Demystifying Kidney Function

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Agenda

- Review of key biological concepts
- Kidney Gross Anatomy
- Basic Kidney Physiology
- The Nephron
- Renal function – Filtrate and Reabsorption
- Glucose Example
- Intro to Diuretics
- Case Study

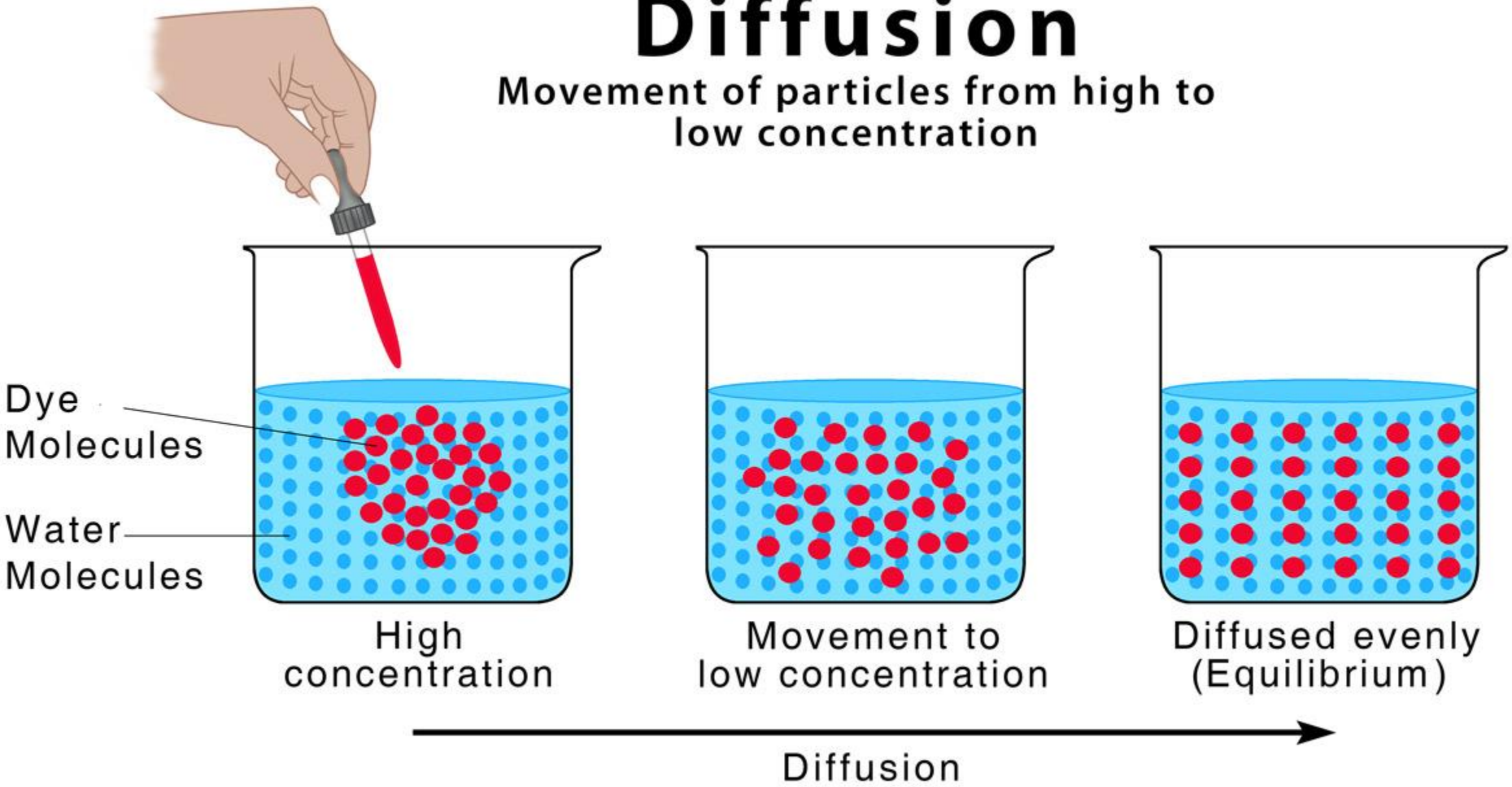
Review of Key Biological Concepts

Diffusion



Diffusion

Movement of particles from high to low concentration



ScienceFacts.net

Review of Key Biological Concepts

Diffusion

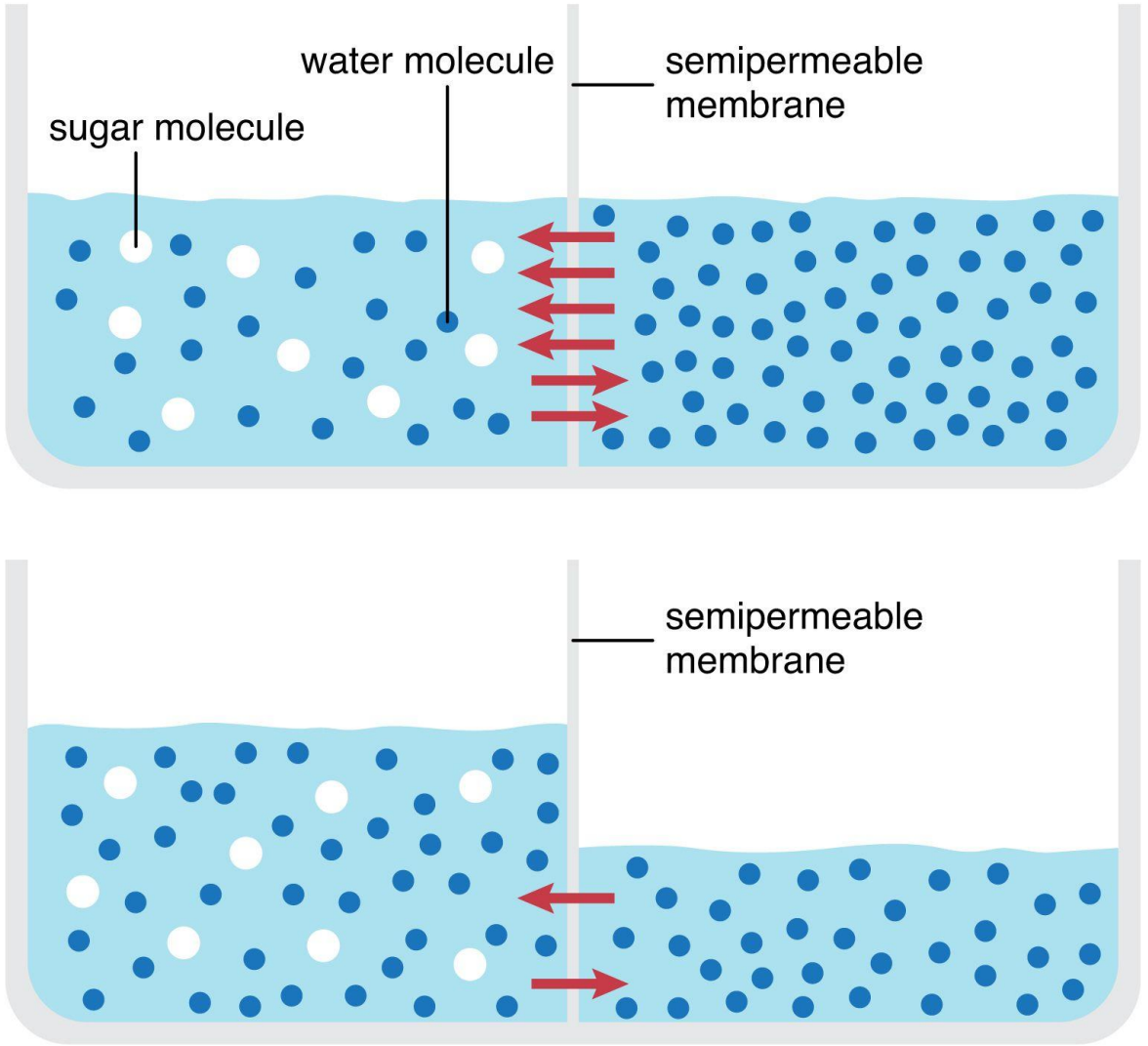
Distribution of the particle in a solution



