Excretion: Lesson objectives

At the end of the lessons, students should be able to:

- Define and explain the importance of excretion.
- Identify the component parts of the mammalian urinary system and state the function of each part
- Relate the structure of the mammalian kidney to its function
- Discuss the role of ADH and collecting duct in osmoregulation
- Label the parts of the nephron and relate these structures to the functions of ultra-filtration and selective reabsorption.
- Outline the mechanism of dialysis (haemo-dialysis) in the case of kidney failure.

Excretion

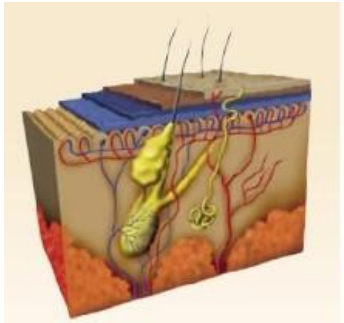
- is a process by which metabolic waste products and toxic materials are removed from an organism's body

- Urea is a waste product from the deamination of excess amino acids in the liver

- Kidney to filter waste products from the blood to prevent the accumulation of the

8.2 Excretion in Humans

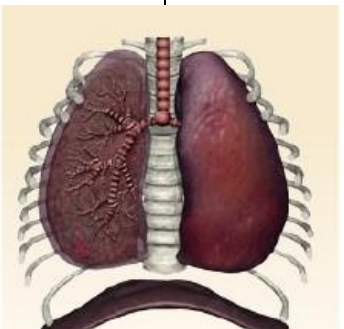
Waste products excreted by:



skin

- urea
- excess water
- excess salts

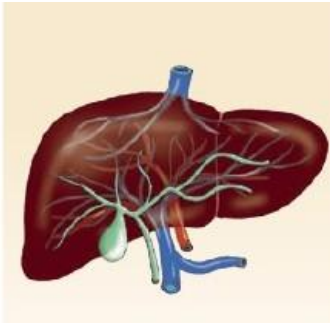
in sweat



lungs

- carbon dioxide
- excess water

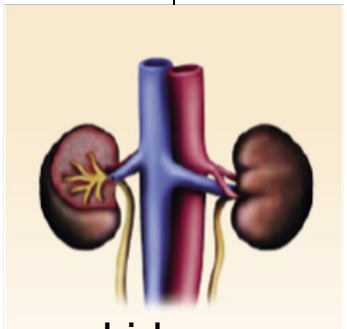
in expired air



liver

- bile pigments

in faeces through the intestines



kidneys

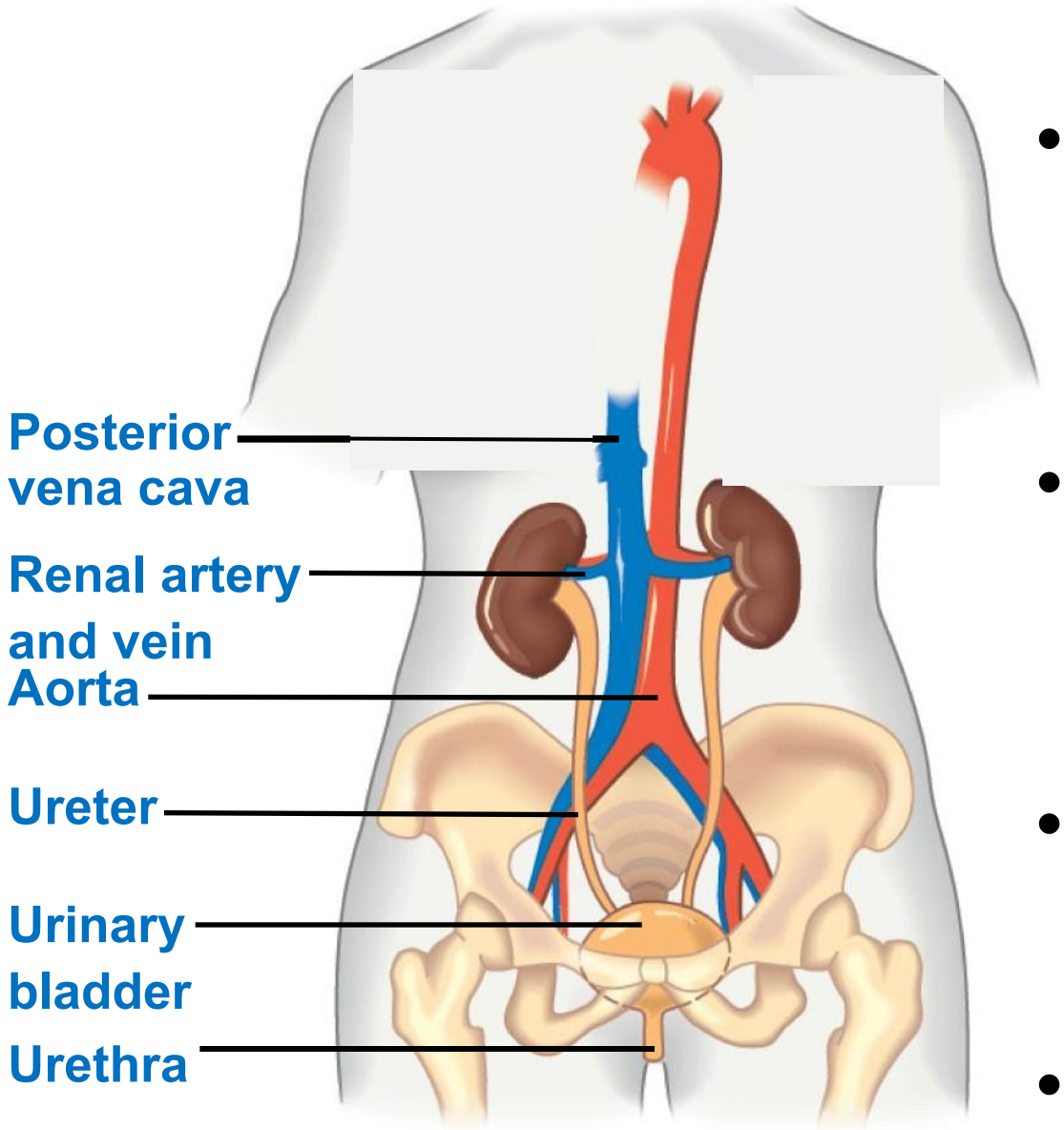
- urea
- excess water
- excess salts

in urine

8.2 Excretion in Humans

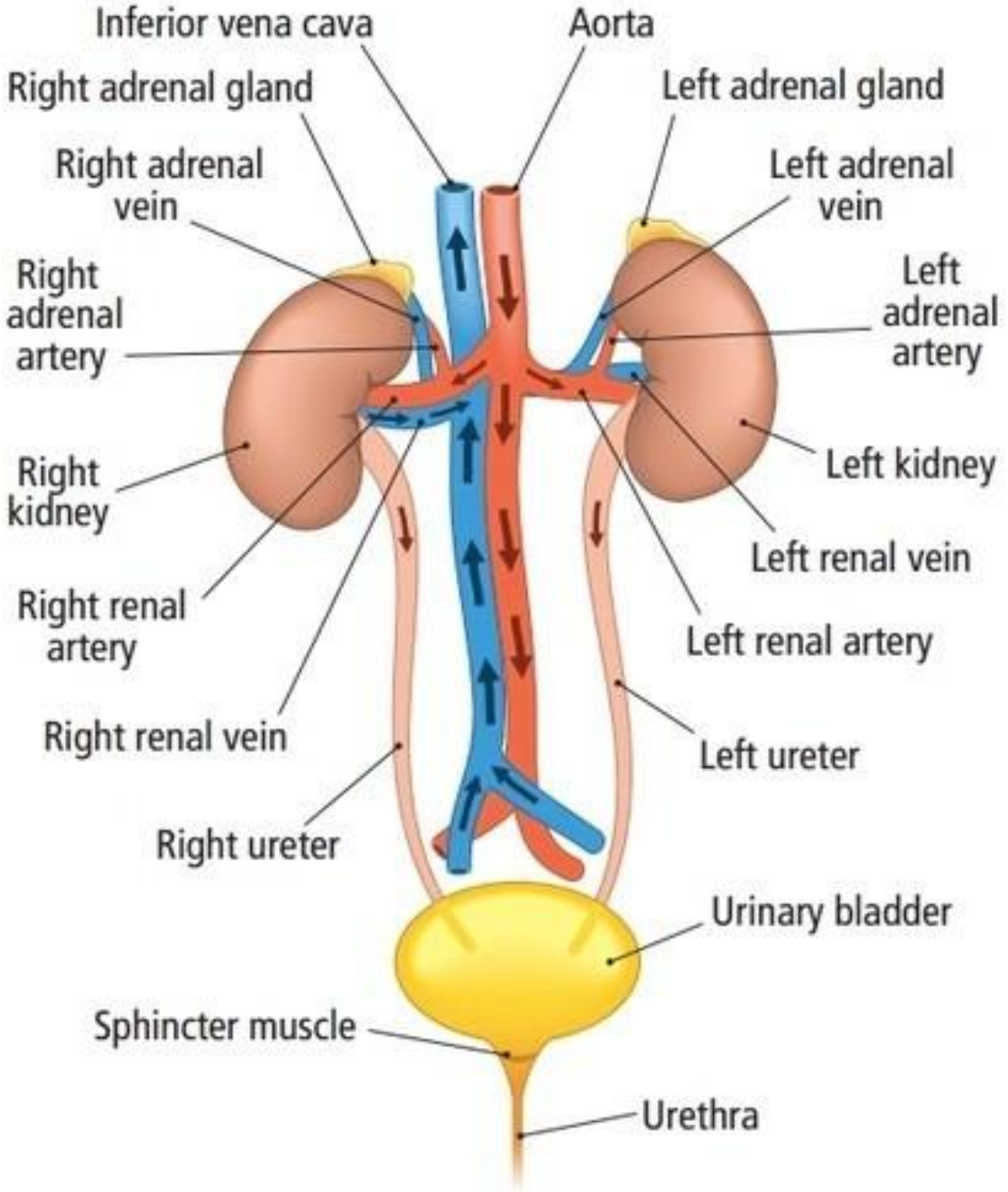
Excretory product	Organ	Mode of excretion
Carbon dioxide	Lungs	Expired air
Urea and excess mineral salts	Kidneys Skin	Urine Sweat
Excess water	Kidneys Skin Lungs	Urine Sweat Expired air (as water vapour)
Bile pigments (from breakdown of haemoglobin)	Liver	Faeces via the intestines

Structure of the Mammalian Urinary System



- Supplied with blood by renal arteries and drained by renal veins
- Urine exits each kidney through the ureter

- Both ureters drain into a urinary bladder
- Urine is expelled through a


Inferior vena cava
Aorta
Right adrenal gland
Left adrenal gland
Right adrenal vein
Left adrenal vein
Right adrenal artery
Left adrenal artery
Right kidney
Left kidney
Left renal vein
Right renal artery
Left renal artery
Right renal vein
Left ureter
Right ureter
Urinary bladder
Sphincter muscle
Urethra

Experiment 8A (Pg 89 to 90)

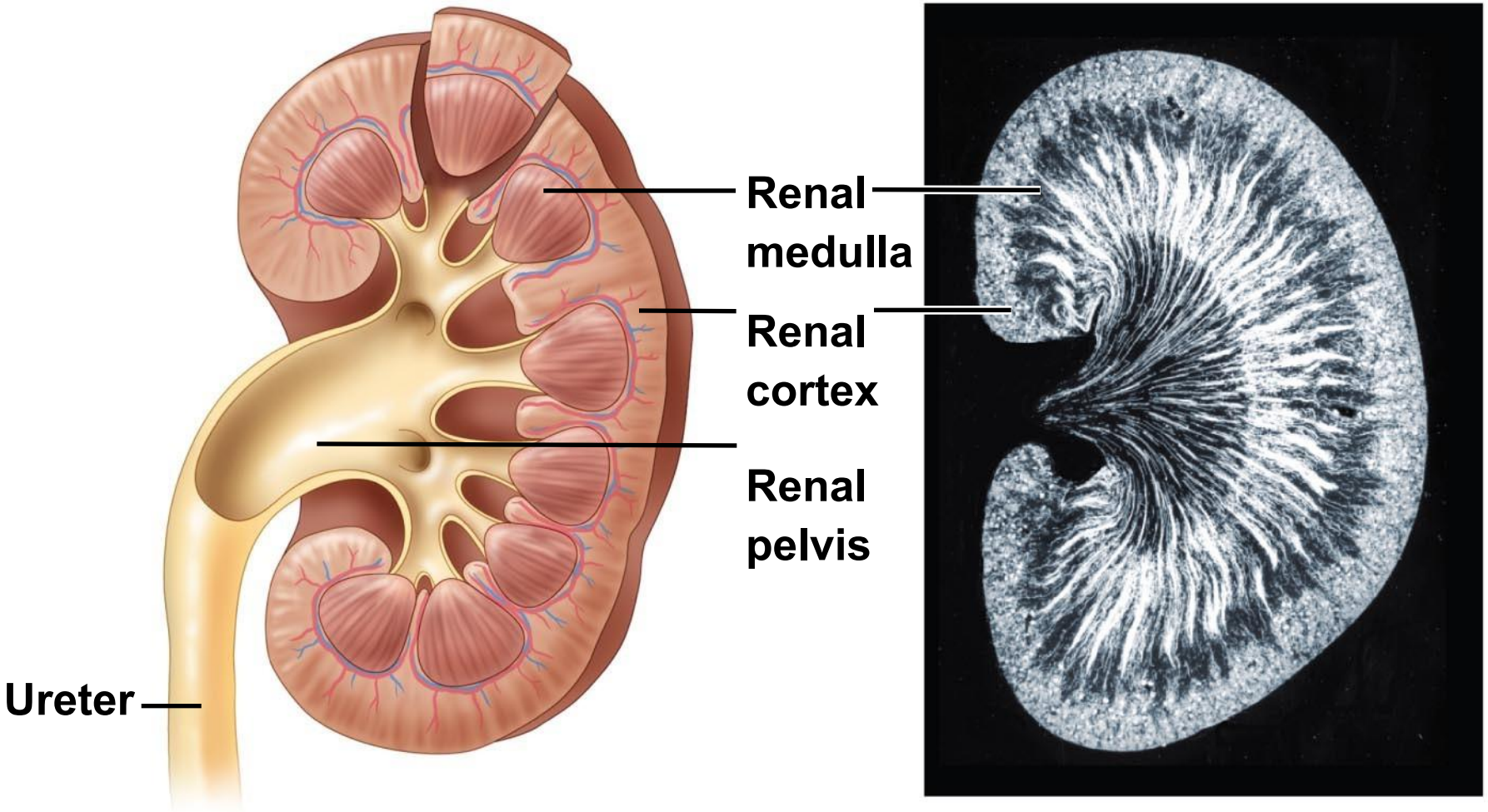
Examining the mammalian excretory system

Assignment:

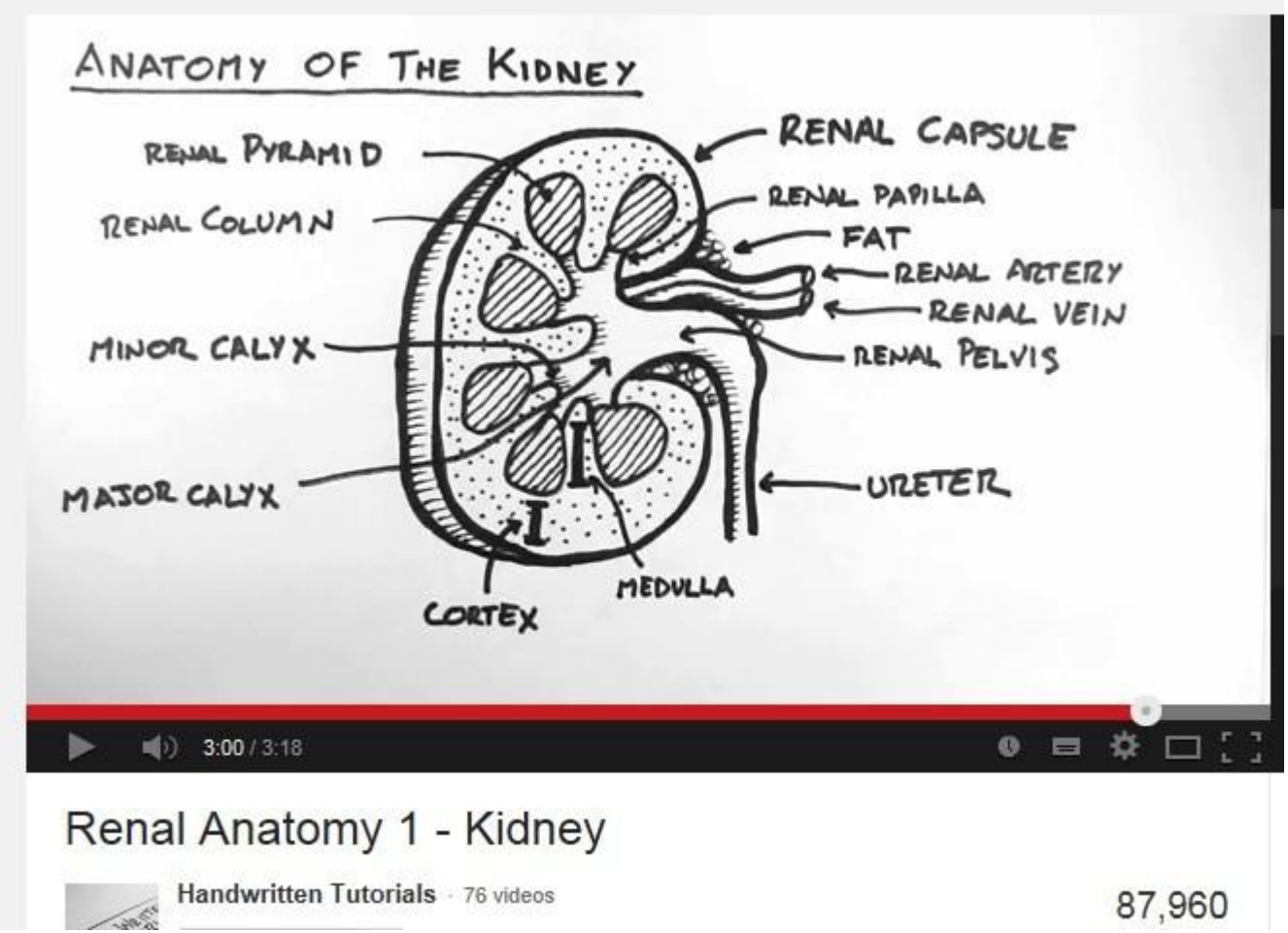
- Complete drawing of the human urinary system on page 90, Question 2

- an outer renal cortex and
- an inner renal medulla

https://www.youtube.com/watch?v=W0GpIMNTPYg

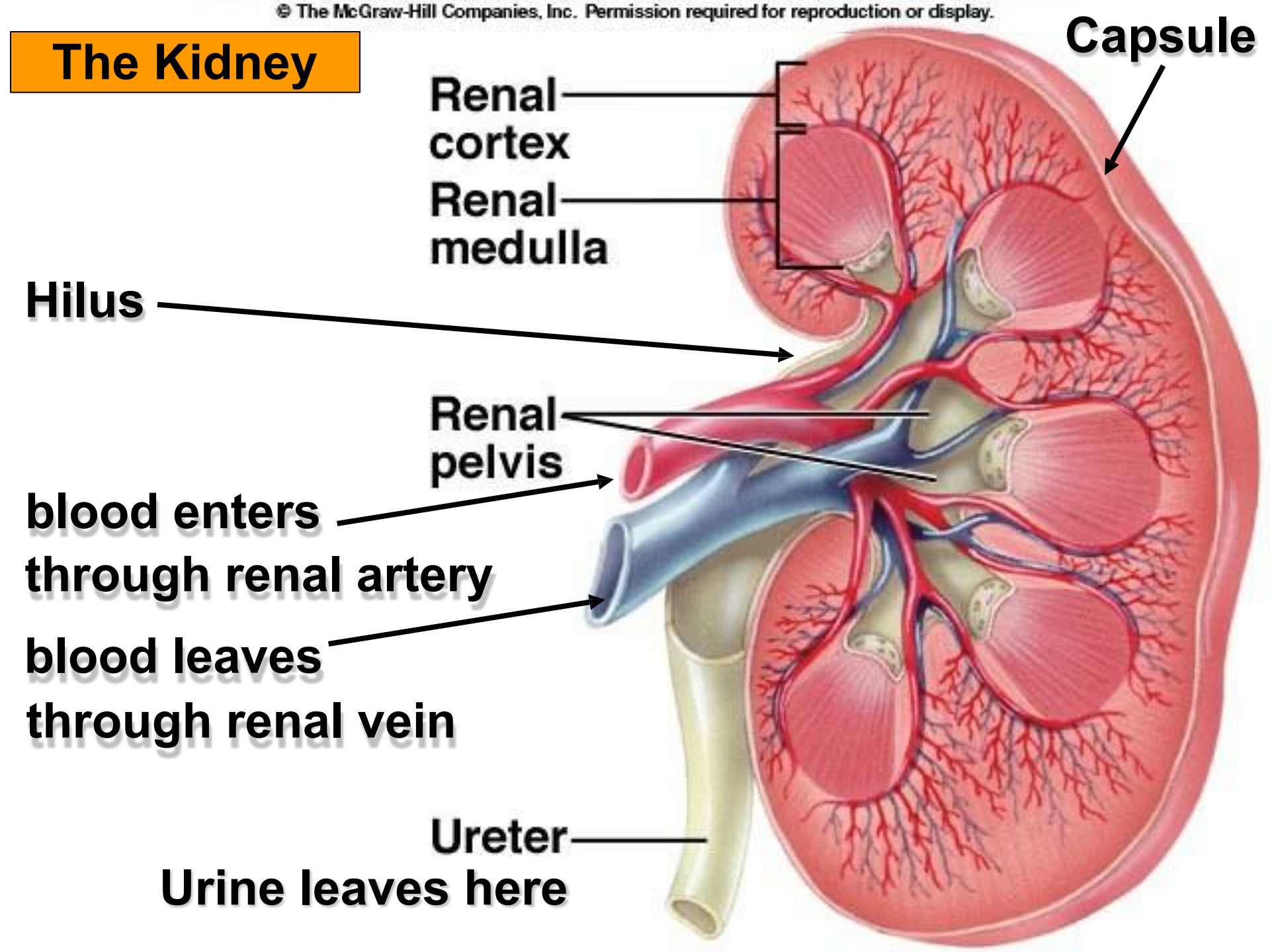


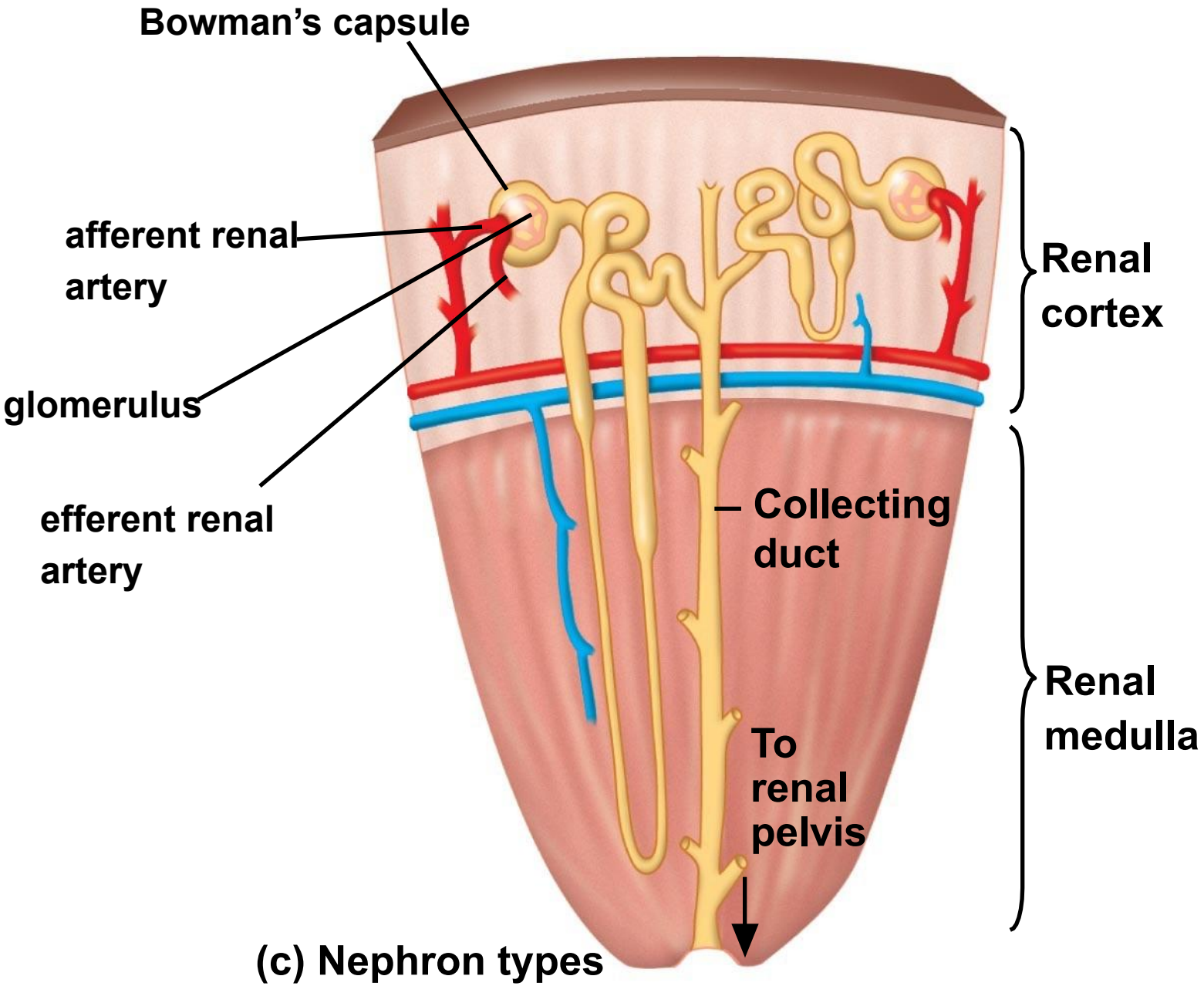
The Kidney Anatomy (Click link below for video)



http://www.youtube.com/watch?v=7bpTiqe5R6c&index=2&list=PLzl4lgX_3RvcgRqo810pAcz9trinh0Irl

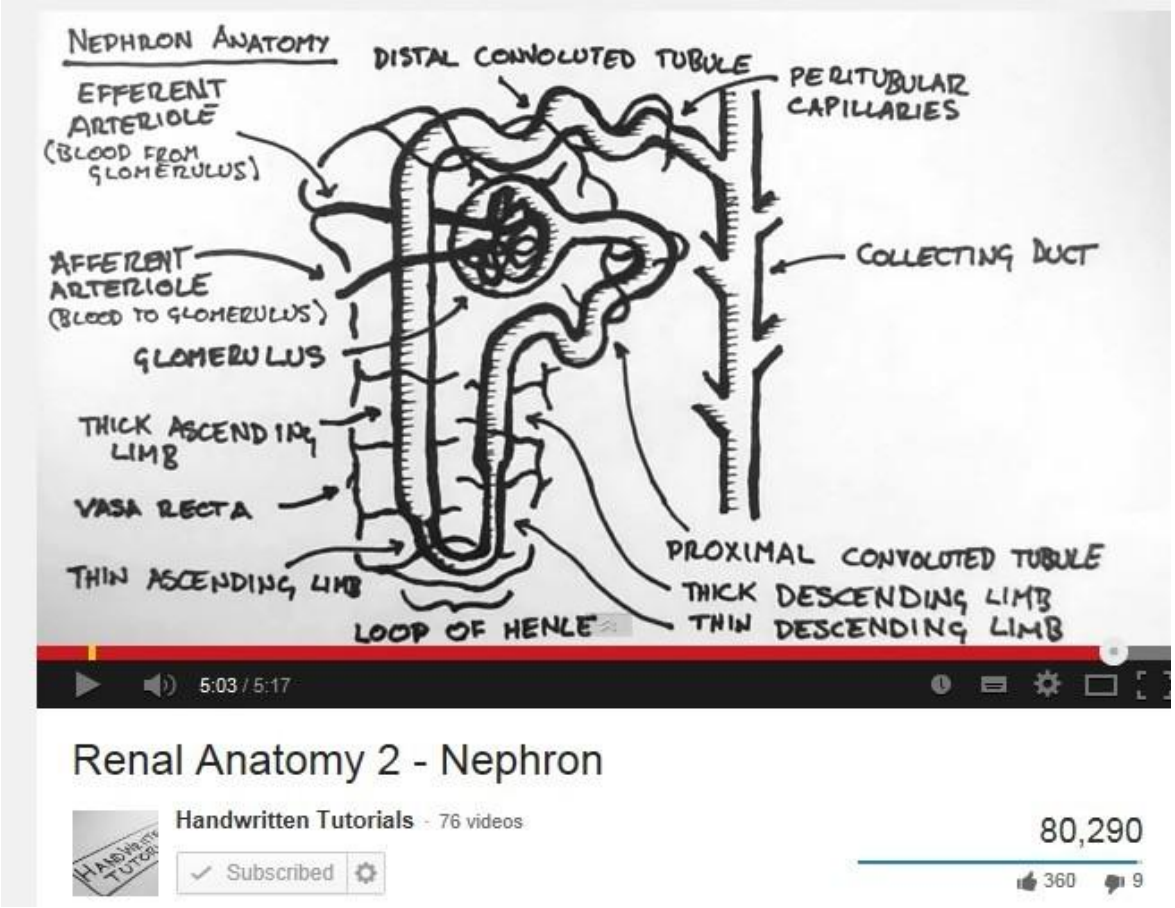
The Kidney





(c) Nephron types

The Nephron Anatomy (Click link below for video)



http://www.youtube.com/watch?v=k5lF1j7b3fI&list=PLzl4lgX_3RvcgRqo810pAcz9trinh0Irl&index=2

