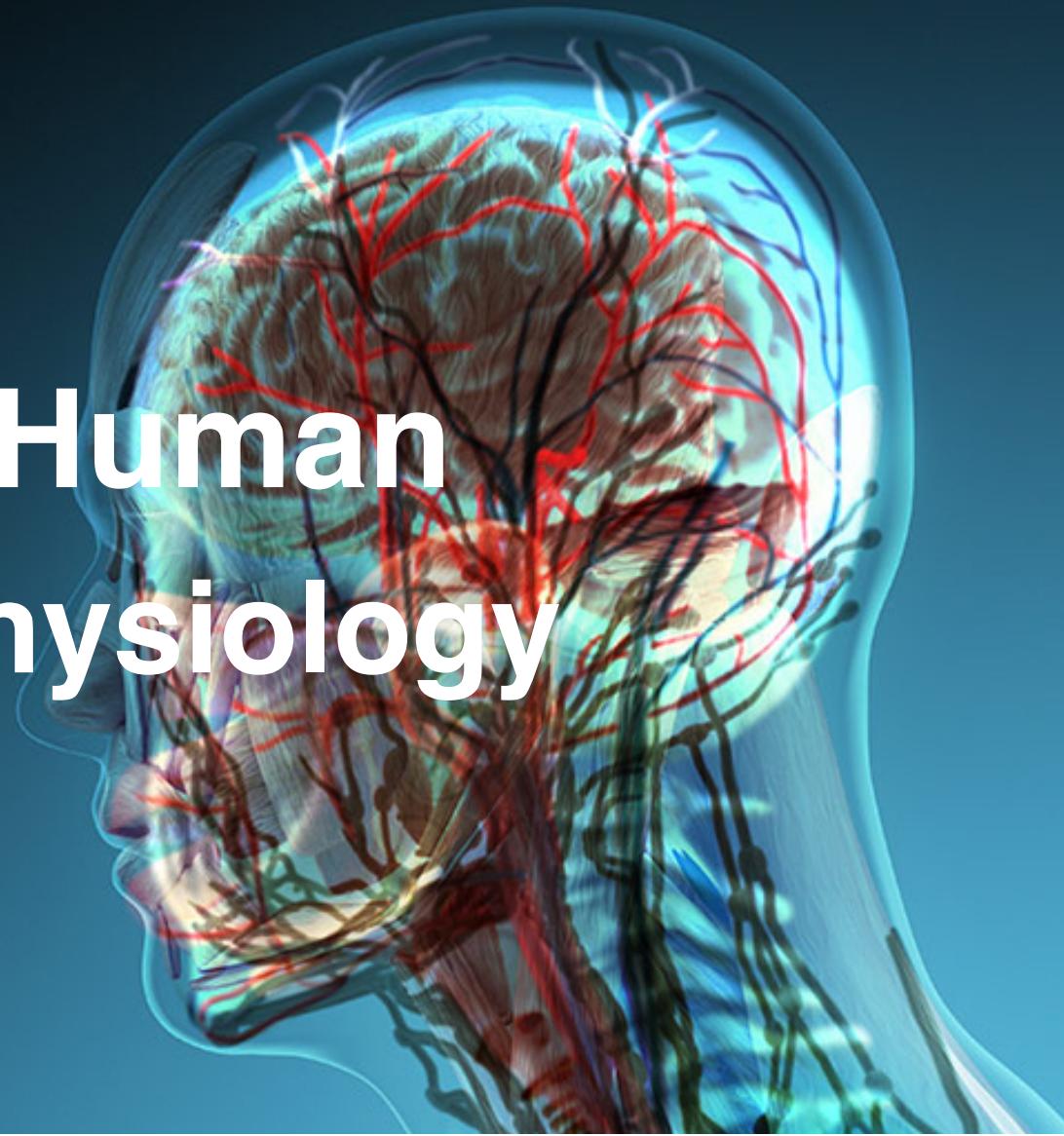
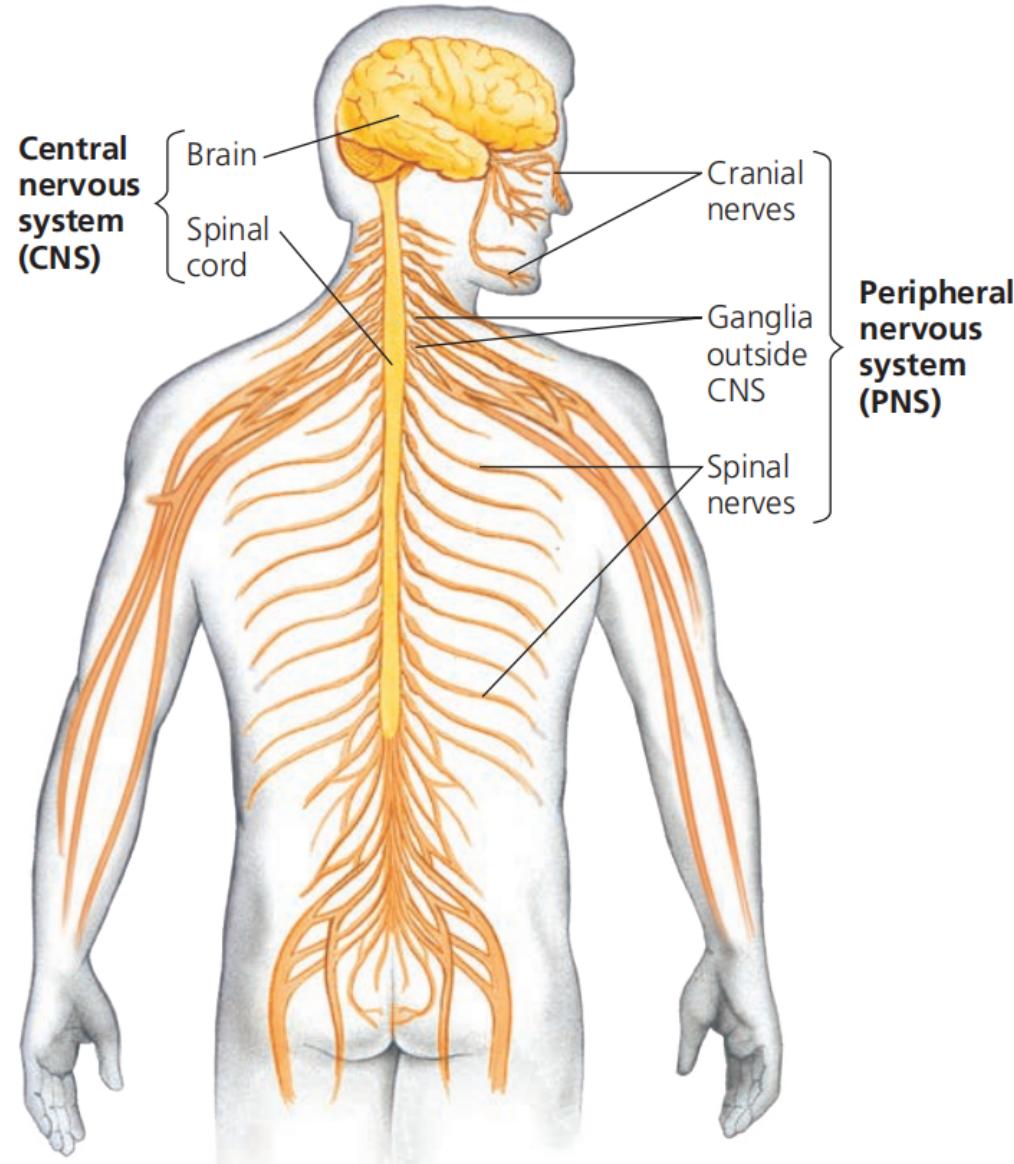
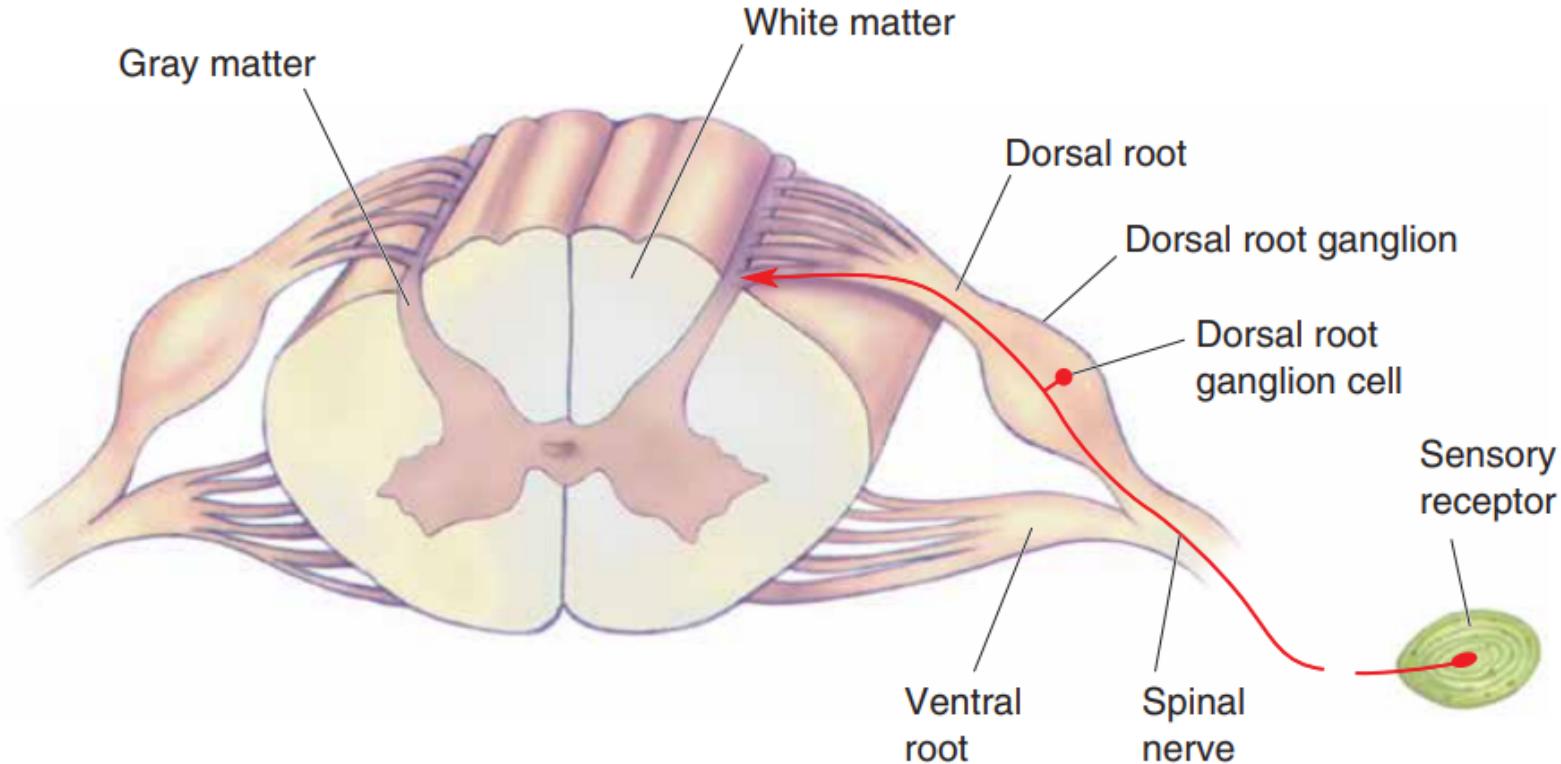


Human Physiology

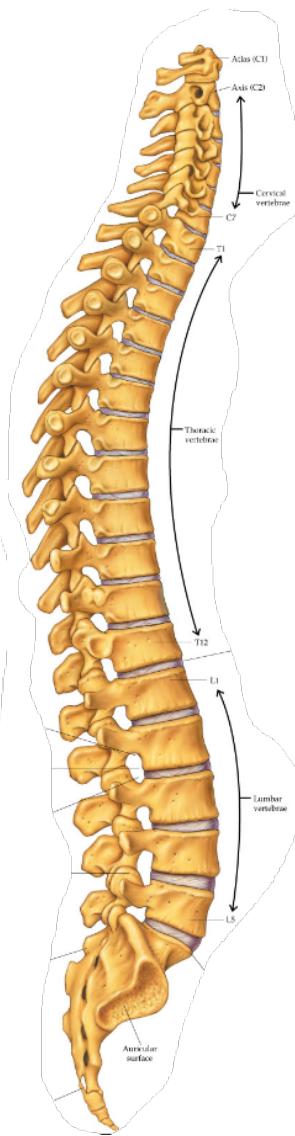
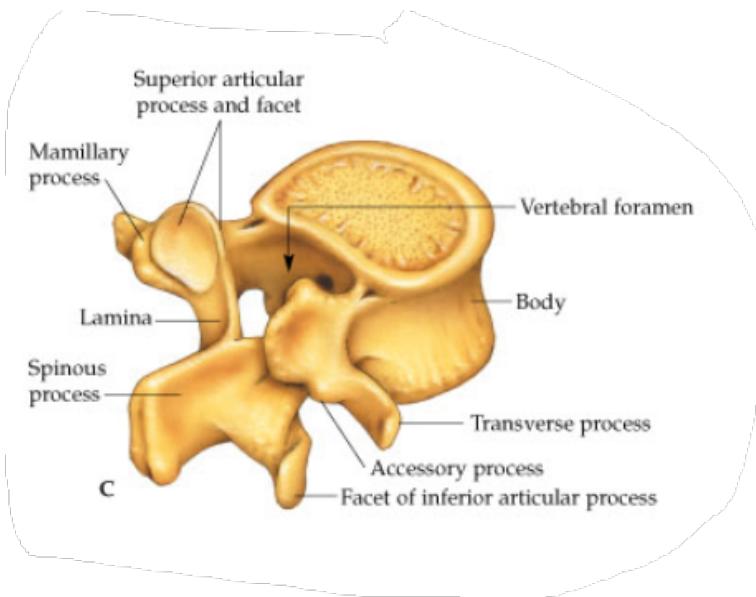


Nervous system



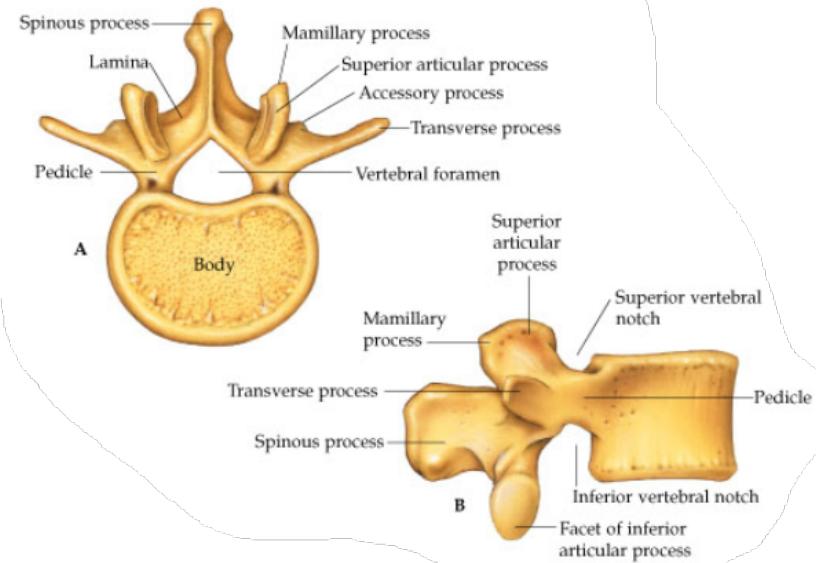


Nervous system

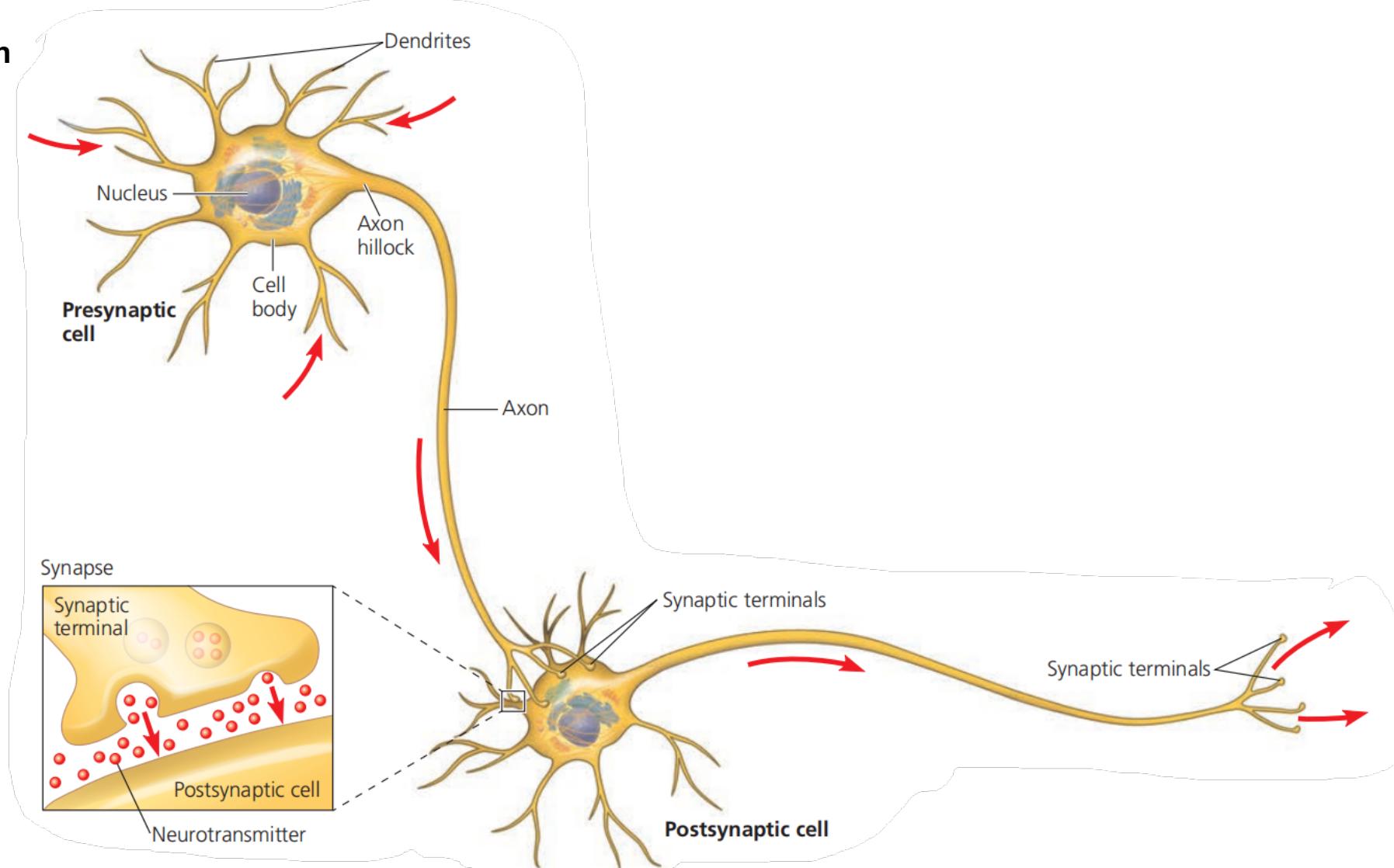


Second Lumbar Vertebra

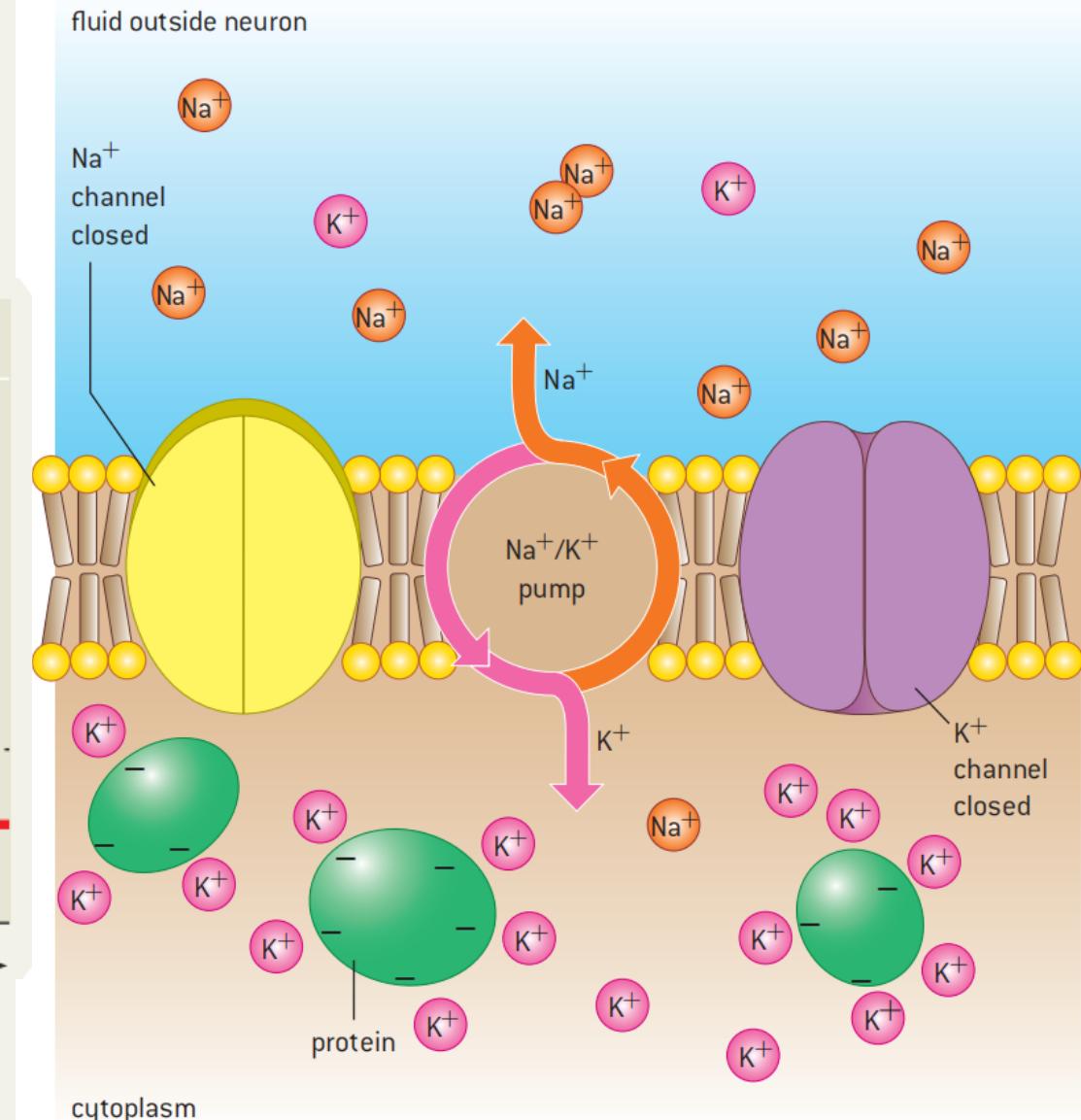
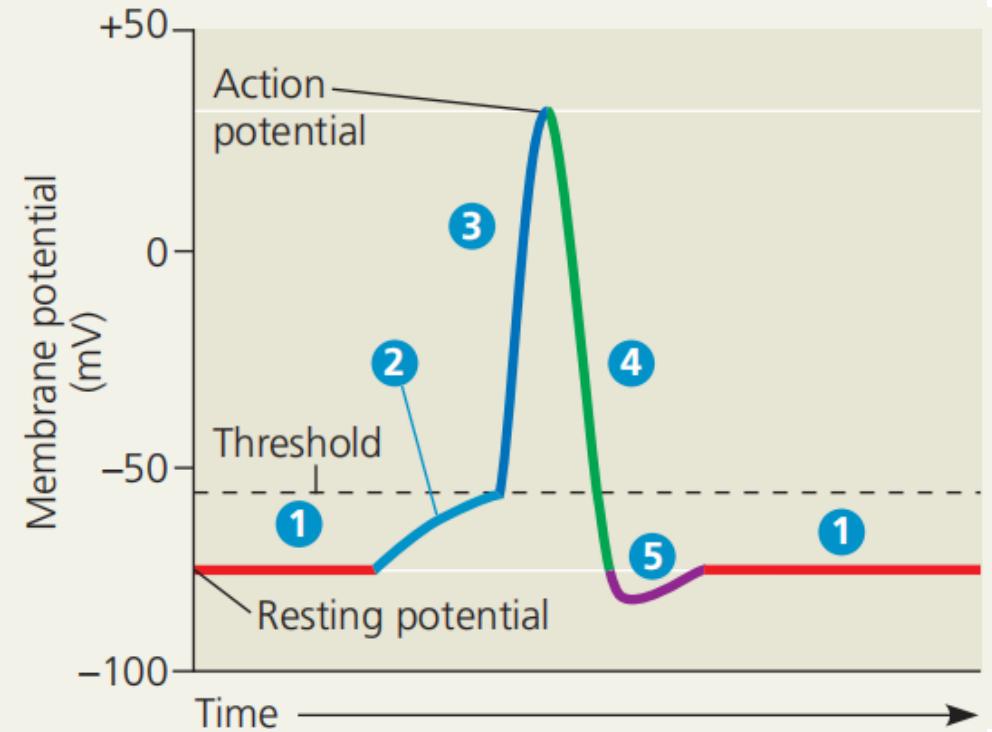
A—Superior view, B—Lateral view, C—Posterolateral oblique view



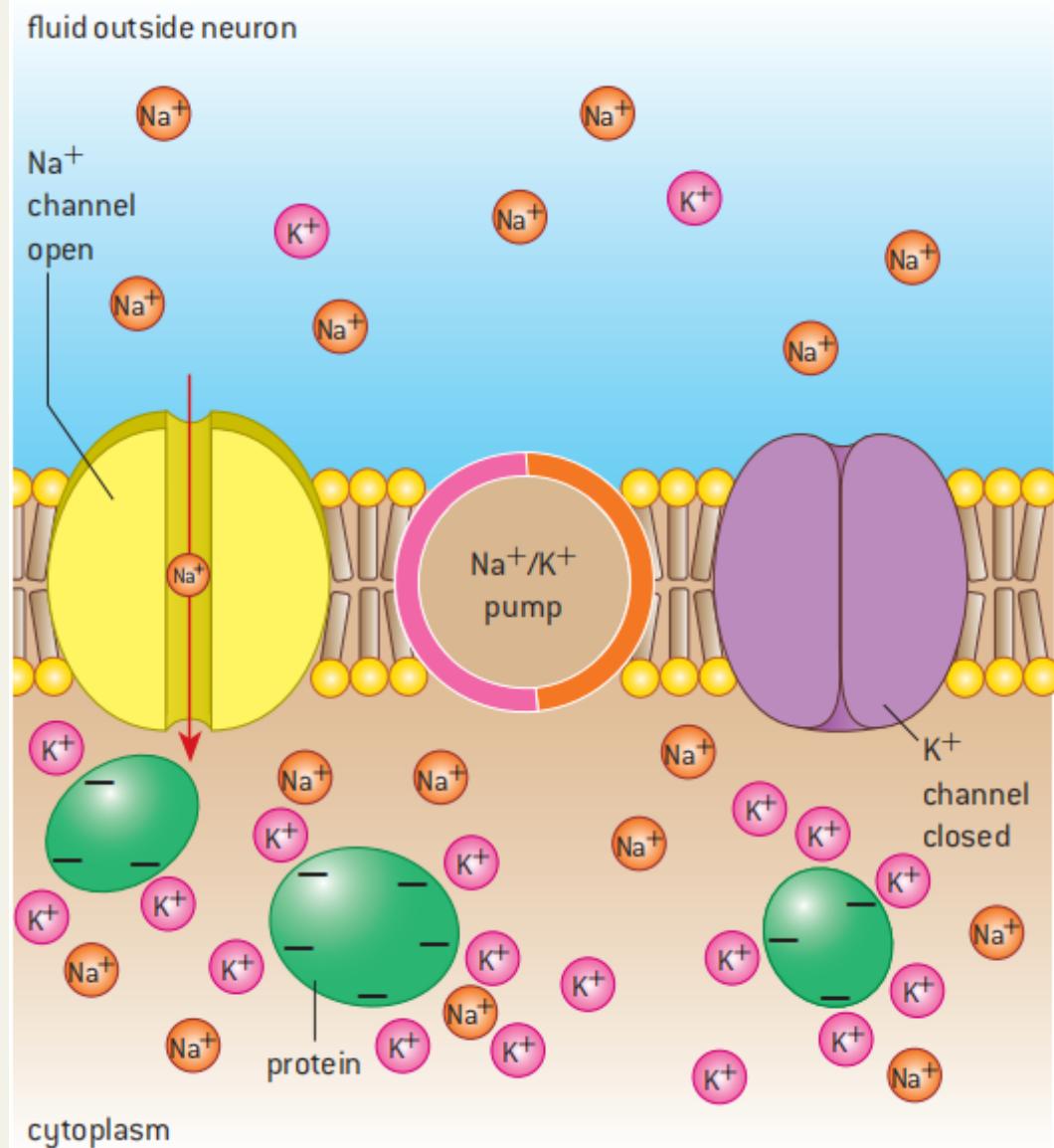
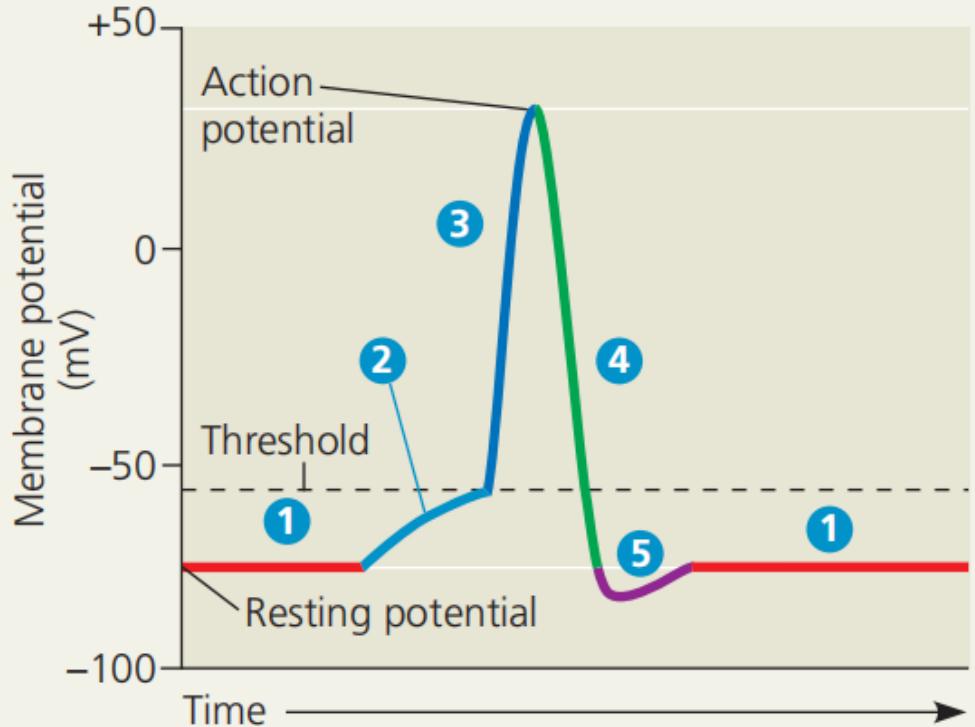
Neuron



