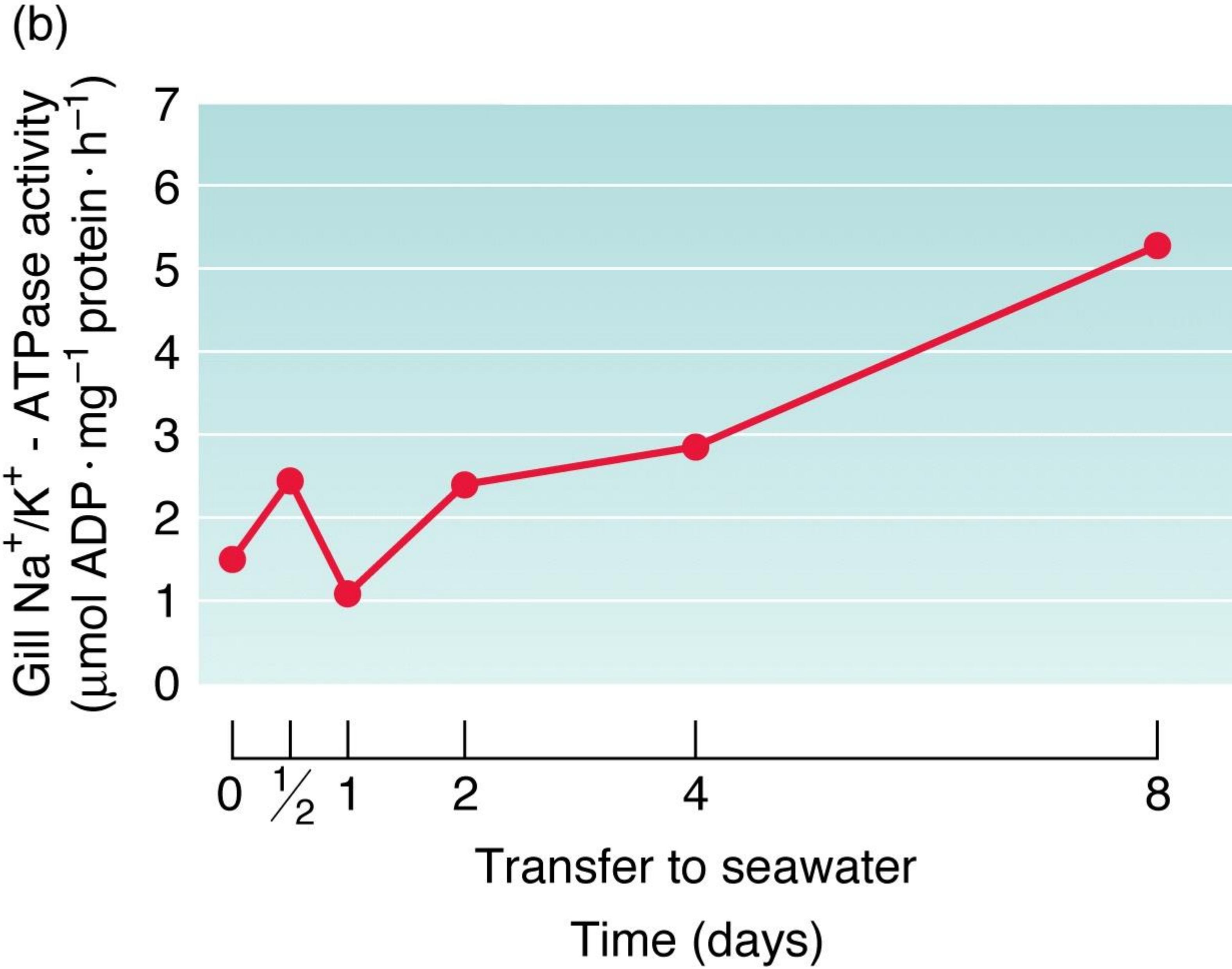
(e) Section across gill lamellar epithelium



(a)




(a)
Plasma cortisol (ng · ml⁻¹)
175
150
125
100
75
50
25
0
250
225
200
175
Plasma sodium (mEq · l⁻¹)
Cortisol
Sodium
0
½
1
2
4
8
Transfer to seawater
Time (days)



(b)
Gill Na+/K+ - ATPase activity
(μmol ADP · mg−1 protein · h−1)
7
6
5
4
3
2
1
0
0
½
1
2
4
8
Transfer to seawater
Time (days)

Table 14-10 **Physiological acclimatizations that accompany the movement of fish to water of differing salinity**

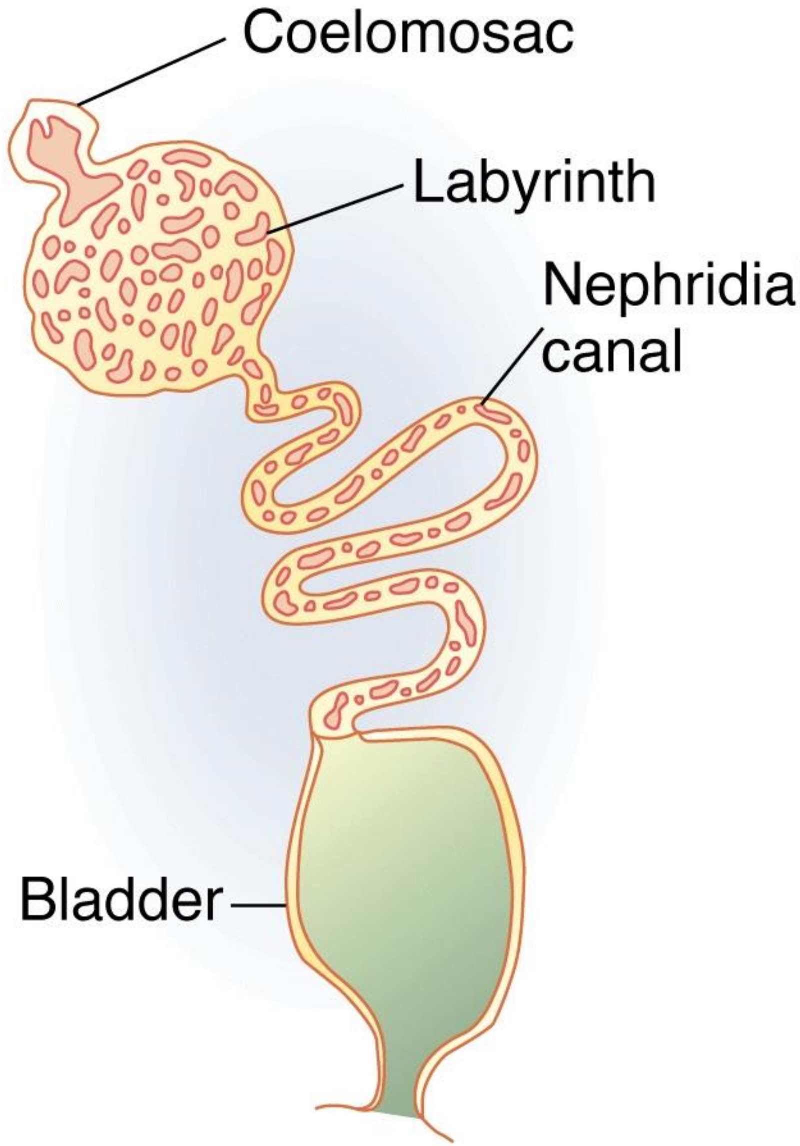
(A) From freshwater to seawater

1. The proton pump that powers active uptake of NaCl is down-regulated.
2. The rise in the flux of Na^+ into the body raises plasma Na^+, stimulating an increase in plasma cortisol and growth hormone levels.
3. Hormones induce the proliferation of chloride cells and an increase in the infolding of their basolateral membranes.
4. The changes above cause an increase in the activity of the Na^+/K^+ pump and the secretion of NaCl.
5. Plasma Na^+ levels return to normal.