Review of Key Biological Concepts

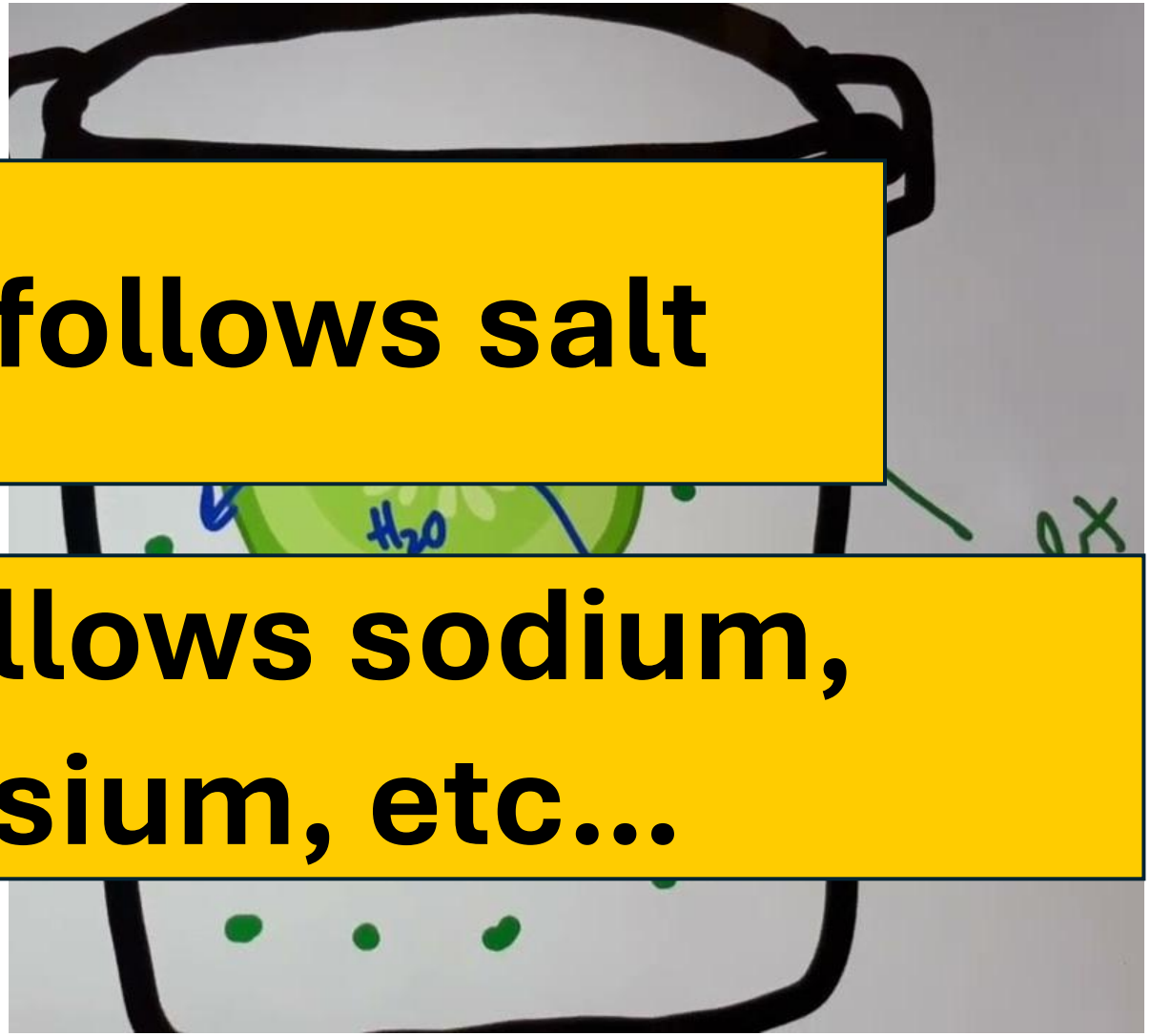
Osmosis

Water tries to dilute the particle across a membrane



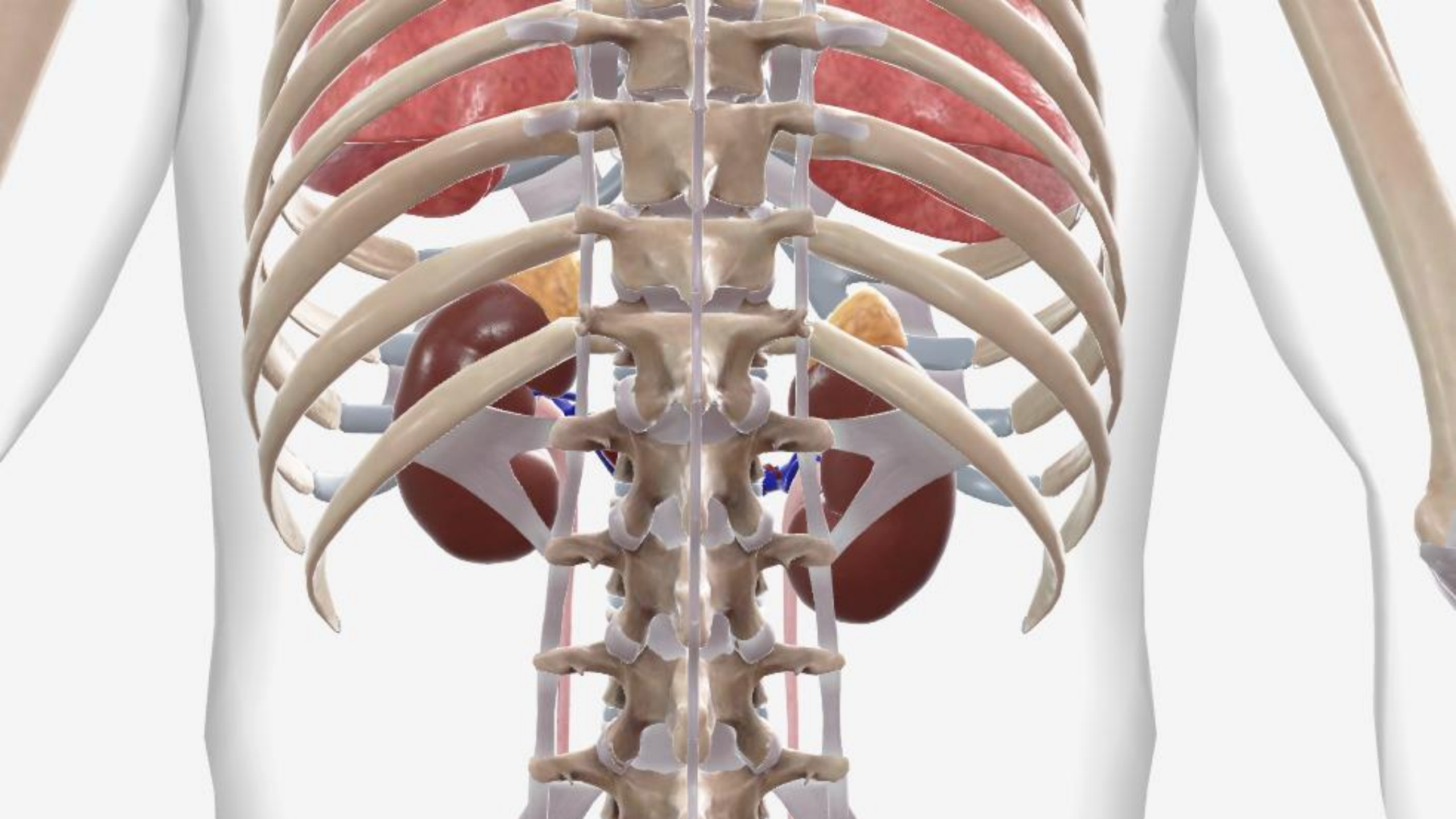
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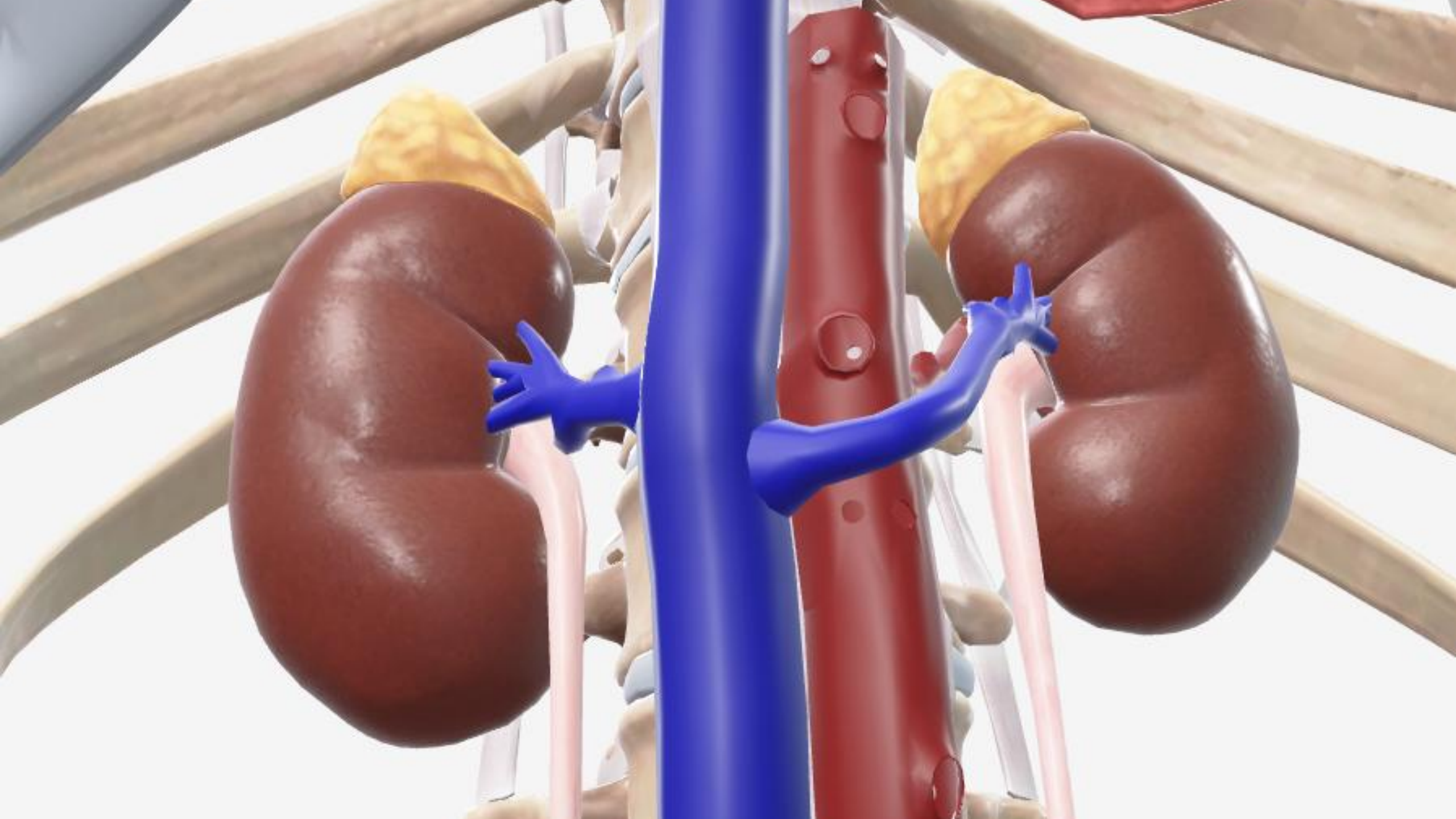


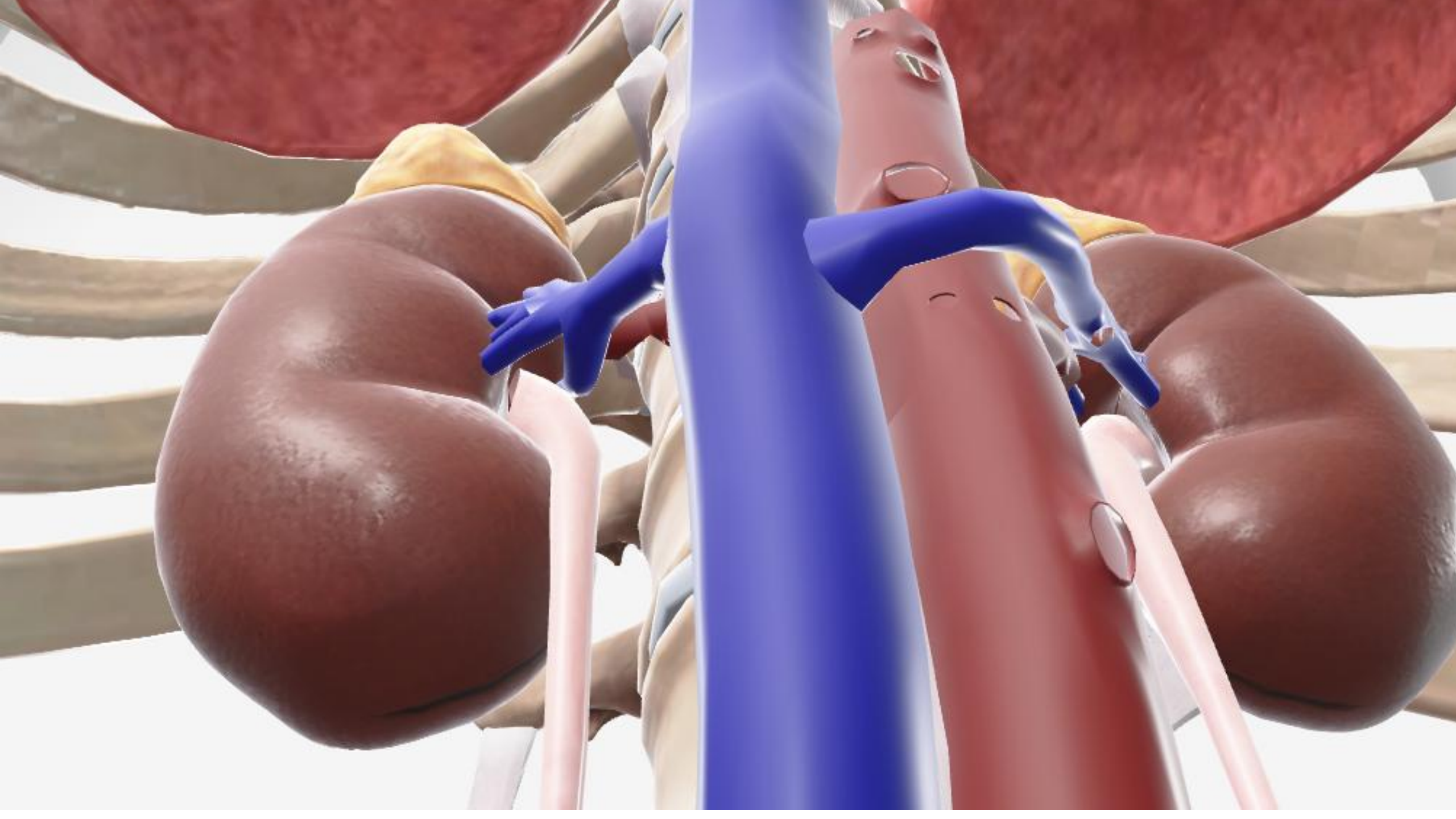


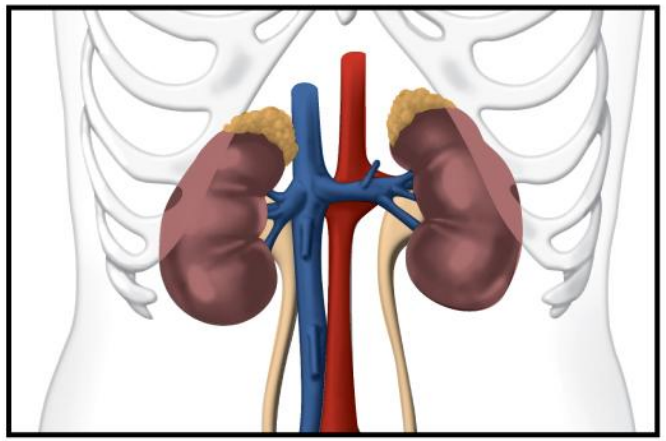
Water follows salt

Water follows sodium, potassium, etc…









Cortical blood vessels

Interlobar blood vessels

Renal vein

Renal nerve

Renal hilum

Arcuate blood vessels

Minor calyx

Major calyx

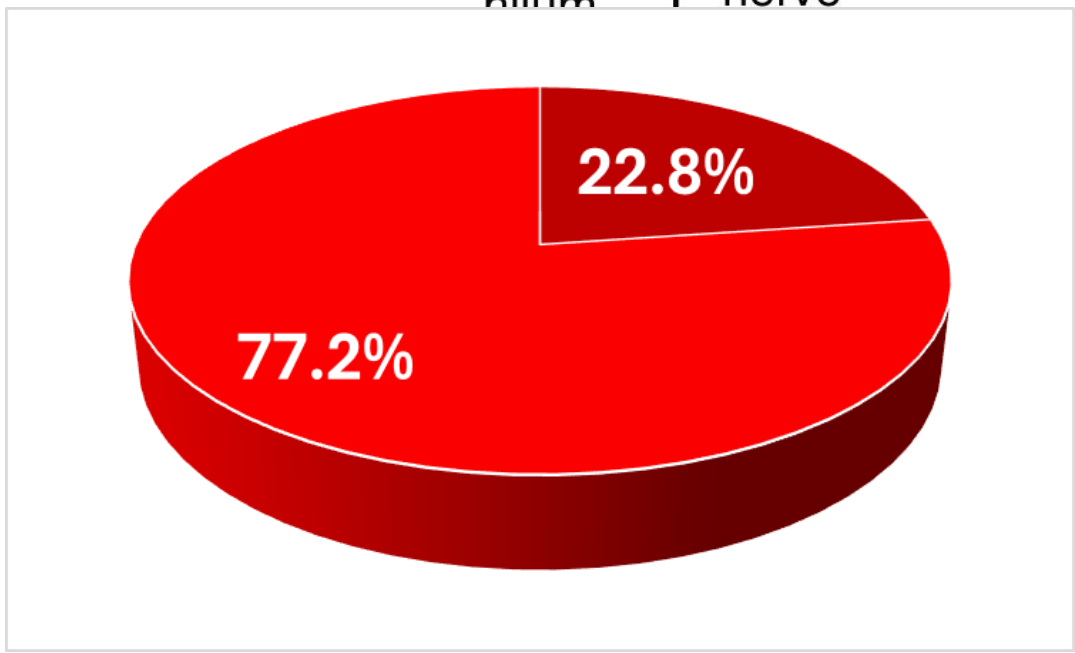
Renal pelvis

Pyramid

Papilla

Renal column

Cortex



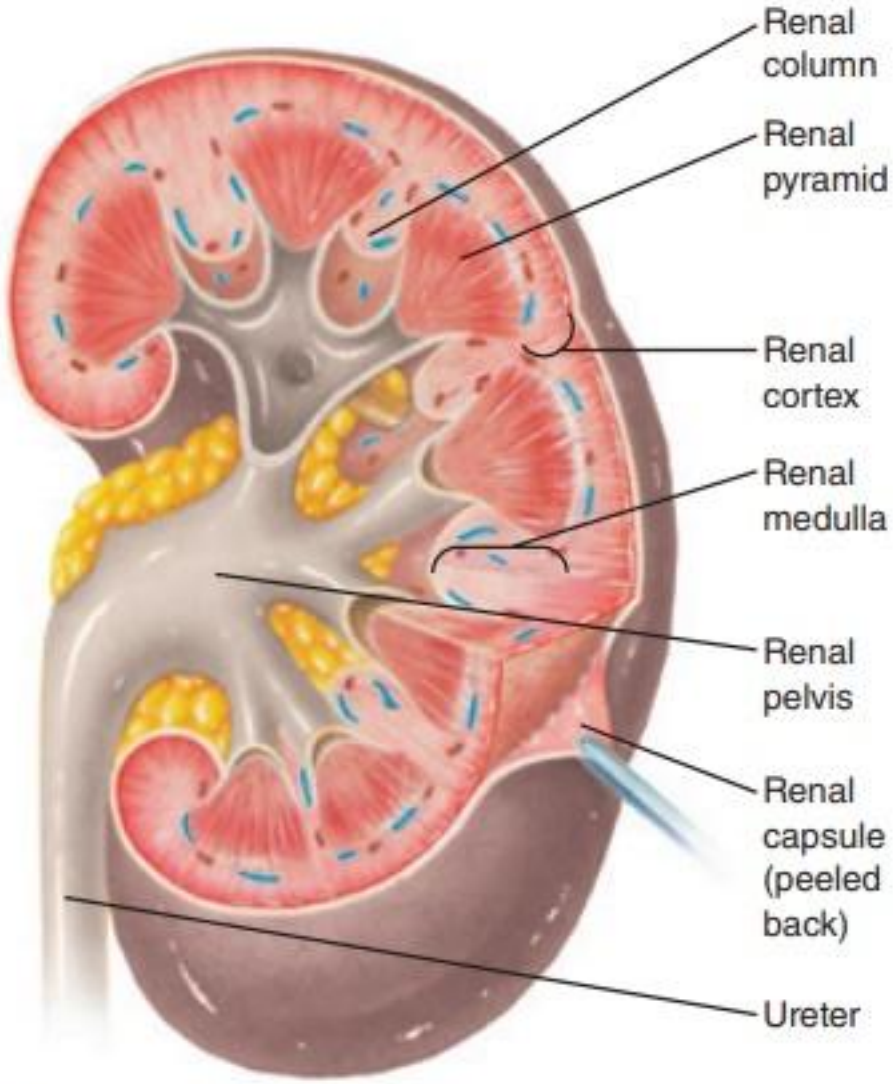


FIGURE 22-2 Gross anatomy of the kidney.

