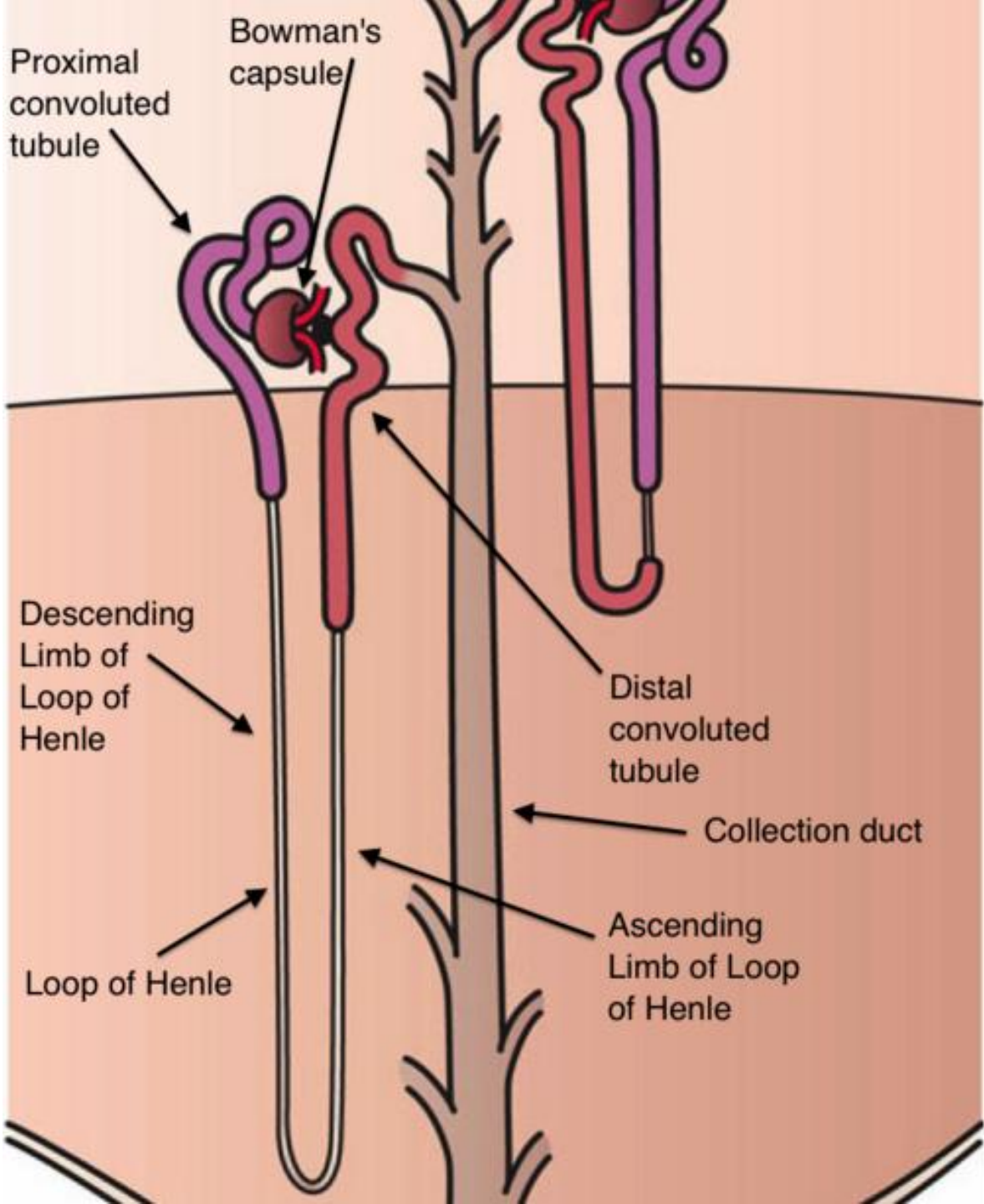
DP Biology – D3.3 (HL extension)

The kidney and blood flow

- How do humans keep internal conditions constant?
- Why is it useful for organisms to keep internal conditions constant?