Table 14-10 Physiological acclimatizations that accompany the movement of fish to water of differing salinity

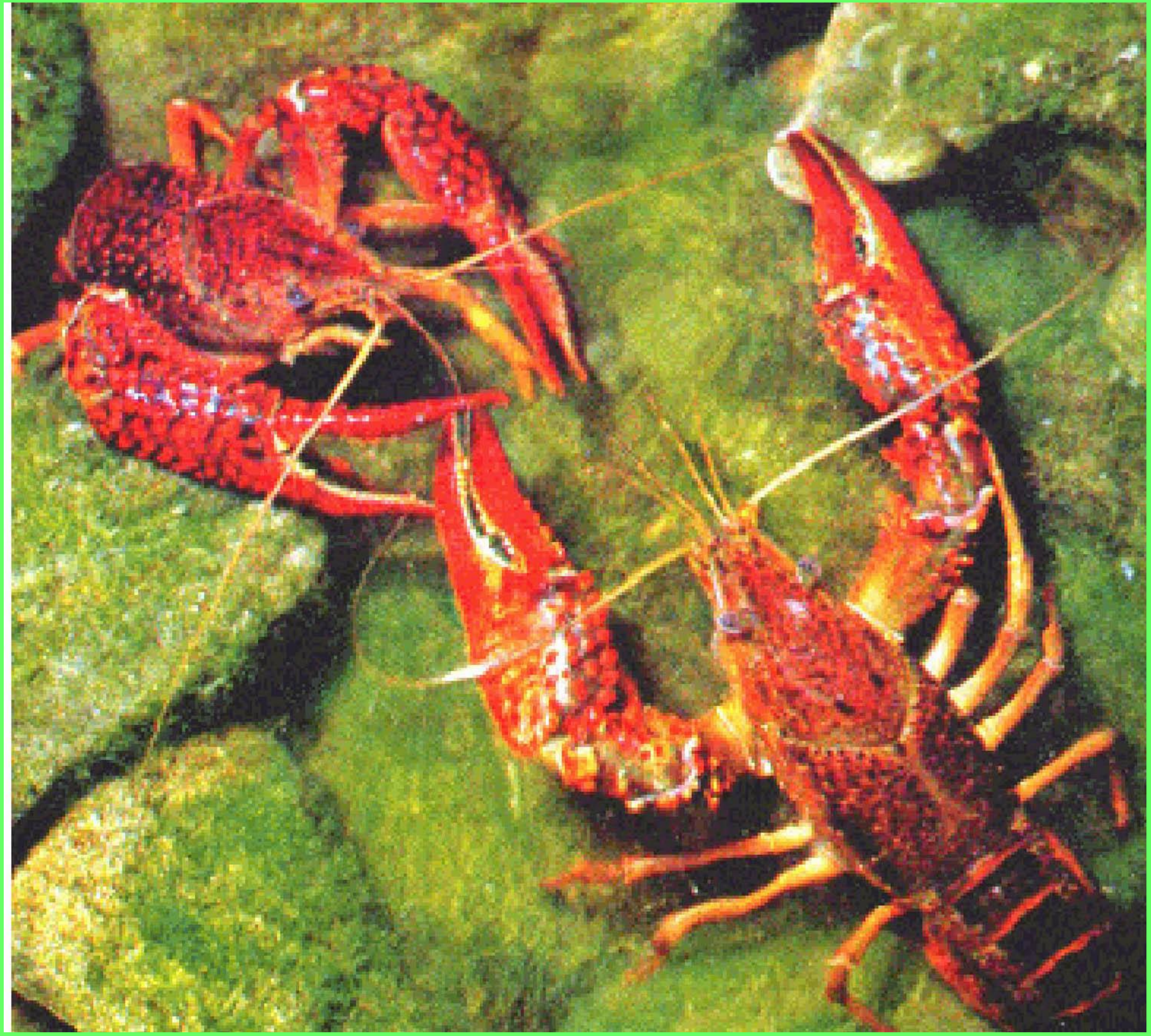
(B) From seawater to freshwater

1. The paracellular gaps between chloride and accessory cells close in response to low external Na^+ levels, causing NaCl efflux to fall rapidly.
2. Plasma prolactin levels increase.
3. Prolactin causes the number of chloride cells to decrease and the apical pits to disappear.
4. As a result, the activity of the Na^+/K^+ pump falls.
5. Up-regulation of the proton pump returns the fish to the freshwater condition.