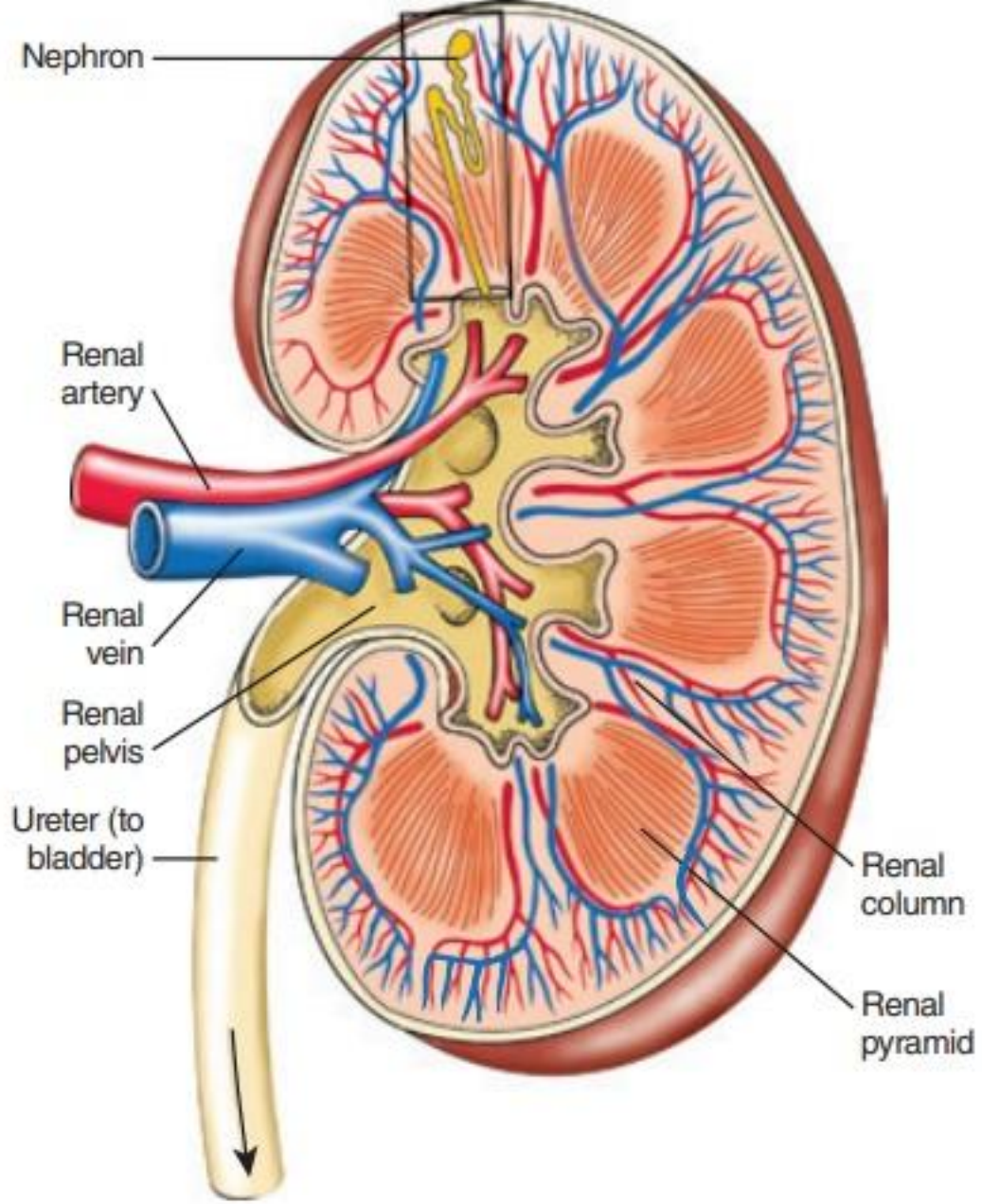


FIGURE 22-3 Kidney structures, showing renal artery and its branches.

Nephron

Overview of Functions

Vascular component

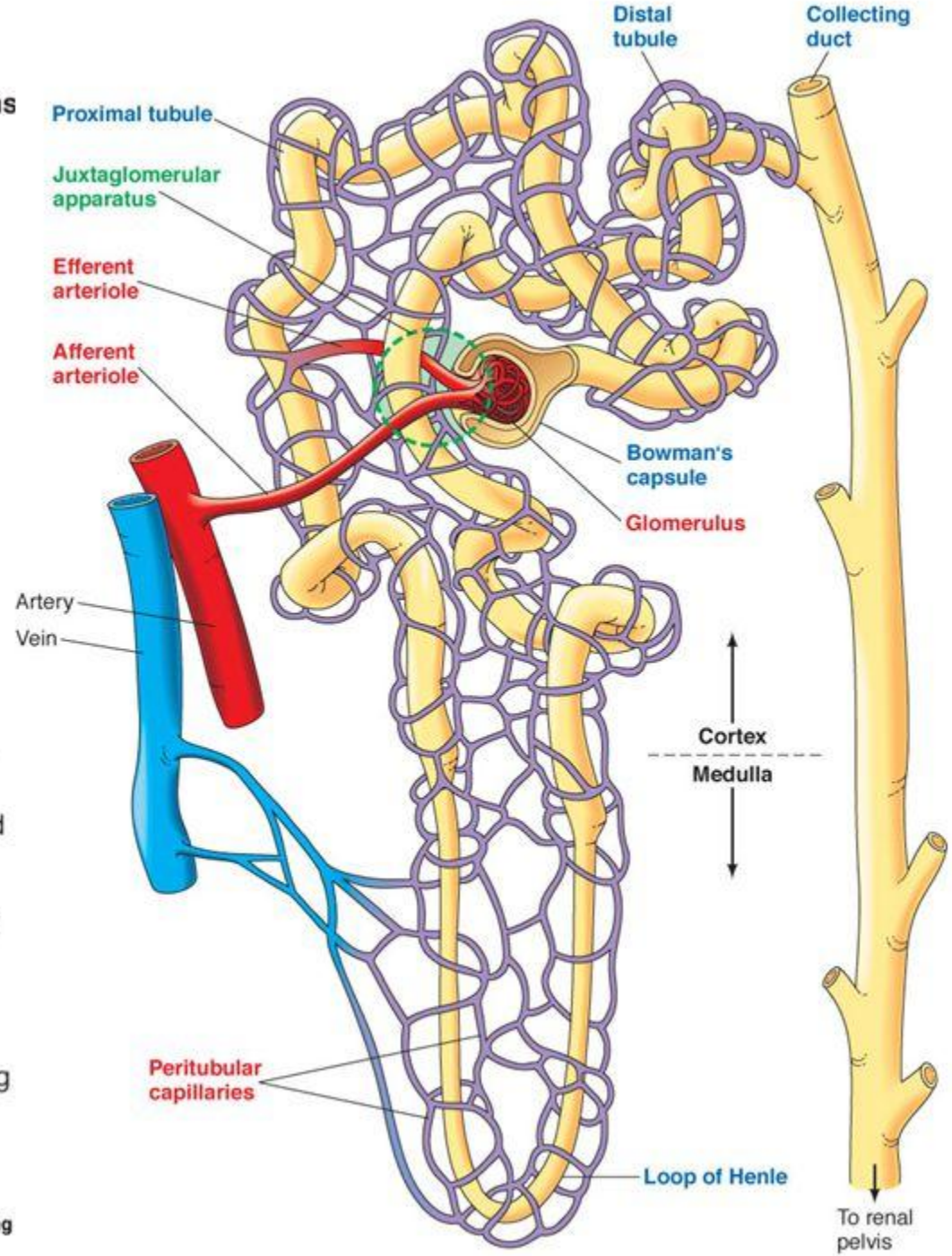
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Combined vascular/tubular component

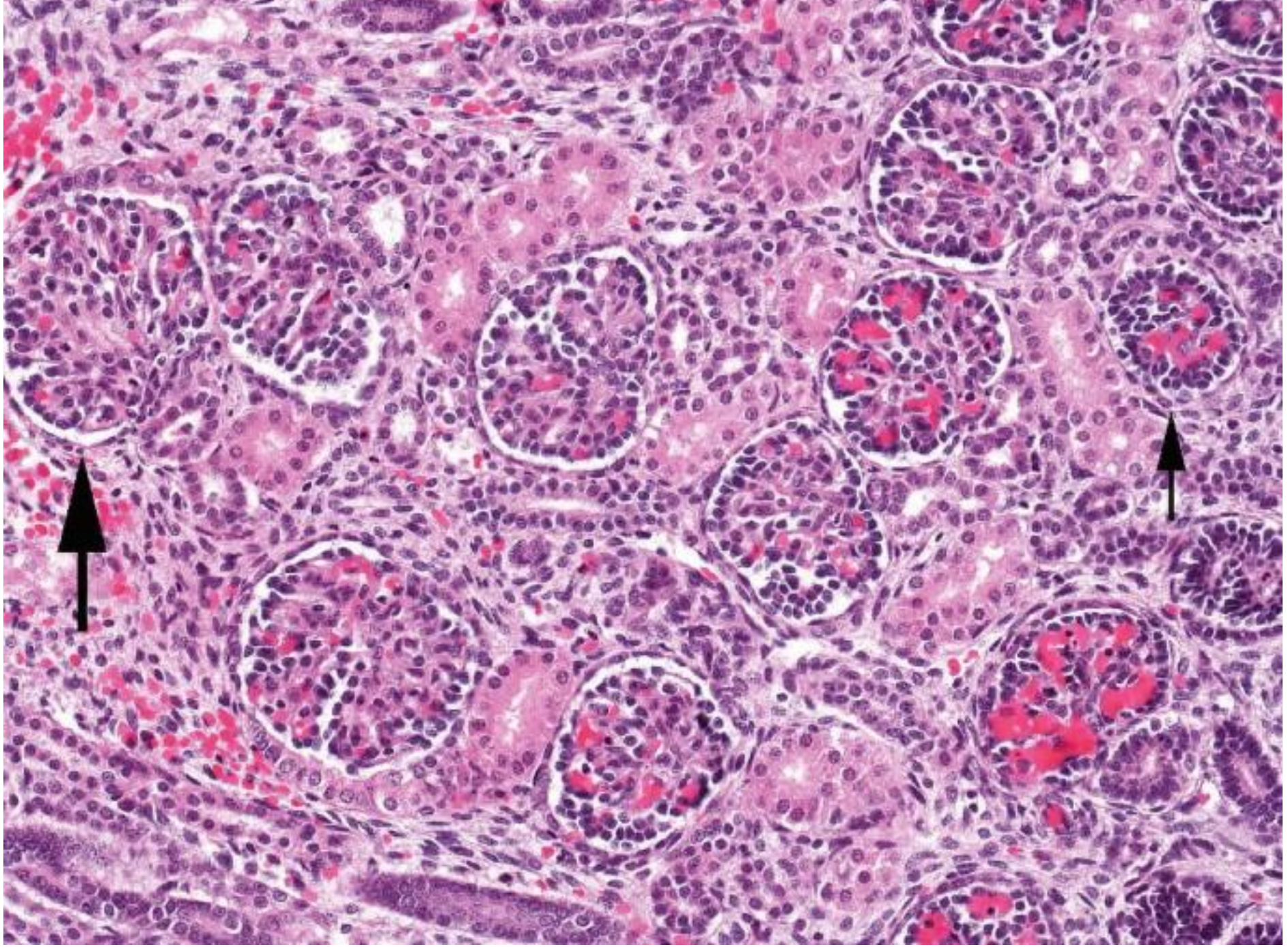
- Juxtaglomerular apparatus—produces substances involved in the control of kidney function