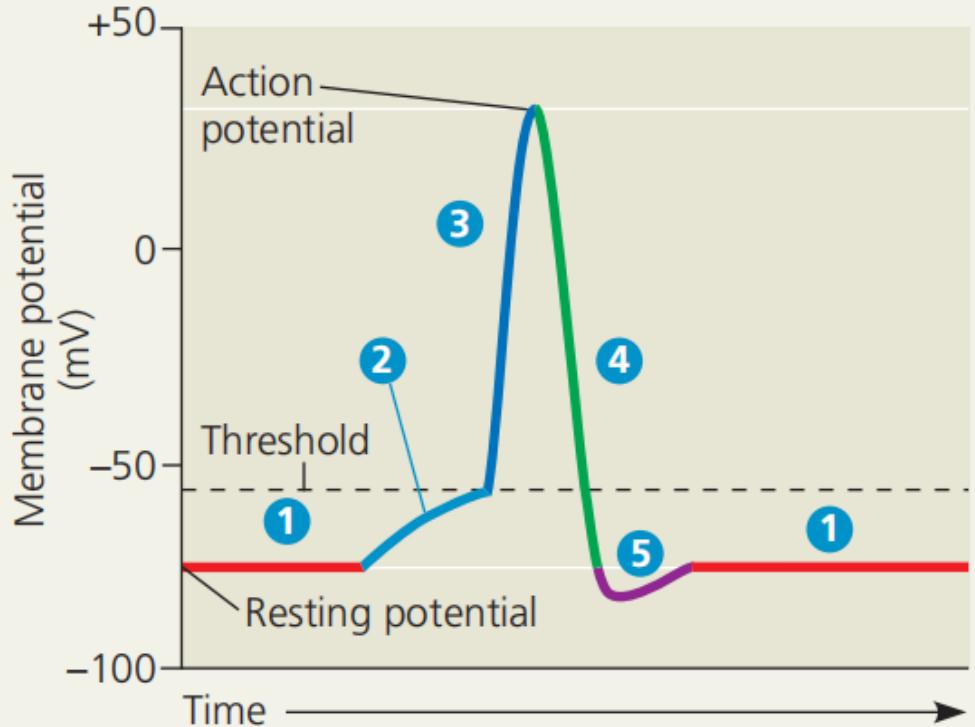
Membrane potential



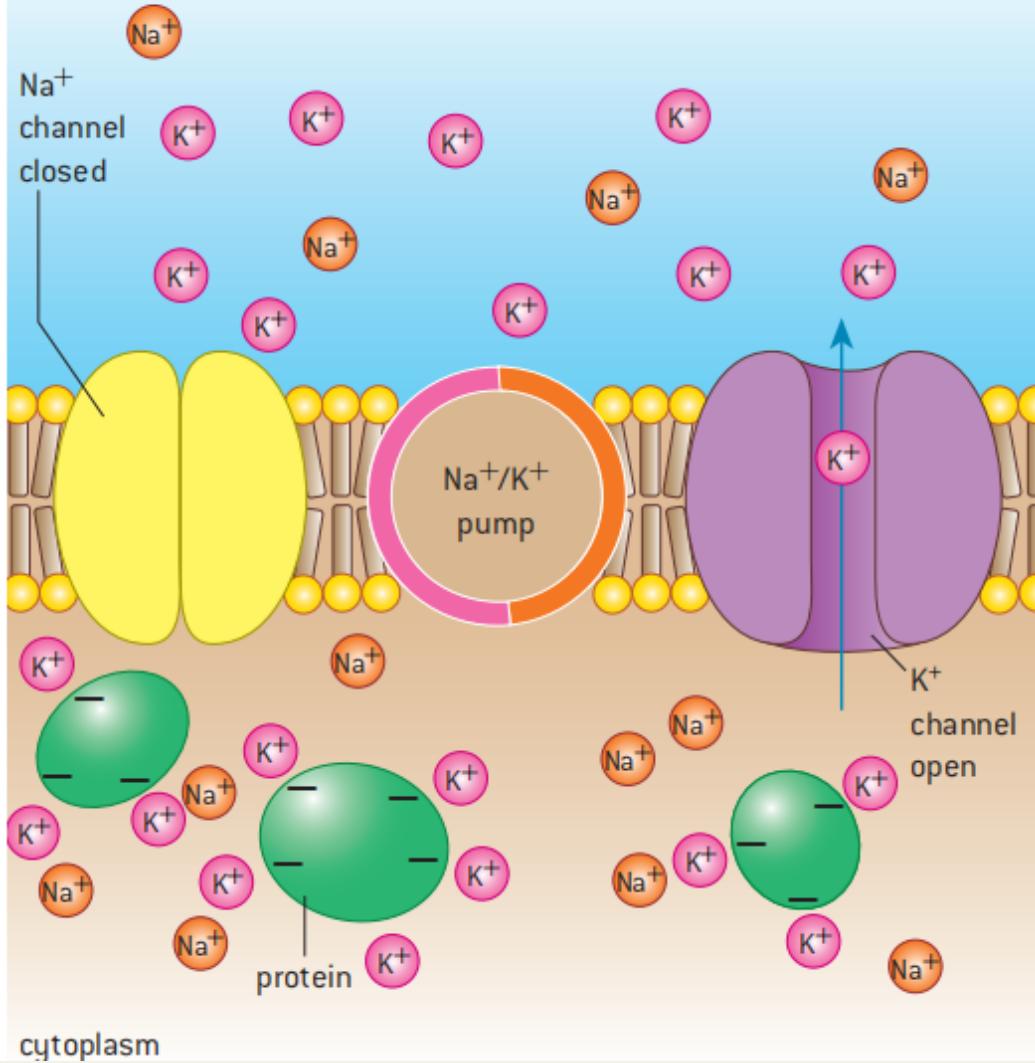
Membrane potential



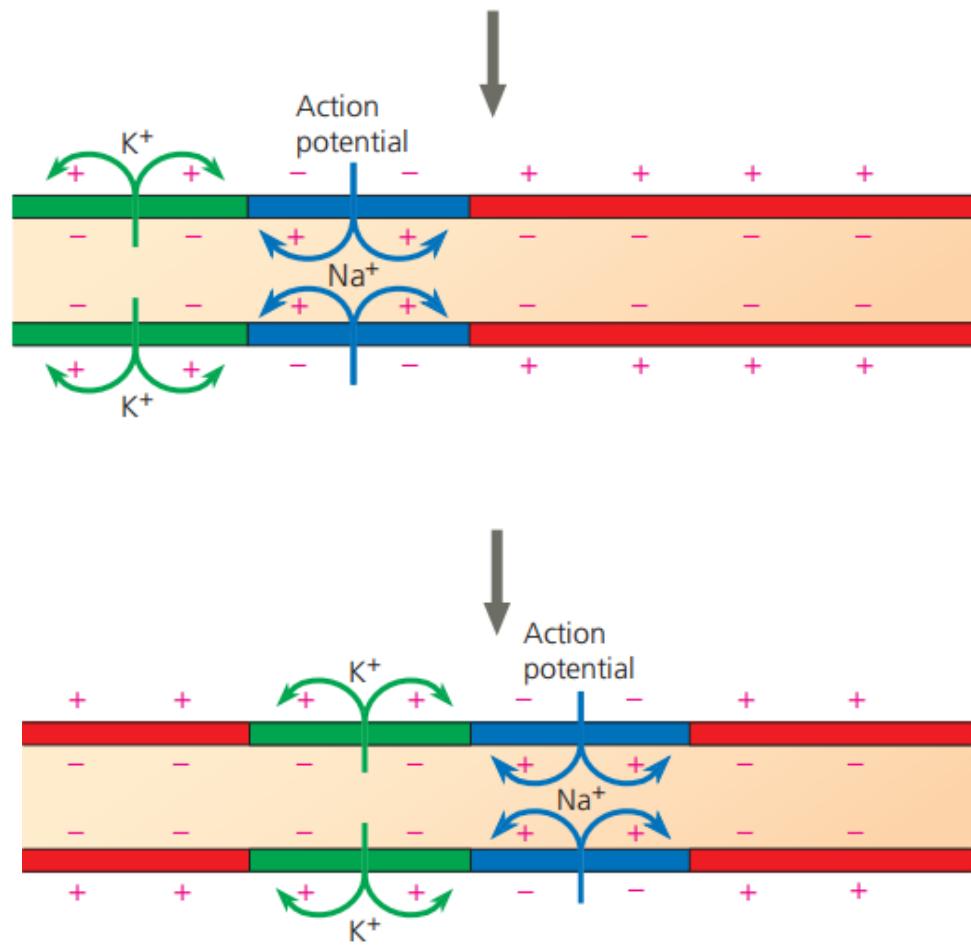
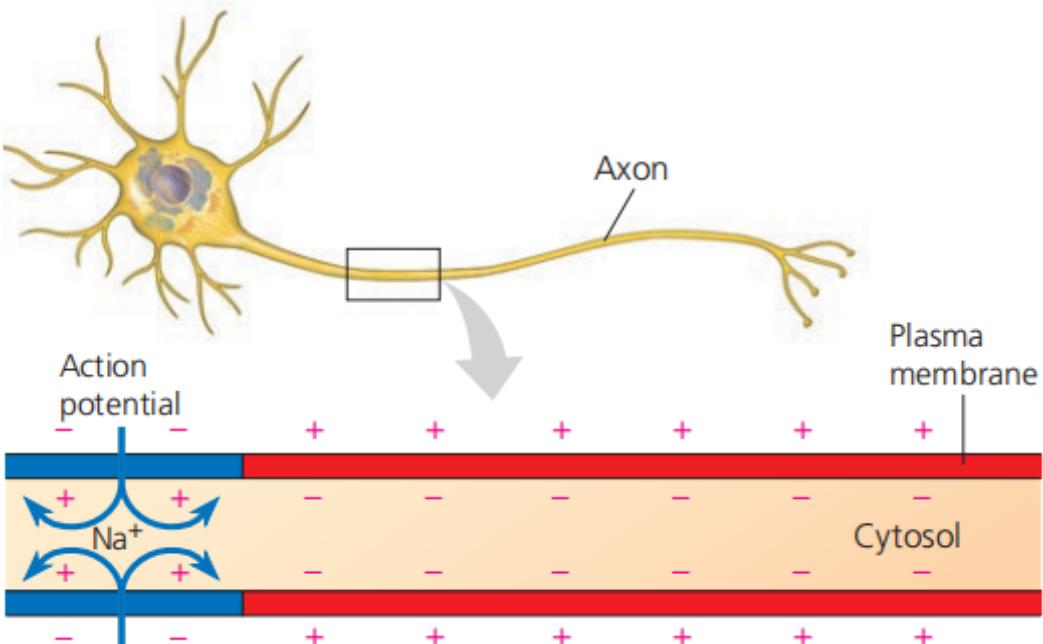
Membrane potential



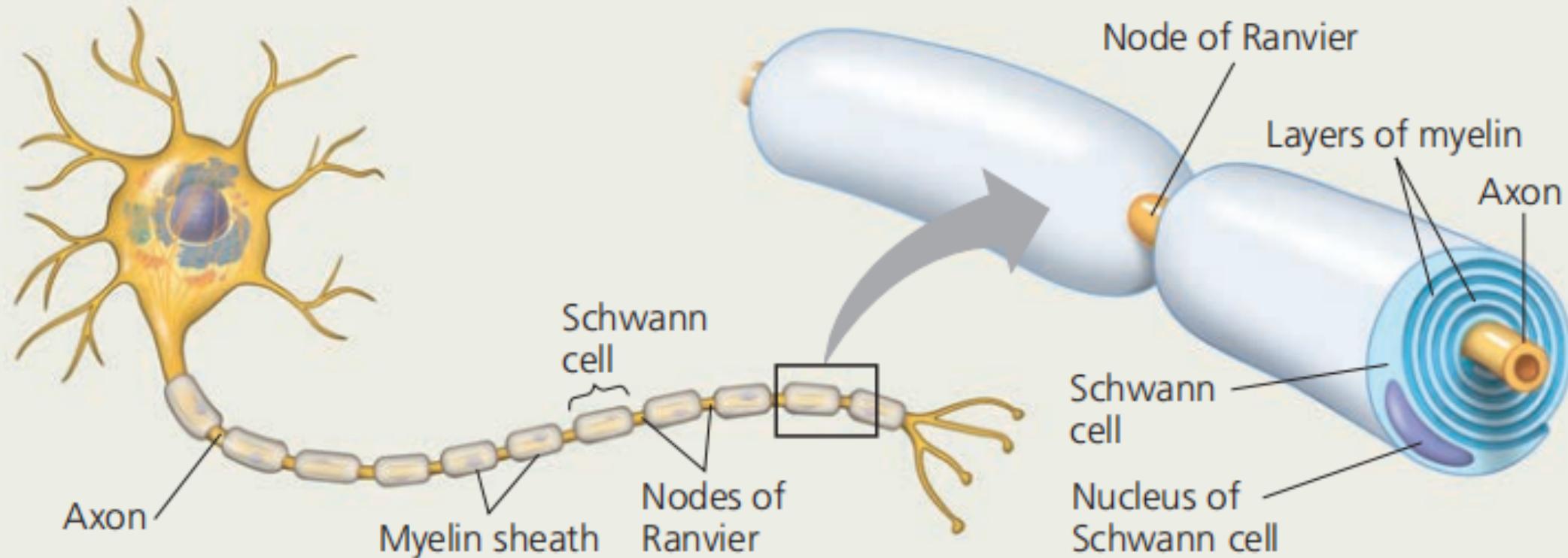
fluid outside neuron



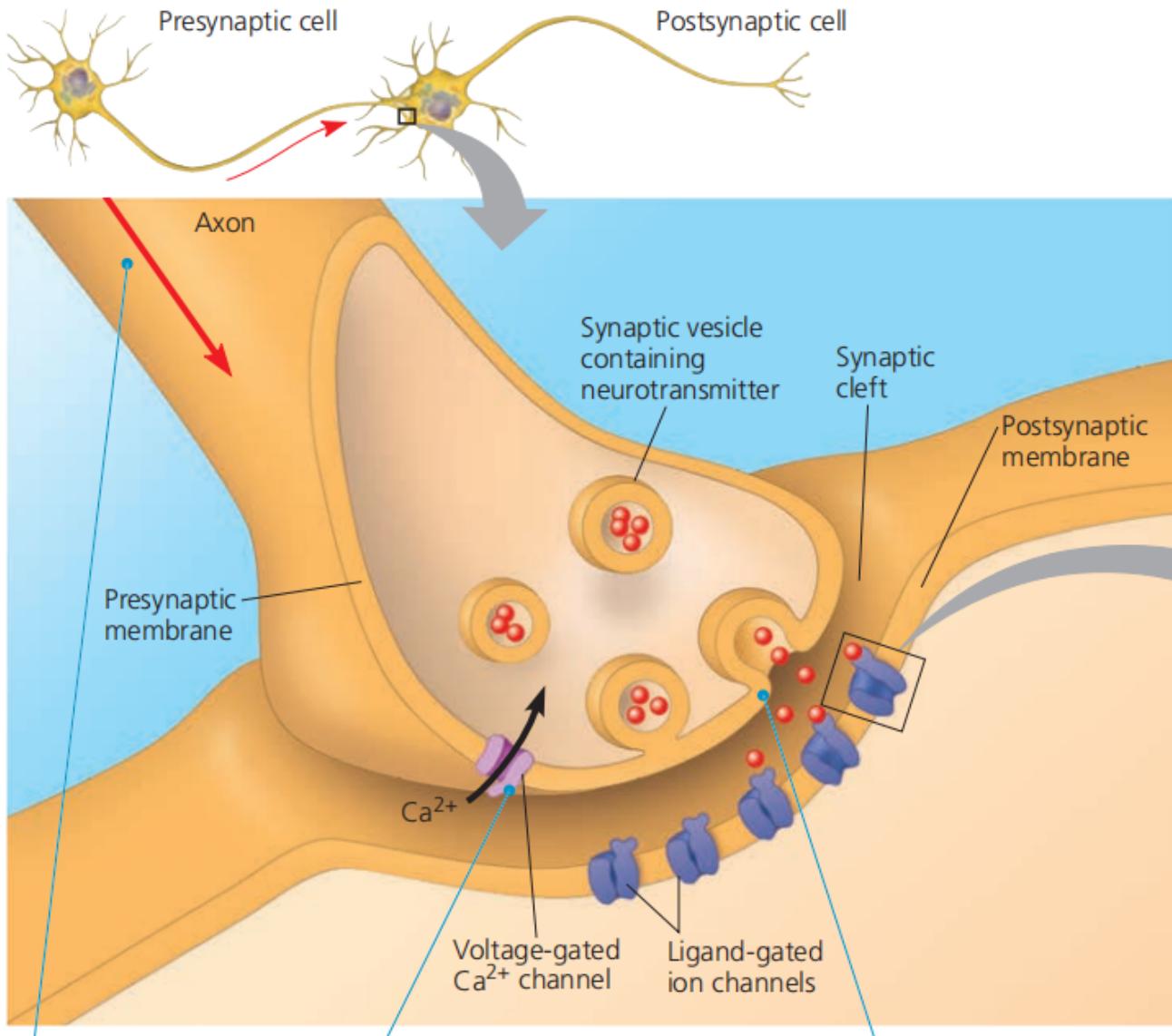
Local current



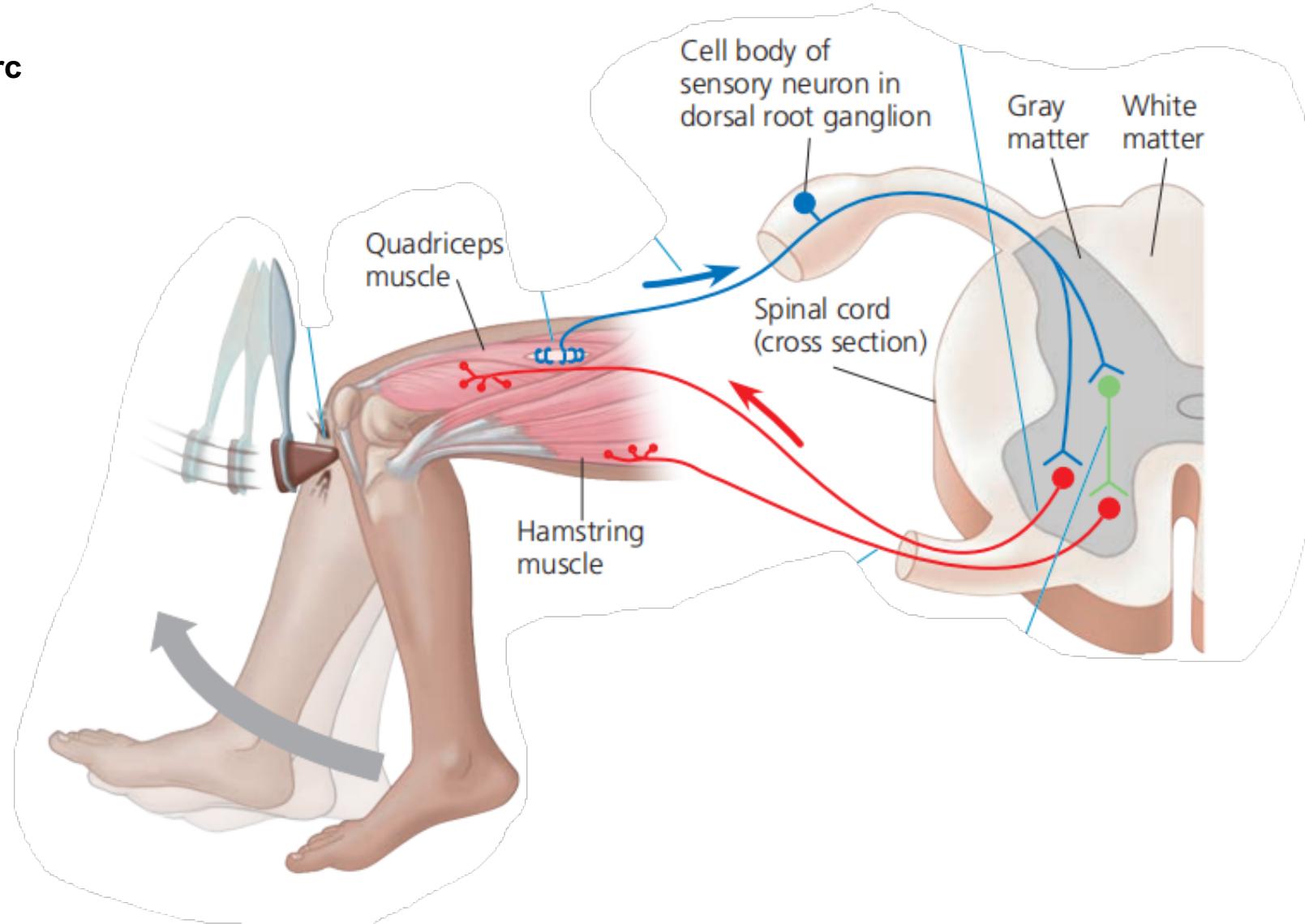
Saltatory conduction



Synapse



Reflex arc



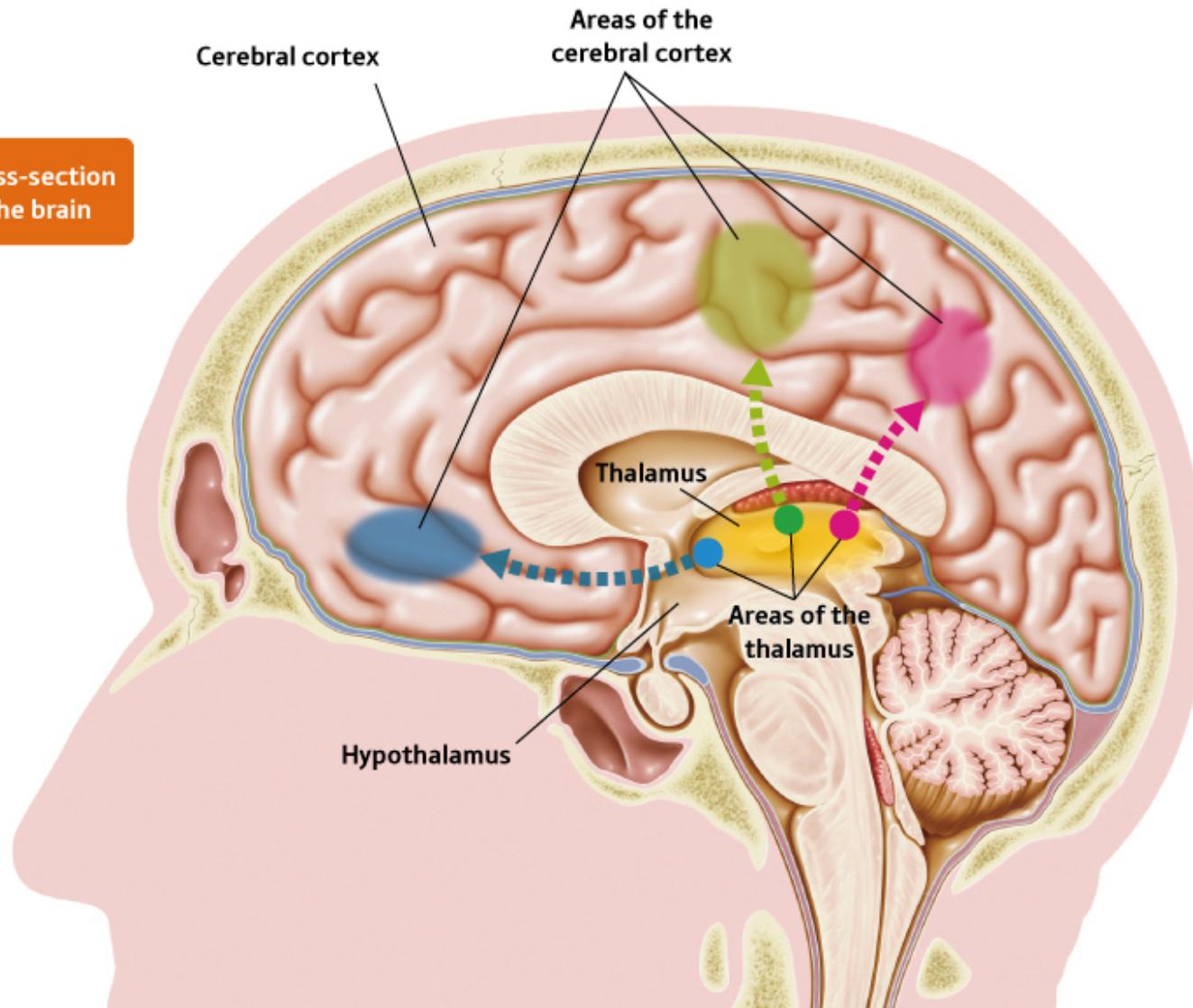


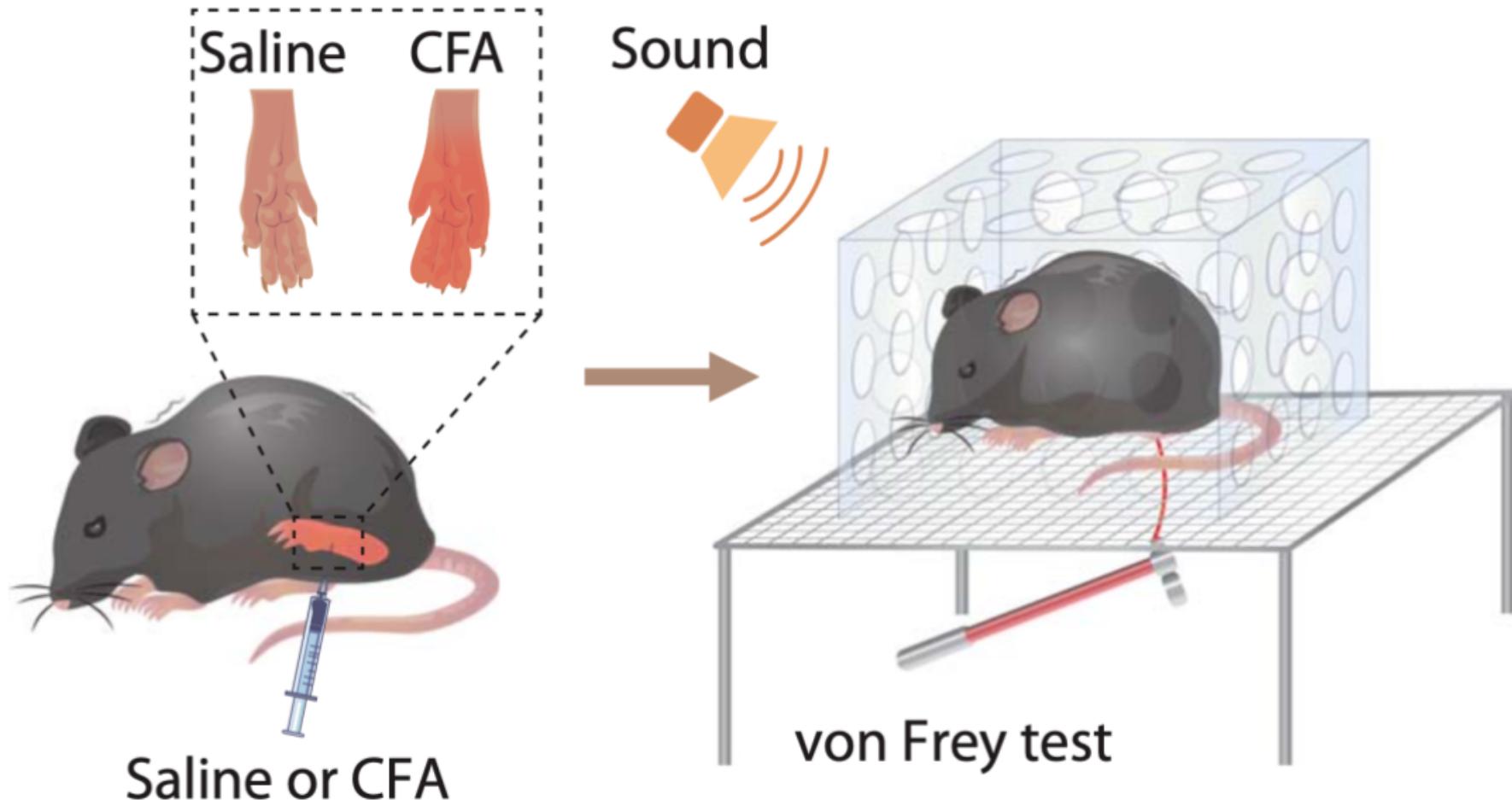
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Sound induces analgesia through corticothalamic circuits

WENJIE ZHOU  , CHONGHUAN YE  , HAITAO WANG  , YU MAO  , WEIJIA ZHANG  , AN LIU  , CHEN-LING YANG  , TIANMING LI, LAUREN HAYASHI  , WAN ZHAO  , LIN CHEN  , YUANYUAN LIU , WENJUAN TAO  , AND ZHI ZHANG  [fewer](#) [Authors Info & Affiliations](#)

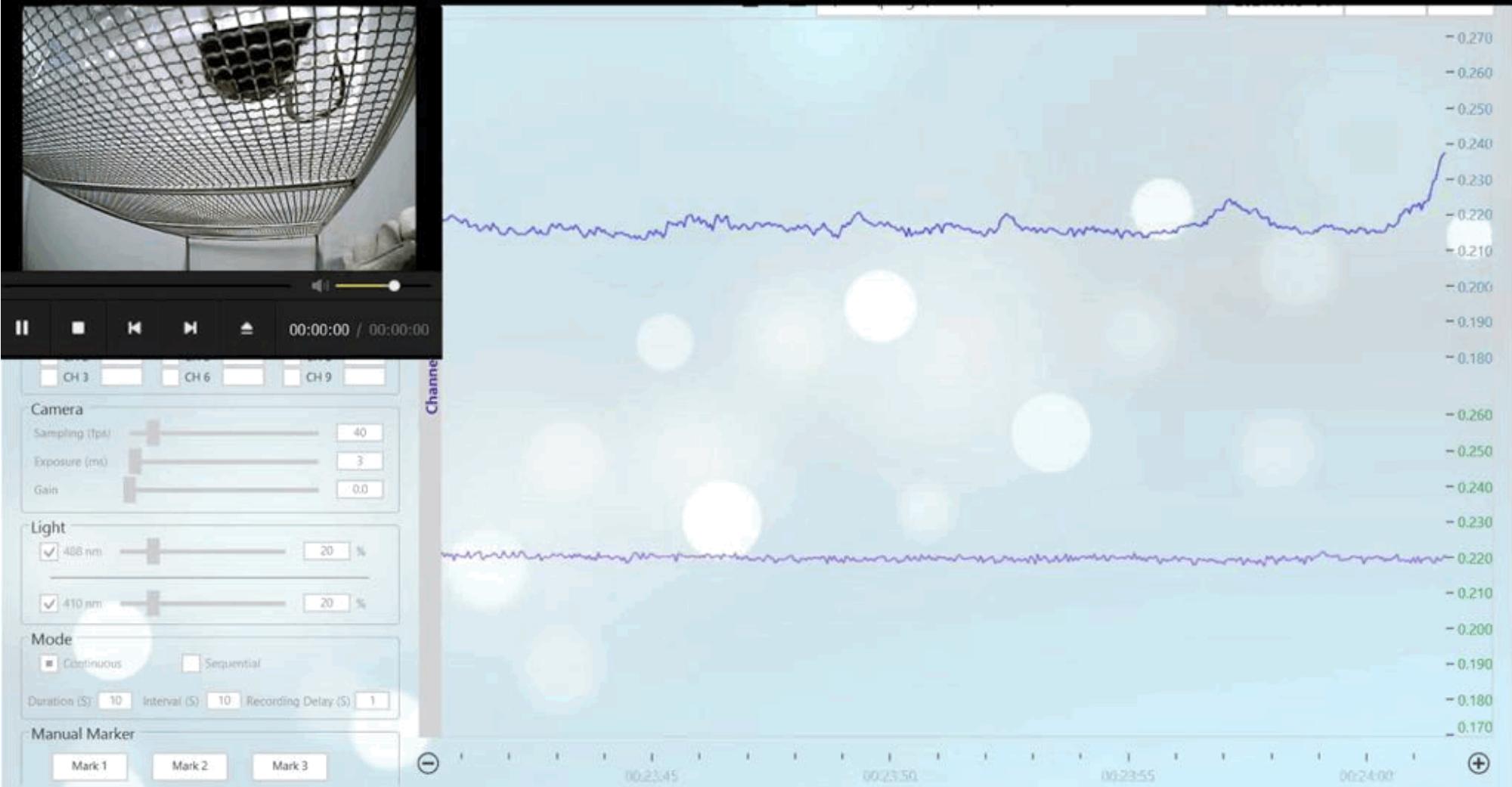
Cross-section
of the brain

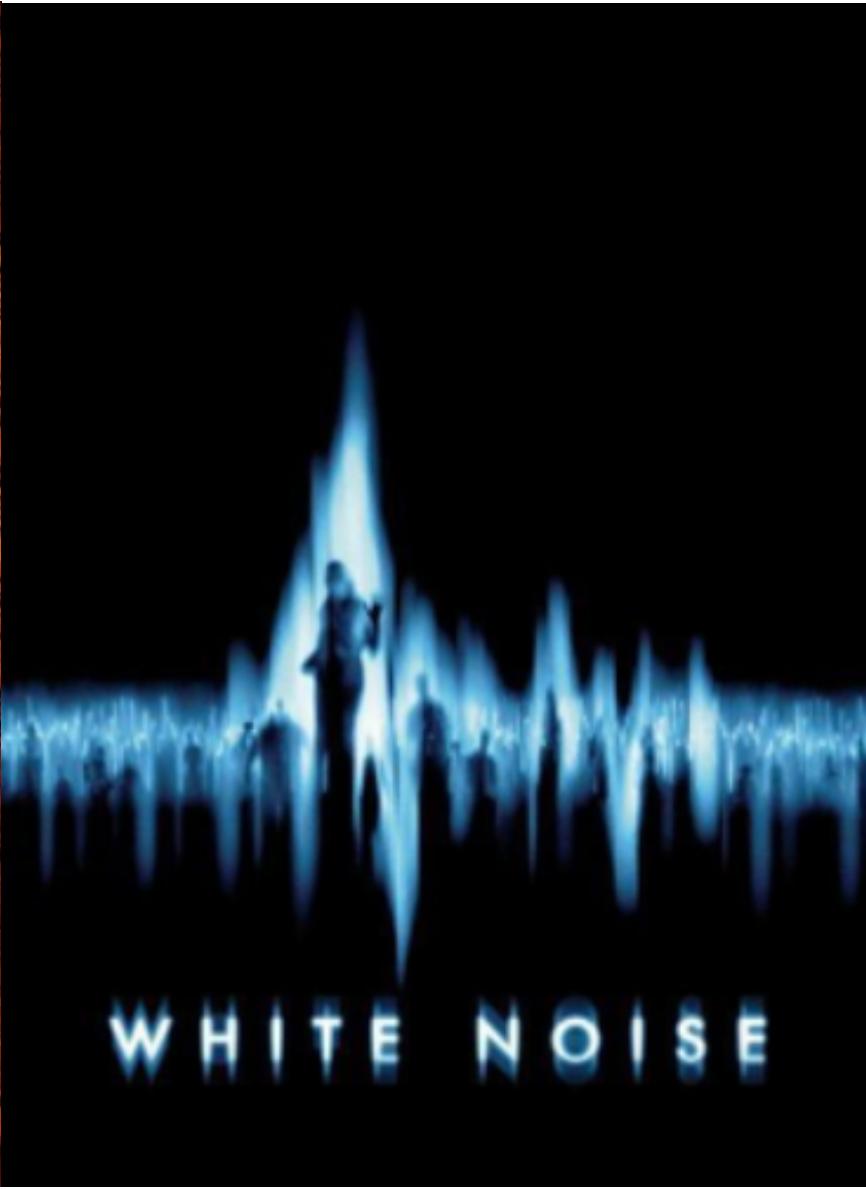
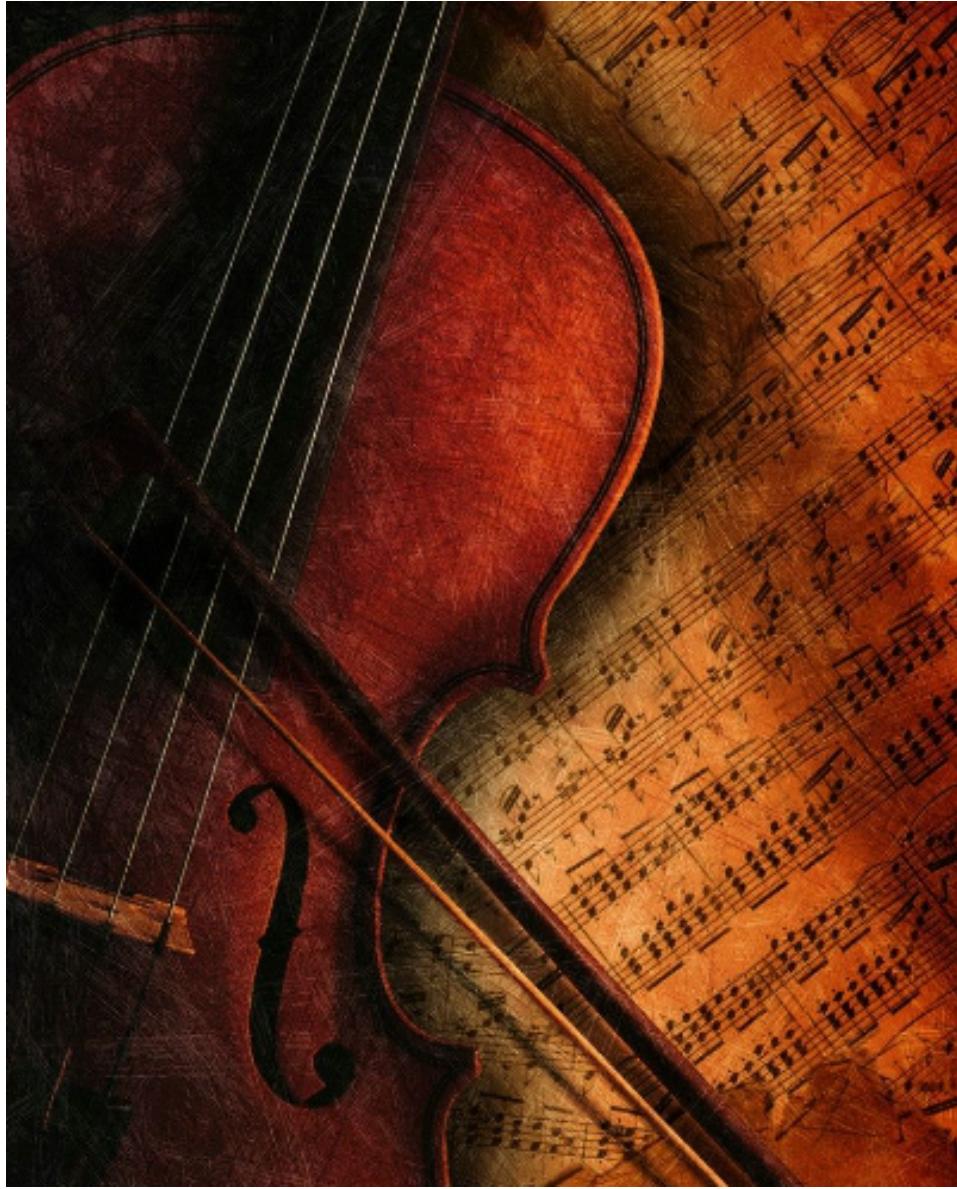