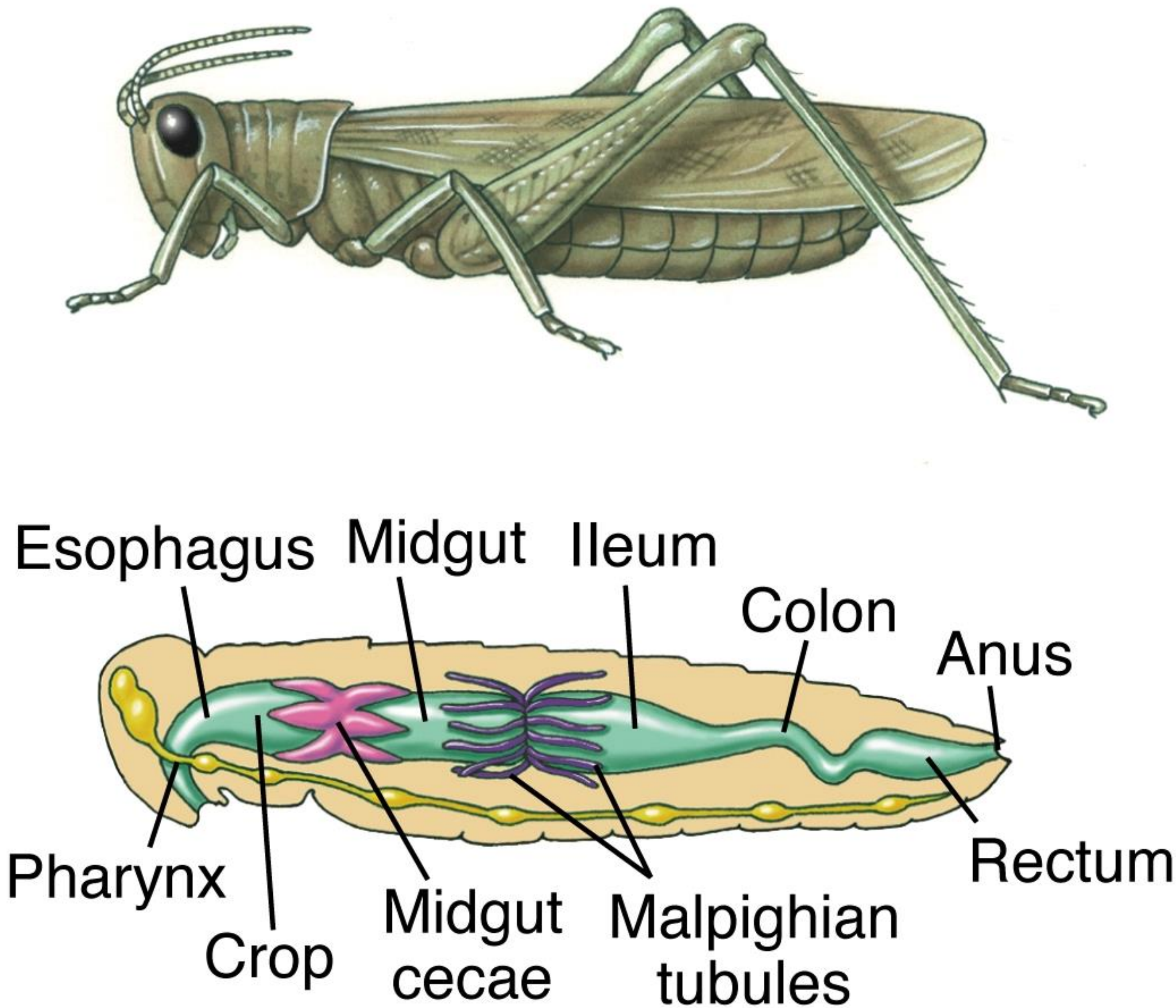


Crayfish antennal gland

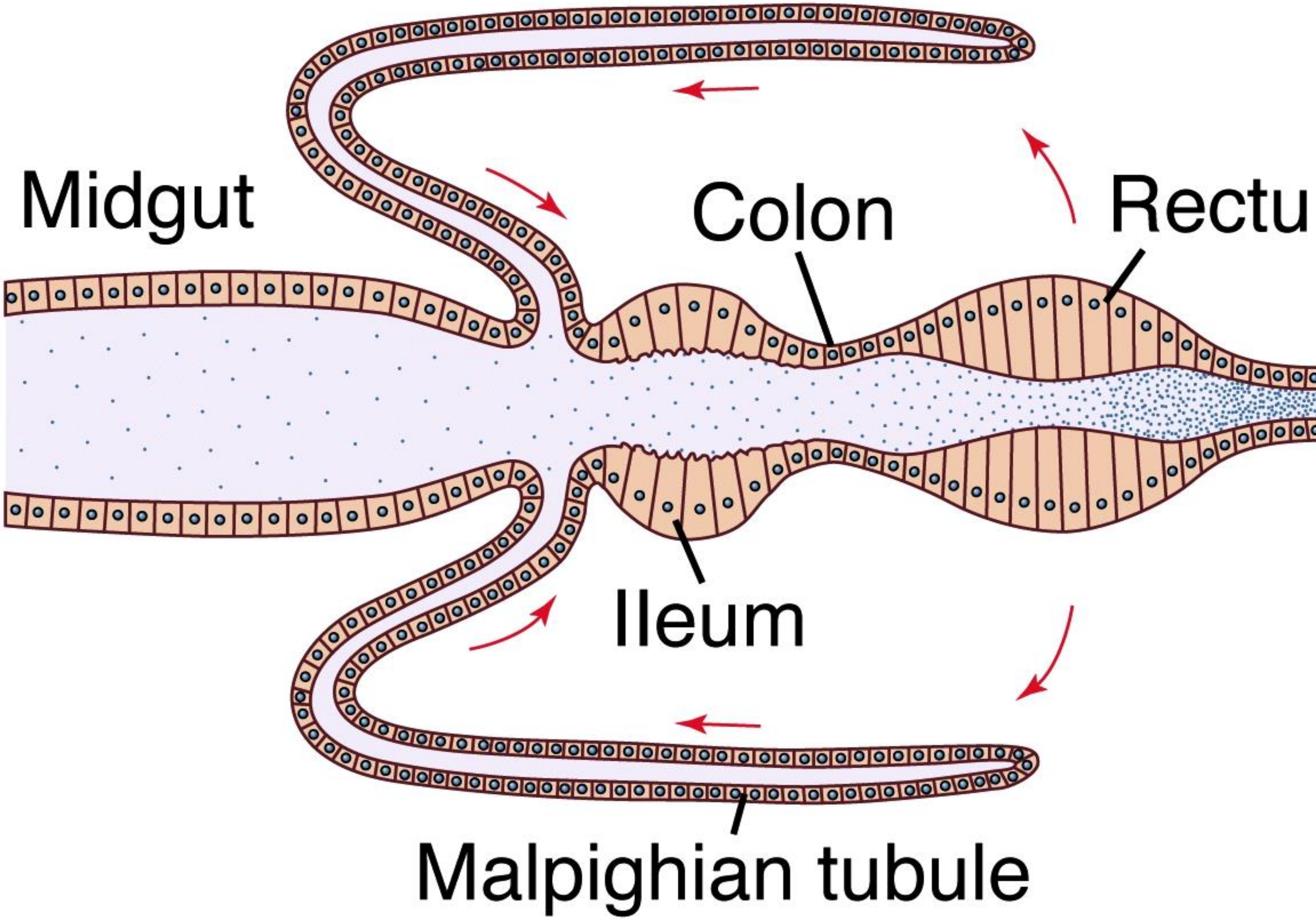
Urine Release

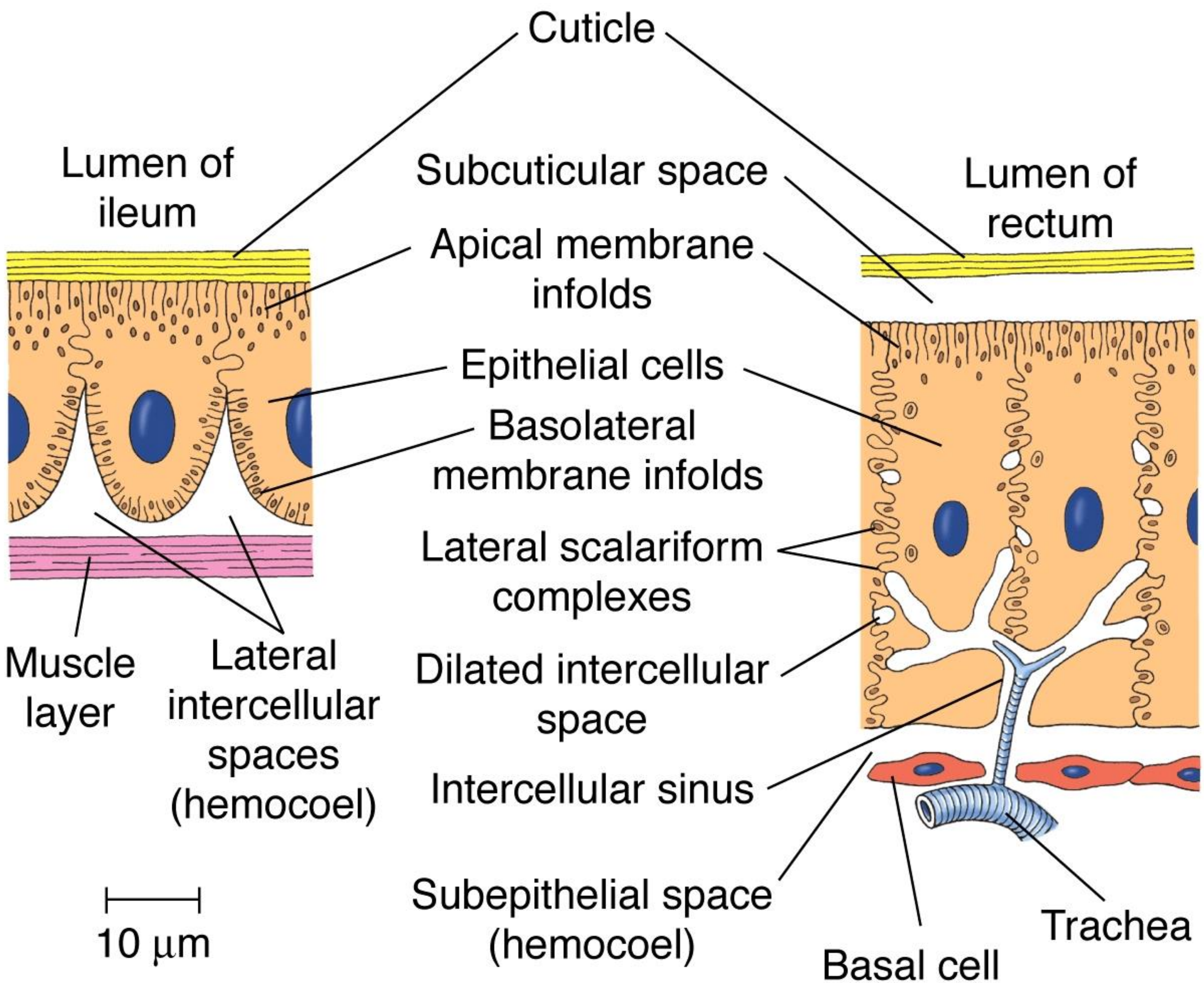


(a)