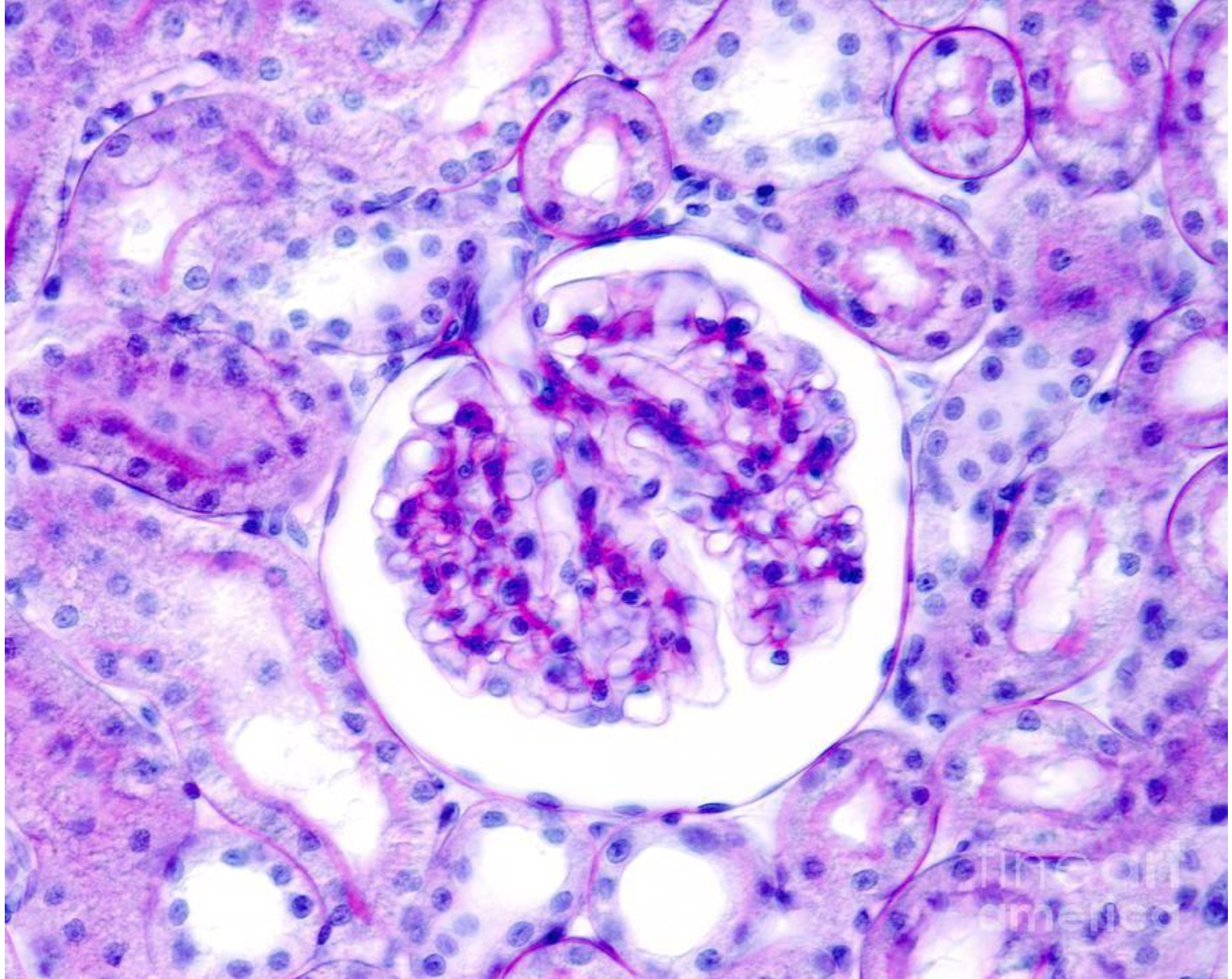
Tubular component

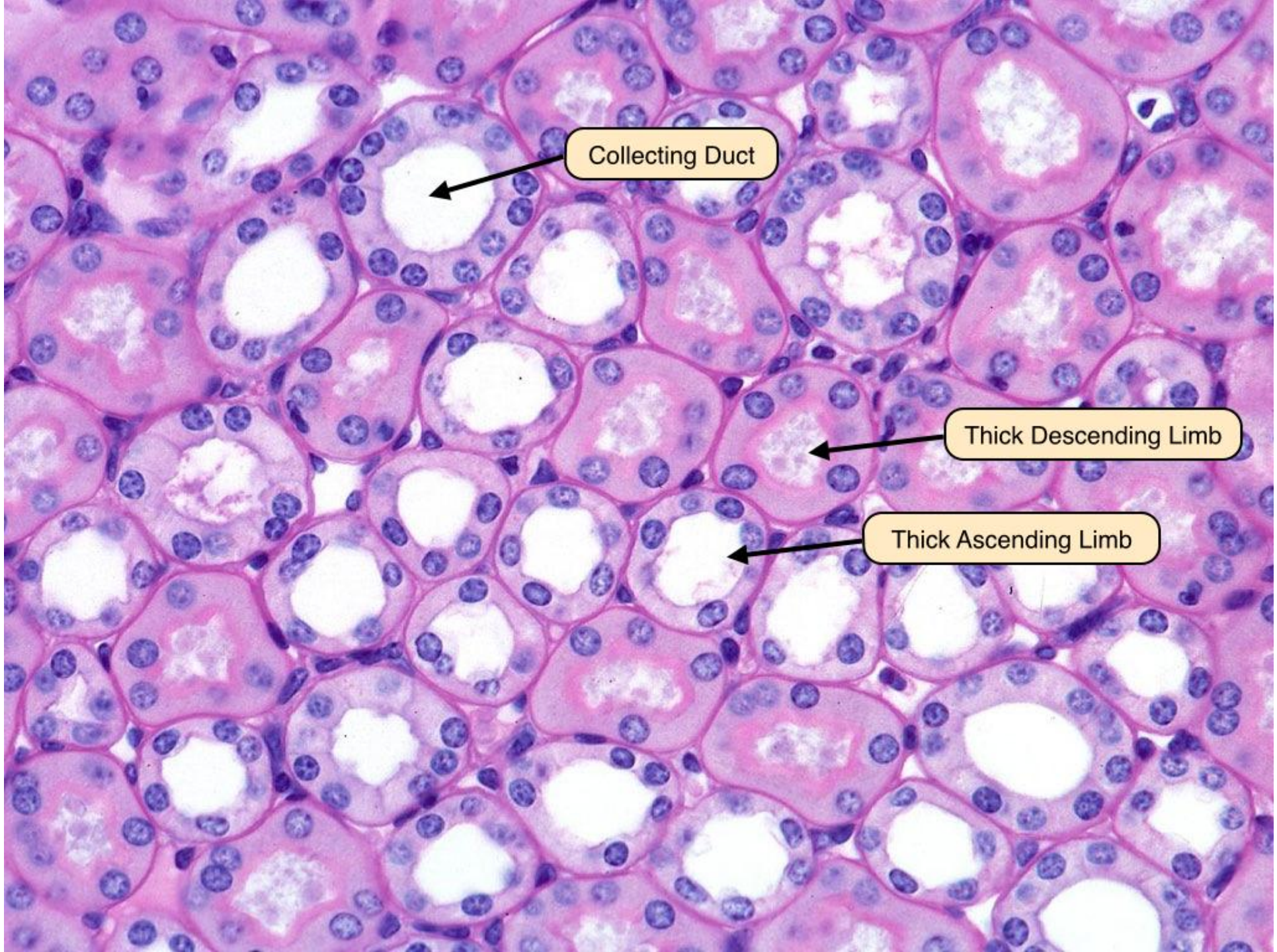
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- Distal tubule and collecting duct—variable, controlled reabsorption of Na^+ and H_2O and secretion of K^+ and H^+ occur here; fluid leaving the collecting duct is urine, which enters the renal pelvis

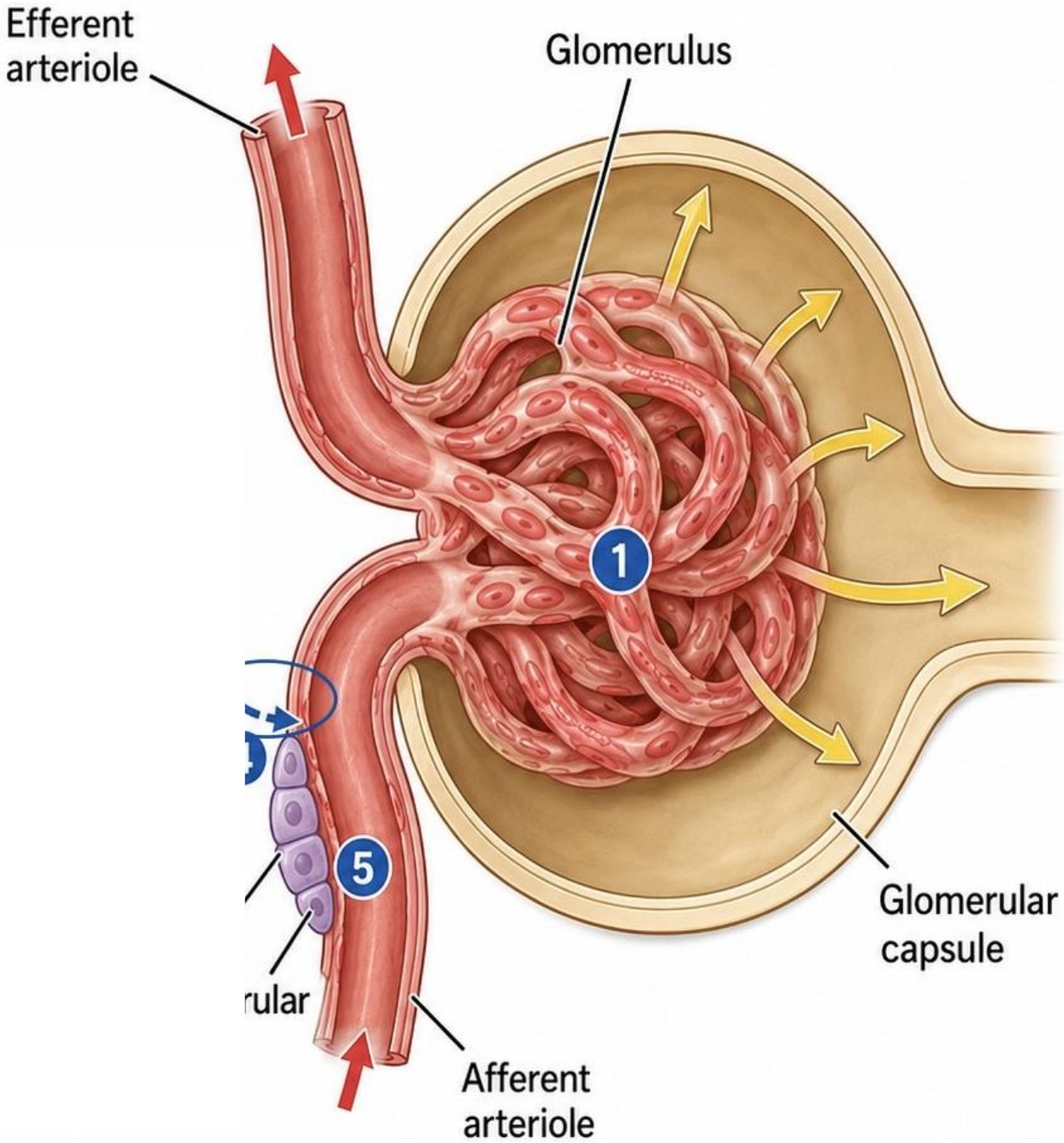


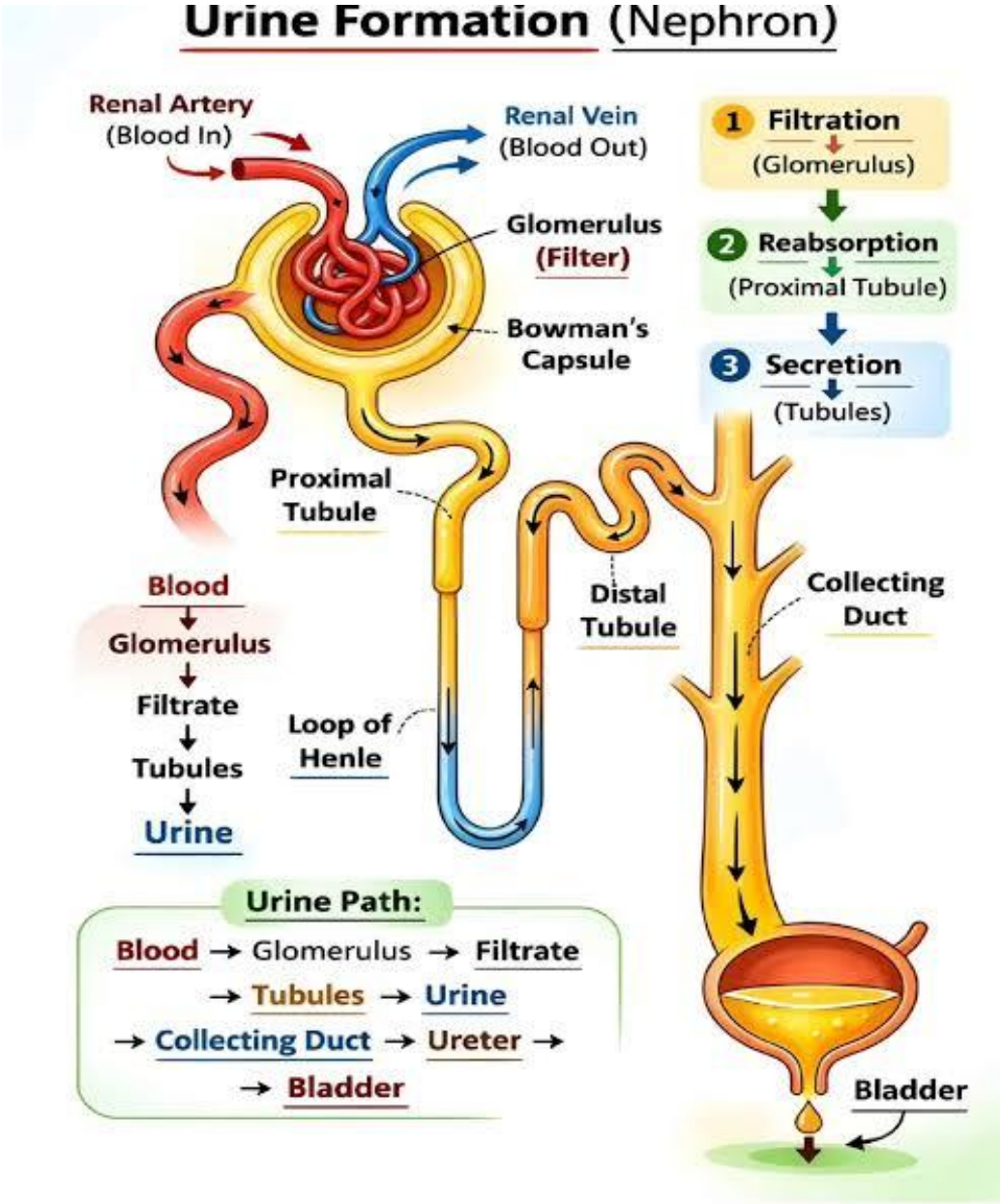
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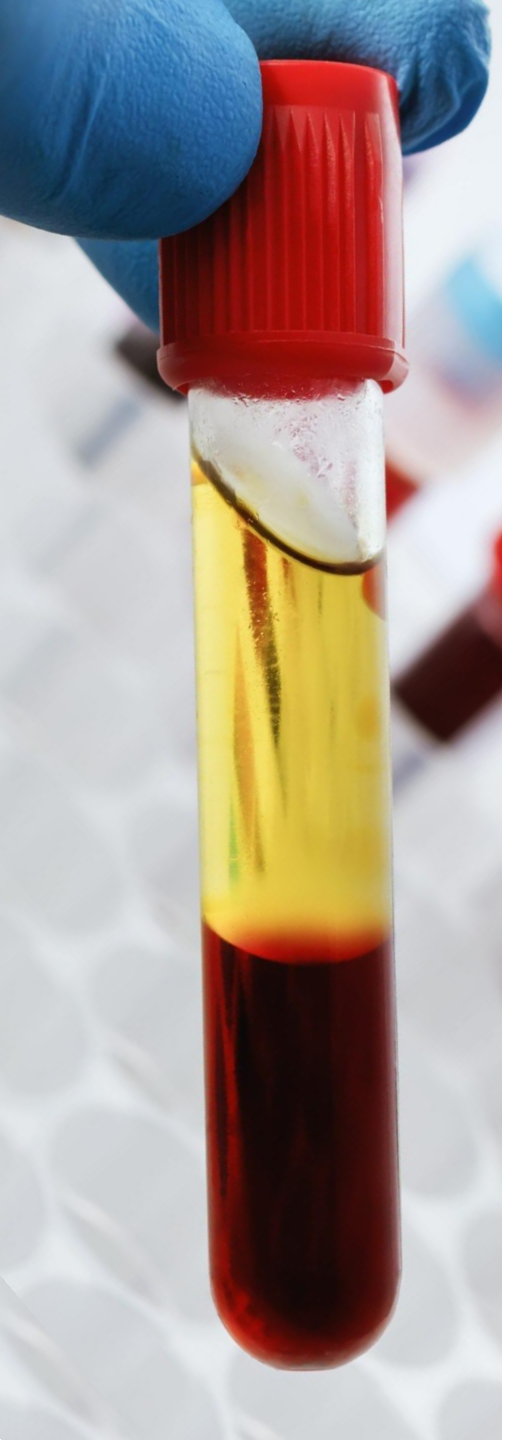