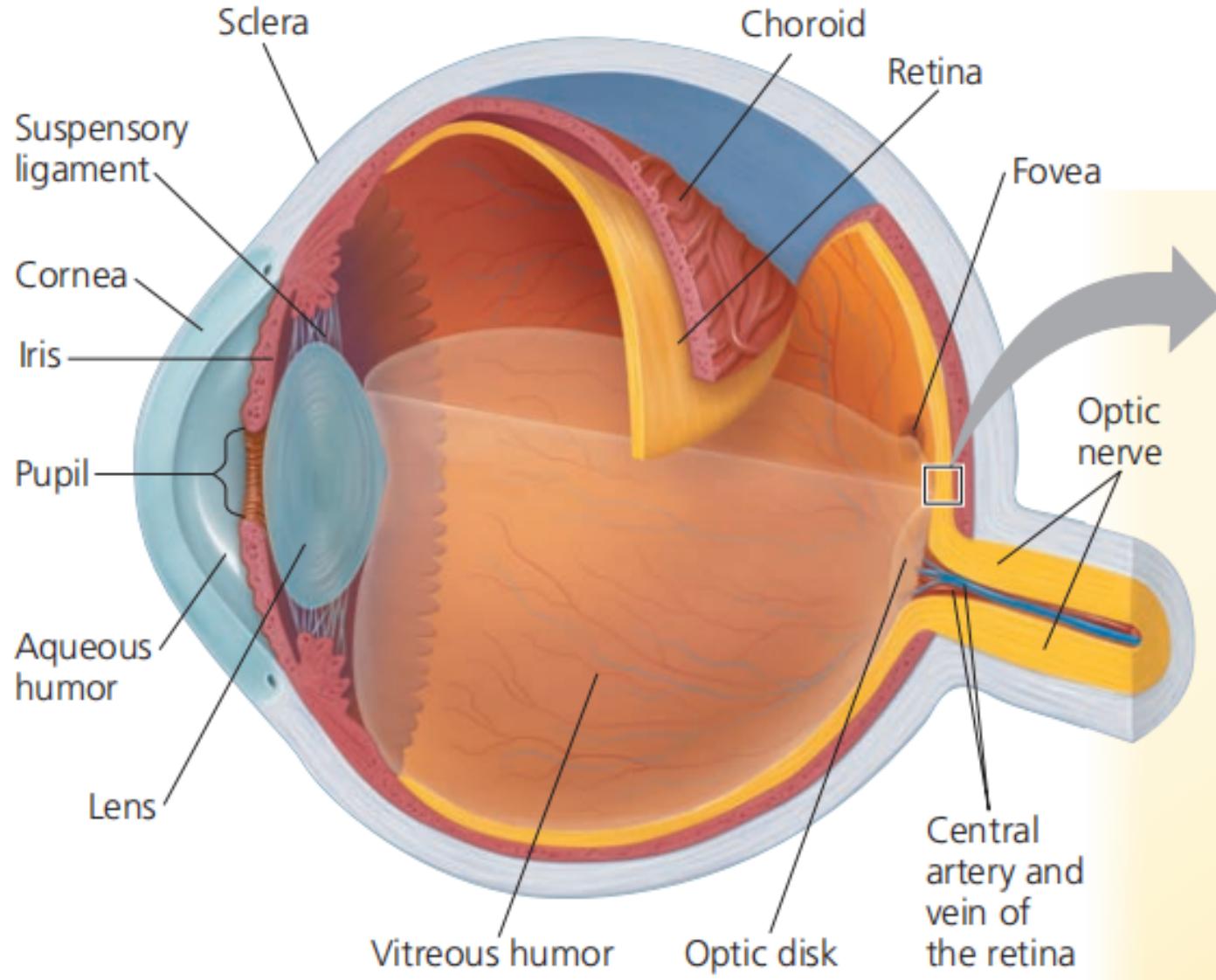
Hindlimb

PO:AAV-DIO-GCam6M

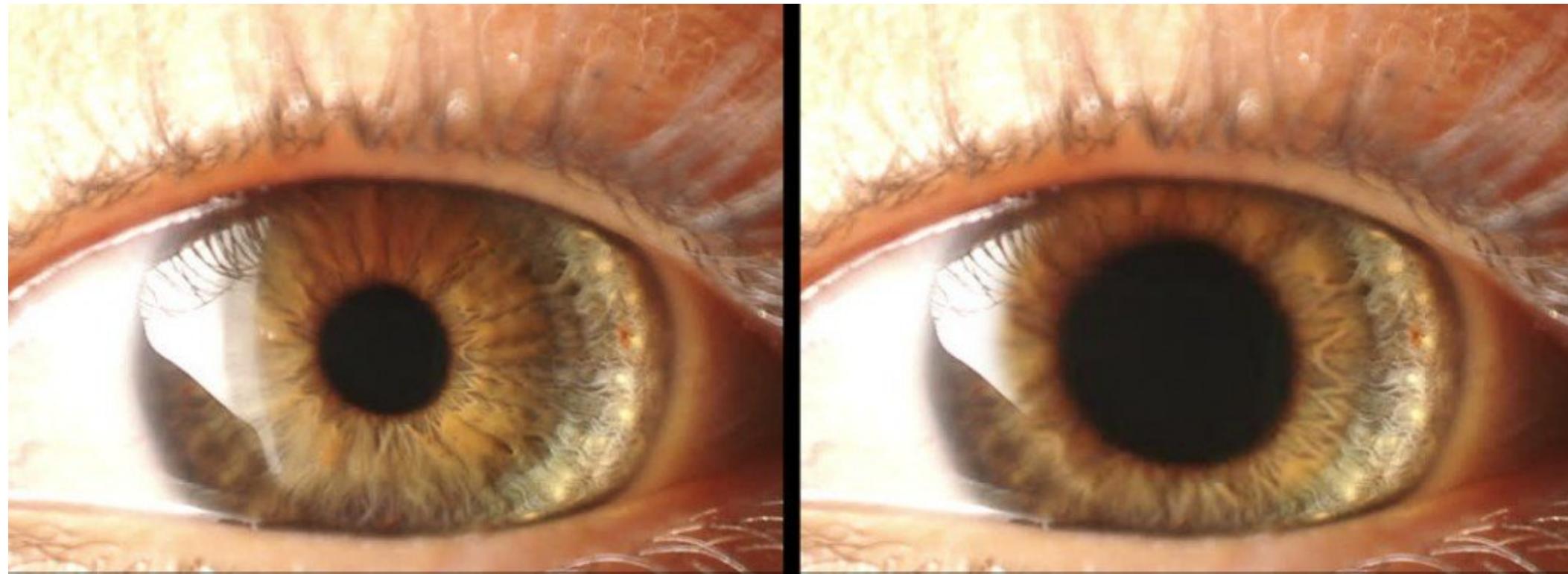




The eye



Pupil reflex

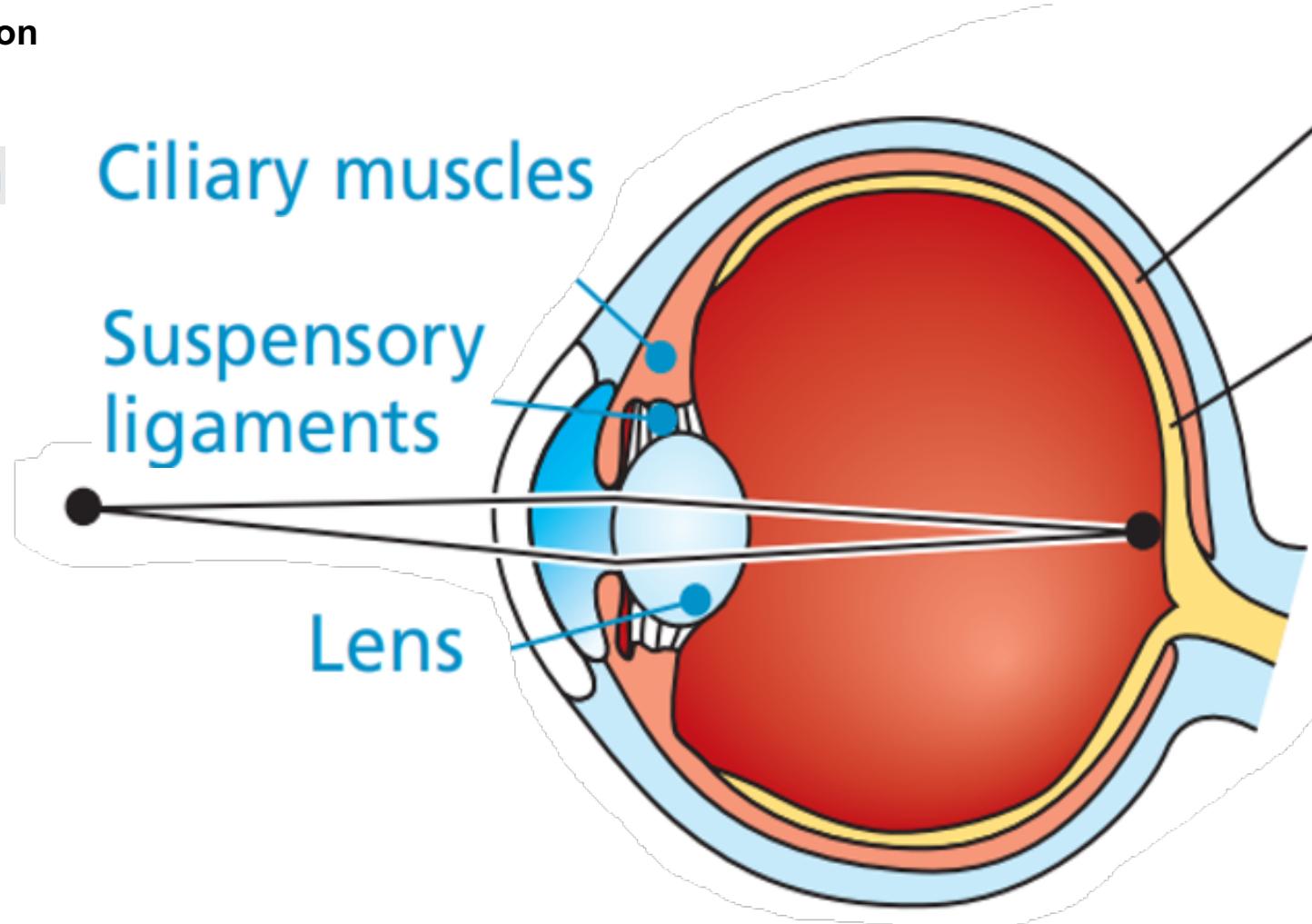


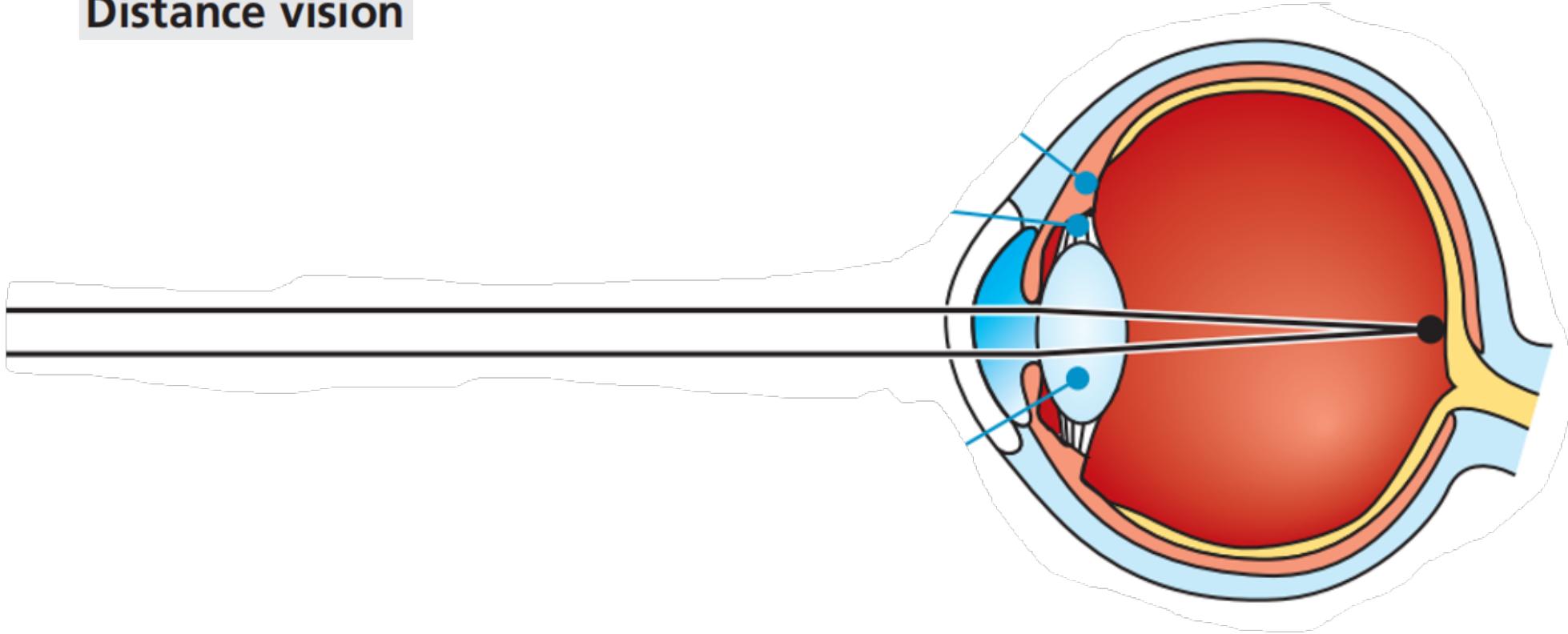
Near vision

Ciliary muscles

Suspensory
ligaments

Lens



Distance vision

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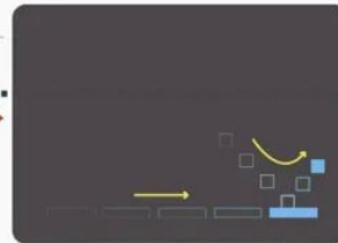
In vitro neurons learn and exhibit sentience when embodied in a simulated game-world

Brett J. Kagan  ¹¹  • Andy C. Kitchen • Nhi T. Tran • Forough Habibollahi • Moein Khajehnejad •
Brady J. Parker • Anjali Bhat • Ben Rollo • Adeel Razi • Karl J. Friston • Show less • Show footnotes

Open Access • Published: October 12, 2022 • DOI: <https://doi.org/10.1016/j.neuron.2022.09.001>

Simulated
Environment:
Pong

External states η



INPUT

Stimulation s

FEEDBACK

Stimulation s

OUTPUT

Recording a

In vitro
Neurons

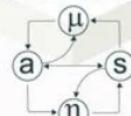
Internal states μ

CLOSED-LOOP SYSTEM

HD-MEA Chip

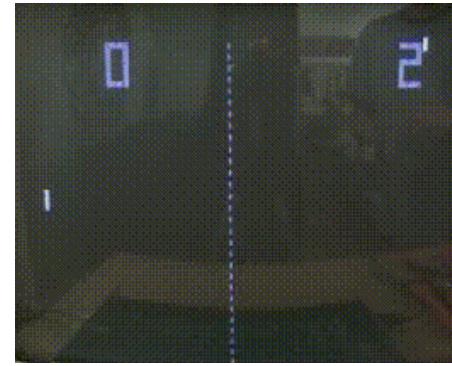
High-density
multielectrode array

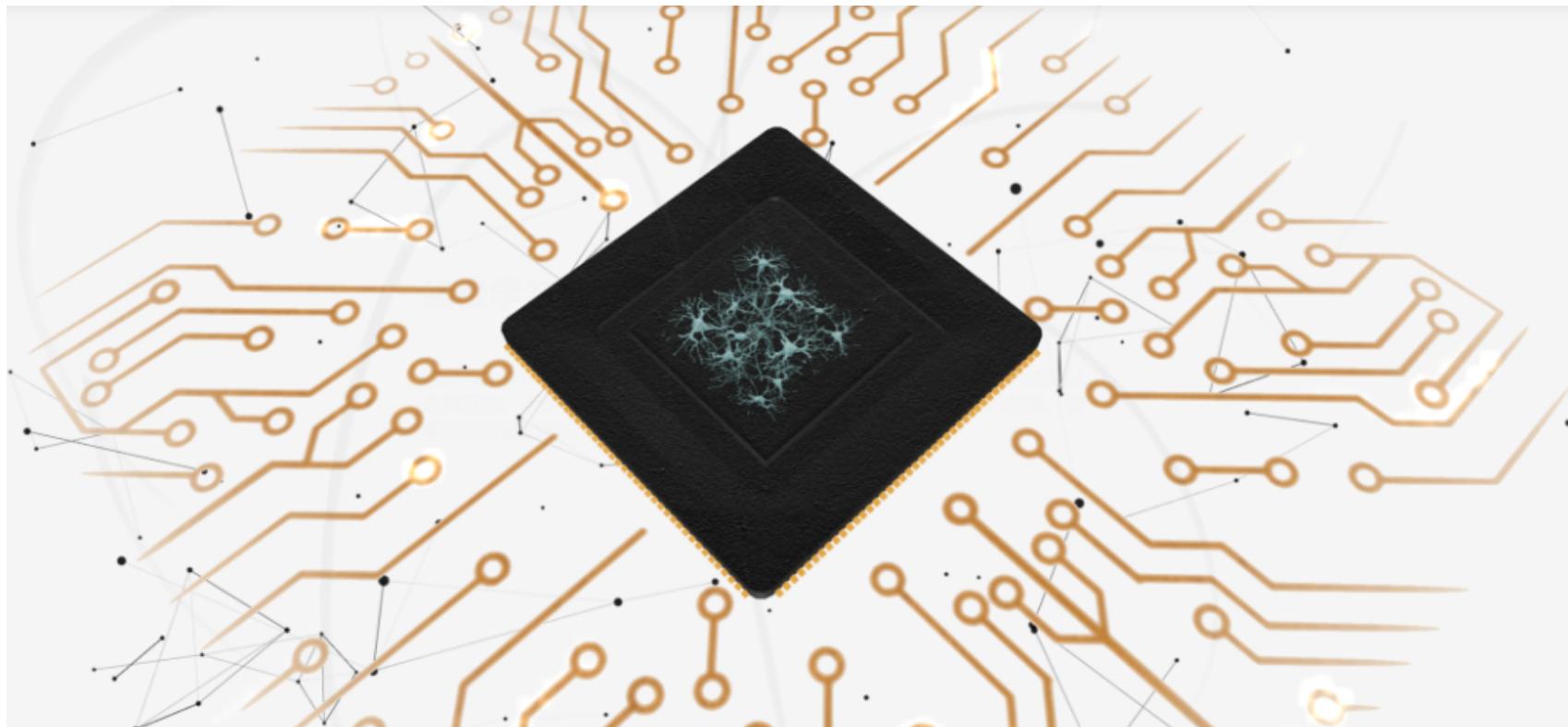
Internal states

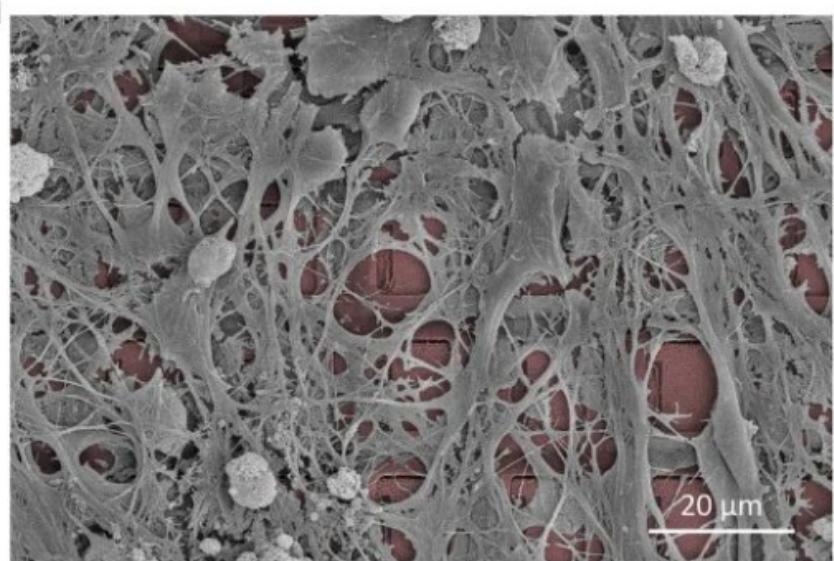
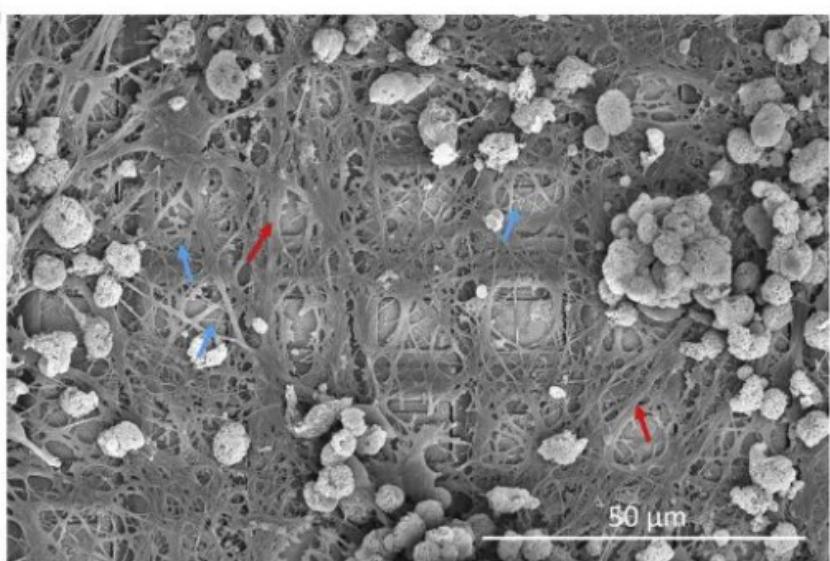
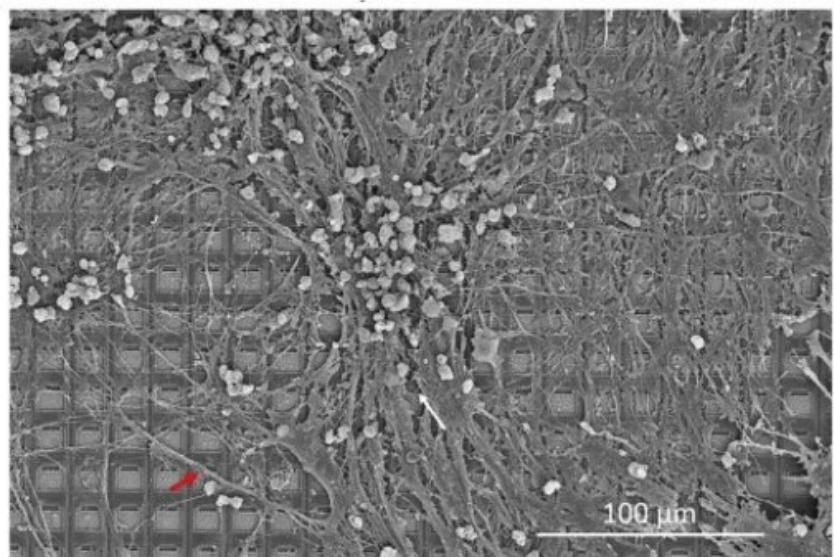
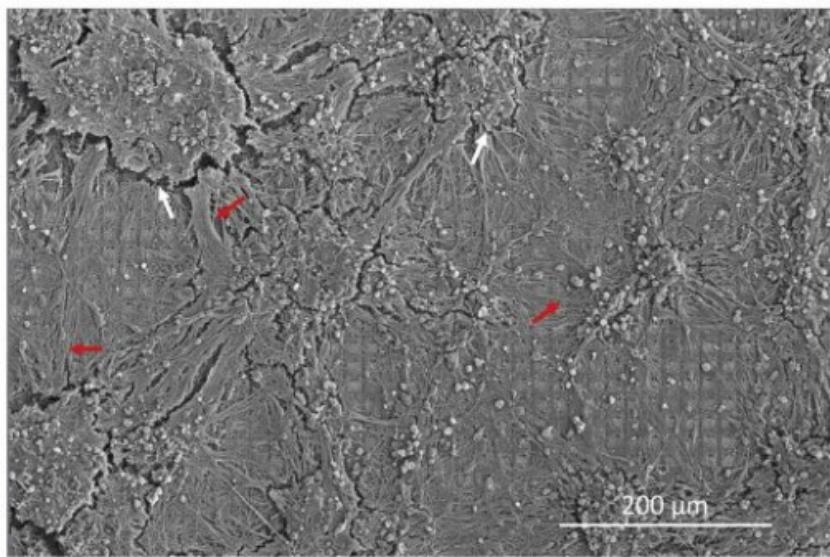