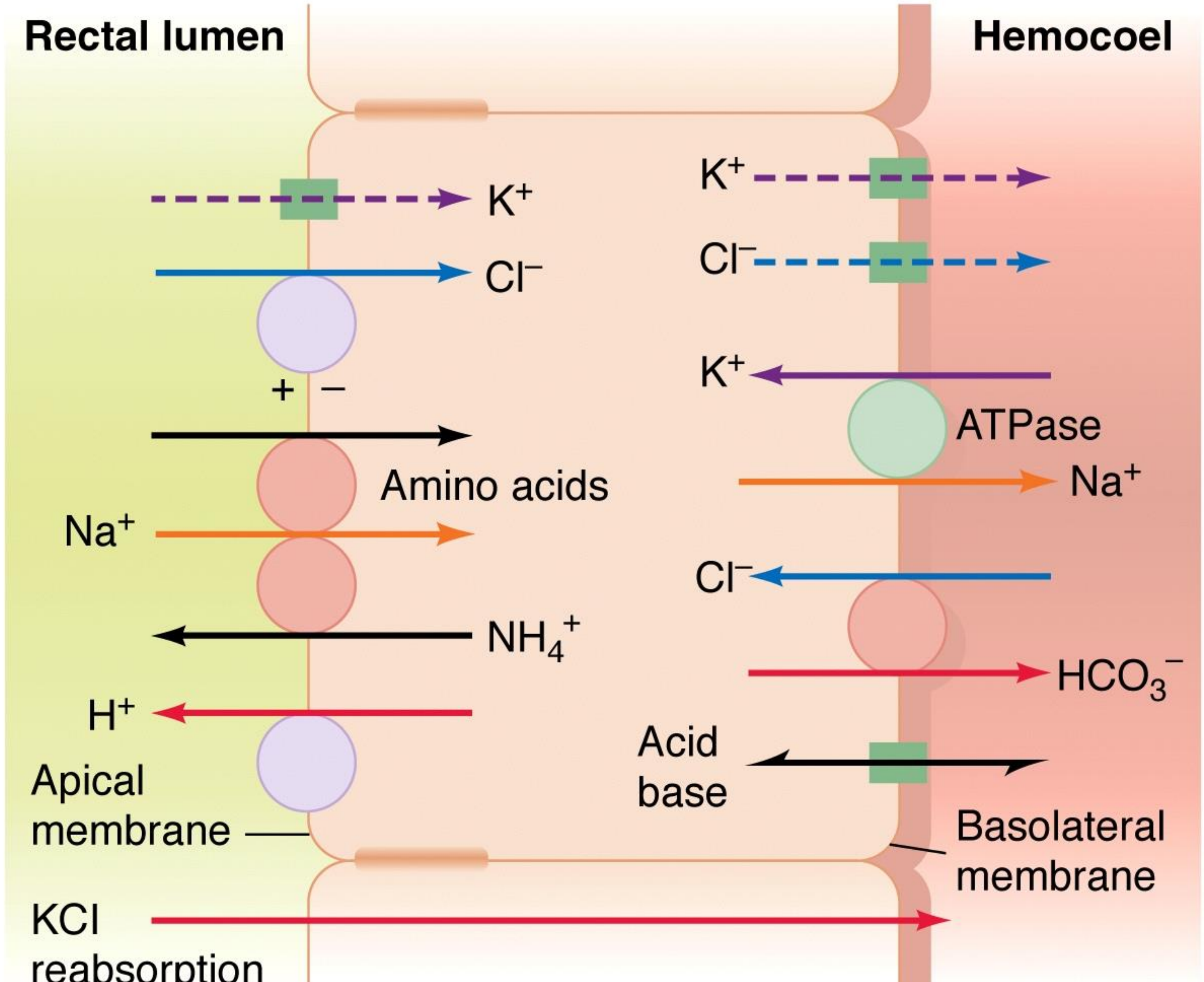

Esophagus
Midgut
Ileum
Colon
Anus
Pharynx
Crop
Midgut cecae
Malpighian tubules
Rectum

(b)

