

[illegible]

The lecturer



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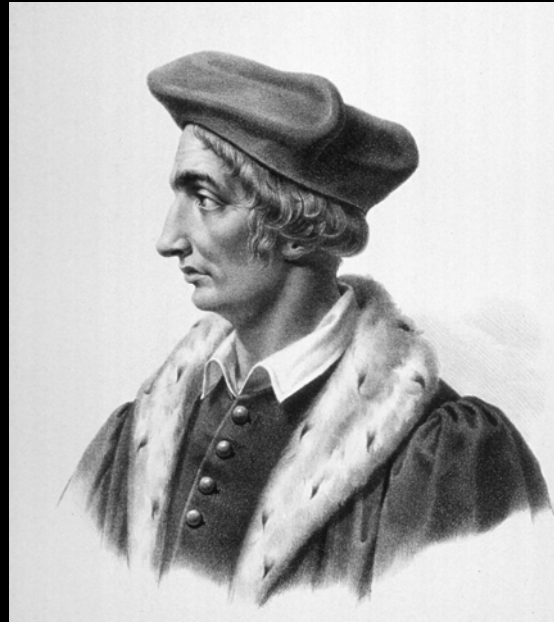
E-mail: *ztadic@biol.pmf.hr*

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How did it get its name?

Physiology - *gr.* φύσις (phúsis) = nature, origin +
grč. λογία (logia) = studies (of)
= ***the scientific study of functions & mechanisms
in a living system.***

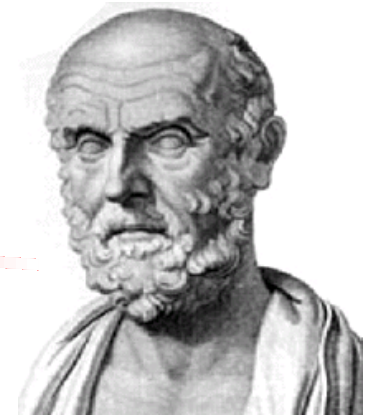


Jean François Fernel
(1497-1558)

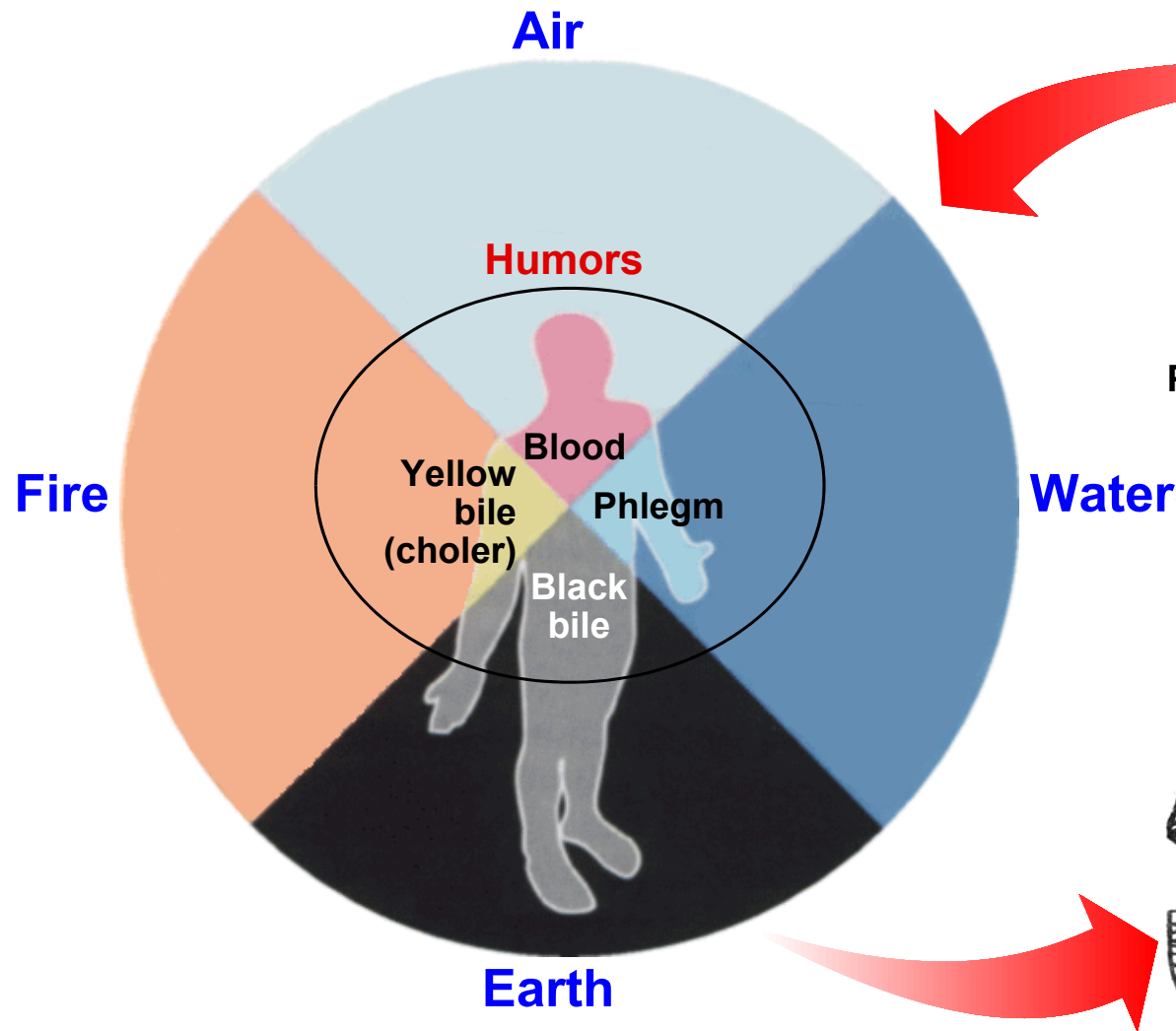


How did it begin?

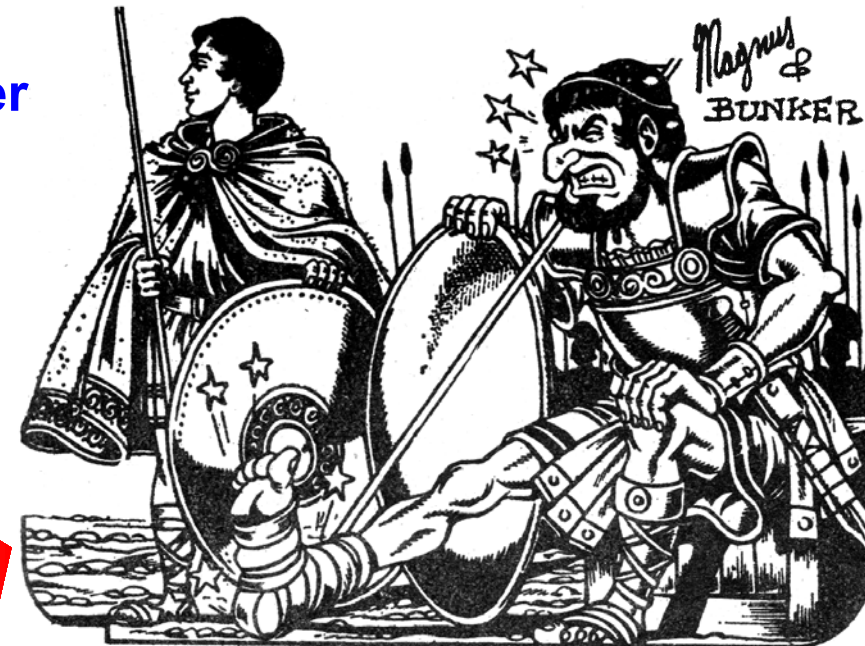
The Ancient Greeks and the human body



Hippocrates
(cca. 460 - cca. 380)

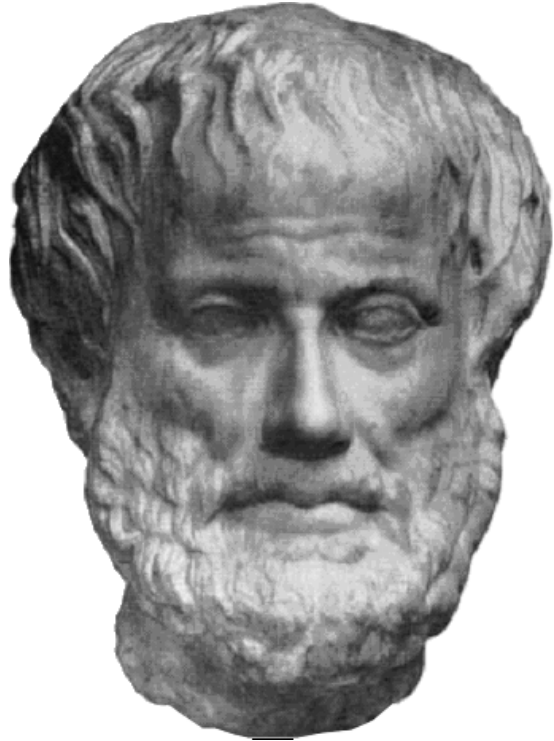


Patroclus & Achilles soon after landing near Troy



Due to horrible disturbances in humors, Achilles suffers from excruciating pain in heel (hence, "The Achilles Heel"). 😞

Aristotle and his view on the human body



**Aristotle
(384-322 BCE)**

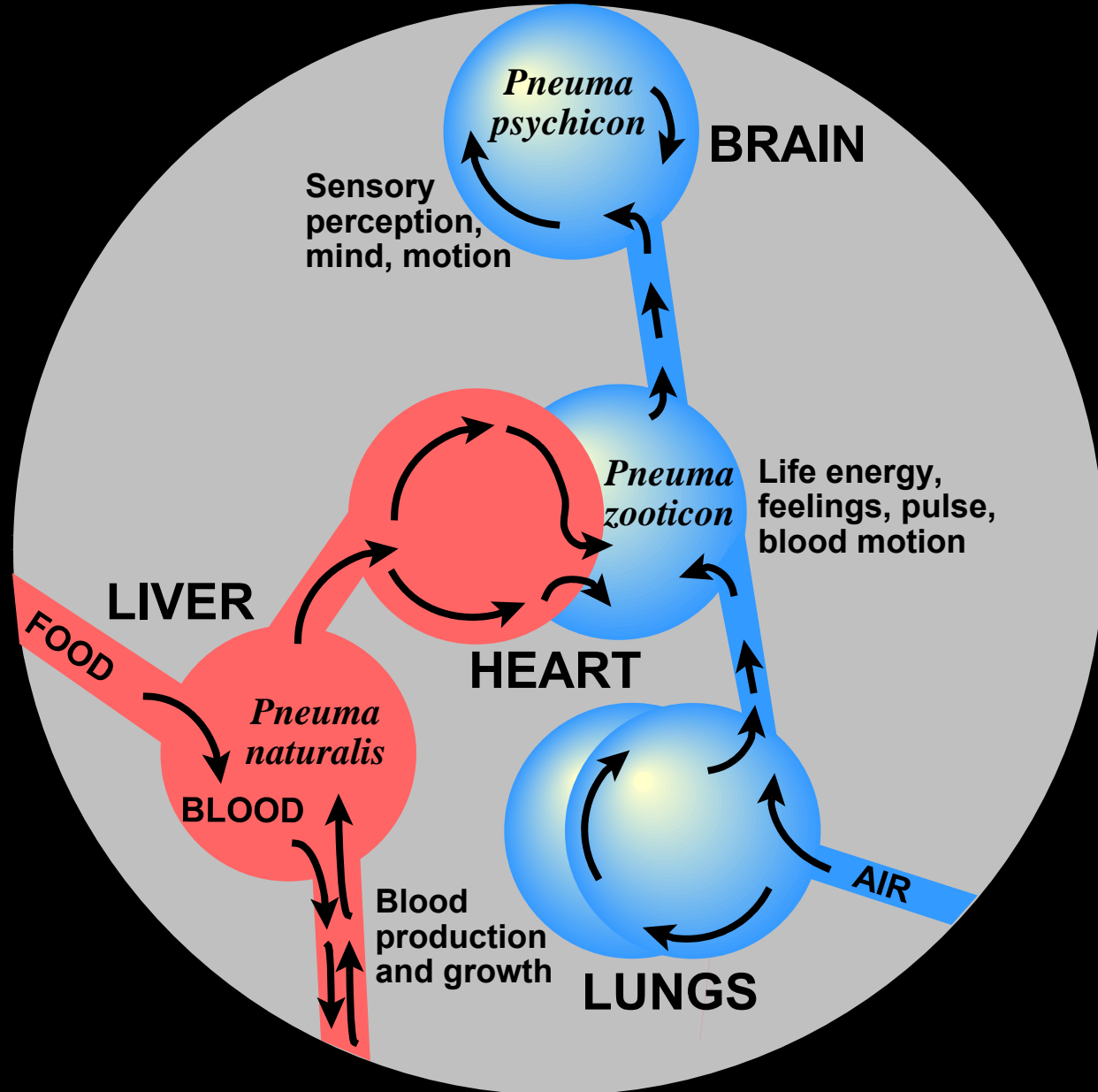
- **Description of cardiovascular system with the heart in its center.**
- **Heart - the center of intellect and the blood-heating furnace.**
- **Lungs - the ventilation & the cooling system for the heart.**
- **How is blood flow between the arteries and the veins accomplished?**



Galen's 'pneumatology' or Galenism



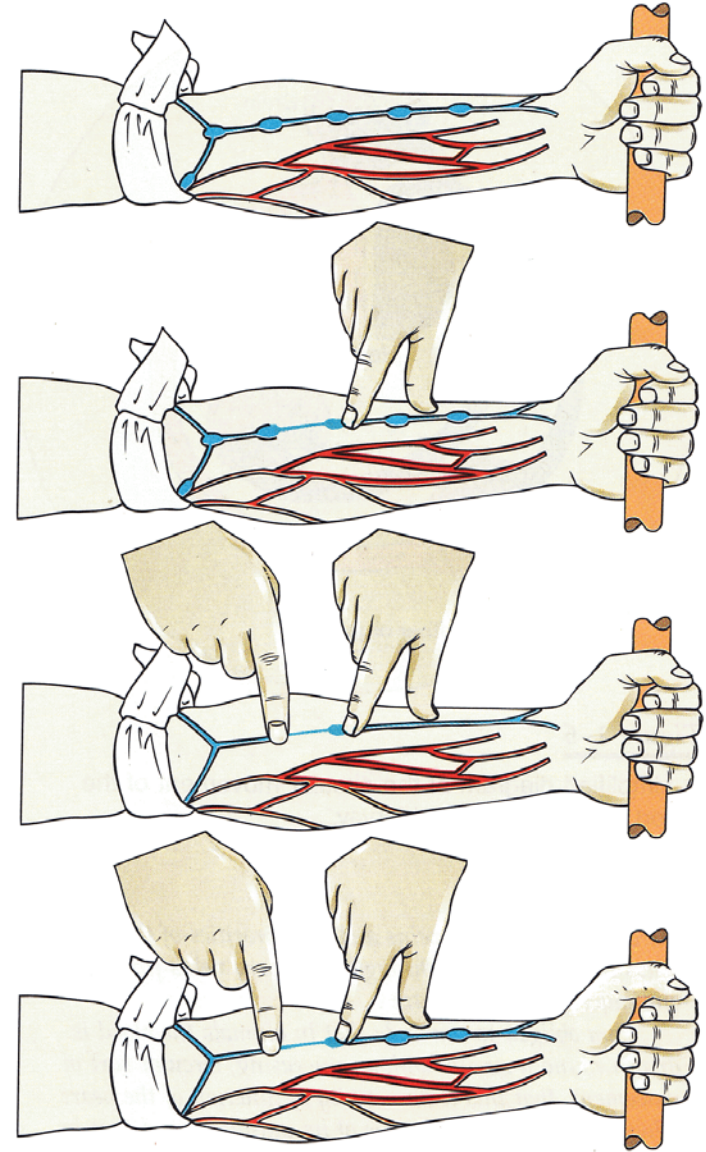
Galen
(Claudius Galenus)
(cca. 130 - cca. 210)



William Harvey and the start of modern physiology

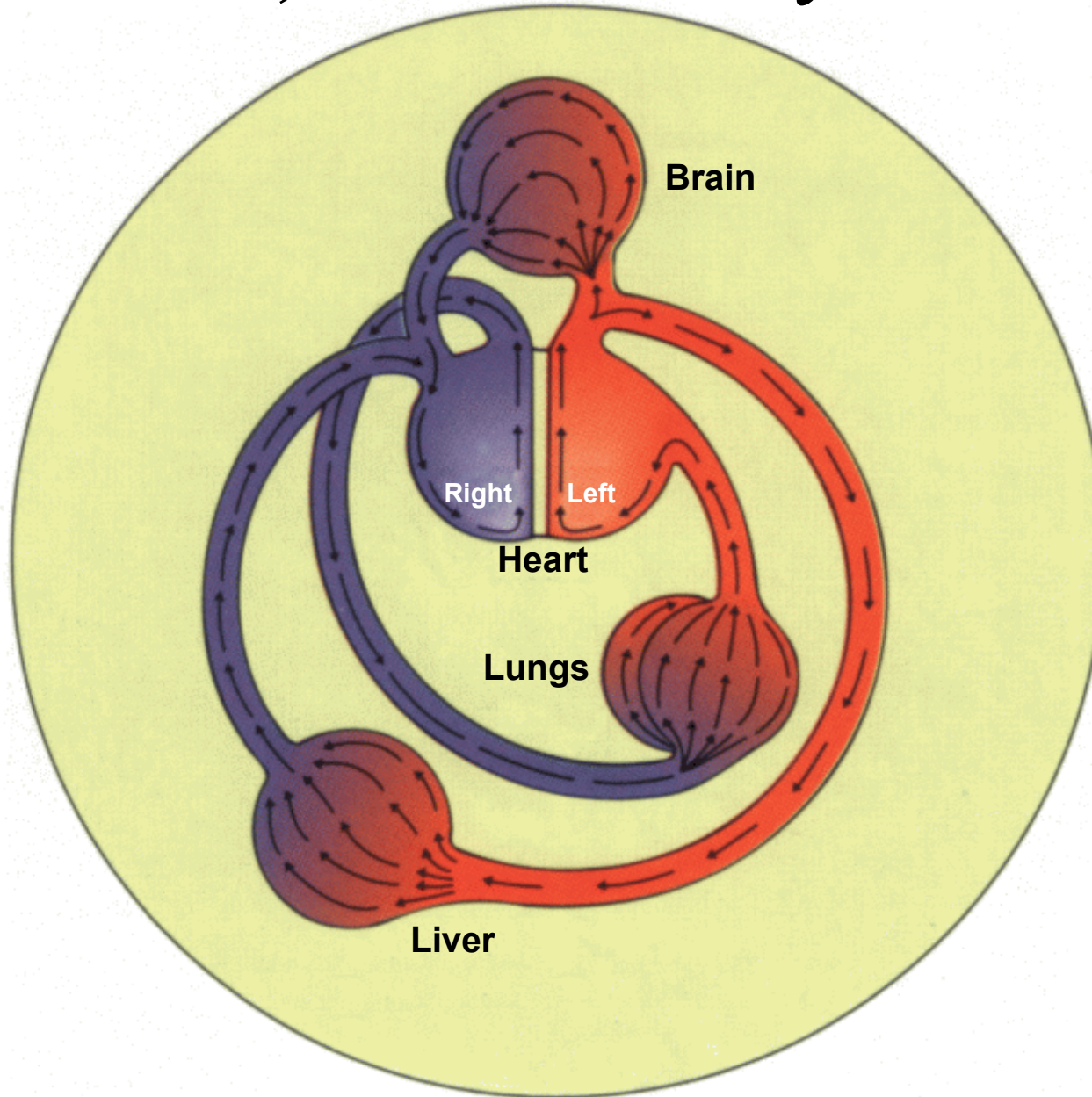


William Harvey
(1578-1657)



*“Exercitatio Anatomica de Motu
Cordis et Sanguinis in Animalibus”
(1628)*

Blood circulation, as described by William Harvey

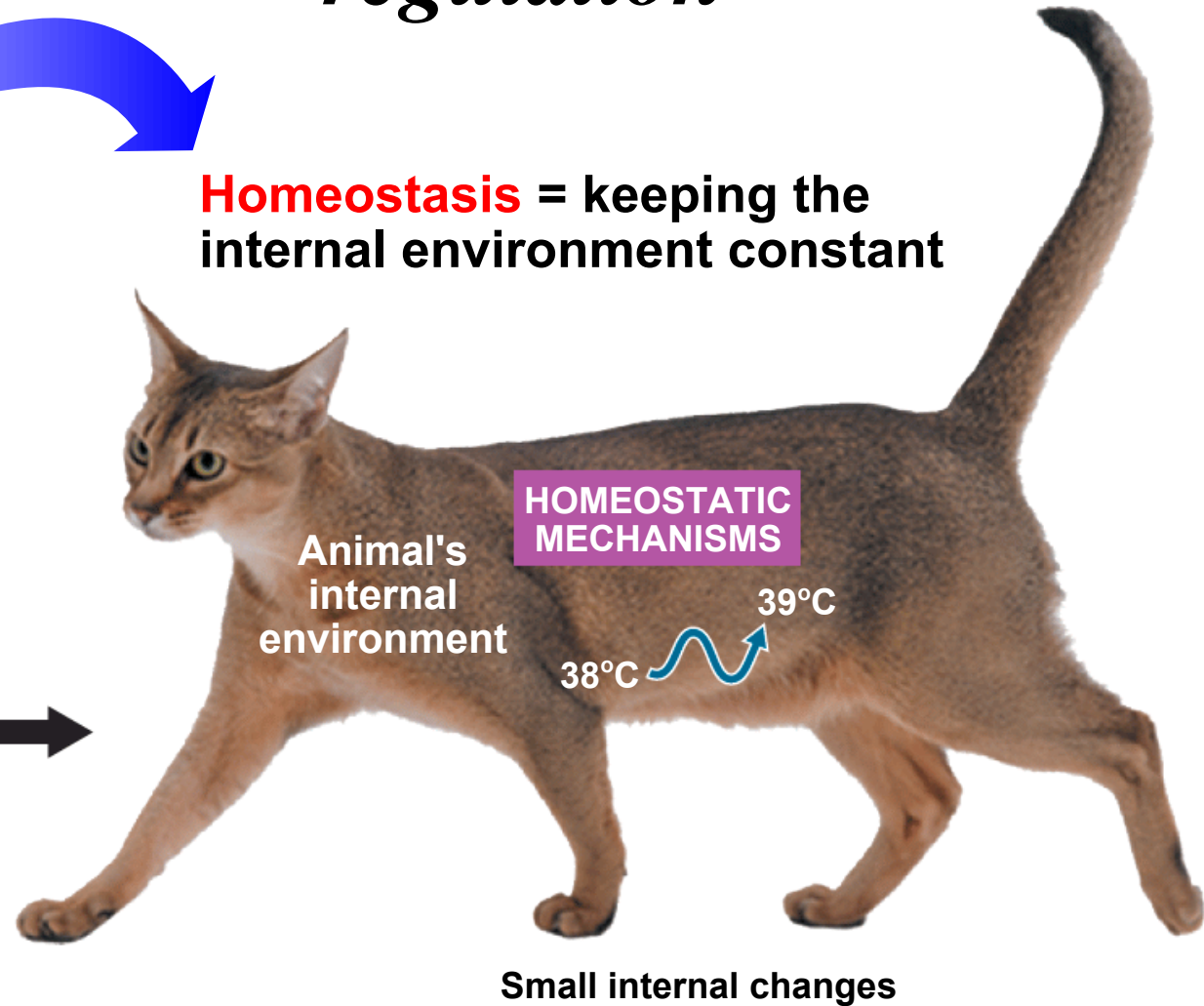
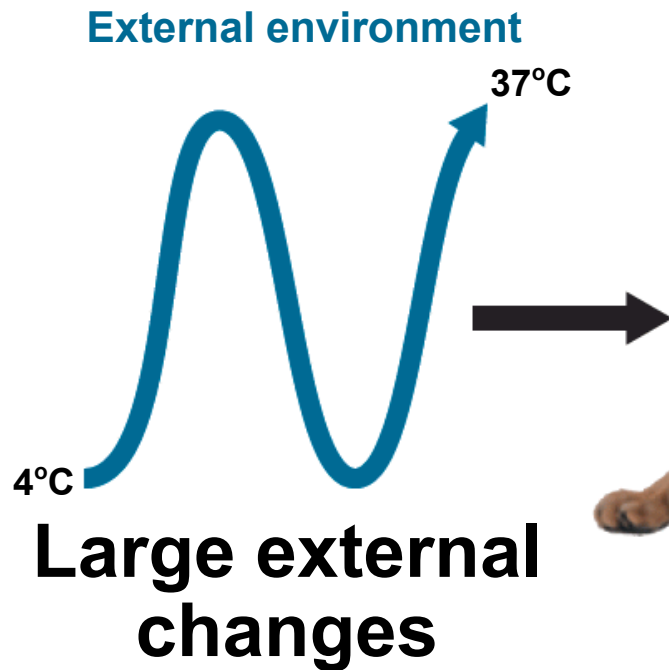


Homeostasis - the basis of physiological regulation

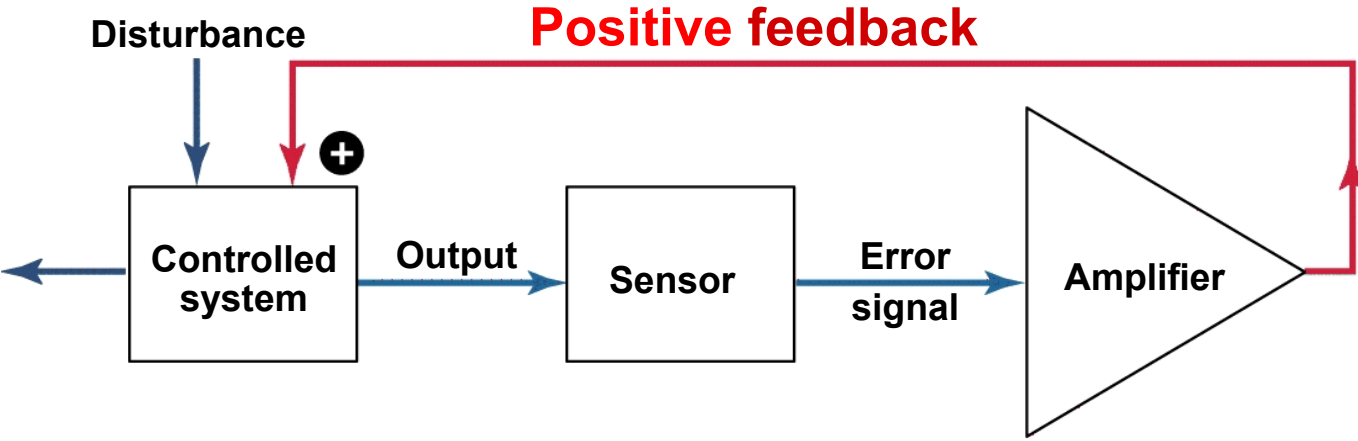
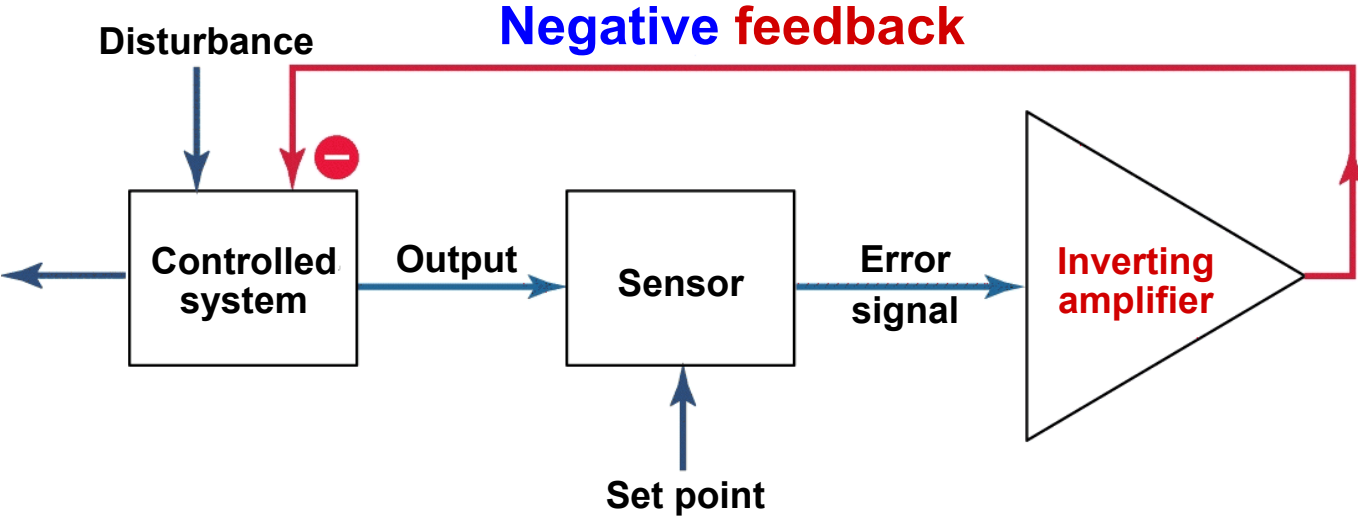


Walter B. Cannon
(1871-1945)

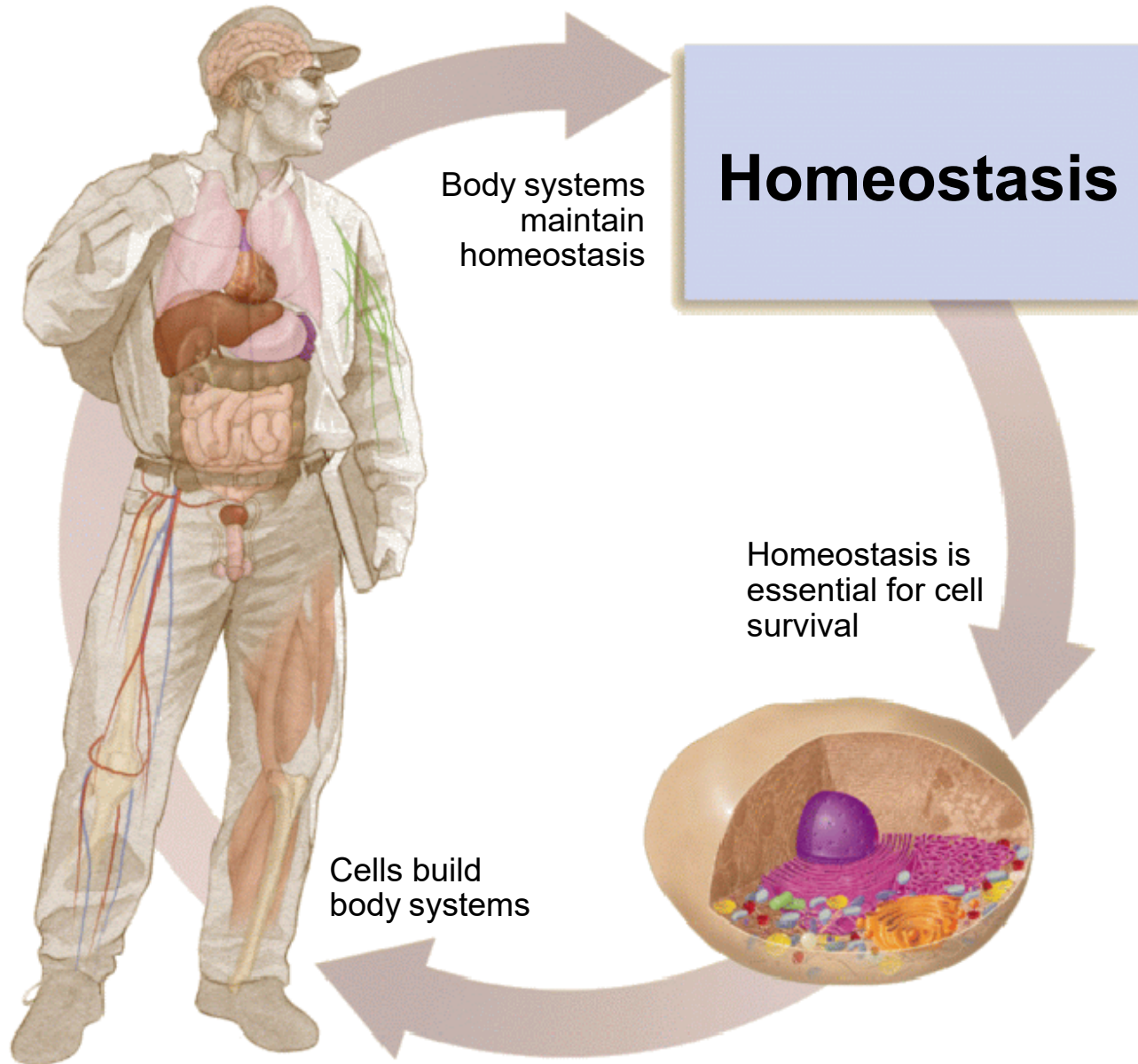
Homeostasis = keeping the internal environment constant



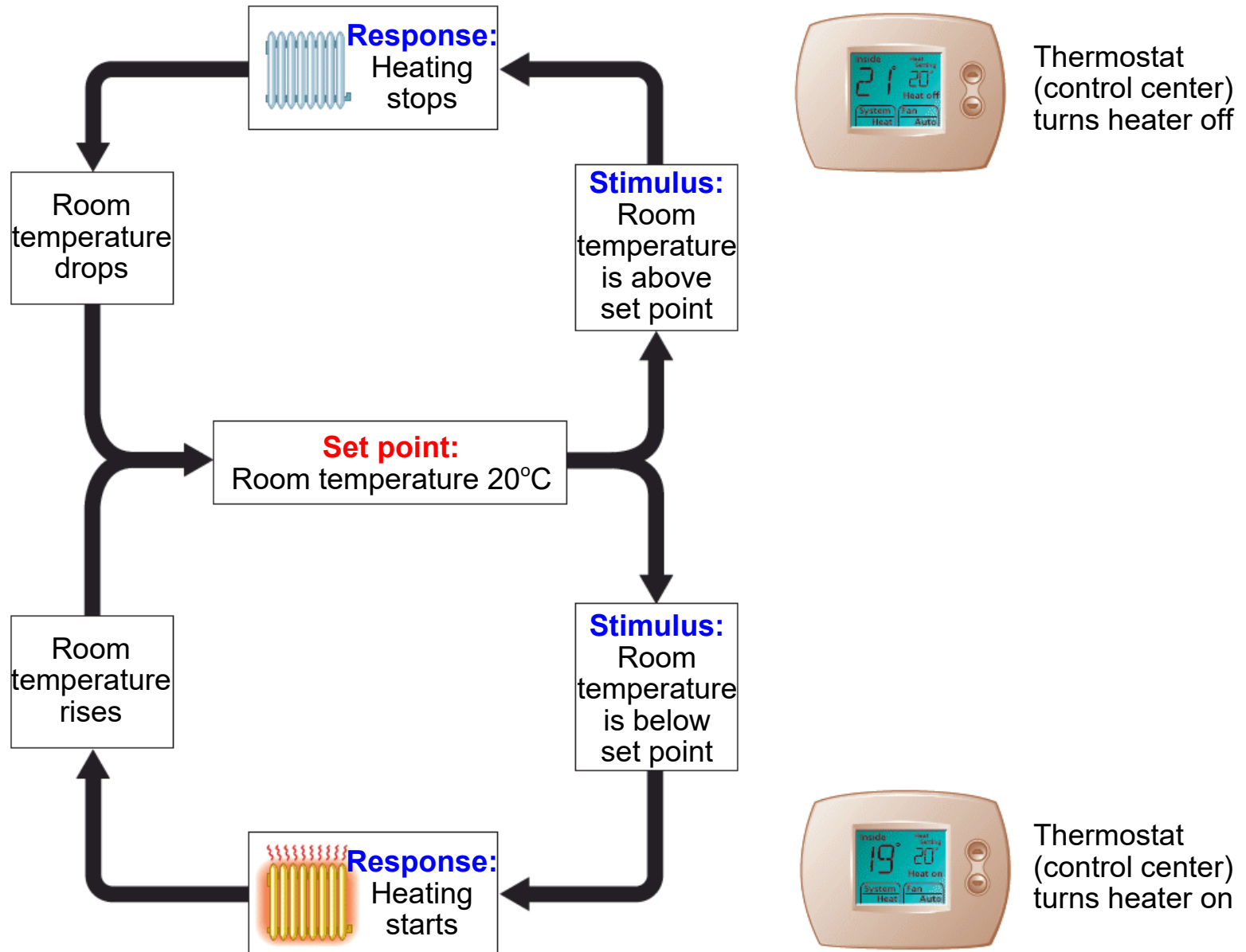
Homerostasis is maintained using negative feedback



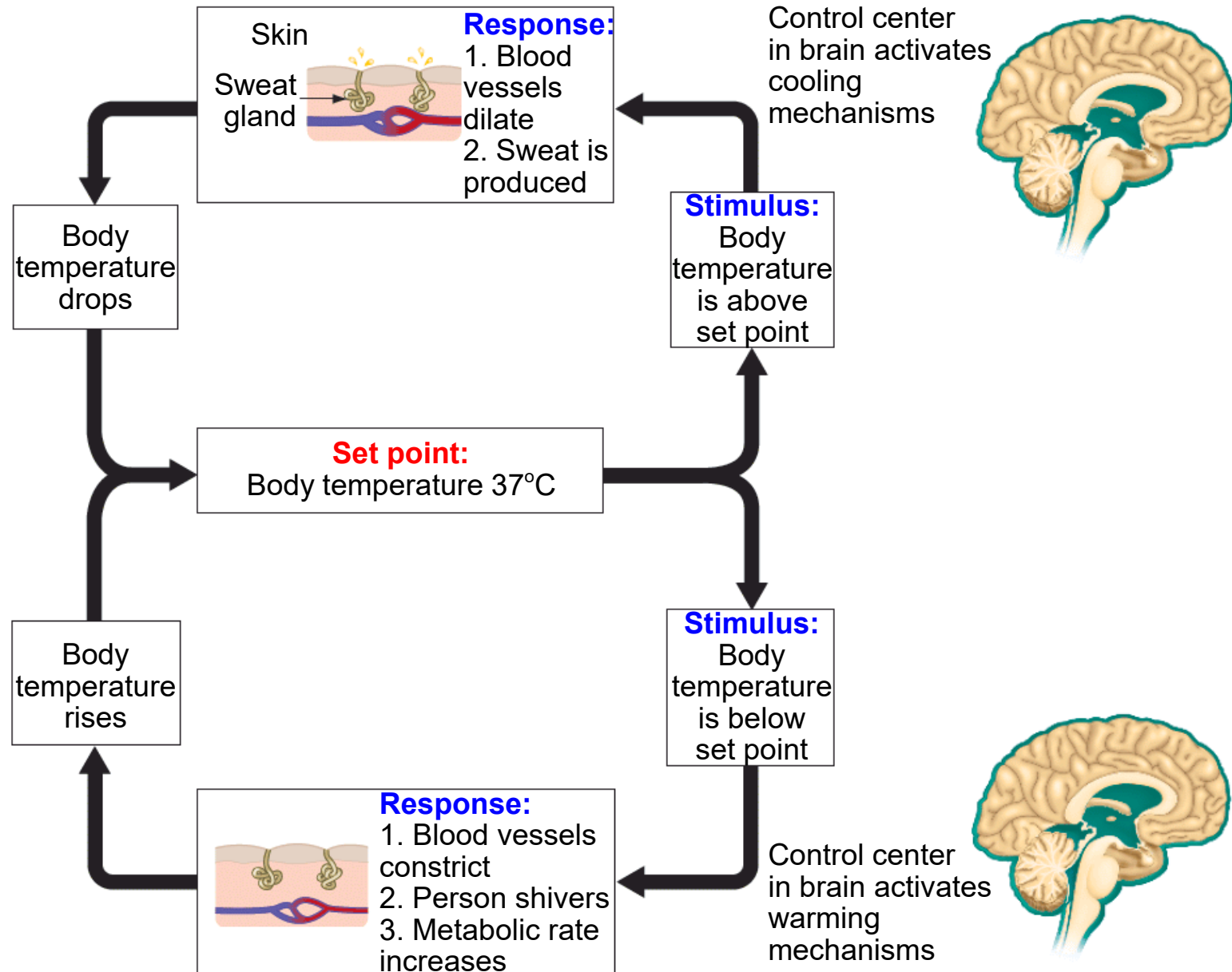
Why is homeostasis important?