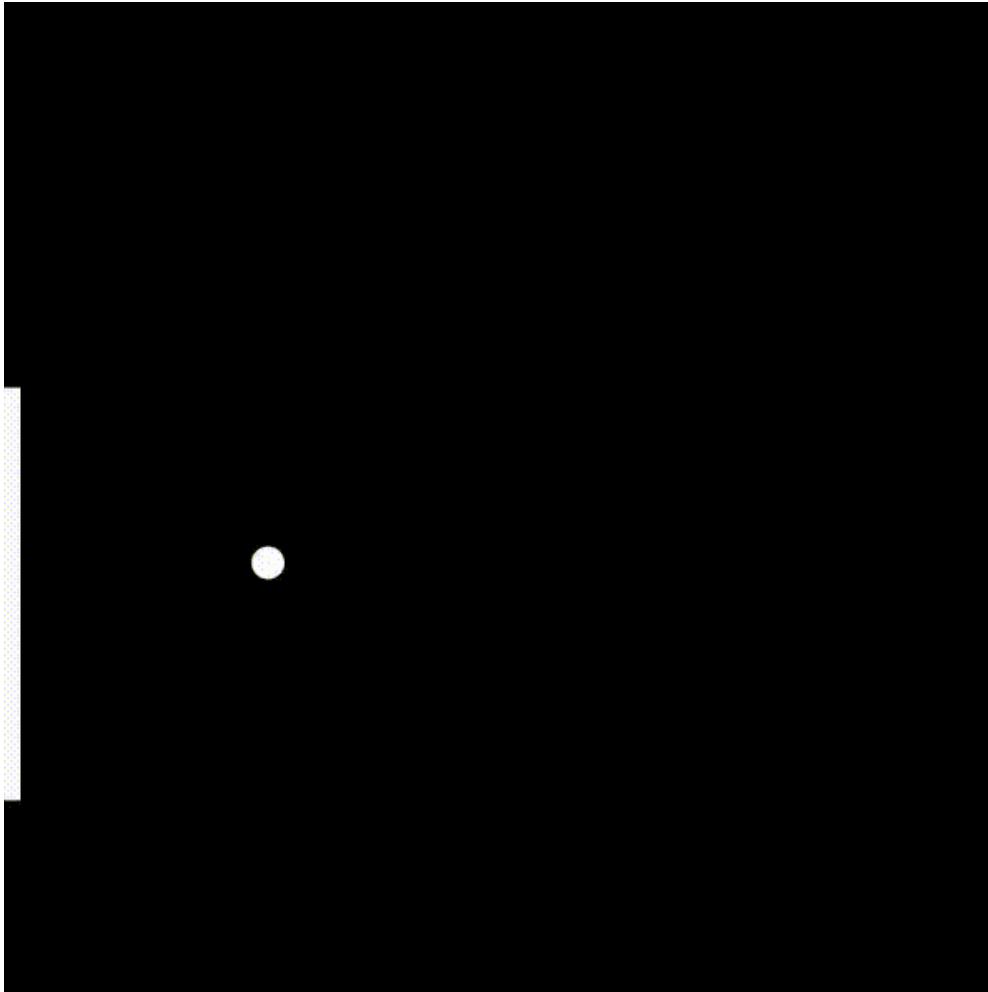
External states

Free Energy Principle



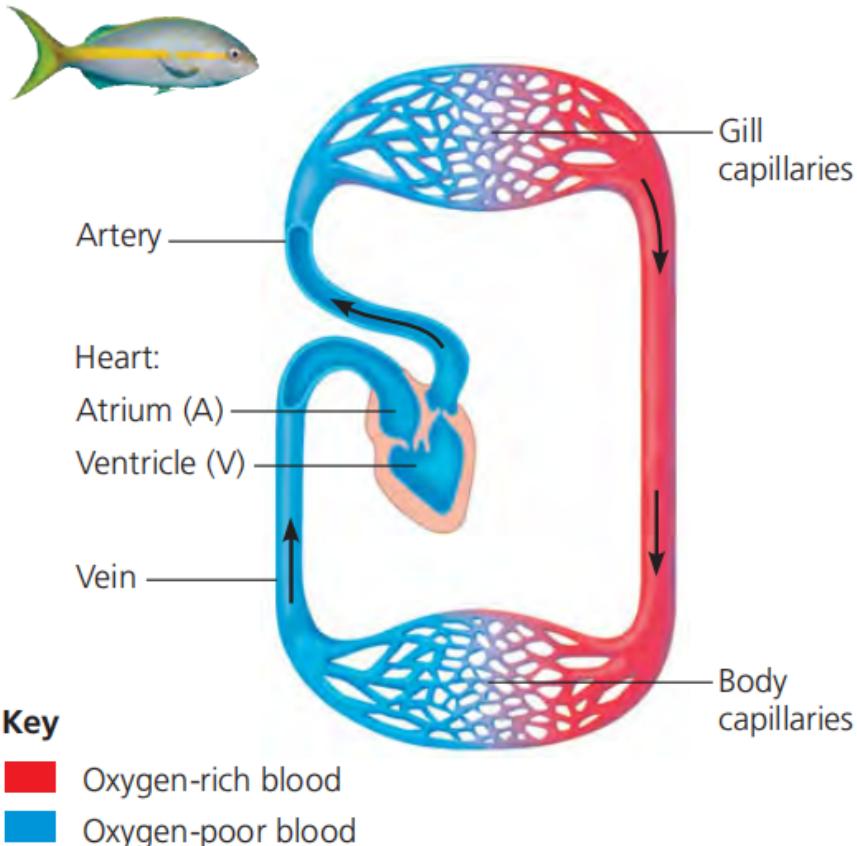




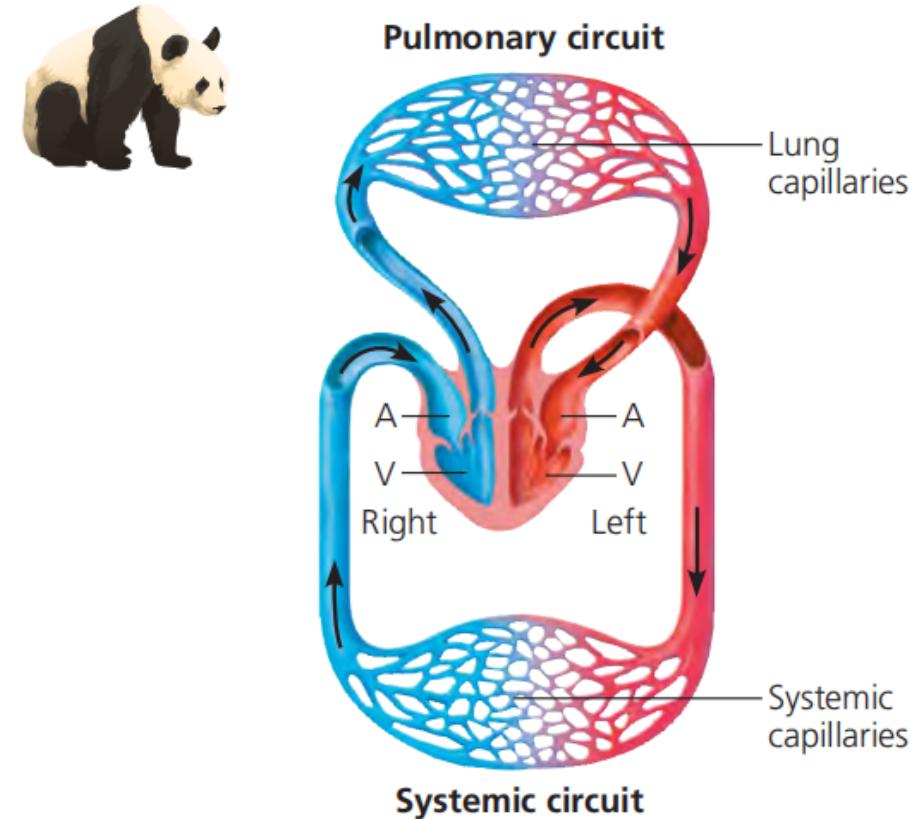


Circulatory system

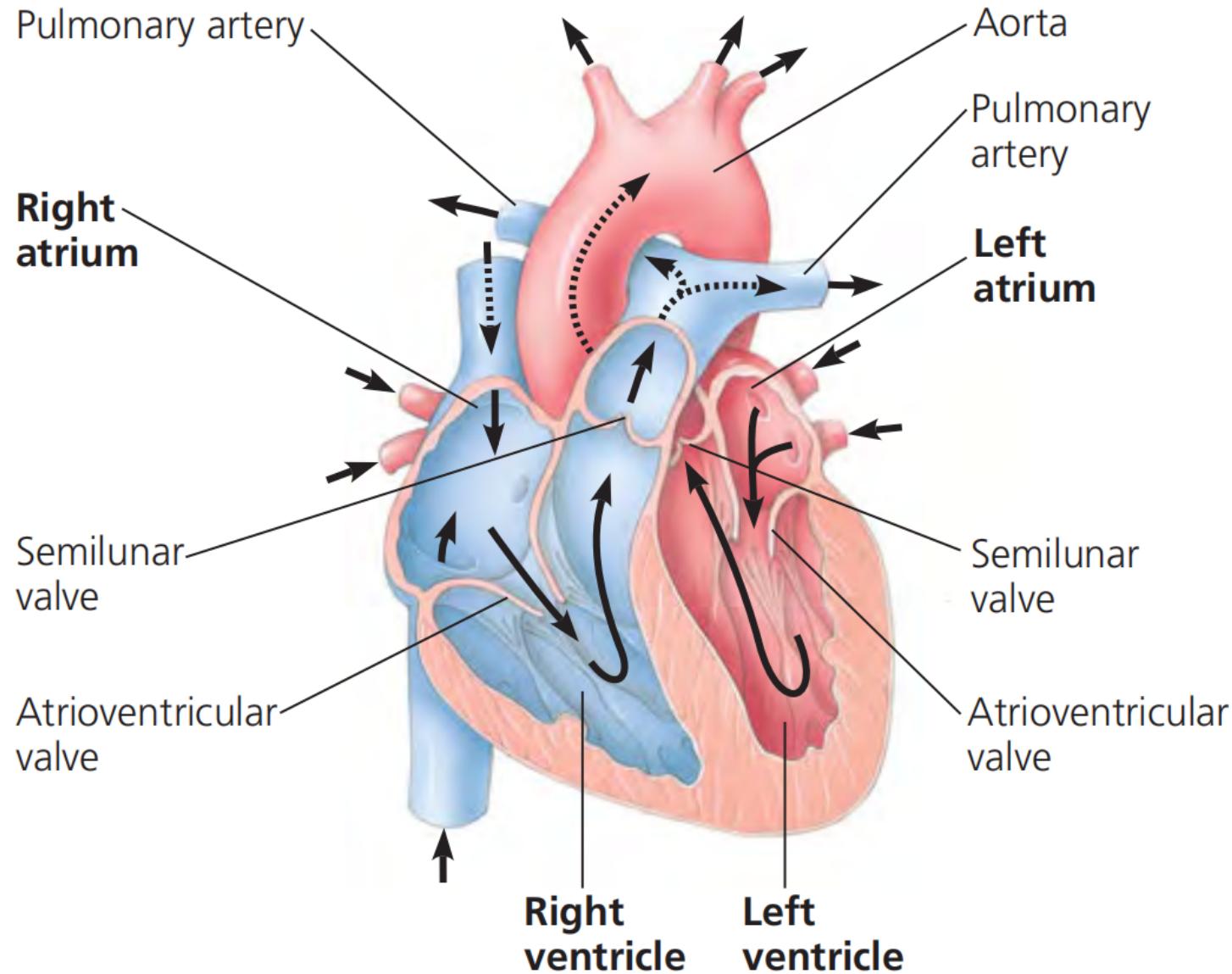
(a) Single circulation



(b) Double circulation

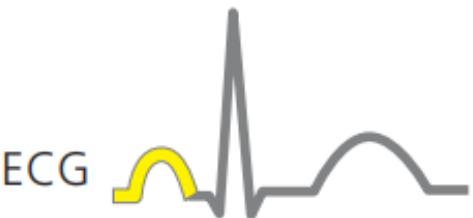
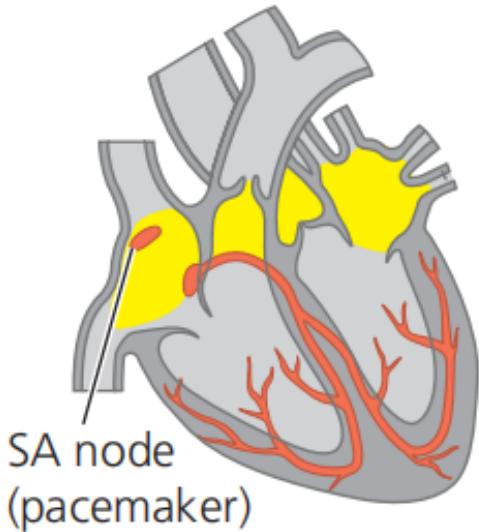


The heart

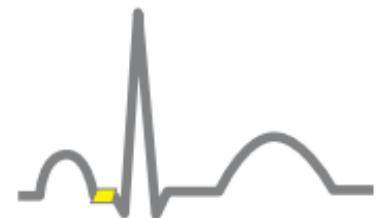
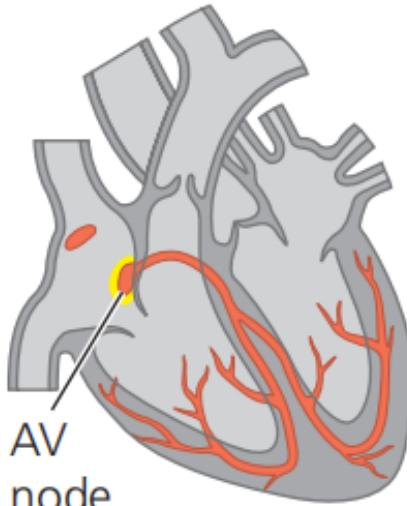


The heart

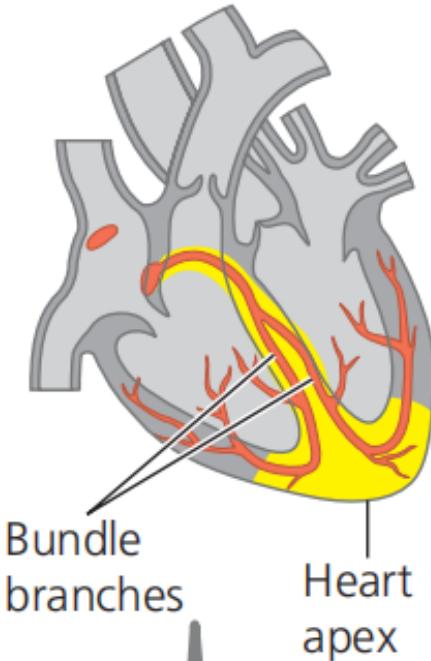
- 1 Signals (yellow) from SA node spread through atria.



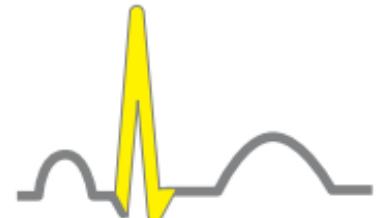
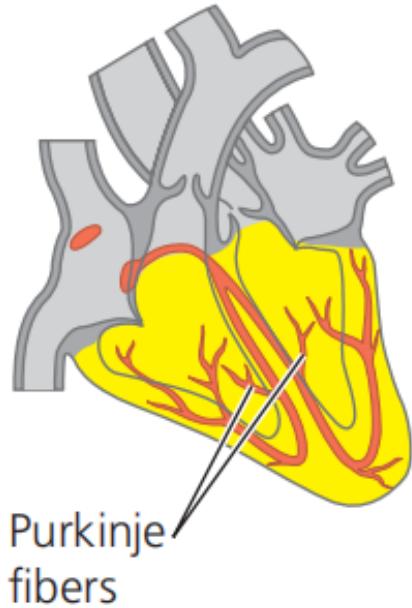
- 2 Signals are delayed at AV node.

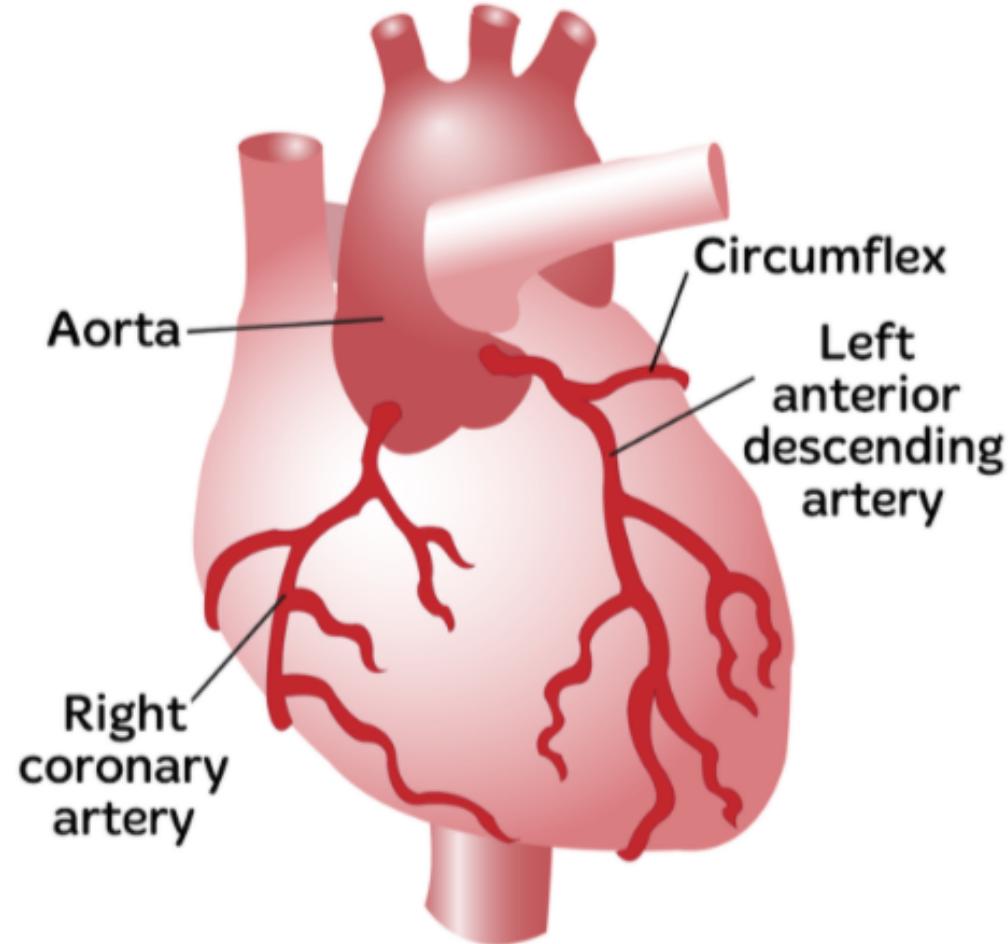


- 3 Bundle branches pass signals to heart apex.

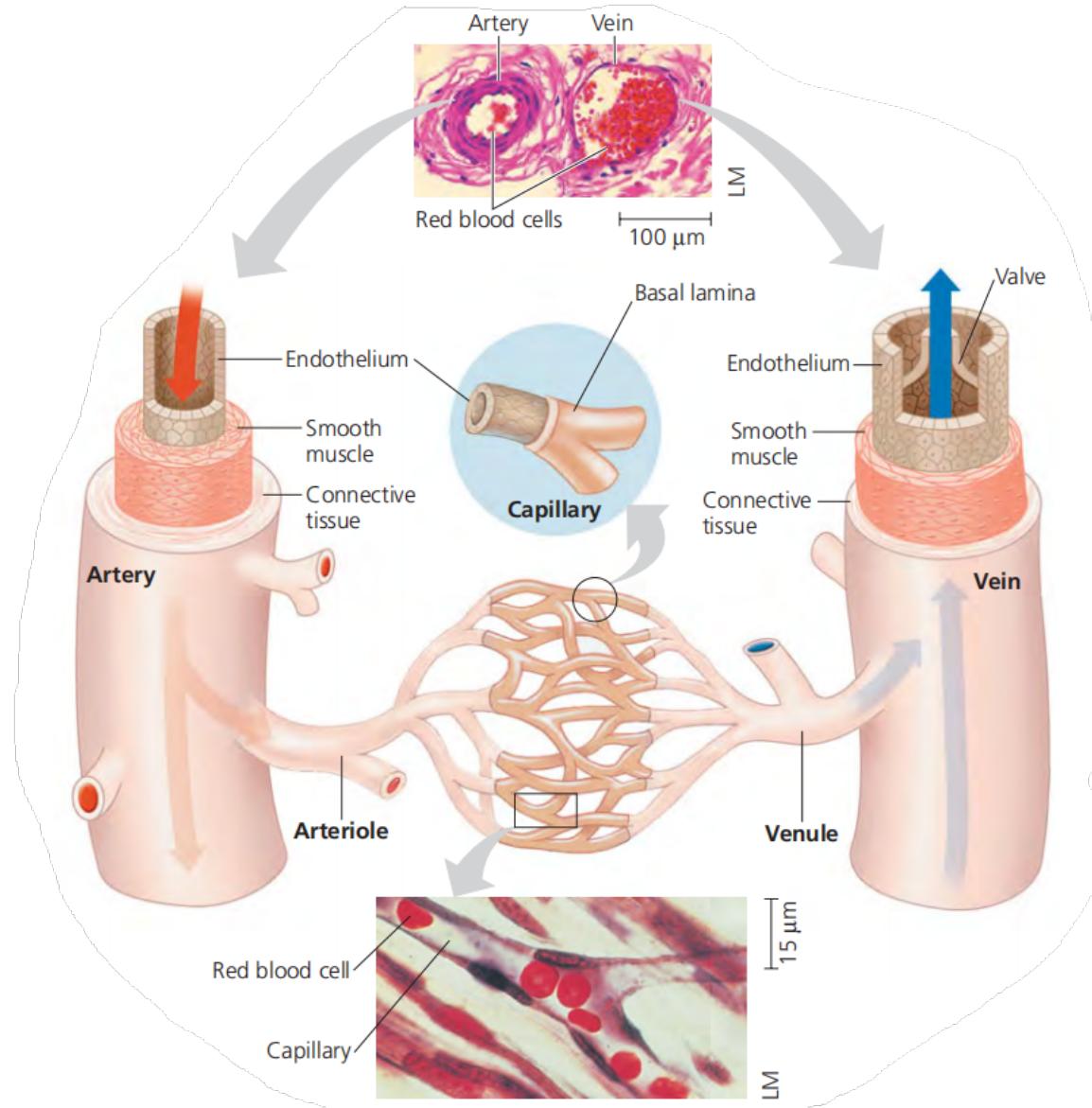


- 4 Signals spread throughout ventricles.



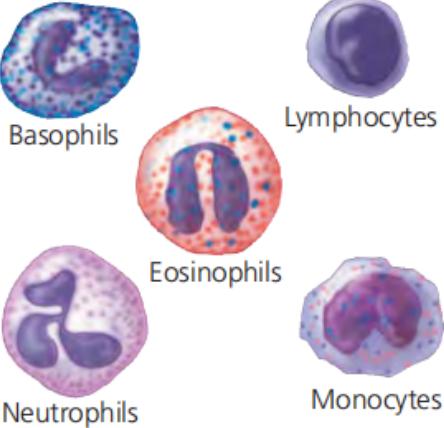


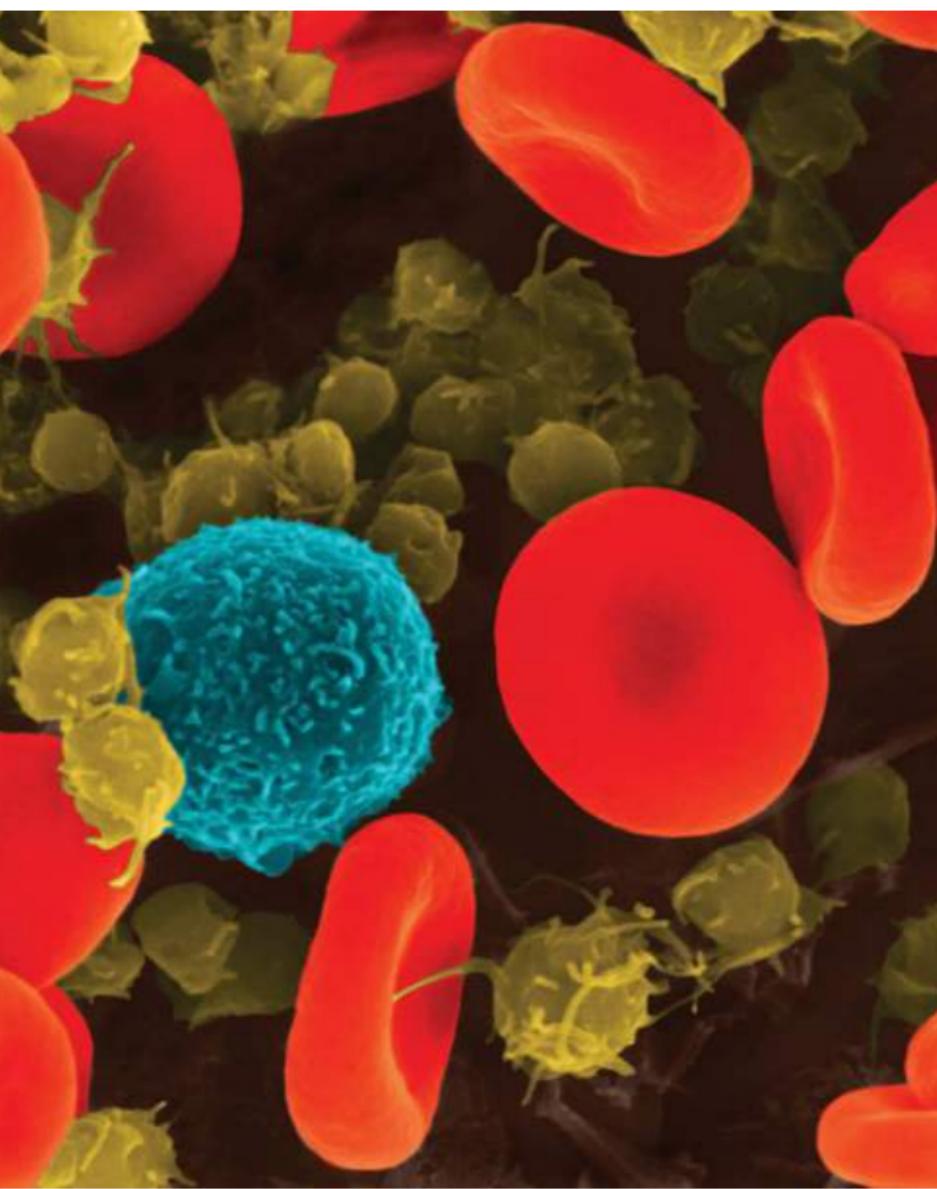
Blood vessels



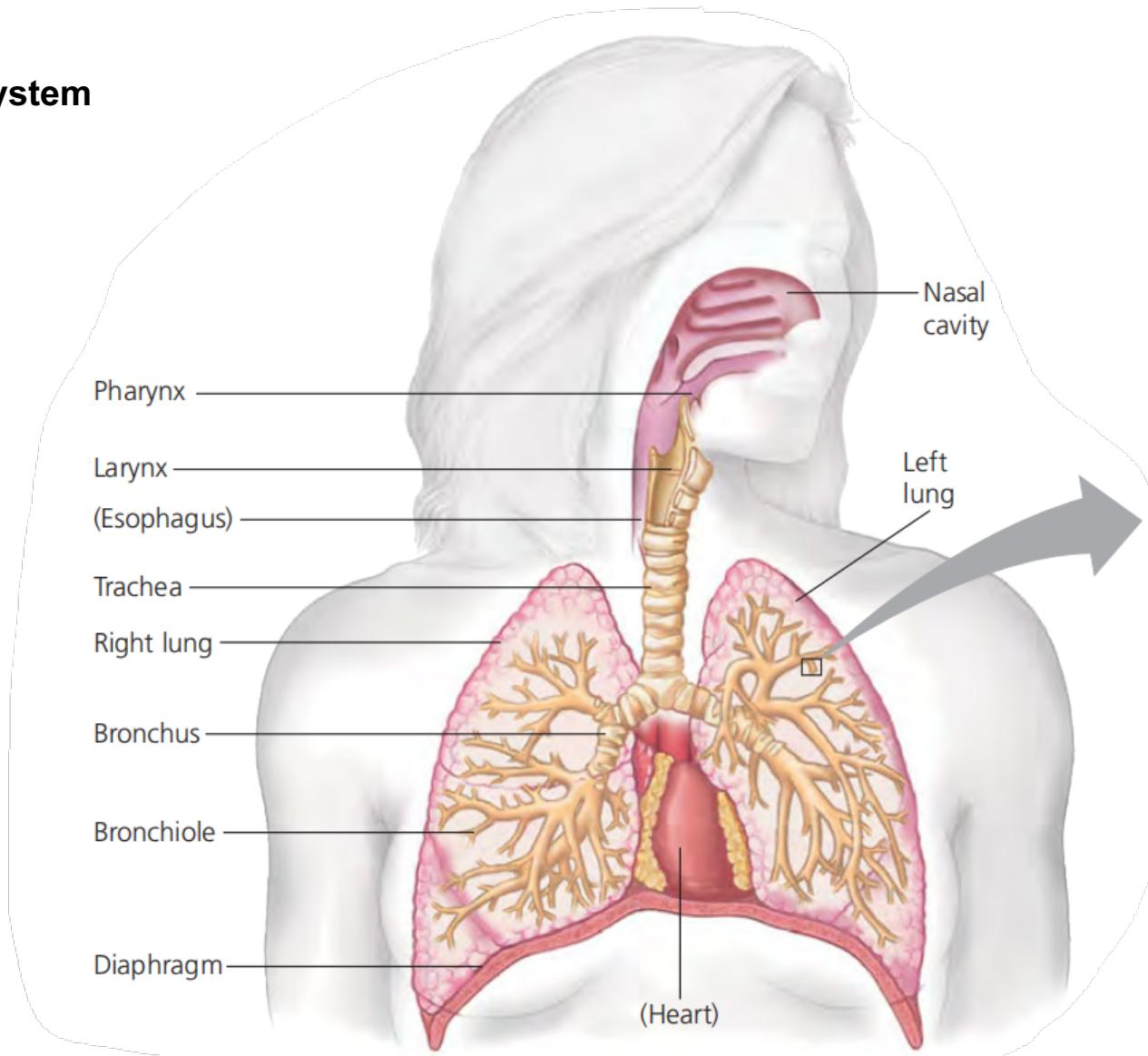
The blood

Plasma 55%	
Constituent	Major functions
Water	Solvent for carrying other substances
Ions (blood electrolytes) Sodium Potassium Calcium Magnesium Chloride Bicarbonate	Osmotic balance, pH buffering, and regulation of membrane permeability
Plasma proteins Albumin Fibrinogen Immunoglobulins (antibodies)	Osmotic balance, pH buffering Clotting Defense
Substances transported by blood	
Nutrients (such as glucose, fatty acids, vitamins) Waste products of metabolism Respiratory gases (O_2 and CO_2) Hormones	

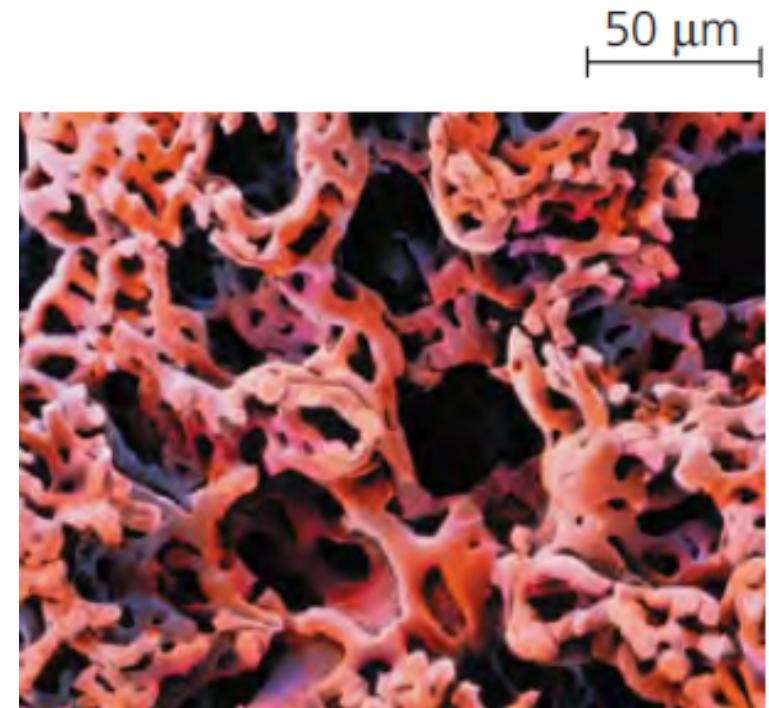
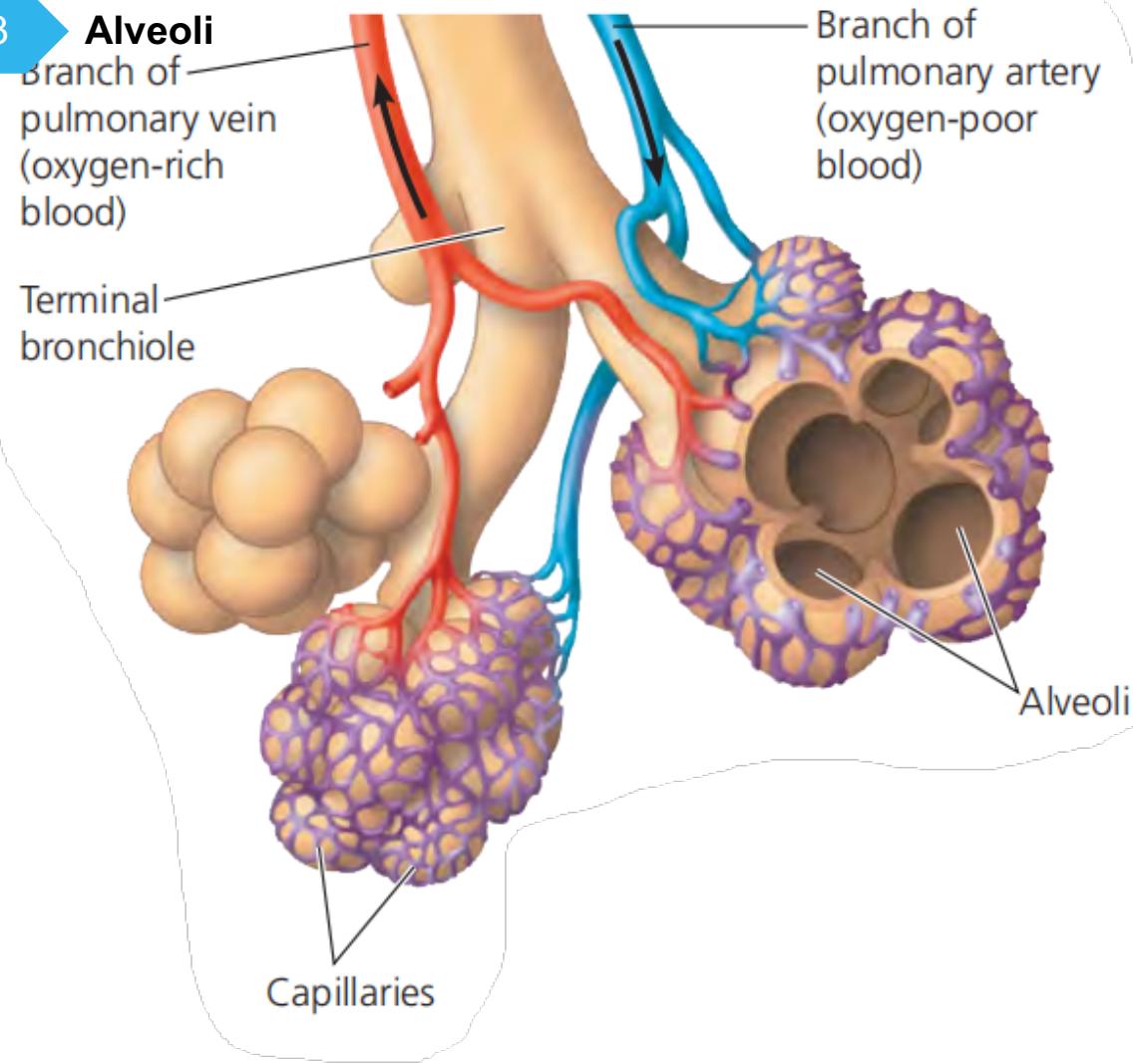
Cellular elements 45%		
Cell type	Number per μL (mm^3) of blood	Functions
Leukocytes (white blood cells) 	5,000–10,000	Defense and immunity
Platelets 	250,000–400,000	Blood clotting
Erythrocytes (red blood cells) 	5–6 million	Transport of O_2 and some CO_2