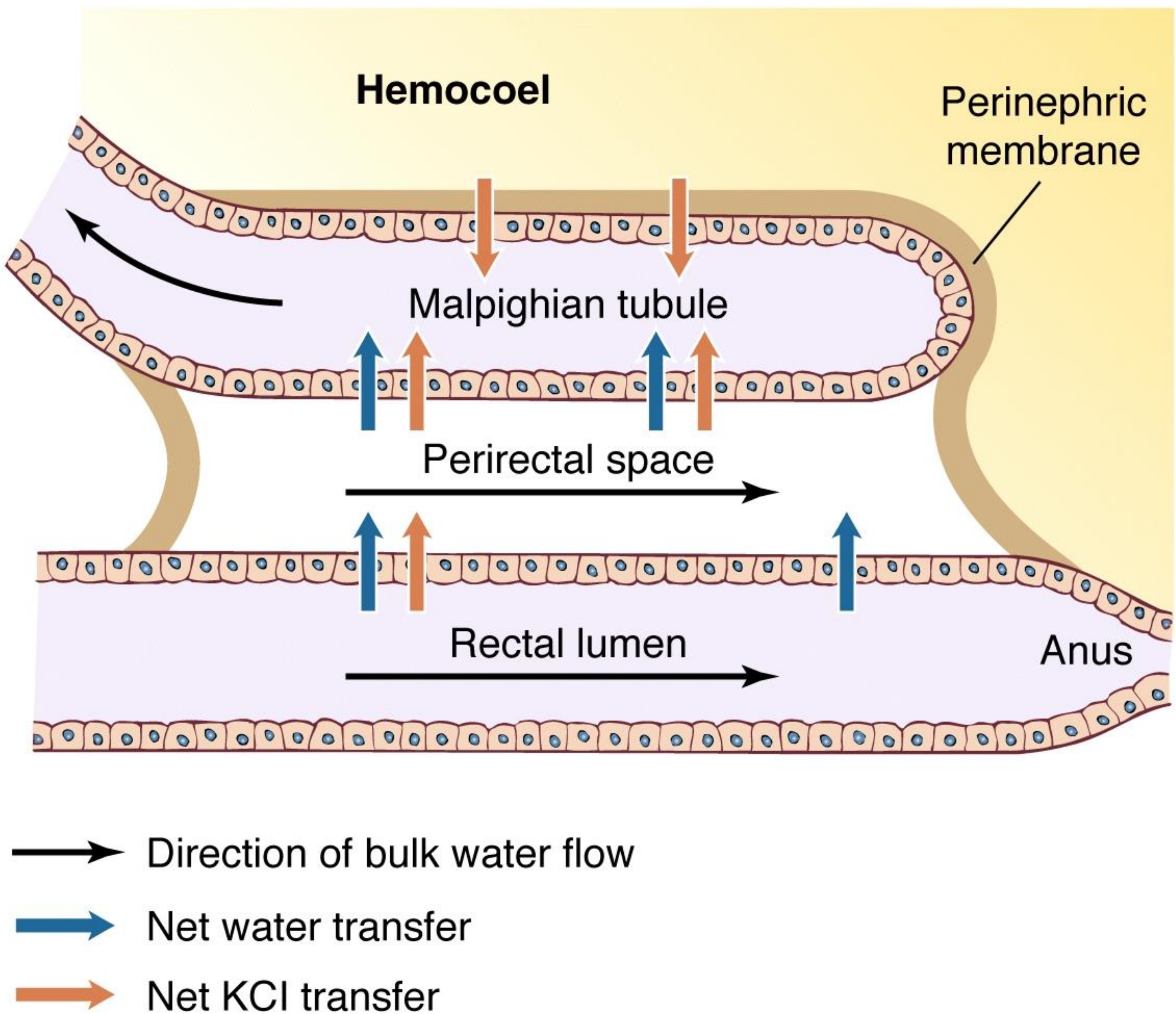


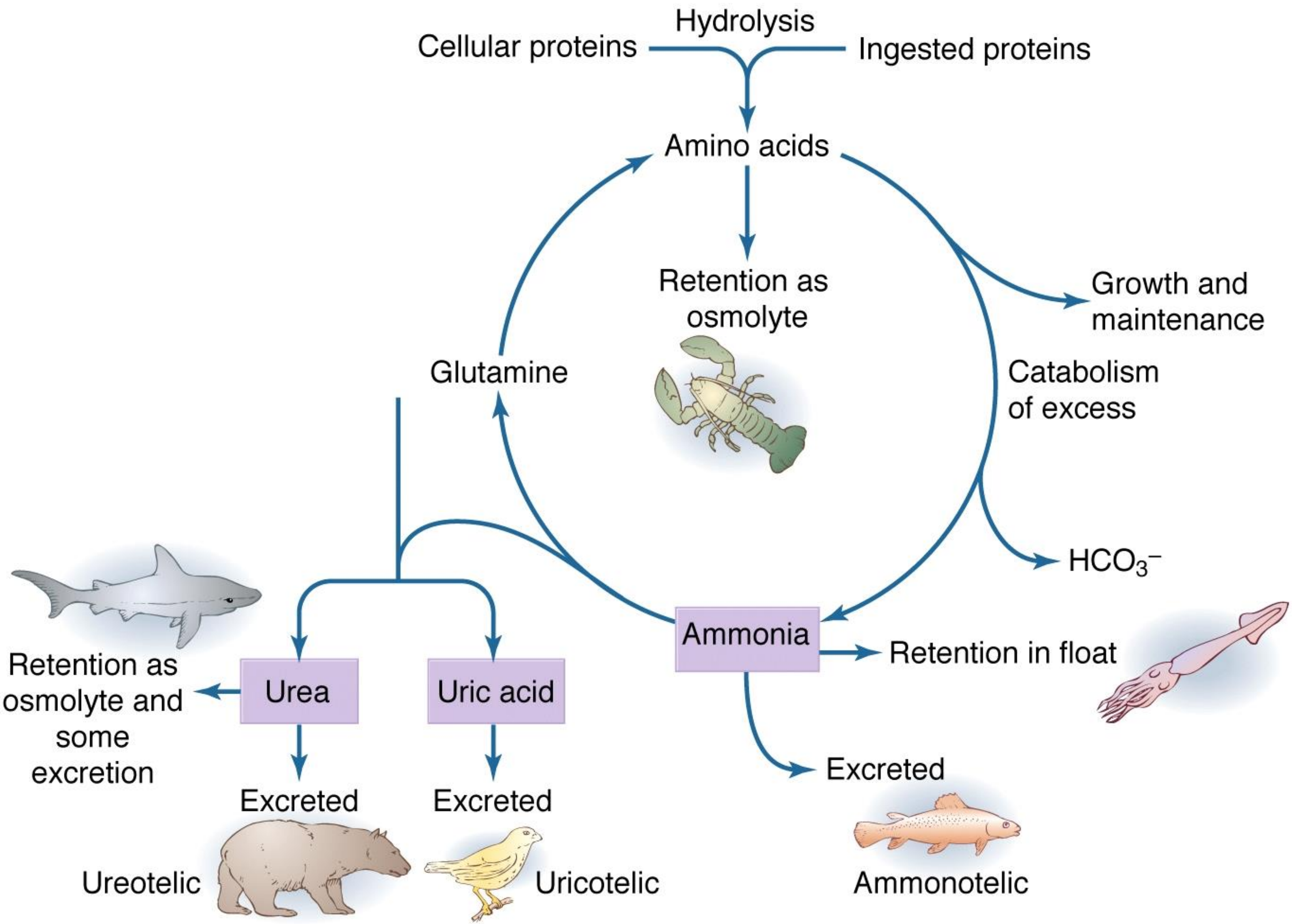


Cuticle
Lumen of ileum
Subcuticular space
Lumen of rectum
Apical membrane infolds
Epithelial cells
Basolateral membrane infolds
Lateral scalariform complexes
Muscle layer
Lateral intercellular spaces (hemocoel)
Dilated intercellular space
Intercellular sinus
Subepithelial space (hemocoel)
Trachea
Basal cell
10 µm