8.2 Excretion in Humans

Blood circulation at the kidney tubule

1. Blood enters the kidney via the **renal artery**.

2. Renal artery branches into many arterioles

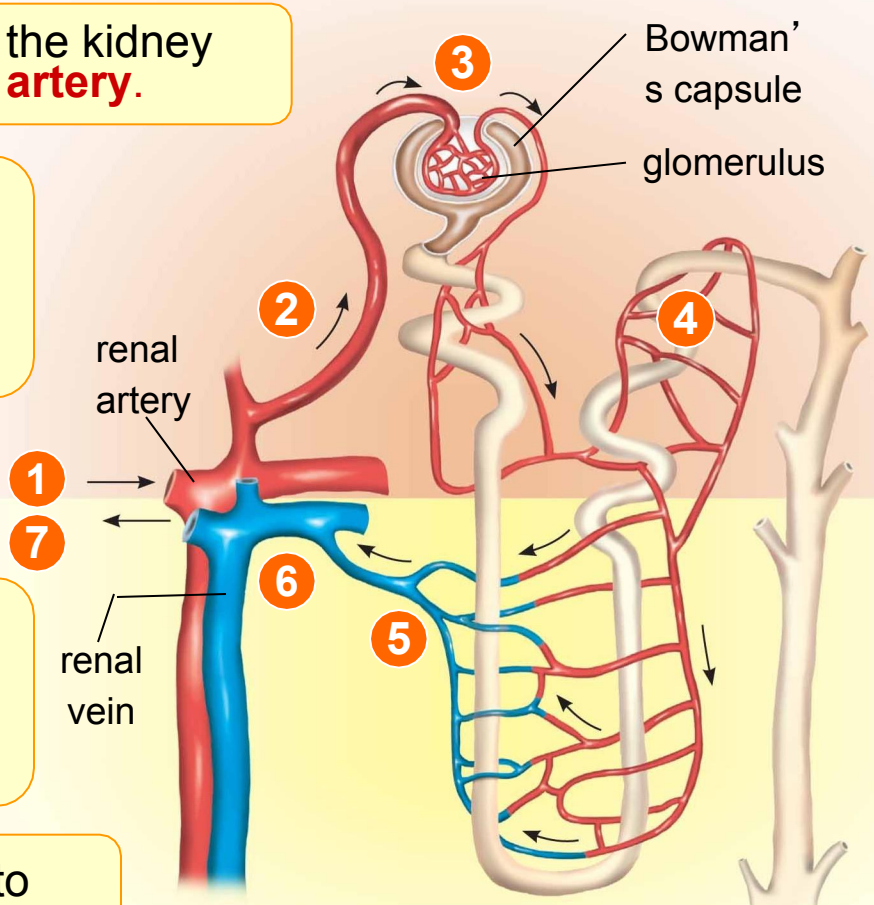
3. Arterioles branch into a mass of blood capillaries (**glomerulus**)

4. Blood leaves glomerulus and enters blood capillaries surrounding the kidney tubule

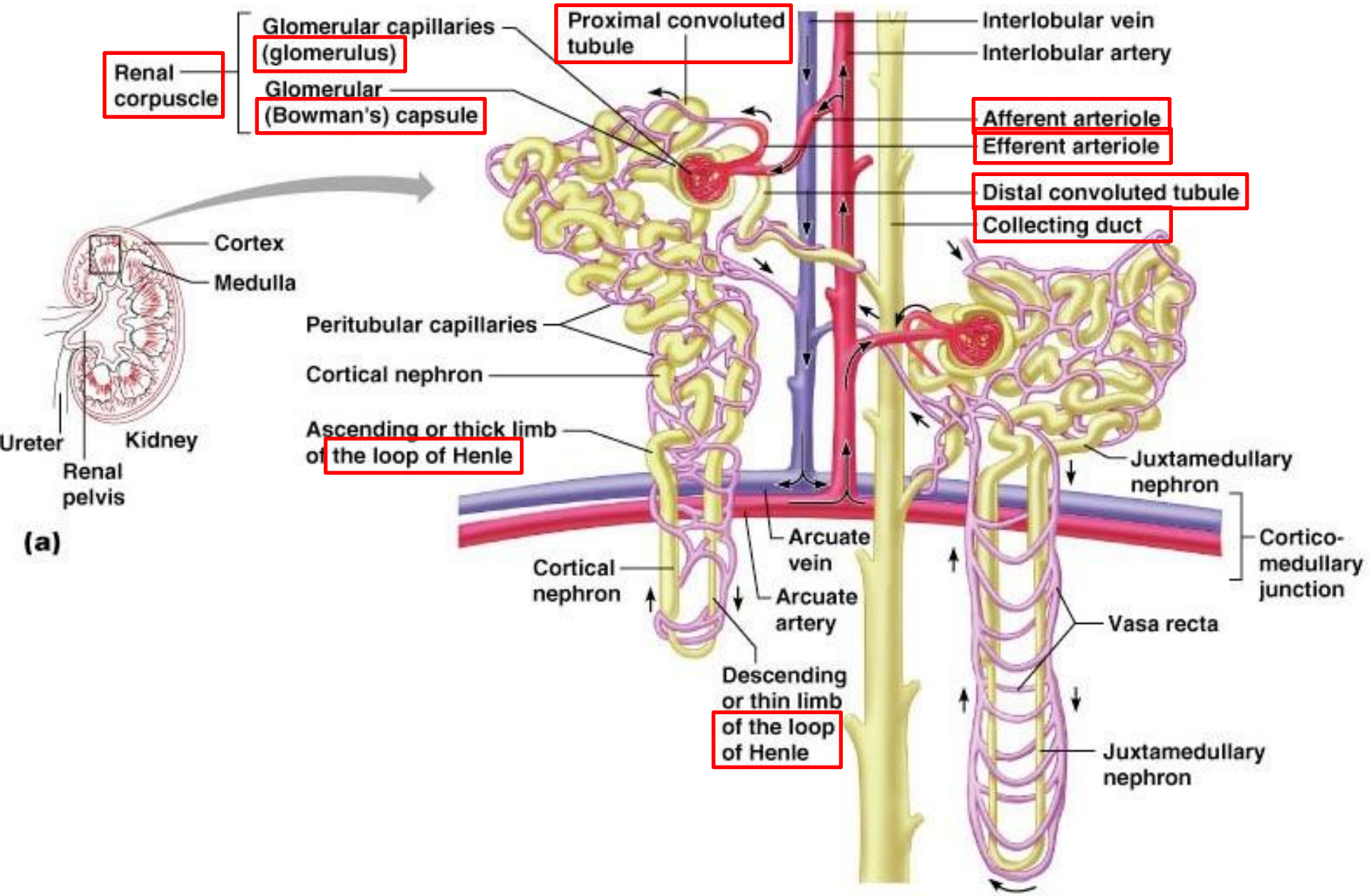
5. Blood capillaries unite to form venules

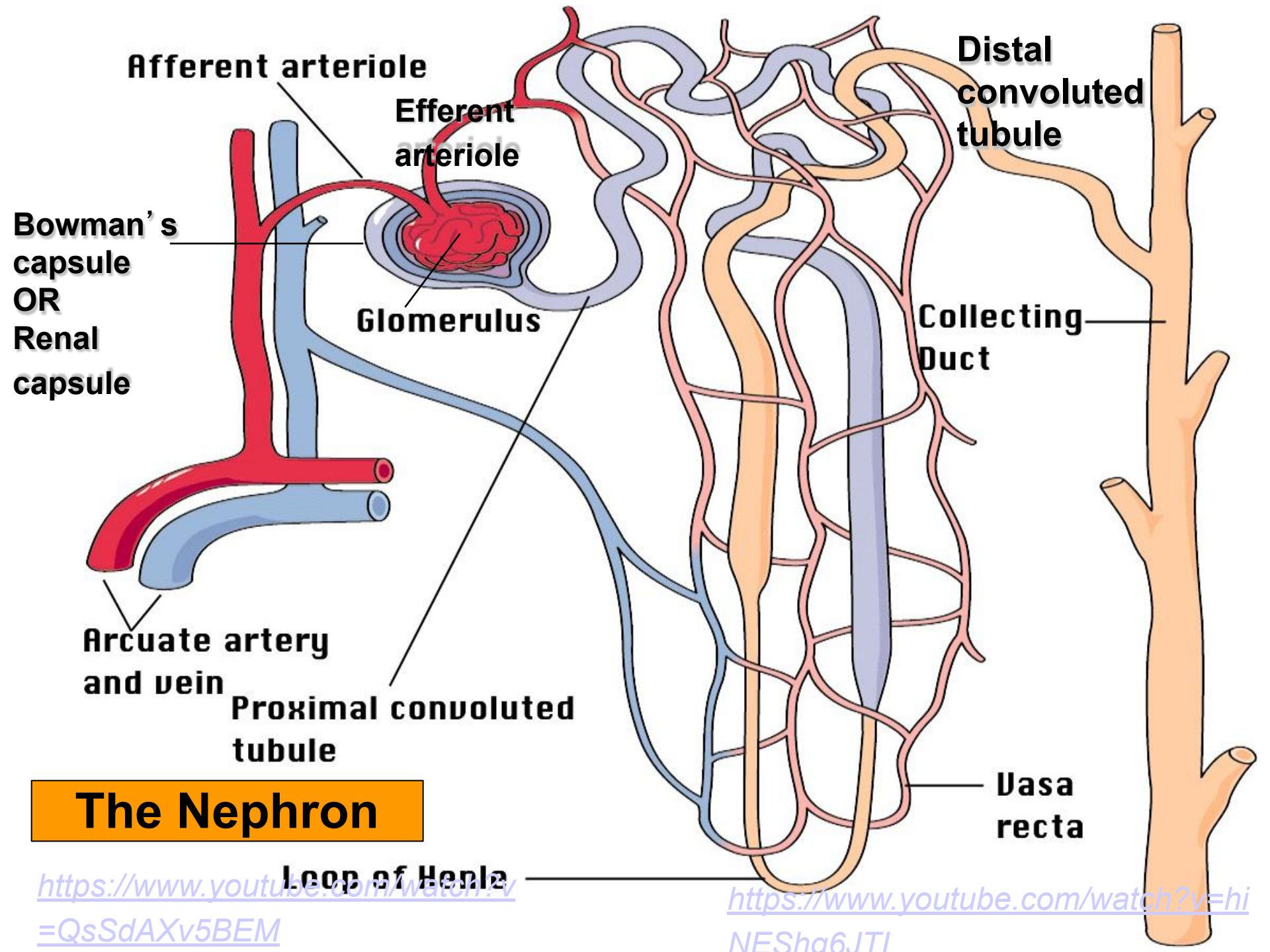
6. Venules join to form **renal vein**.

7. Blood exits the kidney via the renal vein



The Nephron


Renal corpuscle
Glomerular capillaries (glomerulus)
Glomerular (Bowman's) capsule
Proximal convoluted tubule
Interlobular vein
Interlobular artery
Afferent arteriole
Efferent arteriole
Distal convoluted tubule
Collecting duct
Cortex
Medulla
Ureter
Kidney
Renal pelvis
(a)
Peritubular capillaries
Cortical nephron
Ascending or thick limb of the loop of Henle
Juxtamedullary nephron
Cortico-medullary junction
Arcuate vein
Arcuate artery
Cortical nephron
Vasa recta
Descending or thin limb of the loop of Henle
Juxtamedullary nephron



The Nephron

https://www.youtube.com/watch?v=QsSdAXv5BEM

https://www.youtube.com/watch?v=hiNEShq6JTI

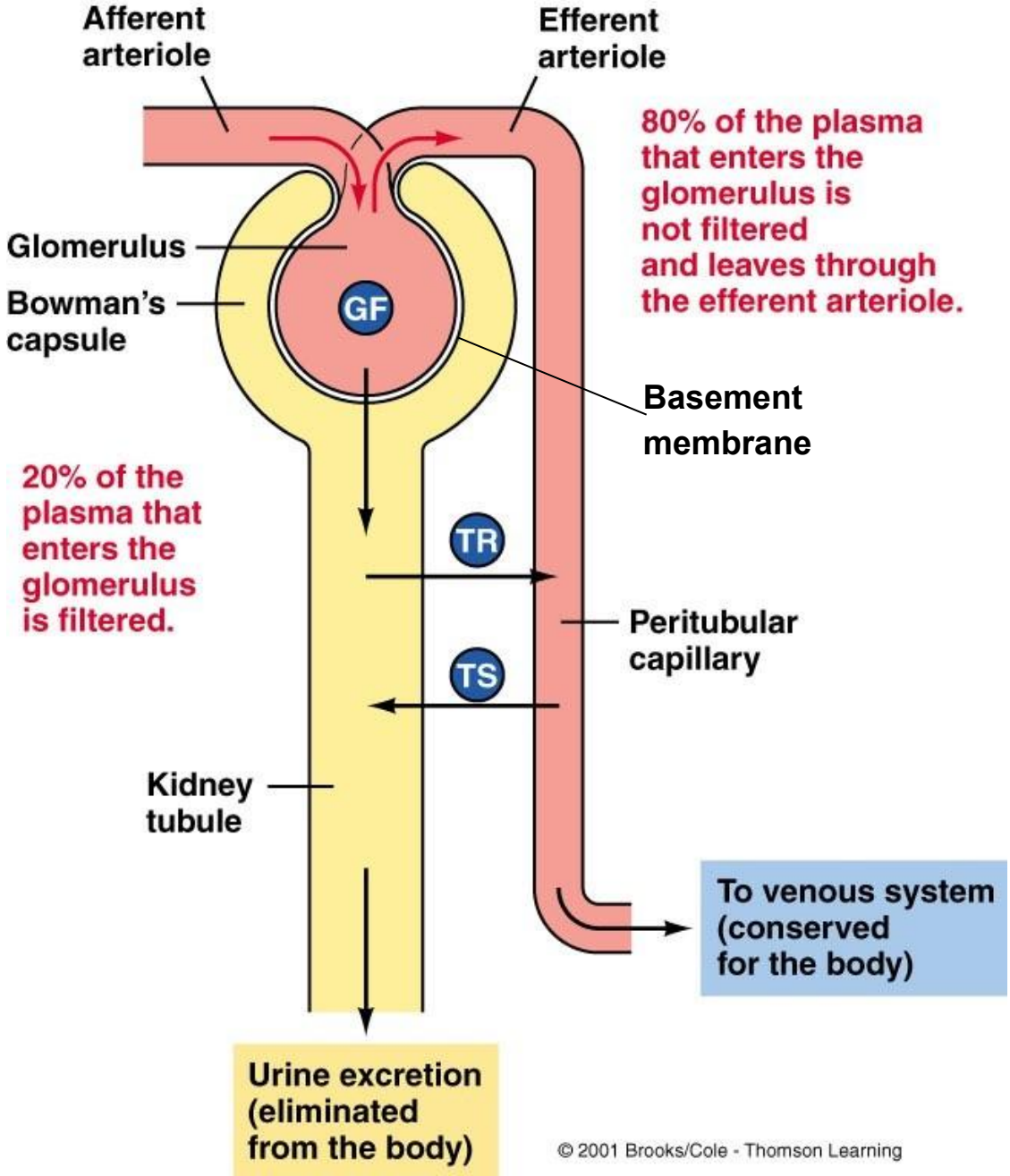
Urine formation

1) Glomerular filtration (Ultrafiltration)

- water and small molecules (plasma) forced out from blood (due to high pressure in glomerulus) into Bowman's capsule (through basement membrane)

2) Tubular (selective) reabsorption

- water (by osmosis) and essential molecules (by active transport) reabsorbed from kidney tubule to (blood in) capillaries