Technical (thermoregulatory) homeostasis

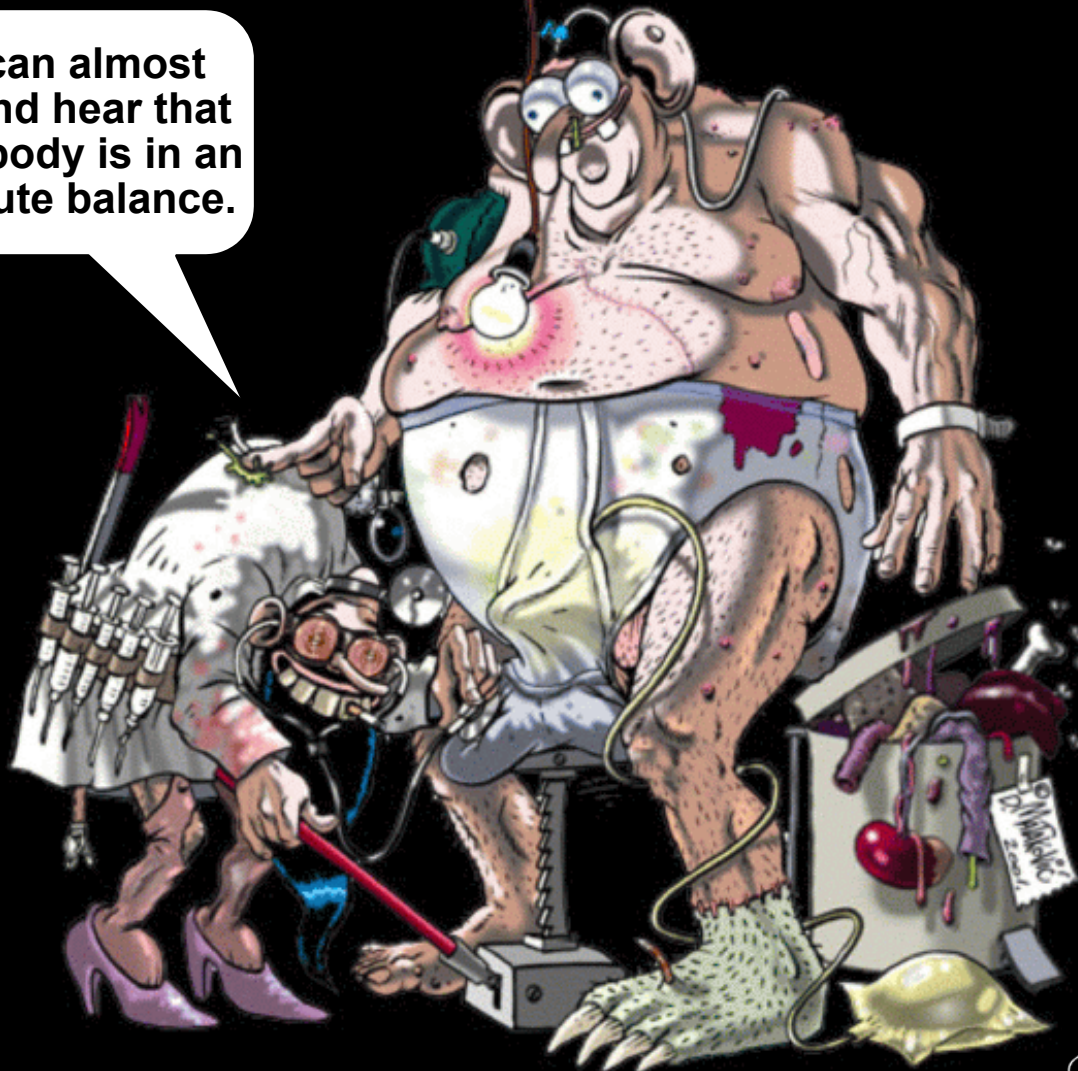


Biological (thermoregulatory) homeostasis

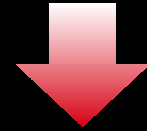


Physiology as one of the foundations of medicine

Sir, I can almost feel and hear that your body is in an absolute balance.



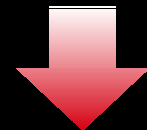
Anatomy



Physiology



Pathology, Pathophysiology



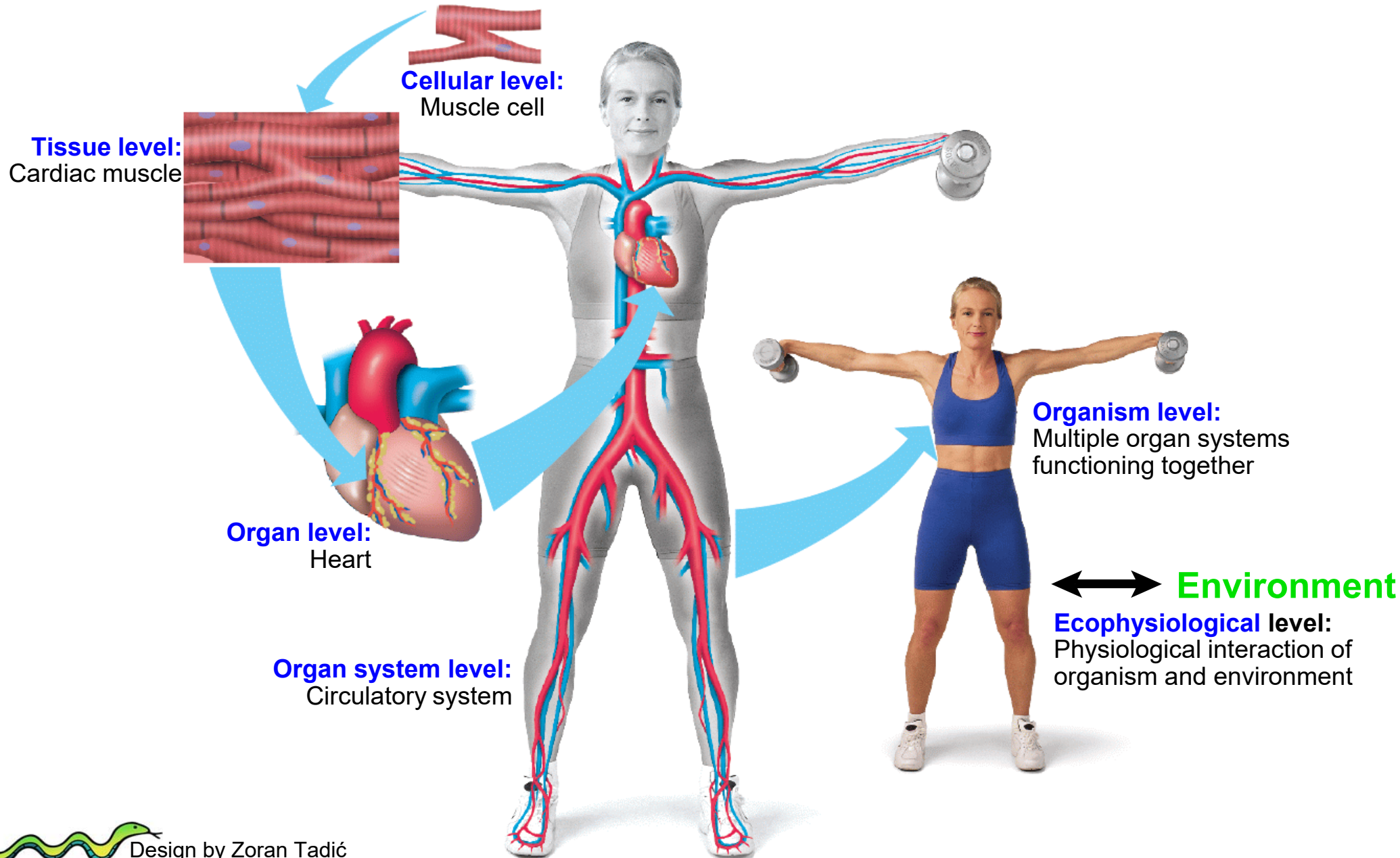
Internal medicine

Kako sam sistematski išao na pregled

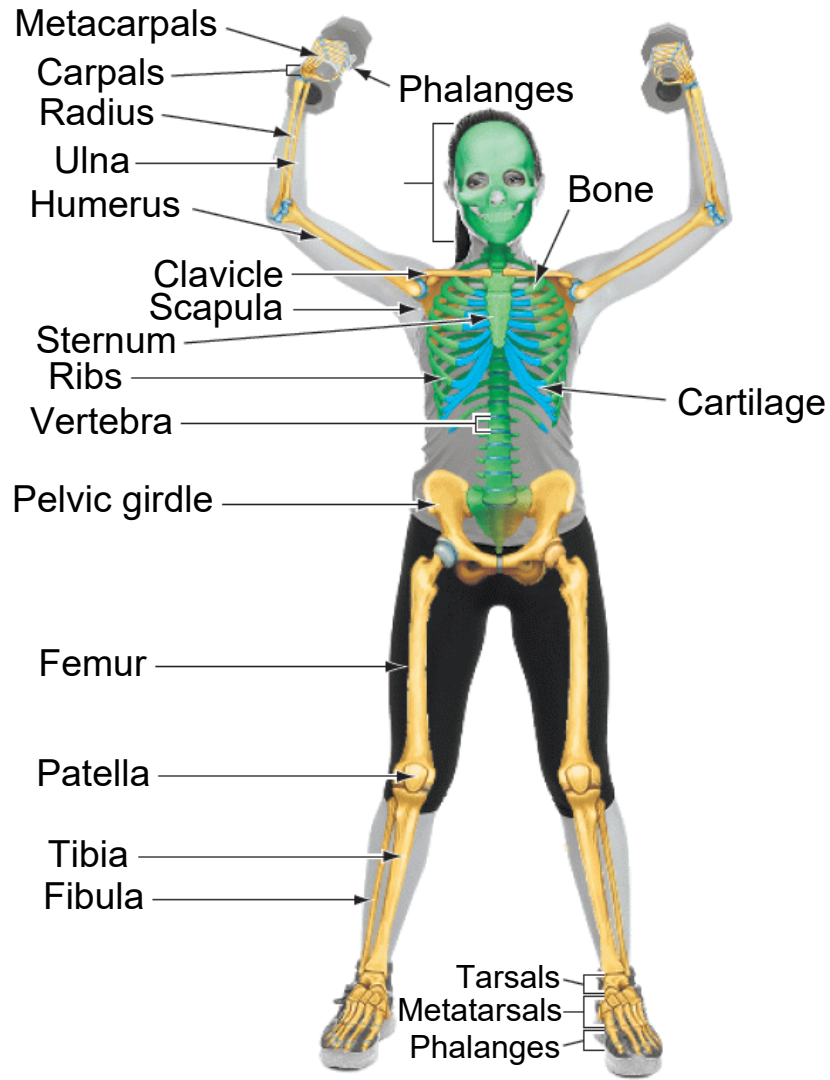
D. M. Gholik



Physiology as a multilayered science

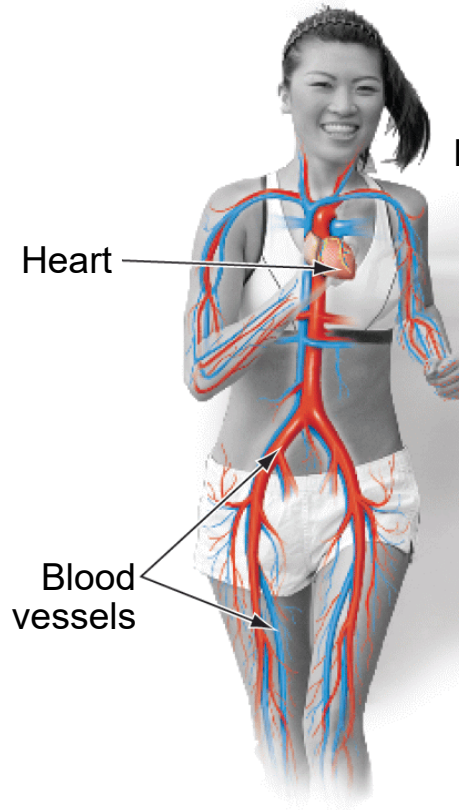


The physiological systems 1



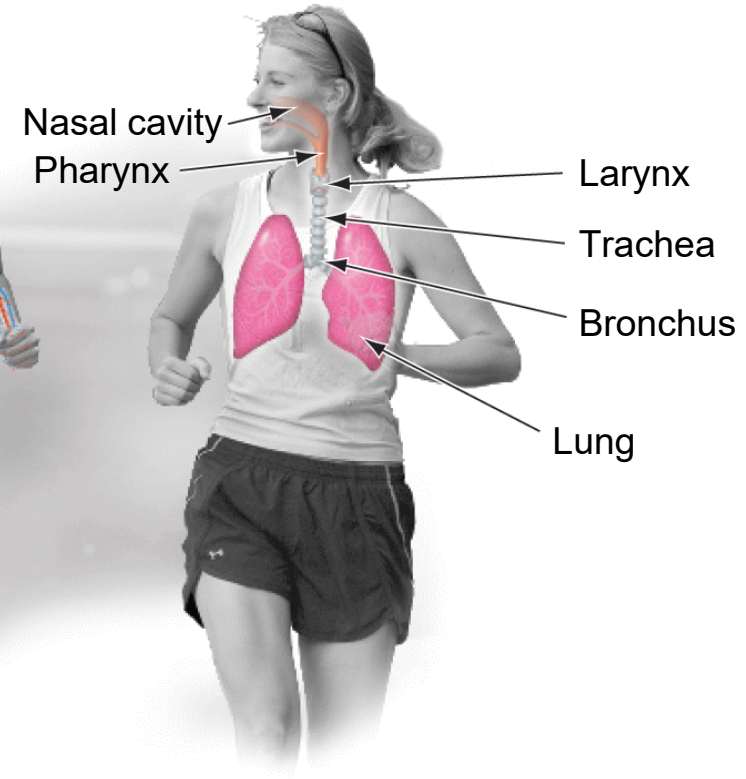
The skeletal system

(supports body and anchors muscles)



The circulatory system

(transports substances throughout body)

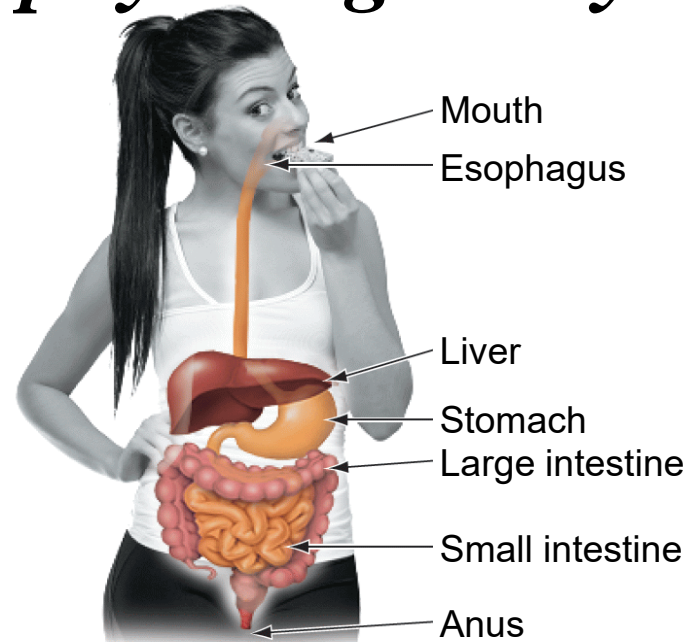


The respiratory system

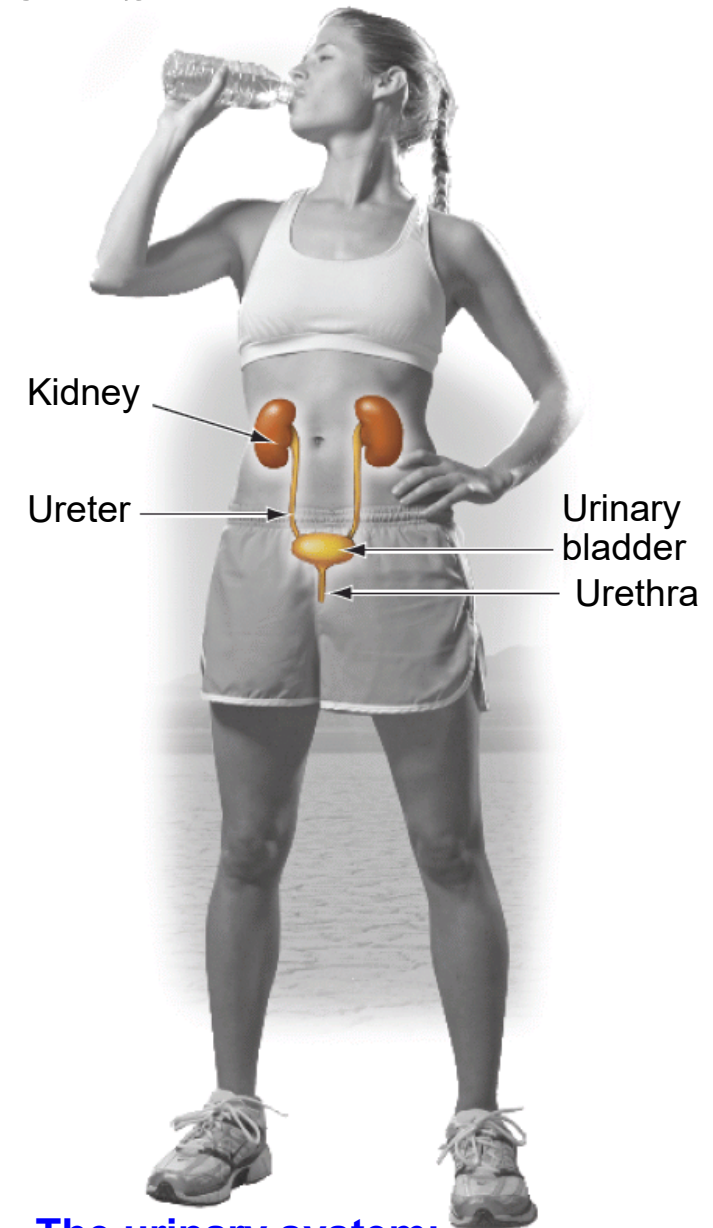
(exchanges CO_2 and O_2 between blood and air)



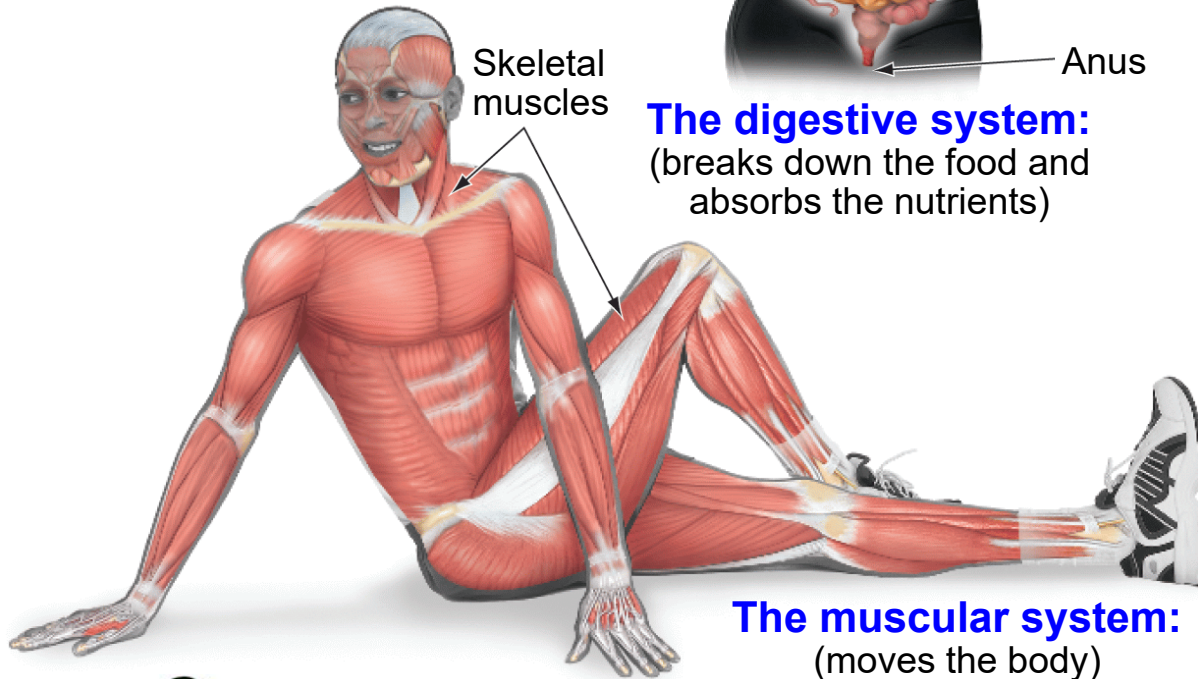
The physiological systems 2



The digestive system:
(breaks down the food and
absorbs the nutrients)



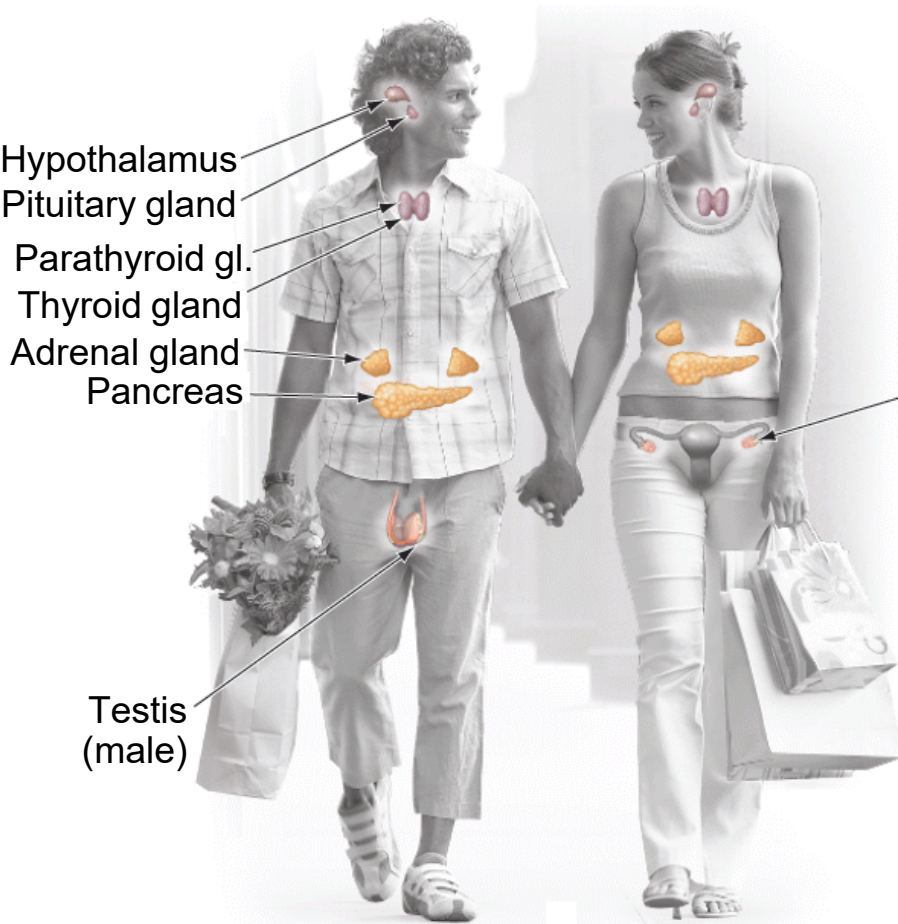
The urinary system:
(rids body of certain wastes)



The muscular system:
(moves the body)



The physiological systems 3

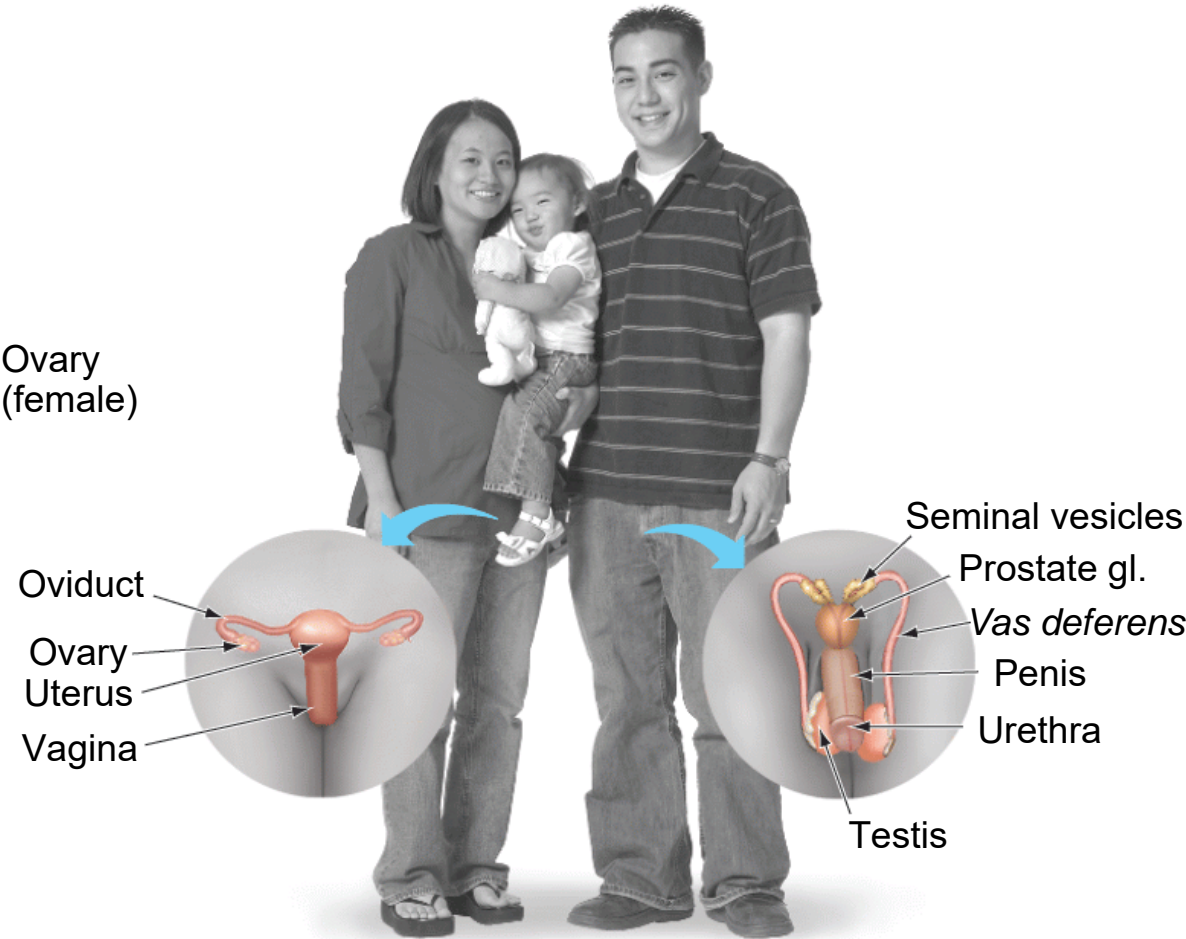


Testis
(male)

Ovary
(female)

The endocrine system:

(secretes hormones that regulate body processes)



Oviduct

Ovary

Uterus

Vagina

Seminal vesicles

Prostate gl.

Vas deferens

Penis

Urethra

Testis

The reproductive system:

(produces gametes and offspring)

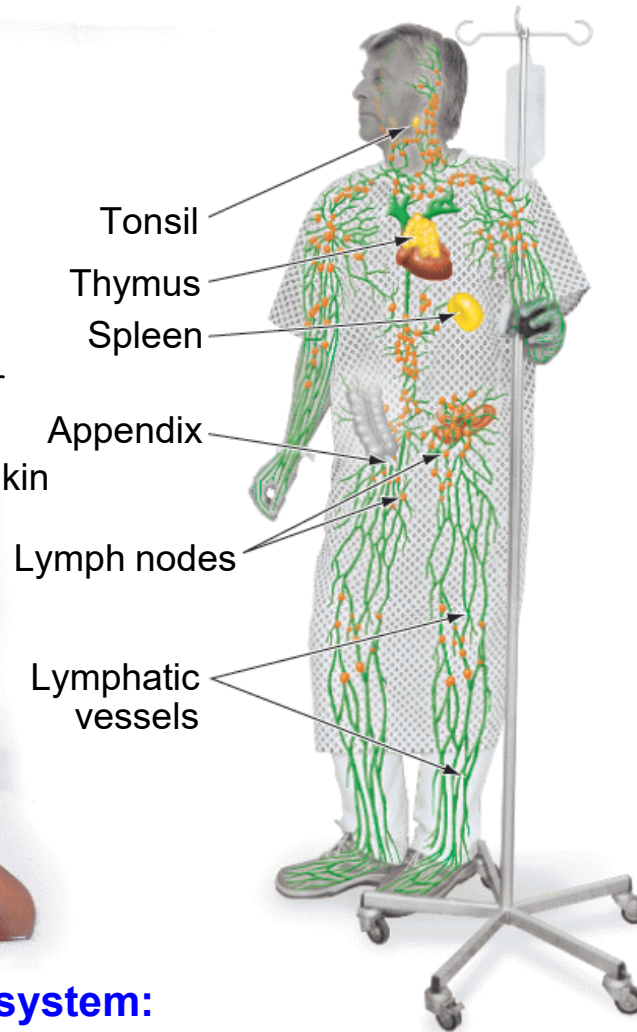


The physiological systems 4



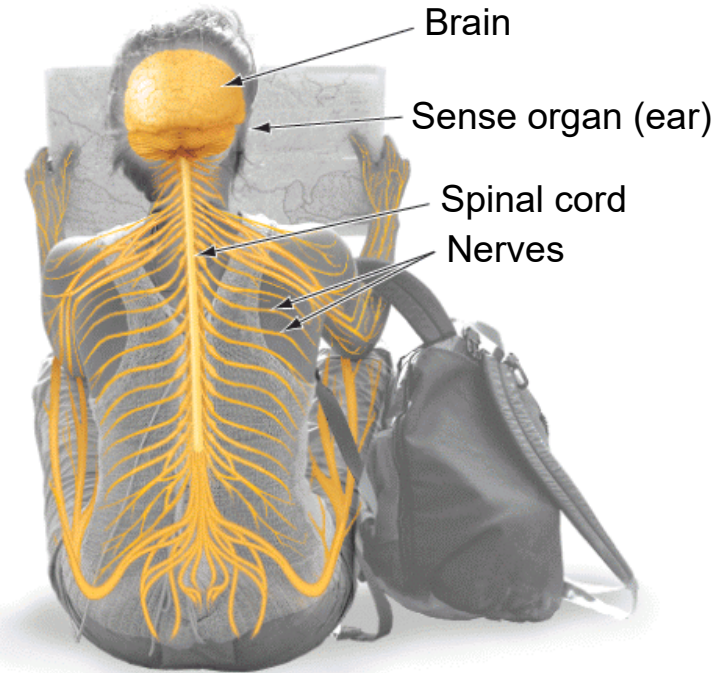
Hair
Skin
Nail

The integumentary system:
(protects body)



Tonsil
Thymus
Spleen
Appendix
Lymph nodes
Lymphatic vessels

The immune system:
(defends against disease)



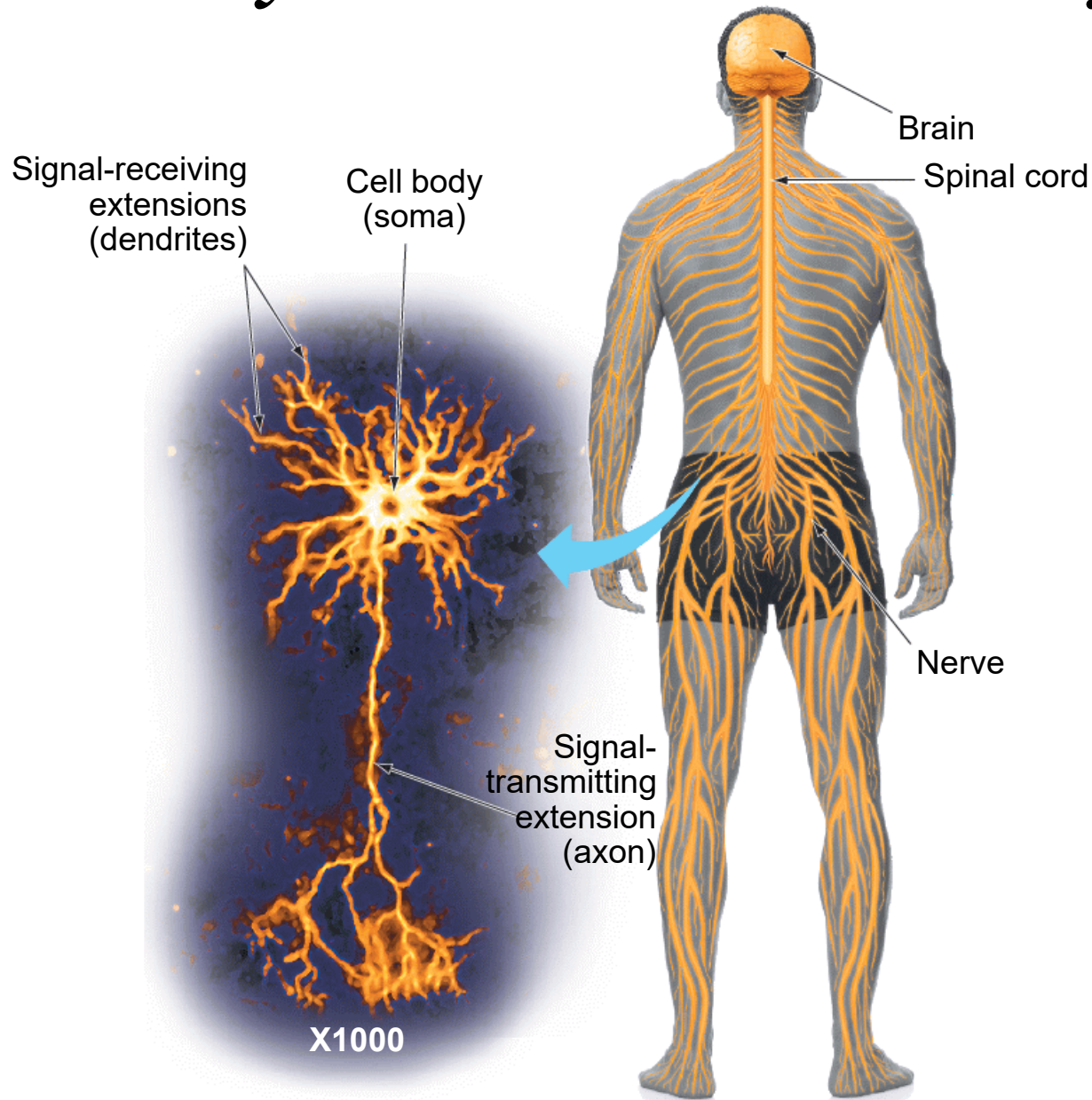
Brain
Sense organ (ear)
Spinal cord
Nerves