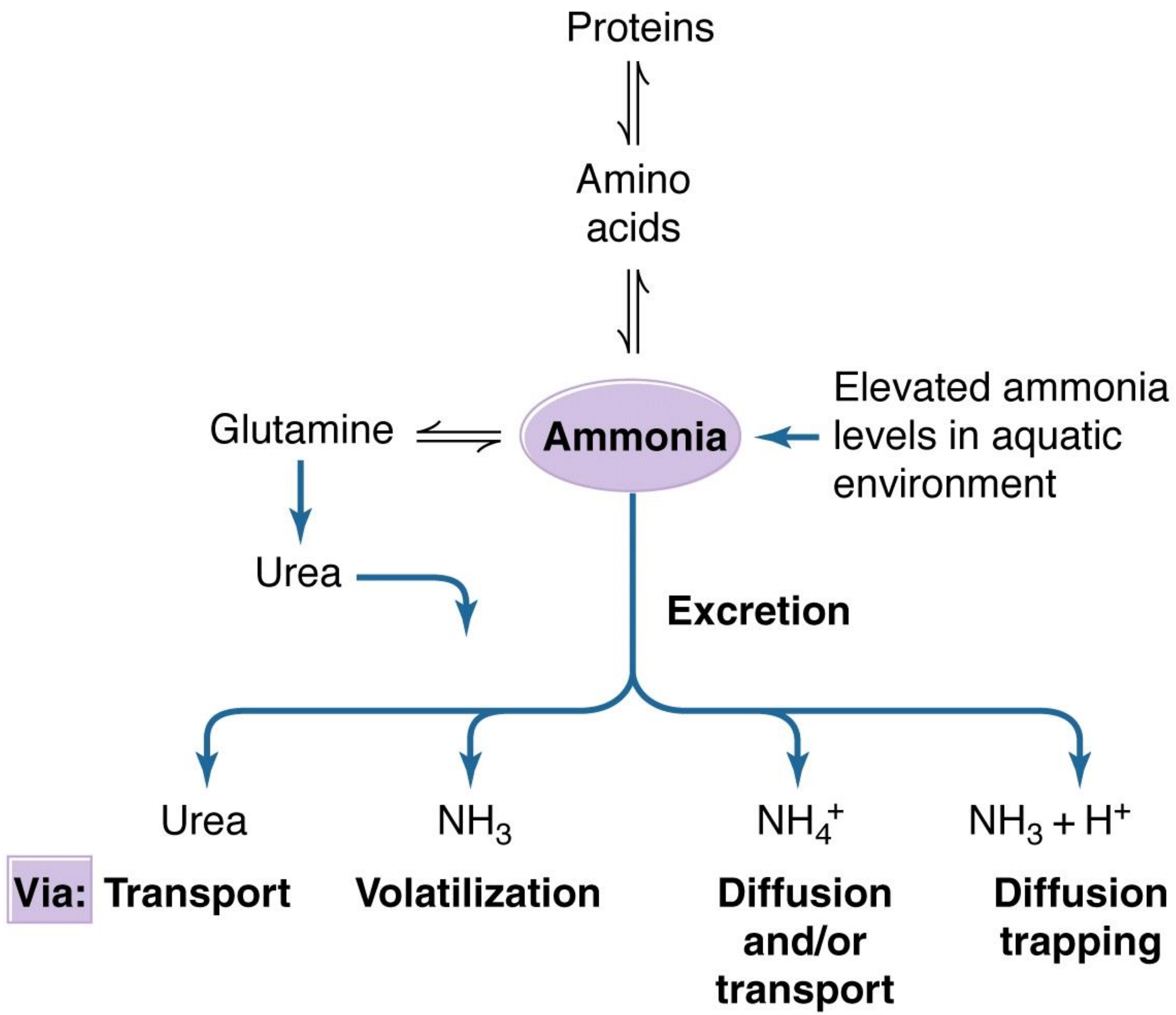


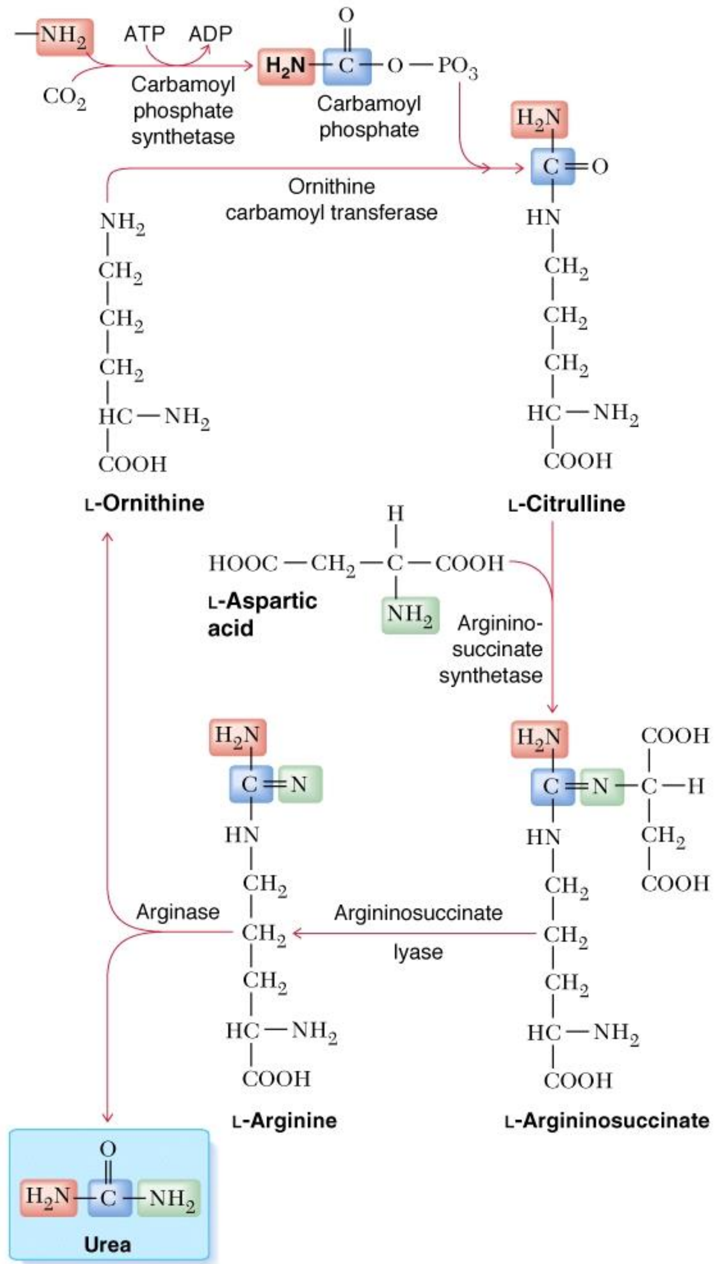
Rectal lumen
Hemocoel
K+
Cl−
+ −
Amino acids
Na+
NH4+
H+
Apical membrane
KCl reabsorption
K+
Cl−
K+
ATPase
Na+
Cl−
HCO3−
Acid base
Basolateral membrane


Hemocoel
Perinephric membrane
Malpighian tubule
Perirectal space
Rectal lumen
Anus
Direction of bulk water flow
Net water transfer
Net KCl transfer

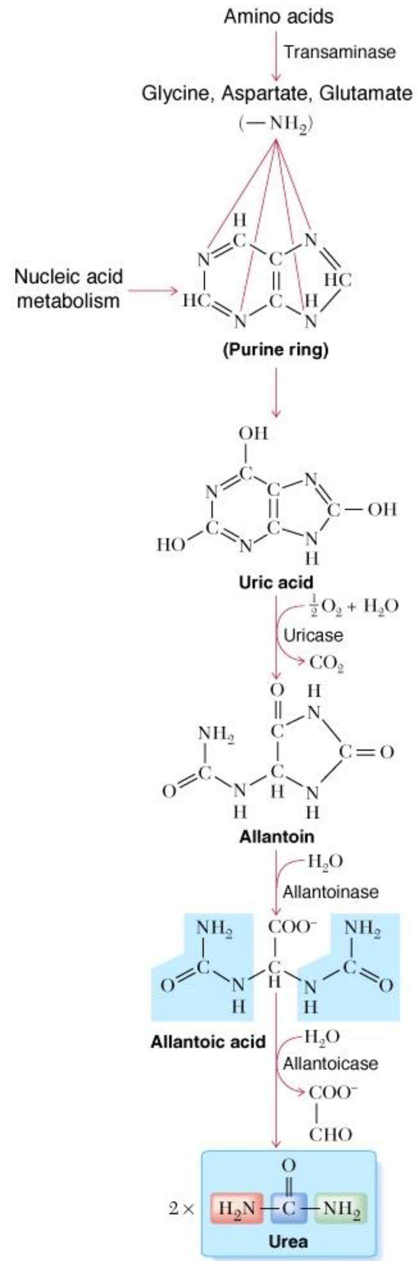


Hydrolysis
Cellular proteins
Ingested proteins
Amino acids
Retention as osmolyte
Growth and maintenance
Glutamine
Catabolism of excess
HCO_3^-
Ammonia
Retention in float
Excreted
Ammonotelic
Urea
Uric acid
Retention as osmolyte and some excretion
Excreted
Excreted
Ureotelic
Uricotelic