HL statements D3.3.7–11. Textbook pp. 768–778.
Image: a nephron. Holly Fischer, CC BY 3.0.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	D3.3.7–8	Distinguish excretion from osmoregulation, and explain ultrafiltration and selective reabsorption
2	D3.3.9–10	Explain how the loop of Henle and ADH let the kidney control water reabsorption
3	D3.3.11	Explain how blood supply to organs changes with sleep, rest and exercise

Excretion and osmoregulation

D3.3.7

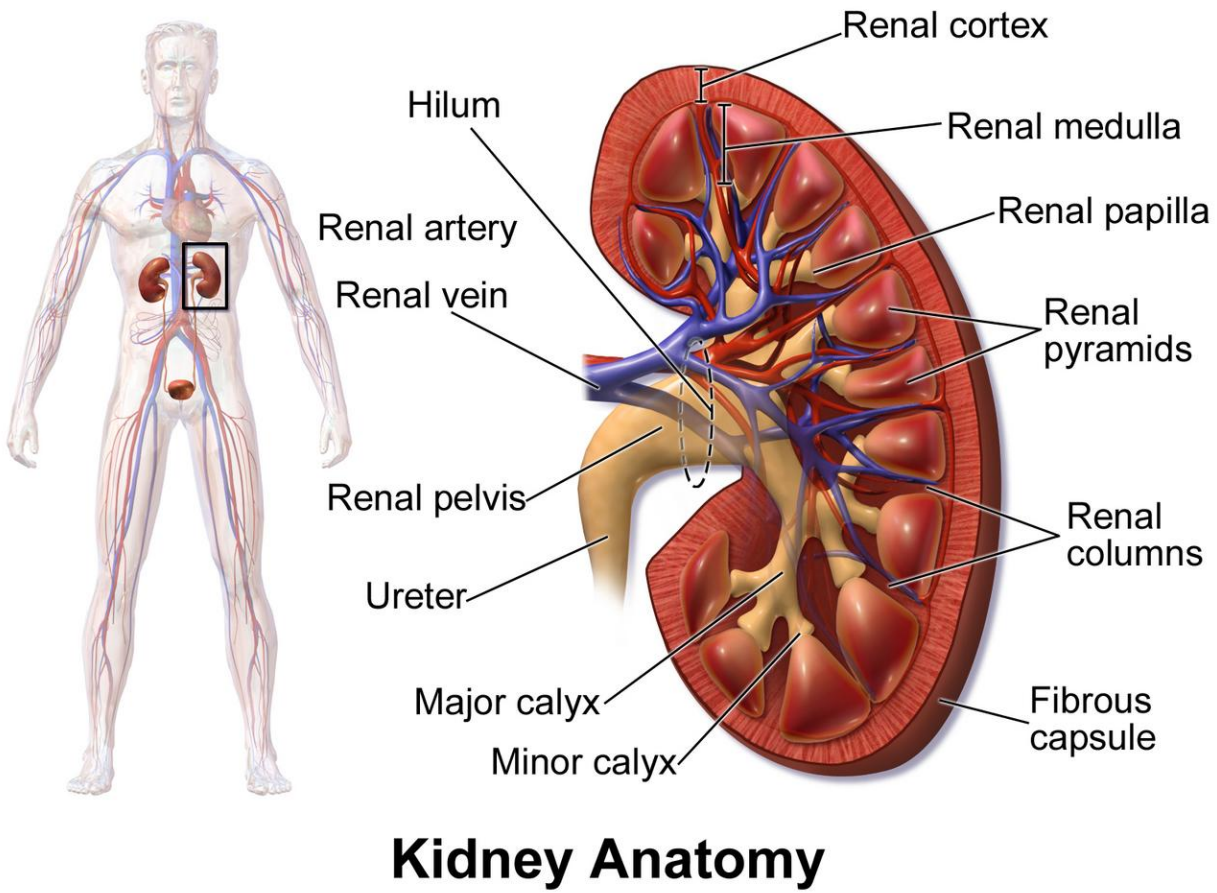
	Excretion	Osmoregulation
Meaning	Removing waste products of metabolism	Controlling the osmotic concentration of body fluids
Main example	Urea, made in the liver from excess amino acids	Keeping blood plasma at about 0.3 osmol L^{-1}
In the kidney	Urea and toxins are filtered and left in the urine	The volume of water reabsorbed is varied