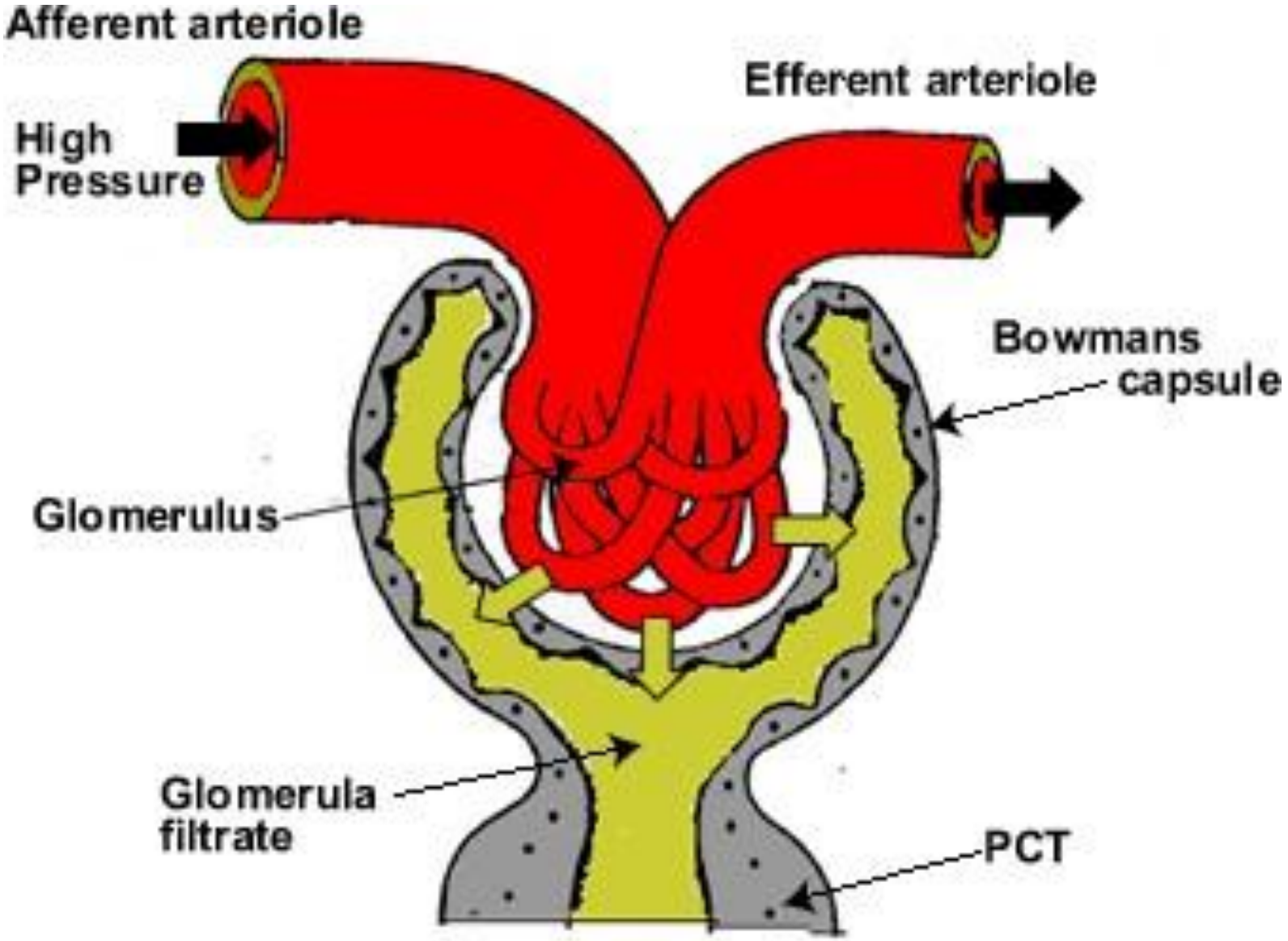


Urine formation - Ultrafiltration

- In the renal corpuscle or Malpighian corpuscle (glomerulus + Bowman's capsule), renal artery which brings blood to the kidney is split up into numerous arterioles, each entering a nephron.

- arterioles split into numerous capillaries which form a knot called a glomerulus.
  - this is surrounded by the Bowman's capsule or renal capsule.

- the afferent arteriole leading into the glomerulus is wider than the efferent arteriole bringing blood out,
  - so there is a high blood pressure in the capillaries of the glomerulus.


Afferent arteriole
Efferent arteriole
High Pressure
Bowmans capsule
Glomerulus
Glomerula filtrate
PCT

Urine formation - Ultrafiltration

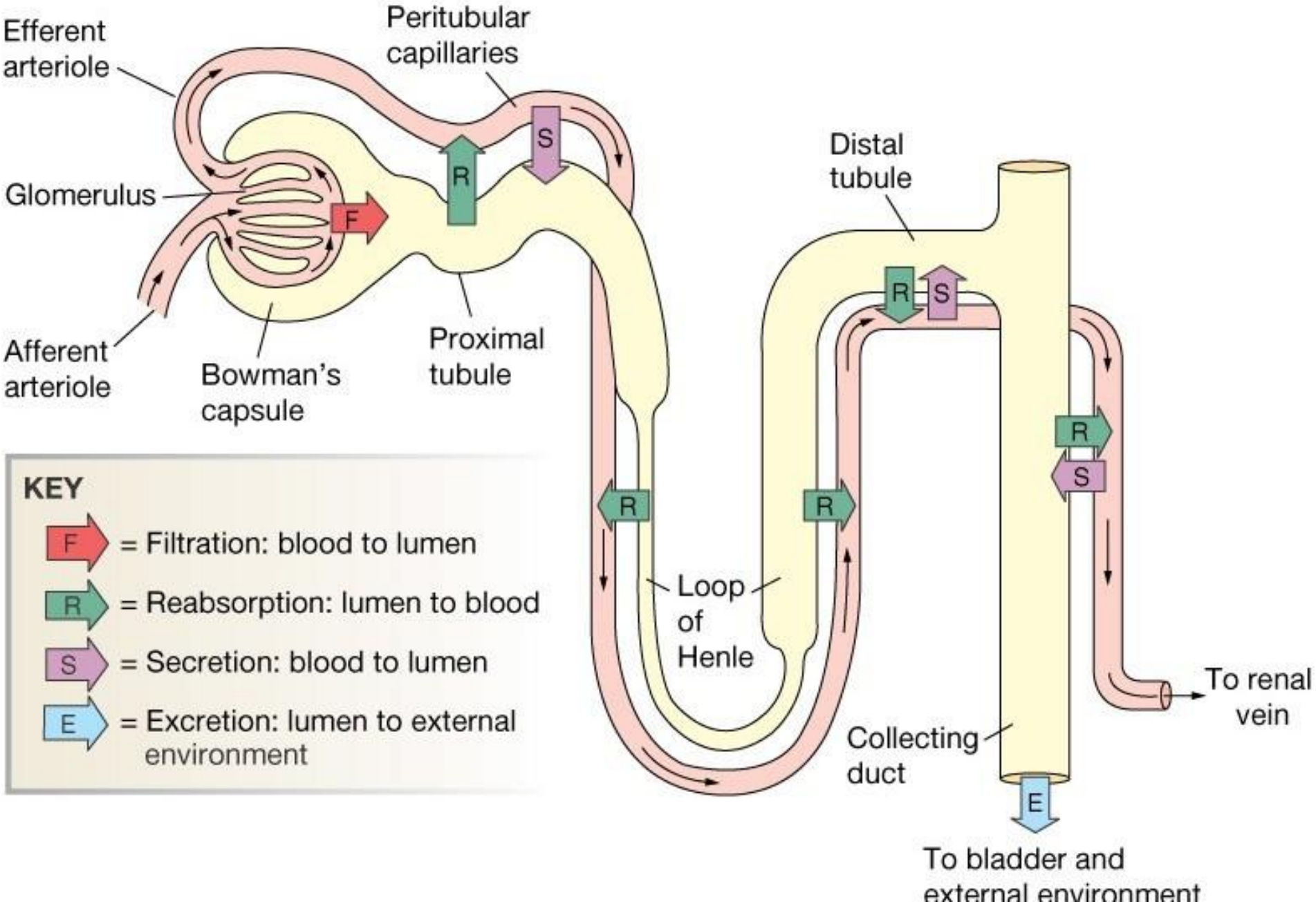
- This high hydrostatic blood pressure forces plasma (along with solutes) out of the blood by ultrafiltration.

- Only blood cells, platelets and the large plasma proteins/fats molecules with plasma remain in the blood.

- A basement membrane (partially permeable membrane) wraps around the glomerular blood capillaries,
  - which has small pores (a filter) that allow water and small molecules to pass through.

- The filtrate collects in the renal (or Bowman's) capsule of the Malpighian (or renal) corpuscle.