Respiratory system



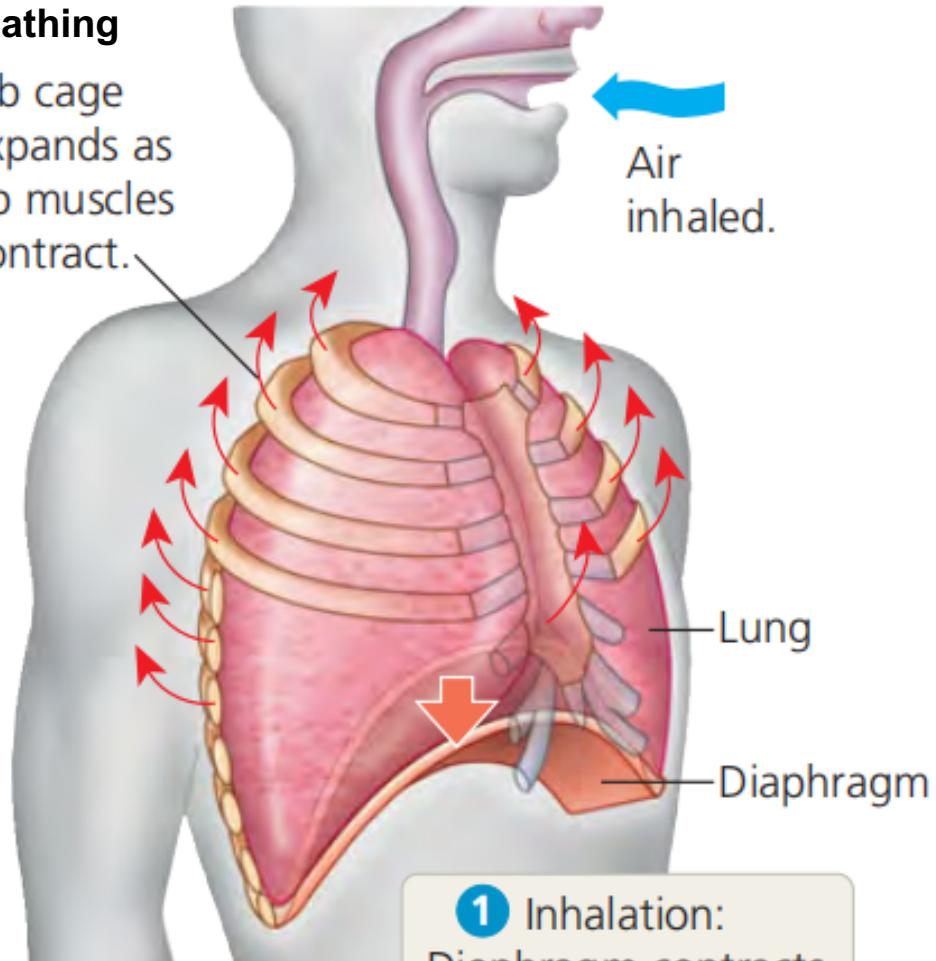
13



Breathing

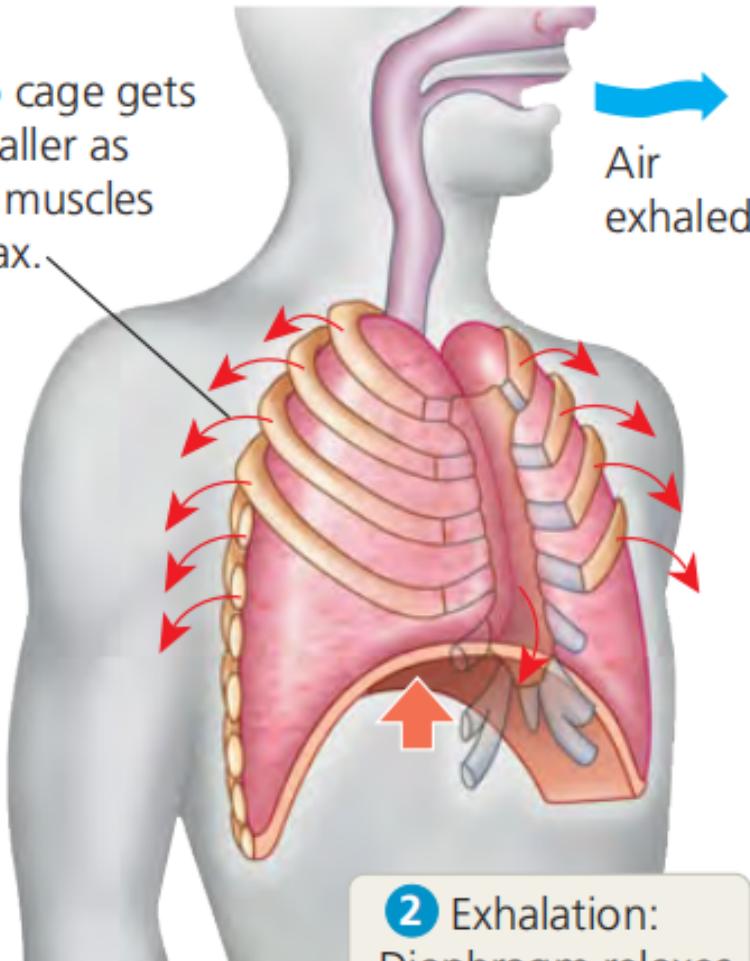
Rib cage expands as rib muscles contract.

Air inhaled.



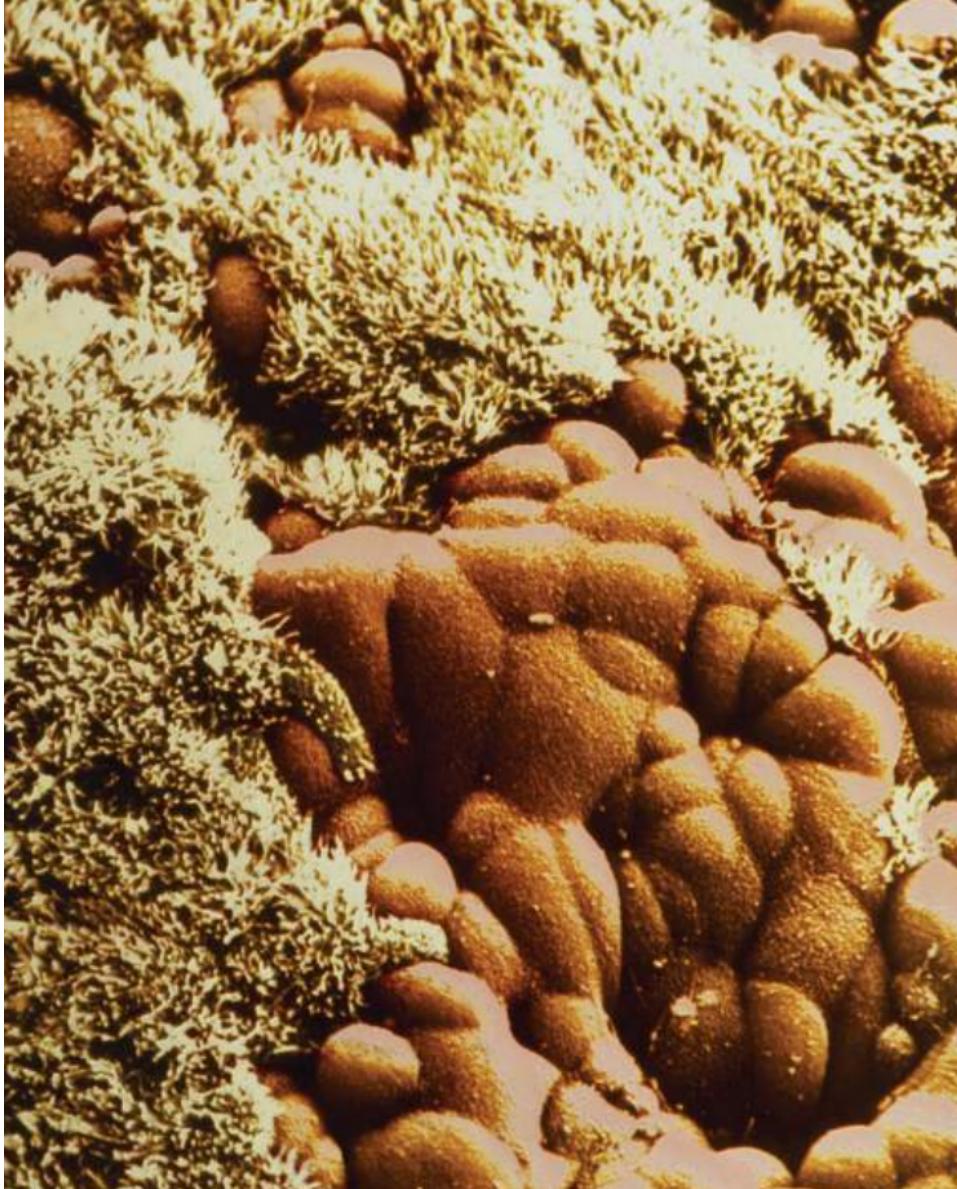
Rib cage gets smaller as rib muscles relax.

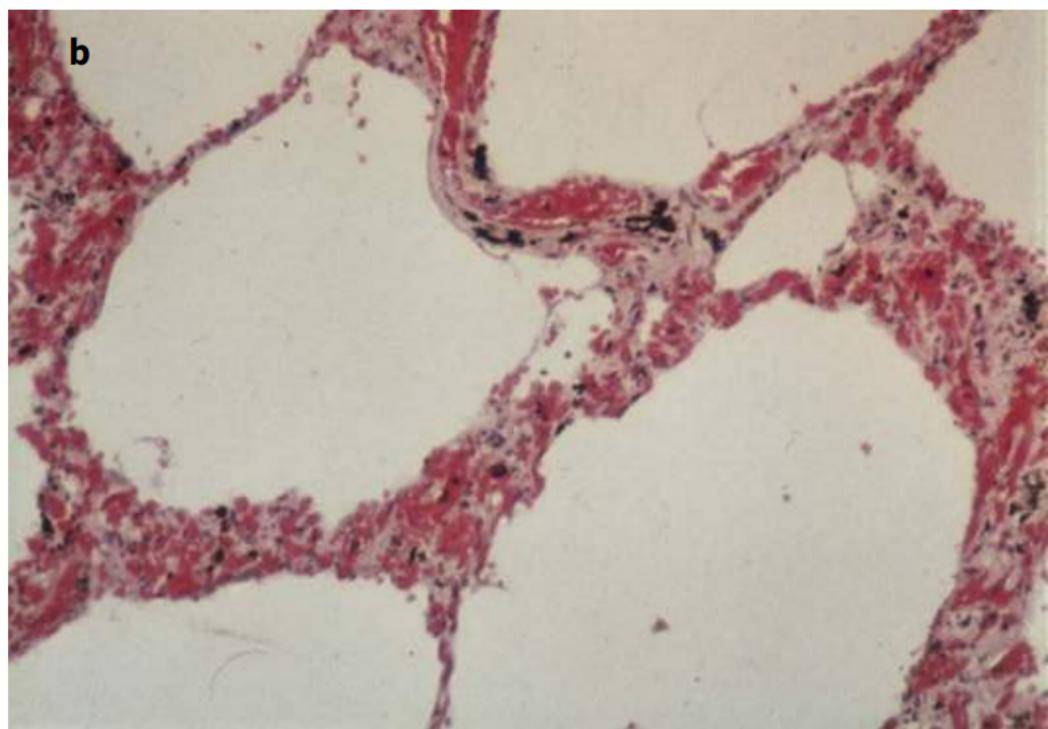
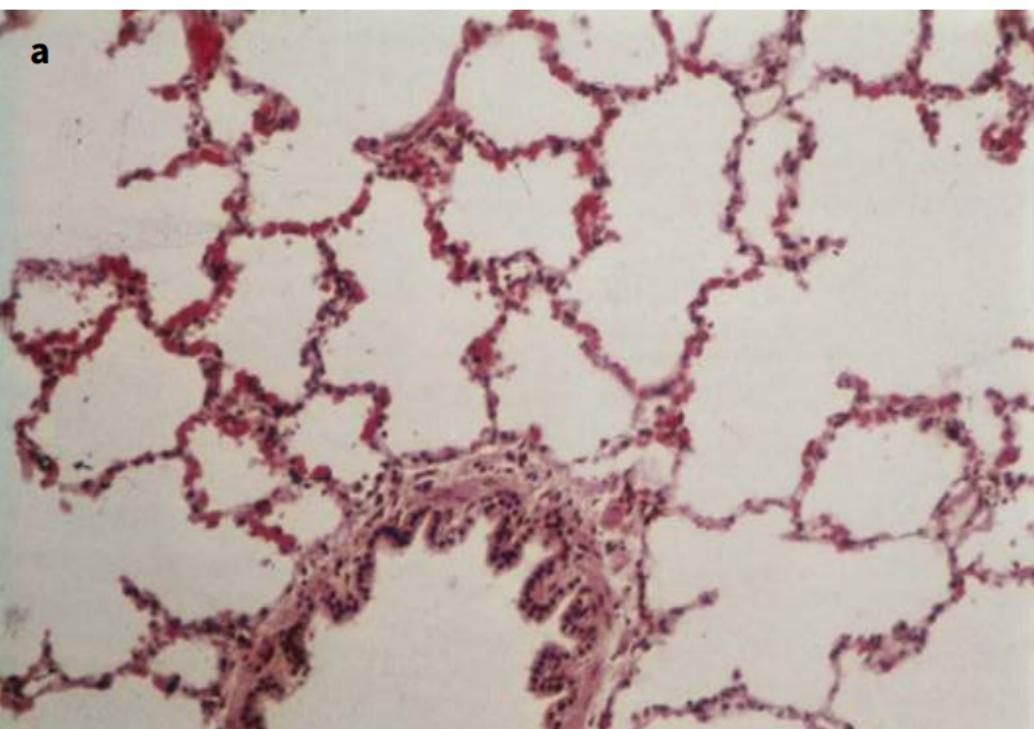
Air exhaled.