Osmotic concentration

Measured in osmoles per litre (osmol L^{-1}): the total concentration of dissolved particles. Too high and cells lose water by osmosis; too low and they swell. The kidney keeps it steady even though we drink and sweat different amounts each day.

The kidney

D3.3.7



Kidney anatomy. BruceBlaus, CC BY 3.0.

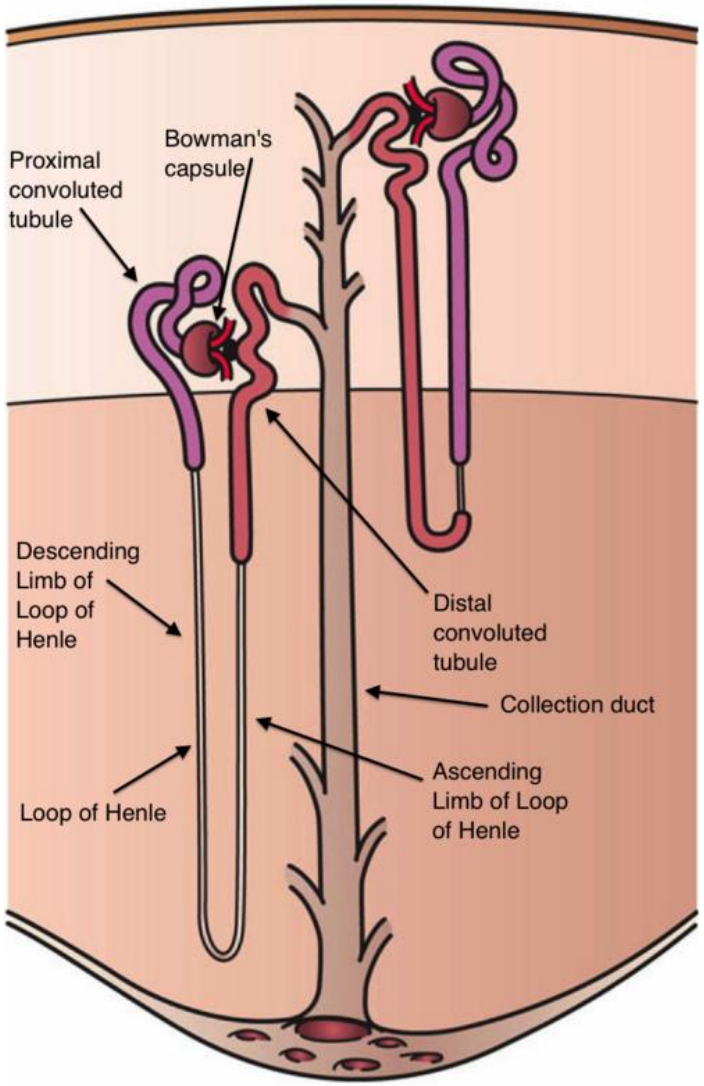
- **Renal artery** brings blood; **renal vein** takes it away
- Outer **cortex** and inner **medulla**
- About a million **nephrons** in each kidney
- Urine collects in the pelvis and leaves through the **ureter** to the bladder

Scale

About 180 dm^3 of filtrate a day becomes about 1.5 dm^3 of urine.