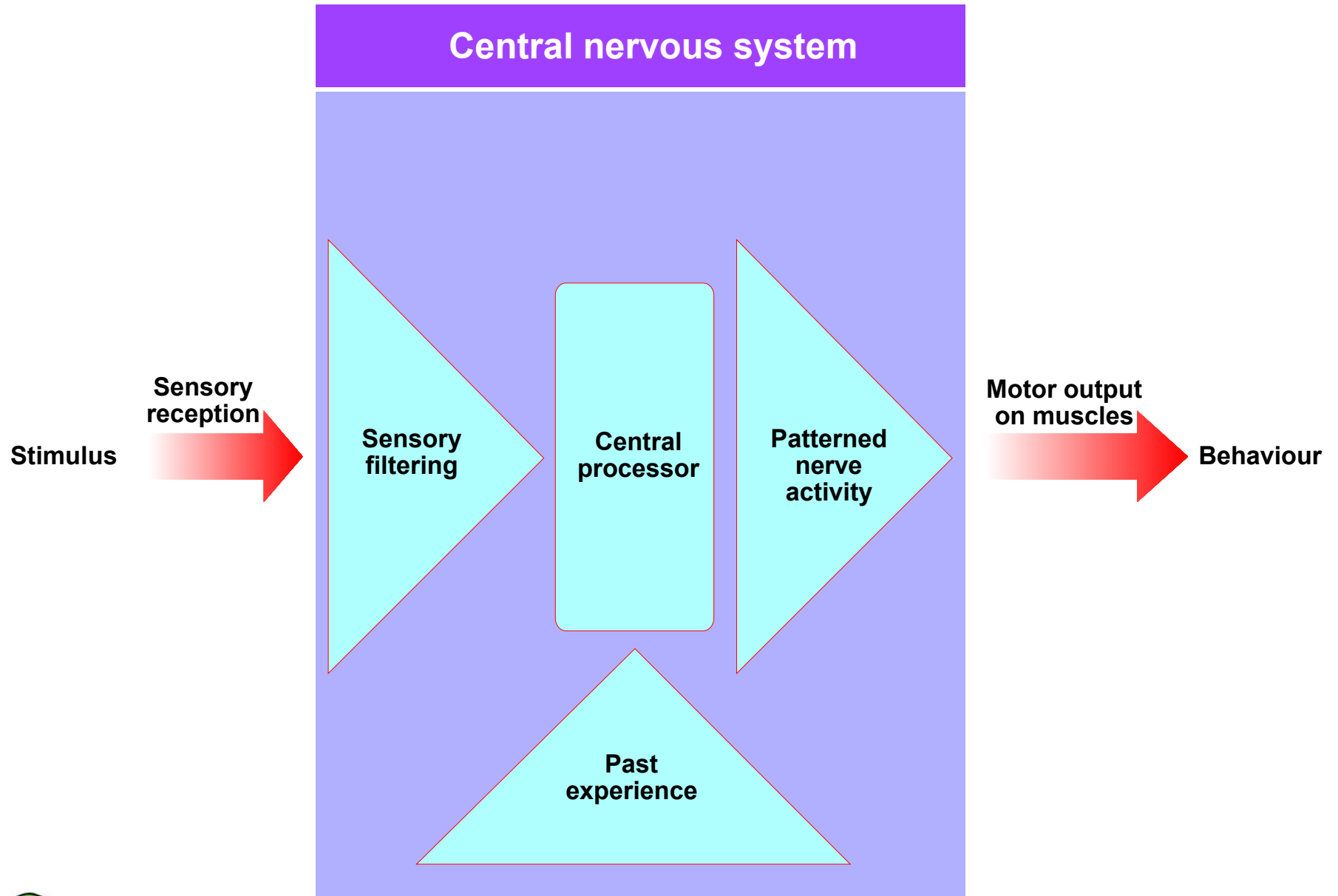
The nervous system:
(processes sensory information
and controls responses)



The nervous system

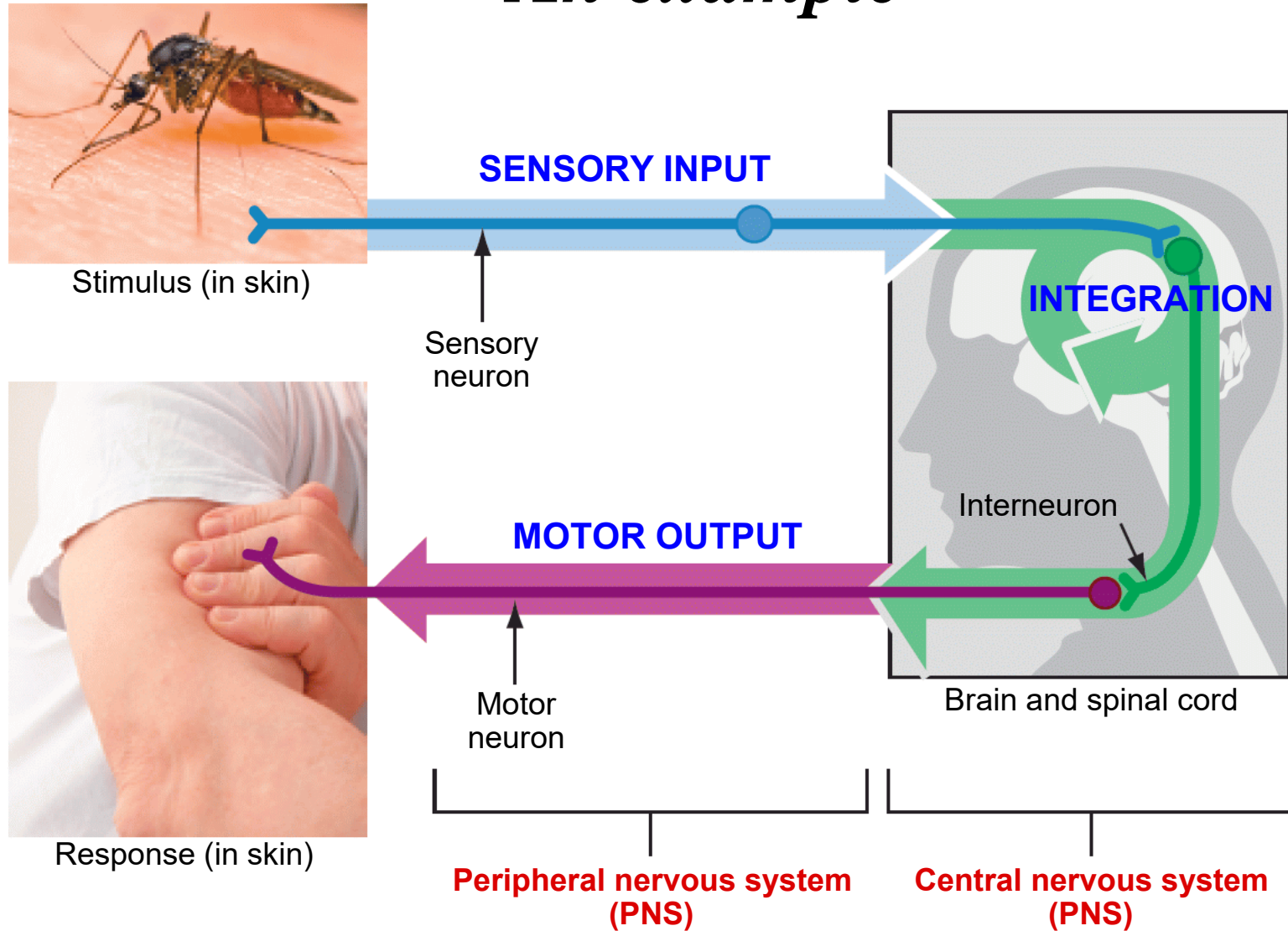
The control system #1: The nervous system



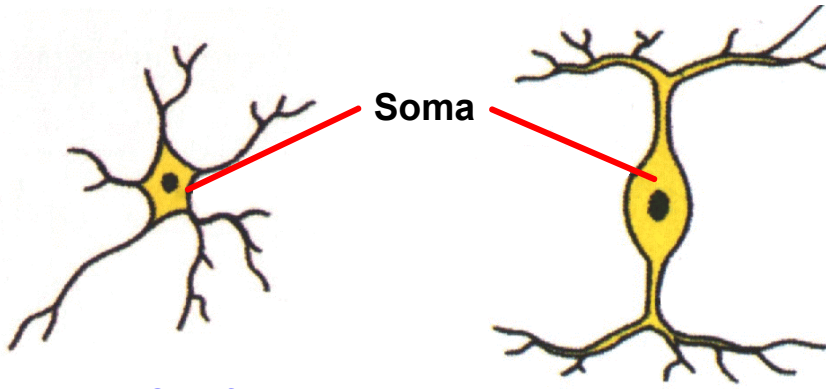


The flow of information through nervous system:

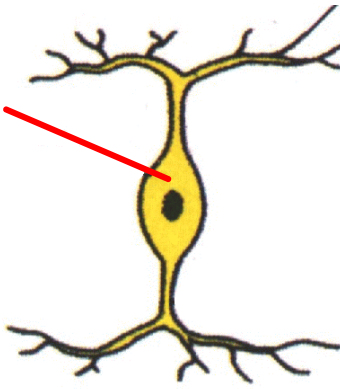
An example



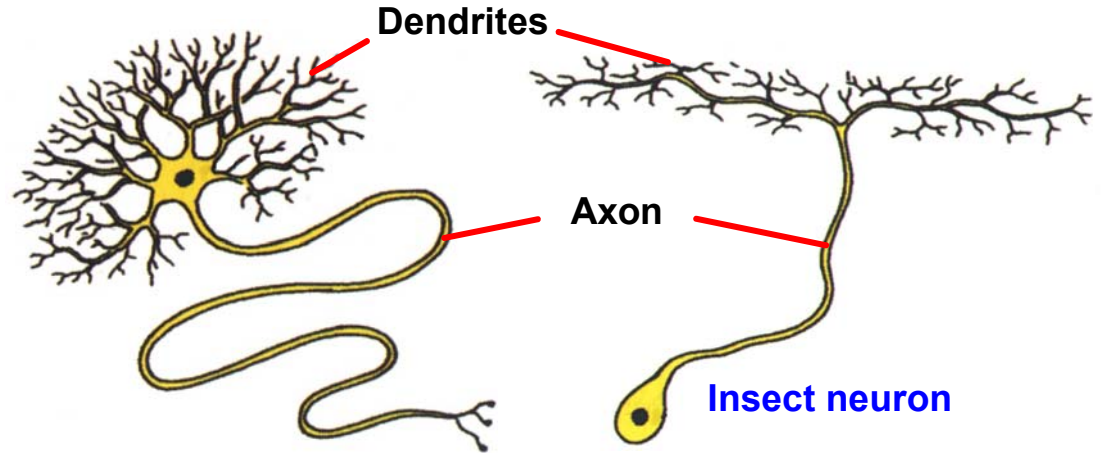
The world of (various) neurons



Cell from
coelenterate
nerve net

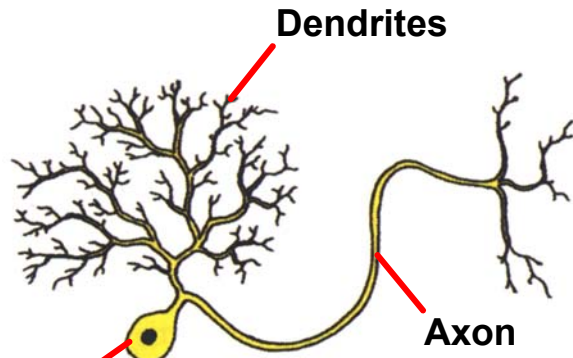


Bipolar cell from
vertebrate retina

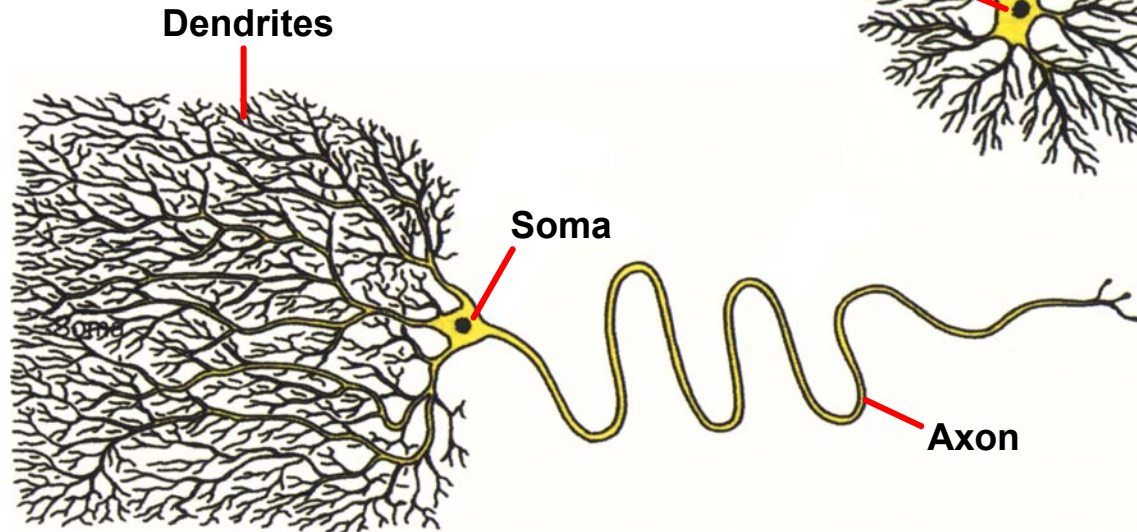


Motor neuron from
vertebrate spinal cord

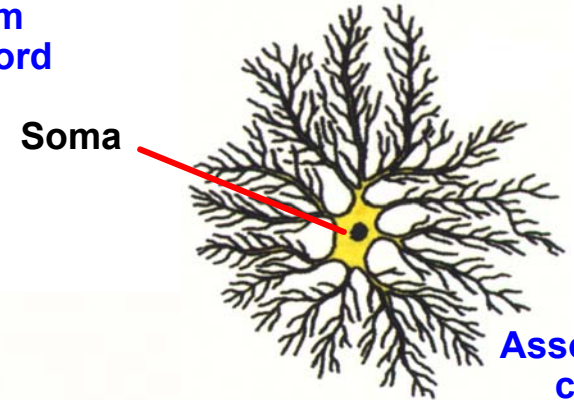
Insect neuron



Insect neuron



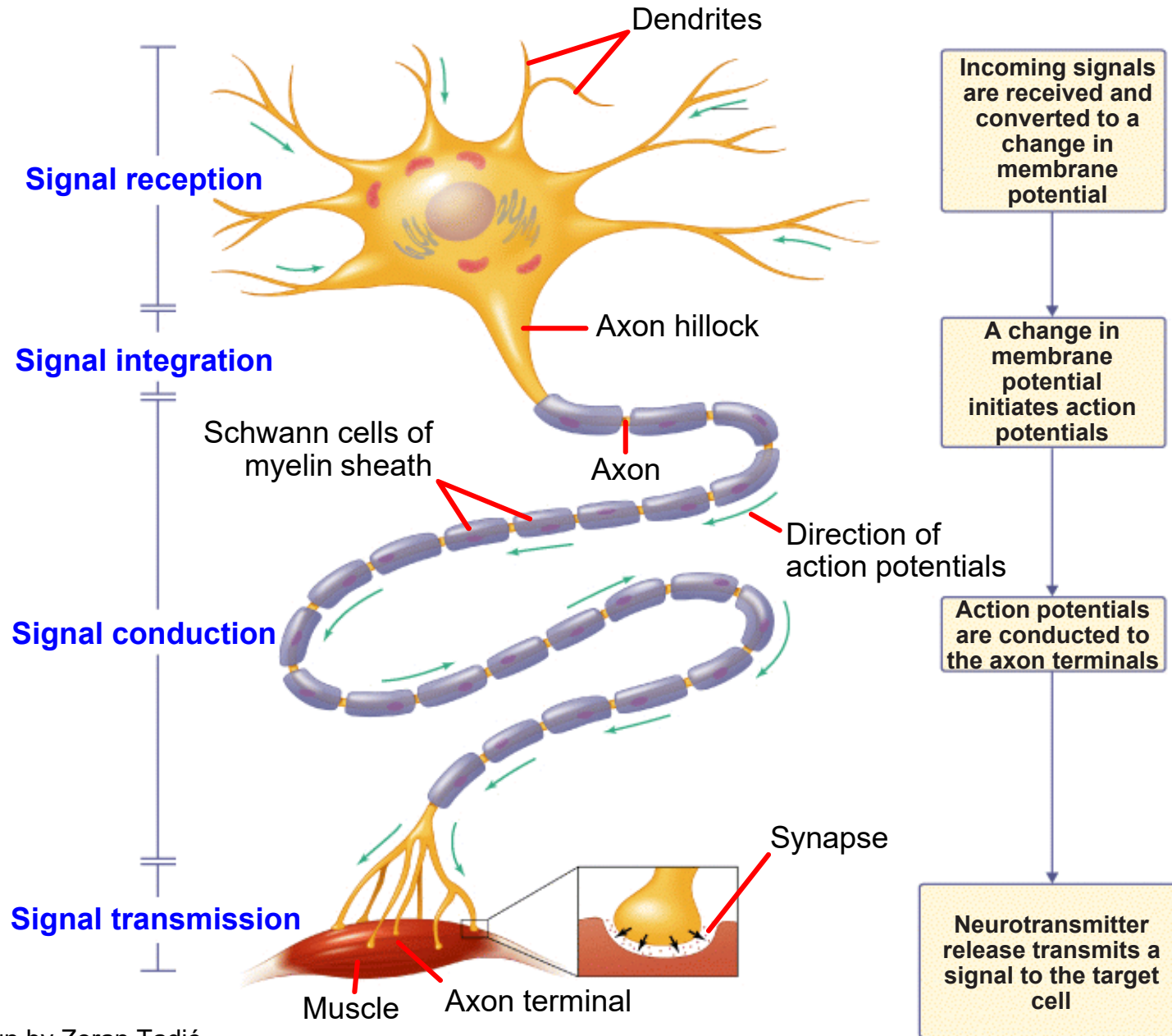
Purkinje cell from mammalian cerebellum



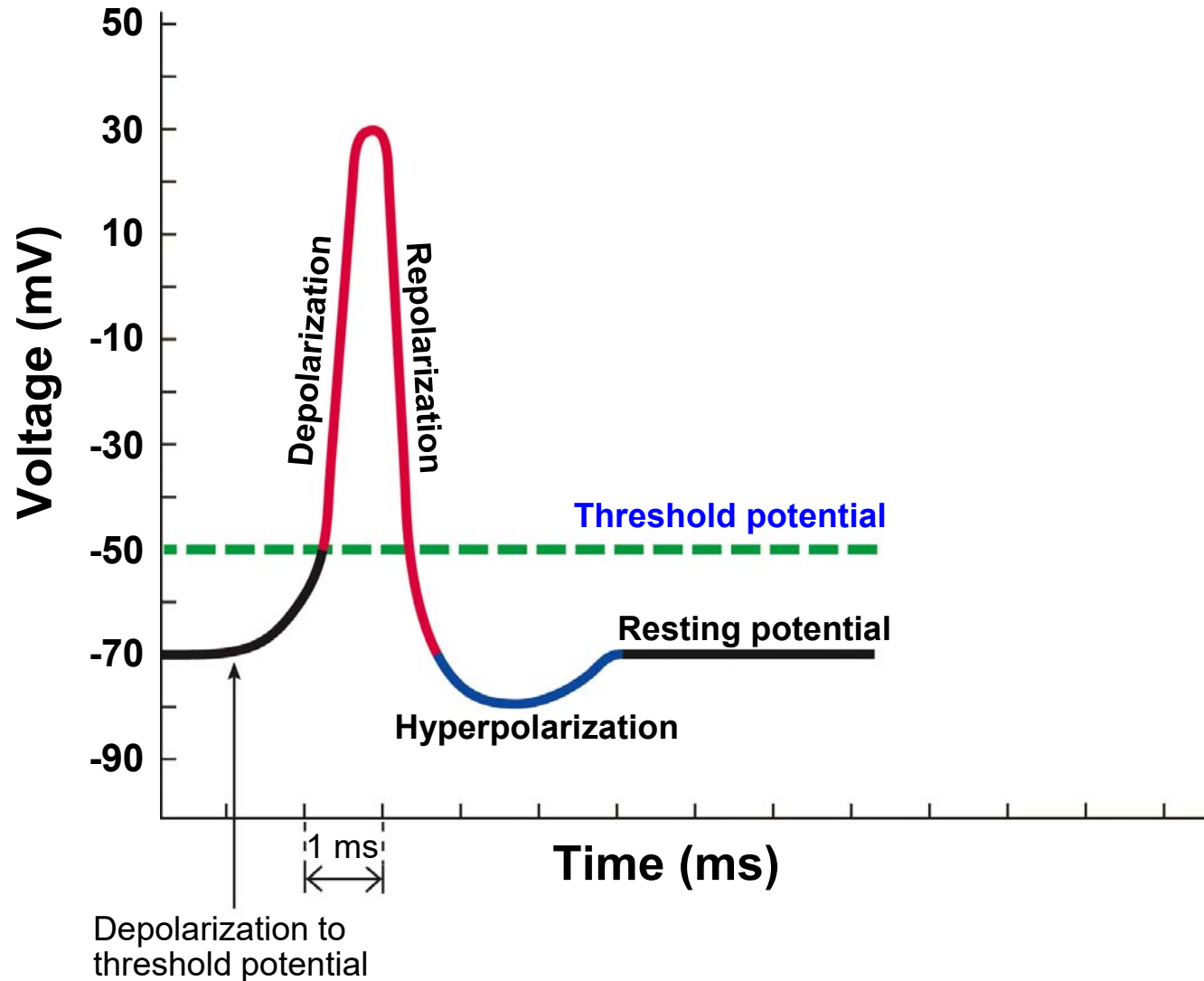
Association
cell from
mammalian
thalamus



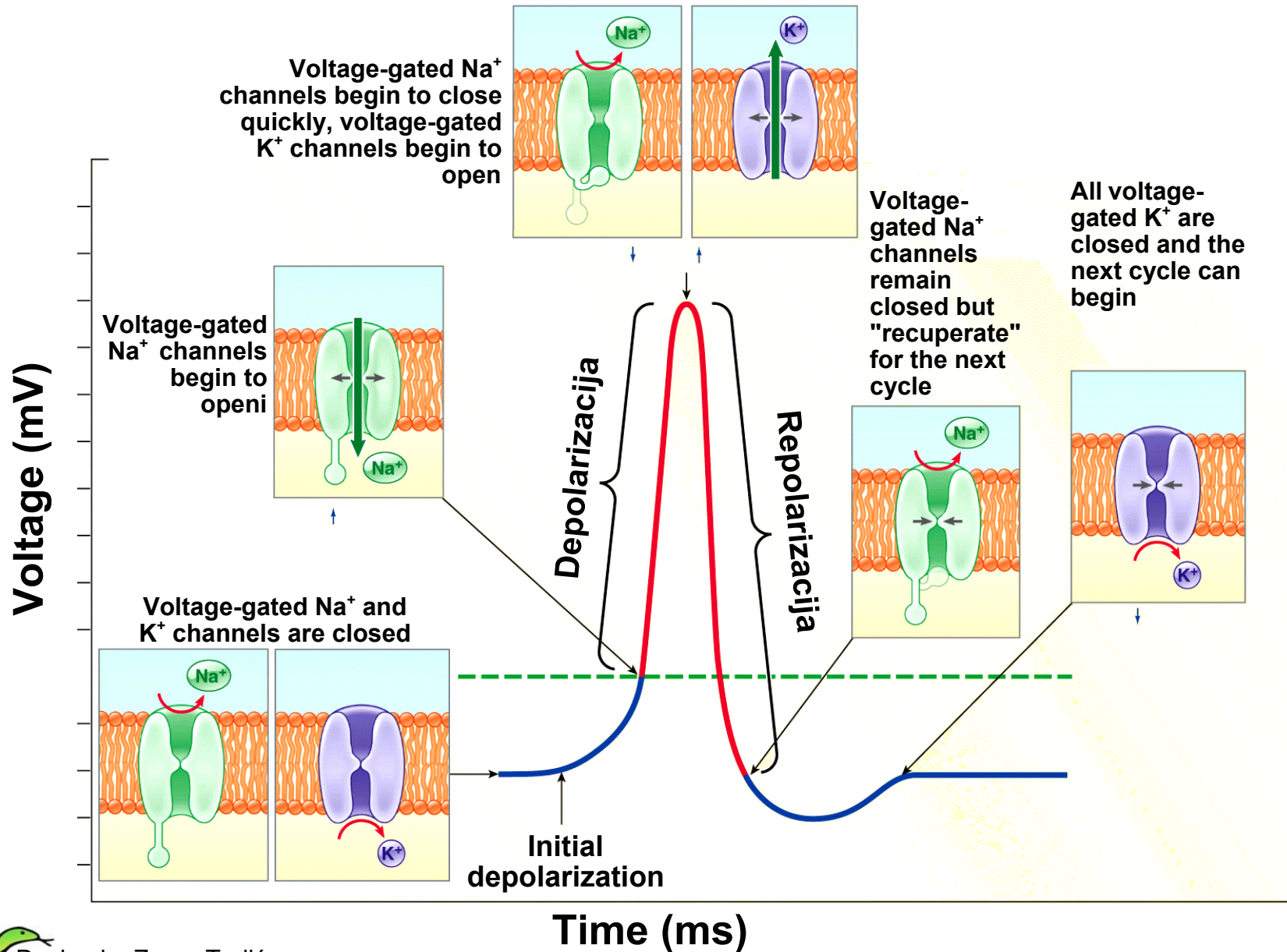
The structure and function of a neuron



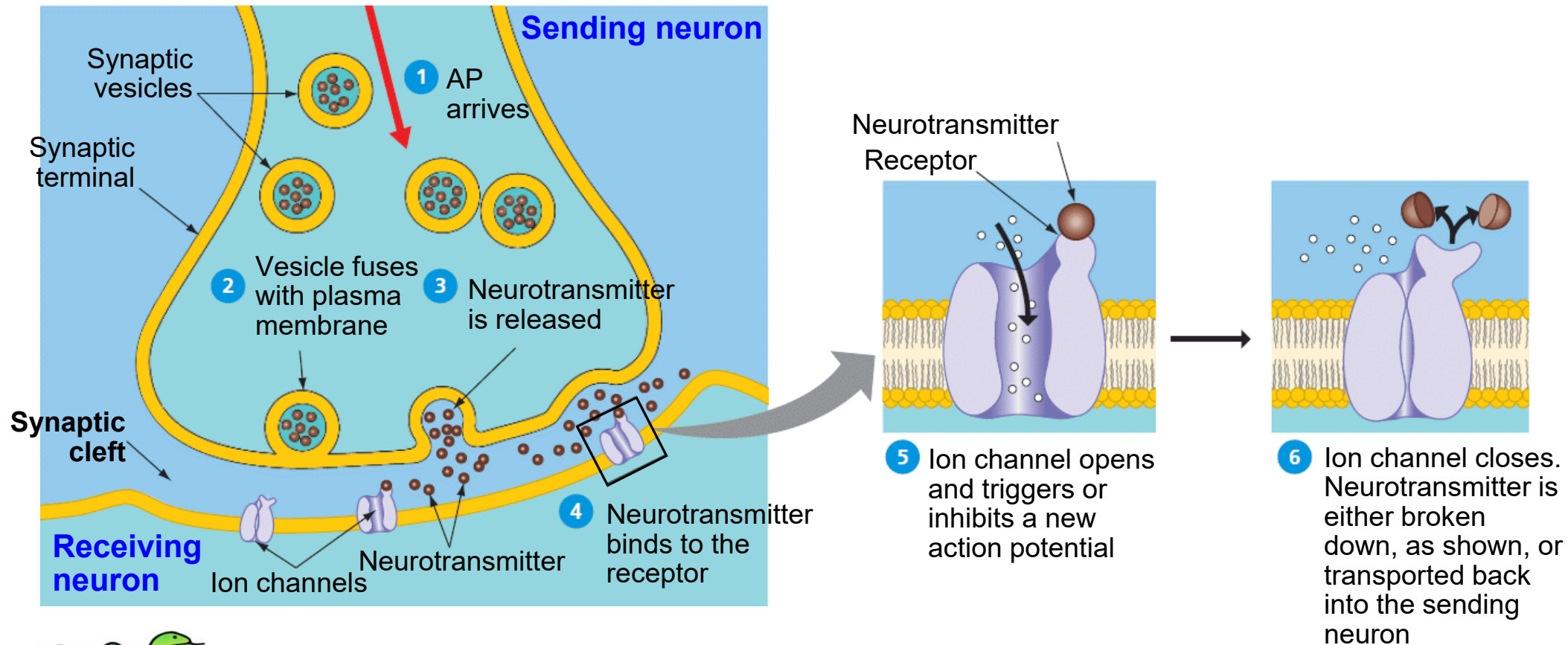
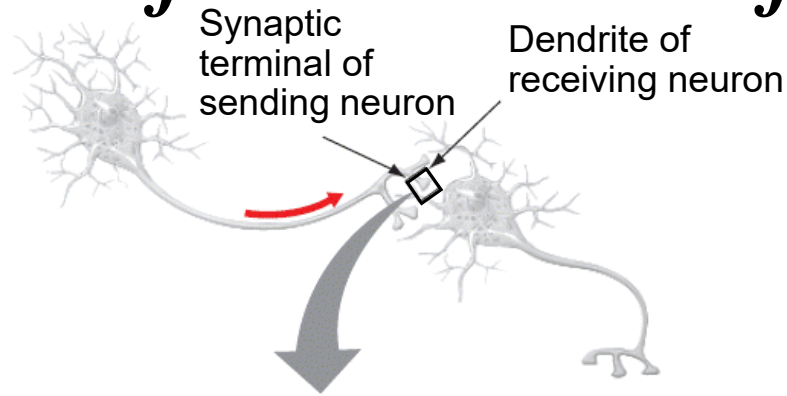
The action potential - basic electric phenomenon of the nervous system



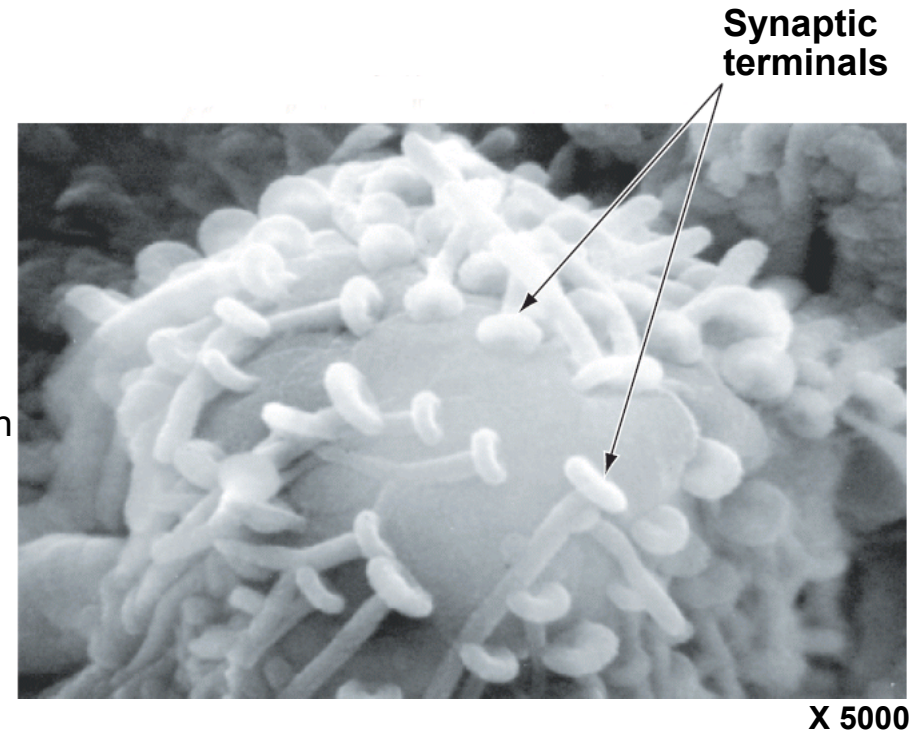
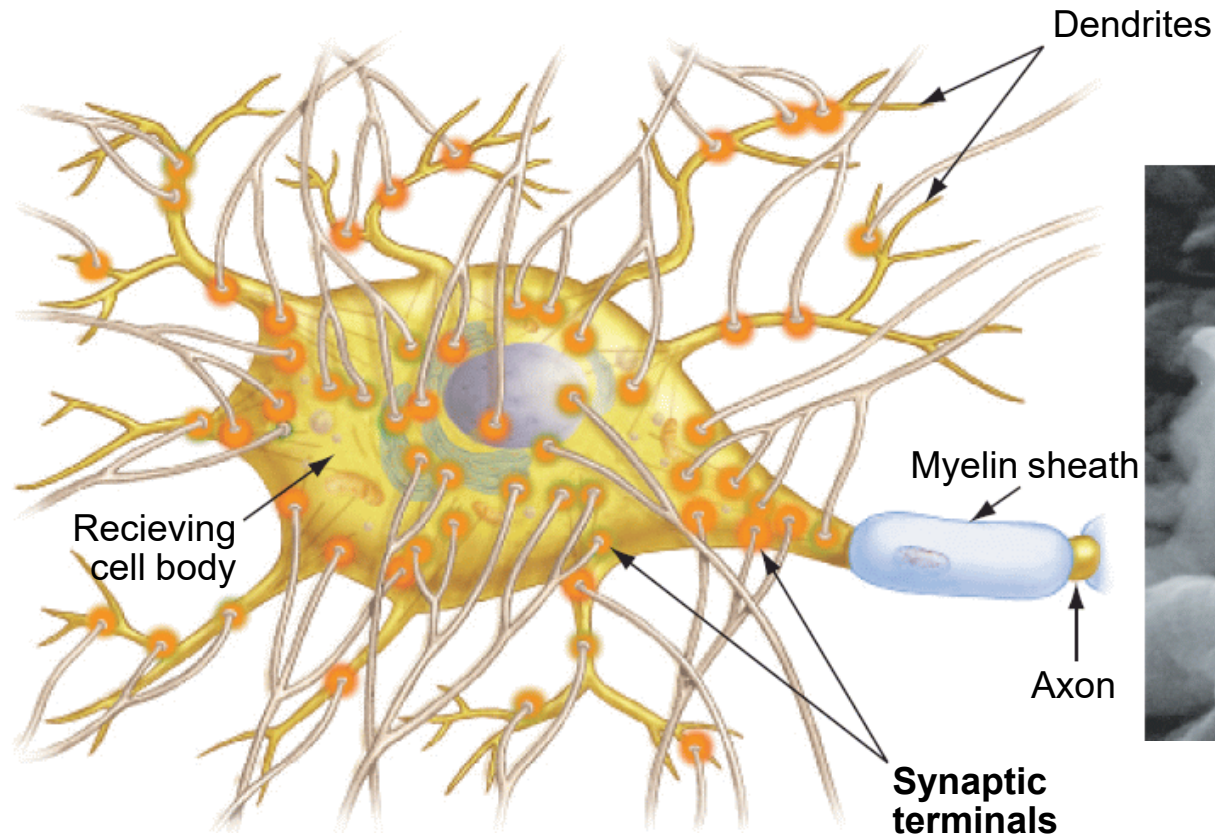
How is an action potential generated?