Urine formation



Urine formation

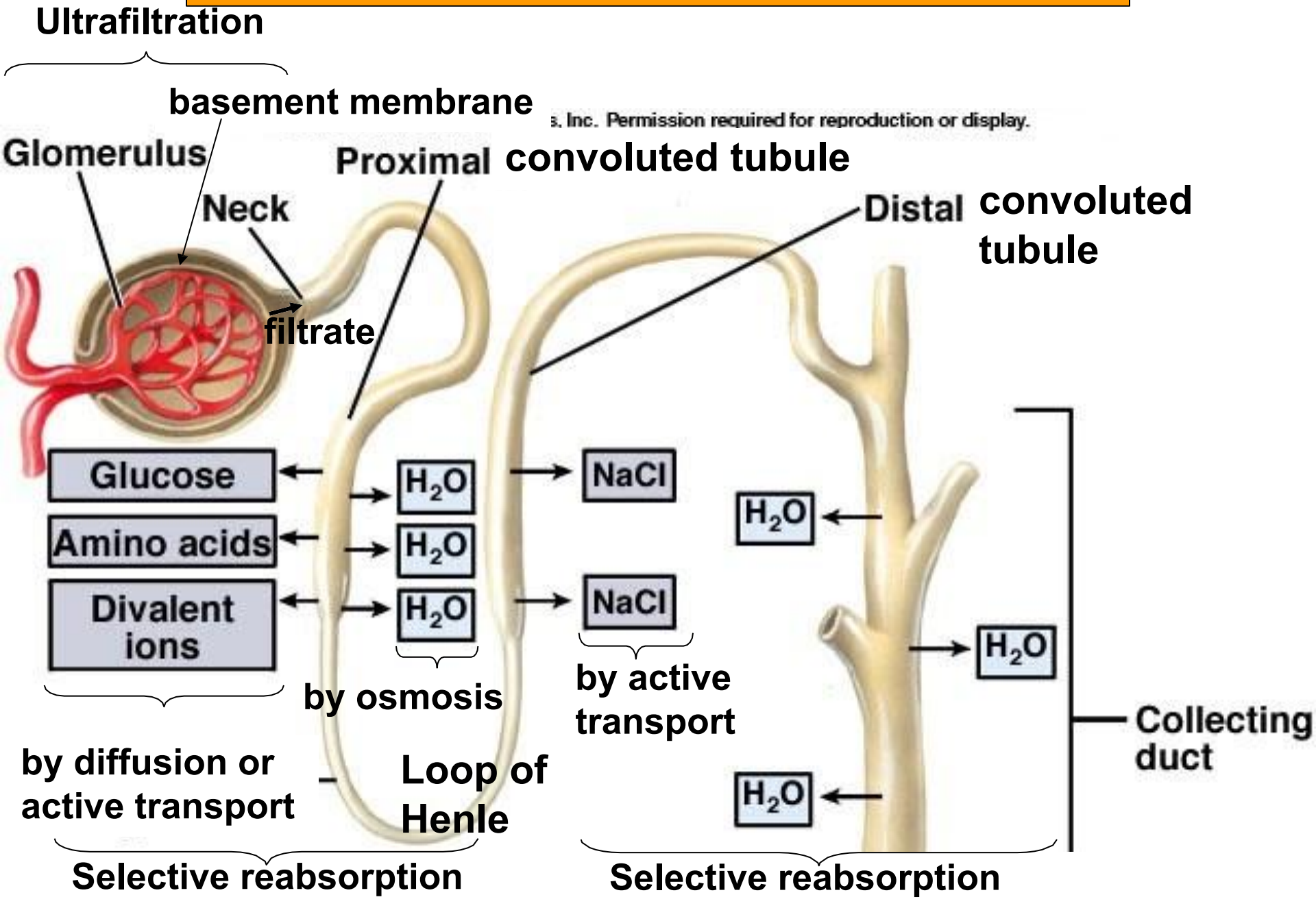
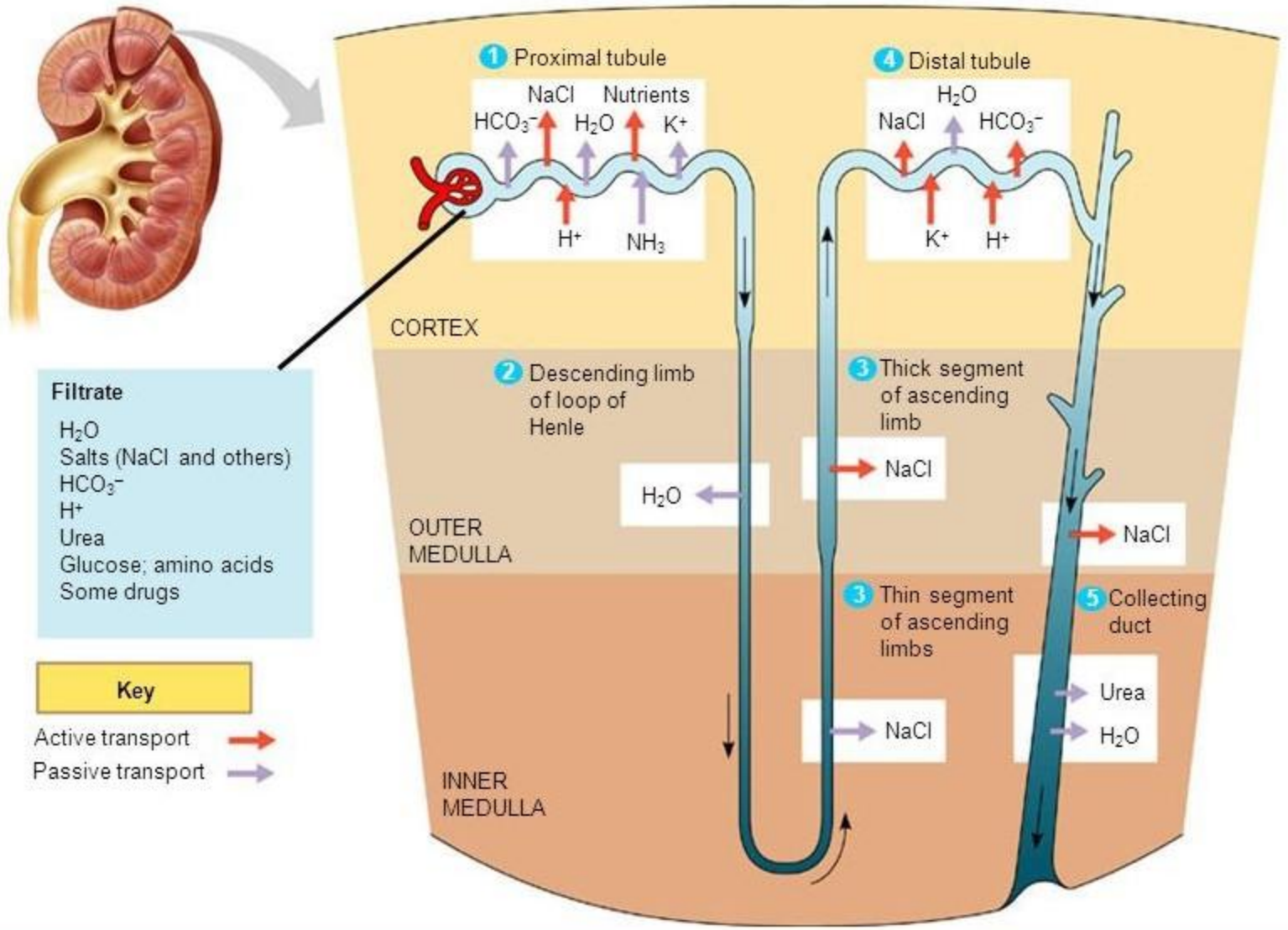
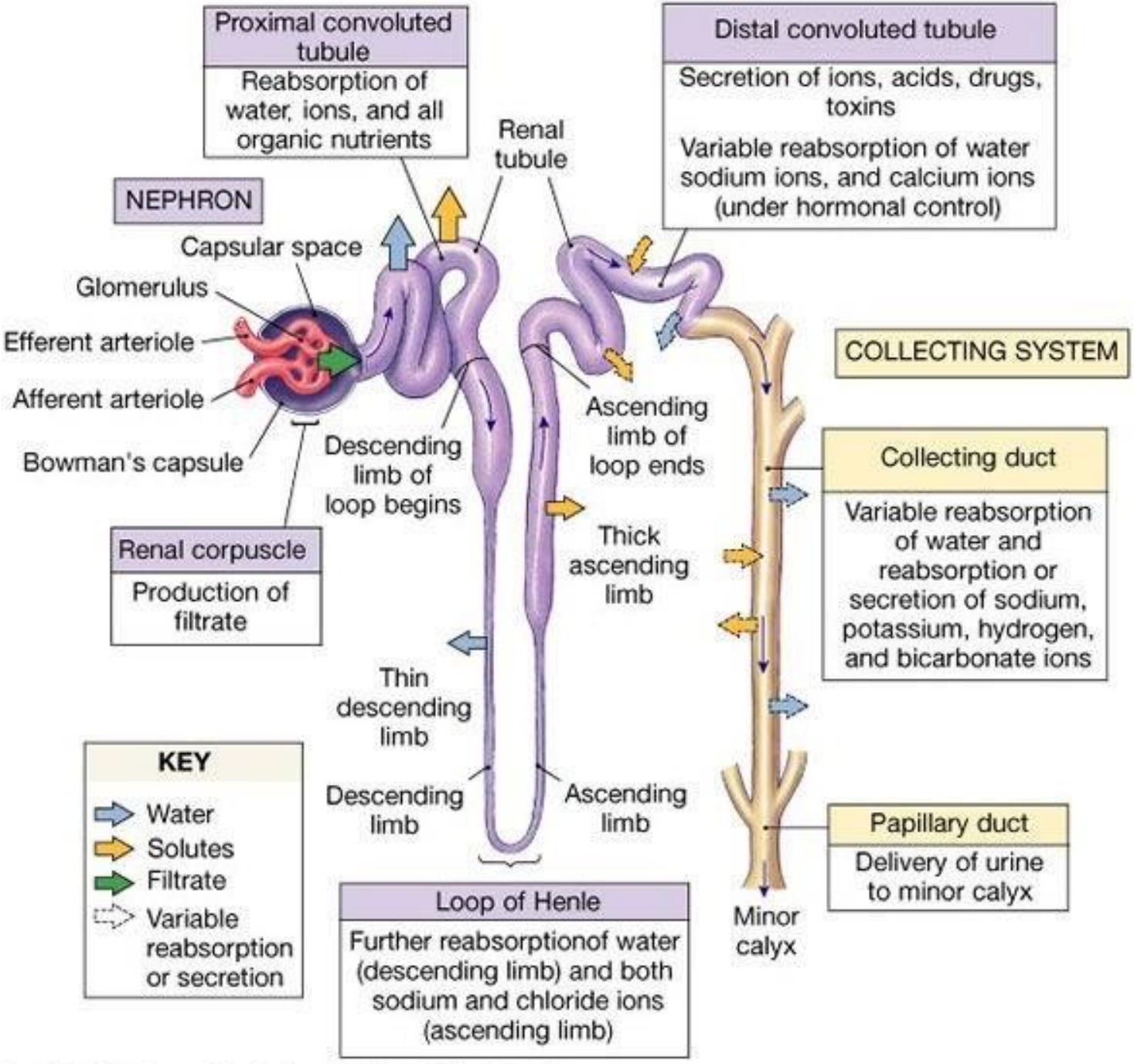
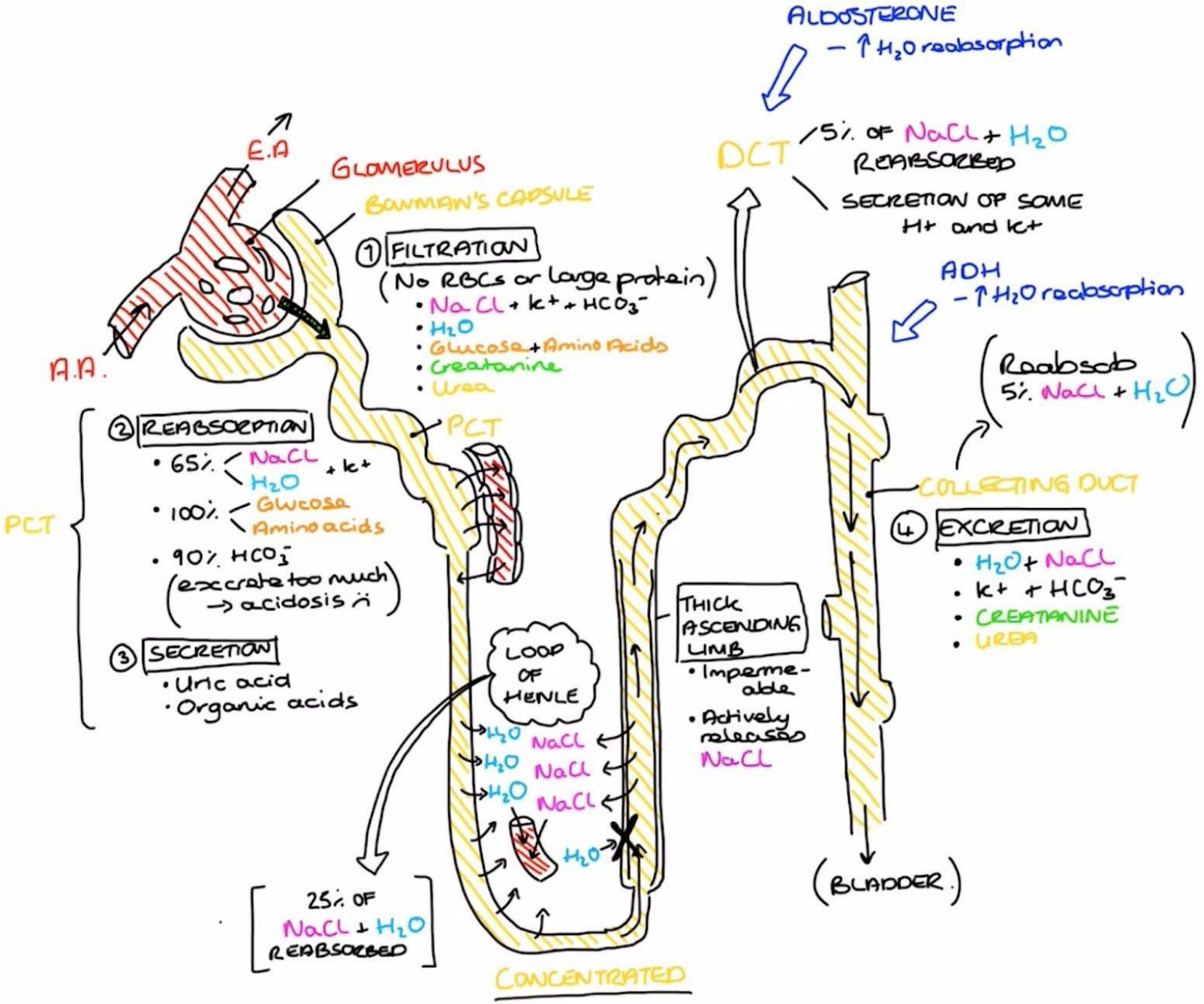


Figure 44.14 The nephron and collecting duct: regional functions of the transport epithelium






ALDOSTERONE
– ↑ H_2O reabsorption
E.A
GLOMERULUS
BOWMAN'S CAPSULE
A.A.
① FILTRATION
(No RBCs or large protein)
• NaCl + k+ + HCO_3^-
• H_2O
• Glucose + Amino Acids
• Creatanine
• Urea
DCT
5% of NaCl + H_2O REABSORBED
SECRETION OF SOME H+ and K+
ADH
– ↑ H_2O reabsorption
(Reabsob 5% NaCl + H_2O)
PCT
② REABSORPTION
• 65% NaCl + H_2O + k+
• 100% Glucose Amino acids
• 90% HCO_3^-
(excrete too much → acidosis ↑)
③ SECRETION
• Uric acid
• Organic acids
PCT
COLLECTING DUCT
④ EXCRETION
• H_2O + NaCl
• k+ + HCO_3^-
• CREATANINE
• UREA
LOOP OF HENLE
THICK ASCENDING LIMB
• Impermeable
• Actively released NaCl
H_2O NaCl
H_2O NaCl
H_2O NaCl
H_2O
25% OF NaCl + H_2O REABSORBED
CONCENTRATED
(BLADDER)

Urine formation – Selective reabsorption

- Selective reabsorption starts in the proximal convoluted tubule (PCT).

- Over 80% of the filtrate in PCT is selectively reabsorbed into the blood.
  - ensure all useful material is returned to the blood.

  - All glucose, amino acids and 85% of mineral ions are reabsorbed by active transport.

  - 80% of water is absorbed back into the blood by osmosis.

Urine formation – Selective reabsorption

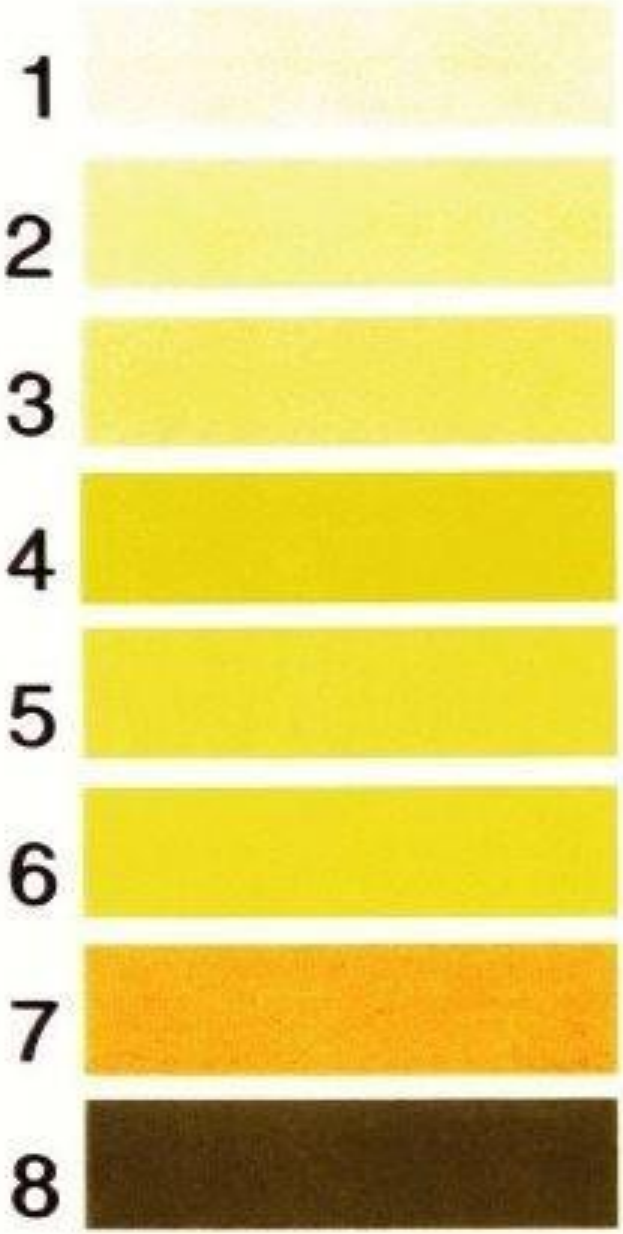
- The proximal convoluted tubule cells have
  - many mitochondria to provide ATP for active transport
  - and microvilli to increase surface area for absorption.

- Water is reabsorbed in the loop of Henle, distal convoluted tubule & collecting duct.

- Some salts (Na^+ ions) are reabsorbed in the distal convoluted tubule.

- Water, salts and metabolic waste products (eg. urea, uric acid, creatinine) passes out of collecting duct into

Am I Hydrated?
Urine Color Chart



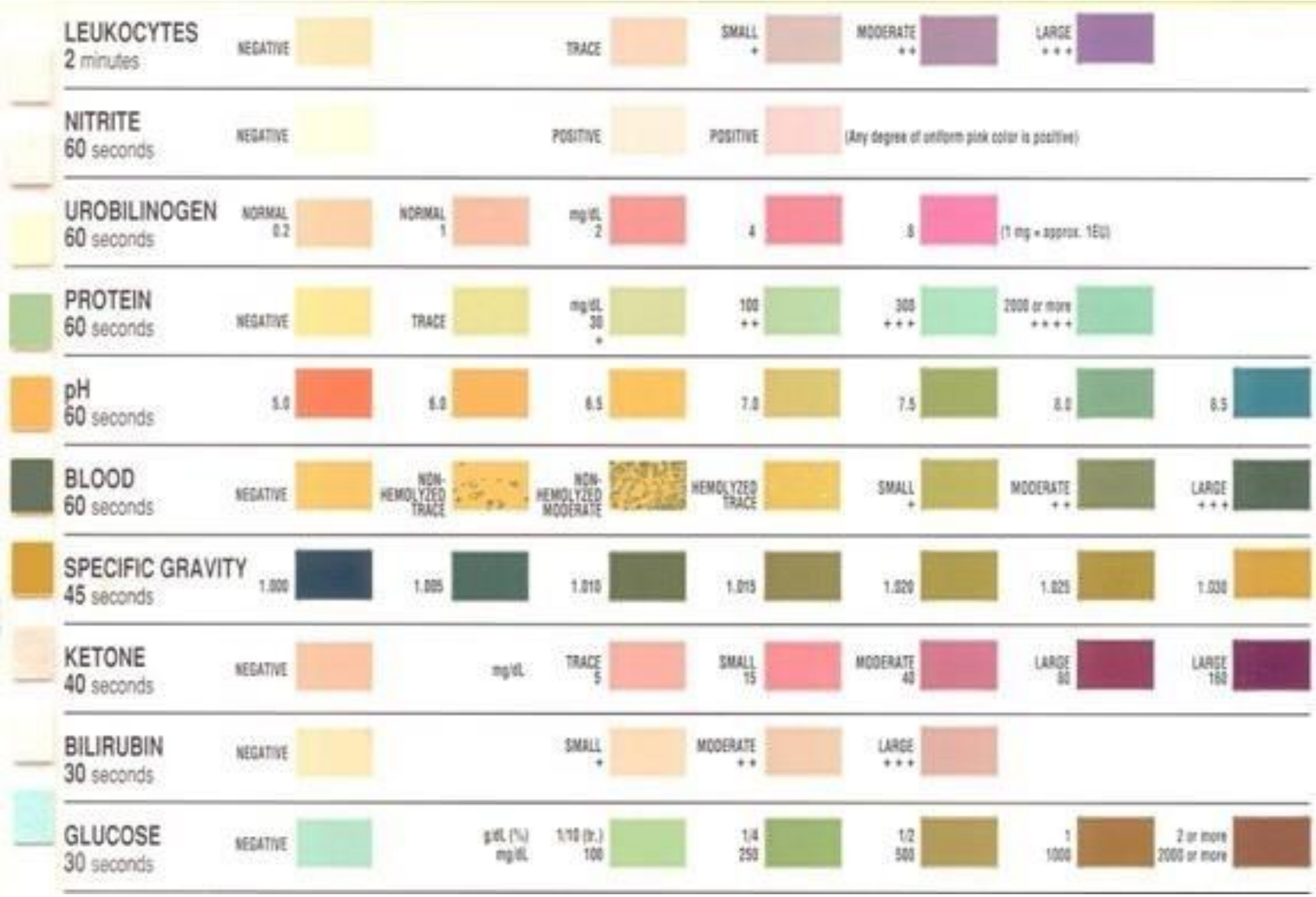
This urine color chart is a simple tool your can use to assess if you are drinking enough fluids throughout day to stay hydrated.