The nephron

D3.3.8



1. **Glomerulus**: a knot of capillaries at high pressure
2. **Bowman's capsule**: the cup around it, where filtrate collects
3. **Proximal convoluted tubule**: most reabsorption
4. **Loop of Henle**: dips into the medulla
5. **Distal convoluted tubule**: fine adjustment
6. **Collecting duct**: water reabsorption, then to the pelvis

Blood supply

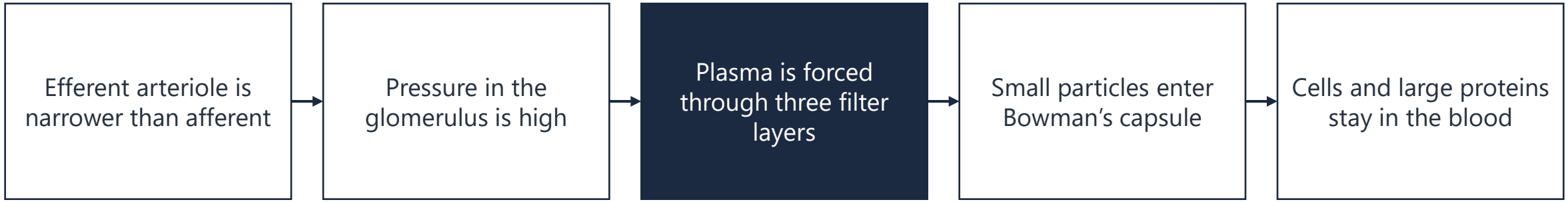
Afferent arteriole in, narrower efferent arteriole out, then capillaries around the tubules.

A nephron. Holly Fischer, CC BY 3.0.

D3.3 Homeostasis (HL) – Textbook pp. 771–772

Ultrafiltration

D3.3.8



Filter layer	Feature
Capillary wall	Fenestrations (pores about 100 nm) let fluid through but not blood cells
Basement membrane	A gel of glycoproteins: the true filter, holding back most proteins
Podocytes	Cells of the capsule wall with foot-like branches around the capillaries; narrow slits between them

Key idea

Filtration is by size, not usefulness: glucose and urea are filtered alike.

What is filtered?

In the filtrate	Approx. per day
Water	180 dm^3
Sodium and chloride ions	1.5 kg as salt
Glucose	180 g
Amino acids	50 g
Urea	55 g

Approximate values for a healthy adult.

Not filtered
Red and white blood cells
Platelets
Plasma proteins such as albumin

Try it

Urine holds about 1.5 dm^3 of water, 30 g of urea and no glucose. Calculate the percentage of the filtered water and urea that is reabsorbed.