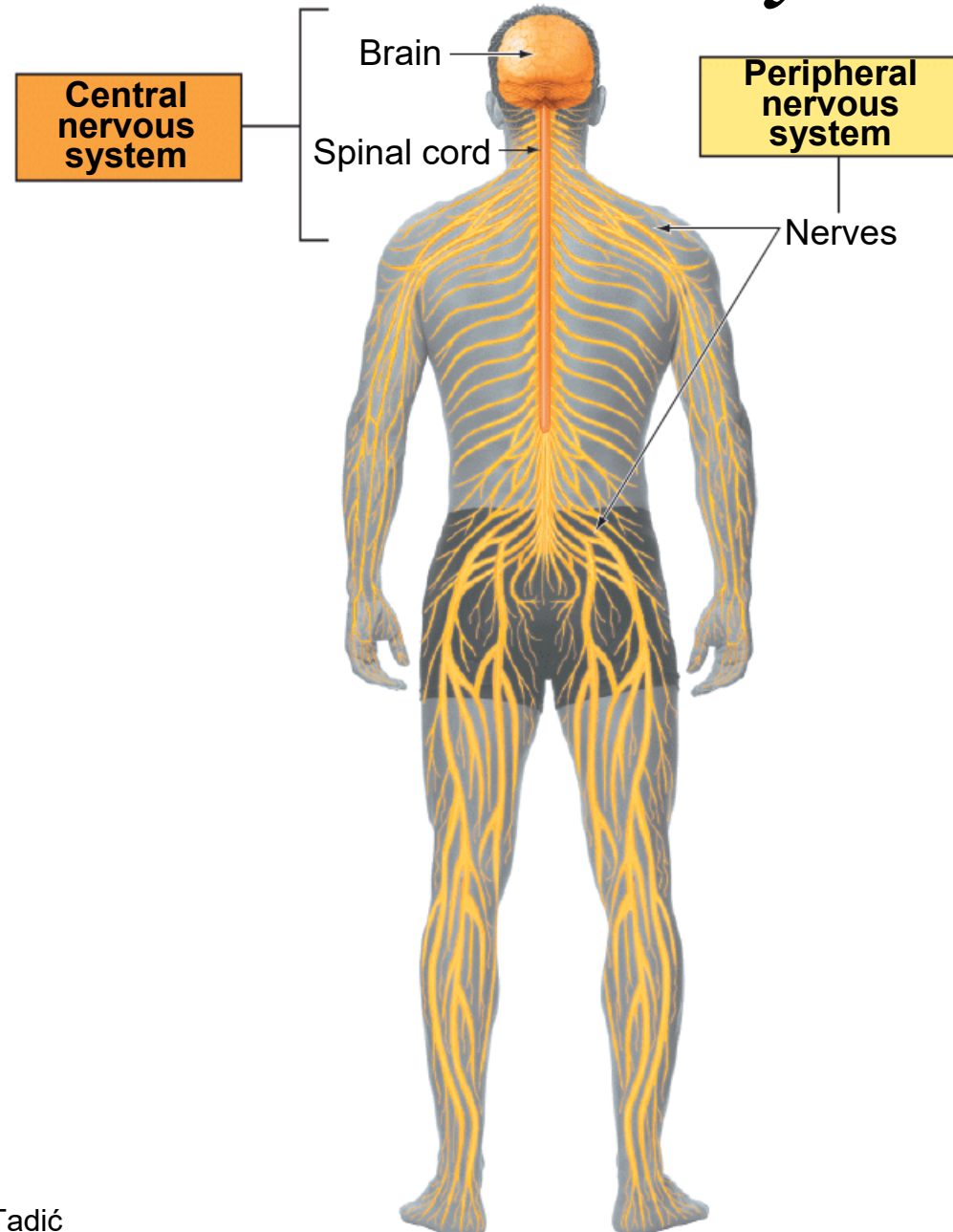
How is information transferred to another neuron?






Multiple synaptic inputs of the neuron



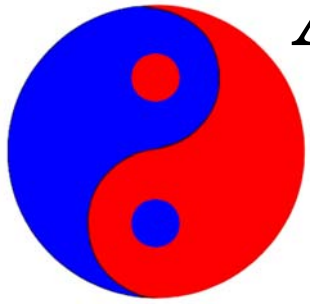
Human nervous system



Functional division of the peripheral nervous system

| PERIPHERAL NERVOUS SYSTEM | | |
|--|---|--|
| Motor system (voluntary) | Autonomic nervous system (involuntary) | |
| | Parasympathetic division | Sympathetic division |
|  |  |  |
| Control of skeletal muscle | "Rest or digest" | "Fight or flight" |

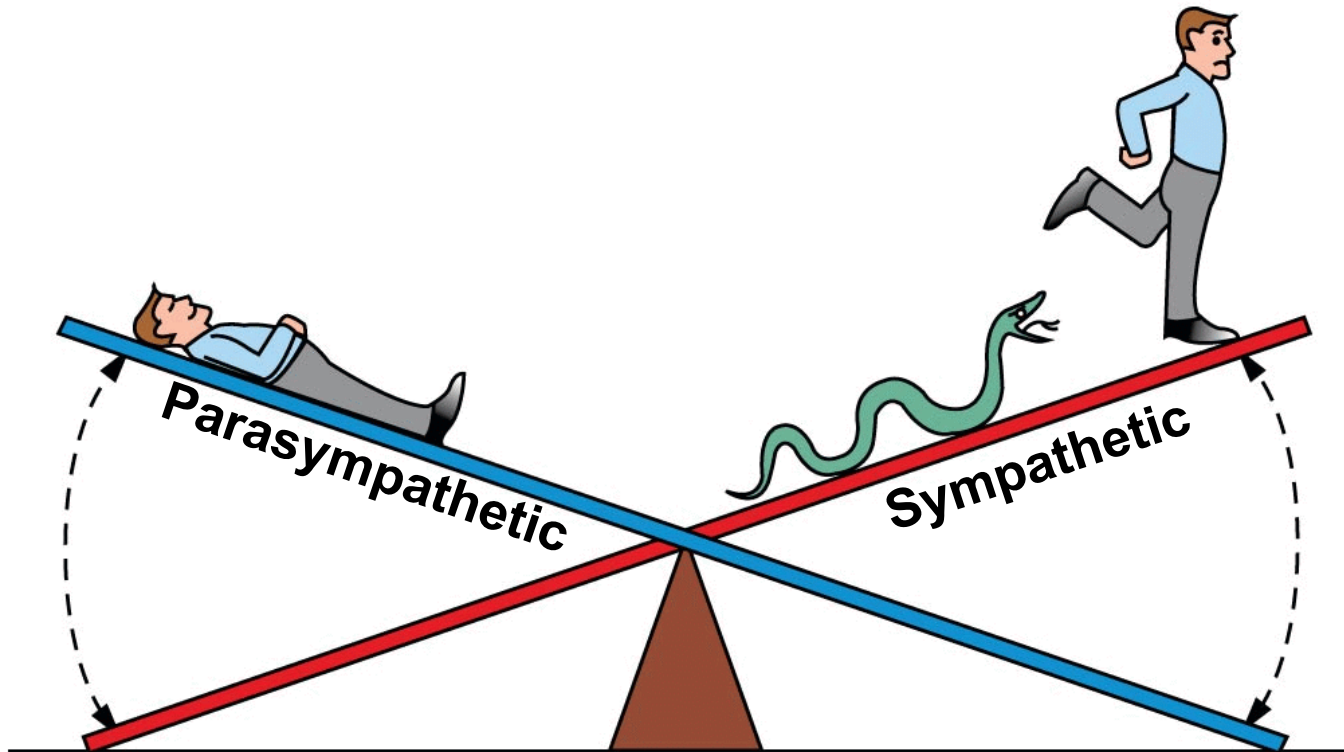




陰陽
yīnyáng

Autonomic nervous system (ANS)

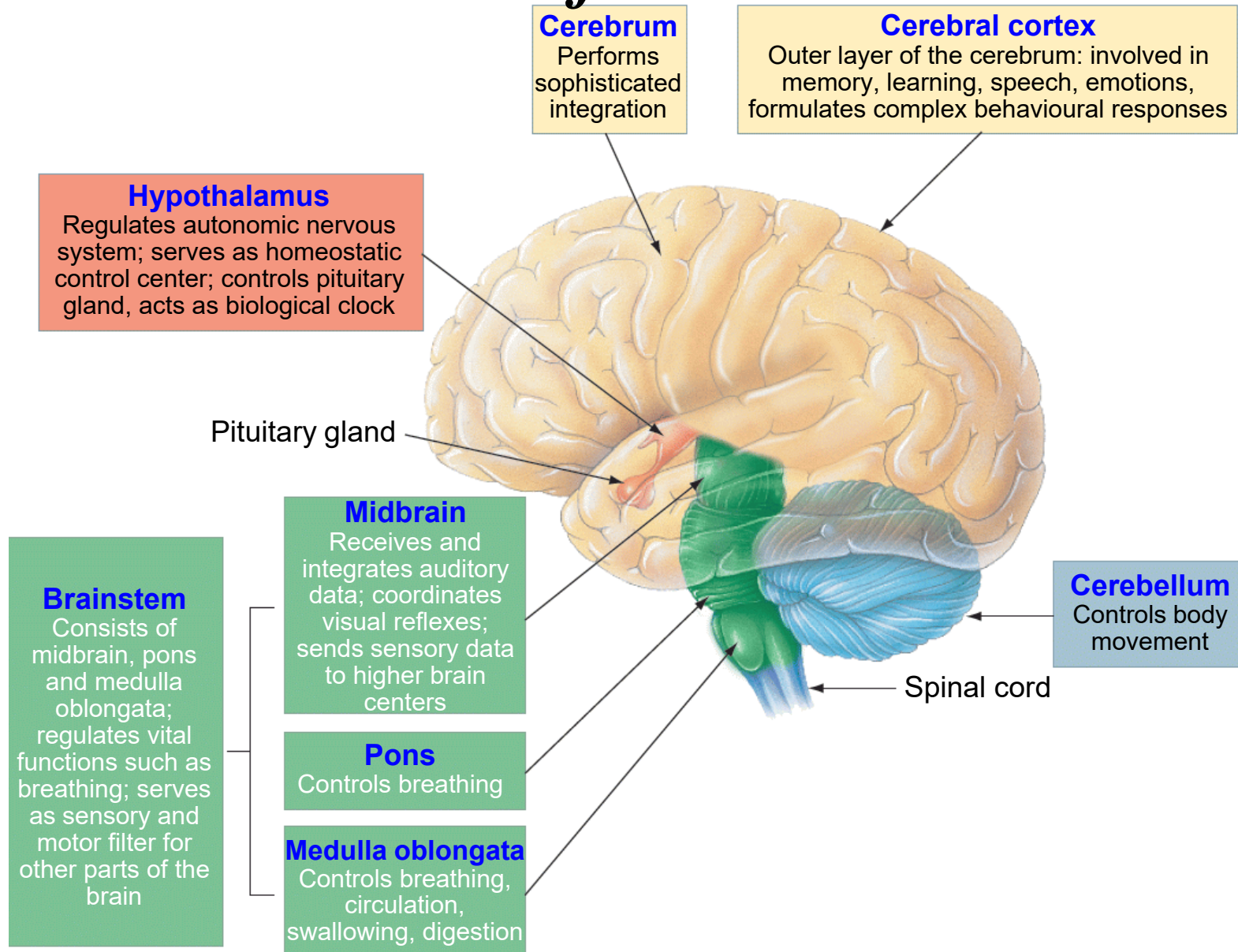
Homeostasis = **yin** + **yang** in balance =
two opposite but interconnected forces =
sympathetic i **parasympathetic** in balance



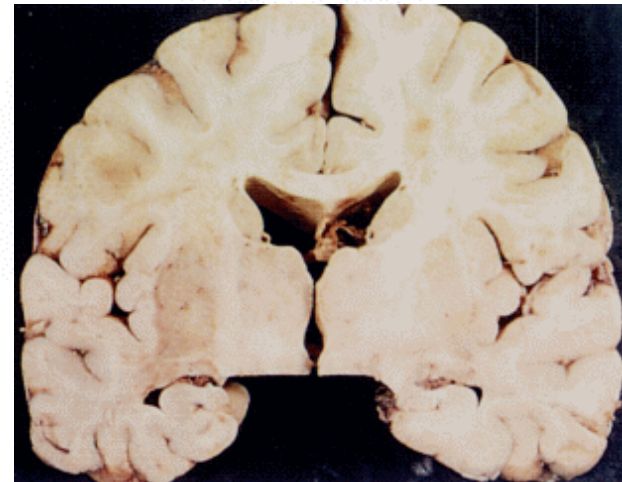
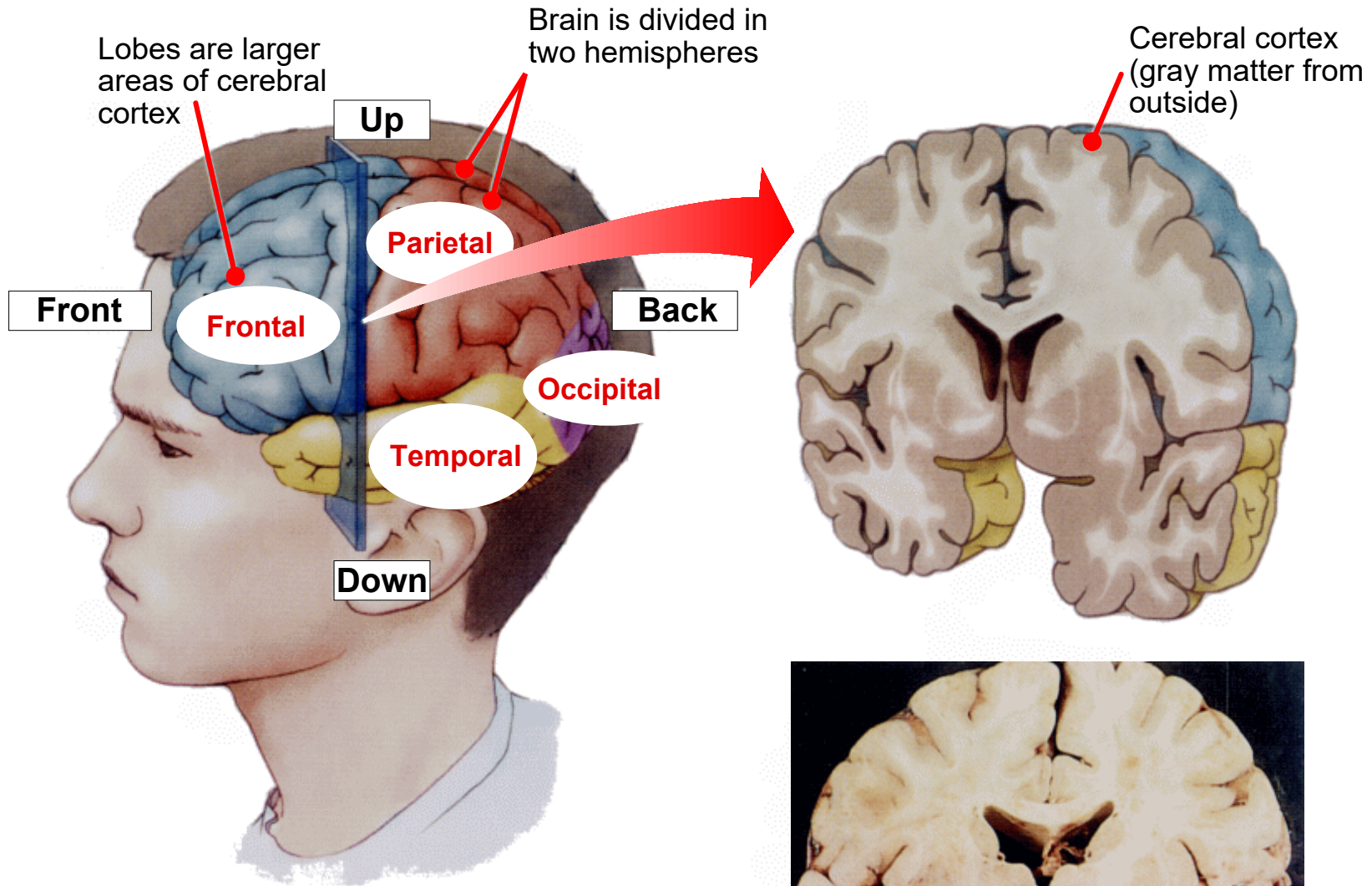
Parasympathetic part of the ANS
controls "rest or digest" body response

Sympathetic part of the ANS
controls "fight or flight" body
response

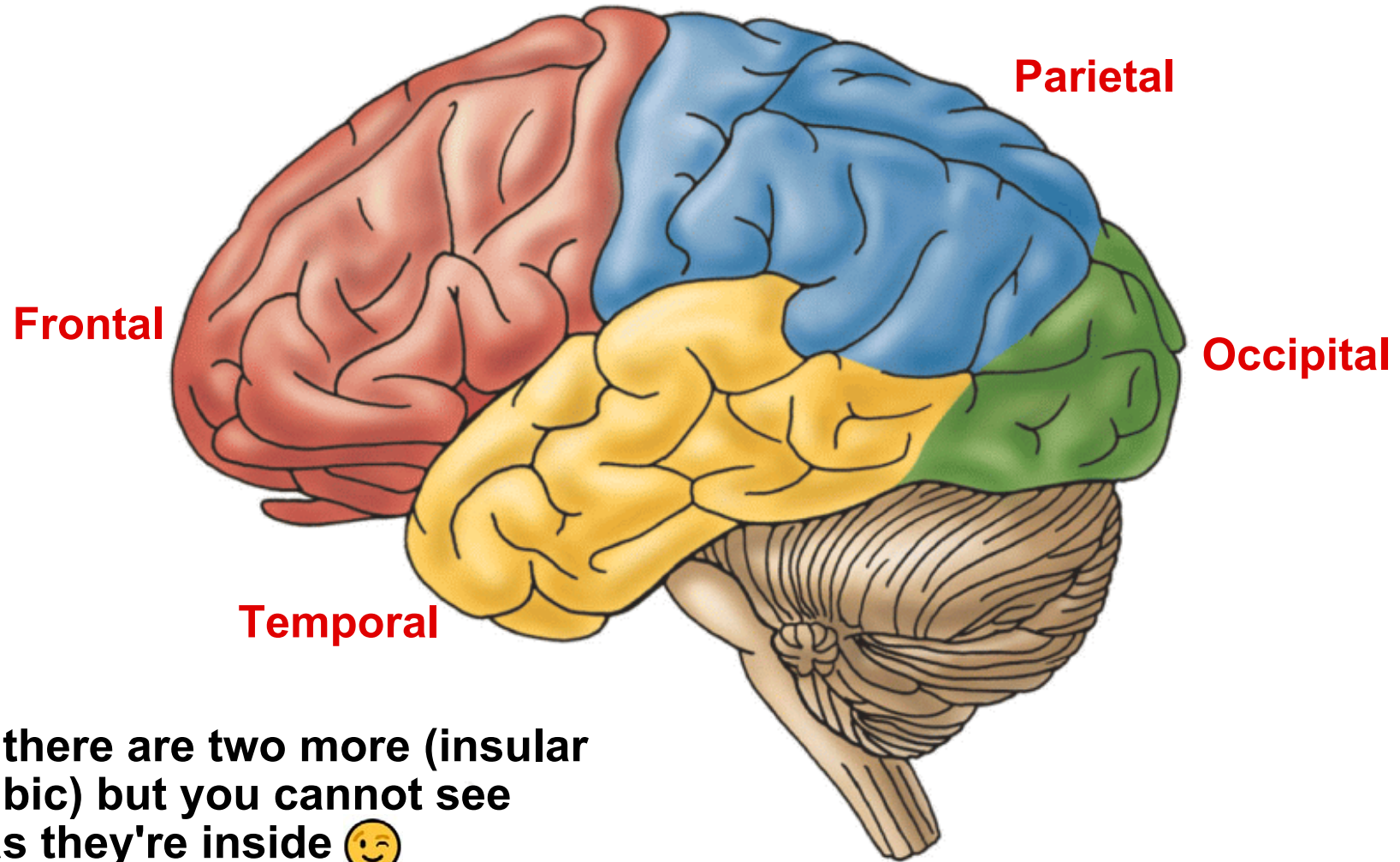
Parts of the brain



Cerebral hemispheres, lobes and cortex



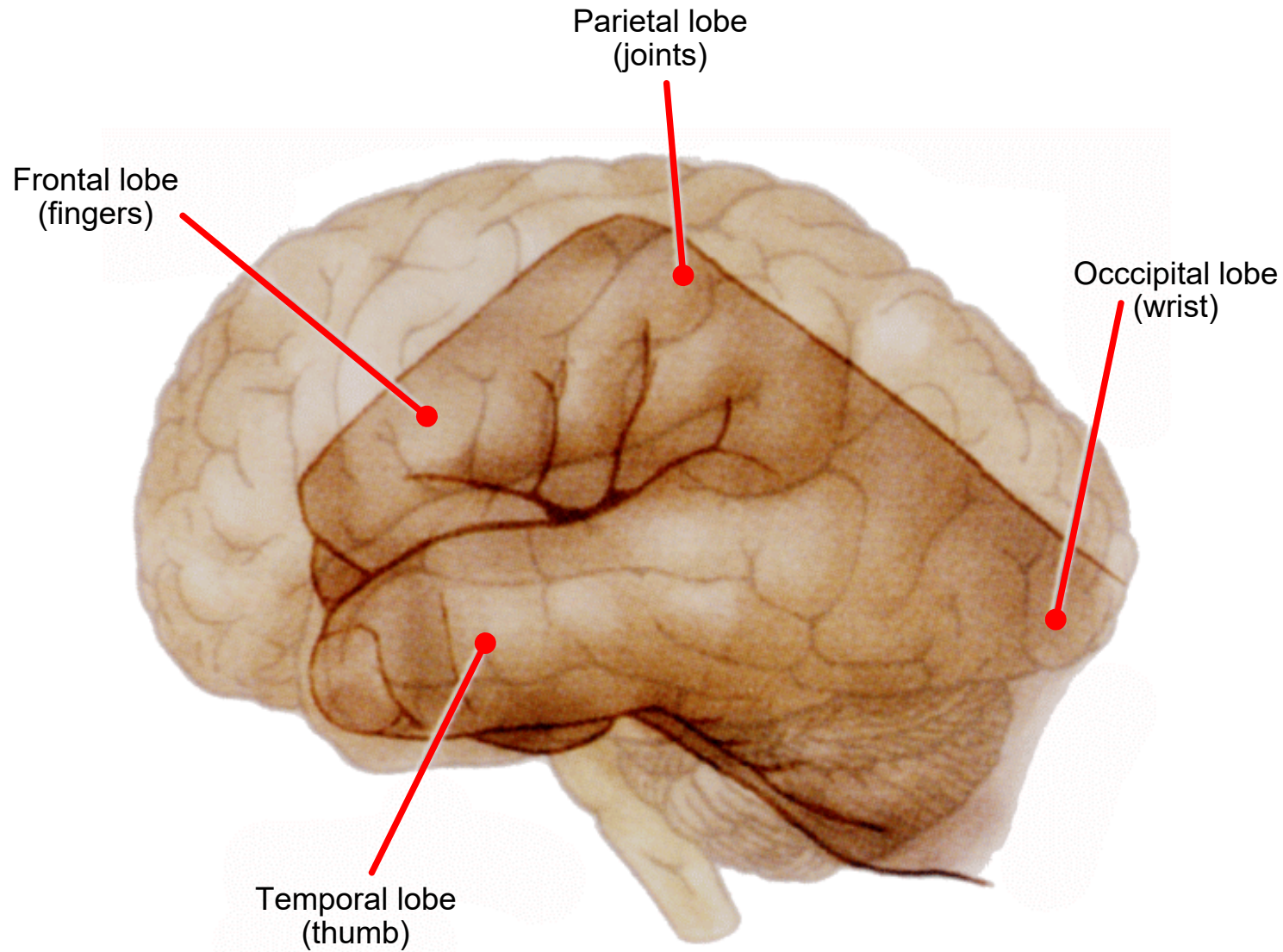
Cerebral lobes. . .



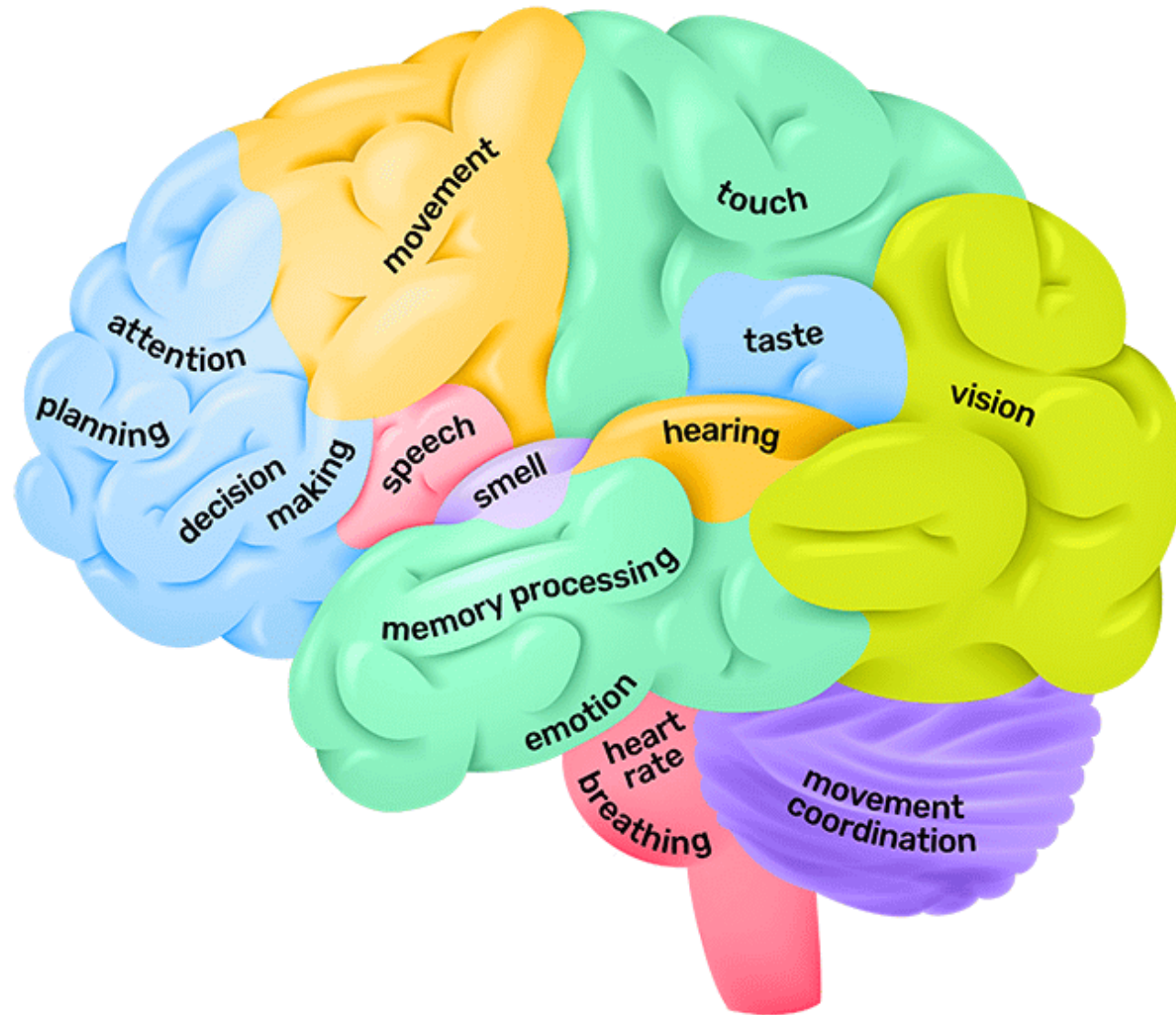
In fact, there are two more (insular and limbic) but you cannot see them, as they're inside 😊



...and how to remember them



Functional areas of the left cerebral hemisphere



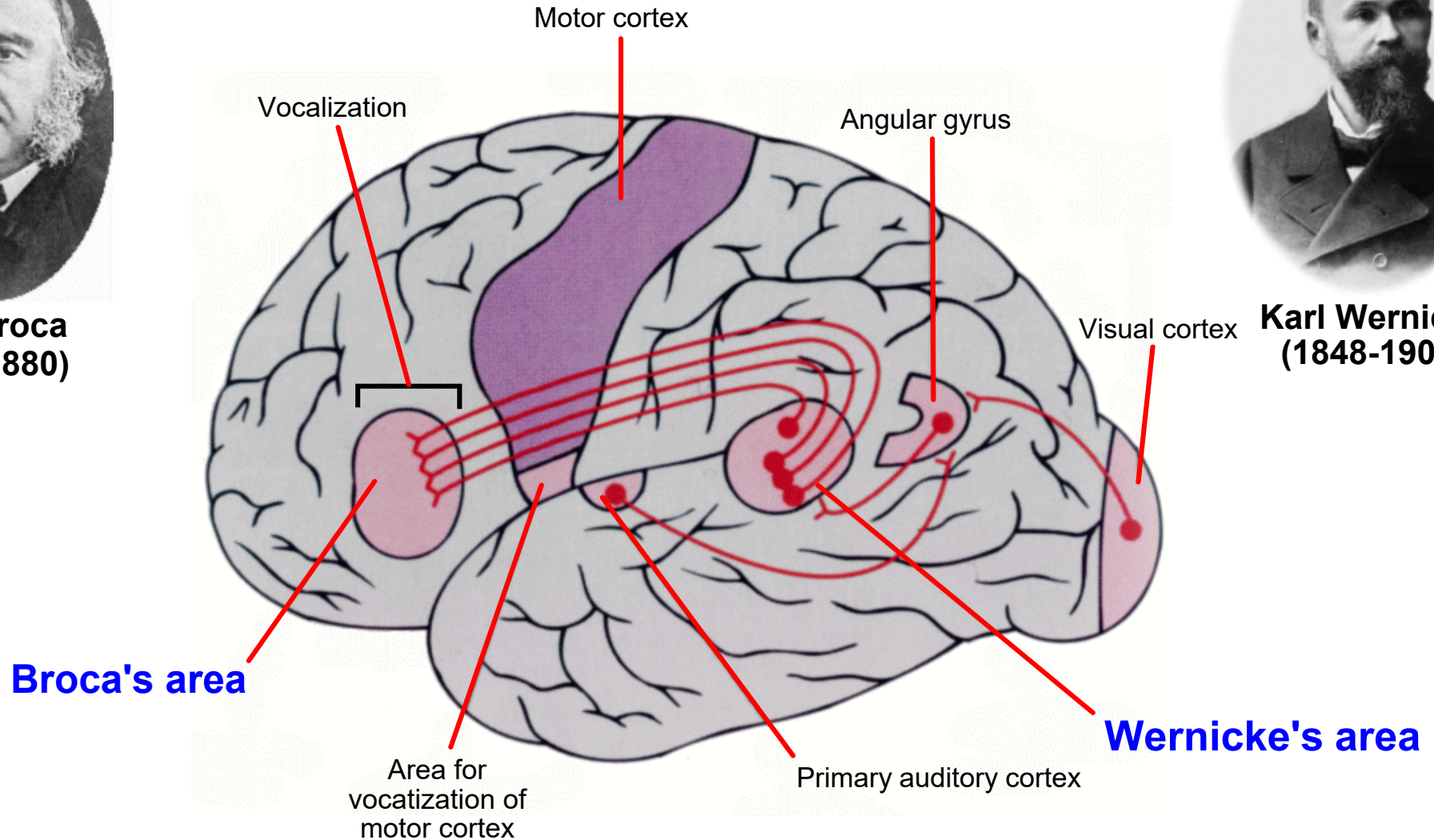
Human language - a higher brain function



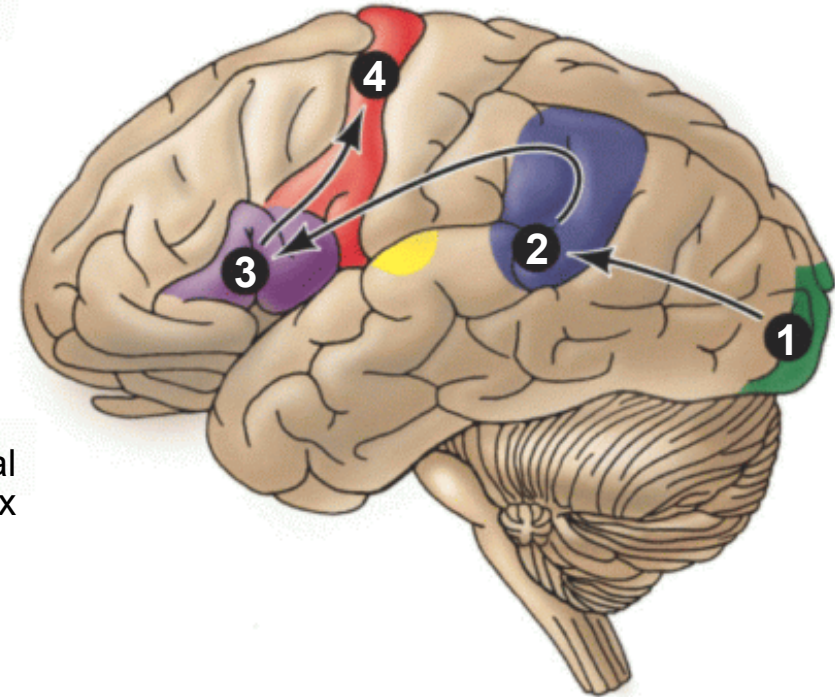
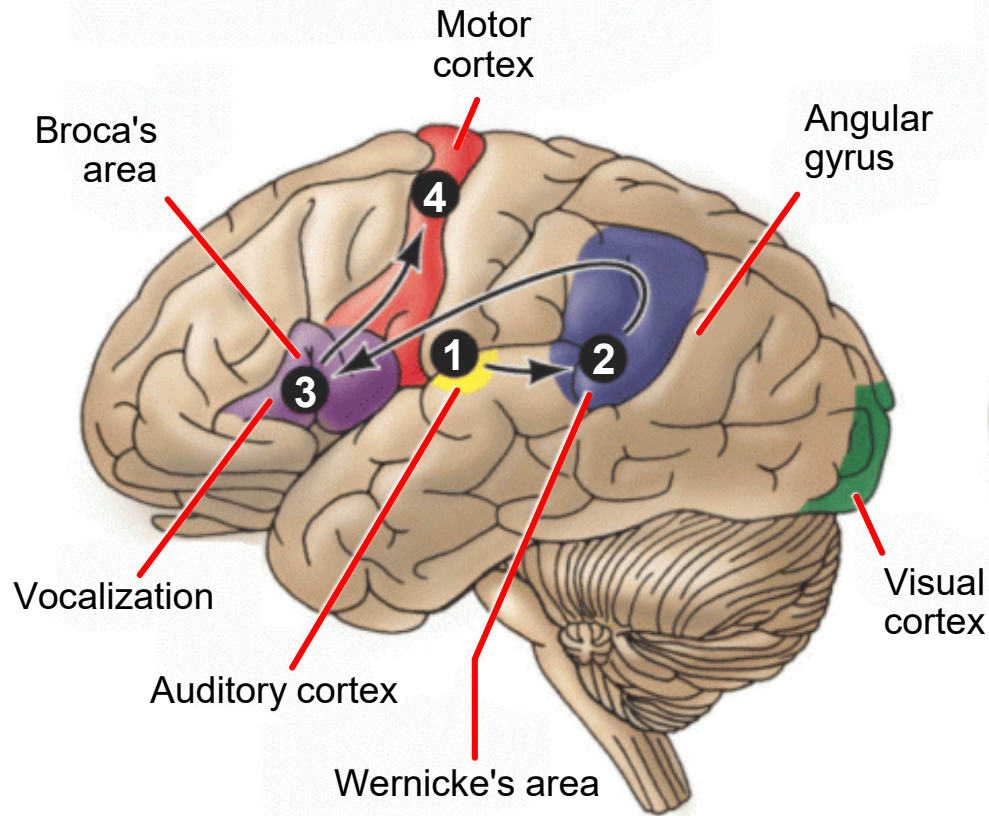
**Paul Broca
(1824-1880)**