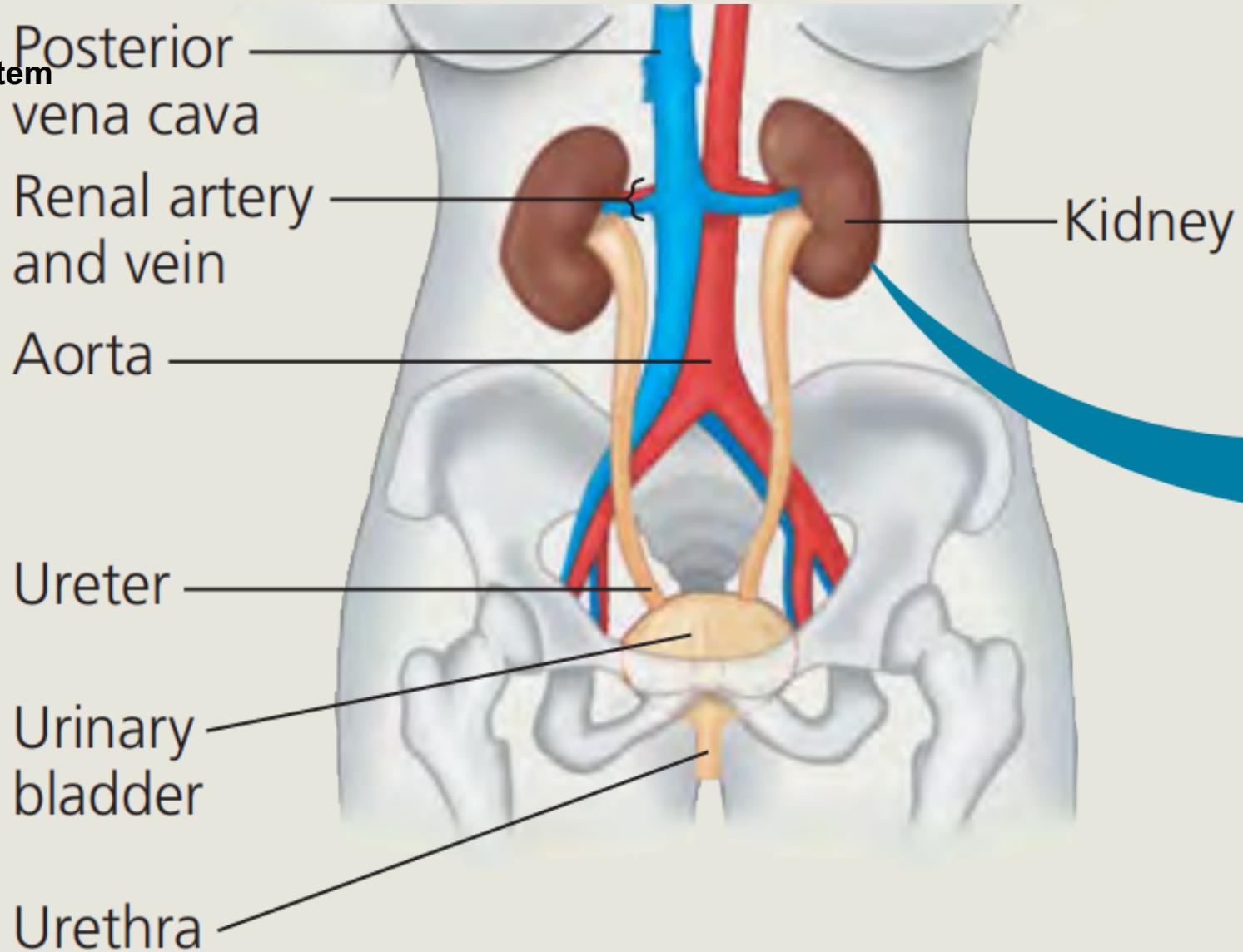
Smoking



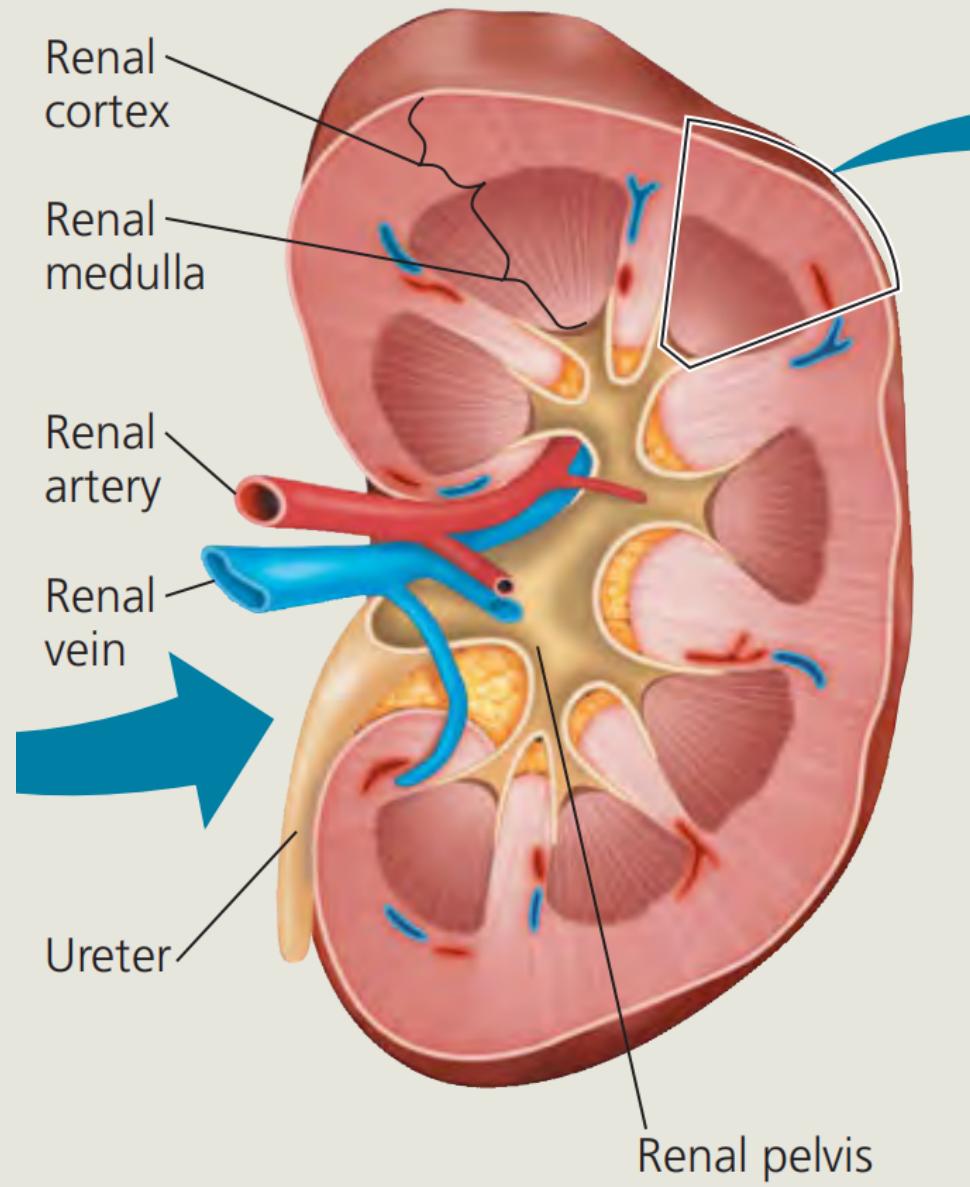




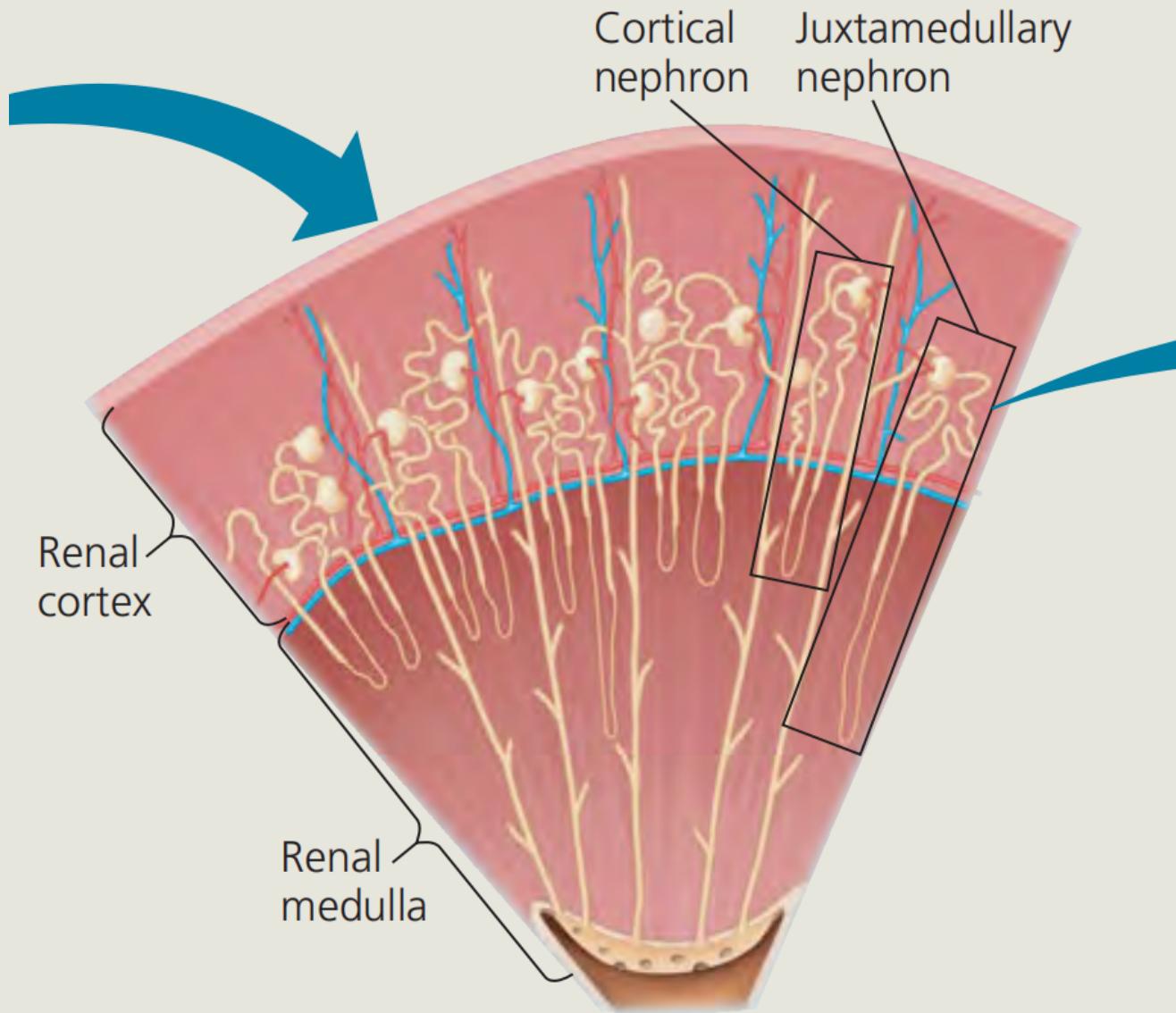
Excretory system



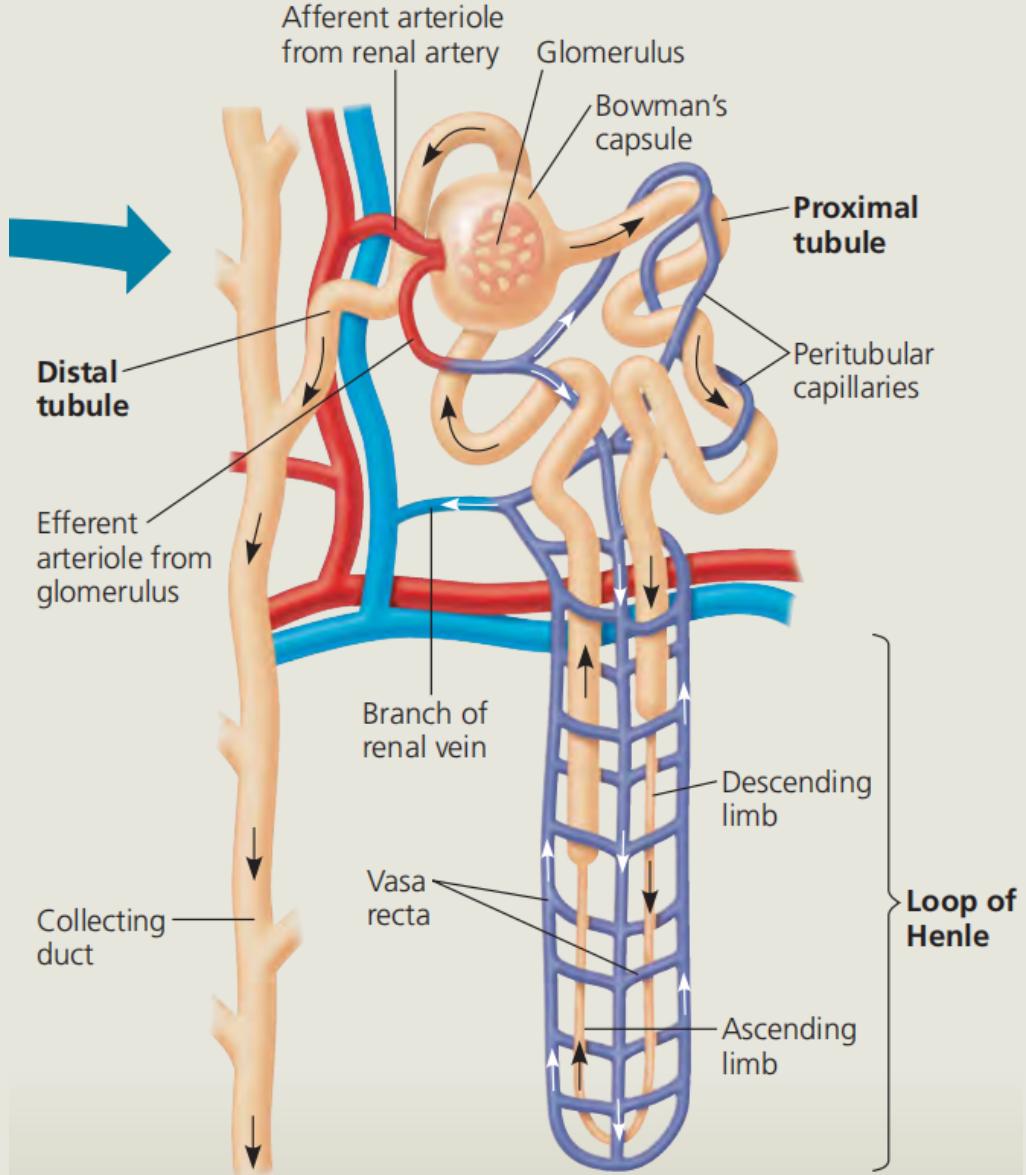
The kidney



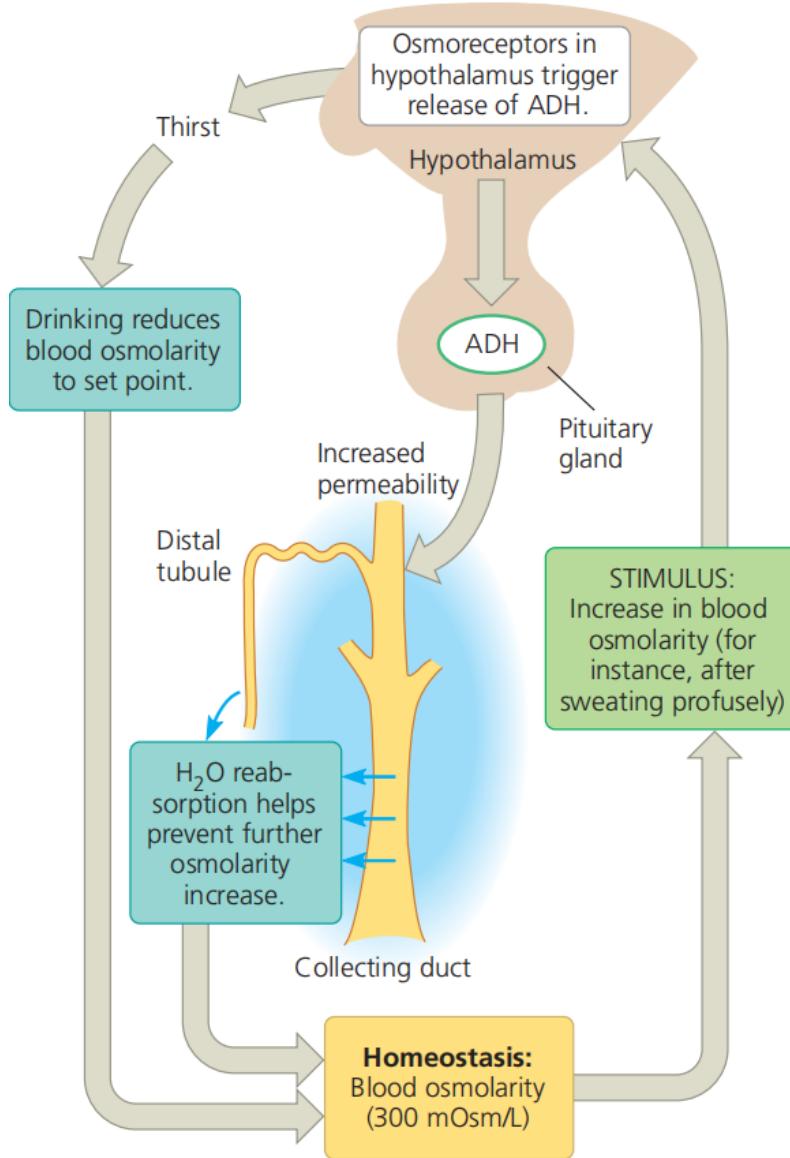
Nephron



Nephron



Osmoregulation

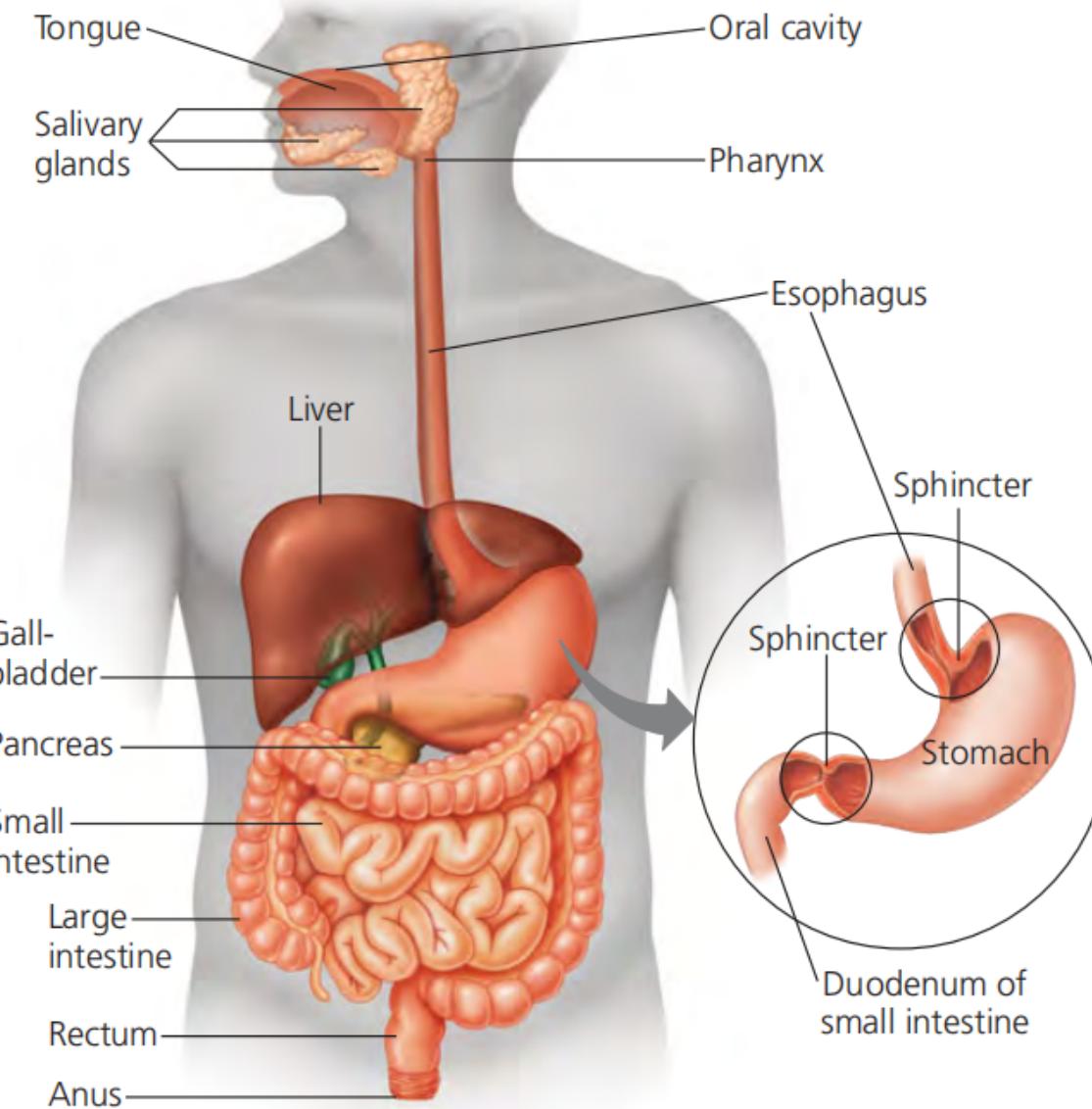


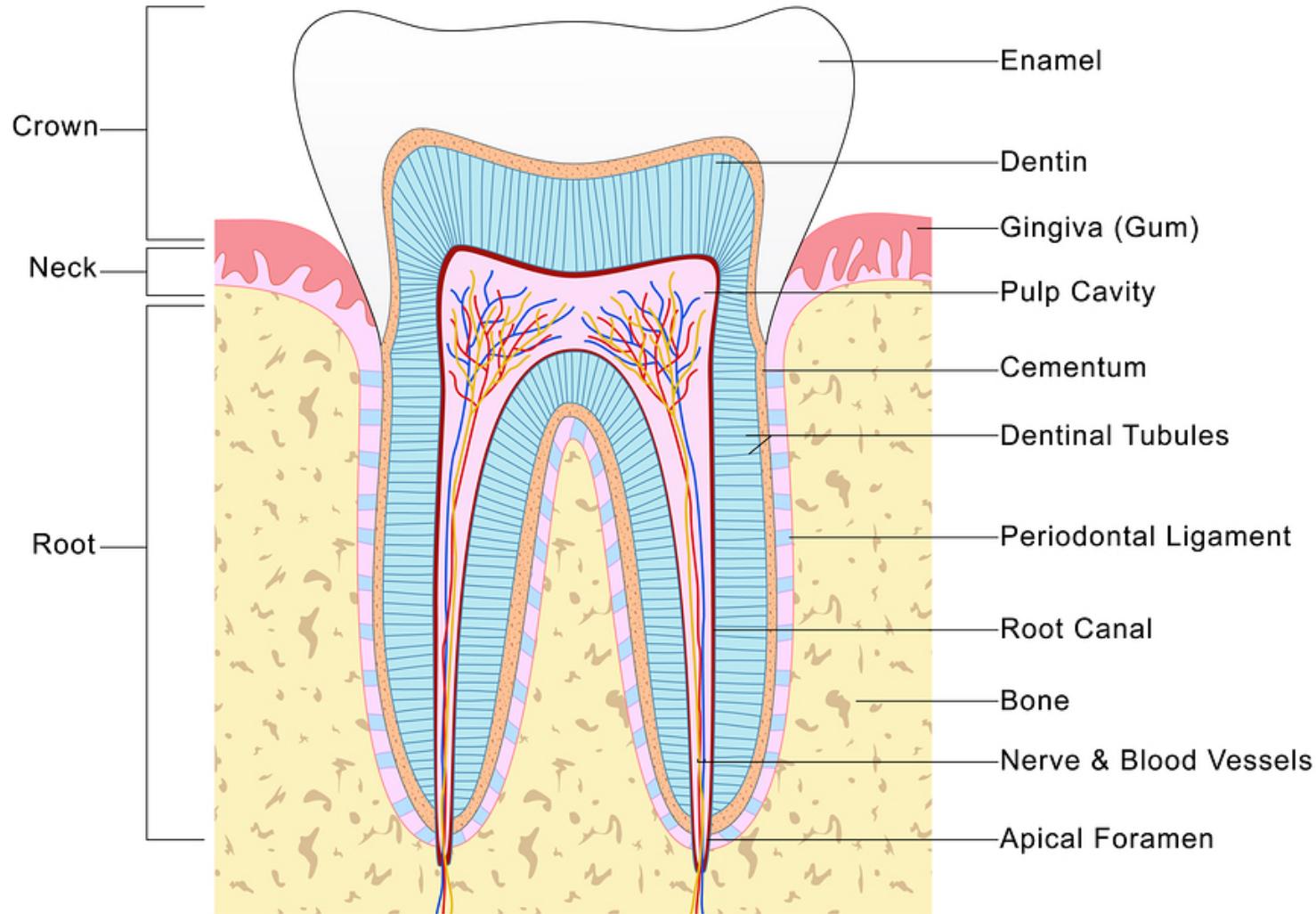


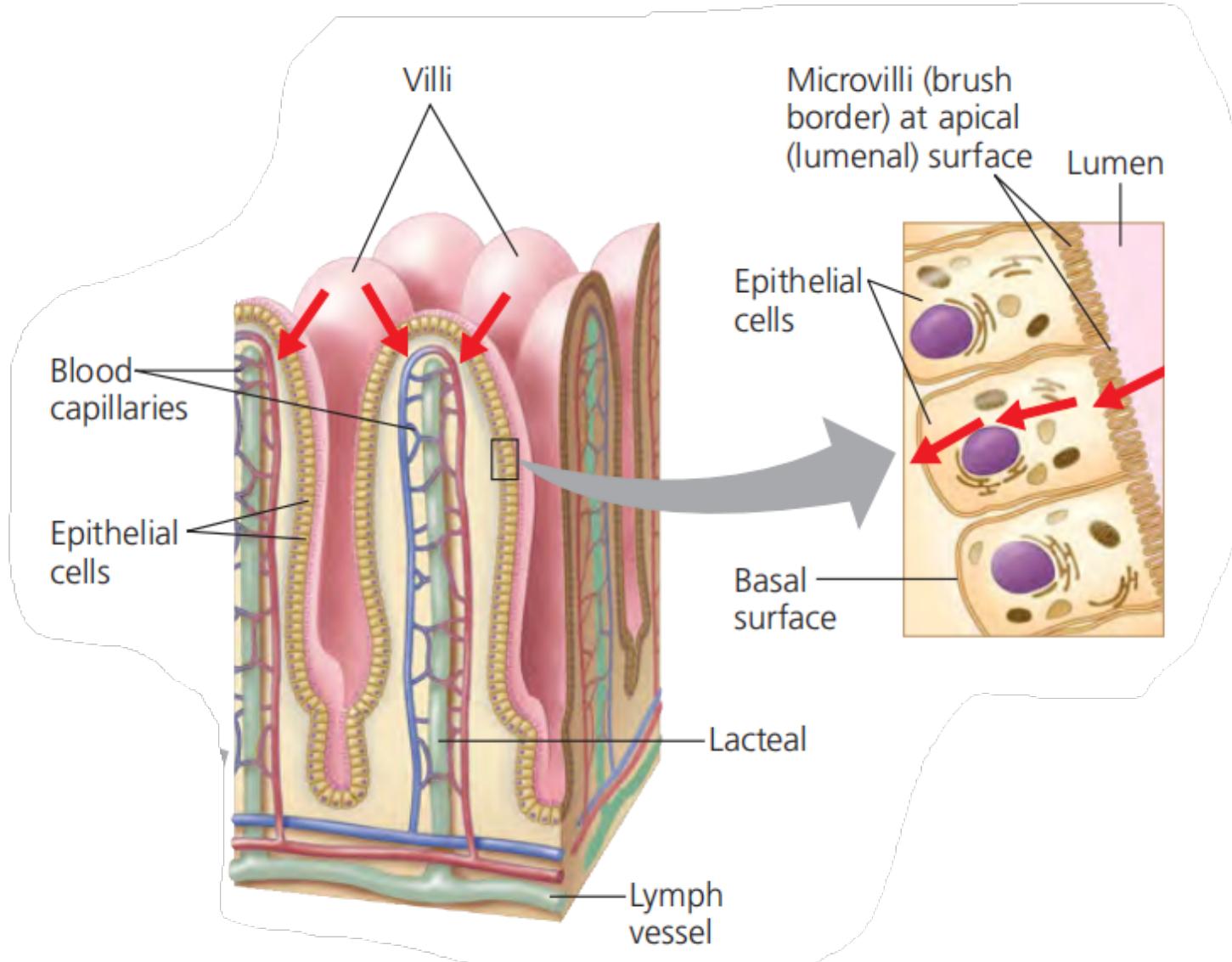
Water

Digestive system

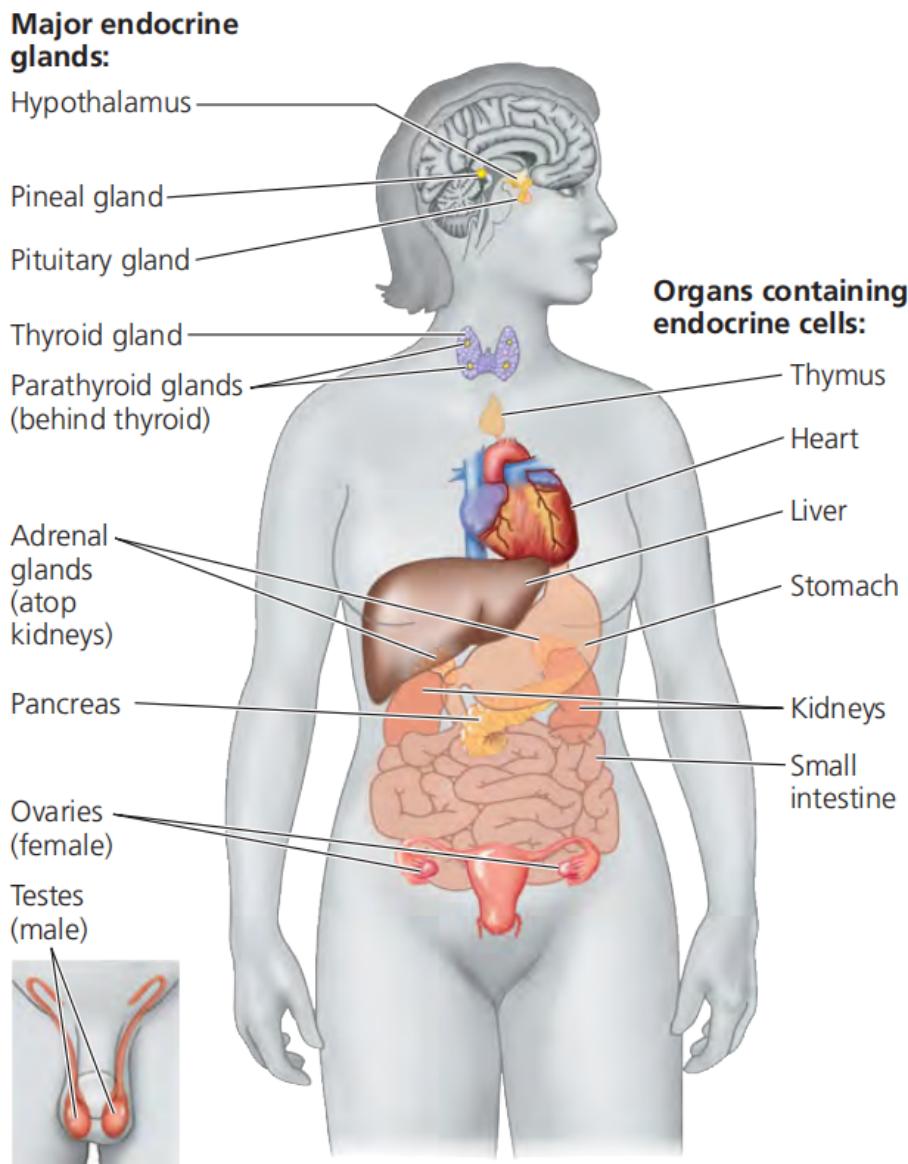
Ingestion
Digestion
Absorption
Assimilation
Egestion





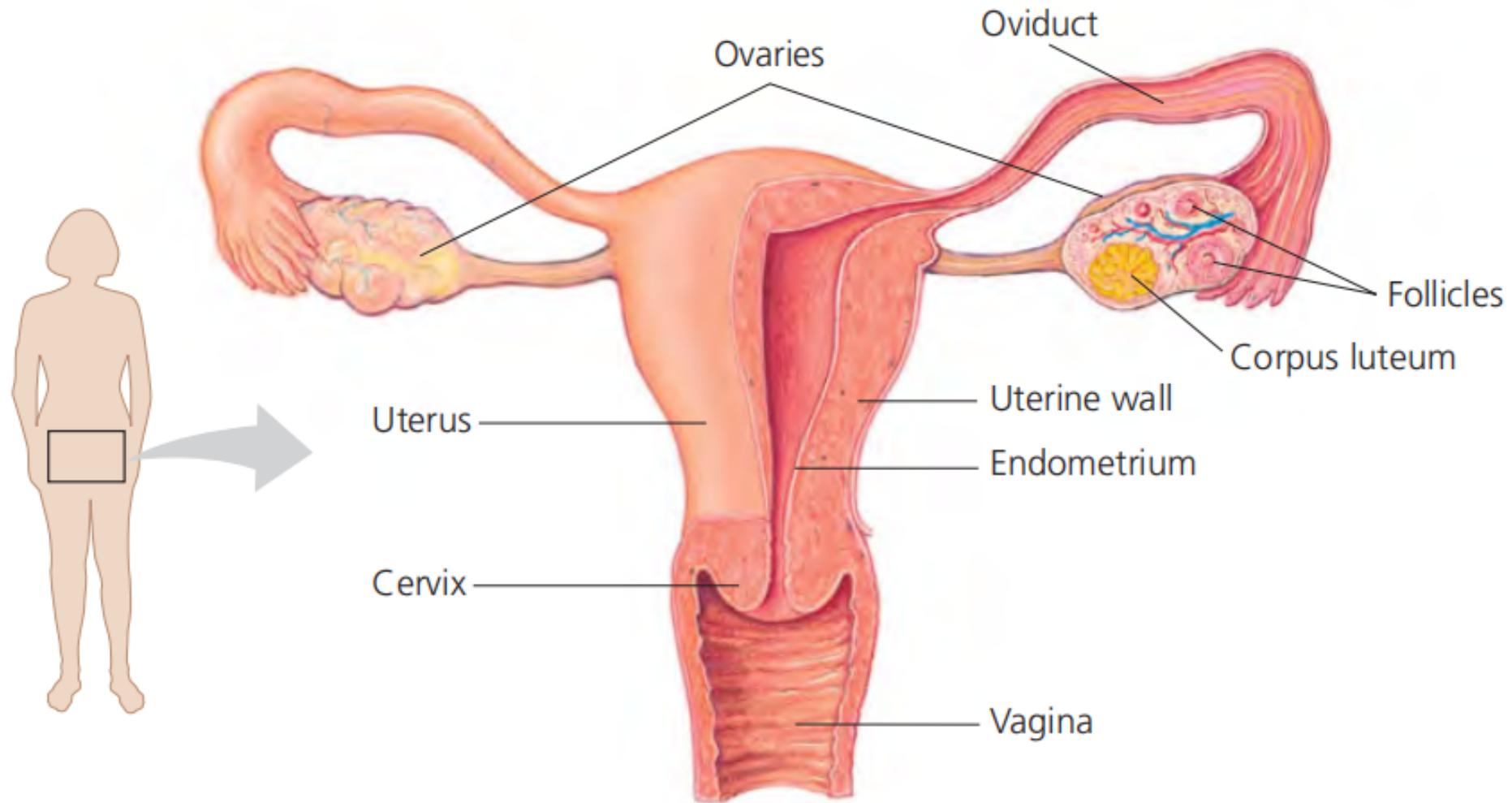
Villi

The endocrine system

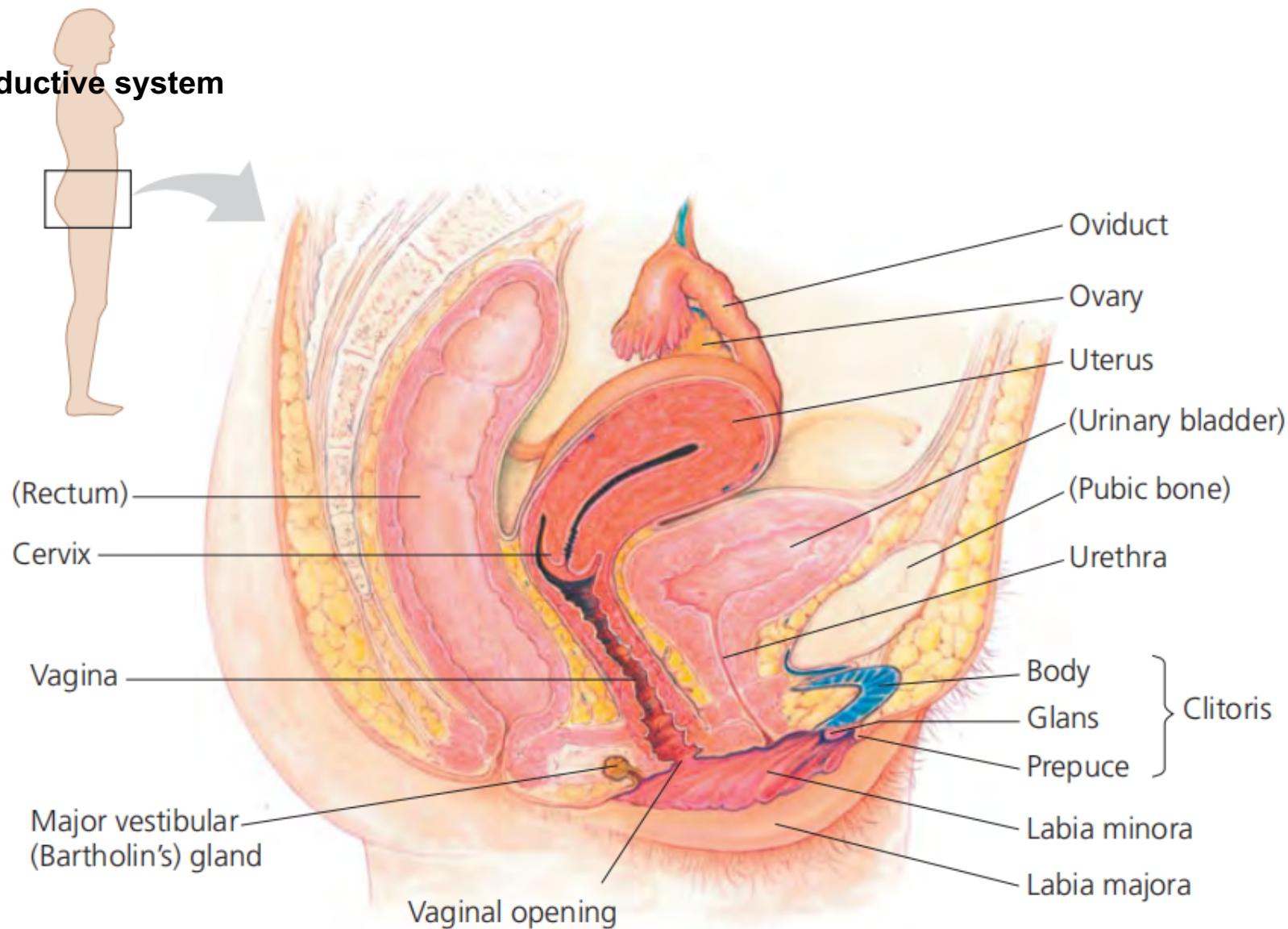




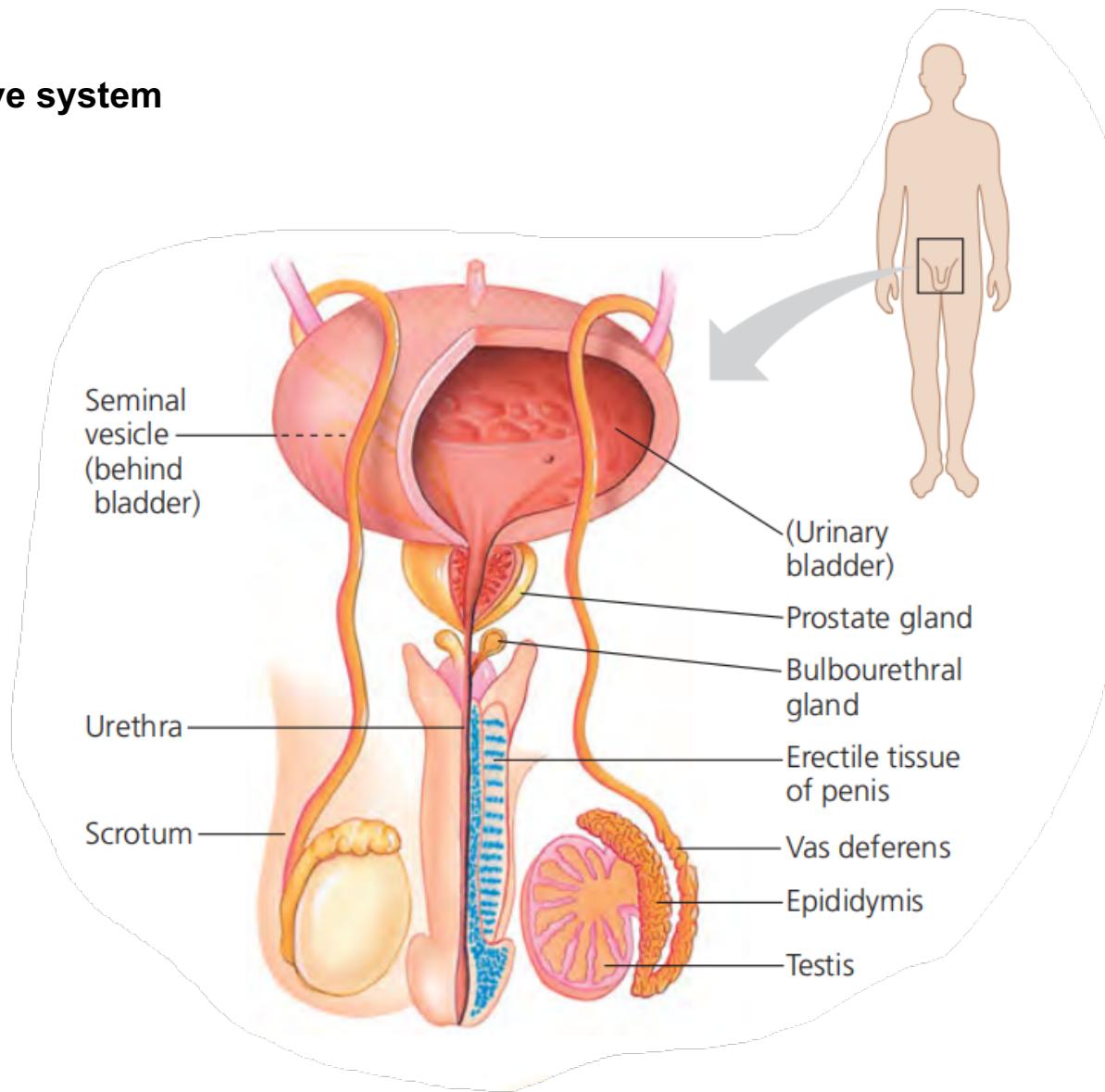
The reproductive system



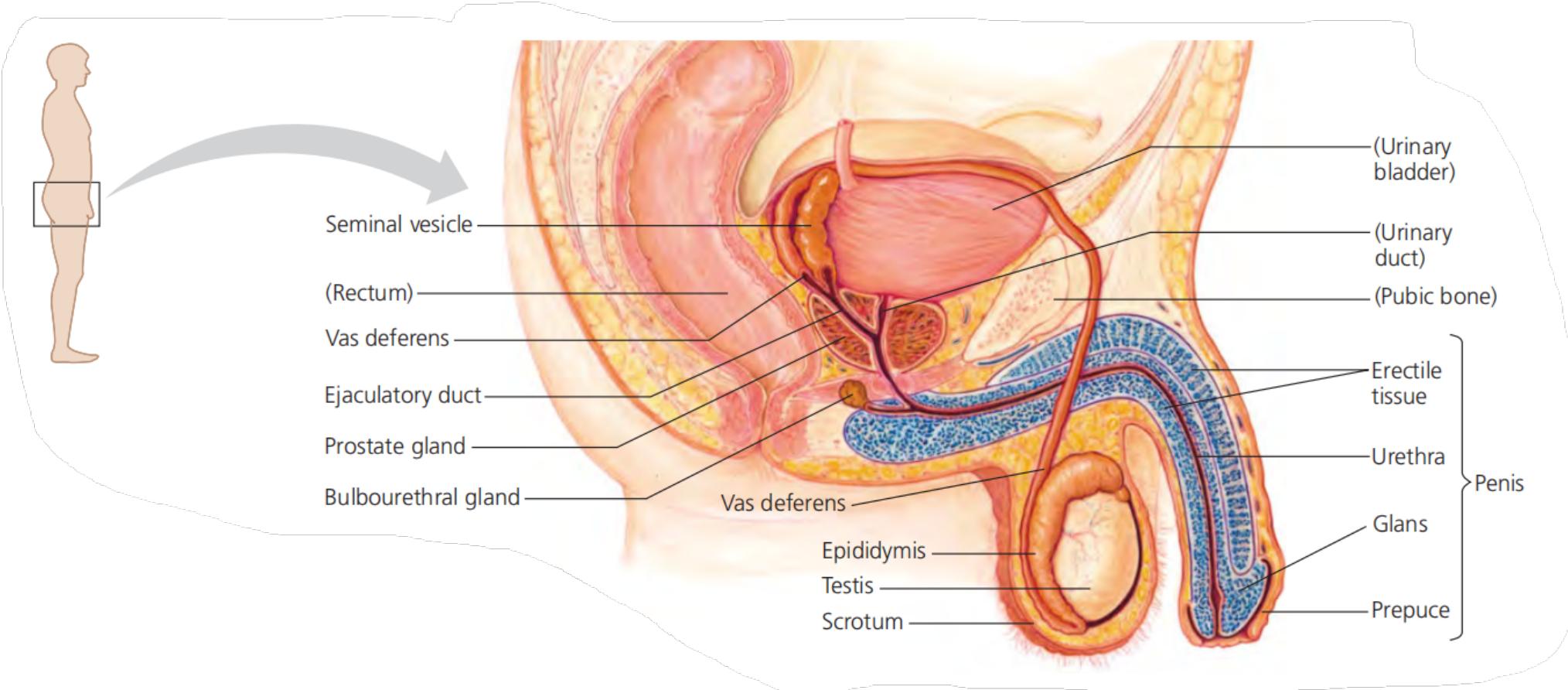
The reproductive system



The reproductive system



The reproductive system

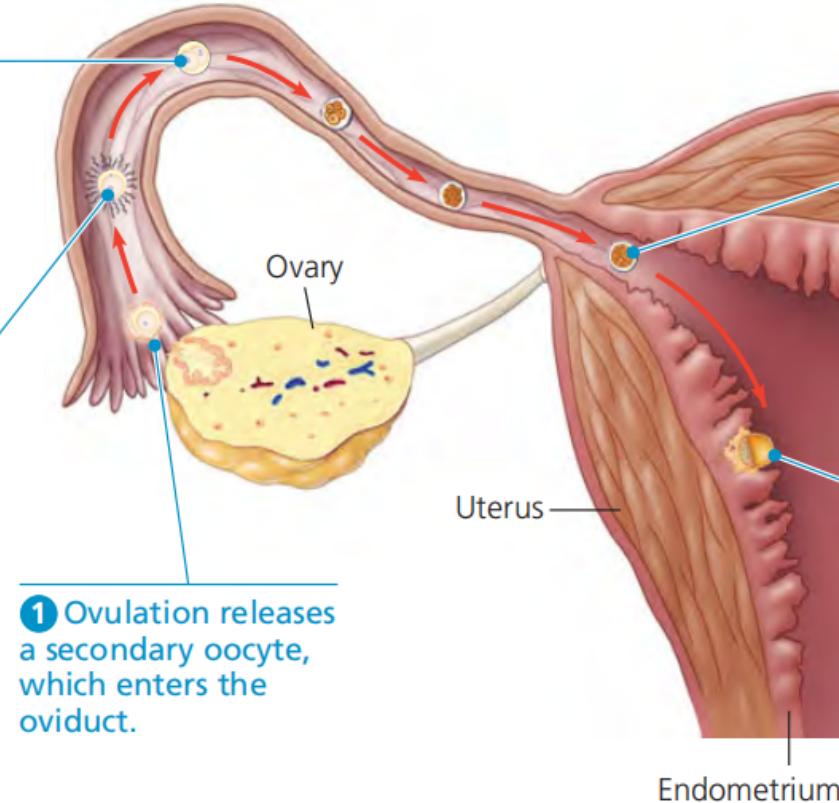


The reproductive system

3 Cleavage (cell division) begins in the oviduct as the embryo is moved toward the uterus by peristalsis and the movements of cilia.



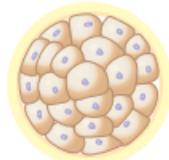
2 Fertilization occurs: A sperm enters the oocyte; meiosis of the oocyte is completed; and the nuclei of the oocyte and the sperm fuse, producing a zygote.



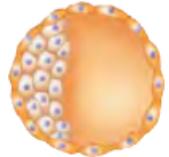
1 Ovulation releases a secondary oocyte, which enters the oviduct.