Selective reabsorption in the proximal tubule

D3.3.8

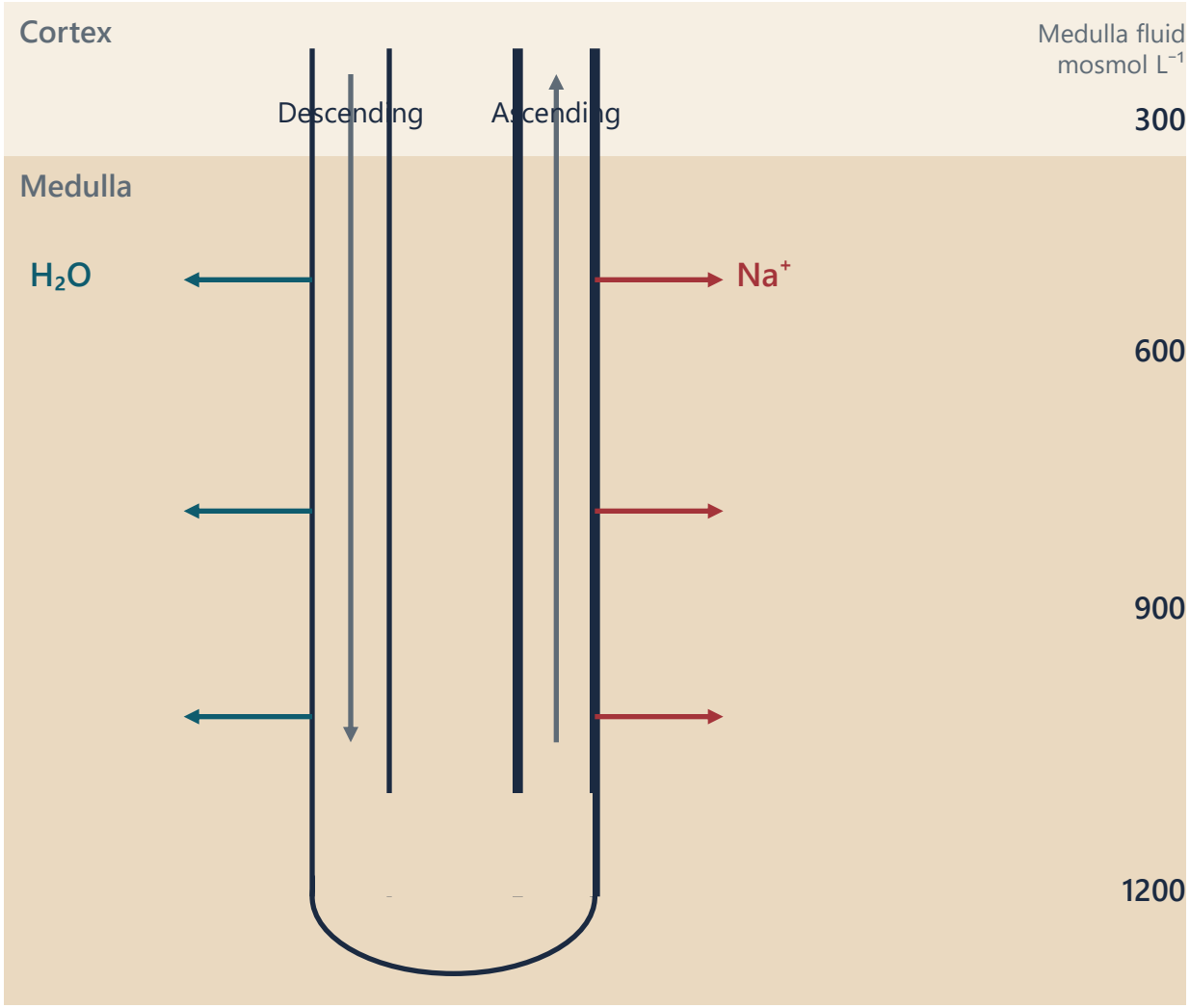
Substance	How it returns to the blood
Na^+	Pumped out of the tubule cells by active transport
Glucose, amino acids	Co-transport with Na^+; all of the glucose normally
Chloride and other ions	Follow Na^+ by diffusion and active transport
Water	Osmosis, following the solutes
Urea	About half diffuses back; the rest stays

- Wall cells have **microvilli**: large surface area
- Many **mitochondria**: ATP for pumps
- Tight junctions stop leaks between cells
- Close to capillaries

Result

About two thirds of the water and salt, and all the glucose, are reclaimed here. Toxins and much of the urea stay in the filtrate.

The loop of Henle



Simplified. Thick lines: wall impermeable to water.

- **Ascending limb**: Na^+ is pumped out by active transport; the wall is impermeable to water
- So the fluid of the medulla becomes very concentrated, rising with depth
- **Descending limb**: permeable to water, which leaves by osmosis
- The concentrated medulla later draws water out of the **collecting ducts**

Link

Desert mammals have longer loops and more concentrated urine.

ADH and the collecting duct

D3.3.10



Dehydrated

Blood is too concentrated, so ADH secretion rises. More aquaporins sit in the membrane facing the filtrate, so more water is reabsorbed: a small volume of concentrated urine.

Drank a lot

Blood is too dilute, so ADH secretion falls. Aquaporins are taken back into vesicles inside the cells, so the duct wall lets little water through: a large volume of dilute urine.

Osmoregulation by negative feedback

D3.3.10

	Blood too concentrated	Blood too dilute
ADH secretion	Increases	Decreases
Aquaporins	Moved into the cell membrane	Moved back into vesicles
Water reabsorbed	More	Less
Urine	Small volume, concentrated	Large volume, dilute
Effect on blood	Becomes more dilute	Becomes more concentrated

Key idea

Each response reverses the change that caused it: negative feedback (D3.3.2).