**Karl Wernicke
(1848-1904)**

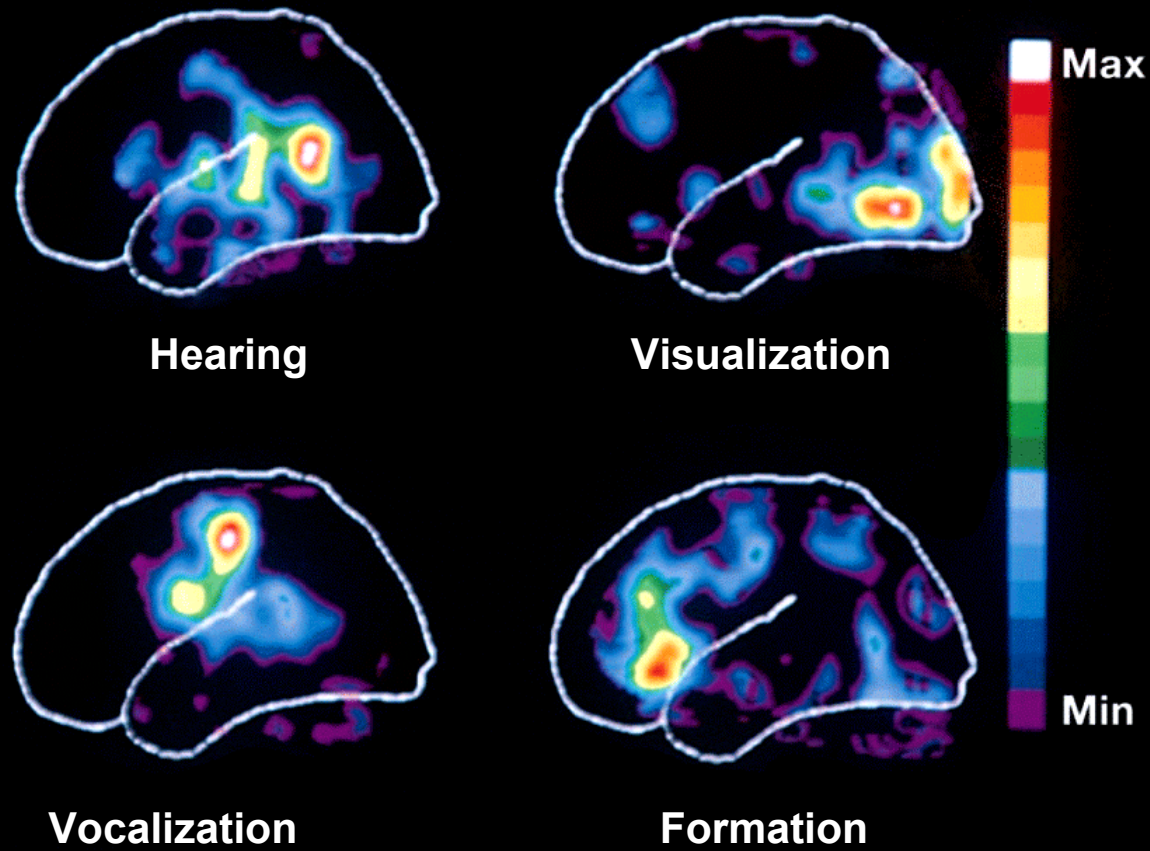


Vocalization of the heard word



Vocalization of the written word

Brain activity during various phases of word recognition and vocalization (MRI scan)



Functions of the frontal lobe

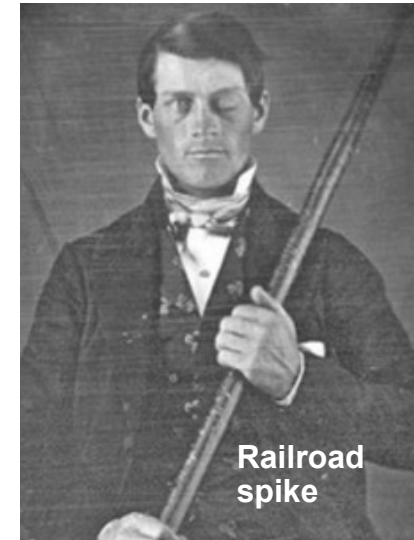
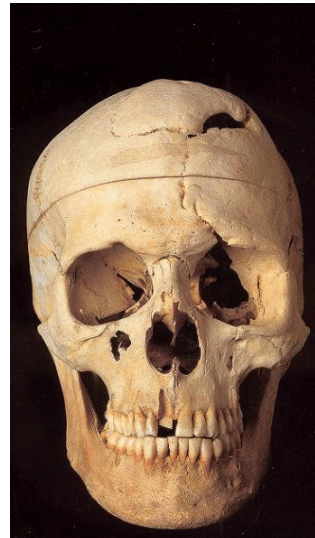
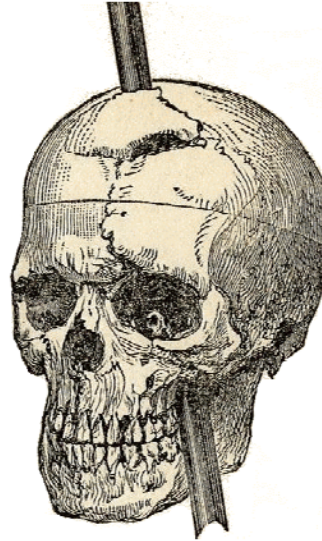
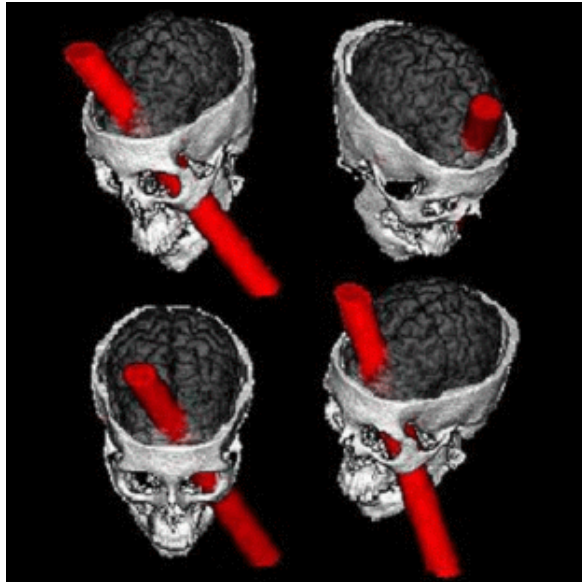
The Nobel Prize for physiology or medicine in 1949



**Egas Moniz
(1874-1955)**



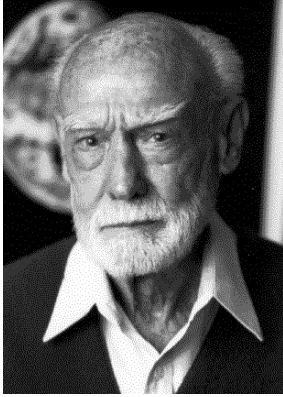
**“for his discovery of the
therapeutic value of leucotomy
in certain psychoses”**



**Railroad
spike**

**Phineas Gage
(1823-1860)**

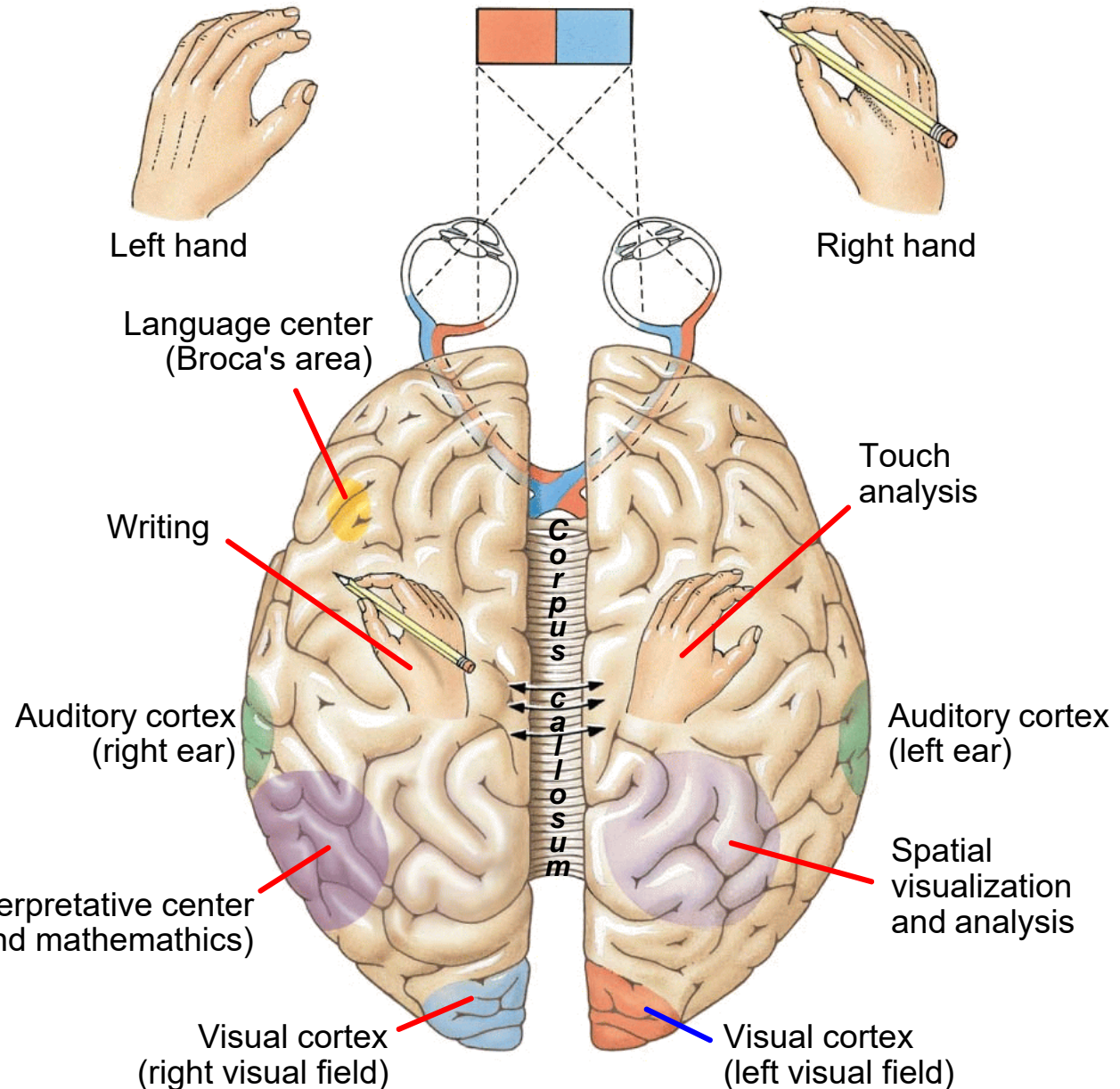
Hemispheres are not functionally symmetrical!



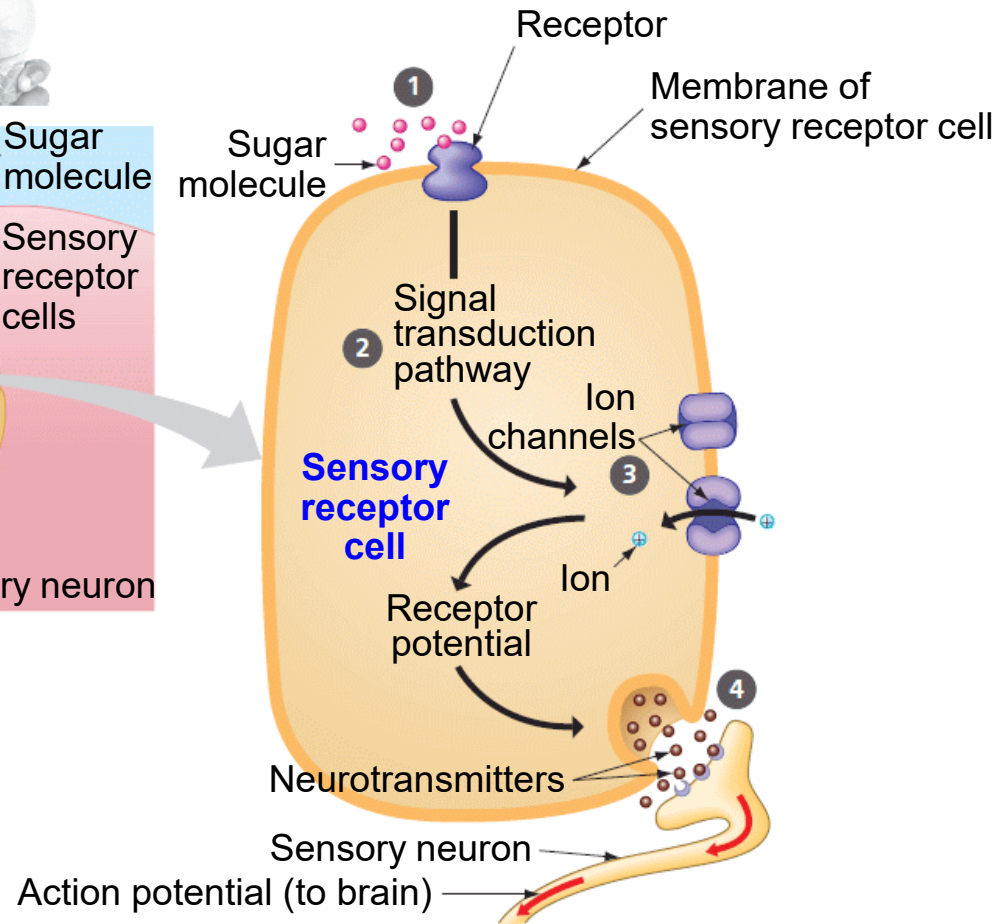
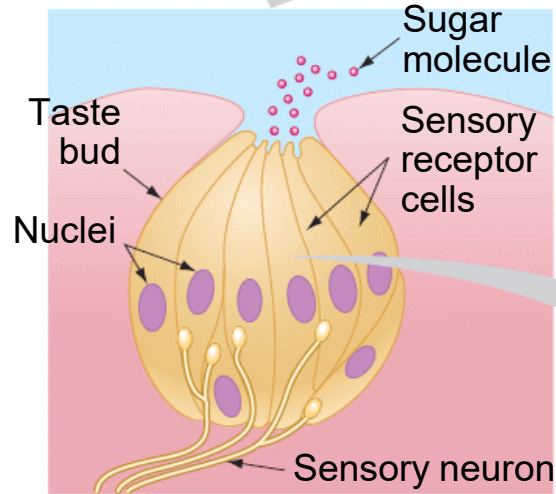
**Roger W. Sperry
(1913-1994)**

**The Nobel Prize for physiology
or medicine in 1981**

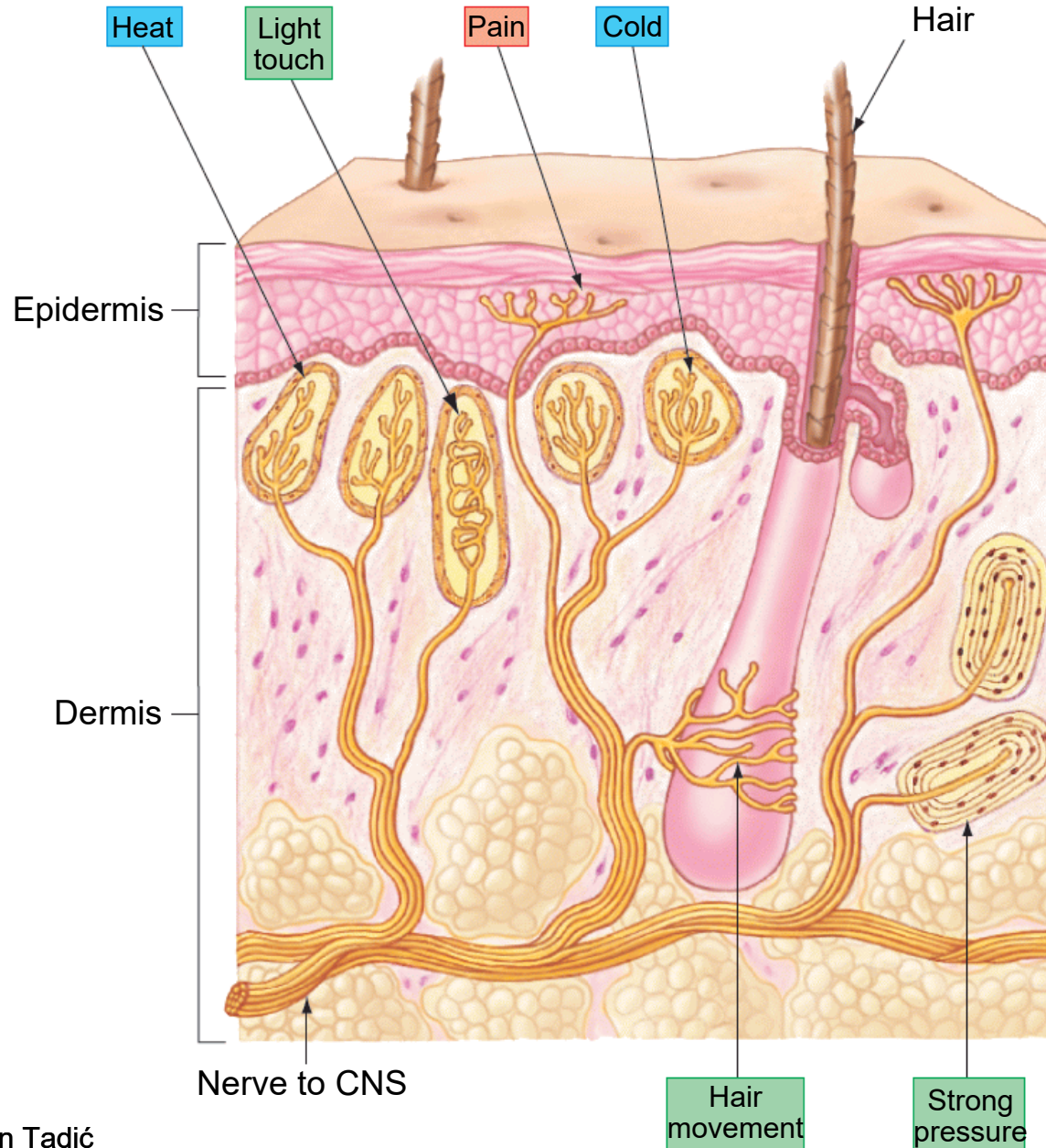
**“for his discoveries concerning the
functional specialization of the
cerebral hemispheres”**



Sensory transduction: An example

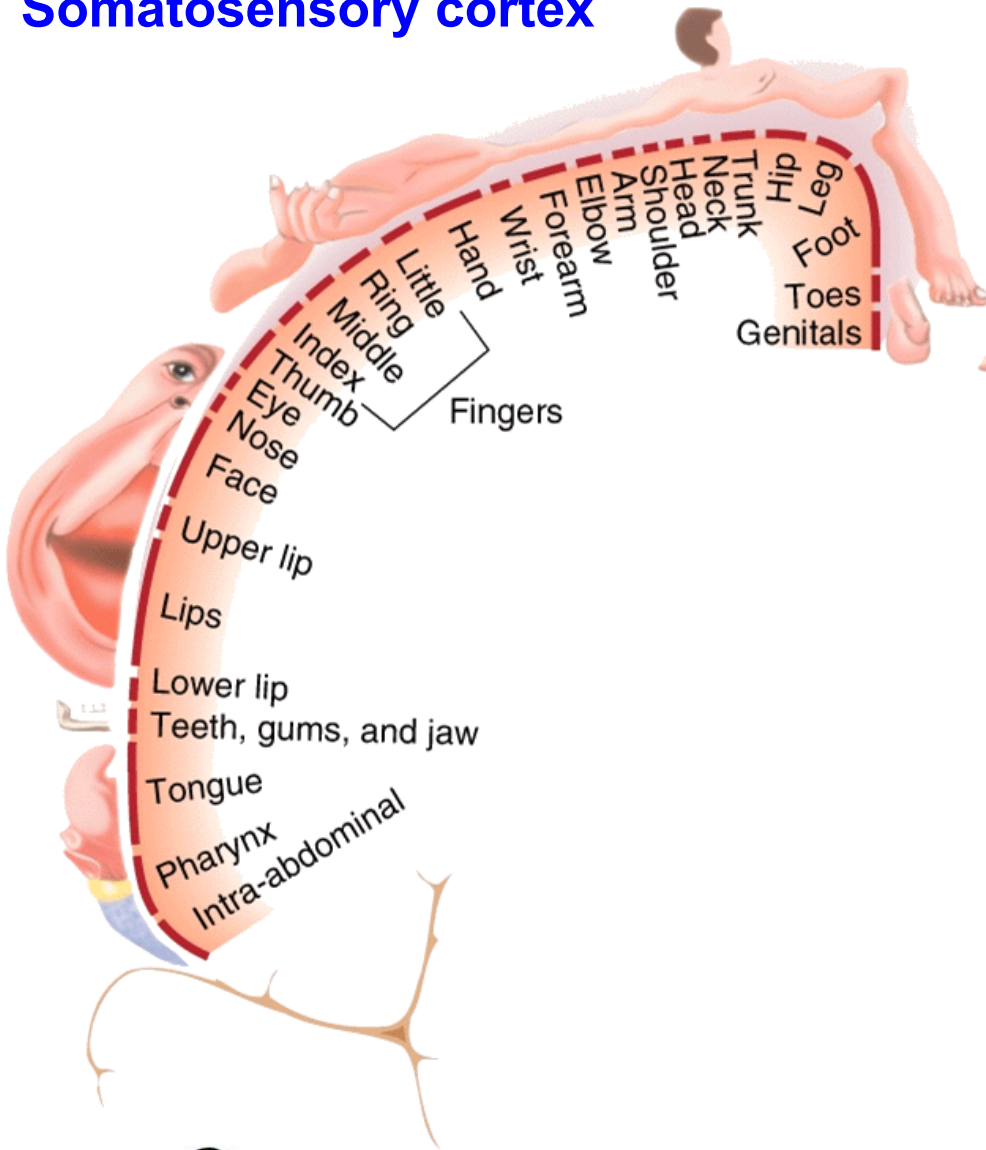


Somatosensory receptors in human skin

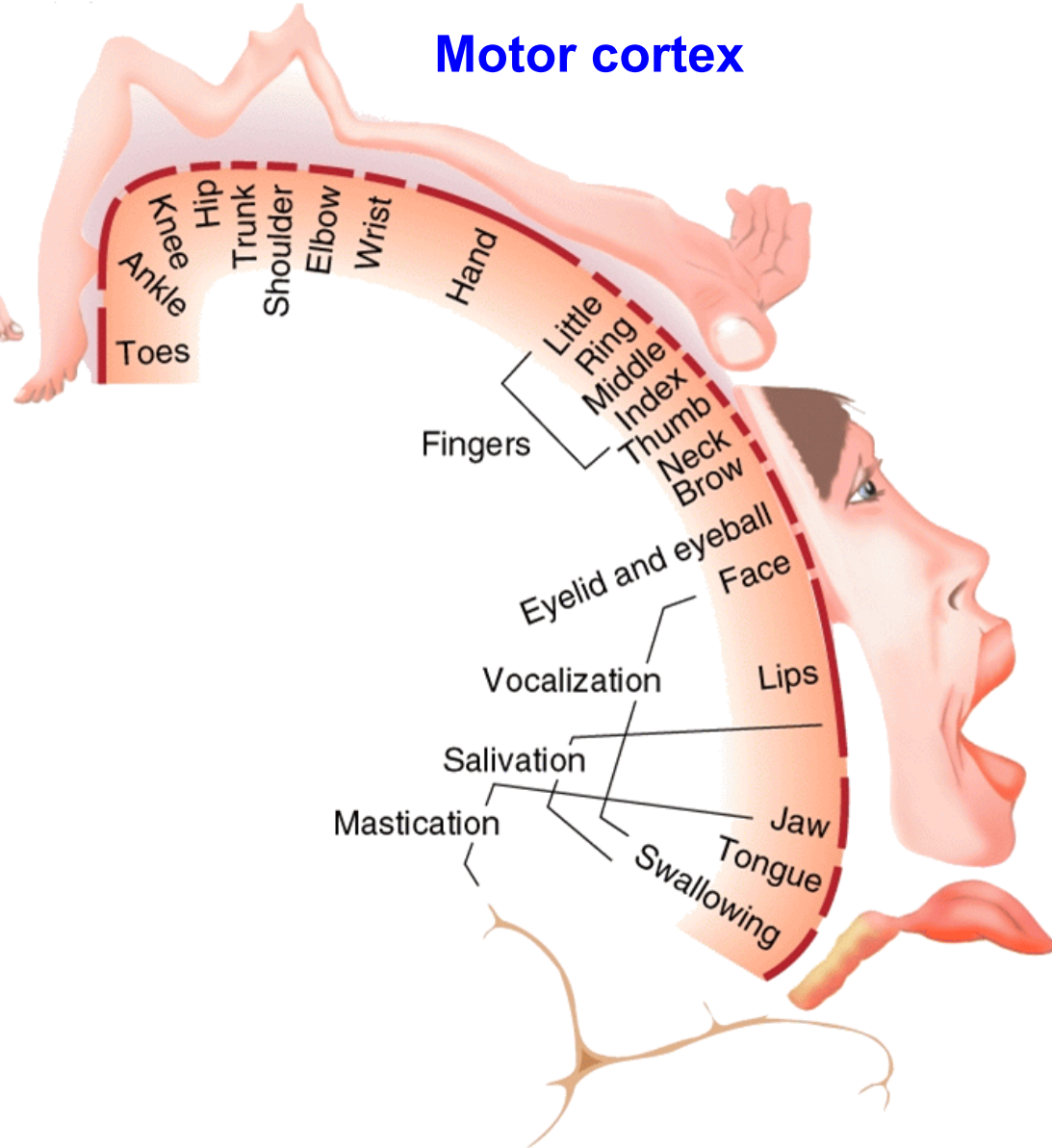


Somatosensory and motor cortical maps

Somatosensory cortex



Motor cortex



Somatosensory and motor homunculi

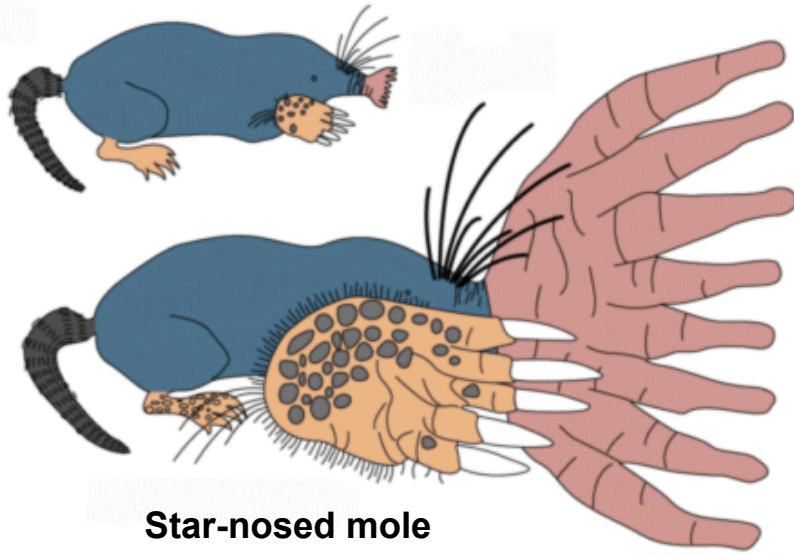


Somatosensory homunculus

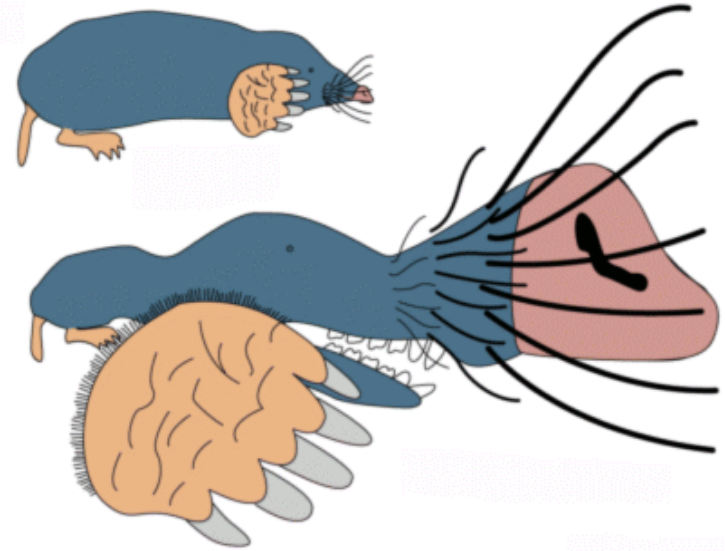


Motor homunculus

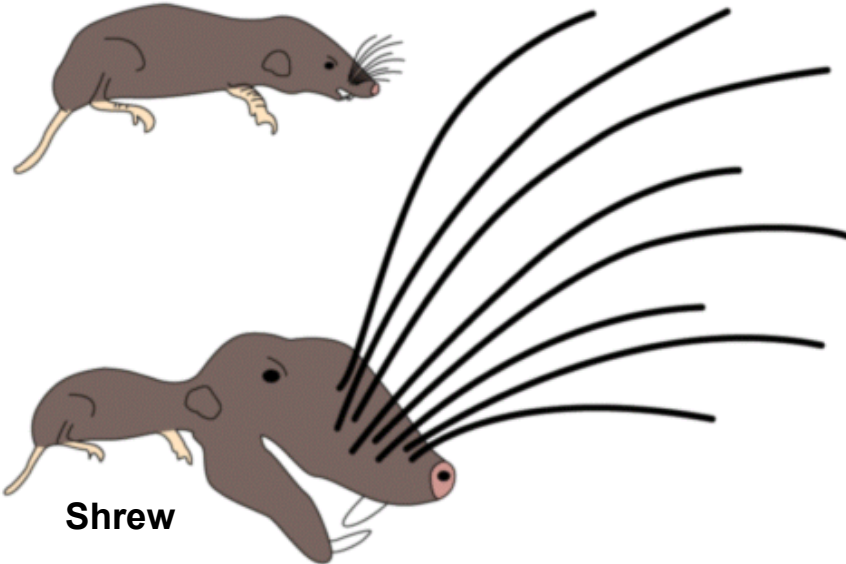
The same applies to the animals!



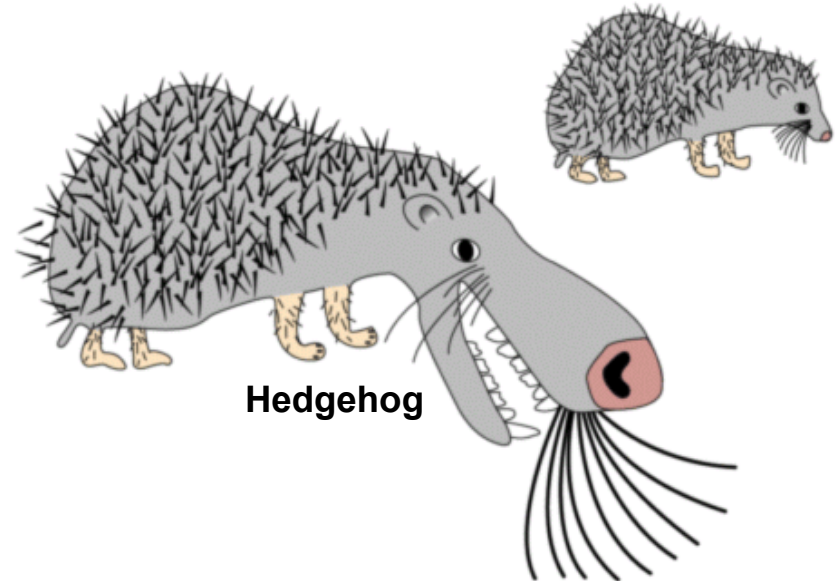
Star-nosed mole



Common mole

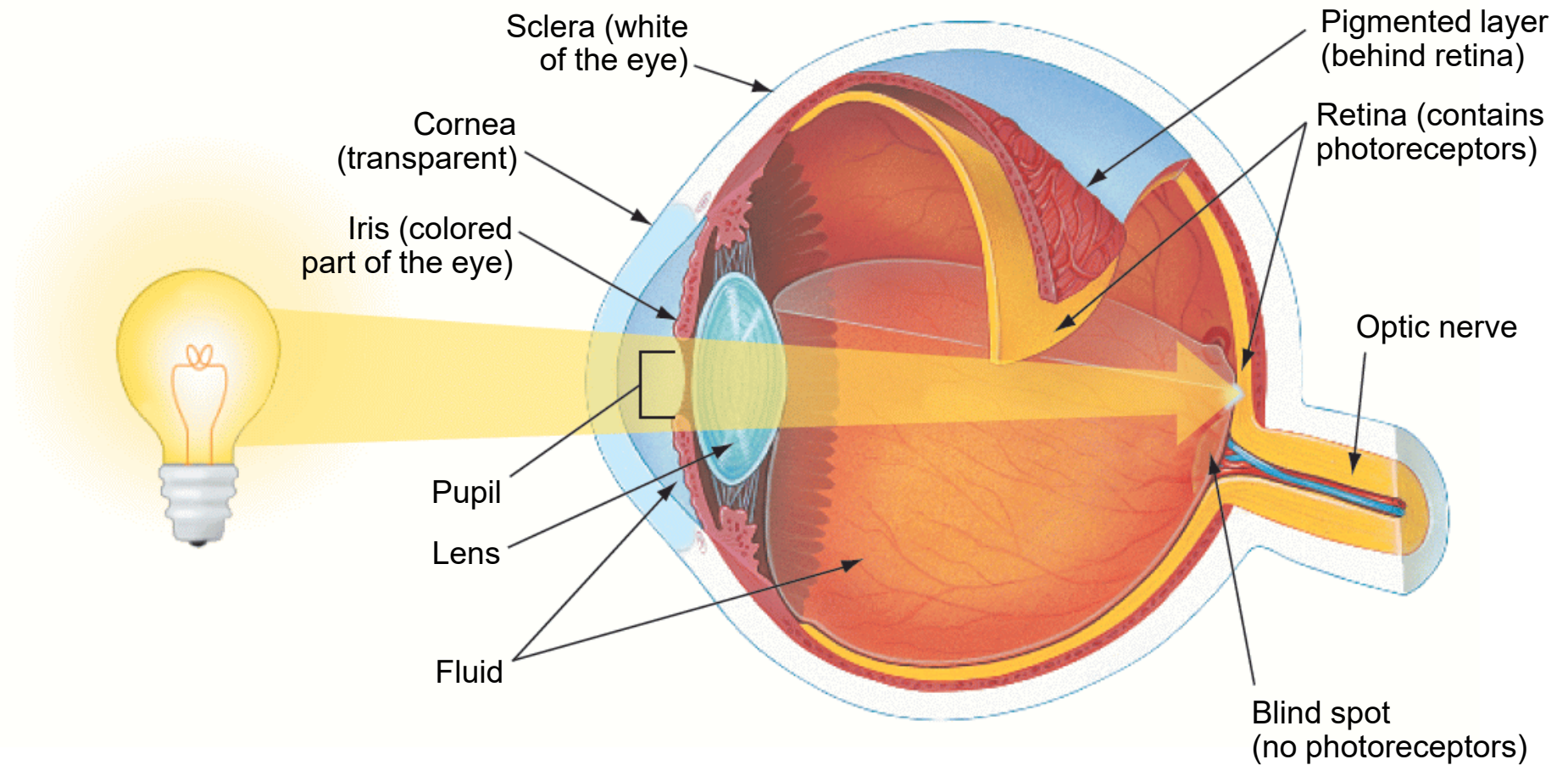


Shrew



Hedgehog

Light path to the retina



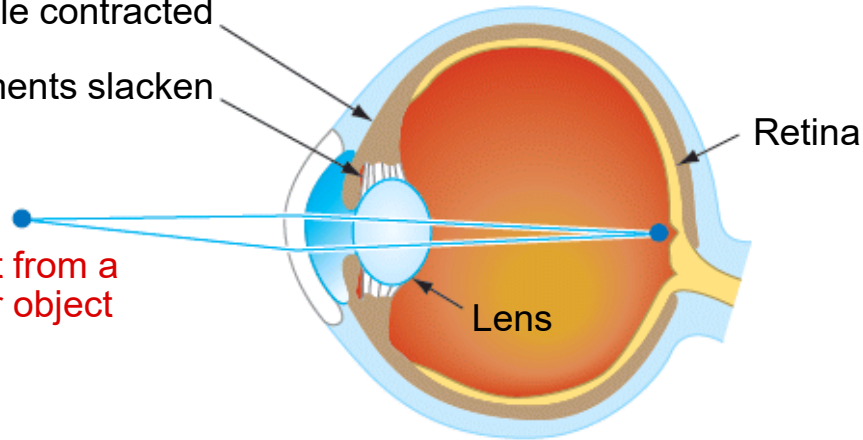
How does the lens focus light?