If your urine matches the colors numbered **1, 2, or 3 you are hydrated**.

If your urine matches the colors numbered **4 through 8 you are dehydrated** and need to drink for more fluid.

Be Aware! If you are taking single vitamin supplements or a multivitamin supplement, some of the vitamins in the supplements can change the color of your urine for a few hours, making it bright yellow or discolored.

http://mc3cb.com/pdf_ap_lecture_s6/C23_6_compostion_properties_urine.pdf


LEUKOCYTES
2 minutes
NEGATIVE
TRACE
SMALL +
MODERATE ++
LARGE +++
NITRITE
60 seconds
NEGATIVE
POSITIVE
POSITIVE
(Any degree of uniform pink color is positive)
UROBILINOGEN
60 seconds
NORMAL 0.2
NORMAL 1
mg/dL 2
4
8
(1 mg = approx. 1EU)
PROTEIN
60 seconds
NEGATIVE
TRACE
mg/dL 30 +
100 ++
300 +++
2000 or more ++++
pH
60 seconds
5.0
6.0
6.5
7.0
7.5
8.0
8.5
BLOOD
60 seconds
NEGATIVE
NON-HEMOLYZED TRACE
NON-HEMOLYZED MODERATE
HEMOLYZED TRACE
SMALL +
MODERATE ++
LARGE +++
SPECIFIC GRAVITY
45 seconds
1.000
1.005
1.010
1.015
1.020
1.025
1.030
KETONE
40 seconds
NEGATIVE
mg/dL
TRACE 5
SMALL 15
MODERATE 40
LARGE 80
LARGE 160
BILIRUBIN
30 seconds
NEGATIVE
SMALL +
MODERATE ++
LARGE +++
GLUCOSE
30 seconds
NEGATIVE
g/dL (%) mg/dL
1/10 (tr.) 100
1/4 250
1/2 500
1 1000
2 or more 2000 or more

Urine formation

Component	Urine	Blood plasma	Blood plasma
Sodium (mEq/l)	147.5		138.4
Potassium	47.5		4.4
Glucose (mg/dL)	0.009	90	90
Proteins	0.000	7500	7500
Urea (mg/dL)	1800.00	305	305
Ammonia	60.00	0.2	0.2

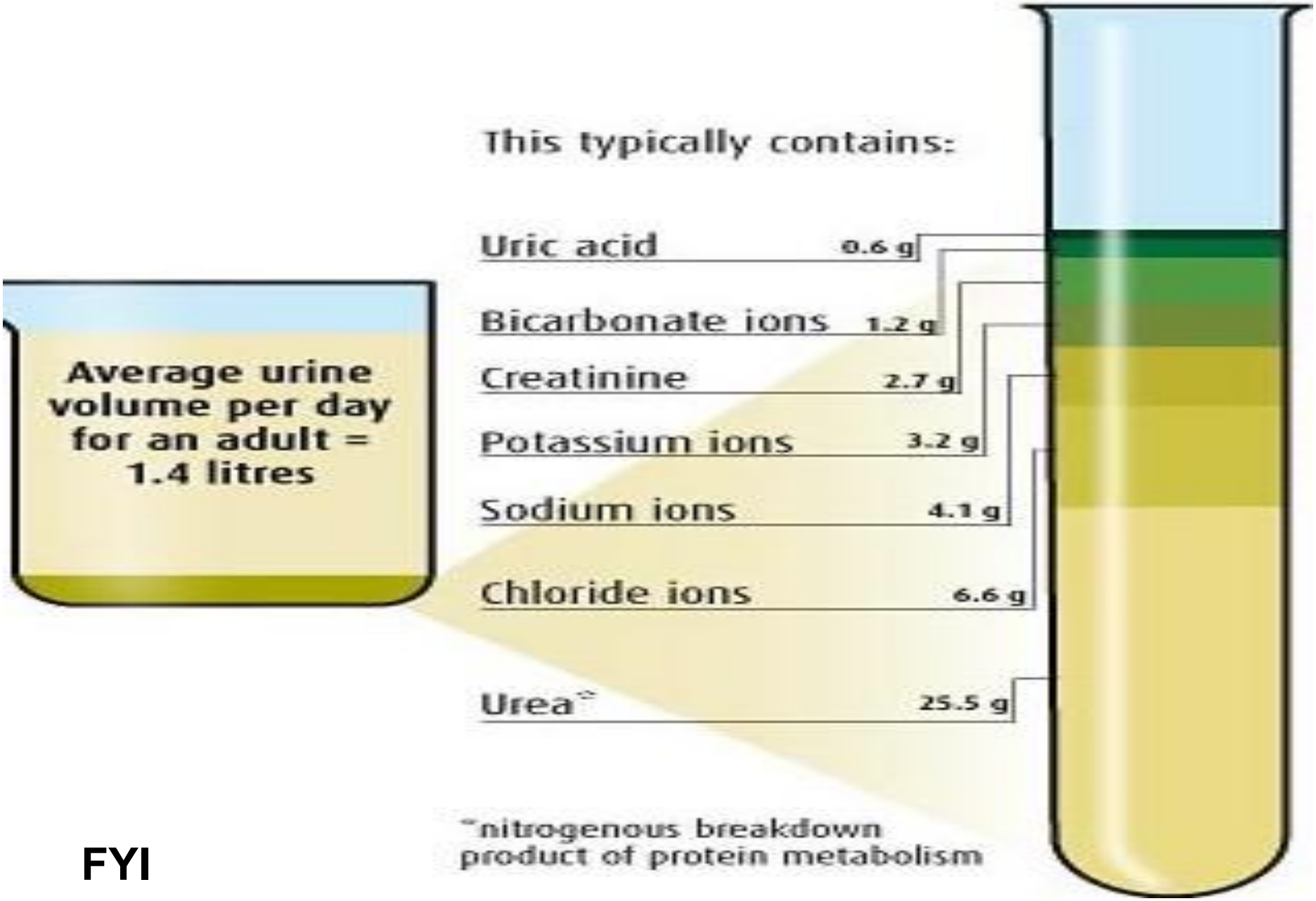
- In healthy people, 100% of glucose is reabsorbed by active transport

- Active transport mechanism have a maximum rate at which they can move substances

- When the maximum threshold is exceeded for people with untreated diabetes,
  - active transport cannot ‘keep up’ to reabsorb back the glucose
  - Excess glucose is excreted in the urine

Chemical Composition of Urine

- Urine is 95% water and 5% solutes
- Nitrogenous wastes include urea, uric acid, and creatinine
- Other normal solutes include:
  - Sodium, potassium, phosphate, and sulfate ions
  - Calcium, magnesium, and bicarbonate ions
- Abnormally high concentrations of any urinary constituents may indicate disease.


Average urine volume per day for an adult = 1.4 litres
This typically contains:
Uric acid 0.6 g
Bicarbonate ions 1.2 g
Creatinine 2.7 g
Potassium ions 3.2 g
Sodium ions 4.1 g
Chloride ions 6.6 g
Urea* 25.5 g
*nitrogenous breakdown product of protein metabolism

FYI

The Stages of Gout Progression

STAGE 1:
High Uric Acid Levels

Uric acid is building up in the blood and starting to form crystals around joints

STAGE 2:
Acute Gout

Symptoms start to occur, causing a painful gout attack

STAGE 3:
Intercritical Gout

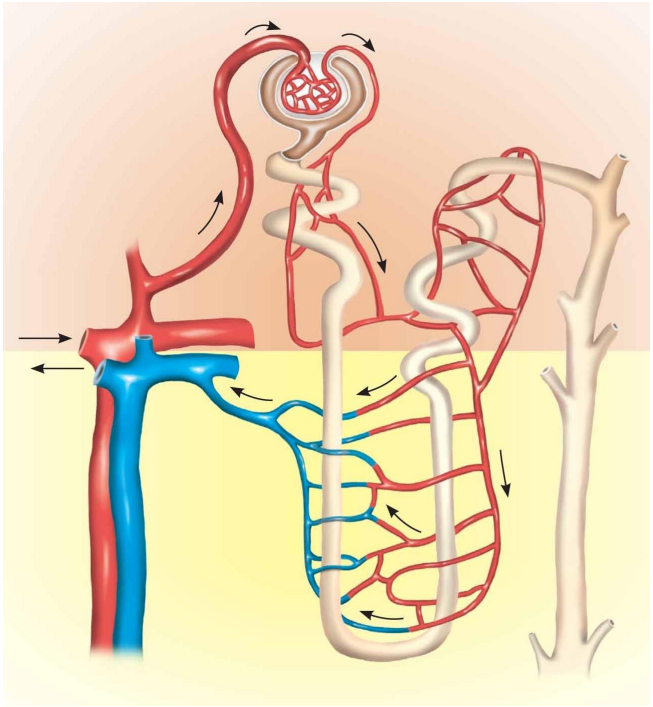
Periods of remission between gout attacks

STAGE 4:
Chronic Gout

Gout pain is frequent and tophi form in joints

Osmoregulation

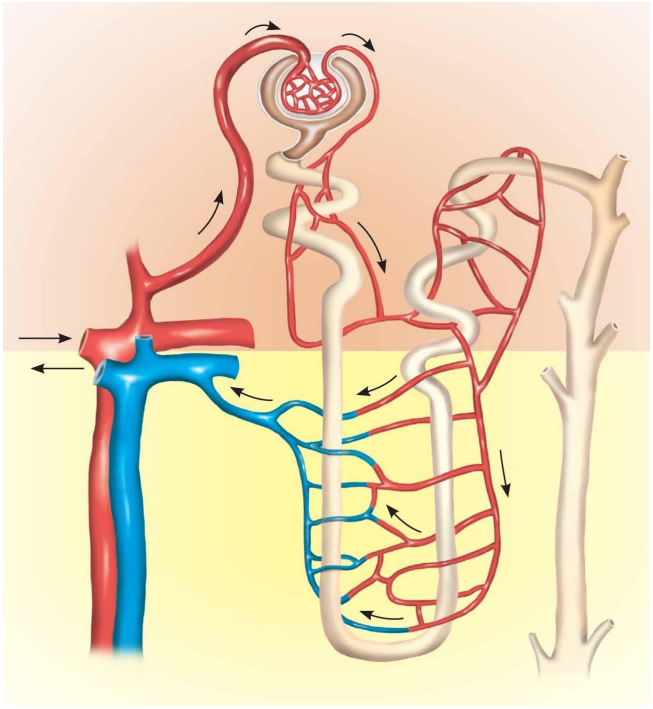
The mechanism of osmoregulation



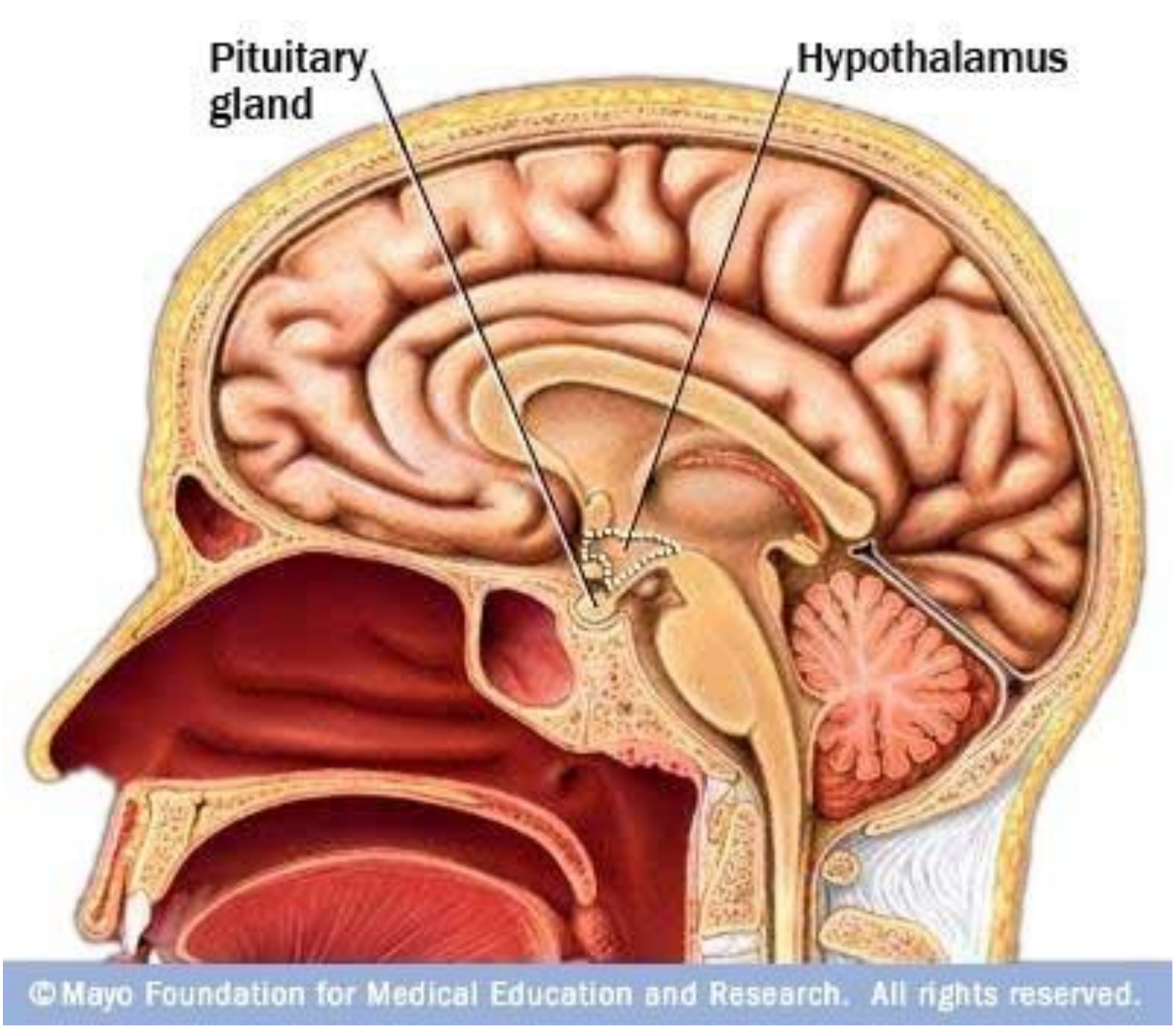
- The amount of water reabsorbed in the kidney tubules is controlled by **ADH**.
- ADH secretion by the **pituitary gland** depends on ‘instructions’ from the hypothalamus.
- The **hypothalamus** has receptors that detect changes in blood water potential.