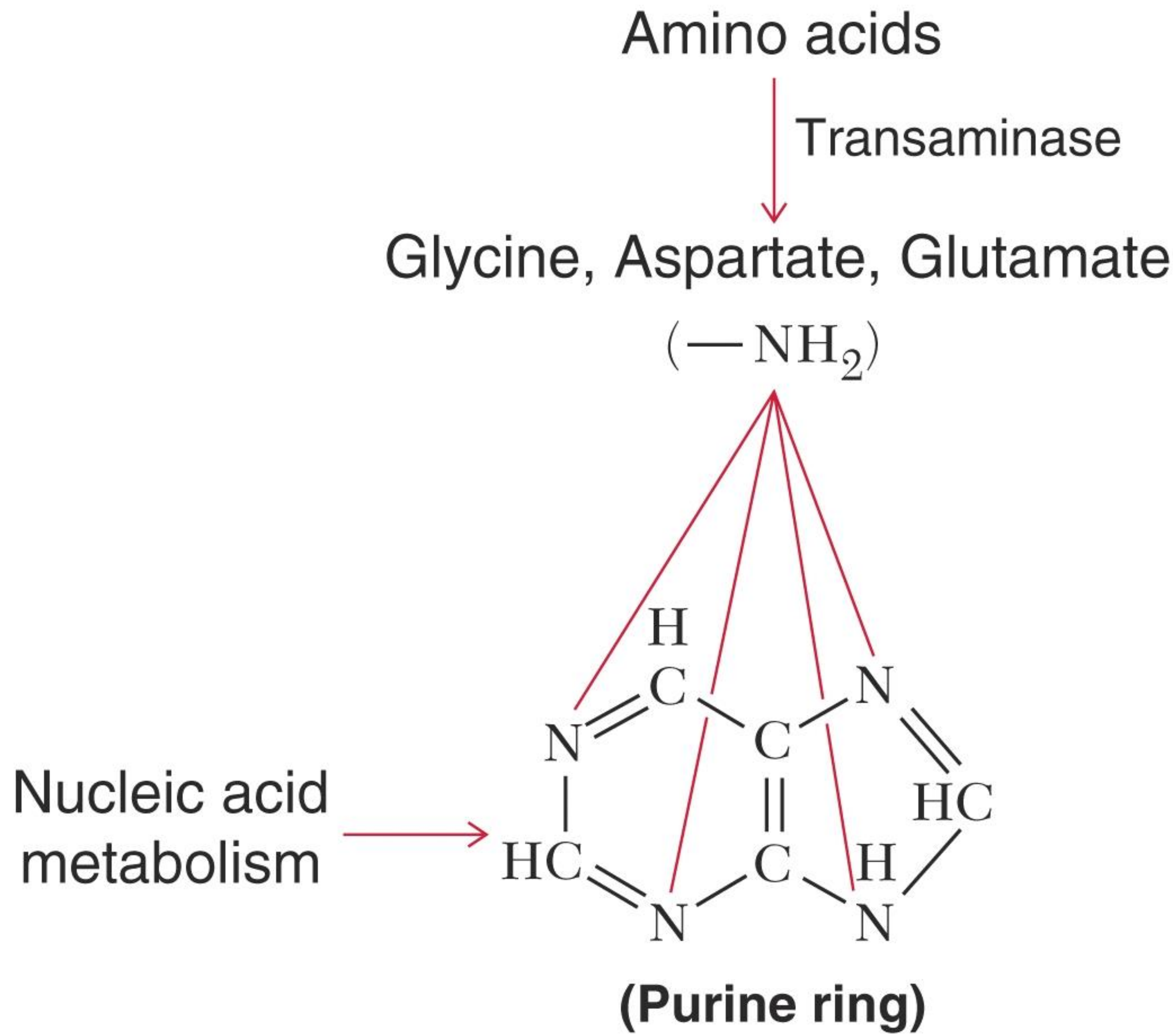

Proteins
Amino acids
Glutamine
Ammonia
Elevated ammonia levels in aquatic environment
Urea
Excretion
Urea
NH_3
NH_4^+
$NH_3 + H^+$
Via: Transport
Volatilization
Diffusion and/or transport
Diffusion trapping

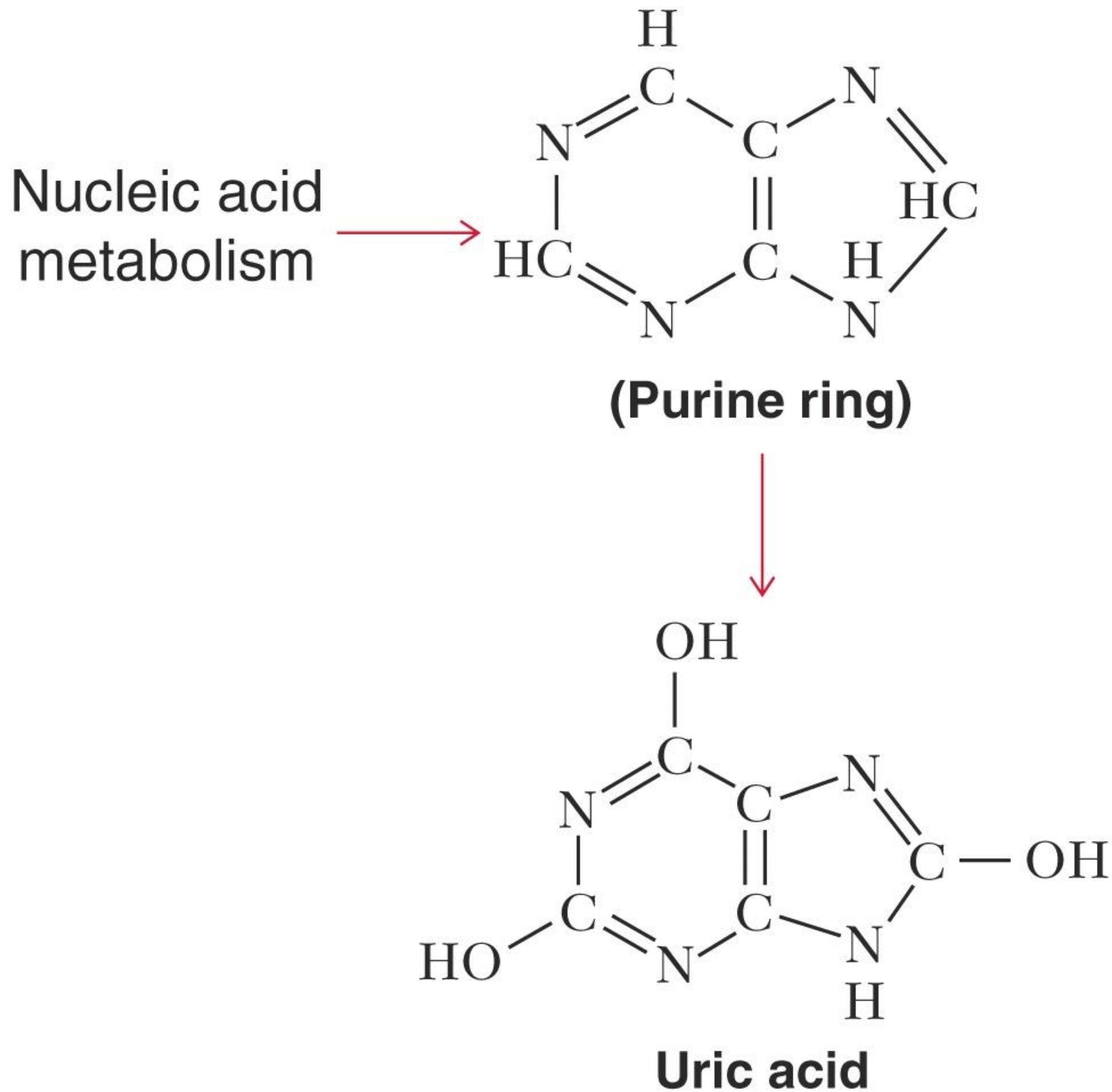


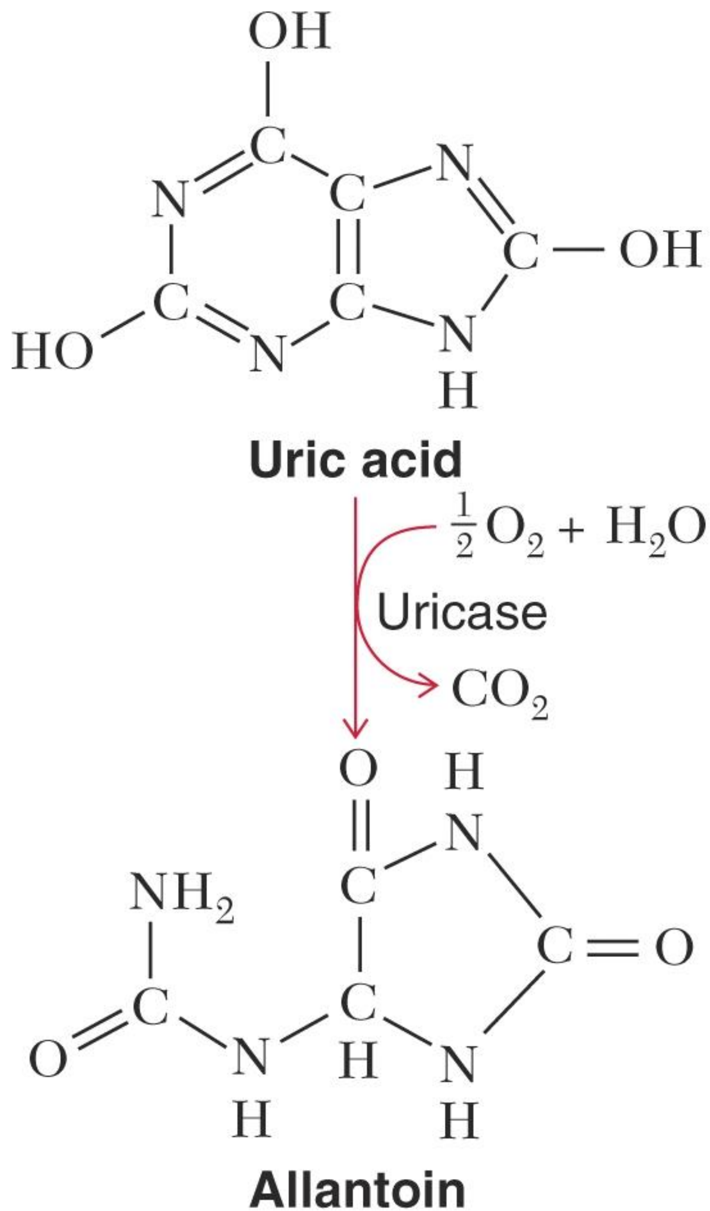
ATP
ADP
CO2
Carbamoyl phosphate synthetase
Carbamoyl phosphate
Ornithine carbamoyl transferase
L-Ornithine
L-Citrulline
L-Aspartic acid
Arginino-succinate synthetase
Arginase
Argininosuccinate lyase
L-Arginine
L-Argininosuccinate
Urea