Watching the near object

Muscle contracted

Ligaments slacken

Light from a
near object

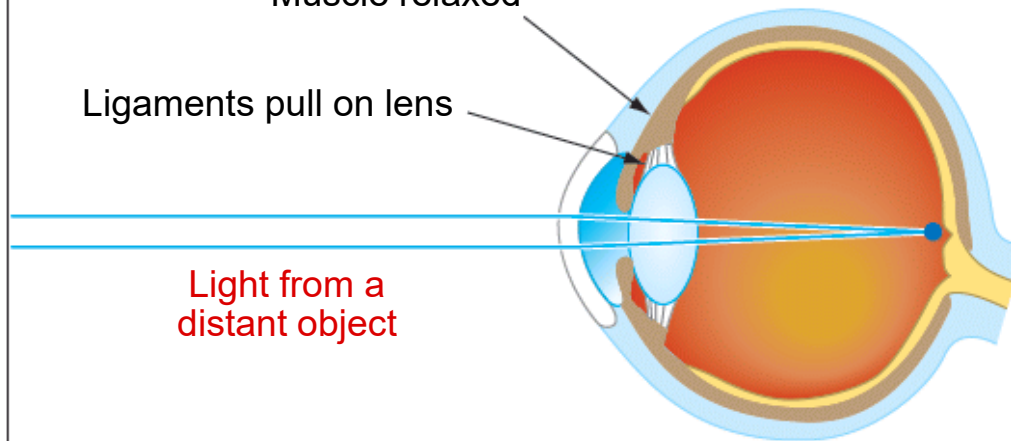


Watching the far object

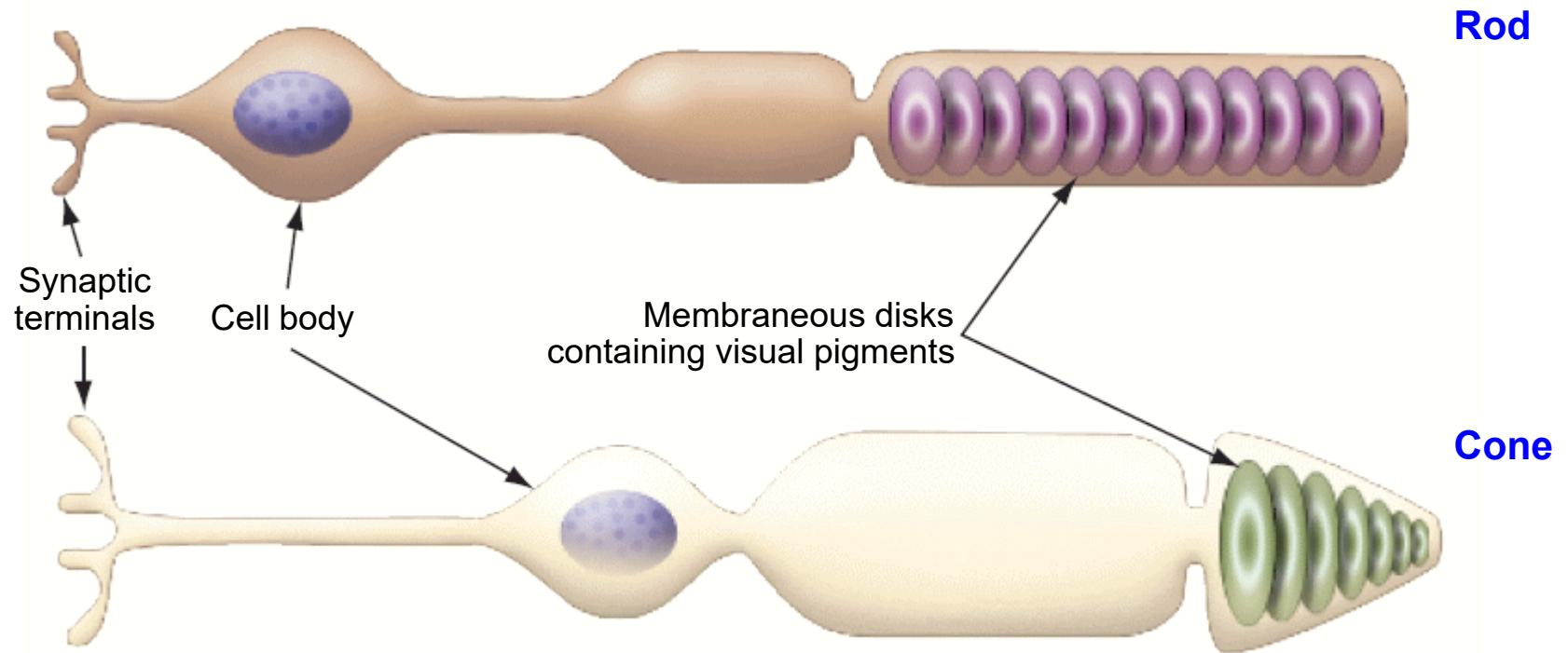
Muscle relaxed

Ligaments pull on lens

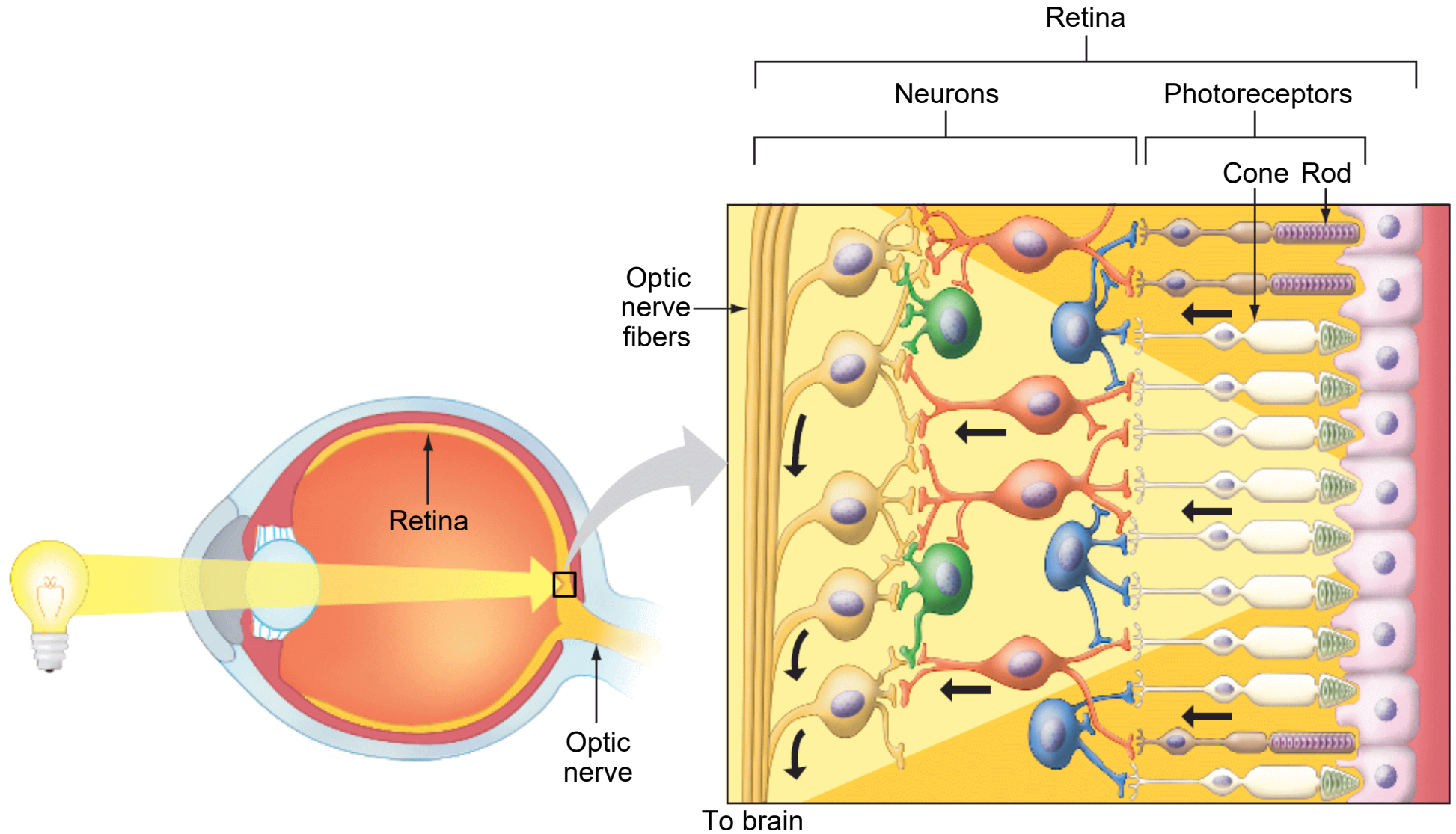
Light from a
distant object



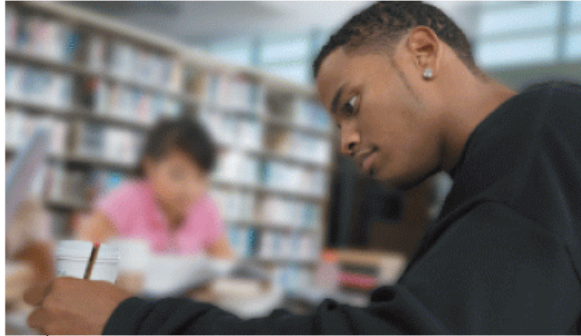
Photoreceptors in human retina



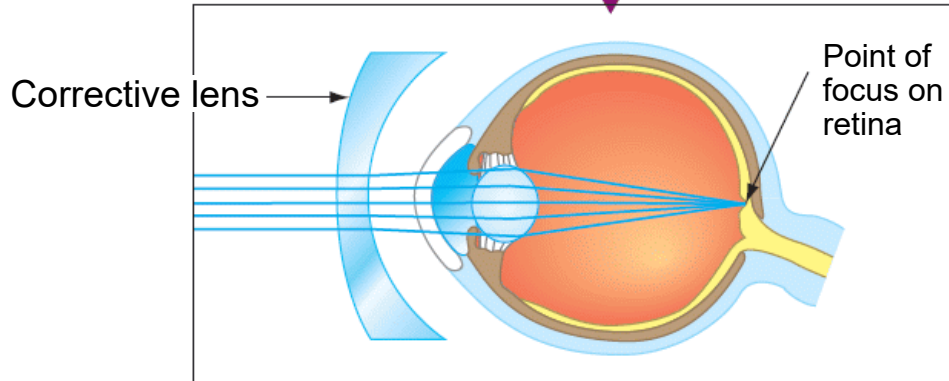
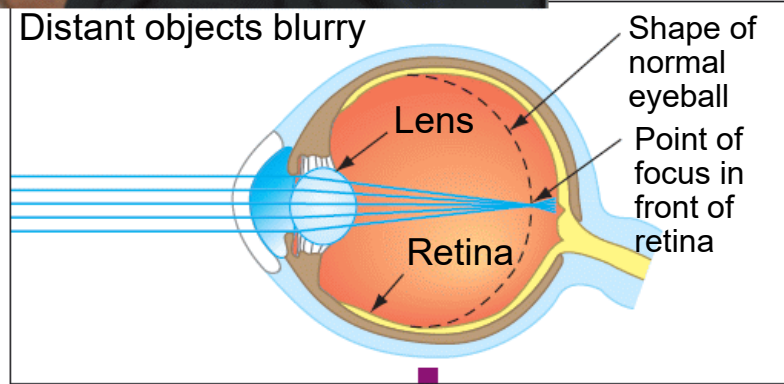
Photoreceptor arrangement in retina



Myopic and hyperopic eye



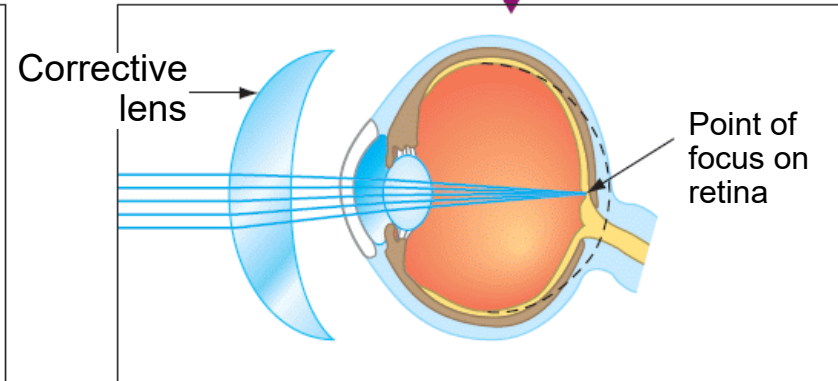
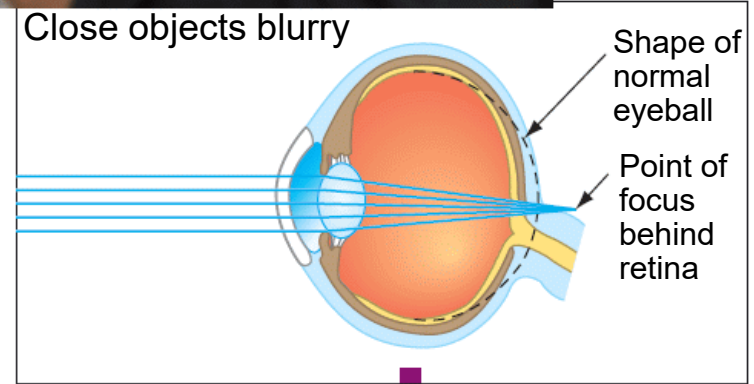
Distant objects blurry



Myopic eye (eyeball too long)



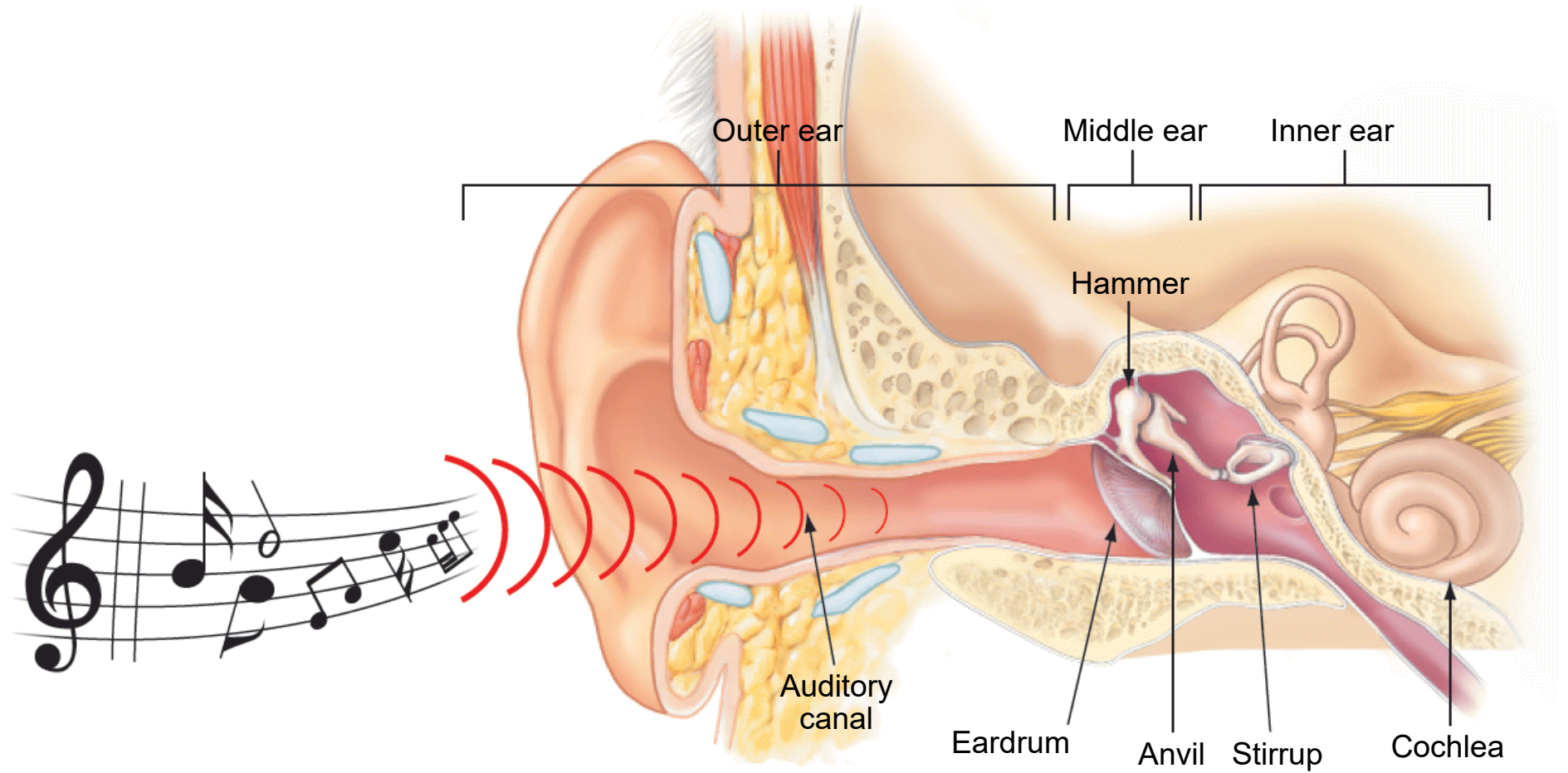
Close objects blurry



Hyperopic eye (eyeball too short)



Pathway of sound to the ear



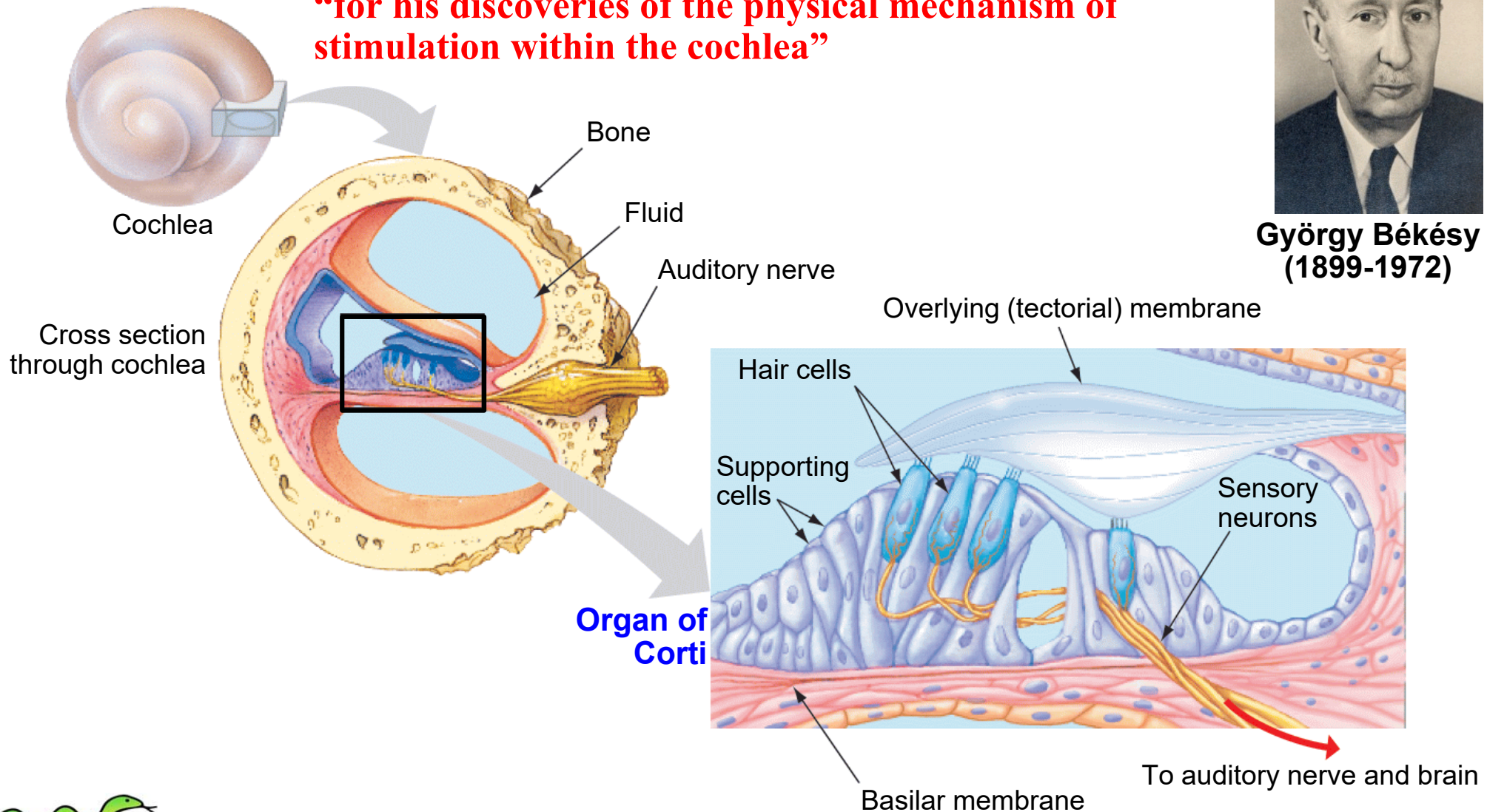
The structure and function of cochlea

The Nobel Prize for physiology or medicine in 1961

“for his discoveries of the physical mechanism of stimulation within the cochlea”



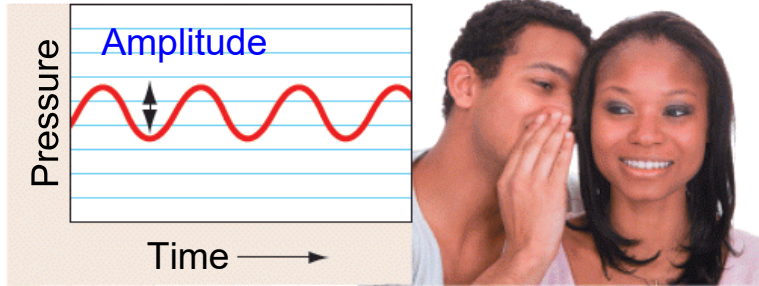
György Békésy
(1899-1972)



Sound characteristics and their coding by cochlea

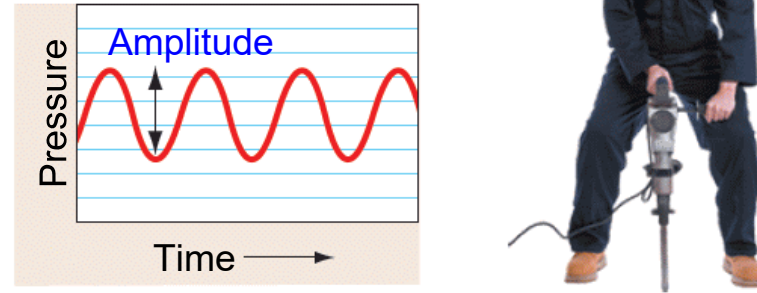
INTENSITY OF SOUND

Low amplitude = soft sound



A less intense sound produces smaller waves in the inner ear fluid, which results in fewer action potentials being sent to the brain.

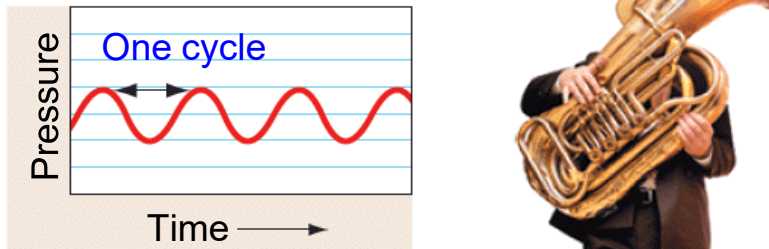
High amplitude = loud sound



A more intense sound produces larger waves in the inner ear fluid, which results in more action potentials being sent to the brain.

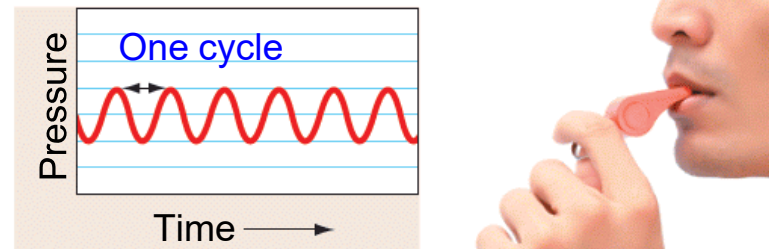
THE PITCH OF SOUND

Low frequency = low pitch



Low-frequency sounds cause hair cells deep in the inner ear to vibrate. Action potentials generated in this region of the ear are perceived as low sounds.

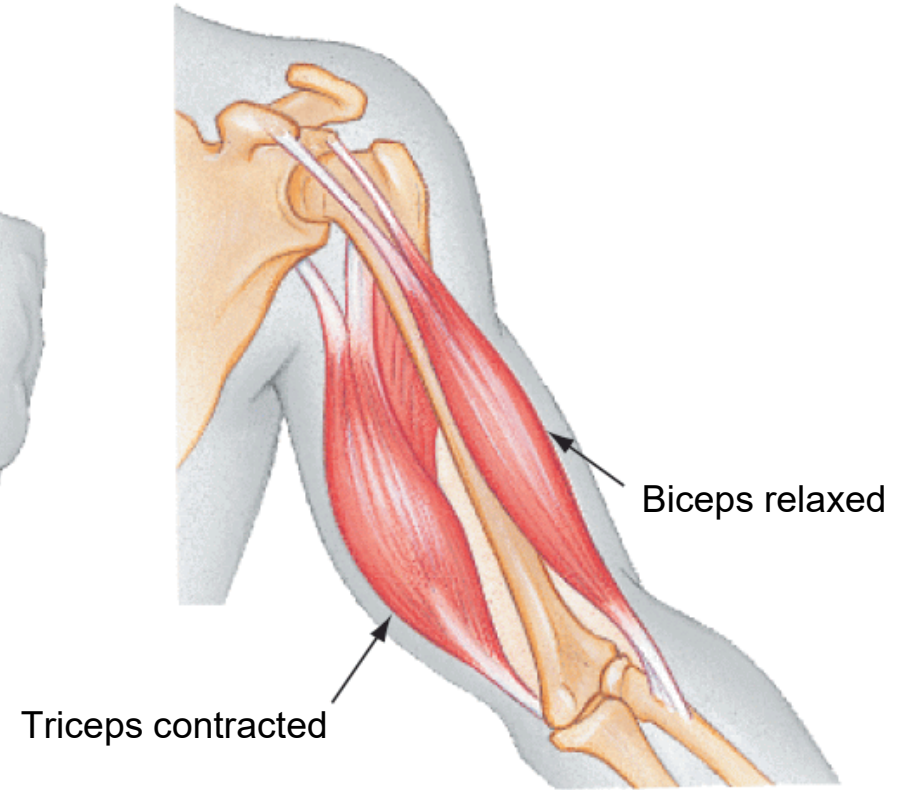
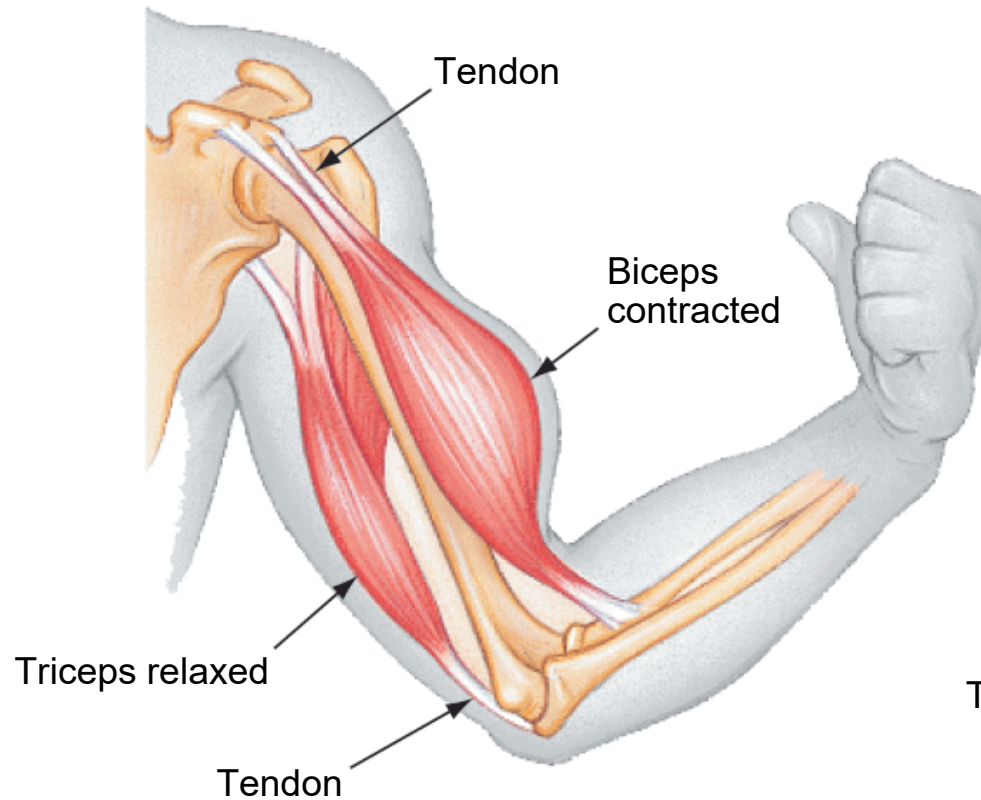
High frequency = high pitch



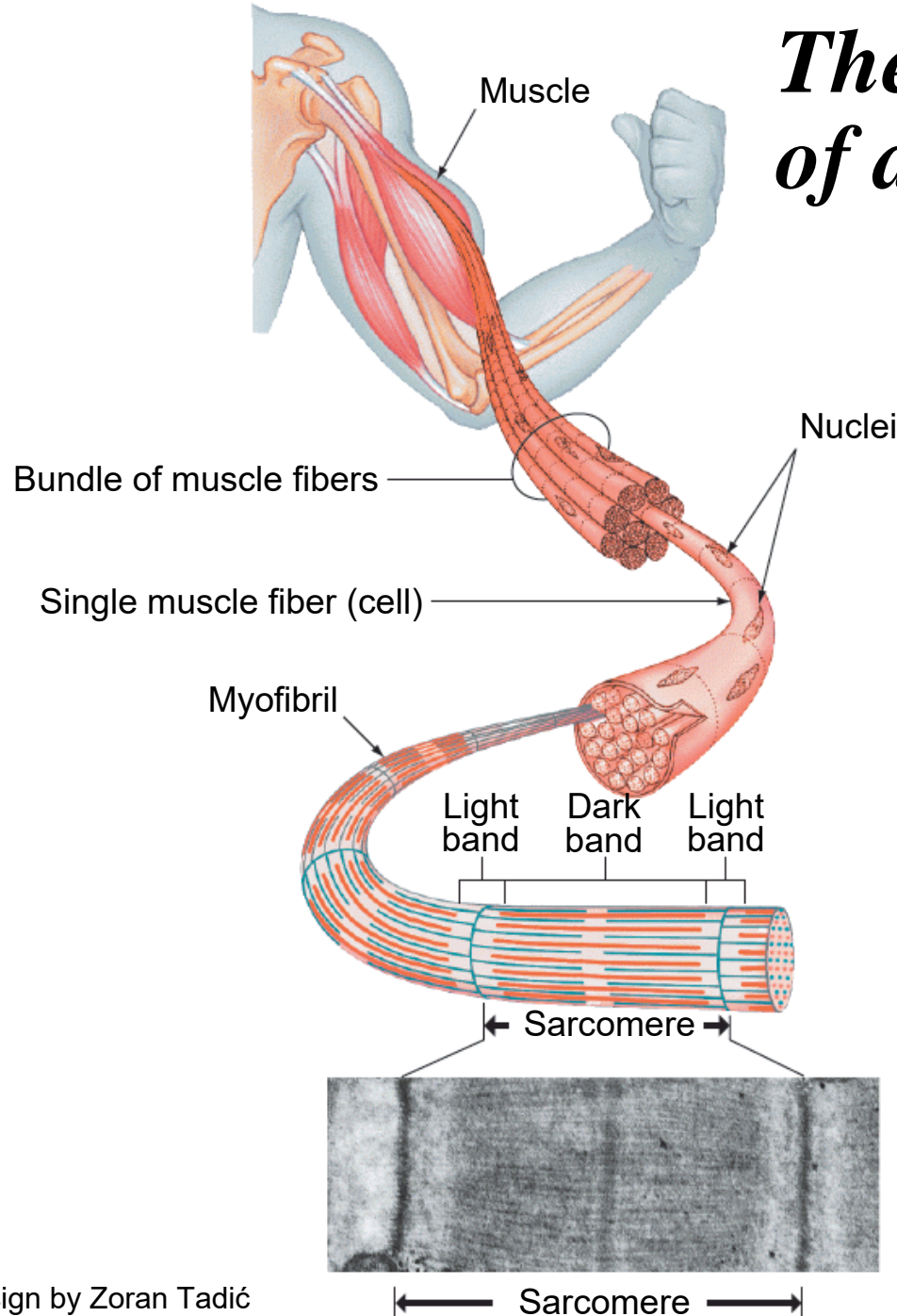
High-frequency sounds cause hair cells at the entrance of the inner ear to vibrate. Action potentials generated in this region of the ear are perceived as high sounds.