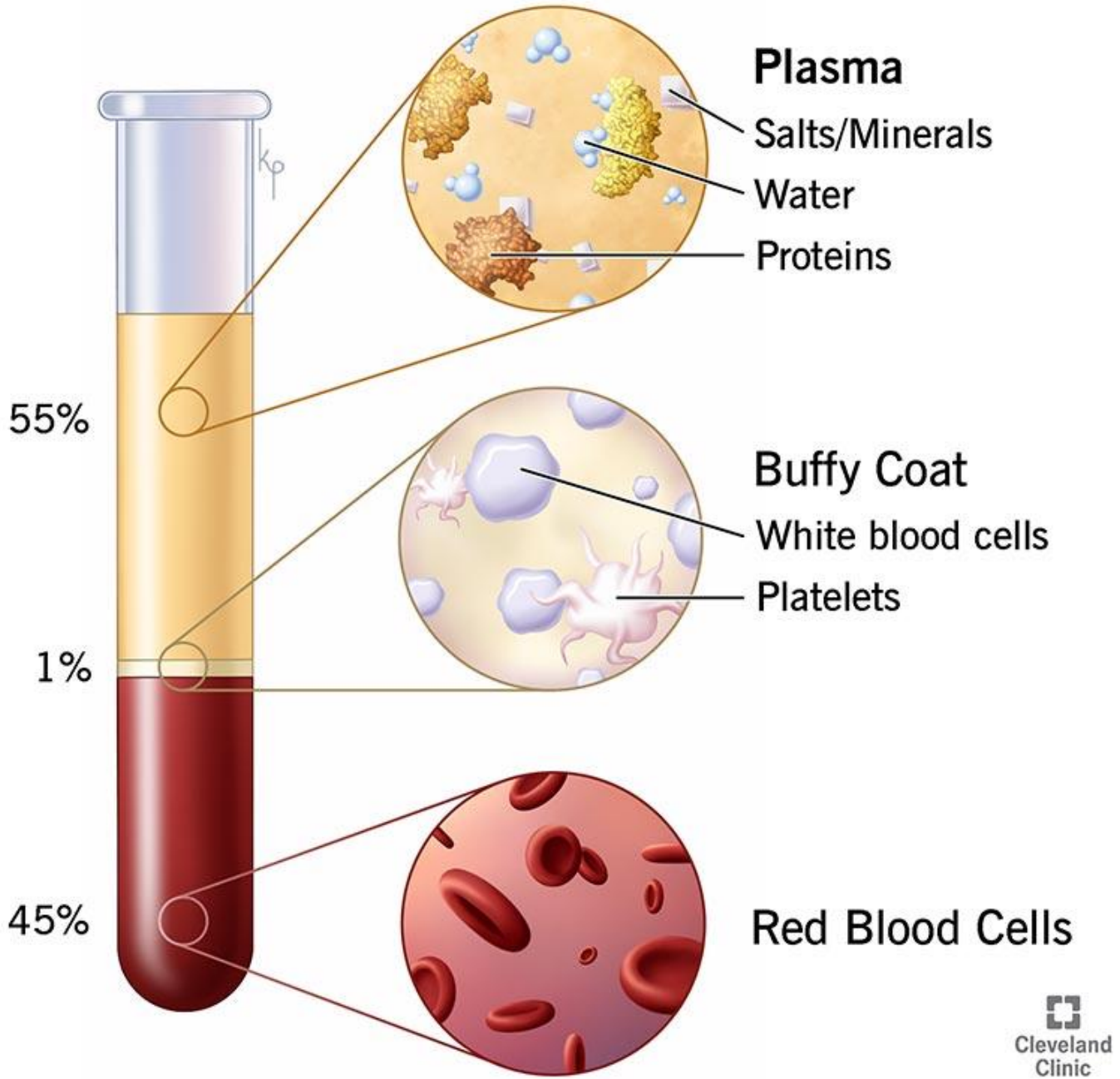



Collecting Duct
Thick Descending Limb
Thick Ascending Limb

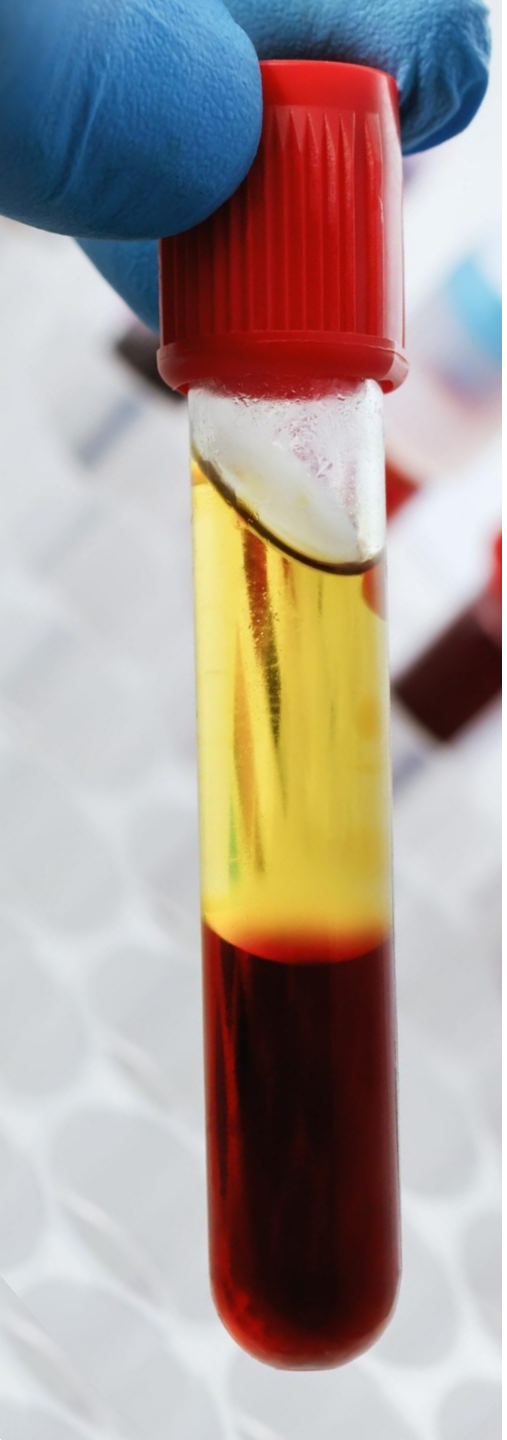

Efferent arteriole
Glomerulus
1
5
rular
Glomerular capsule
Afferent arteriole

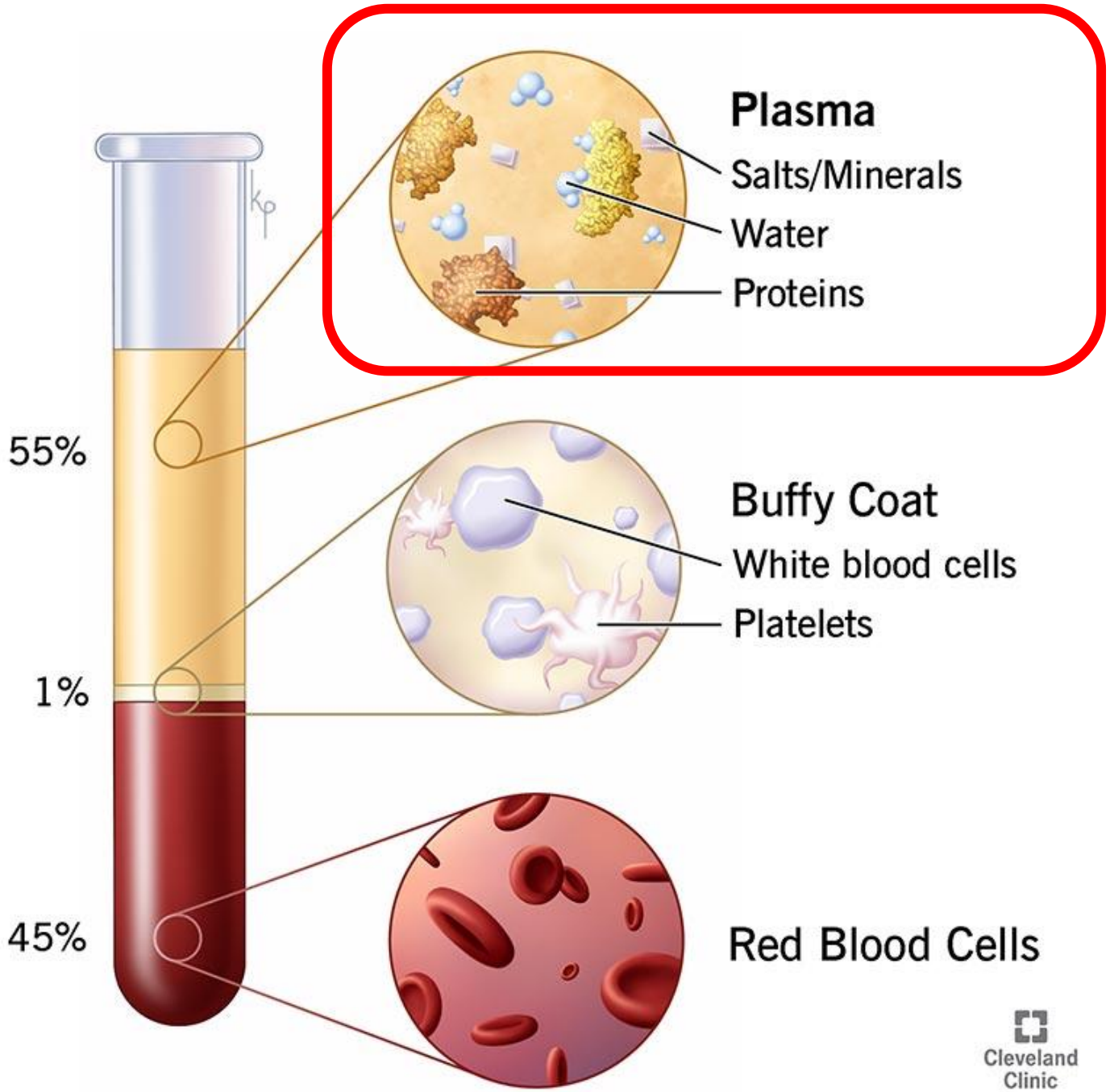

Urine Formation (Nephron)
Renal Artery (Blood In)
Renal Vein (Blood Out)
Glomerulus (Filter)
Bowman's Capsule
1 Filtration (Glomerulus)
2 Reabsorption (Proximal Tubule)
3 Secretion (Tubules)
Proximal Tubule
Distal Tubule
Collecting Duct
Loop of Henle
Blood
Glomerulus
Filtrate
Tubules
Urine
Urine Path:
Blood → Glomerulus → Filtrate → Tubules → Urine → Collecting Duct → Ureter → Bladder
Bladder