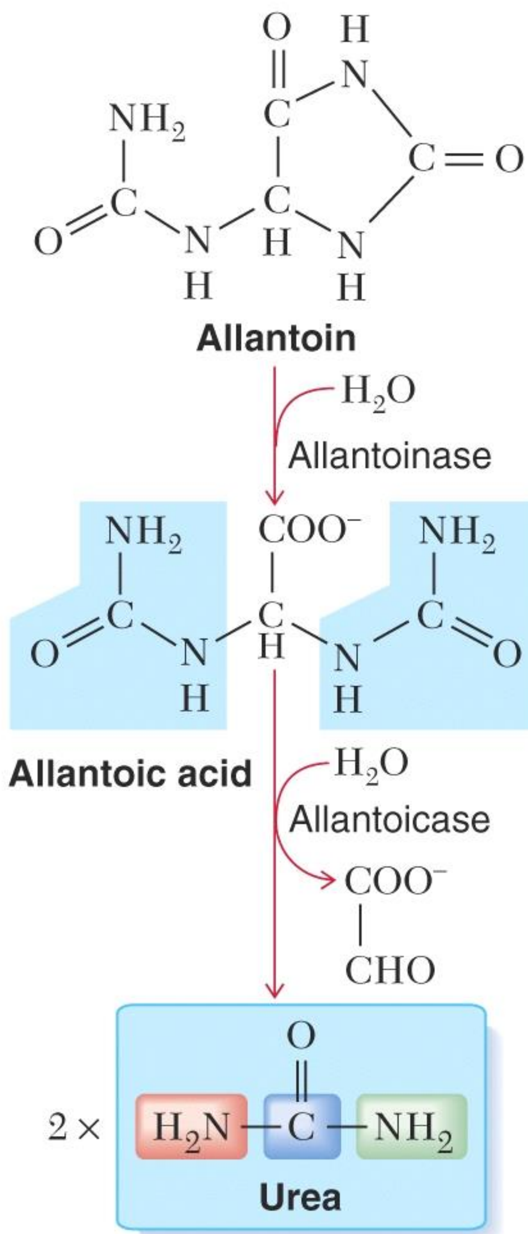
Amino acids
Transaminase
Glycine, Aspartate, Glutamate
(—NH2)
Nucleic acid metabolism
(Purine ring)
Uric acid
½O2 + H2O
Uricase
CO2
Allantoin
H2O
Allantoinase
Allantoic acid
H2O
Allantoicase
COO⁻
CHO
2 ×
Urea

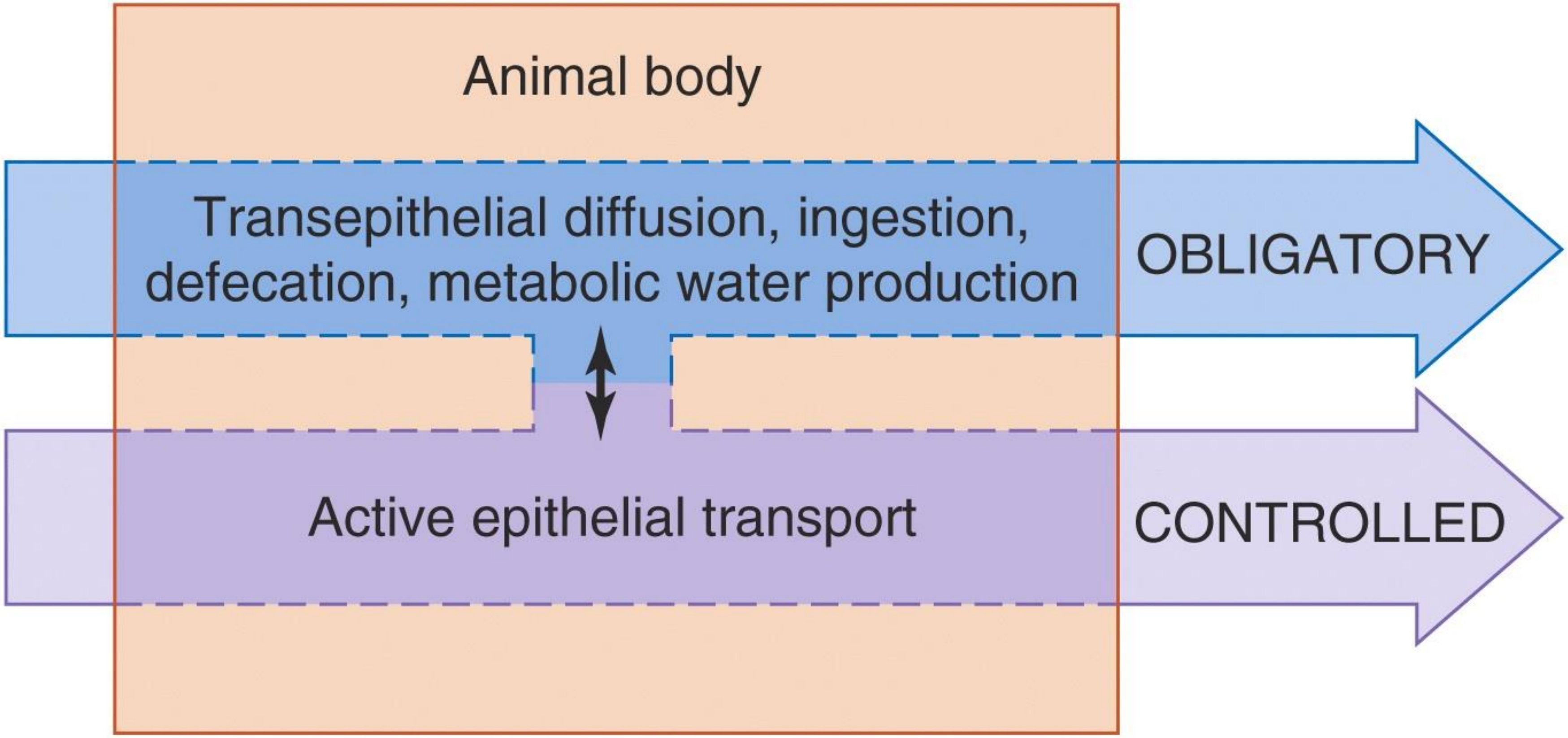

Amino acids
Transaminase
Glycine, Aspartate, Glutamate
(—NH2)
Nucleic acid
metabolism
H
C
N
N
C
HC
HC
C
H
N
N
(Purine ring)


Nucleic acid metabolism
(Purine ring)
Uric acid



OH
N
C
C
N
C
OH
HO
C
N
C
N
H
Uric acid
$\frac{1}{2}O_2 + H_2O$
Uricase
CO_2
O
H
N
C
NH$_2$
C
O
O
C
N
C
H
N
H
H
Allantoin


Allantoin
H_2O
Allantoinase
Allantoic acid
H_2O
Allantoicase
COO^-
CHO
2 ×
Urea



Animal body
Transepithelial diffusion, ingestion, defecation, metabolic water production
OBLIGATORY
Active epithelial transport
CONTROLLED