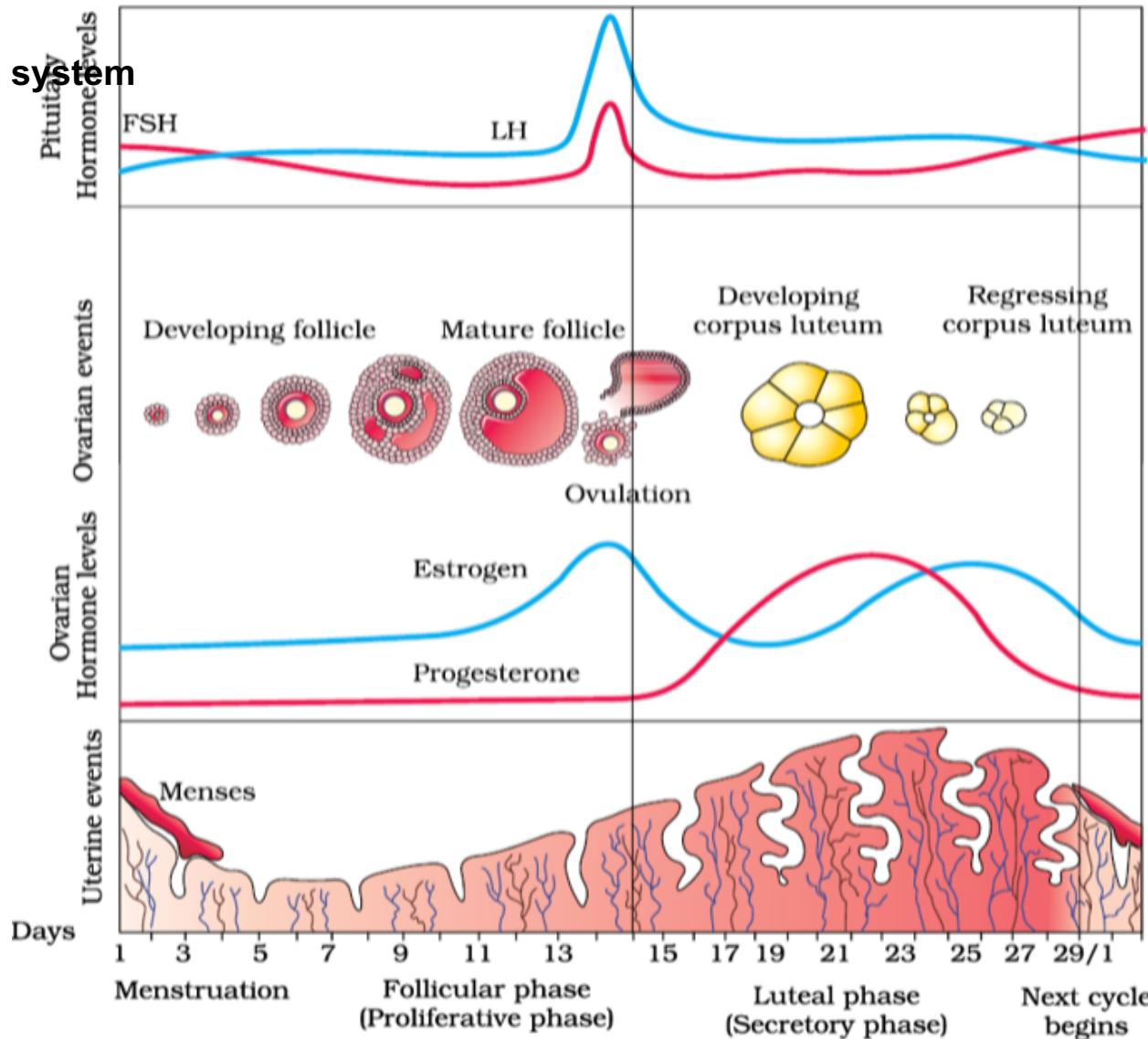
4 Cleavage continues. By the time the embryo reaches the uterus, it is a ball of cells. It floats in the uterus for several days, nourished by endometrial secretions. It becomes a blastocyst.



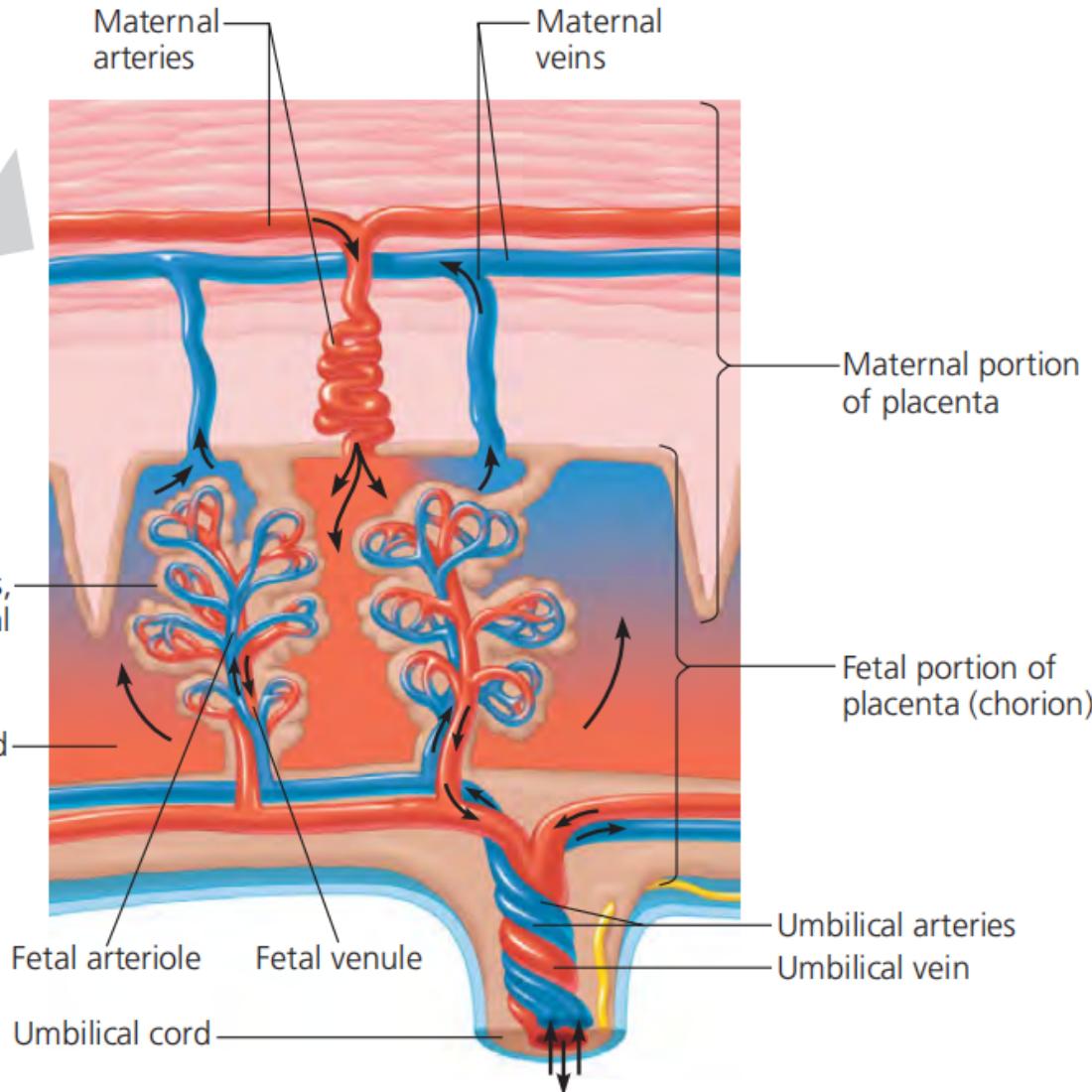
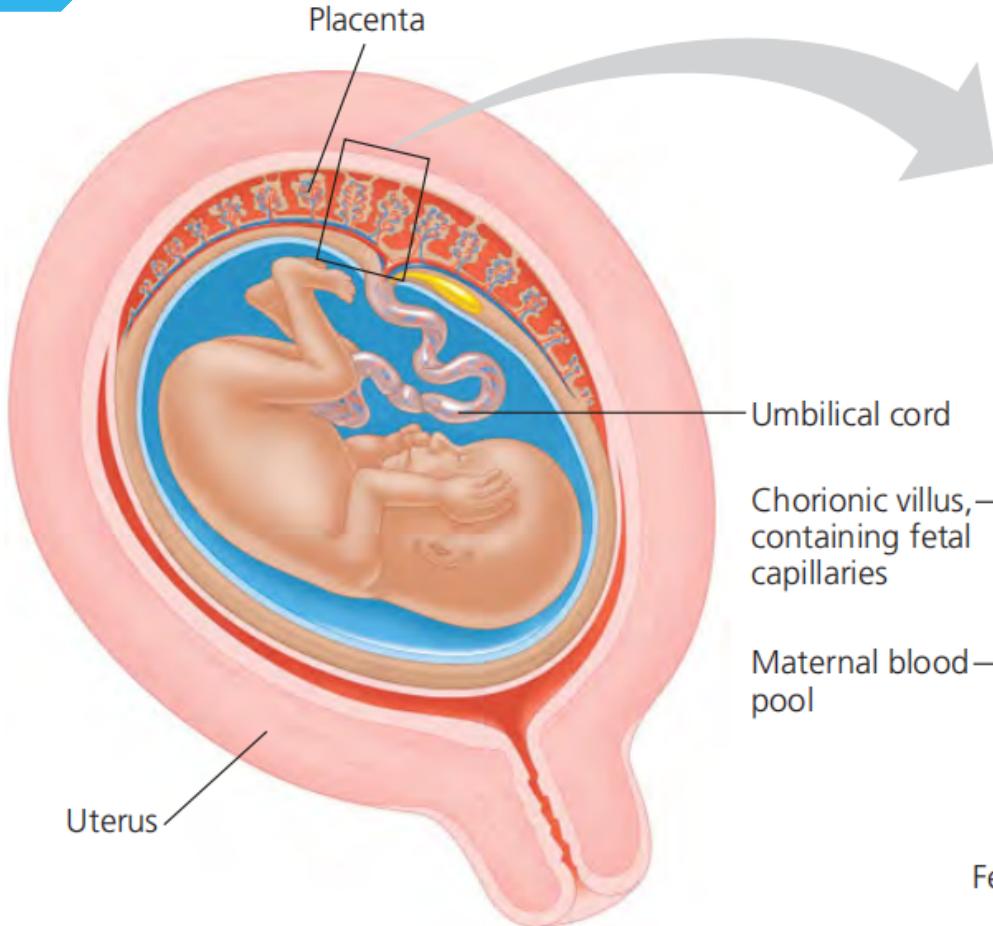
5 The blastocyst implants in the endometrium about 7 days after conception.



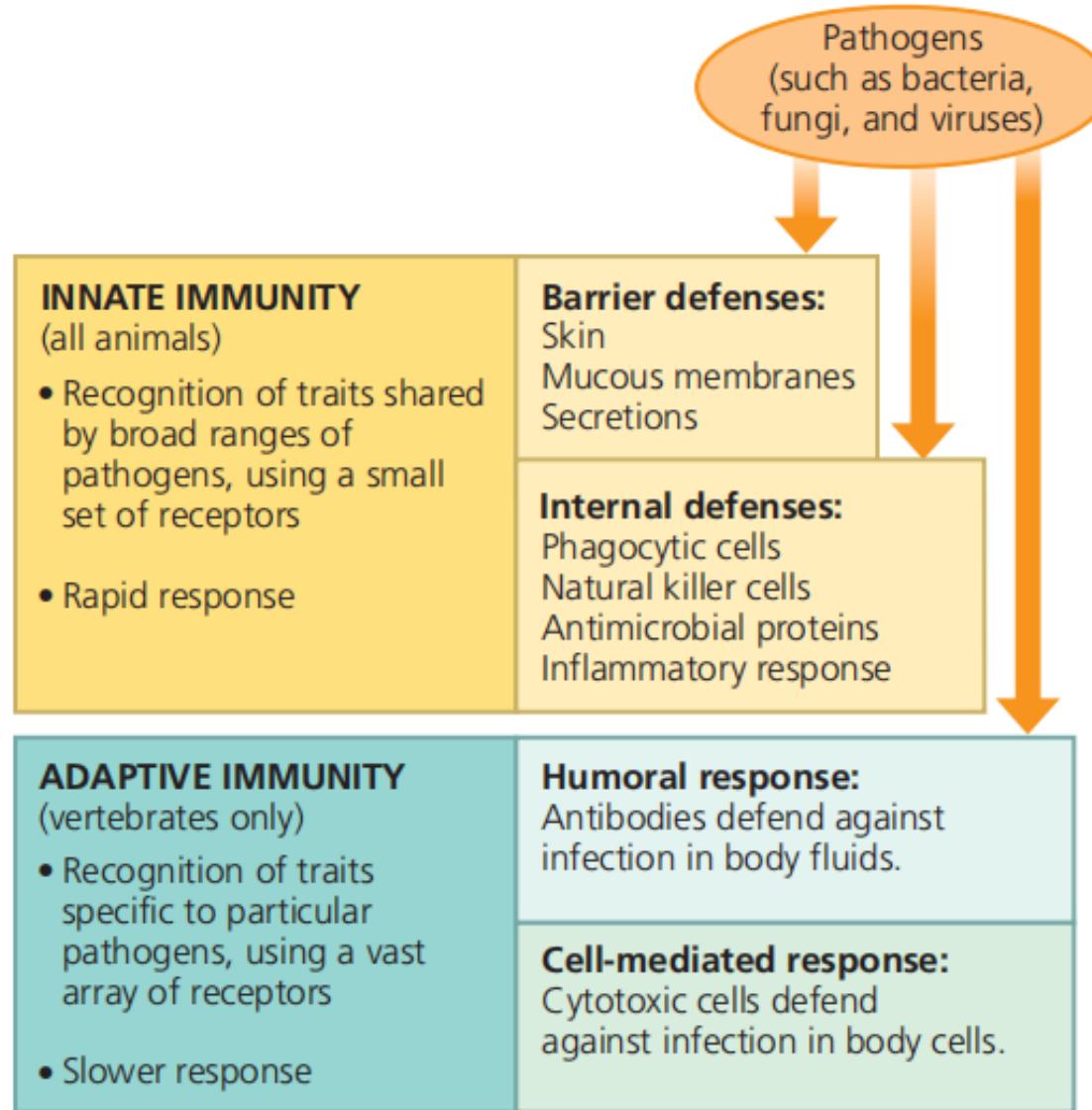
The reproductive system



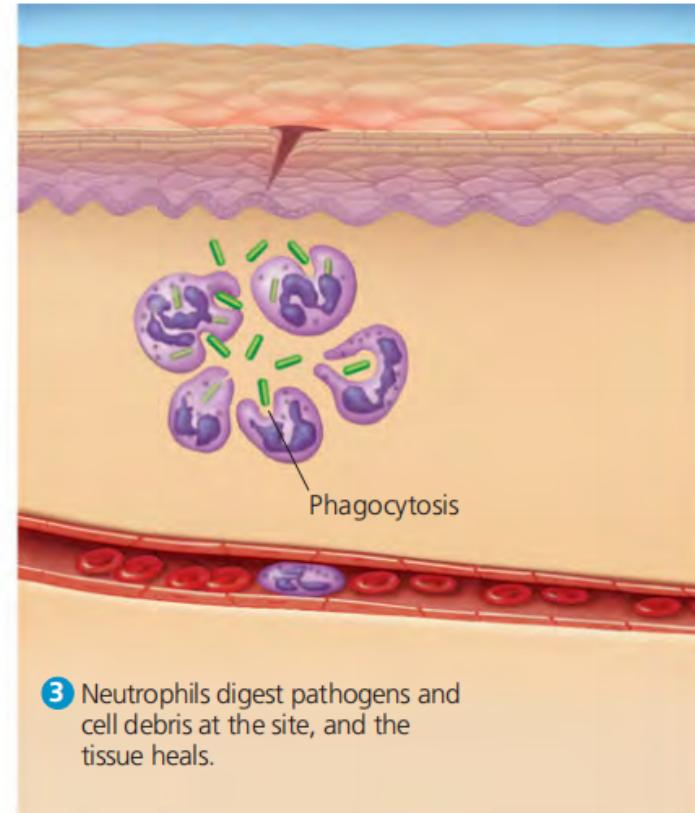
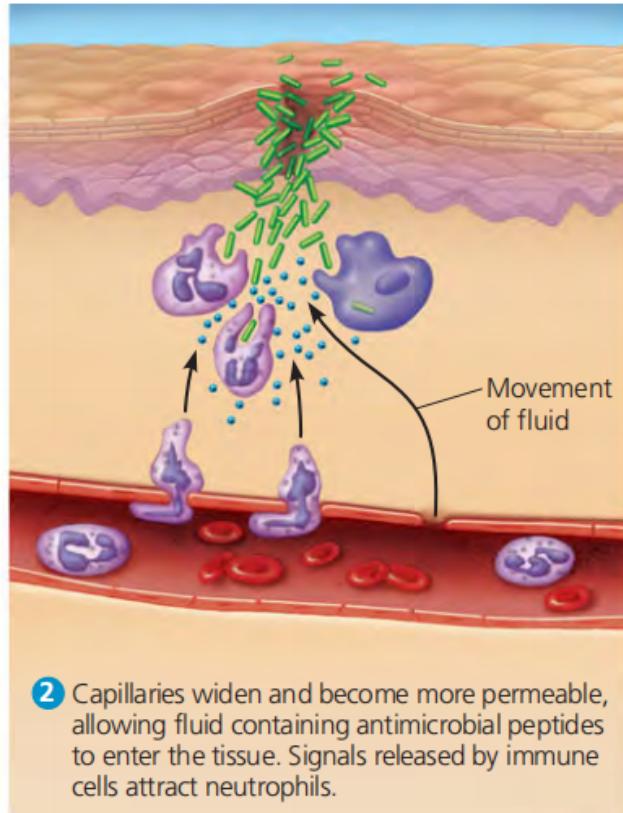
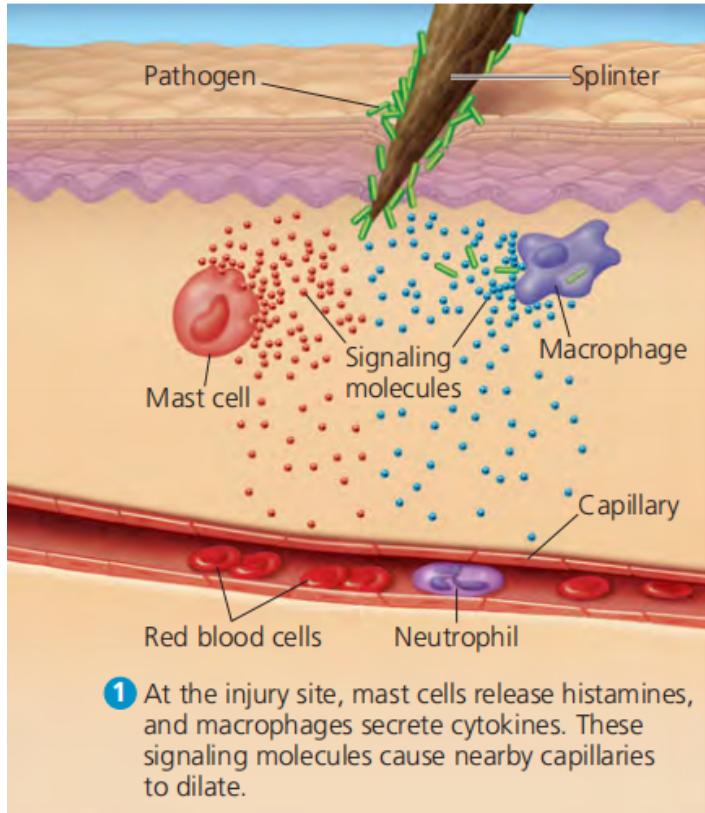
The reproductive system



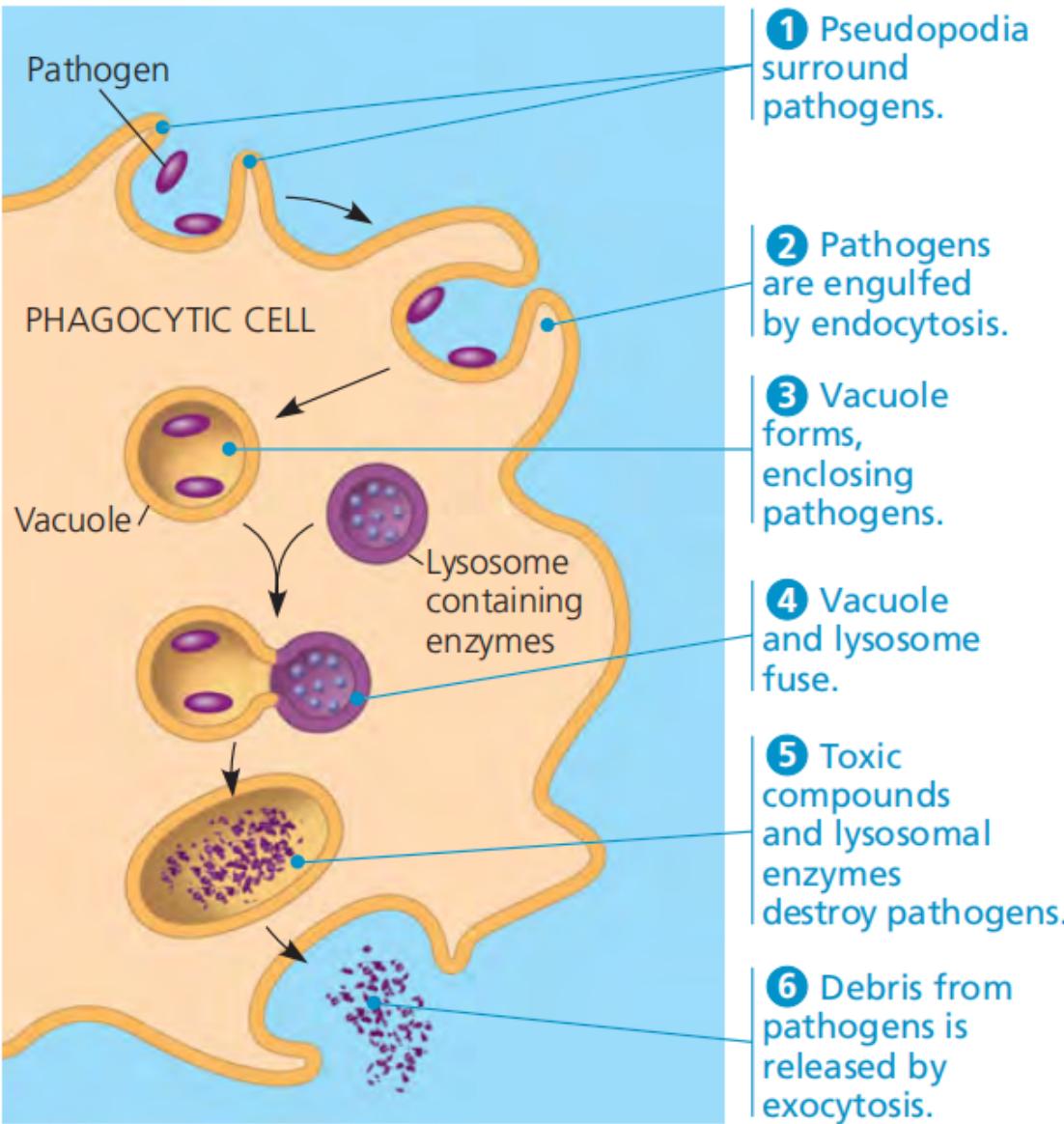
The immune system



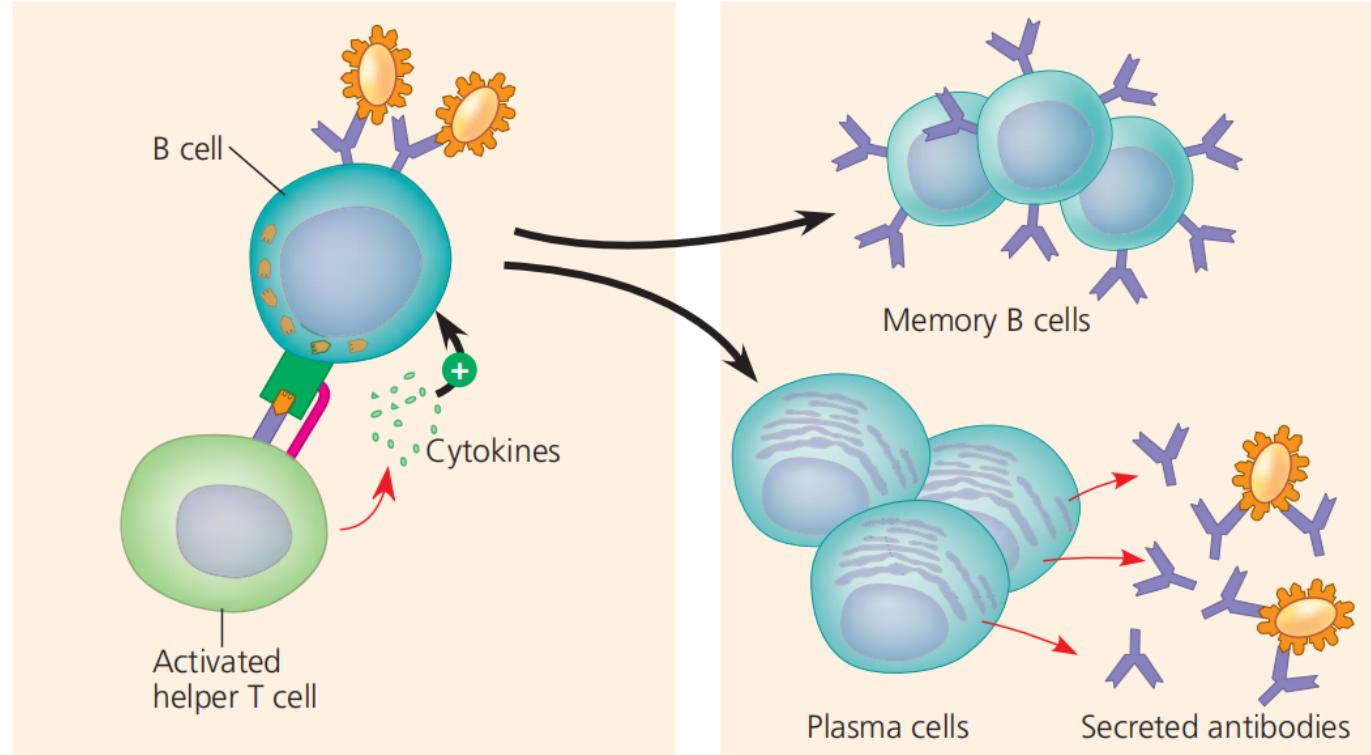
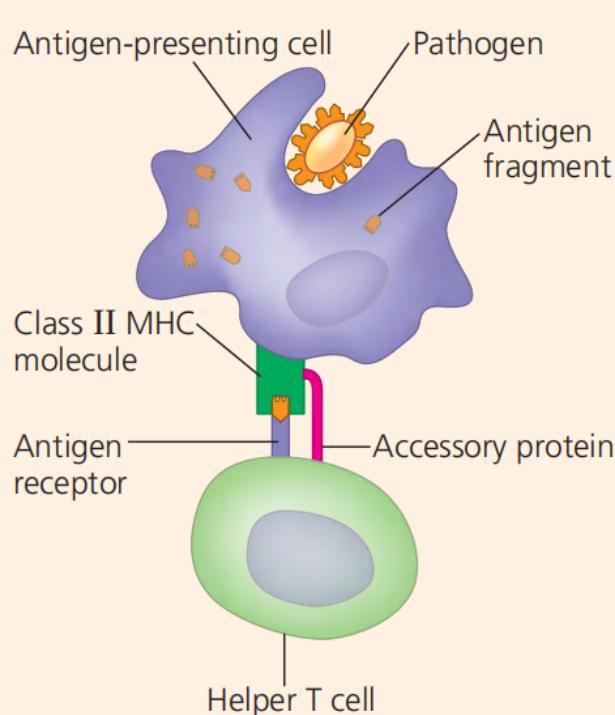
The immune system