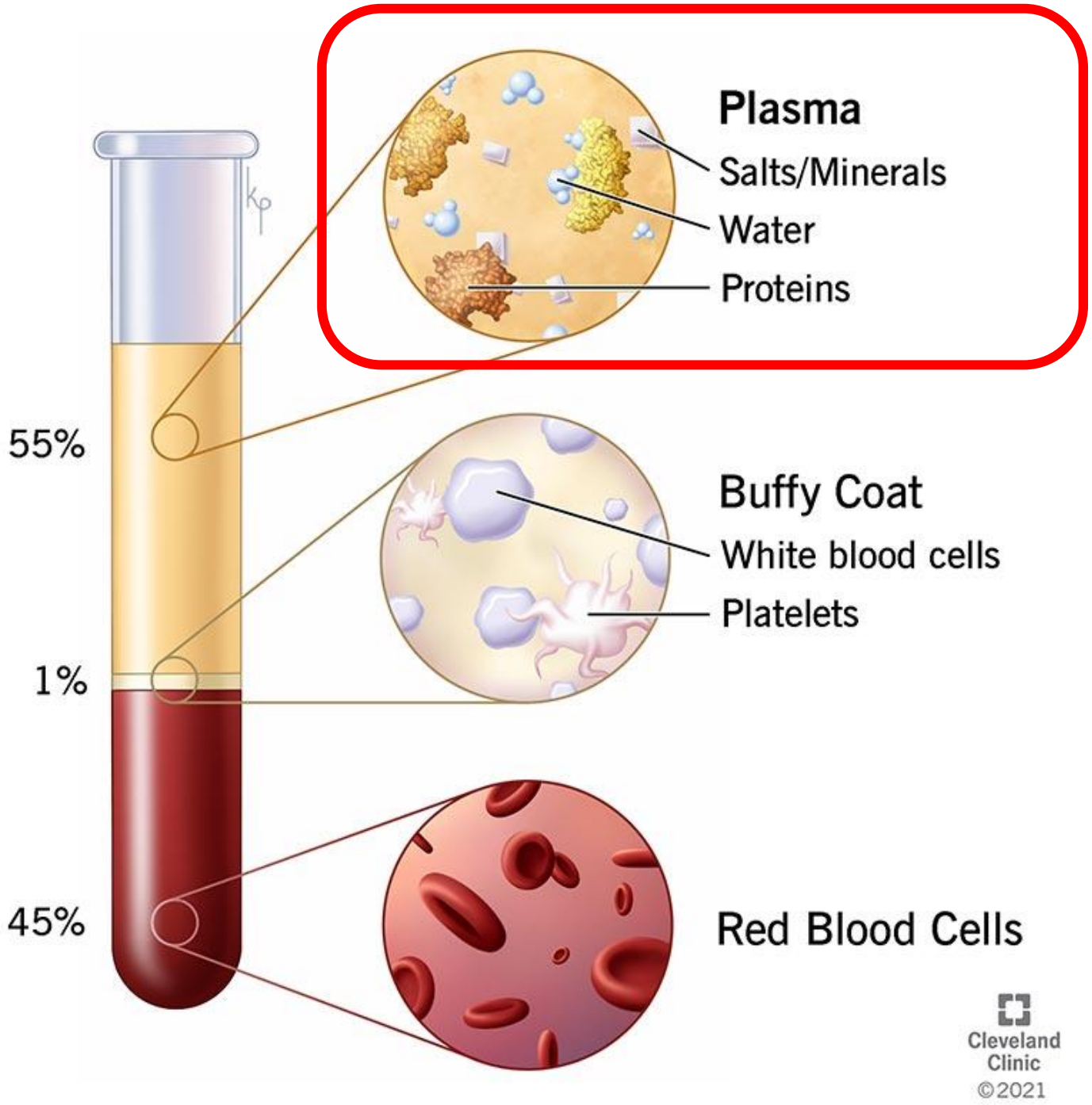


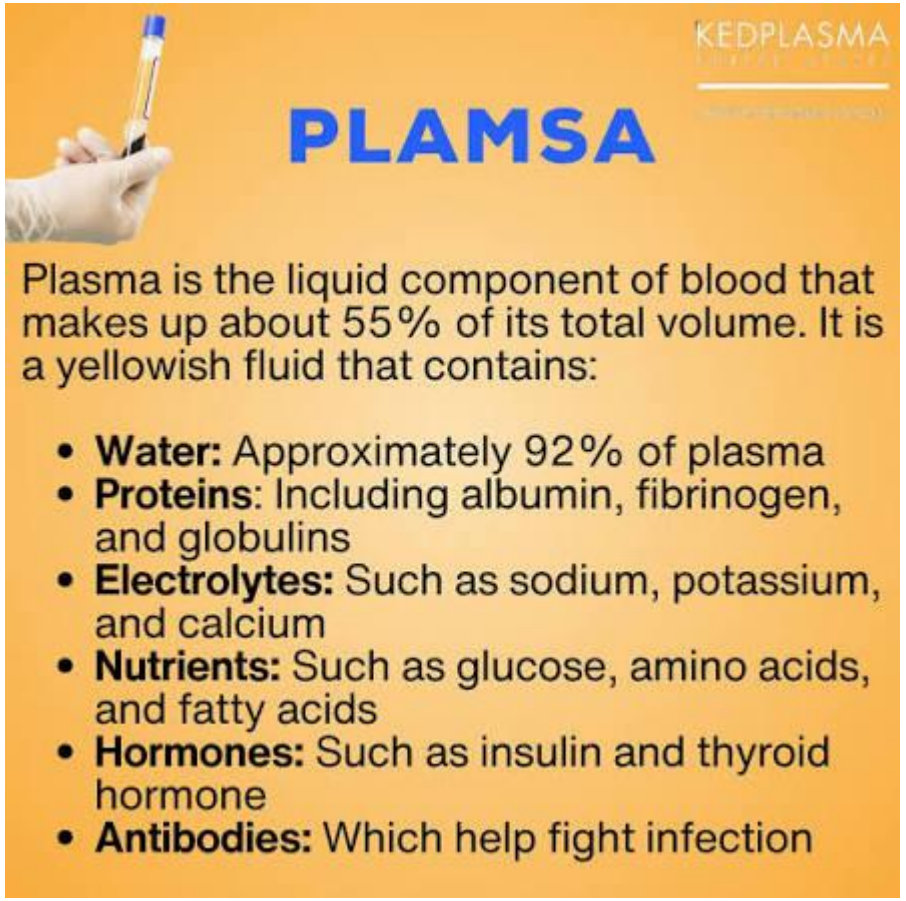


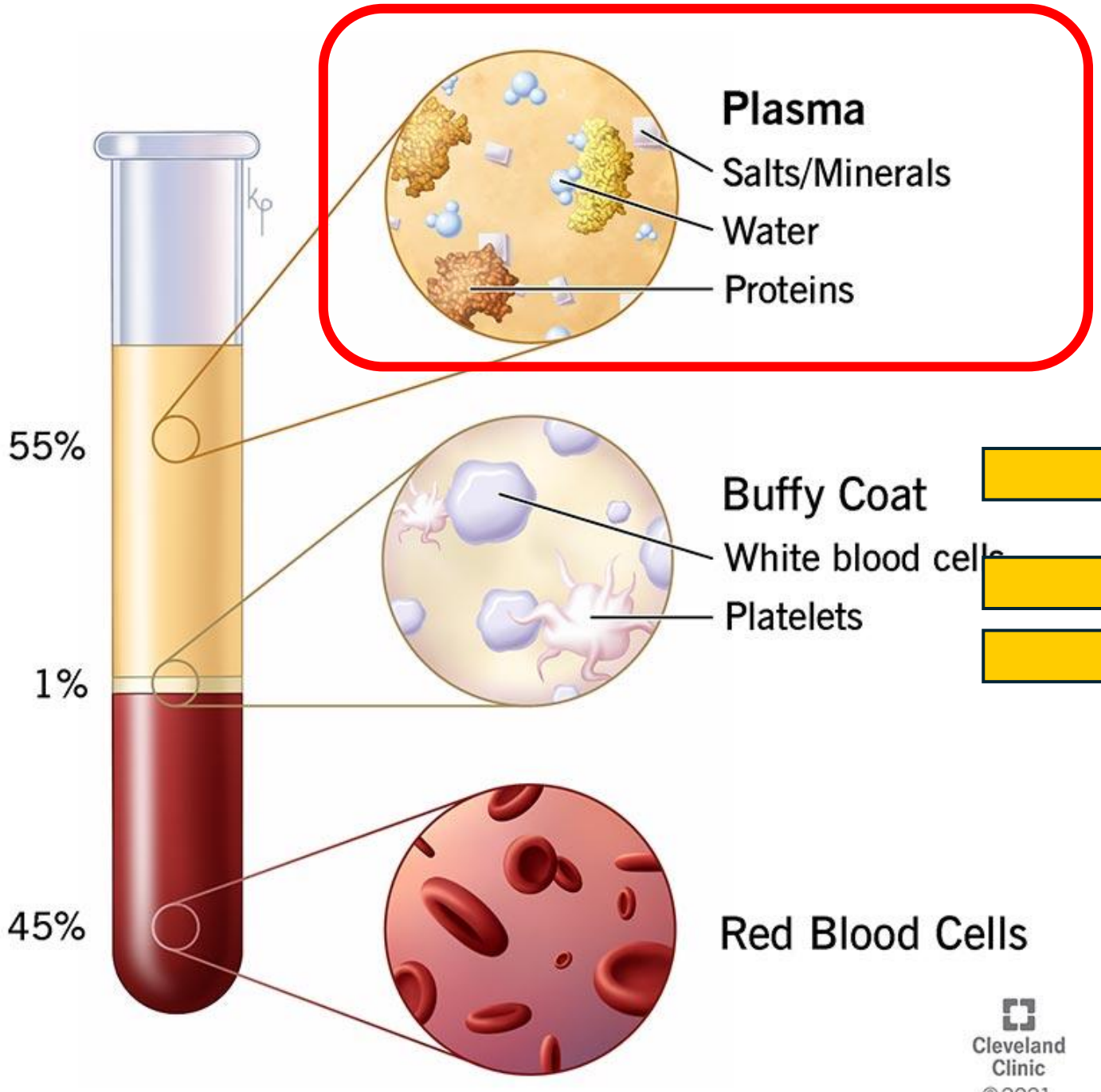
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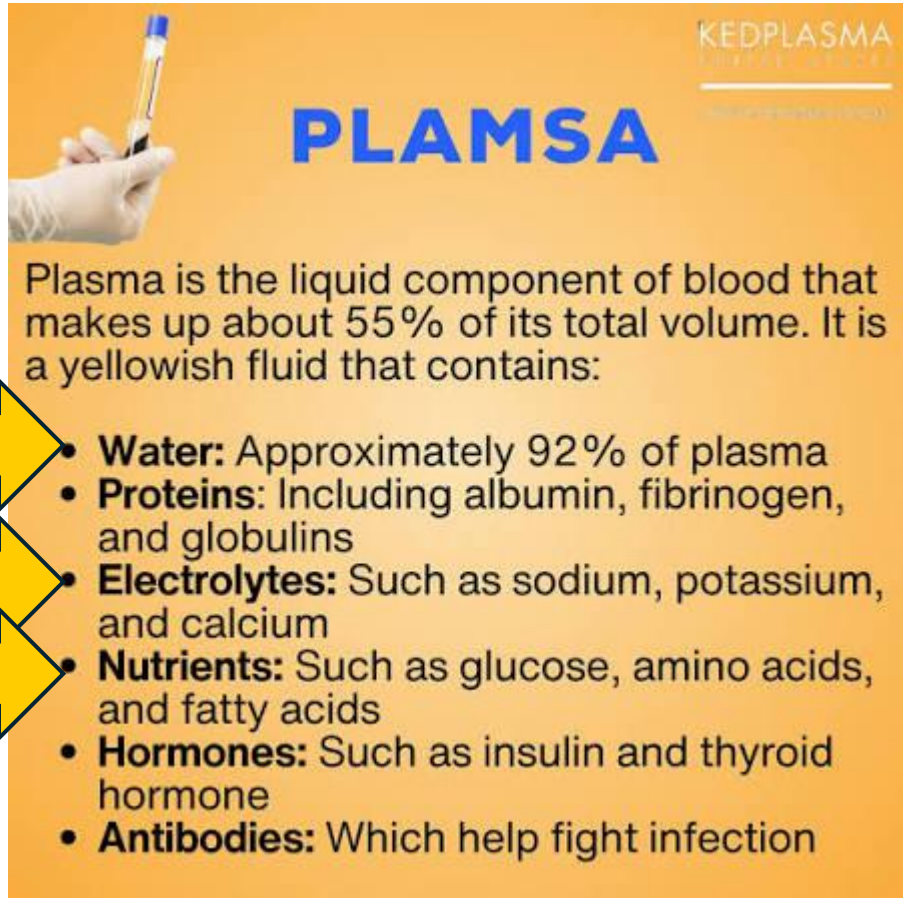



Plasma
Salts/Minerals
Water
Proteins
55%
Buffy Coat
White blood cells
Platelets
1%
45%
Red Blood Cells
Cleveland Clinic
©2021


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KEDPLASMA
PLAMSA
Plasma is the liquid component of blood that makes up about 55% of its total volume. It is a yellowish fluid that contains:
• **Water:** Approximately 92% of plasma
• **Proteins**: Including albumin, fibrinogen, and globulins
• **Electrolytes:** Such as sodium, potassium, and calcium
• **Nutrients:** Such as glucose, amino acids, and fatty acids
• **Hormones:** Such as insulin and thyroid hormone
• **Antibodies:** Which help fight infection


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Nephron

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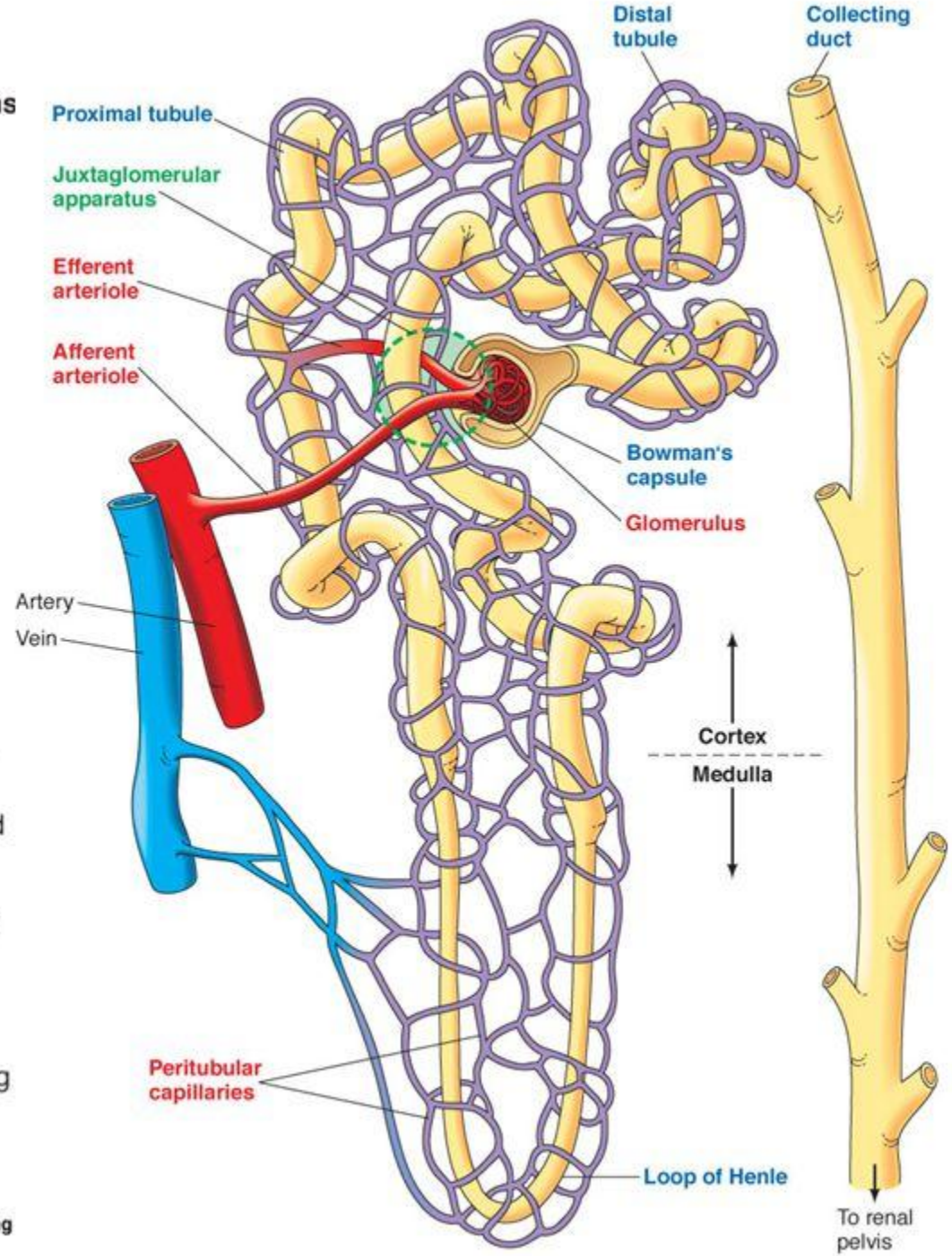
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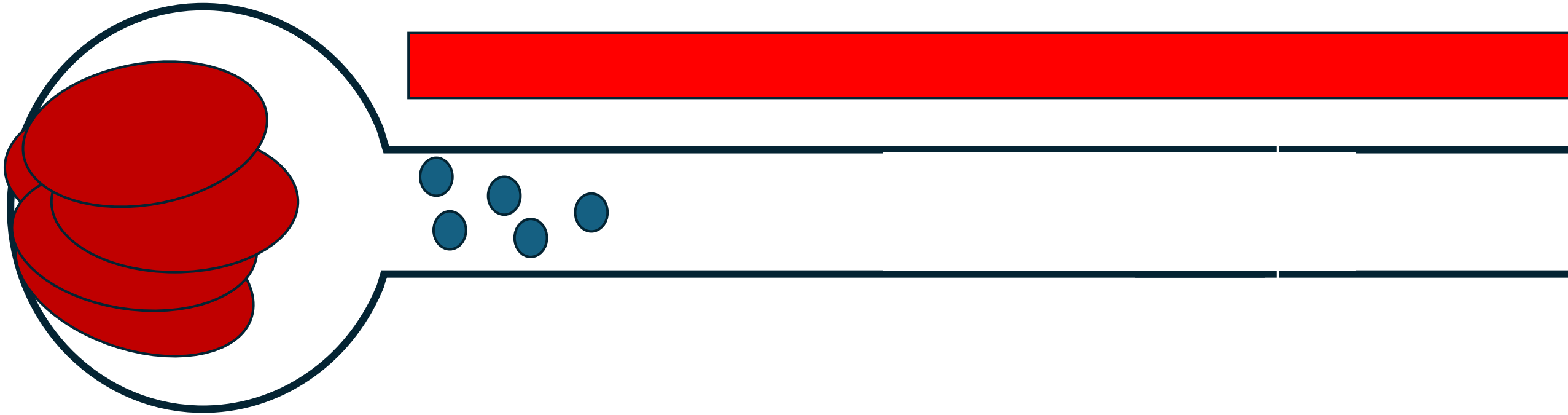
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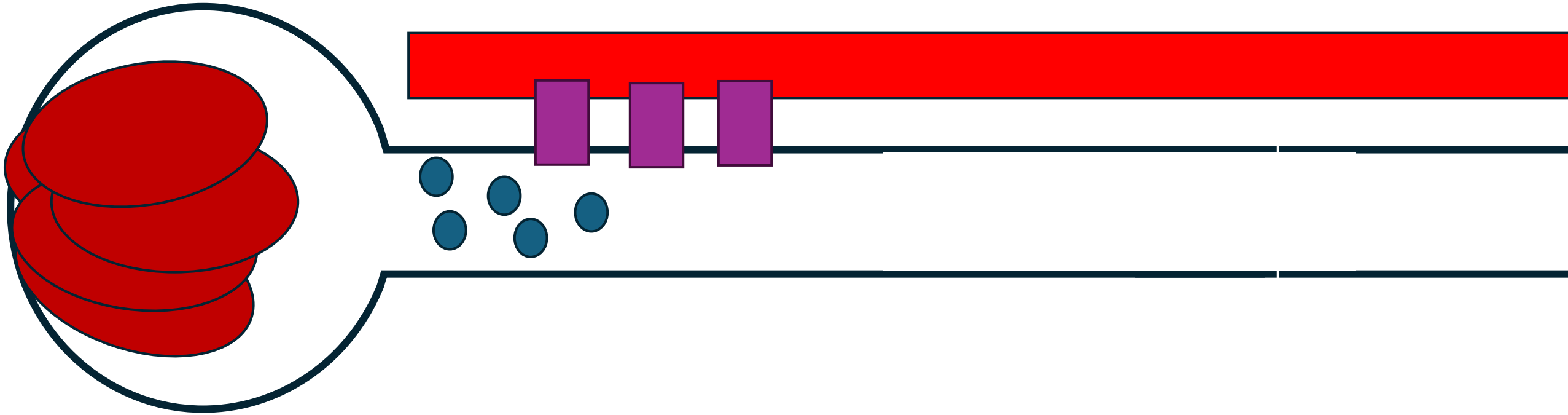
Reabsorption

Particles need _____ to transport cross the membrane back into the blood.