The muscular system

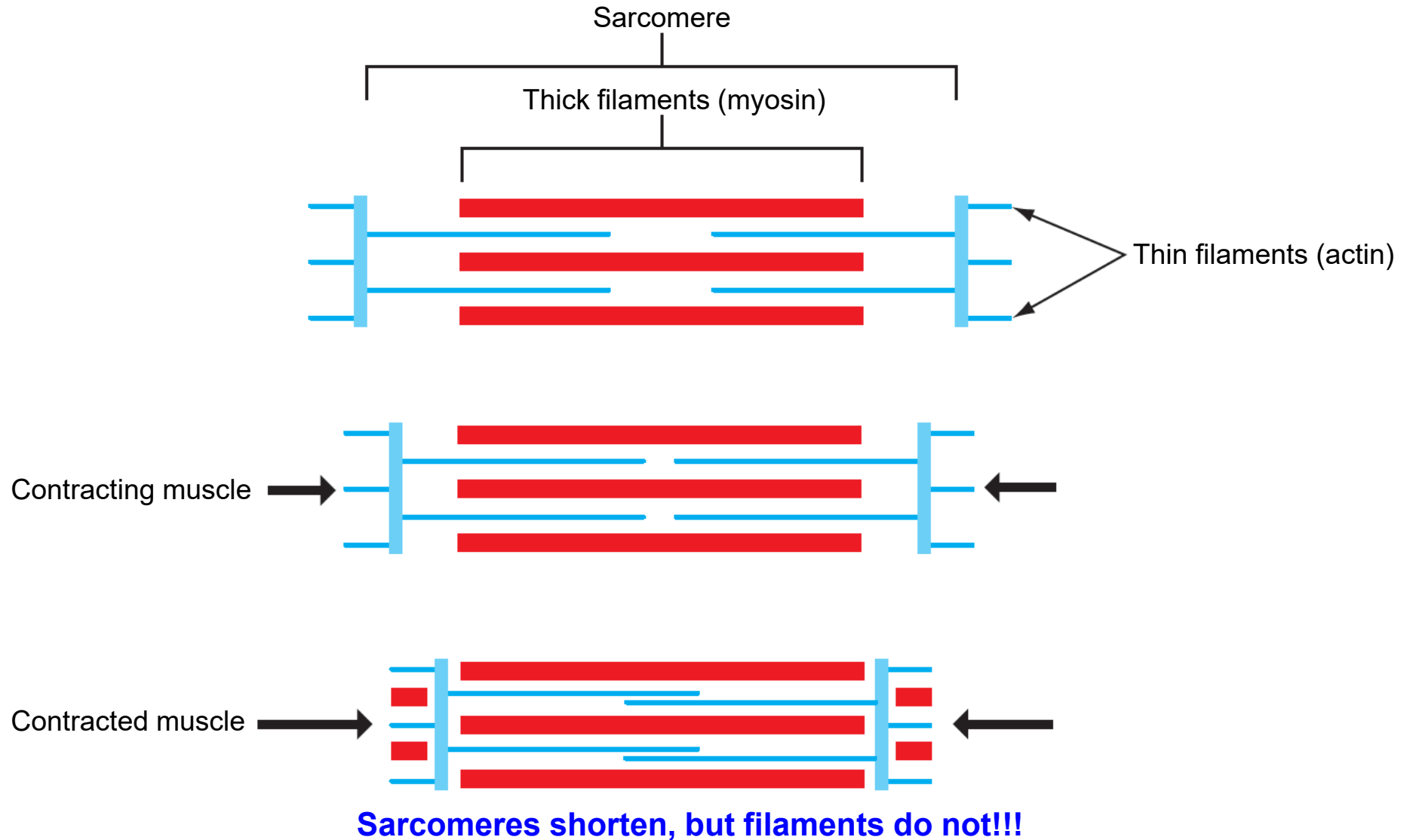
Skeletal muscles are arranged in antagonistic pairs



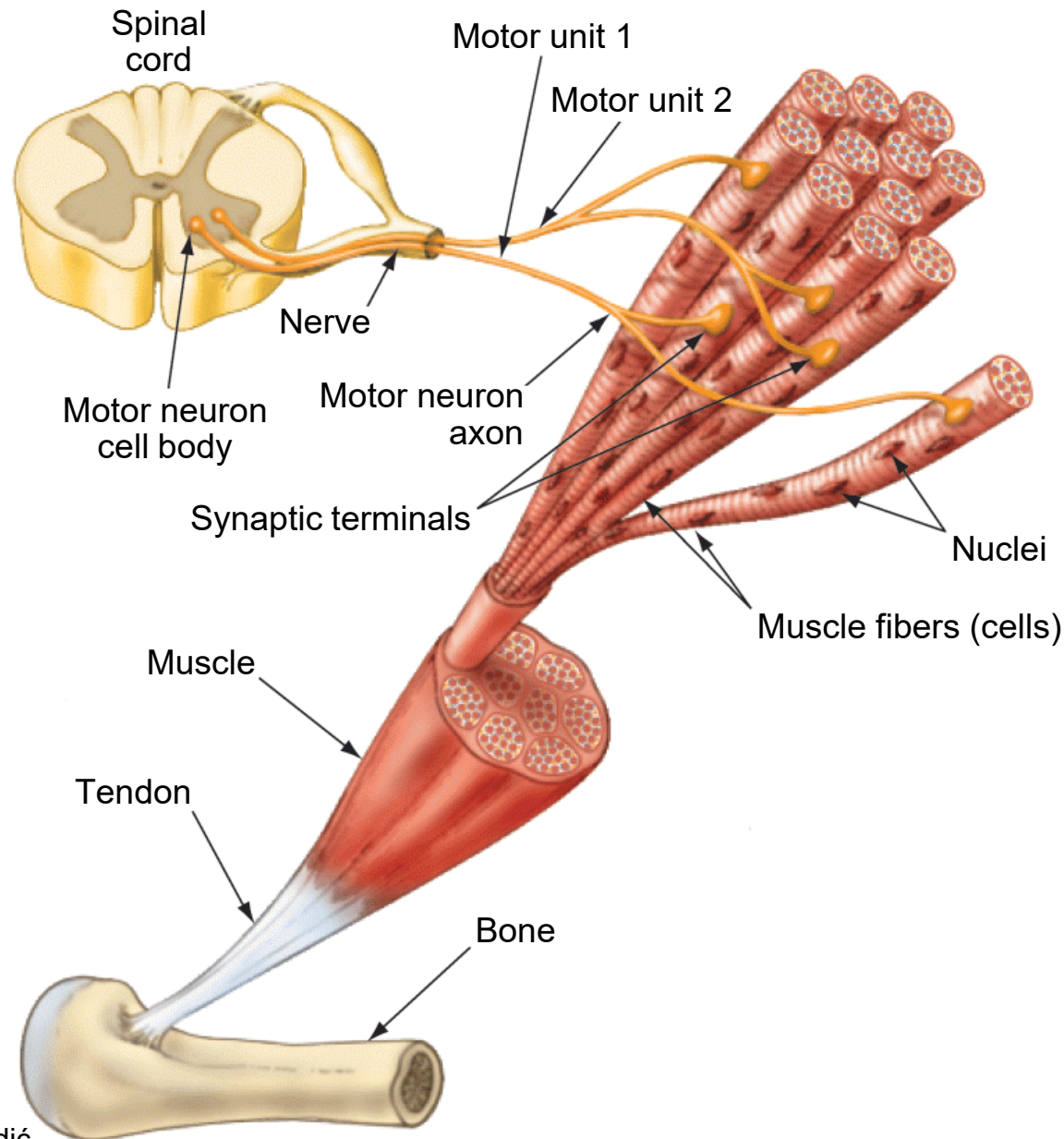
The contraction system of a skeletal muscle



The sliding filaments: actin and myosin



The relationship between motor nerves and muscles



The endocrine system

The human endocrine system

Hypothalamus:

Multiple hormones from the hypothalamus directly control the pituitary gland

Pituitary gland:

Anterior pituitary

Releases numerous hormones that affect the activity of other endocrine glands and cells of the body; examples include:

- **Human growth hormone (HGH):** Stimulates growth and metabolic functions
- **Thyroid stimulating hormone (TSH):** Stimulates the thyroid to produce thyroid hormone
- **Adrenocorticotropic hormone (ACTH):** Stimulates the adrenal glands to produce stress hormones

Posterior pituitary

- **Oxytocin:** Stimulates contraction of uterus and mammary gland cells
- **Antidiuretic hormone (ADH):** Promotes retention of water by kidneys

Testes (in males):

Androgens: Support sperm formation; promote development and maintenance of male secondary sex characteristics

Thyroid gland:

Thyroid hormone: Stimulates and maintains metabolic processes

Adrenal glands:

Adrenal medulla

Epinephrine and norepinephrine: Raise blood glucose level; increase metabolic activities; constrict certain blood vessels

Adrenal cortex

Numerous hormones, including **Cortisol:** Promotes glucose synthesis

Pancreas:

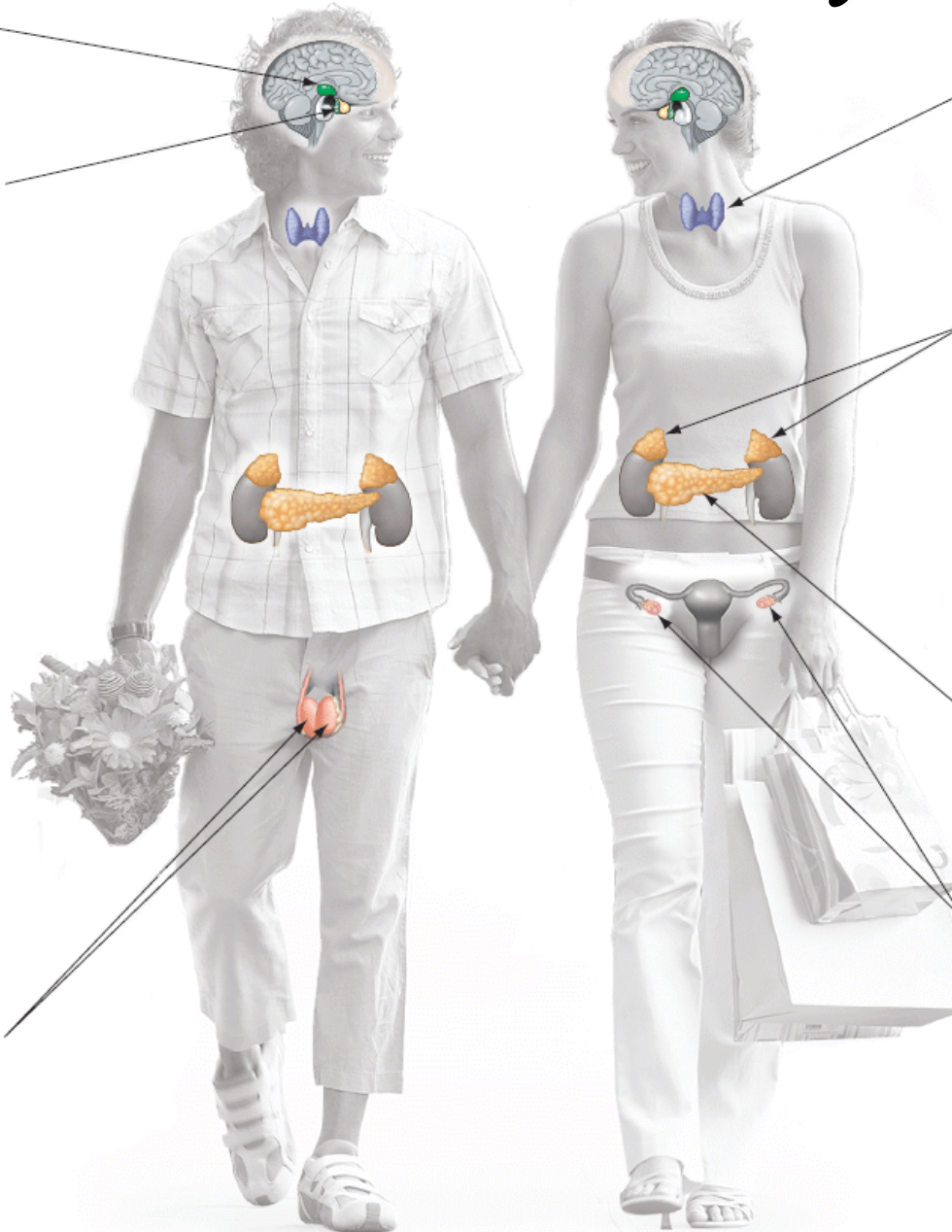
Insulin: Lowers blood glucose level

Glucagon: Raises blood glucose level

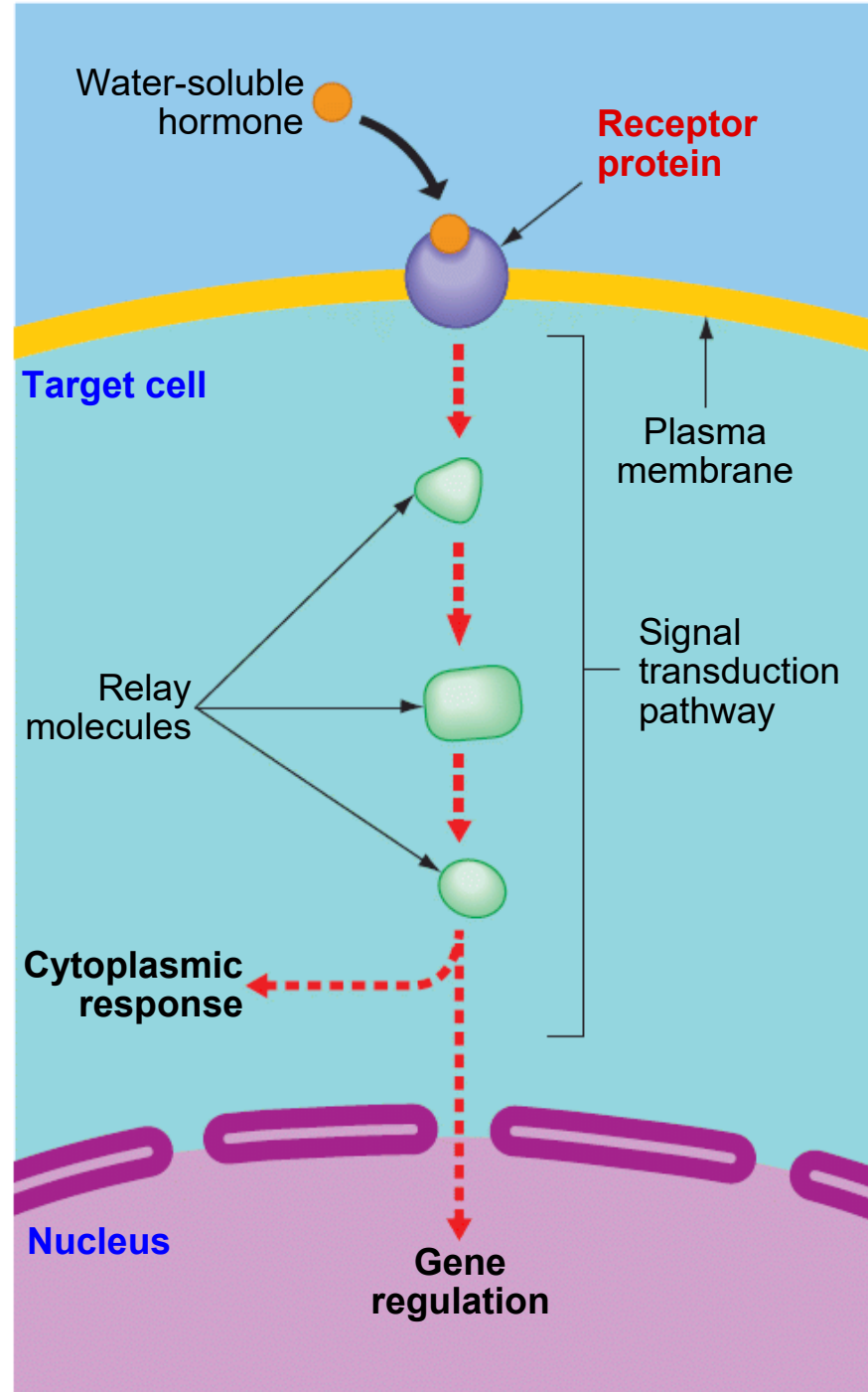
Ovaries (in females):

Estrogens: Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics

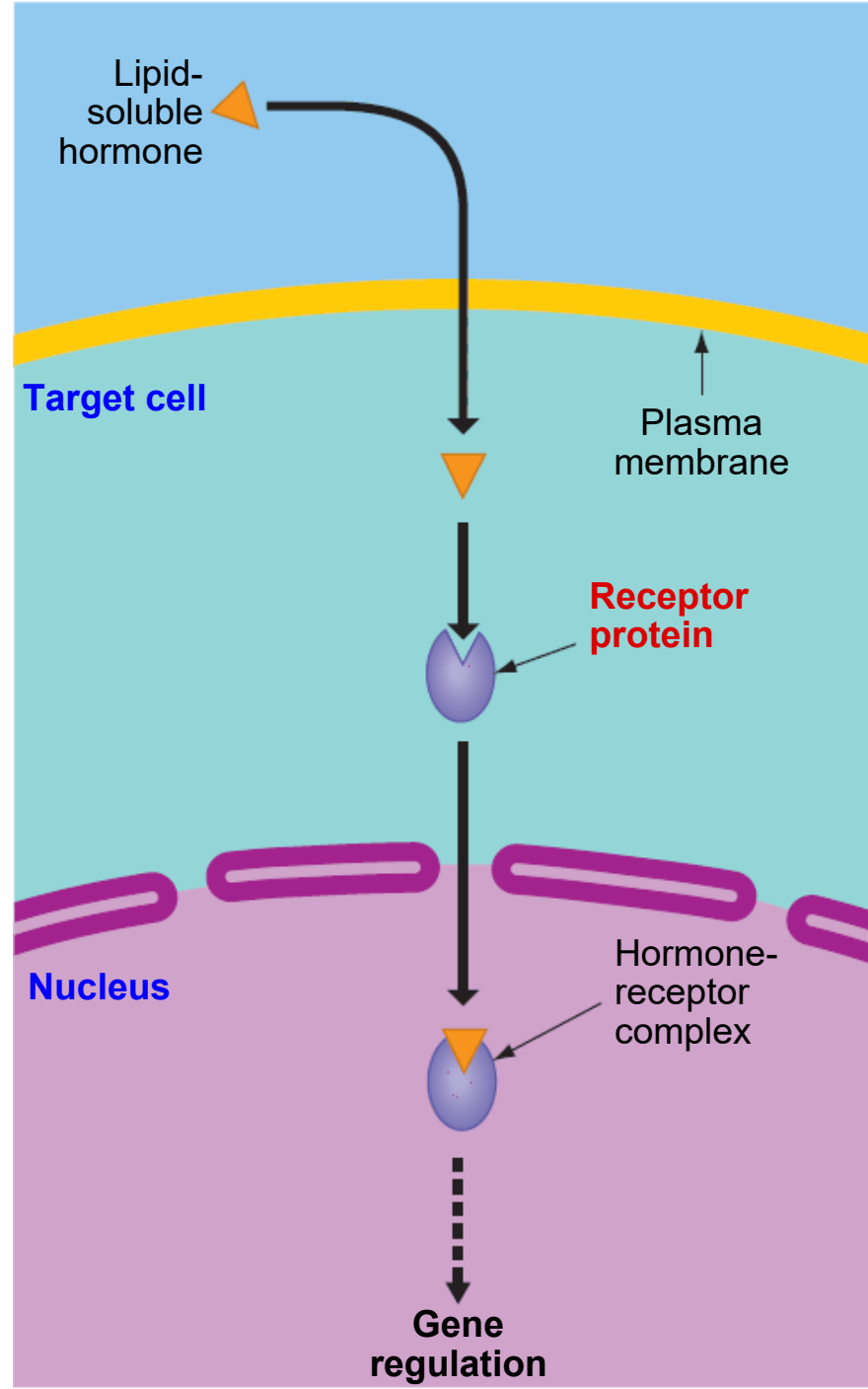
Progesterone: Promotes uterine lining growth



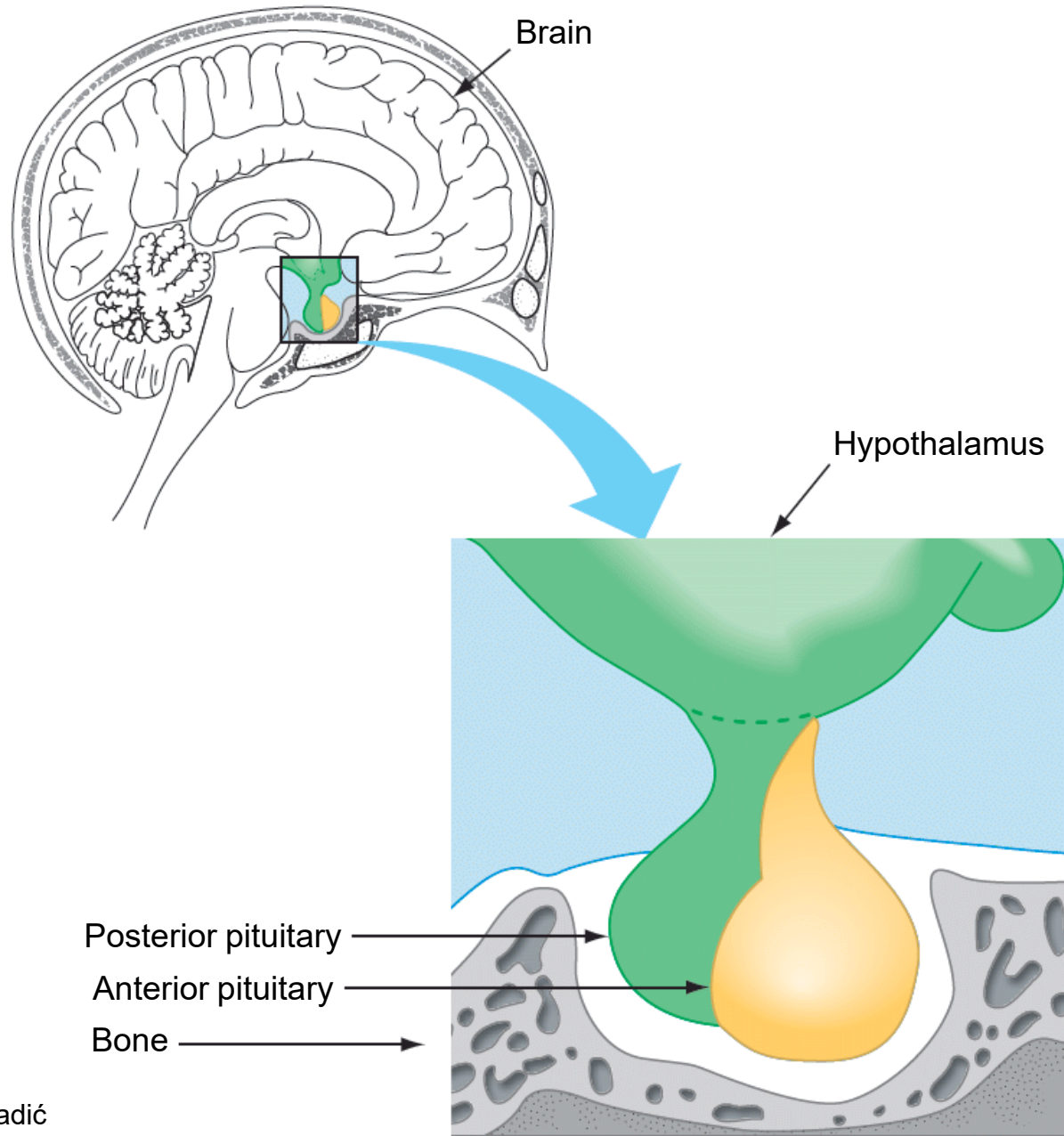
Mechanism of action of water-soluble hormones



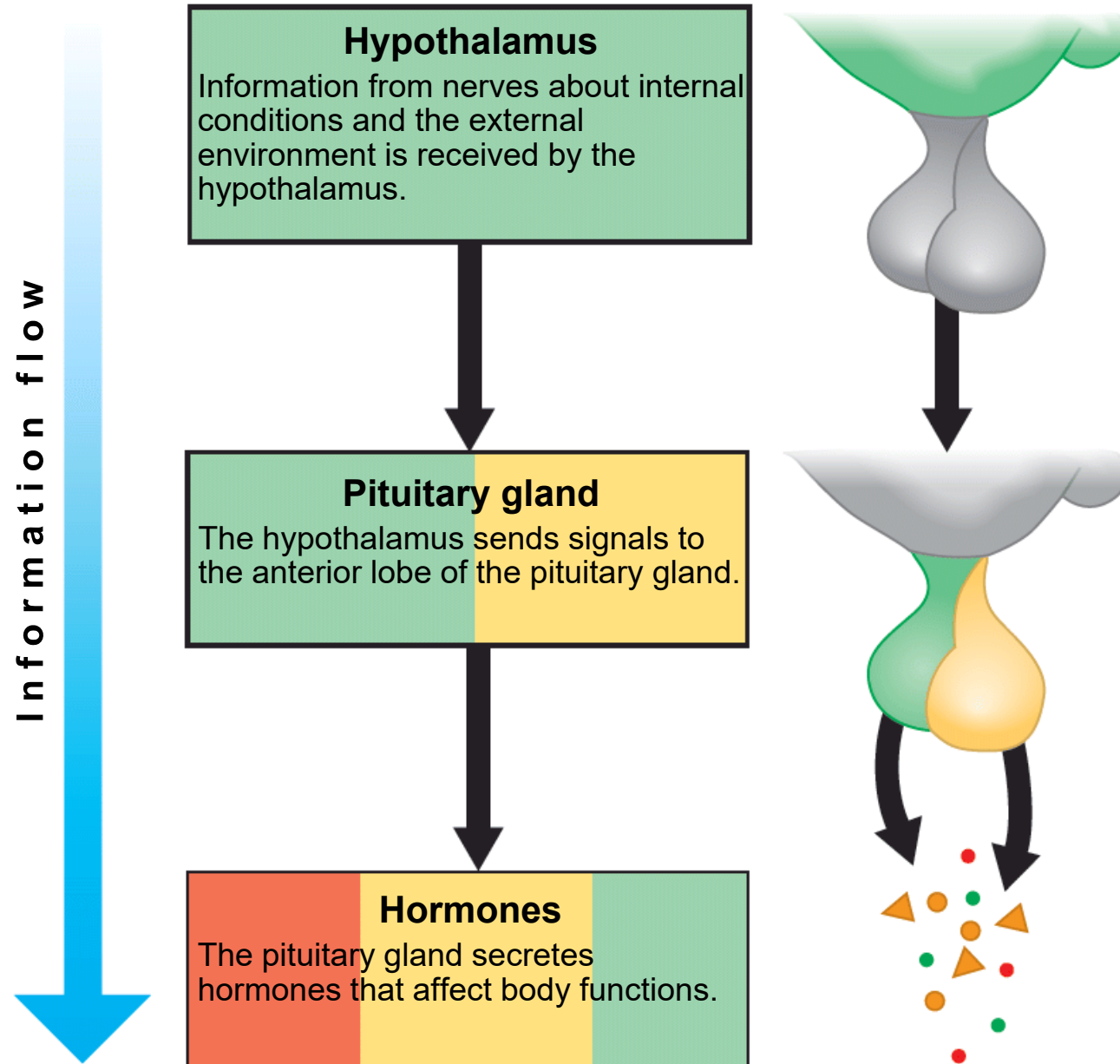
Mechanism of action of lipid-soluble hormones



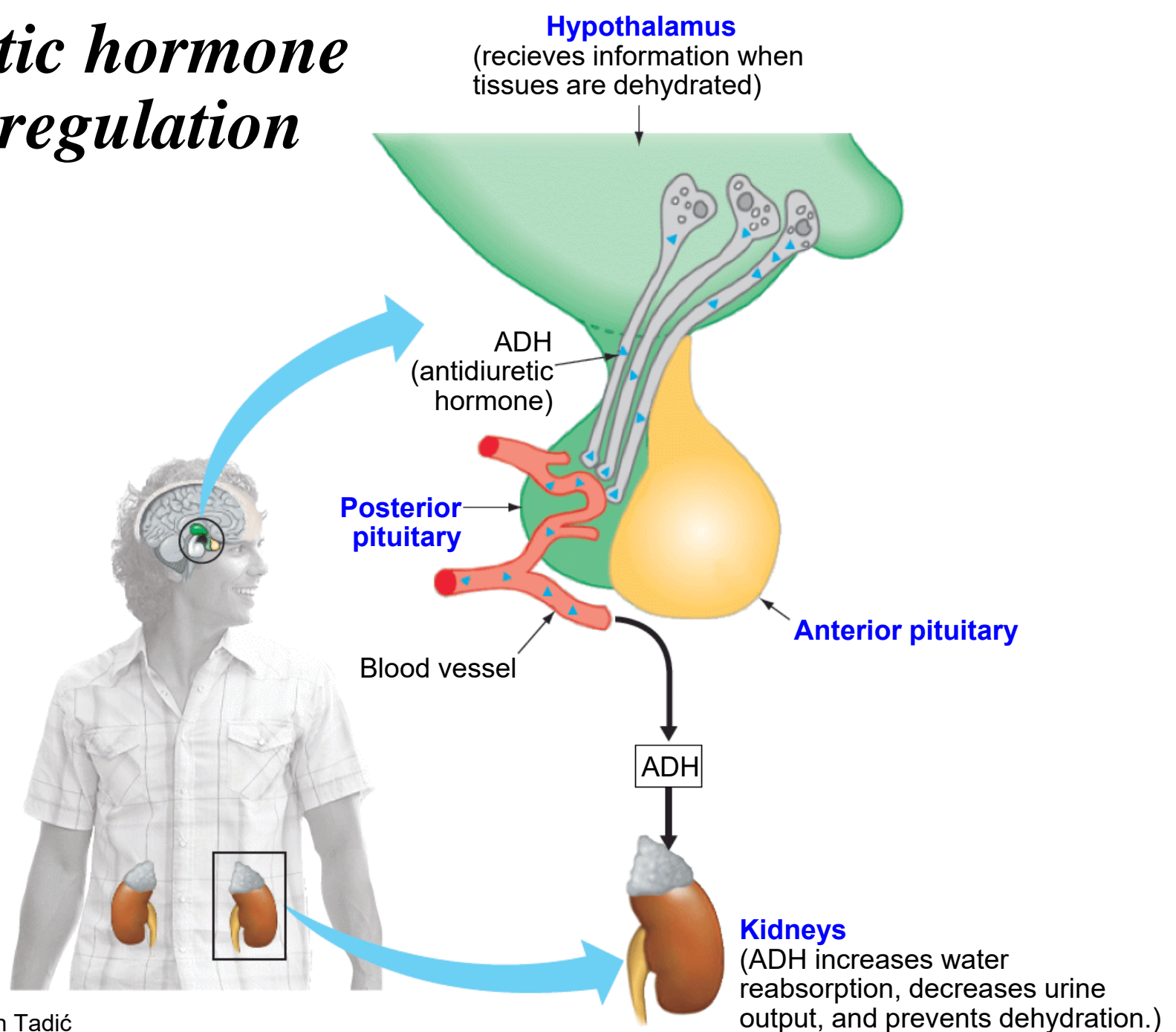
The master axis: Hypothalamus and pituitary gland



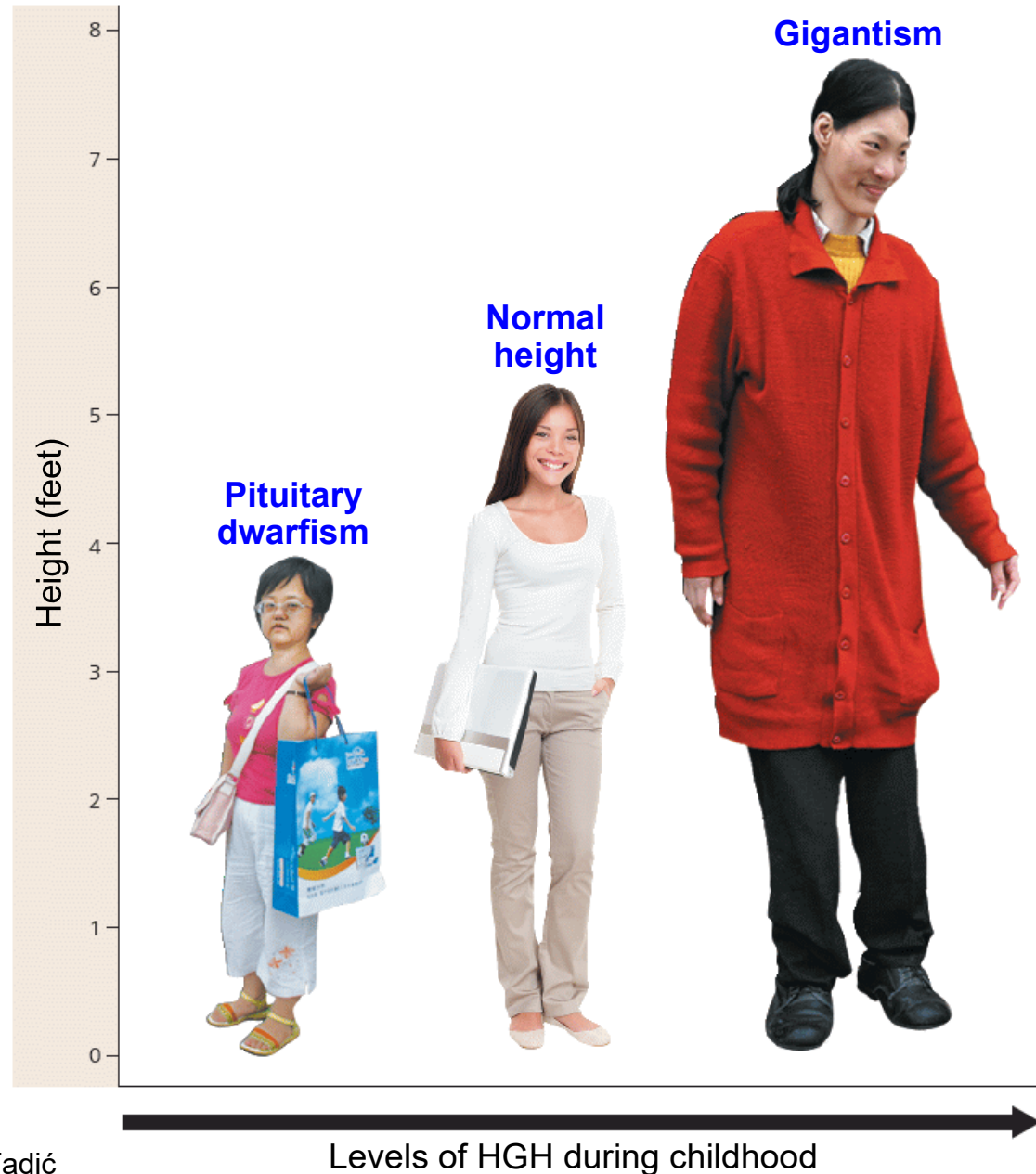
How does hypothalamus control pituitary gland?



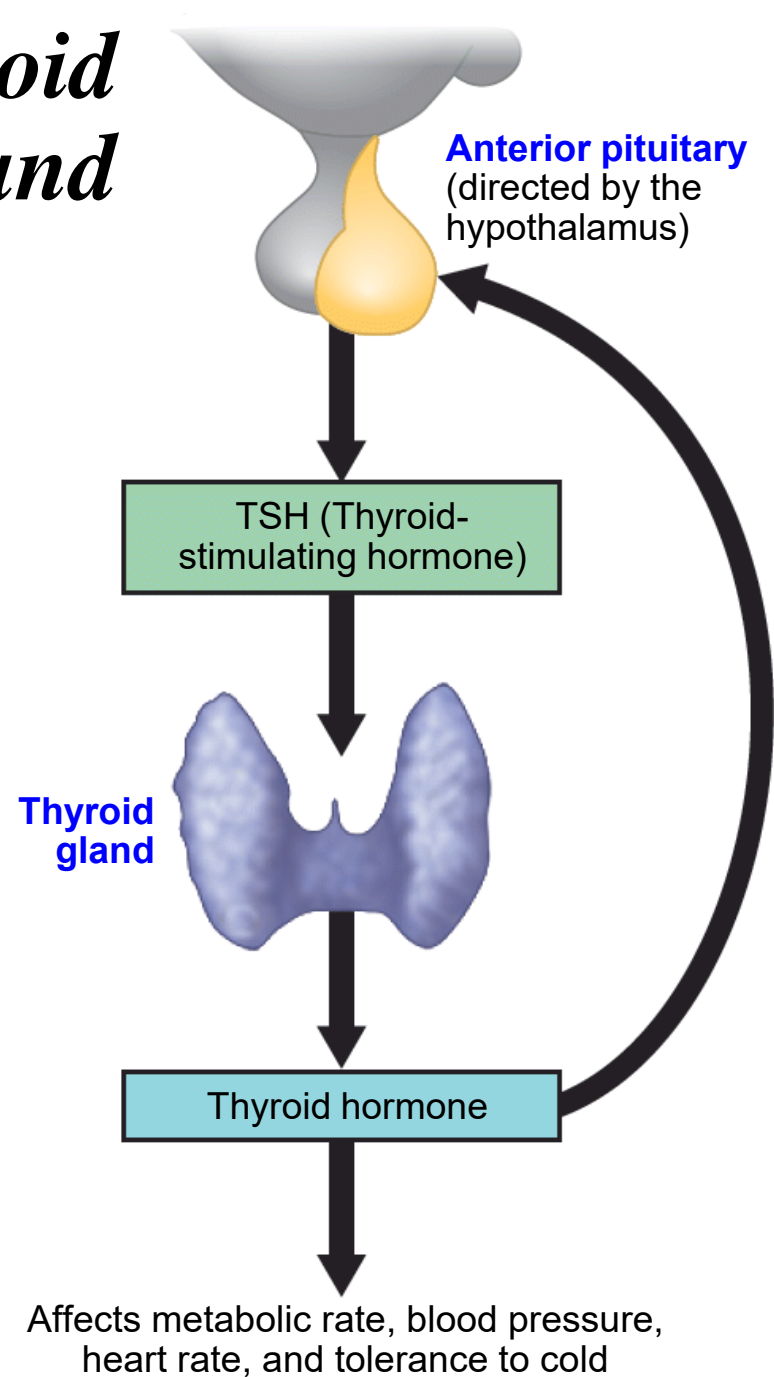
Antidiuretic hormone and osmoregulation



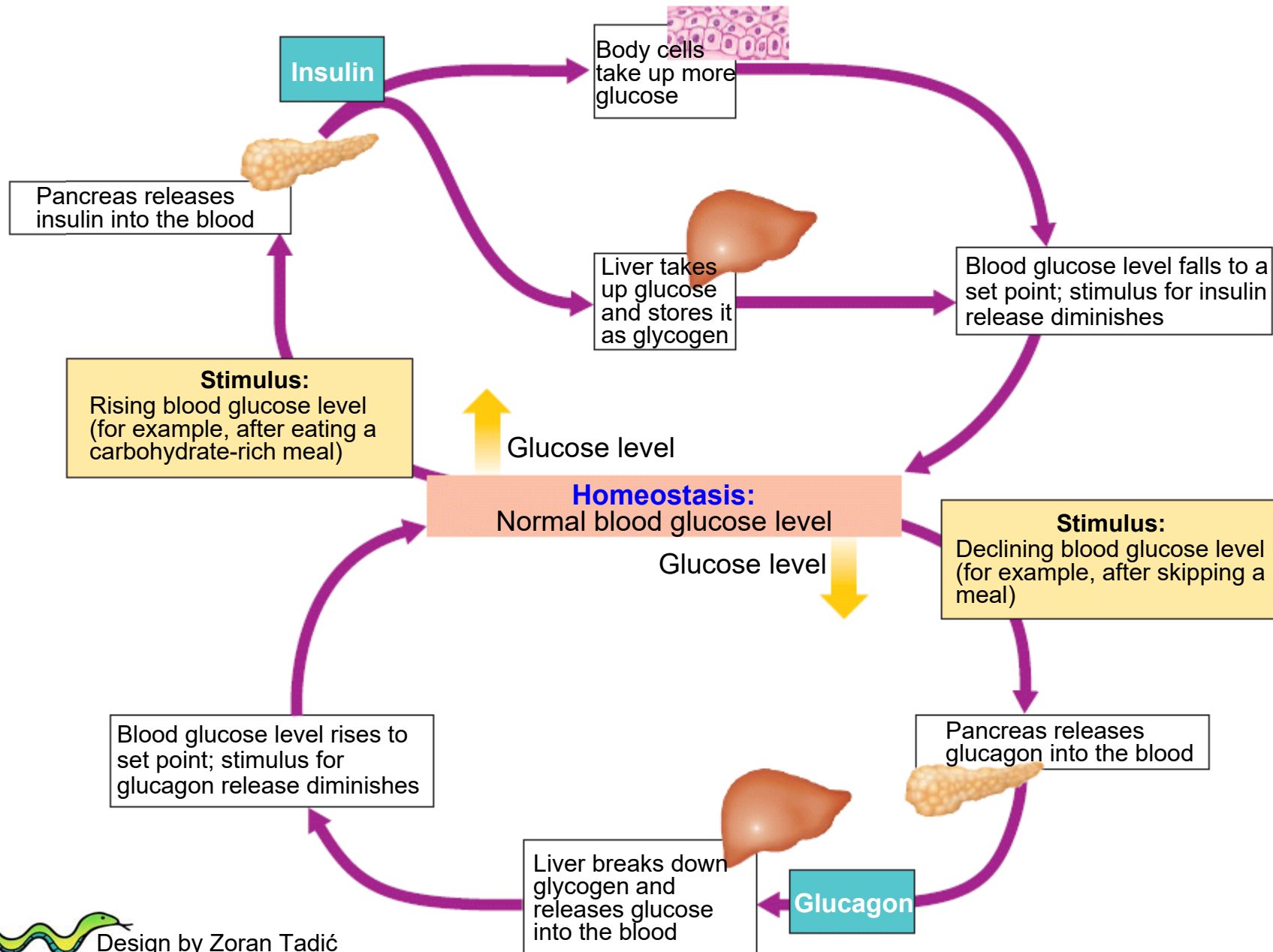
Growth hormone (HGH) secretion during childhood



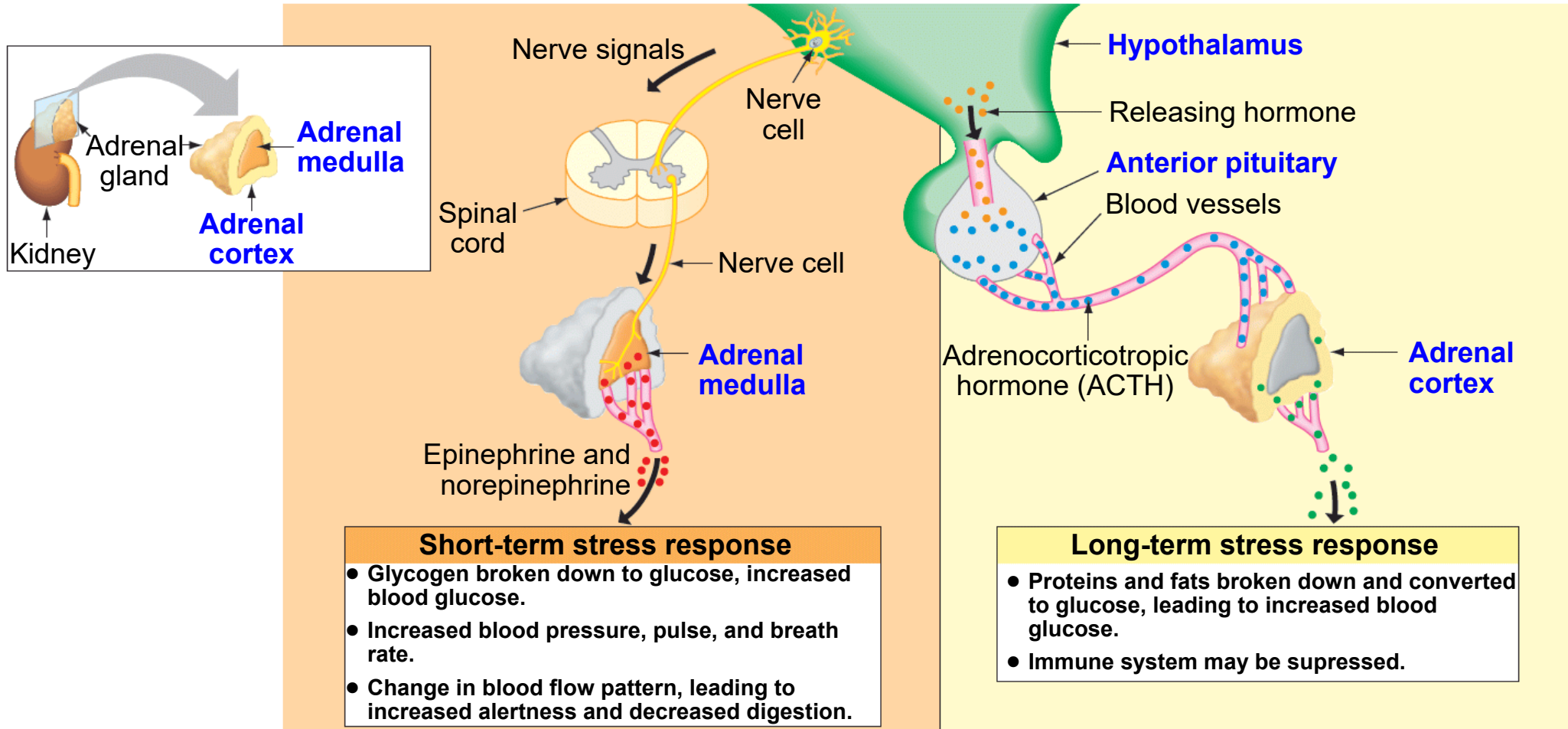
Function of the thyroid gland



Regulation of glucose in the blood



How does adrenal gland regulate stress response?