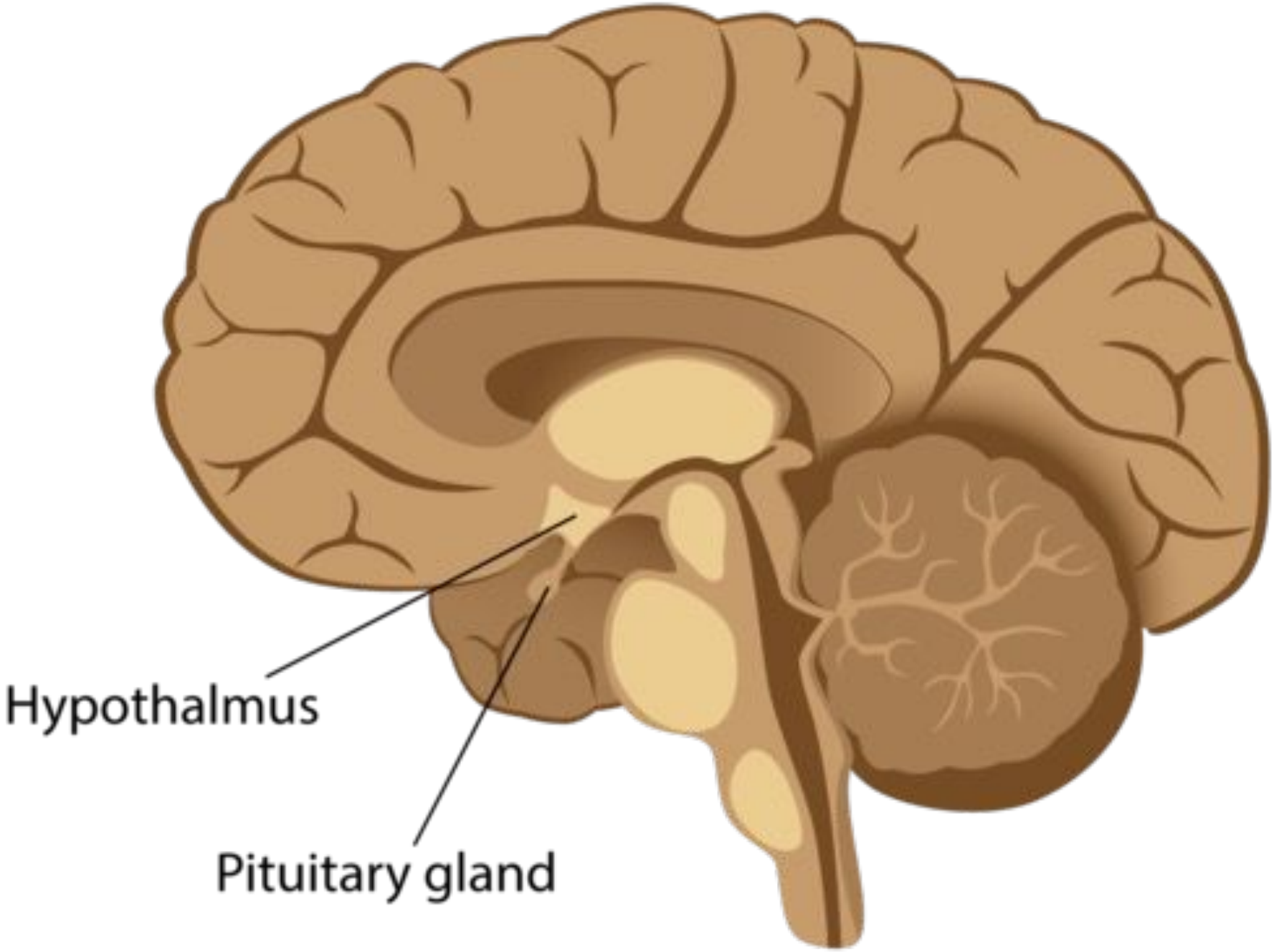
Osmoregulation

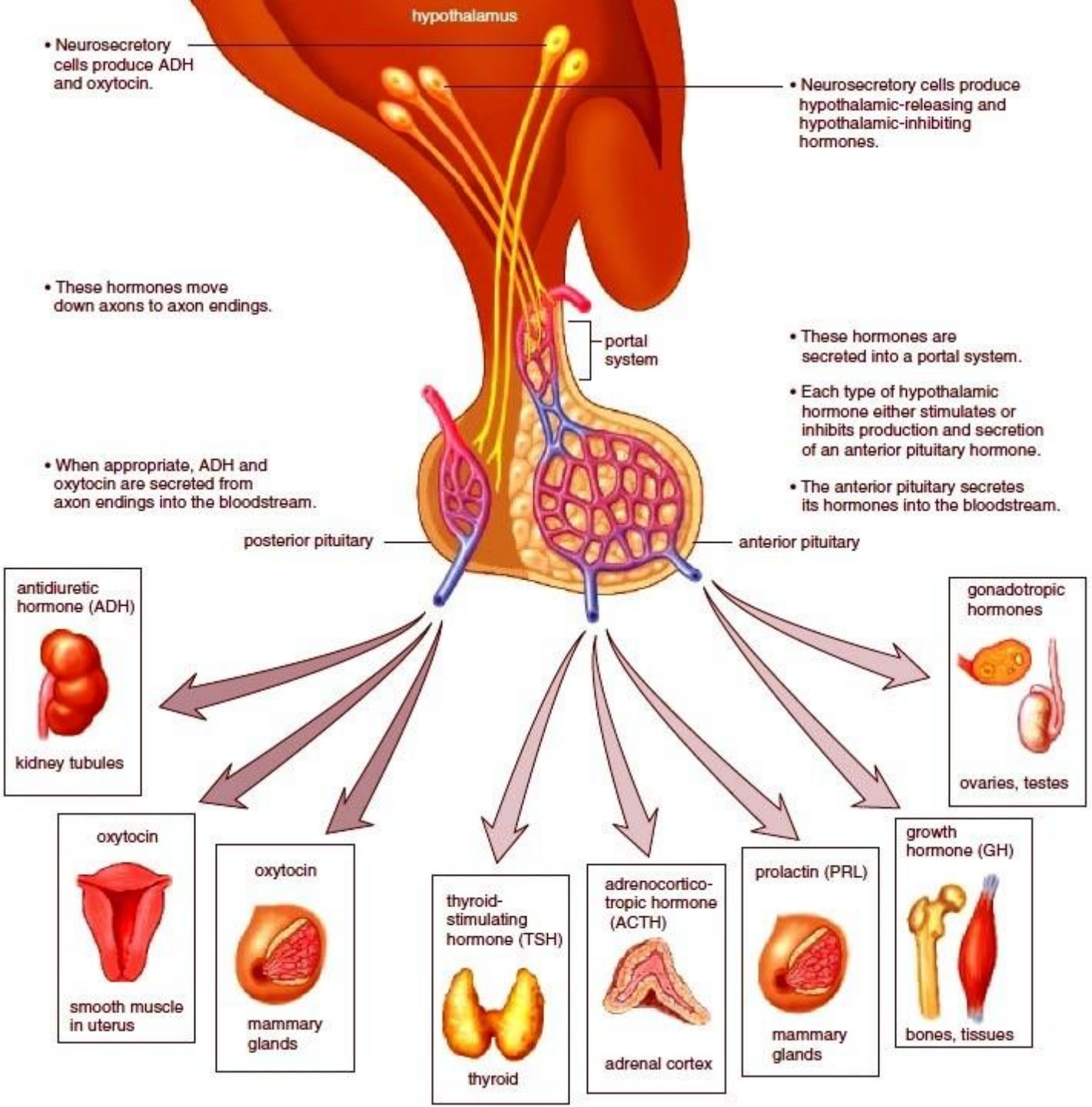
The mechanism of osmoregulation

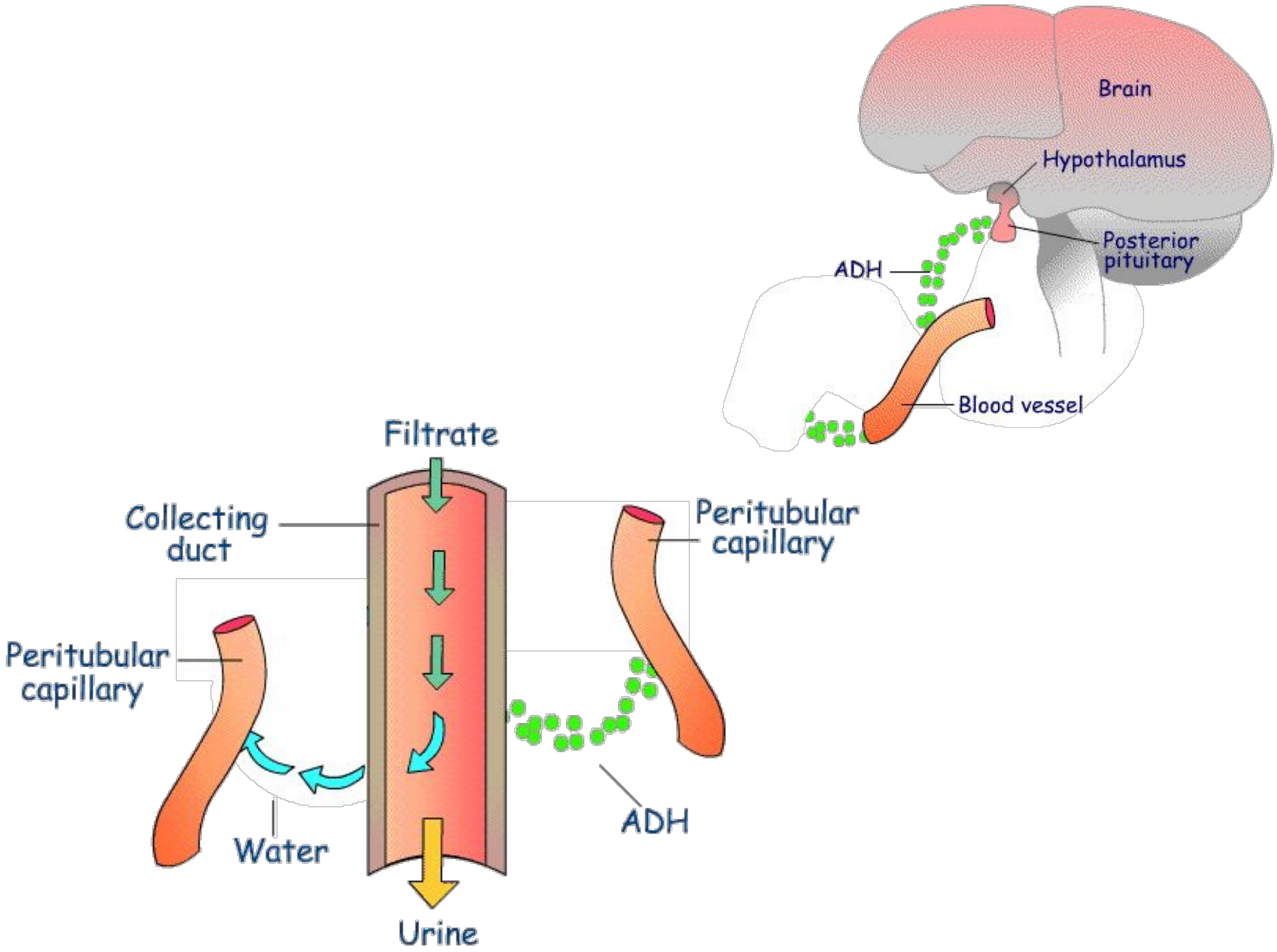


- If there is **excess water** in the blood, less ADH is secreted less water is reabsorbed. The urine excreted is more dilute.
- If the body is **dehydrated**, more ADH is secreted more water reabsorbed. The urine excreted is more concentrated.



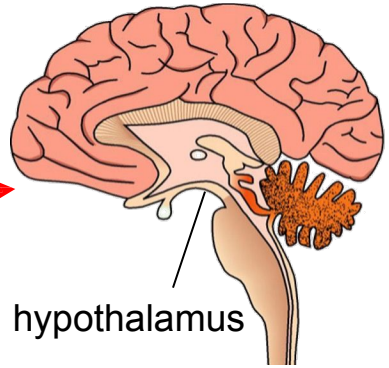

Hypothalmus
Pituitary gland


hypothalamus
• Neurosecretory cells produce ADH and oxytocin.
• Neurosecretory cells produce hypothalamic-releasing and hypothalamic-inhibiting hormones.
• These hormones move down axons to axon endings.
portal system
• These hormones are secreted into a portal system.
• Each type of hypothalamic hormone either stimulates or inhibits production and secretion of an anterior pituitary hormone.
• The anterior pituitary secretes its hormones into the bloodstream.
• When appropriate, ADH and oxytocin are secreted from axon endings into the bloodstream.
posterior pituitary
anterior pituitary
antidiuretic hormone (ADH)
kidney tubules
gonadotropic hormones
ovaries, testes
oxytocin
smooth muscle in uterus
oxytocin
mammary glands
thyroid-stimulating hormone (TSH)
thyroid
adrenocortico-tropic hormone (ACTH)
adrenal cortex
prolactin (PRL)
mammary glands
growth hormone (GH)
bones, tissues


Brain
Hypothalamus
Posterior pituitary
ADH
Blood vessel
Filtrate
Collecting duct
Peritubular capillary
Peritubular capillary
Water
ADH
Urine

Osmoregulation

Osmoregulation (excess water)



stimulates

causes

Water potential of plasma **increases**

Pituitary gland secretes **less ADH**

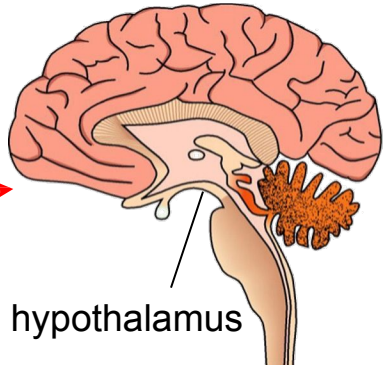
Large intake of water (e.g. drinking)