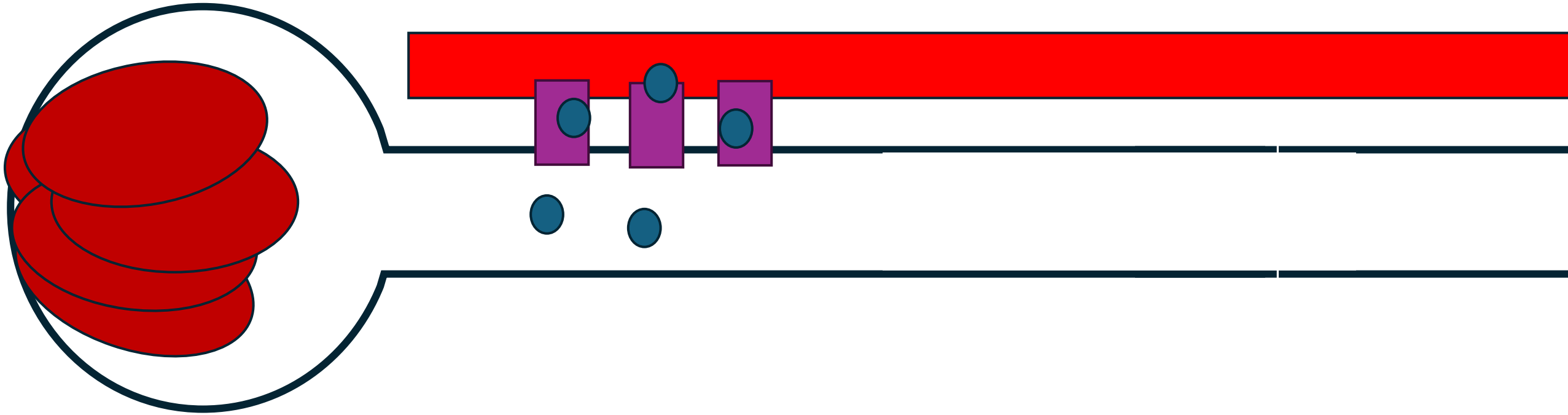
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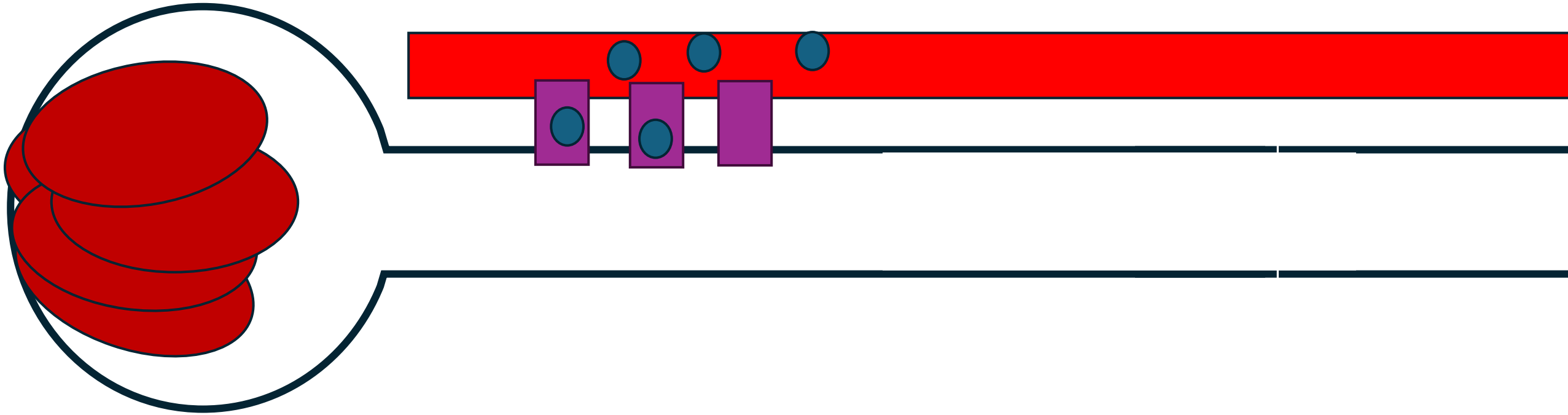
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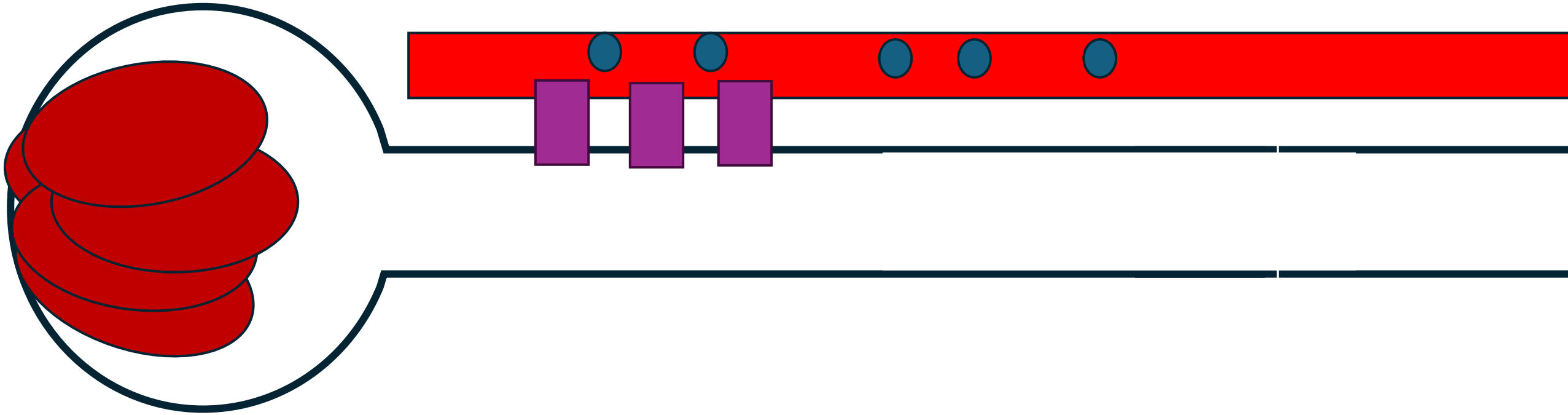
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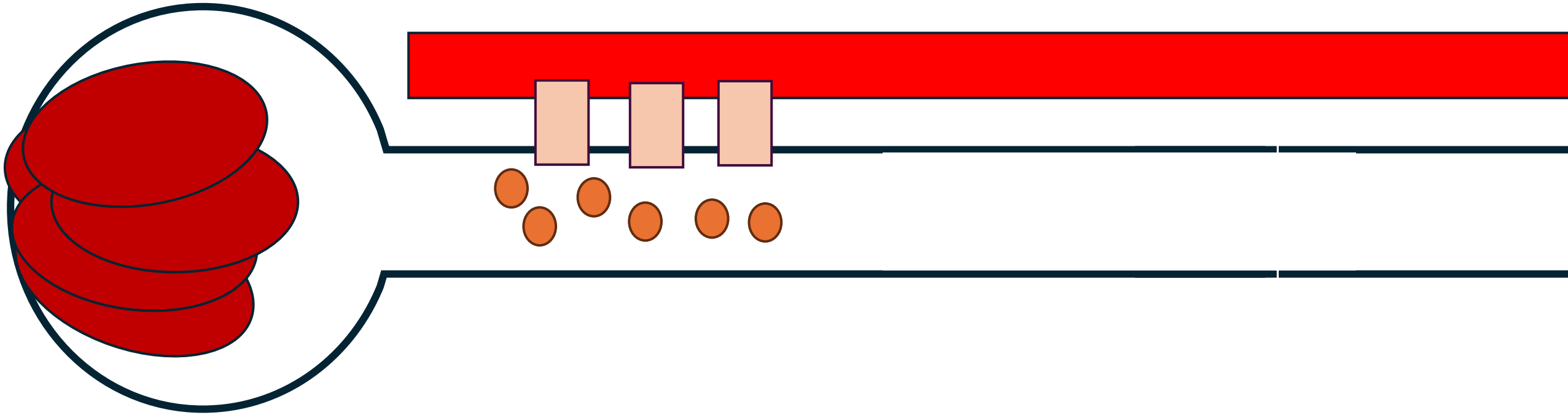


Reabsorption

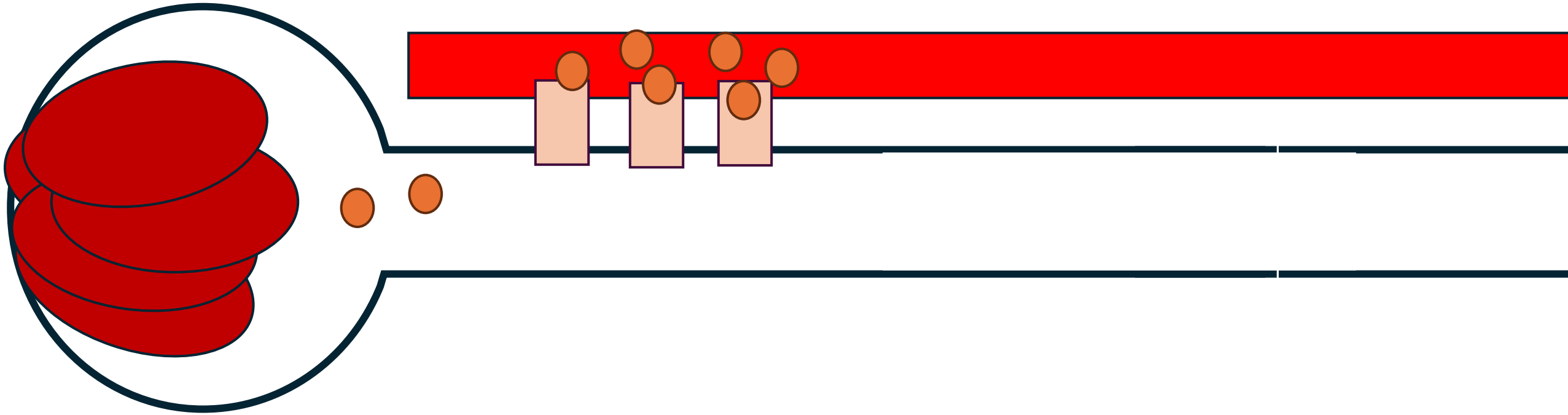
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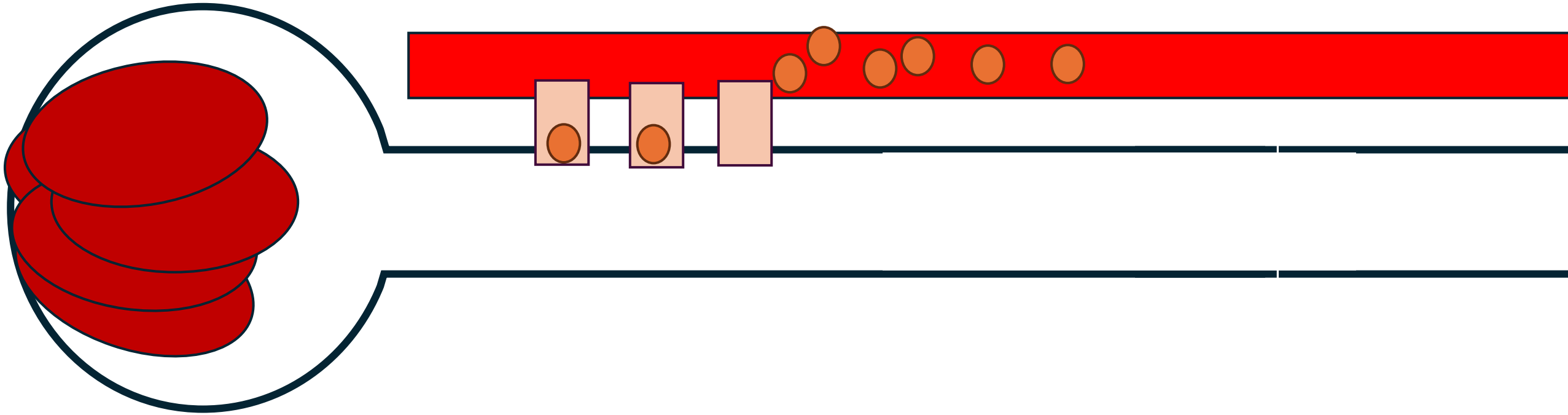
Glucose...



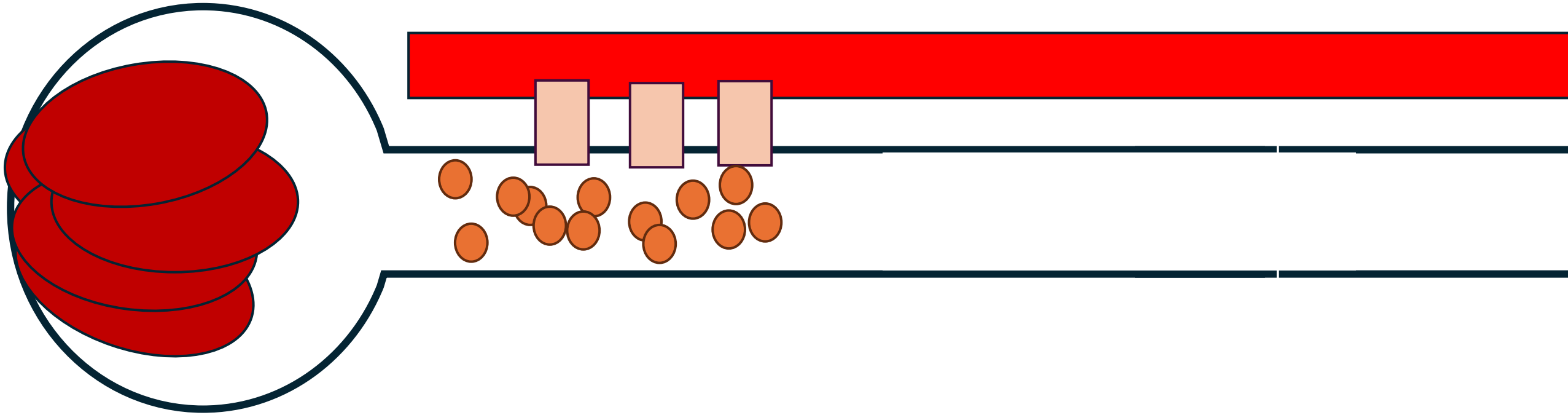
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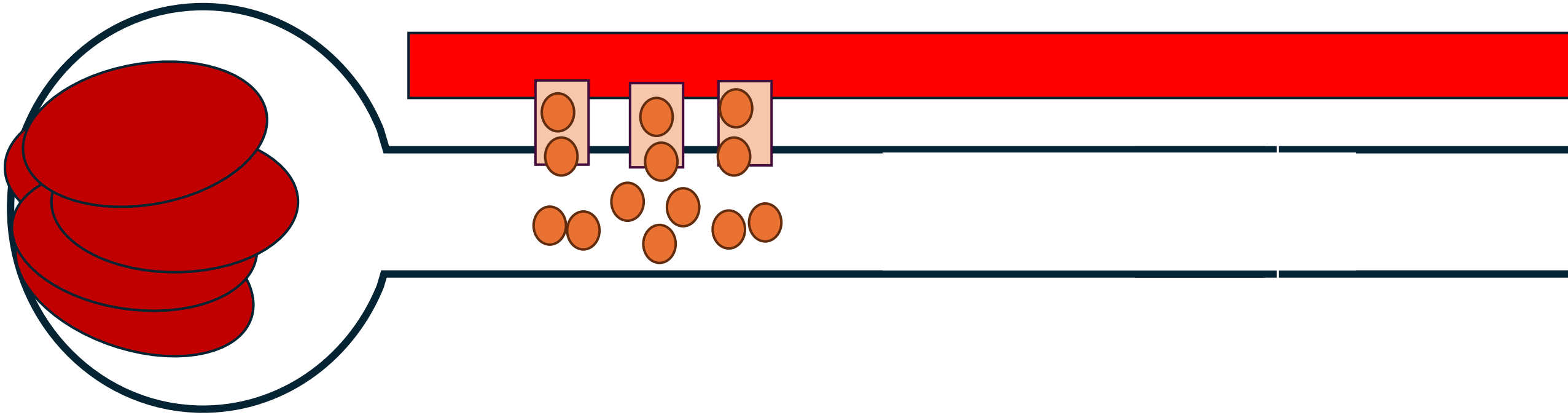
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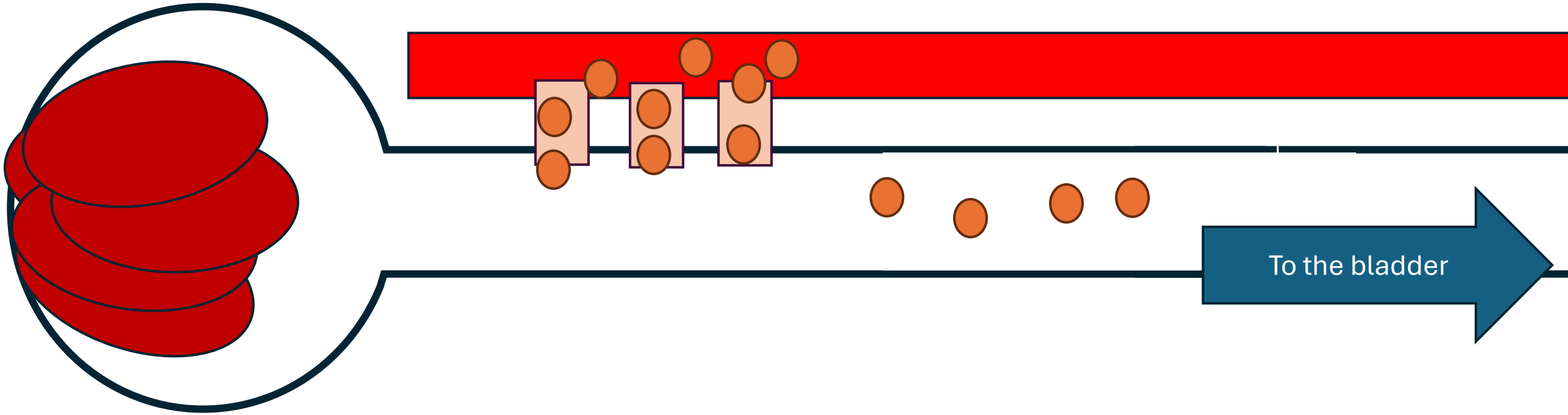
Glucose...