Where does the blood go?

D3.3.11

Organ	Sleep	Wakeful rest	Hard exercise
Skeletal muscle	0.8	1.2	21
Gut	1.6	1.4	0.5
Brain	0.75	0.75	0.85
Kidneys	1.1	1.1	0.6
Total output of heart	5	5.8	25

Approximate blood flow in L min^{-1} for a young adult. Values vary between people.

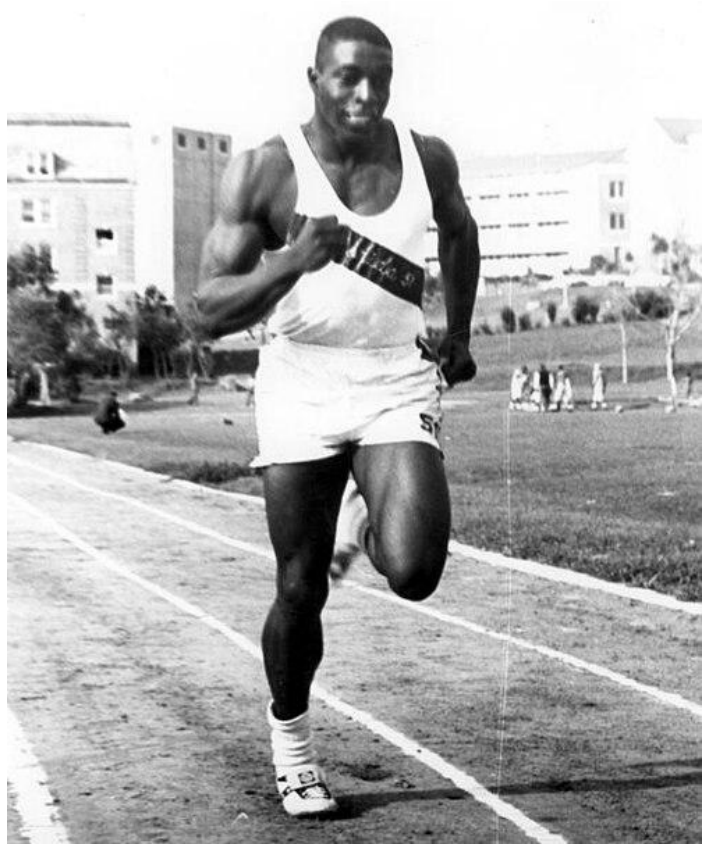
- Exercise: flow to muscle rises about twenty times
- Brain flow stays nearly constant
- Gut and kidney flow fall during exercise

Try it

Calculate the percentage of cardiac output going to muscle at rest and during exercise.

Redirecting blood

D3.3.11



Athlete training on a track, 1960s. Florida Memory, public domain.

- Arterioles have rings of smooth muscle
- **Vasodilation**: the muscle relaxes, widening the arteriole and raising flow
- **Vasoconstriction**: the muscle contracts, narrowing it and cutting flow
- In exercise, arterioles to muscle dilate and those to the gut constrict; heart rate and stroke volume rise
- In sleep, flow to muscle falls and digestion continues

Why keep brain and kidney flow steady?

The brain needs a constant glucose and oxygen supply; the kidneys must keep filtering to control blood composition.

Check that you can explain

1. The difference between excretion and osmoregulation
2. How ultrafiltration happens in the glomerulus and Bowman’s capsule
3. How the proximal tubule reabsorbs useful substances
4. How the loop of Henle makes the medulla concentrated
5. How ADH and aquaporins control water reabsorption in the collecting duct
6. How blood supply to muscle, gut, brain and kidneys changes with activity

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Distinguish between excretion and osmoregulation.
2. State the role of active transport in the ascending limb of the loop of Henle.
3. Explain how ADH reduces the volume of urine.

Image credits

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Blausen 0592 KidneyAnatomy 01.png – BruceBlaus – CC BY 3.0

FAMU athlete Robert Hayes practices running on the track.jpg – Florida Memory – Public domain

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