Water potential of plasma returns to **normal** level

Kidney tubules (DCT and collecting duct) **reabsorb less water**

Osmoregulation

Osmoregulation (dehydration)



stimulates

causes

Water potential of plasma **decreases**

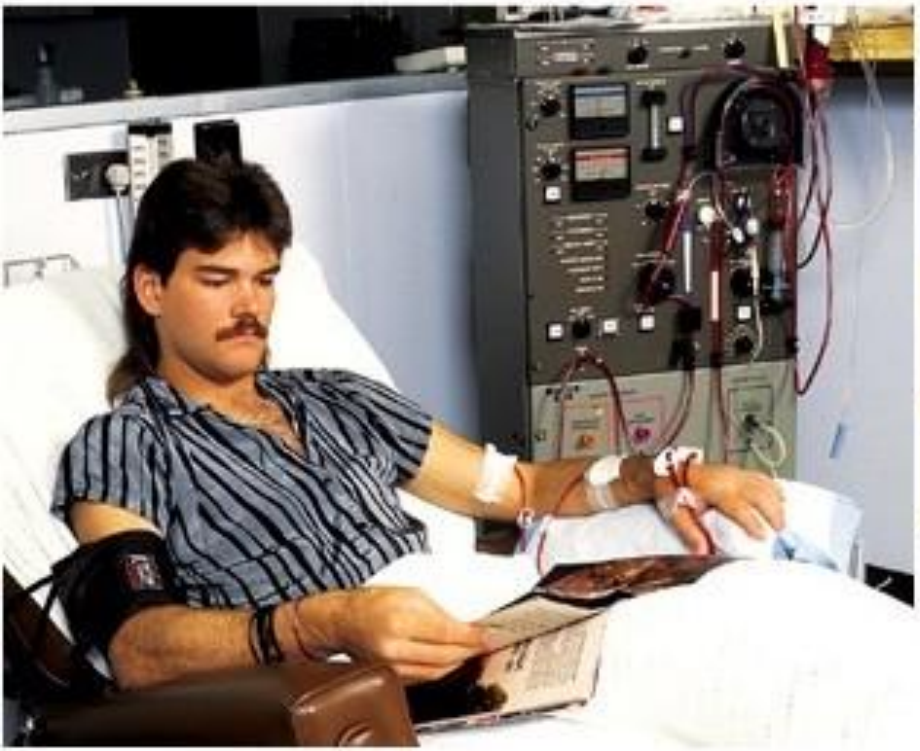
Pituitary gland secretes **more ADH**

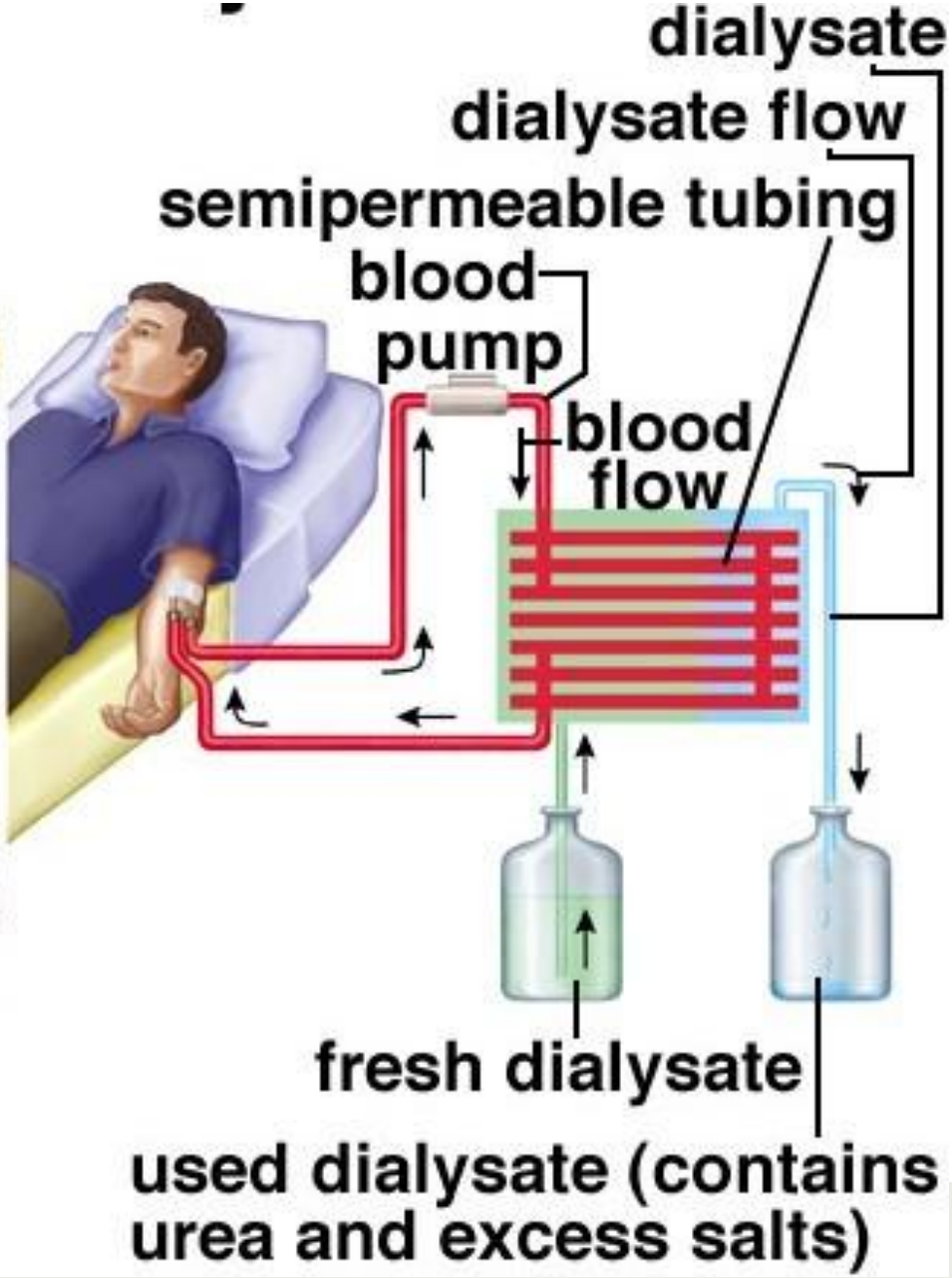
Loss of water through sweating

Kidney tubules (DCT and collecting duct) **reabsorb more water**

Water potential of plasma returns to **normal** level

How Is Blood Cleaned in a Dialysis Machine?





8.5 Kidney Failure

How dialysis works

1. Blood is drawn from a **vein** in the patient's arm

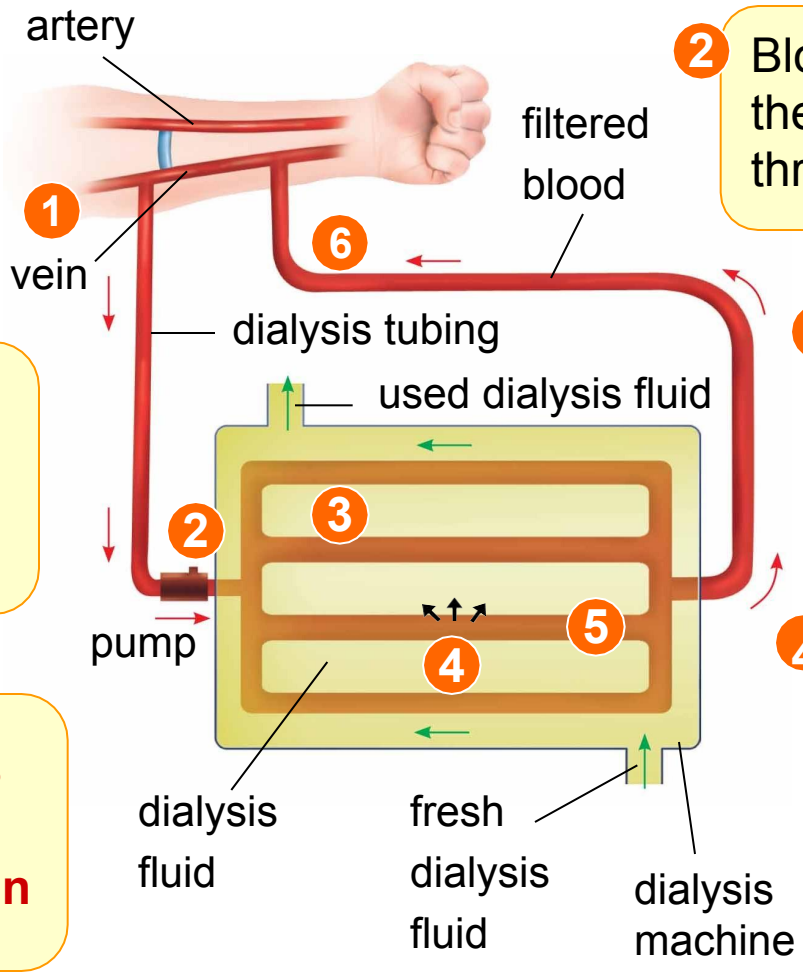
2. Blood is pumped into the dialysis machine through a tubing

3. The tubing is bathed in a **dialysis fluid** and the tubing is **partially-permeable**

4. **Small molecules** (e.g. urea) and metabolic waste products **diffuse** out of the tubing

5. **Larger molecules** (e.g. platelets and blood cells) **remain** in the tubing

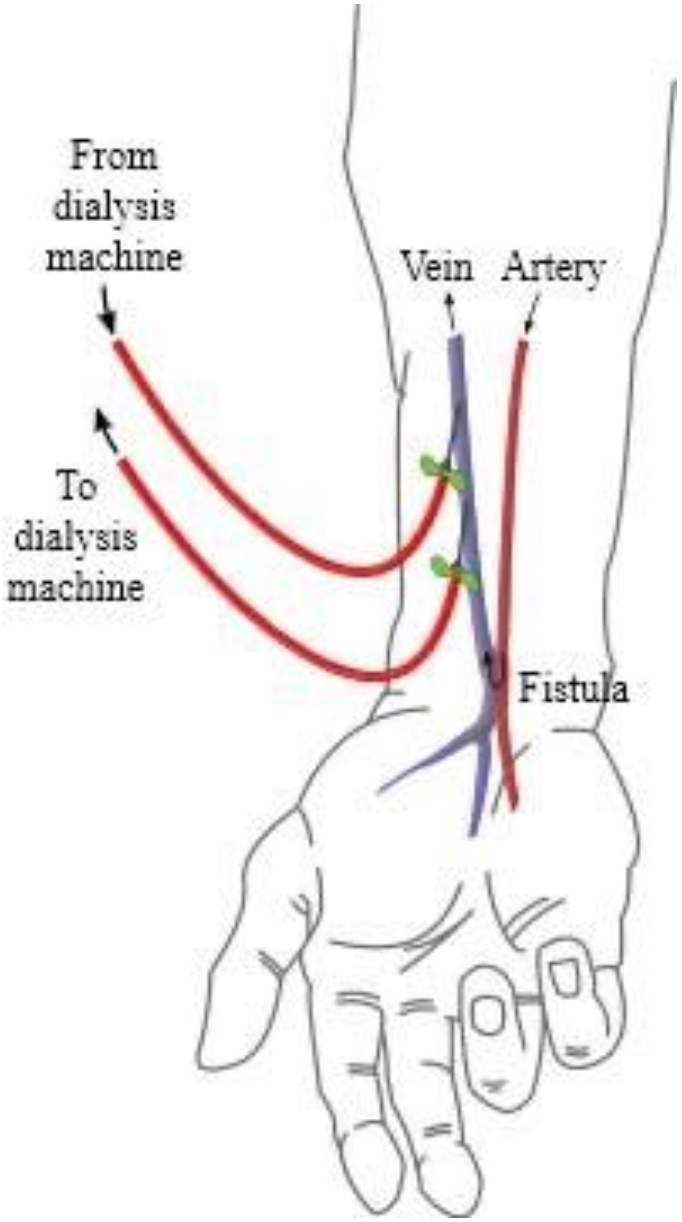
6. The **filtered blood** is returned to a **vein** in the patient's arm



How Is Blood Cleaned in a Dialysis Machine?

- **Kidney dialysis**
  - Process of removing excess fluids and toxins from the blood
    - by continually shunting the patient's blood from the body into a dialysis machine
    - (with a system of partially permeable membrane tubings surrounded by dialysis fluid) for filtering,
    - and then returning the clean blood to the patient's bloodstream
  - Usually 3 treatments a week, 3 – 4 hours at a time
  - May be performed at dialysis center or at home

- These days, a fistula is inserted in a forearm via minor surgery.
- This forms a direct connection of an artery to a vein.
- So, blood is drawn from the vein and filtered blood is returned to the vein.



Extra

- Blood pressure in artery is higher than vein.
- As more blood at higher pressure flows into the vein, the vein becomes larger and stronger over time.
- Increased blood flow through the vein allows a greater amount of blood to pass through the dialysis machine.
- This allows filtration to occur at a pace that enables all the blood to be filtered in a shorter period of time.

How Is Blood Cleaned in a Dialysis Machine?

- Dialysis membrane
  - partially permeable membrane
  - for diffusion of small molecules (eg. urea, water, mineral salts, other waste products)
  - ensures large molecules (eg. Proteins) are not lost.
  - long narrow coiled tubing
    - increases surface area to vol ratio
    - increases diffusion of wastes products

How Is Blood Cleaned in a Dialysis Machine?

- Dialysis fluid
  - essential salt & glucose solution
  - prevents diffusion of salts & glucose from blood into fluid
    - no loss of salts from blood.
  - no urea, uric acid & creatinine (waste products)
    - increases concentration gradient of wastes for faster diffusion

How Is Blood Cleaned in a Dialysis Machine?

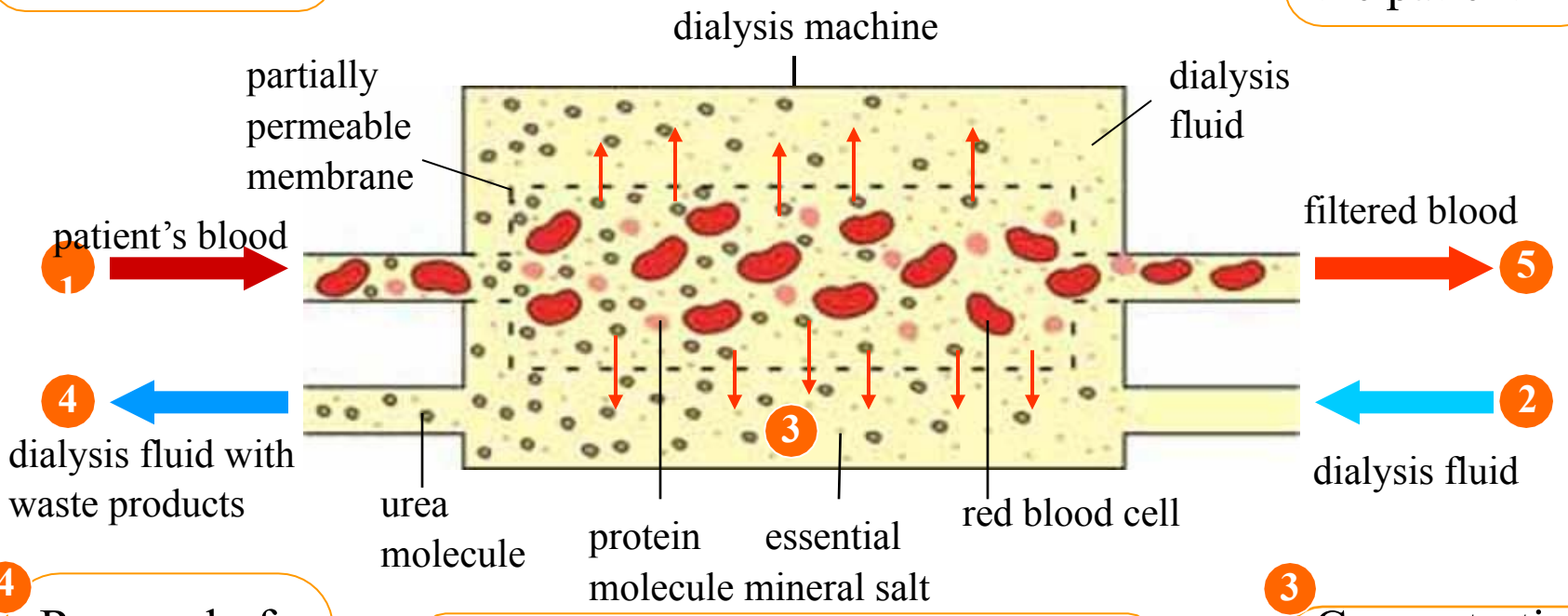
- Direction of blood flow is opposite to the flow of dialysis fluid.
  - maintains the concentration gradient for removal (diffusion) of waste products
- Constant temperature bath
  - maintains temperature of blood returning to body at 36.9° C
- Blood pump
  - moves blood through dialysis machine

Exchange of Substances between the Blood and the Dialysis Fluid

1 Patient's blood enters dialysis machine

2 Dialysis fluid contains the same concentration of essential substances as blood. No metabolic wastes present

5 Filtered blood is returned to the patient



4 Removal of metabolic waste products from the blood

Blood flows in the opposite direction to flow of dialysis fluid

3 Concentration gradient set up between dialysis fluid and blood