Glucose...



Glucose...



Diuretics

BUMEX | bumetanide

Loop diuretic

Oral bioavailability: ~80–90%

Approx. oral equivalent: 1 mg

Approx. IV equivalent: 1 mg

LASIX | furosemide

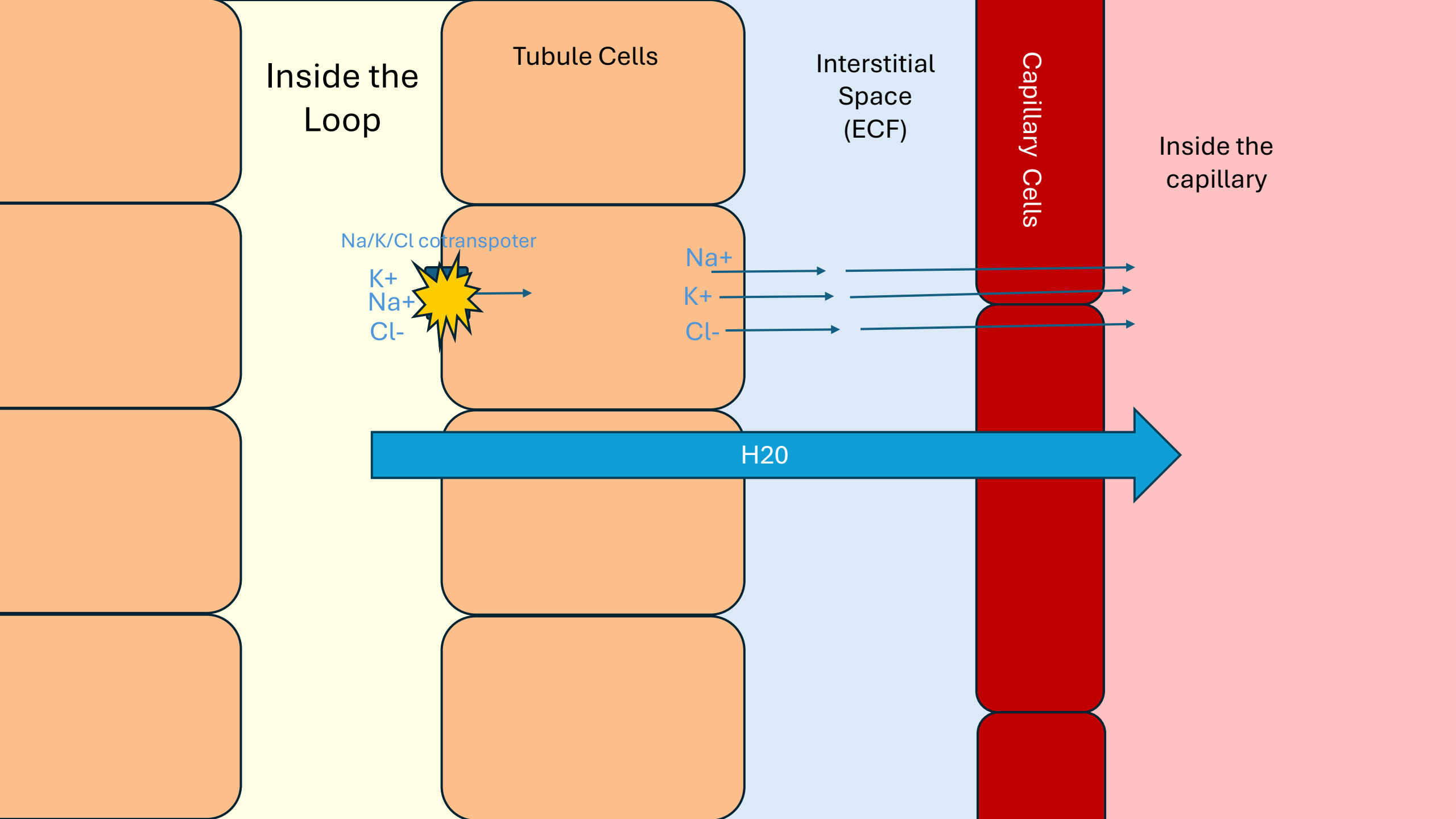
Loop diuretic

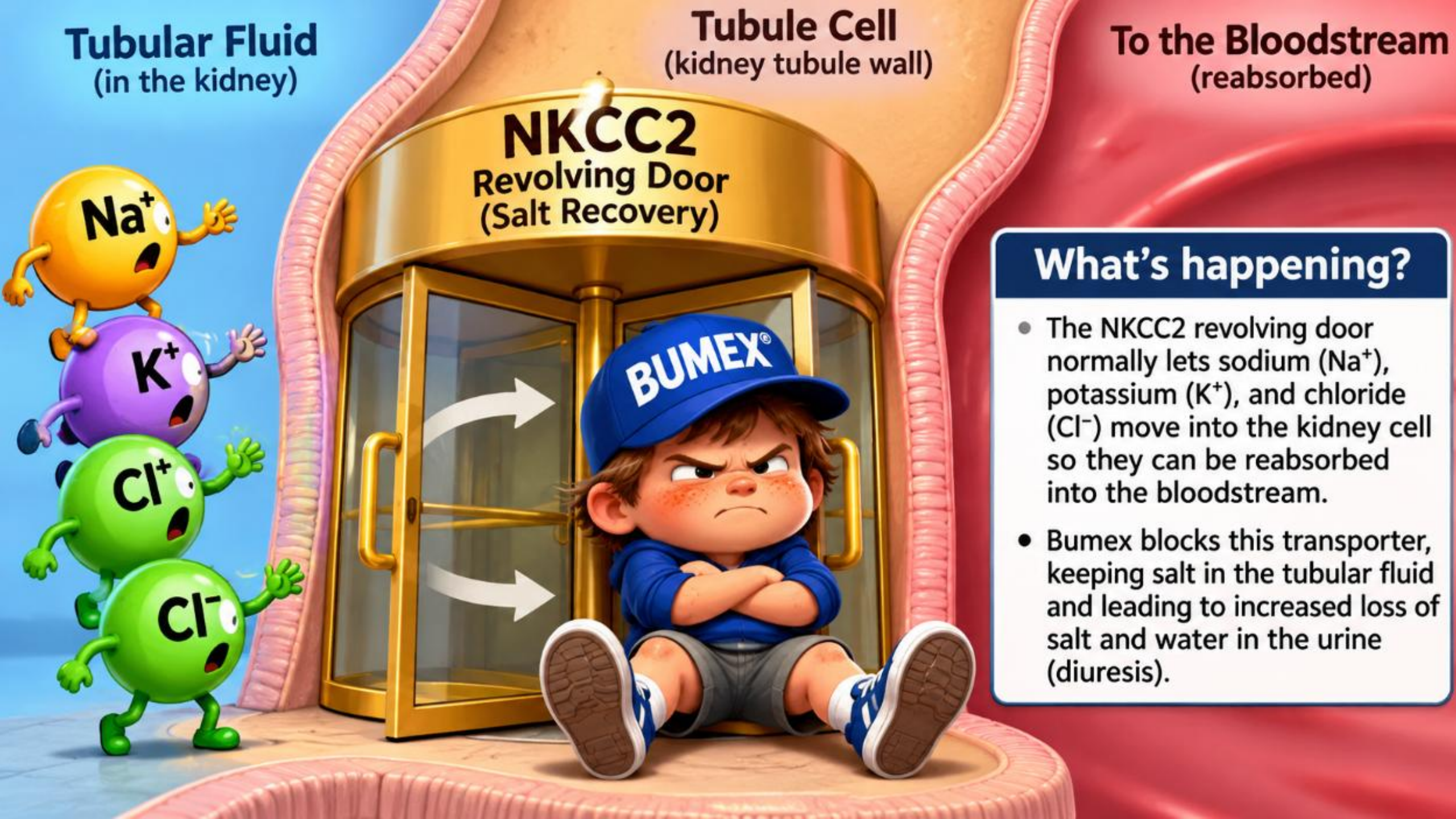
Oral bioavailability: ~50% (variable)

Approx. oral equivalent: 40 mg

Approx. IV equivalent: 20 mg

BOTH BLOCK NKCC2 → ↑ sodium/chloride excretion → ↑ urine output


Inside the Loop
Tubule Cells
Interstitial Space (ECF)
Capillary Cells
Inside the capillary
Na/K/Cl cotranspoter
K+
Na+
Cl-
Na+
K+
Cl-
H20


Tubular Fluid
(in the kidney)
Tubule Cell
(kidney tubule wall)
To the Bloodstream
(reabsorbed)
NKCC2
Revolving Door
(Salt Recovery)
Na+
K+
Cl+
Cl−
BUMEX®
What's happening?
The NKCC2 revolving door normally lets sodium (Na+), potassium (K+), and chloride (Cl−) move into the kidney cell so they can be reabsorbed into the bloodstream.
Bumex blocks this transporter, keeping salt in the tubular fluid and leading to increased loss of salt and water in the urine (diuresis).

Case Study

Dispatch

ALS dispatched to a residence for a 78-year-old male with altered mental status.

His wife reports increasing confusion over three days, difficulty walking, and a near fall today.

History of Present Illness

- Increasing lethargy and intermittent unusual statements
- Poor appetite and decreased oral fluid intake over several days
- Unsteady gait; nearly fell getting out of bed
- No reported fever, head injury, or recent medication changes
- Recognizes his wife but is disoriented to date and situation

Initial Assessment

BP: 96/58 mmHg HR: 62/min, regular RR: 18/min

SpO_2: 95% on room air Temp: 97.8°F Glucose: 112 mg/dL

- GCS 14 (E4 V4 M6); slow responses; no obvious focal deficits
- Weak peripheral pulses; dry oral mucosa
- Clear lungs; no significant peripheral edema

Medical History and Medications

History: heart failure, atrial fibrillation, chronic kidney disease, hypertension, neuropathic pain

- Gabapentin — 800 mg/day
- Bumetanide (Bumex) — dose unknown
- Metoprolol — dose unknown
- Amiodarone — 400 mg/day

New Information: Renal Function

The patient's wife shows recent laboratory results on his portal.

Estimated GFR 20 days ago: 45 mL/min/1.73 m^2

Most recent estimated GFR: 25 mL/min/1.73 m^2

Discussion: What does this trend suggest? What can—and can't—eGFR tell us during rapidly changing kidney function?

Pause and Discuss: Differential Diagnosis

What could explain this patient's altered mental status?

- Medication accumulation or adverse effects
- Dehydration, hypotension, and cerebral hypoperfusion
- Electrolyte or other metabolic disturbance
- Infection, stroke, or other acute neurologic disease
- Uremia (not established by eGFR alone)

How Bumex Works

- Bumetanide is a loop diuretic.
- It blocks NKCC2 in the thick ascending limb of the loop of Henle.
- Less sodium chloride is reabsorbed; urinary salt and water excretion increase.
- The thick ascending limb itself is relatively impermeable to water.
- Loop diuretics also impair the medullary gradient needed to concentrate urine.

Potential Cascade: Volume and Renal Perfusion

Continued diuresis + decreased fluid intake

↓

Possible intravascular volume depletion

↓

Reduced renal perfusion and filtration

↓

Reduced clearance of renally eliminated medications

Important: Heart failure can also cause renal dysfunction through congestion or low effective arterial perfusion. Volume depletion is a hypothesis, not a confirmed diagnosis.

Why Gabapentin Matters

- Gabapentin is eliminated primarily unchanged by the kidneys.
- Declining renal clearance can prolong its half-life and increase exposure—even without a dose change.
- Possible manifestations: somnolence, confusion, ataxia, and myoclonus.
- A reported 800 mg/day dose still warrants review when kidney function deteriorates.
- Do not assume gabapentin toxicity without evaluating other causes.

Discussion: Other Medication Effects

- Metoprolol may lower heart rate and blood pressure.
- Amiodarone can add bradycardic or conduction-slowing effects.
- Bumetanide may contribute to volume depletion when fluid losses exceed intake.

Together, these effects may worsen hypotension or cerebral hypoperfusion. Assess ECG, rhythm, perfusion, and signs of congestion.

Prehospital Priorities

- Assess airway, breathing, circulation, mental status, and glucose.
- Obtain a 12-lead ECG and repeat vital signs.
- Review medications, doses, timing, and recent changes.
- Assess for dehydration AND fluid overload.
- Treat hypotension according to local protocol; use fluids cautiously in heart failure.
- Communicate eGFR trend and possible medication accumulation during handoff.

Illustrative Hospital Course

In this teaching scenario, hospital evaluation identifies worsening renal function on a background of CKD.

The team considers volume depletion and reduced gabapentin clearance as possible contributors. After evaluation and adjustment of treatment, the patient’s mental status improves.

This is a fictionalized teaching outcome—not a documented result from the original patient.

Take-Home Messages

- A stable prescription does not guarantee stable drug exposure.
- Renal dysfunction can increase concentrations of renally cleared medications.
- Loop diuretics can contribute to volume depletion, but heart failure complicates volume assessment.
- Altered mental status requires a broad differential.

Closing question: Why can a medication tolerated for months suddenly become problematic?