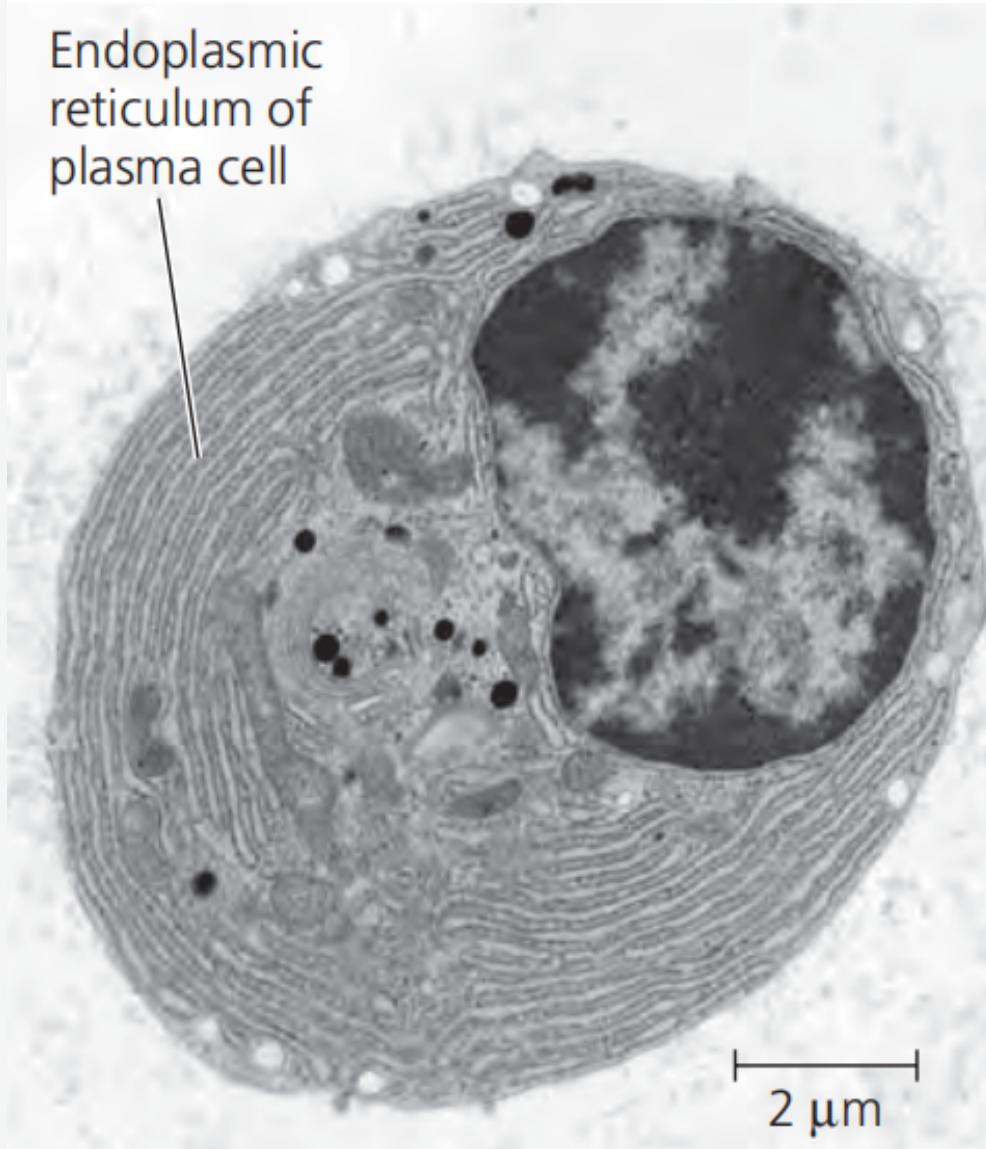
Phagocytosis



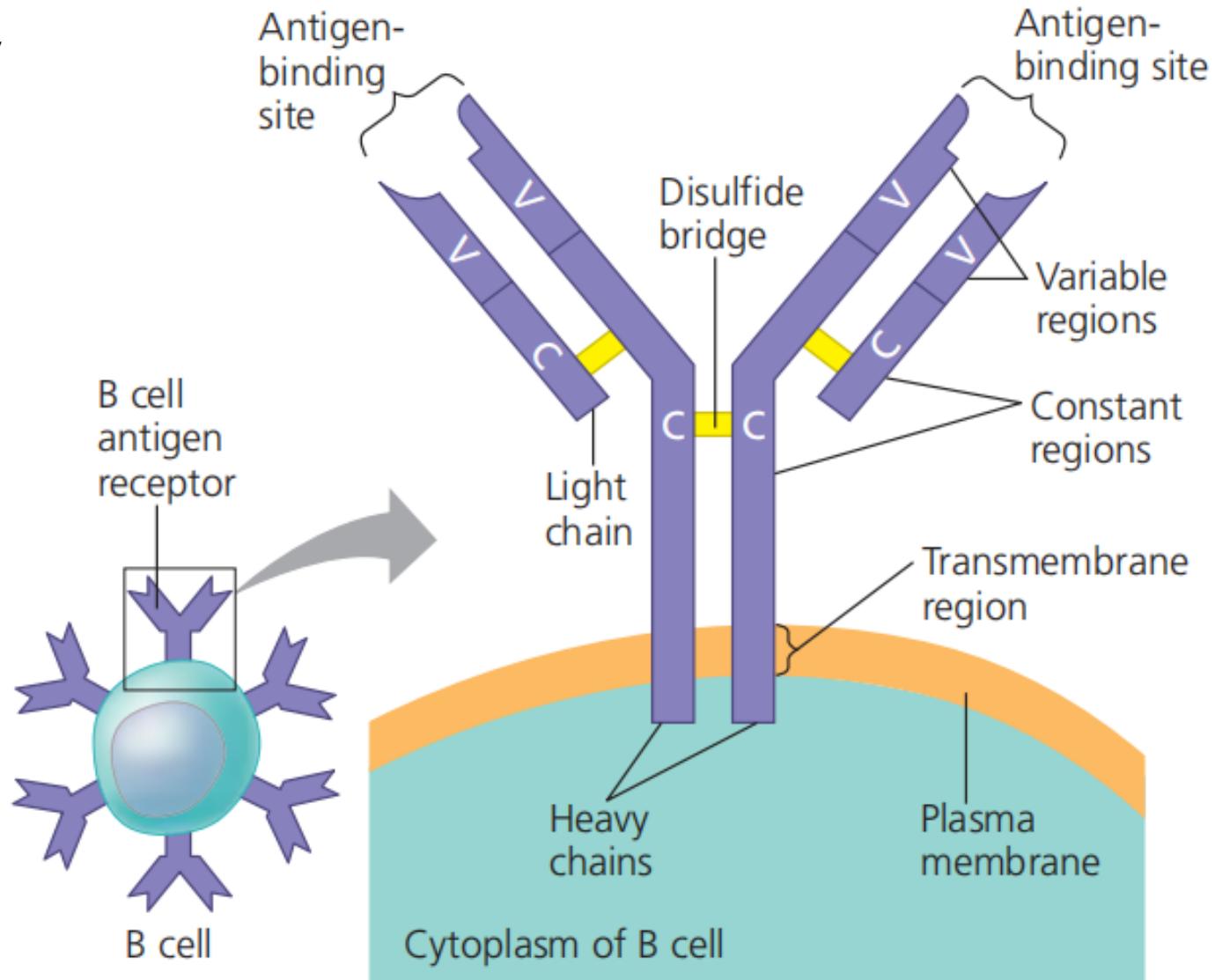
Production of antibodies

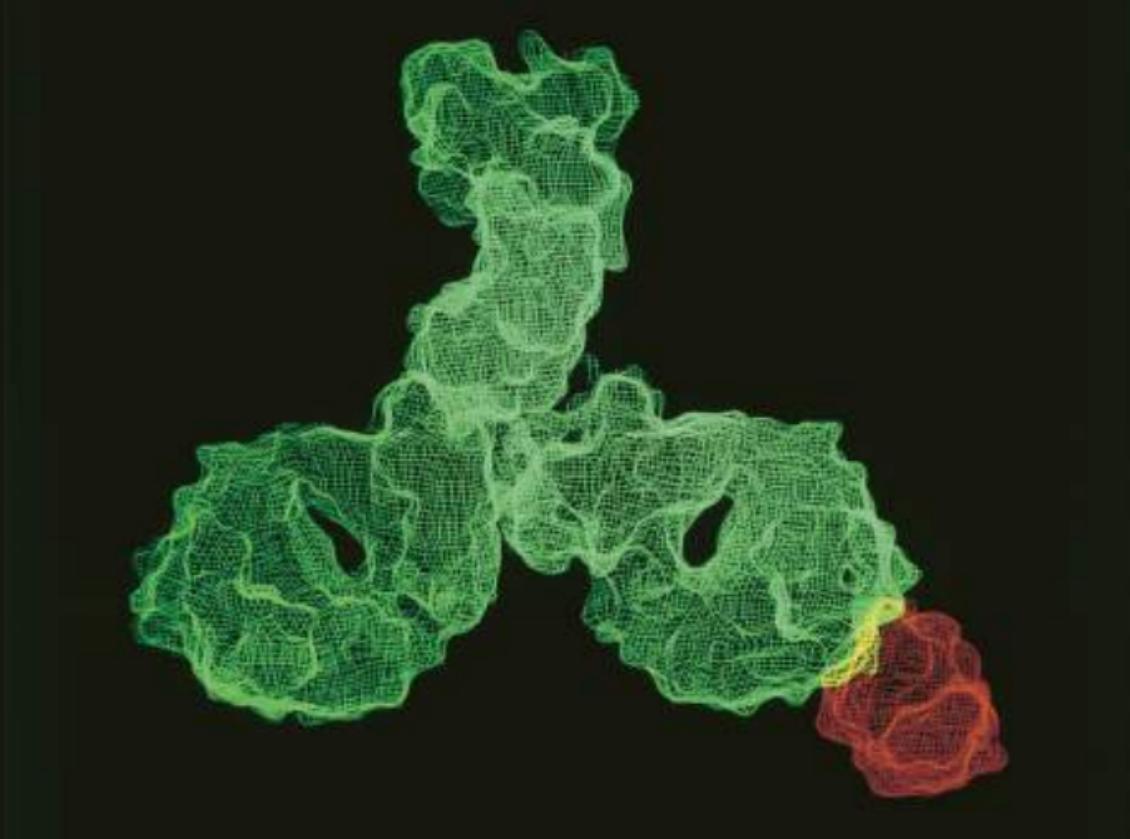


Plasma cell



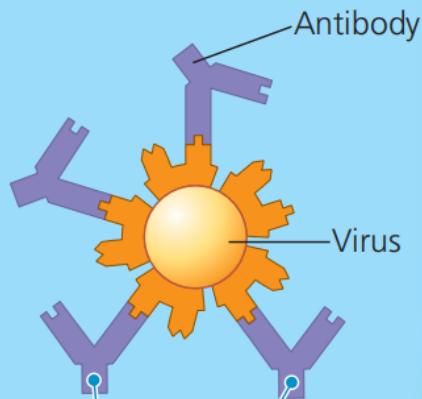
The antibody



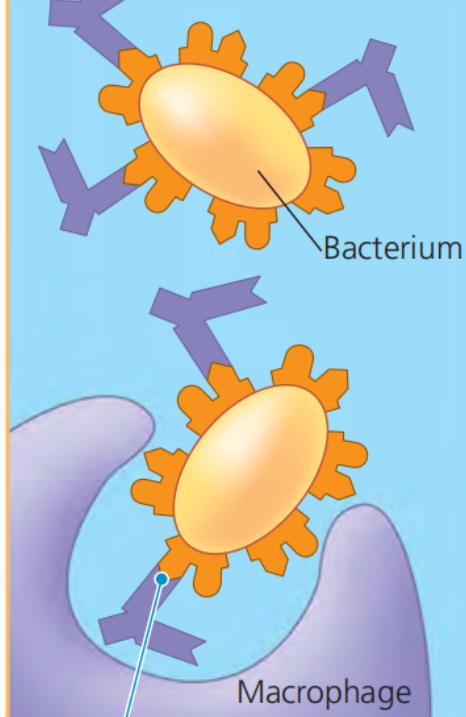


The antibody

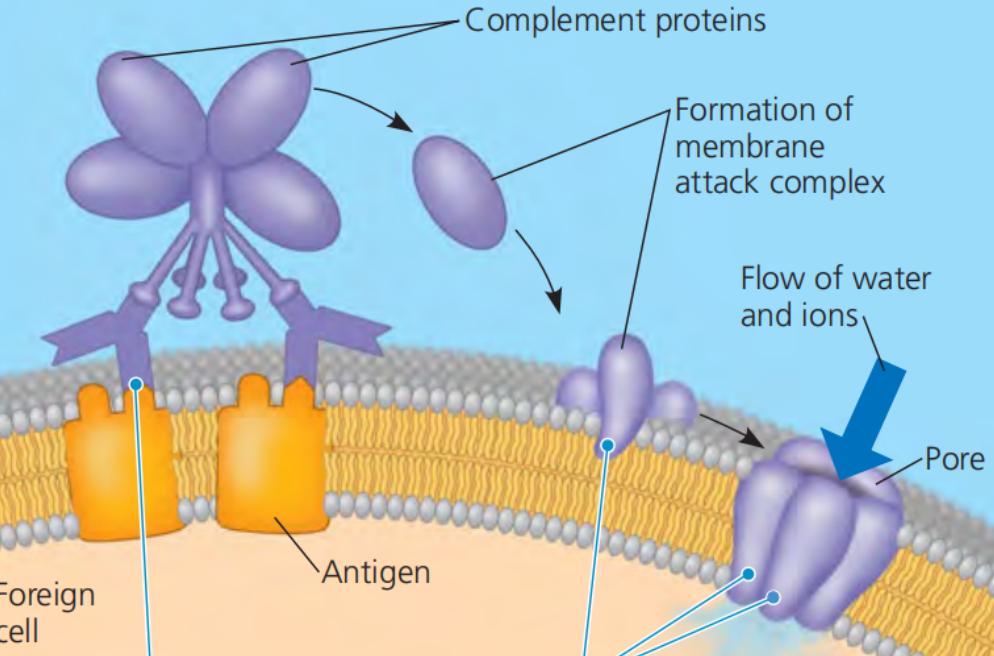
Neutralization



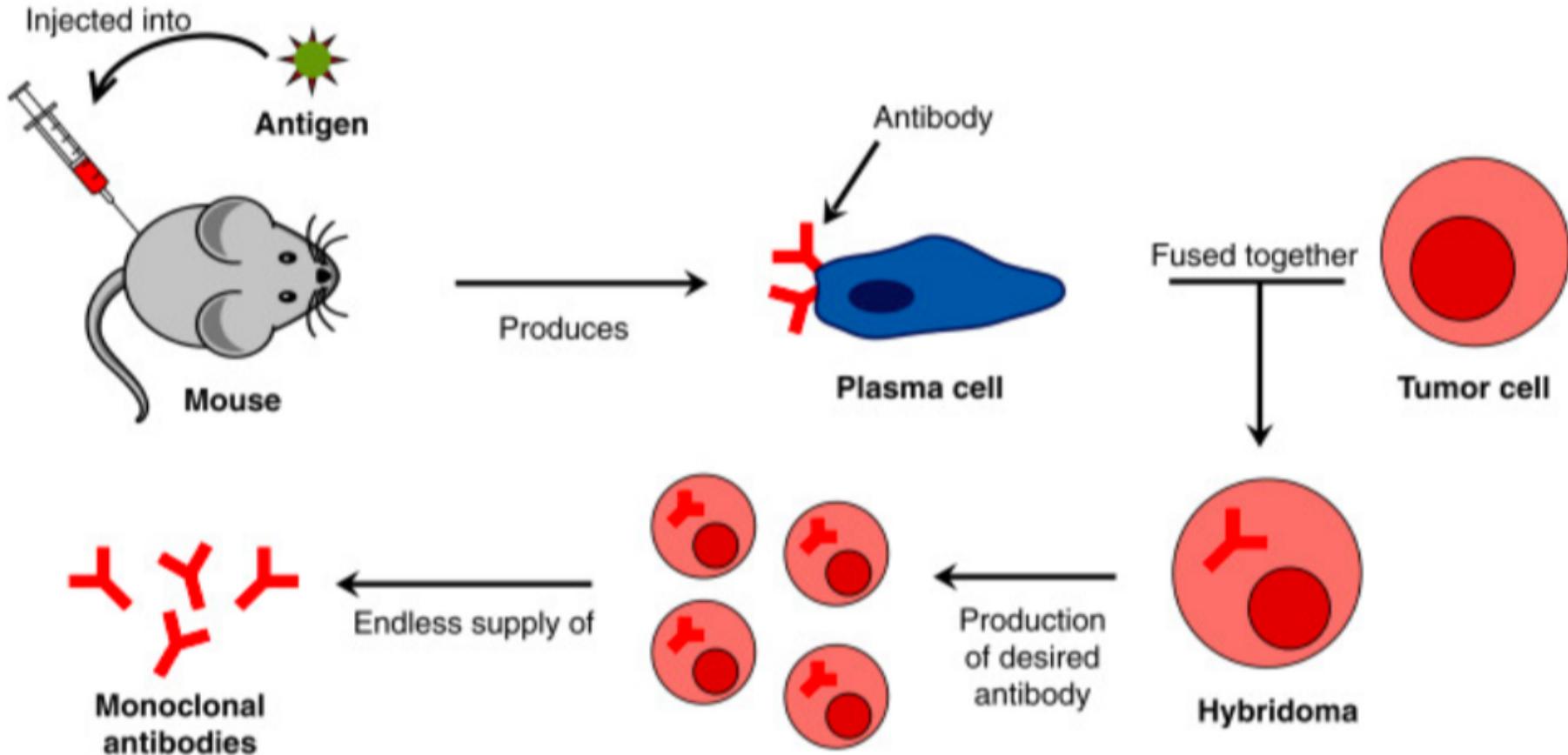
Opsonization



Activation of complement system and pore formation



The antibody



Immunological memory

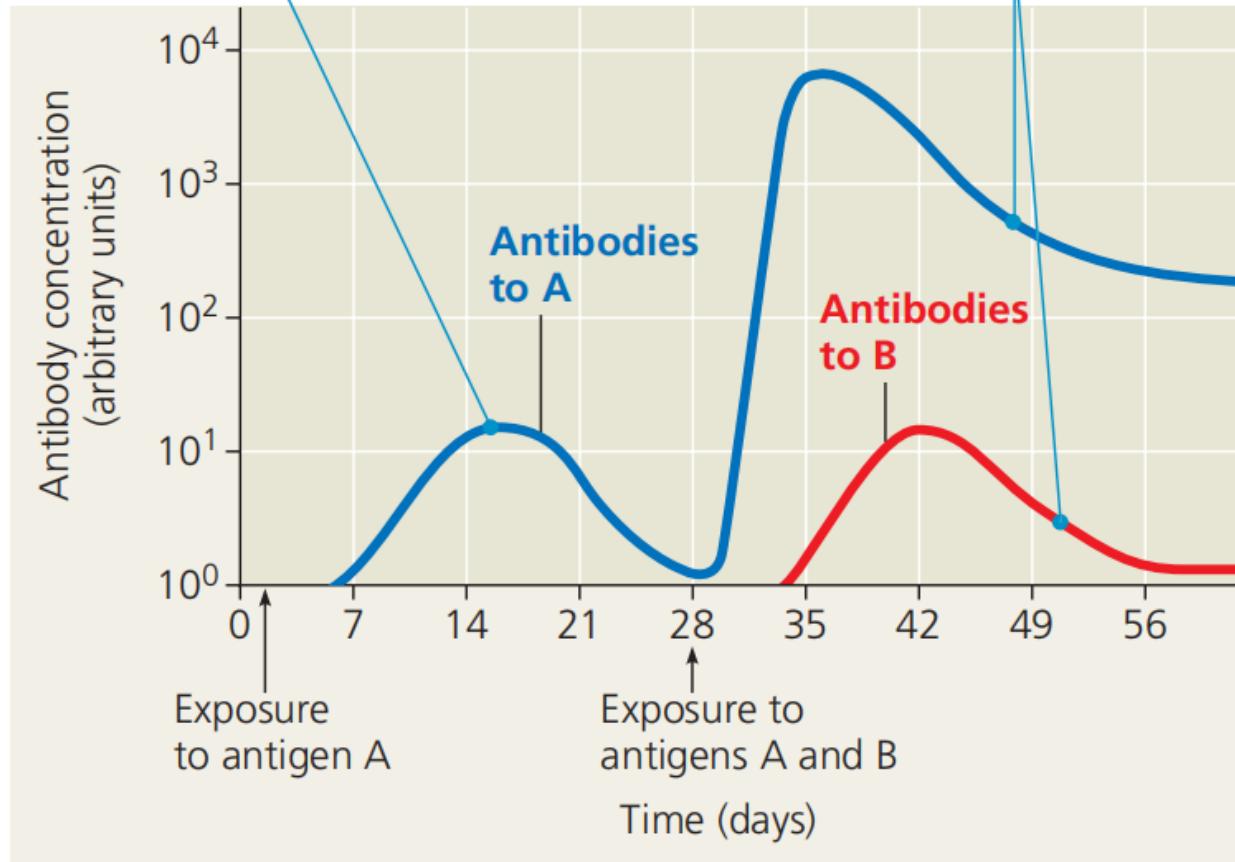
Primary immune response

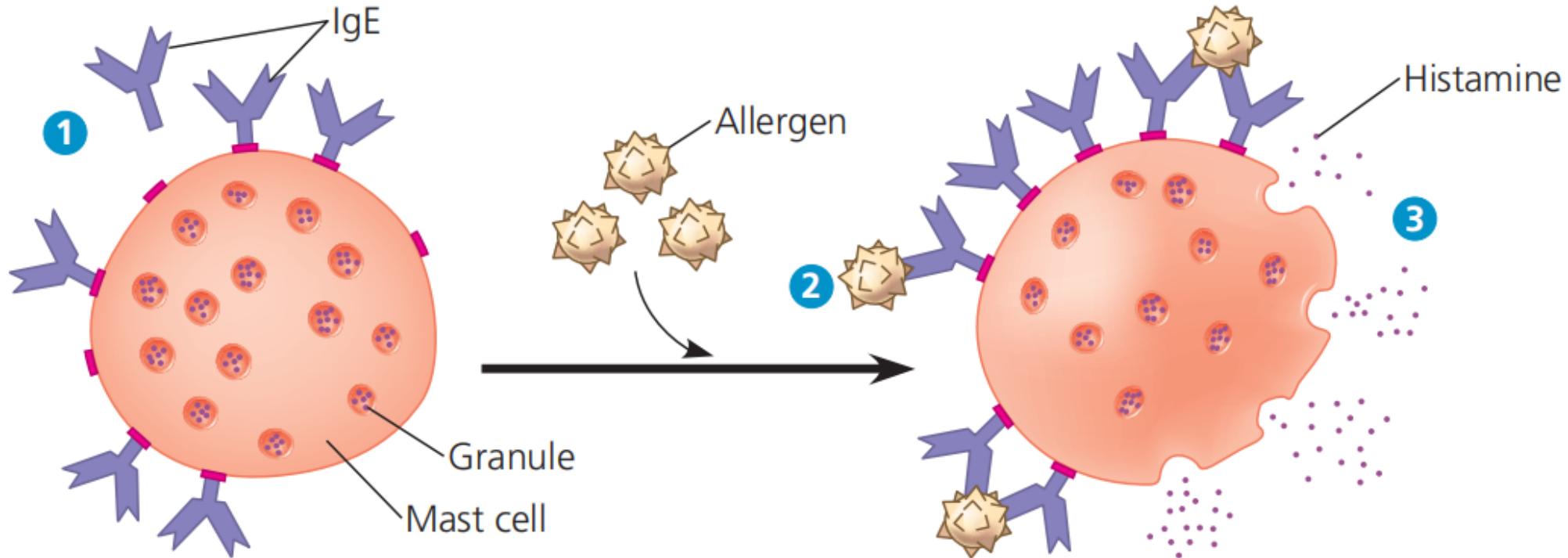
to antigen A produces antibodies to A.

Secondary immune response

to antigen A produces antibodies to A;
primary immune response to antigen B produces antibodies to B.

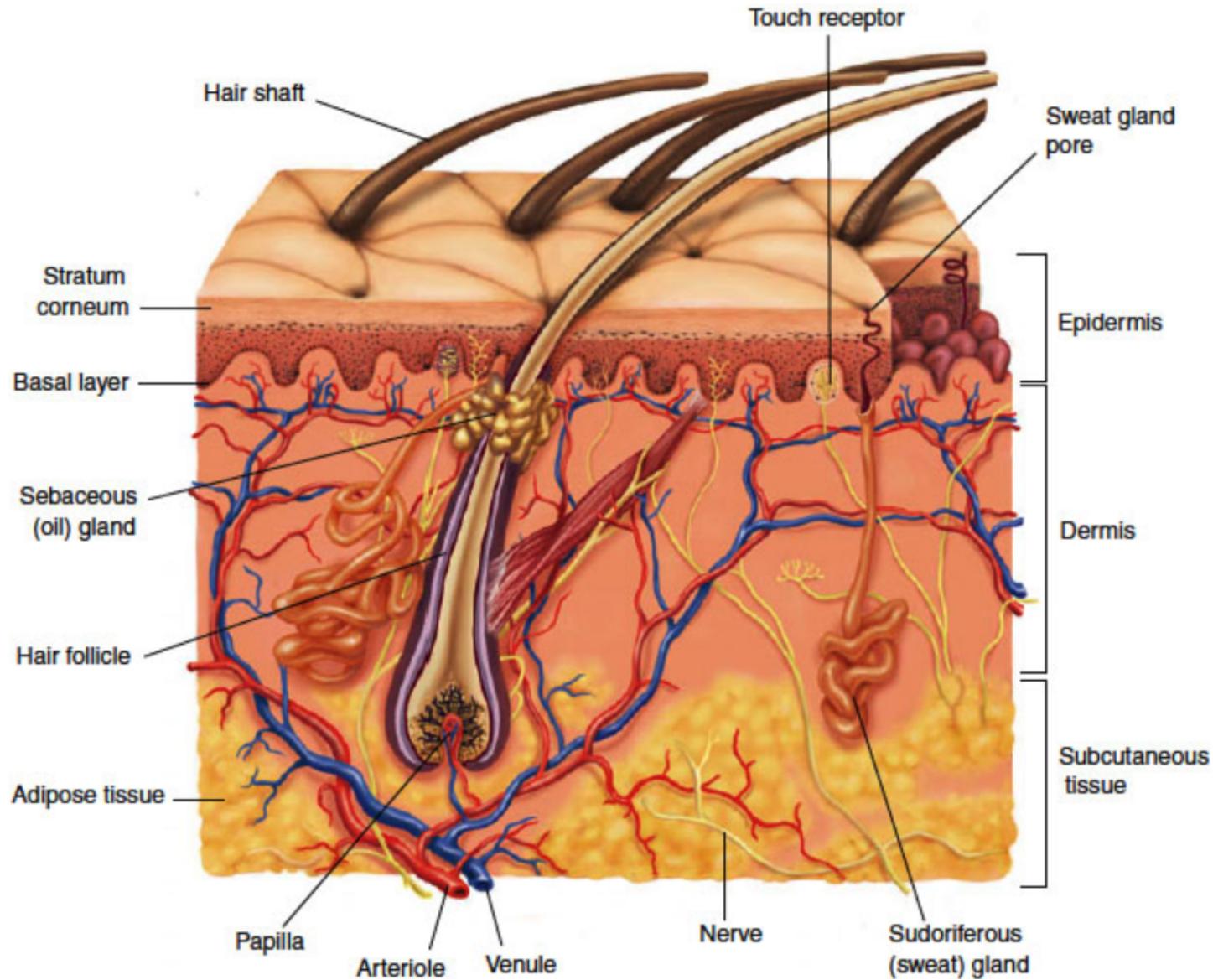
Active/passive
Natural/artificial



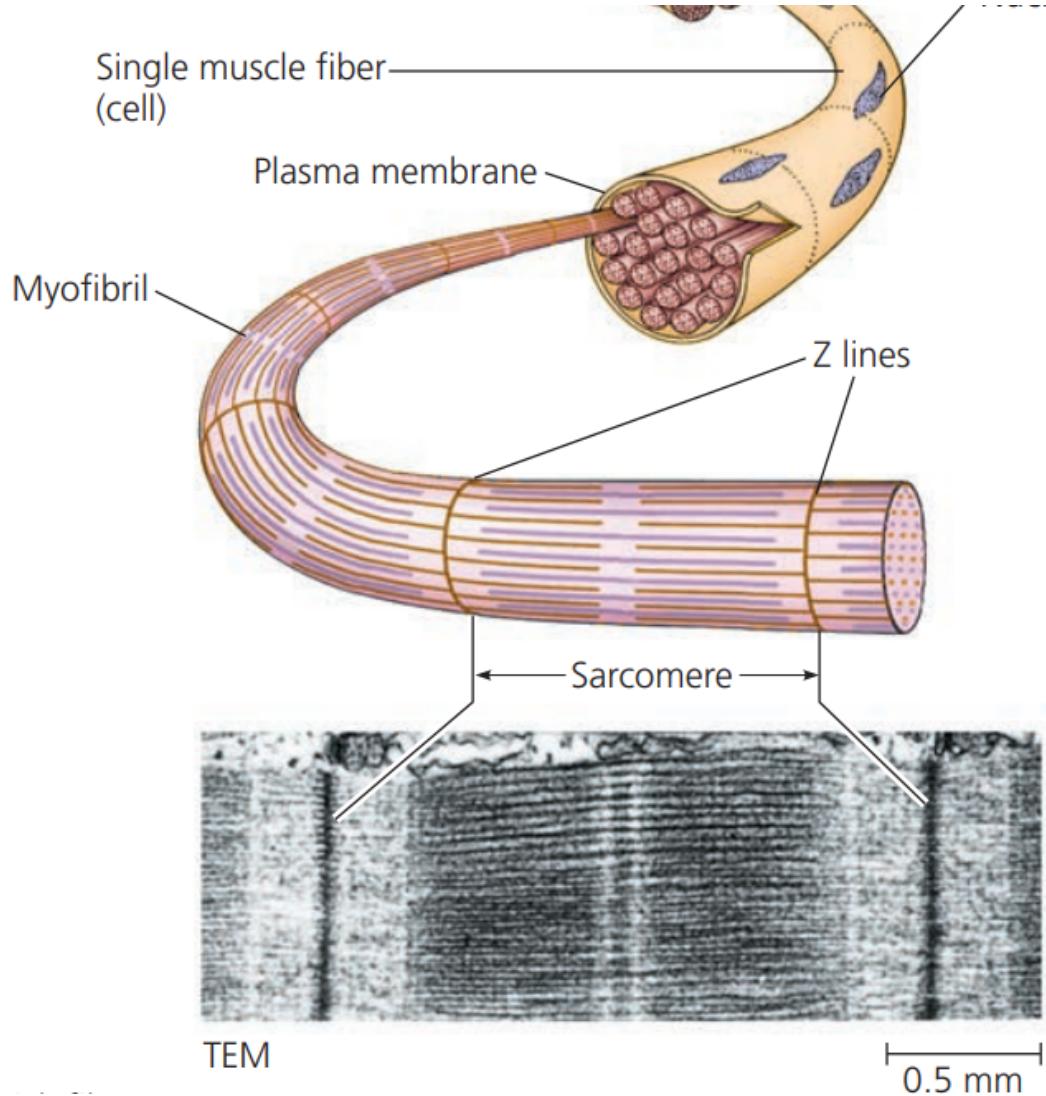
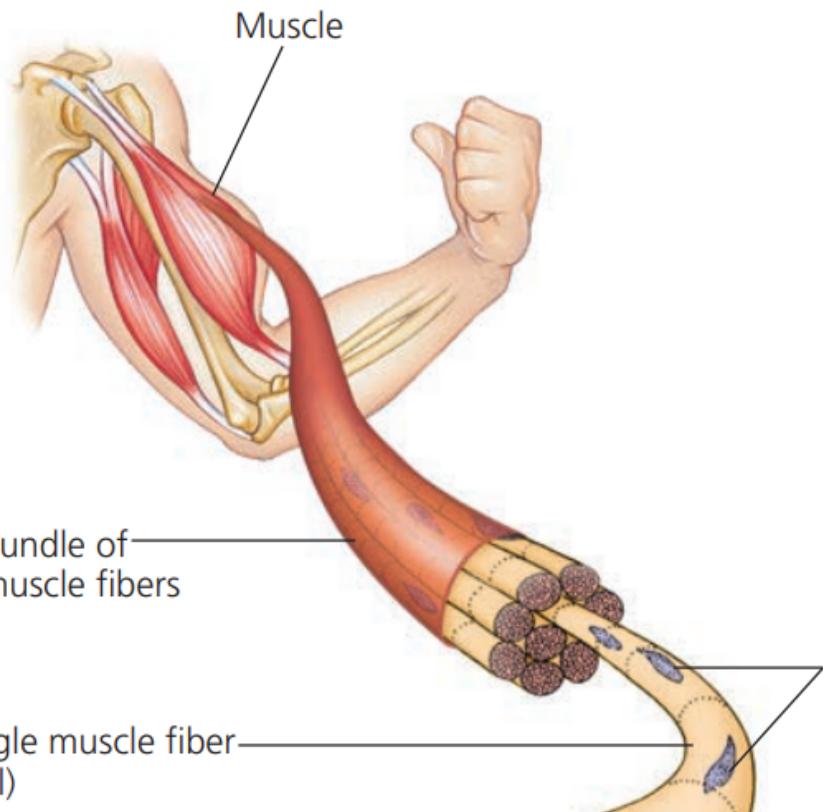


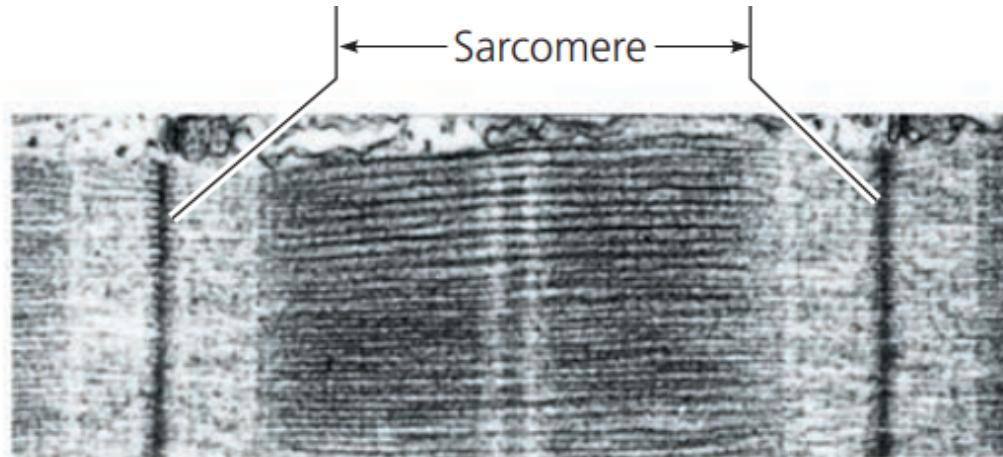
Autoimmune diseases





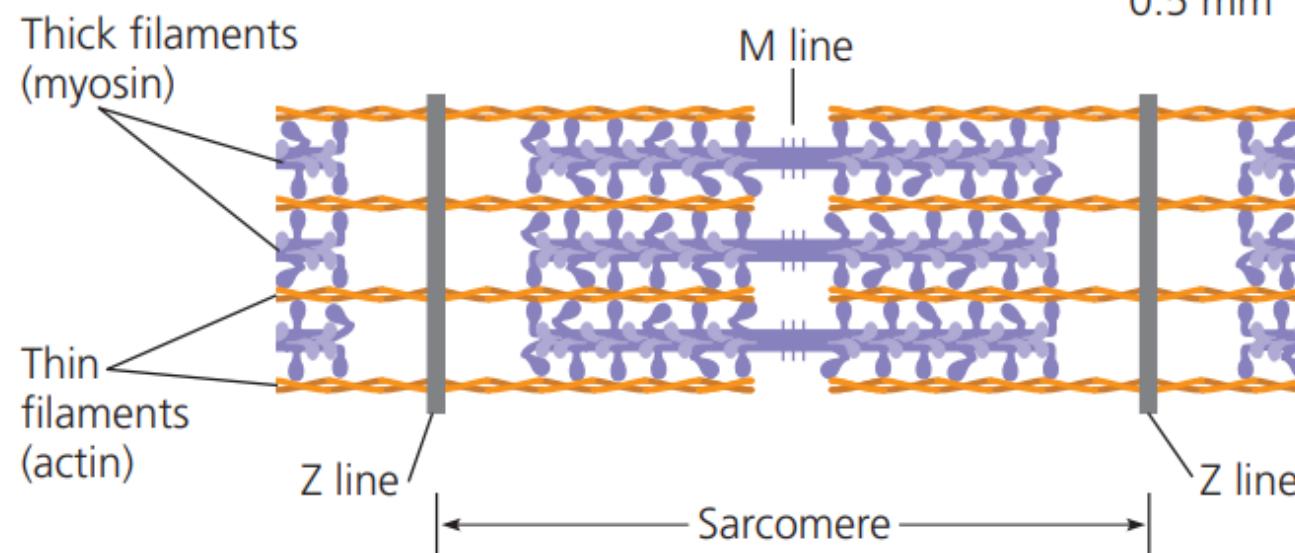
The muscles



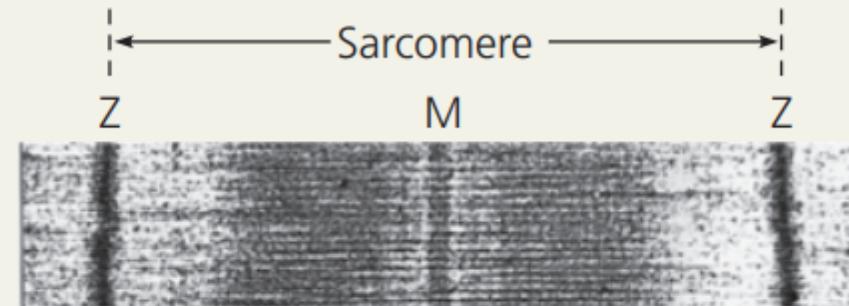
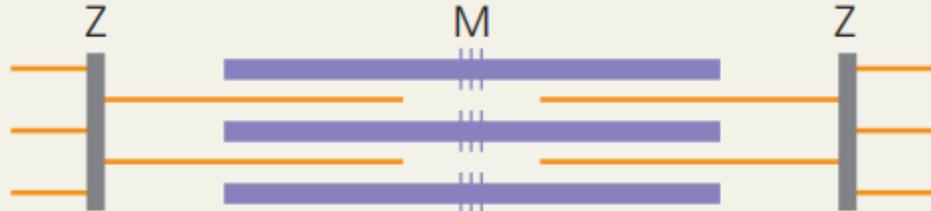


TEM

0.5 mm



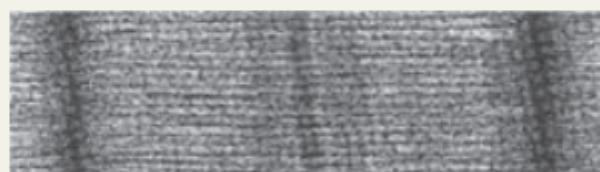
Relaxed muscle



Contracting muscle



Fully contracted muscle



Contracted
sarcomere