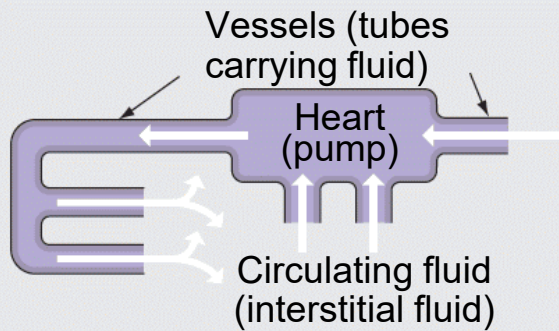
The circulatory system

The diversity of the circulatory systems

CIRCULATORY SYSTEM DIVERSITY

Open circulatory system

Circulating fluid is pumped through open-ended tubes, allowing interstitial fluid to flow out among cells.



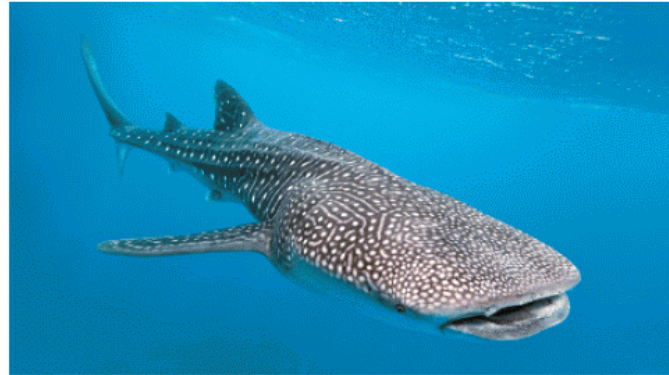
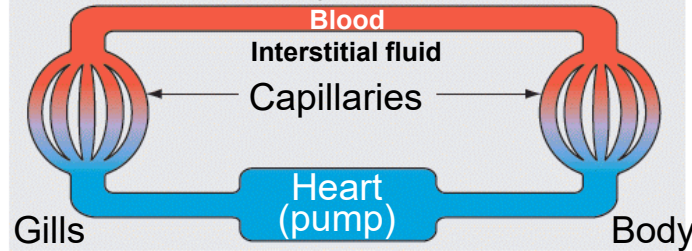
Molluscs, arthropods

Closed circulatory system

Circulating fluid is pumped within a closed set of tubes, keeping blood distinct from the interstitial fluid surrounding cells

Single circulation system

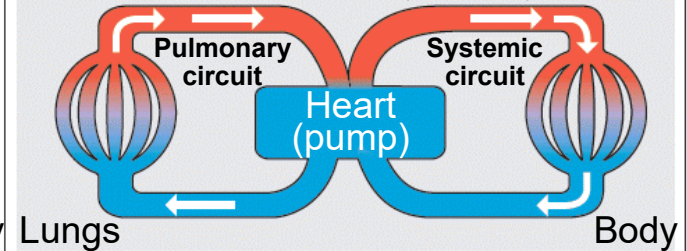
Blood flows through the heart in a single circuit.



Bony fishes, rays, sharks

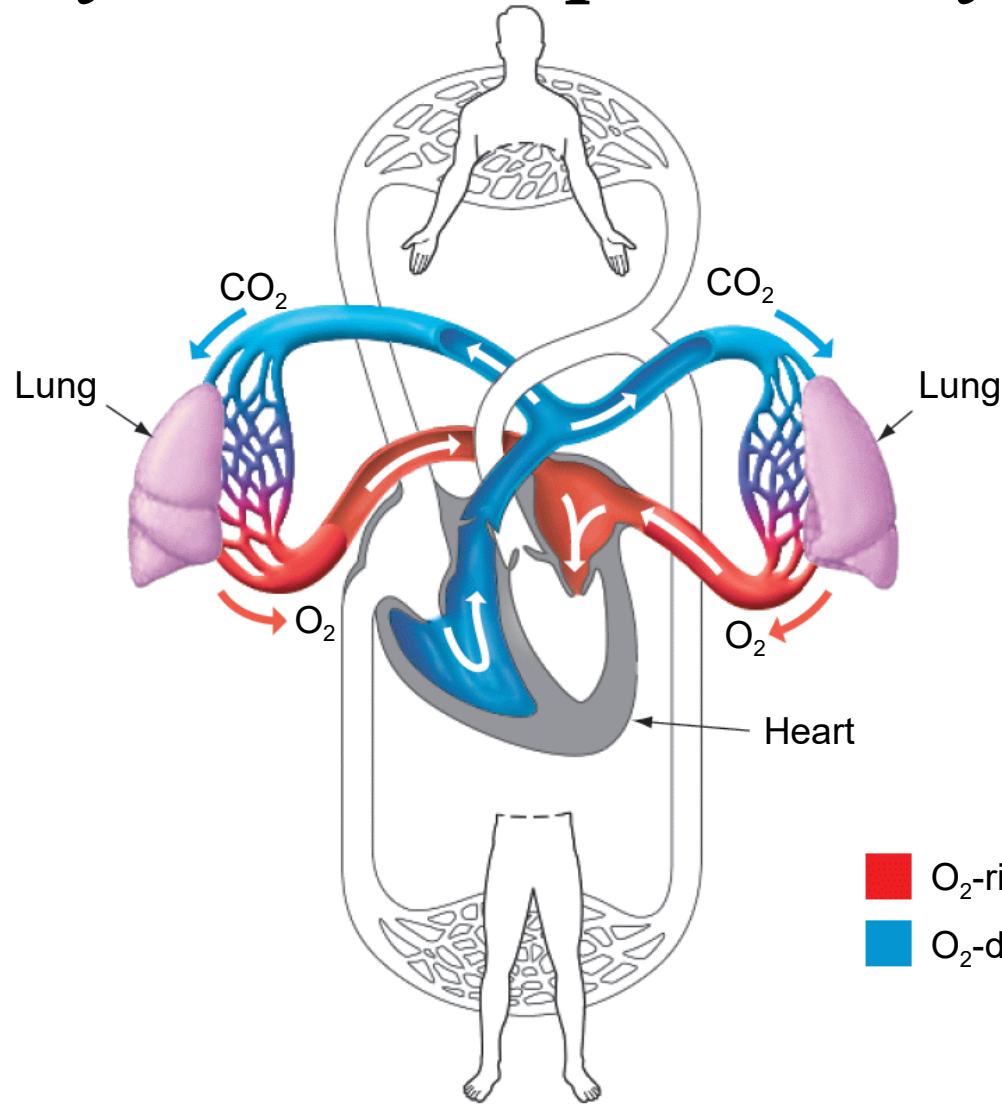
Double circulation system

Blood flows through the heart in two circuits: pulmonary and systemic

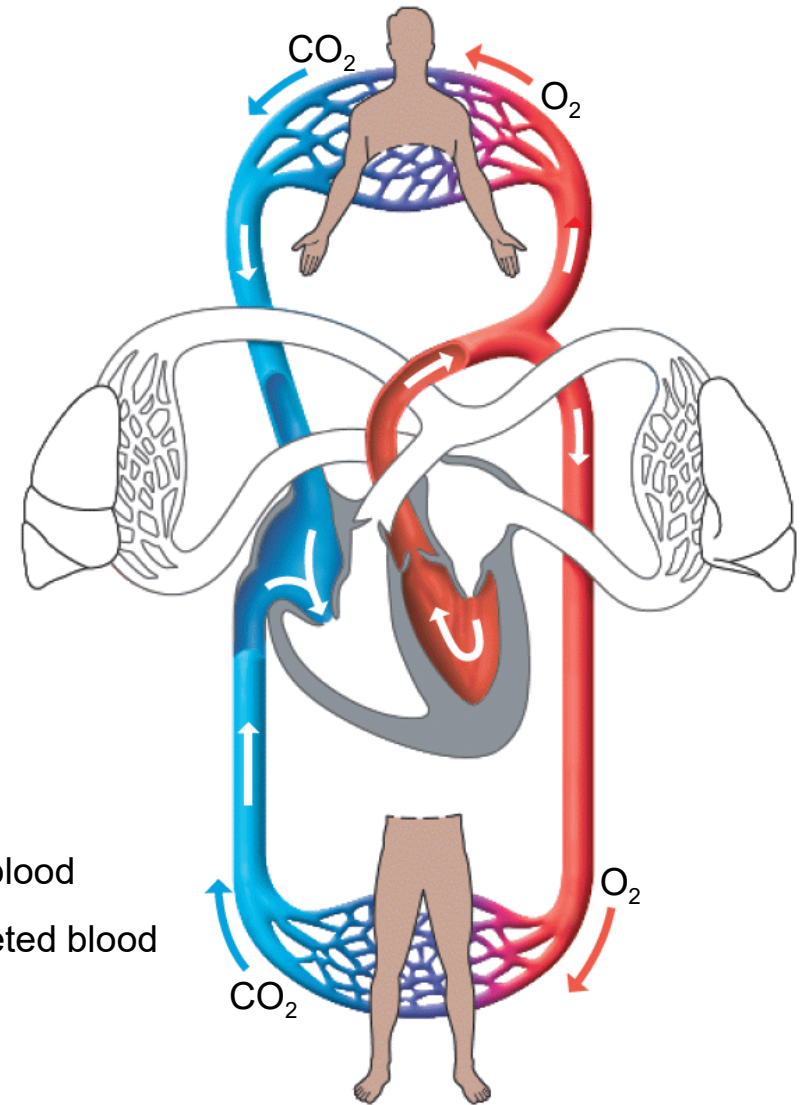


Amphibians, reptiles, birds, mammals

Systemic and pulmonary circuits: different roles



Pulmonary circuit: In organisms with double circulation, the pulmonary circuit transports blood between the heart and lungs.

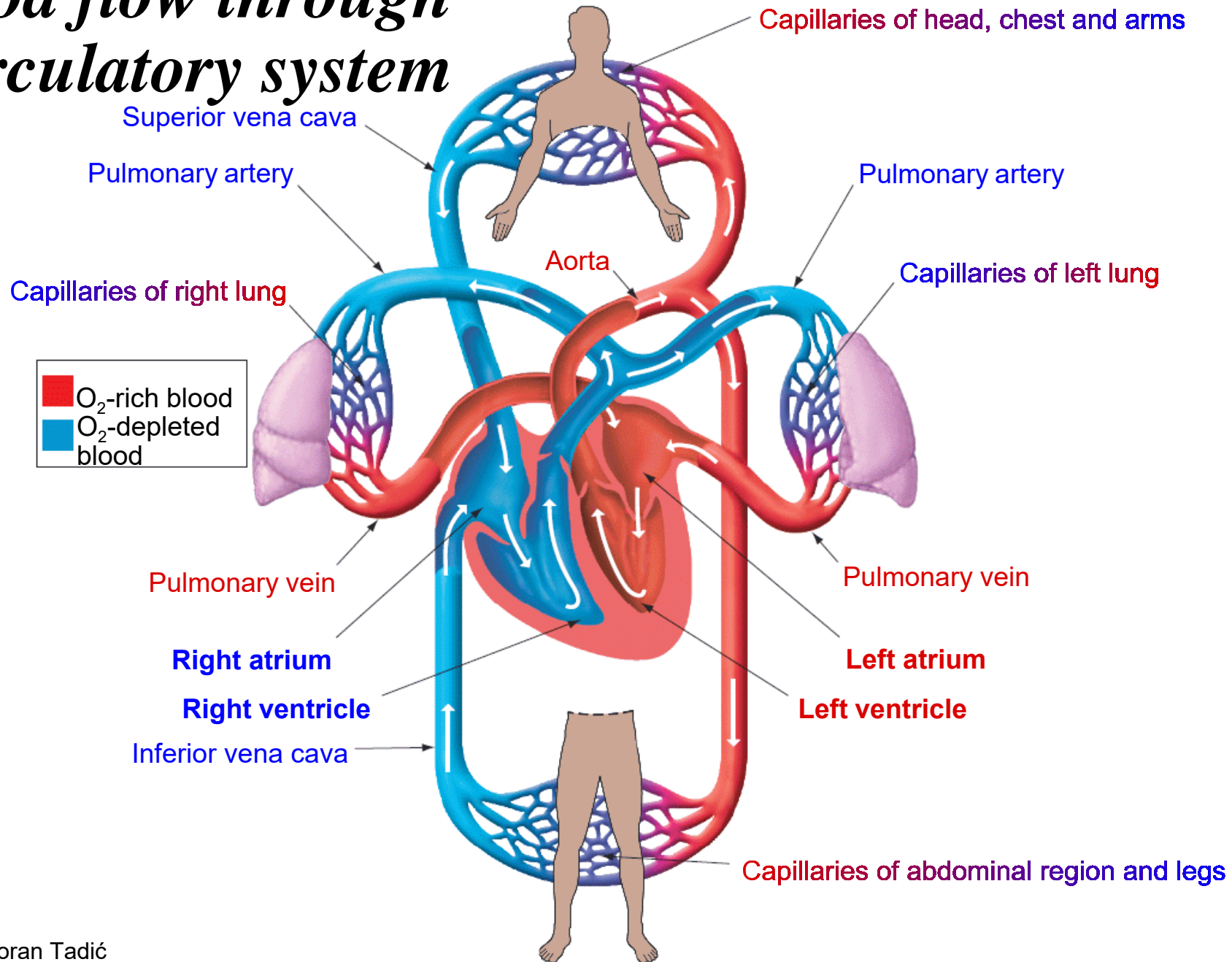


Systemic circuit: The systemic circuit transports blood between the heart and the rest of the body.

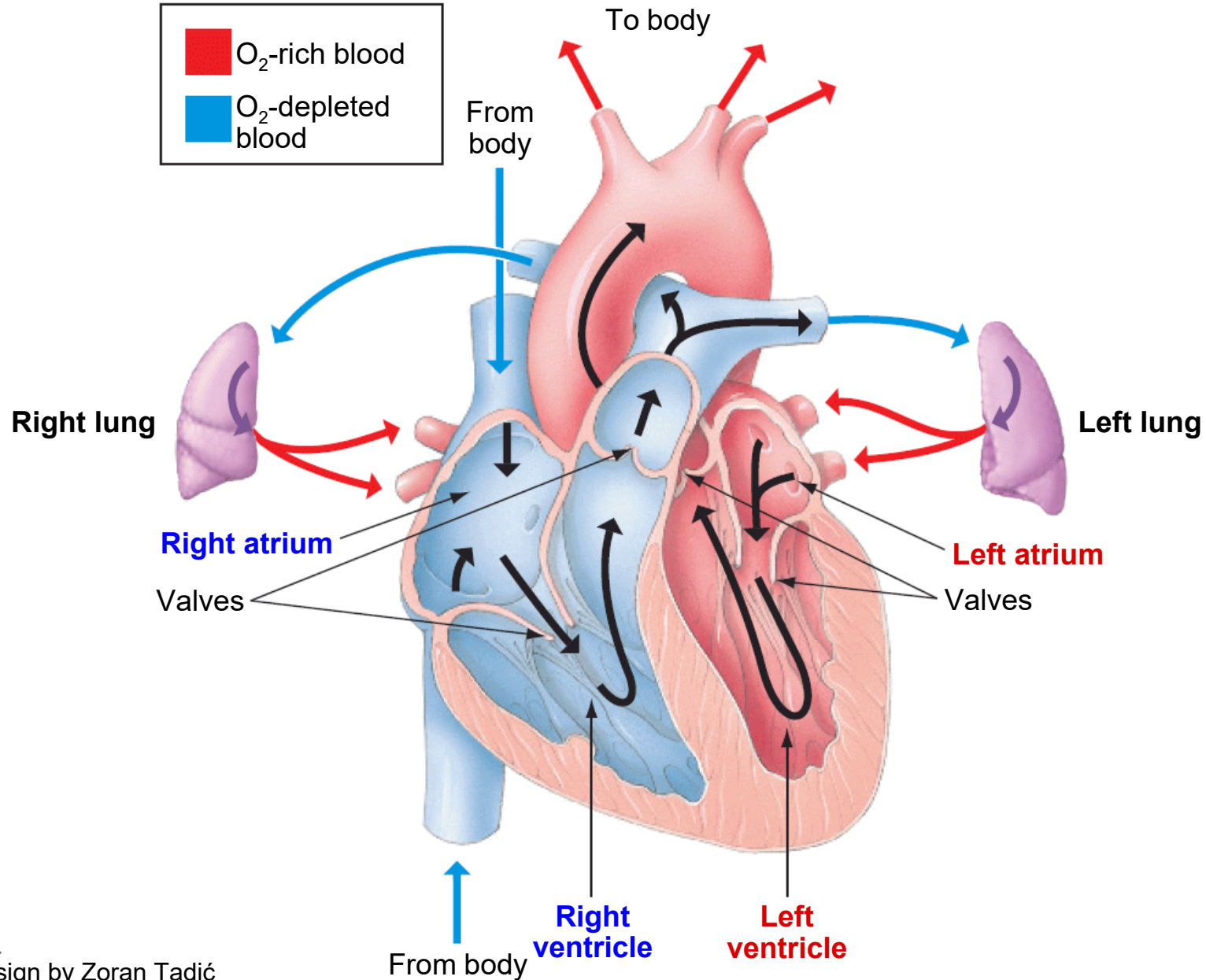
■ O₂-rich blood
■ O₂-depleted blood



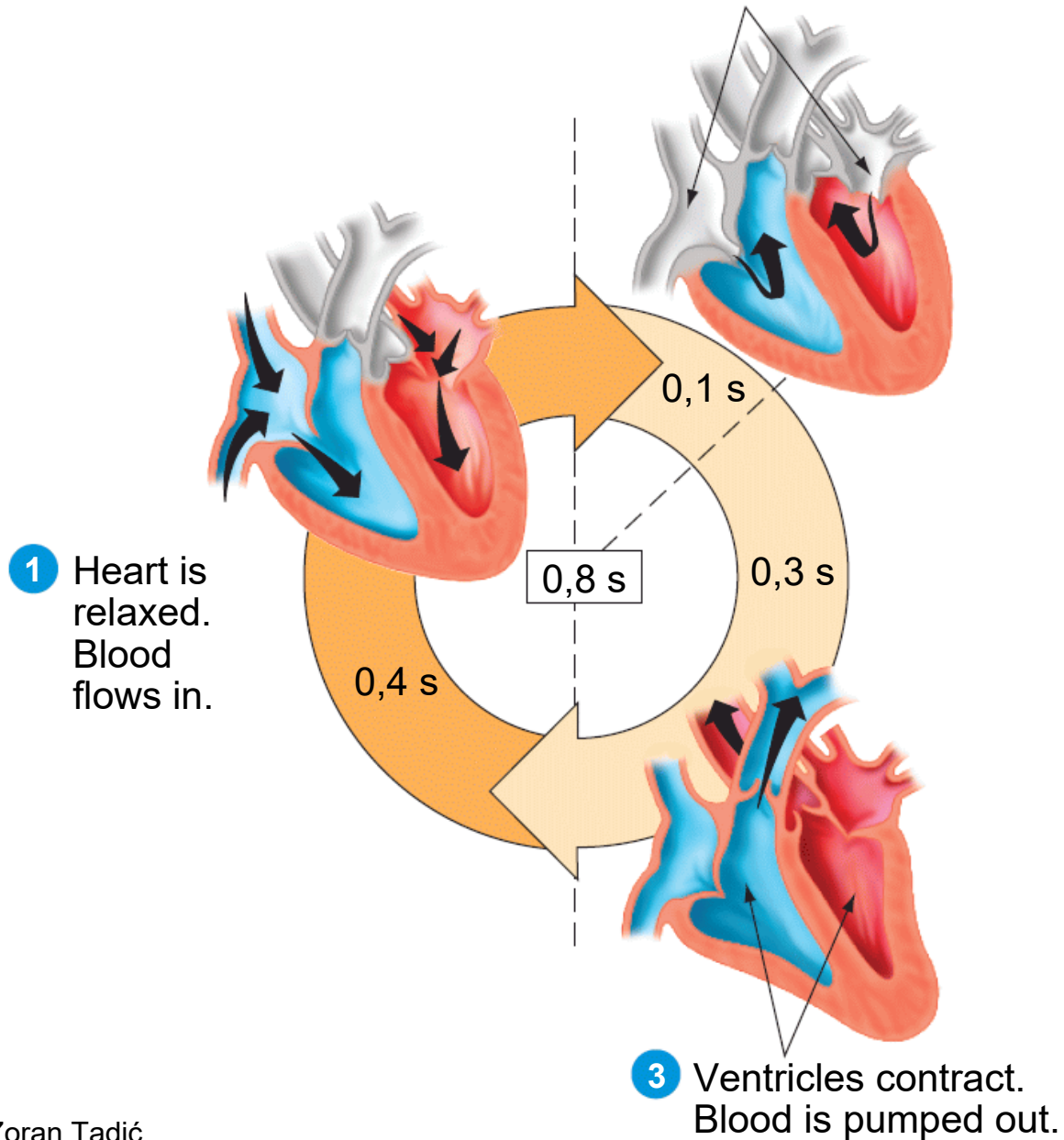
Blood flow through circulatory system



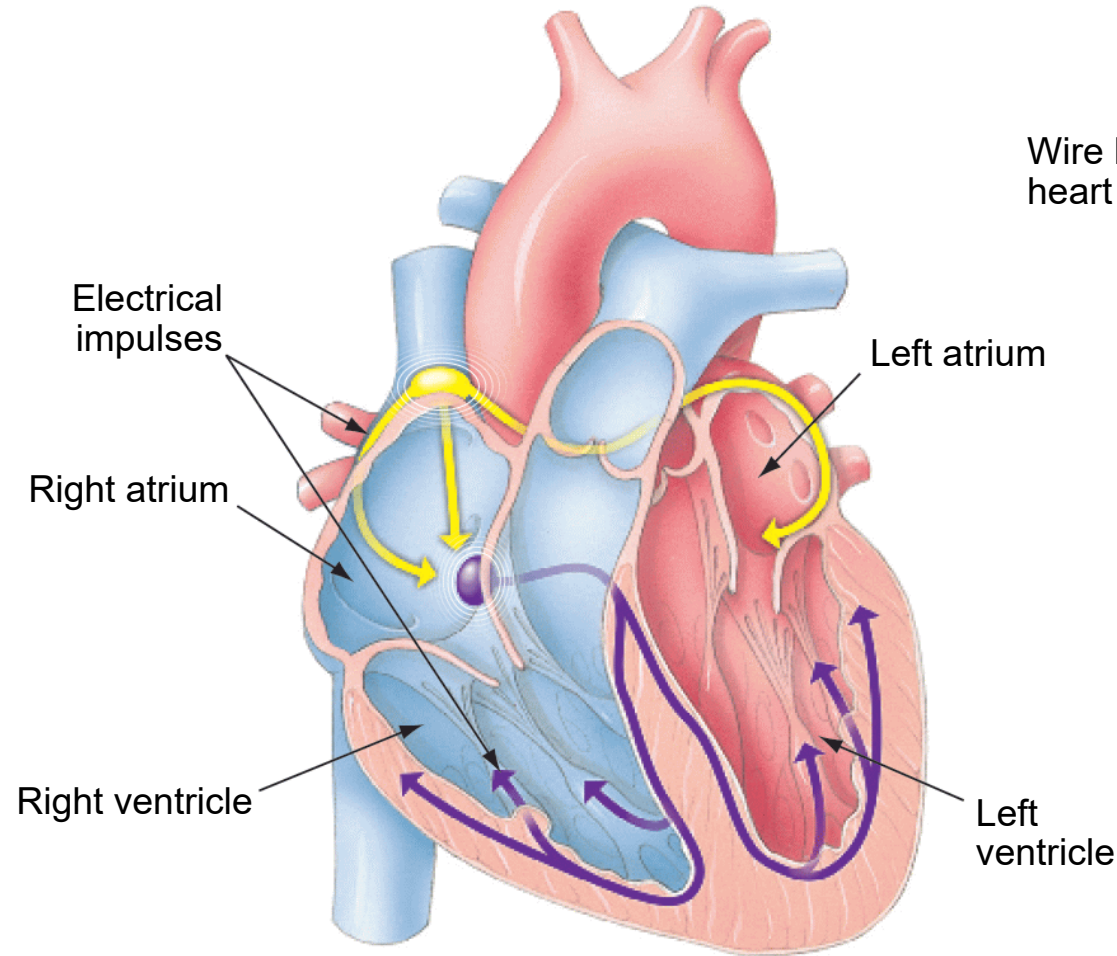
Blood flow through human heart



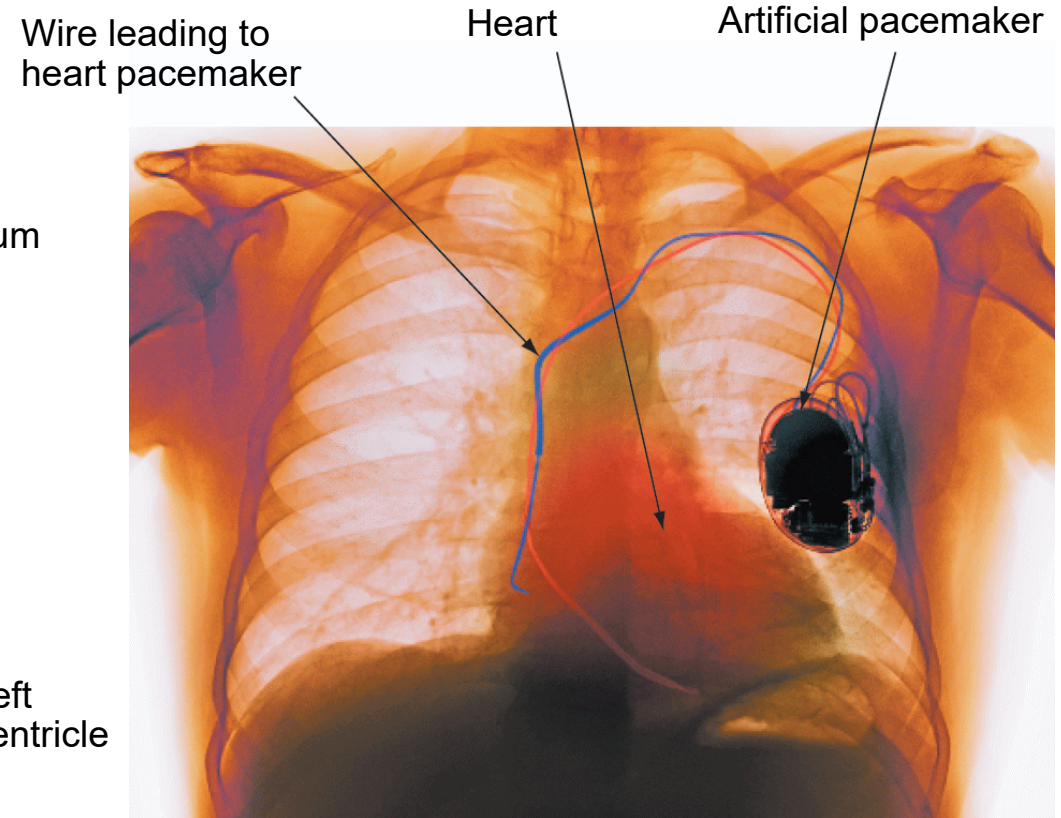
The cardiac cycle



Natural and artificial pacemaker

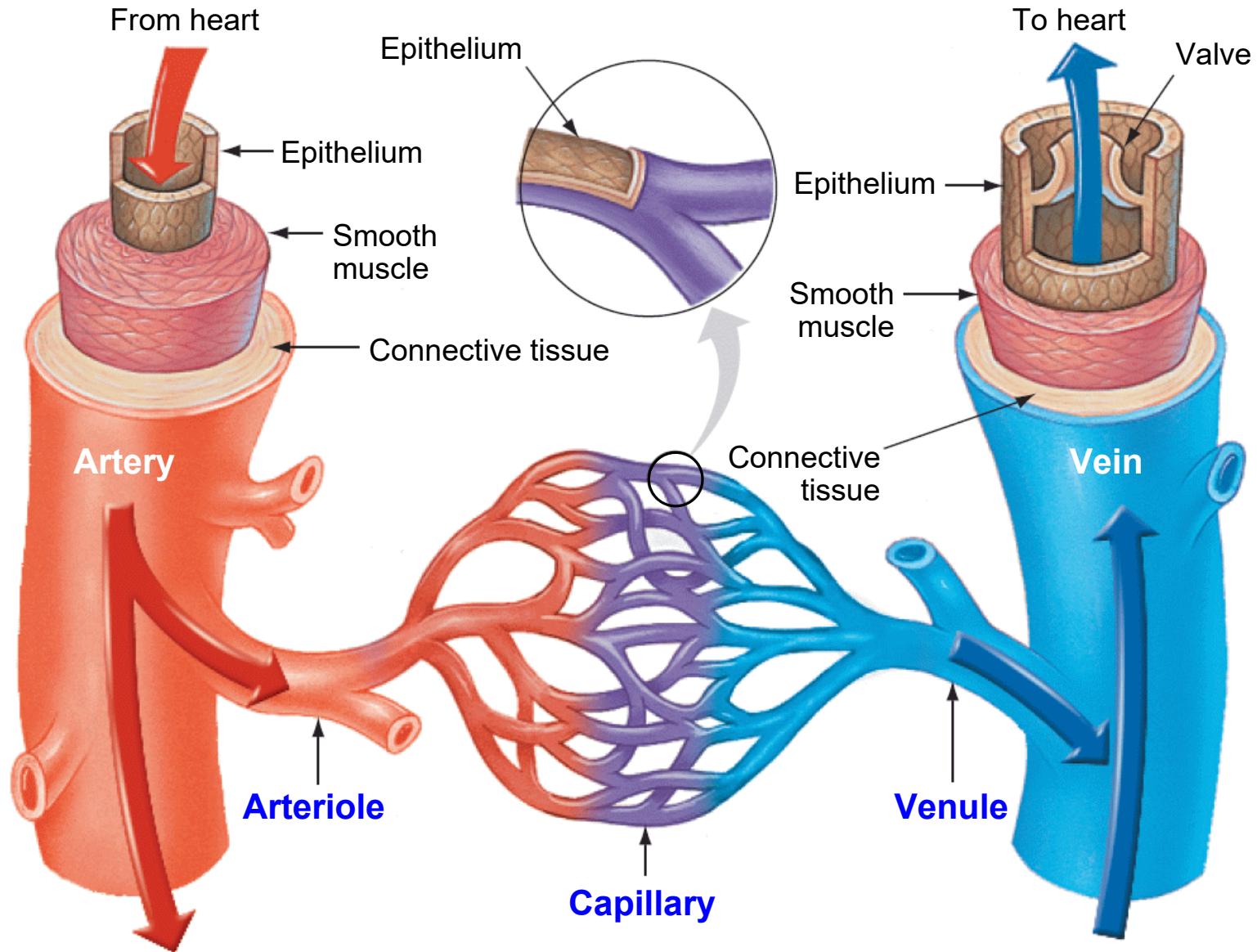


The heart's natural pacemaker. The pacemaker is located in the right atrium. Electrical impulses spread through the heart, first to the atria (shown in yellow arrows), then to the ventricles (purple arrows).

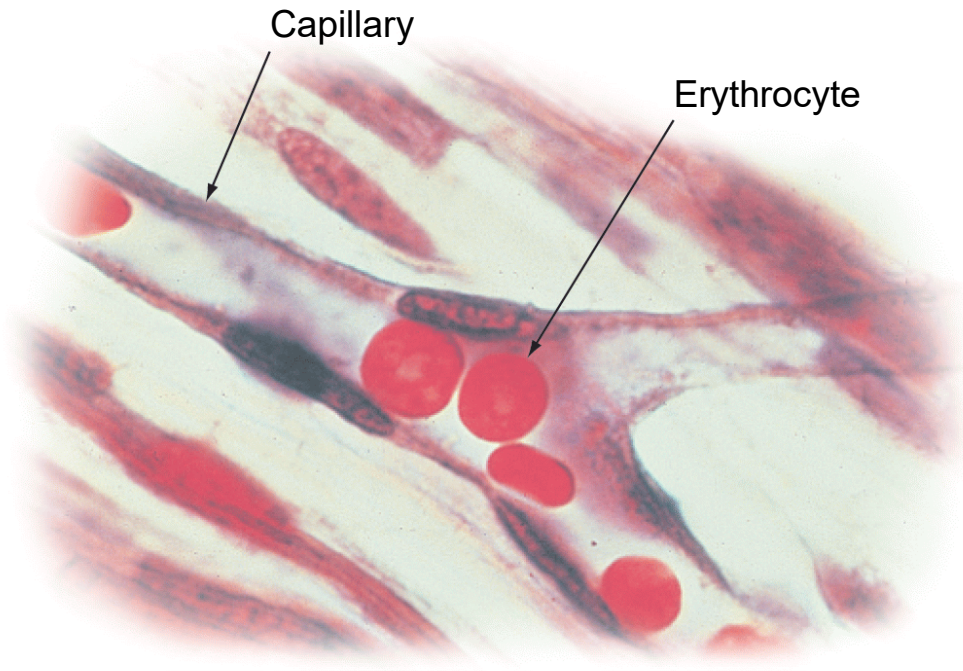


An artificial pacemaker. A small electronic device surgically implanted into chest cavity and connected to the heart's pacemaker by a wire can help maintain proper electrical rhythms in a defective heart.

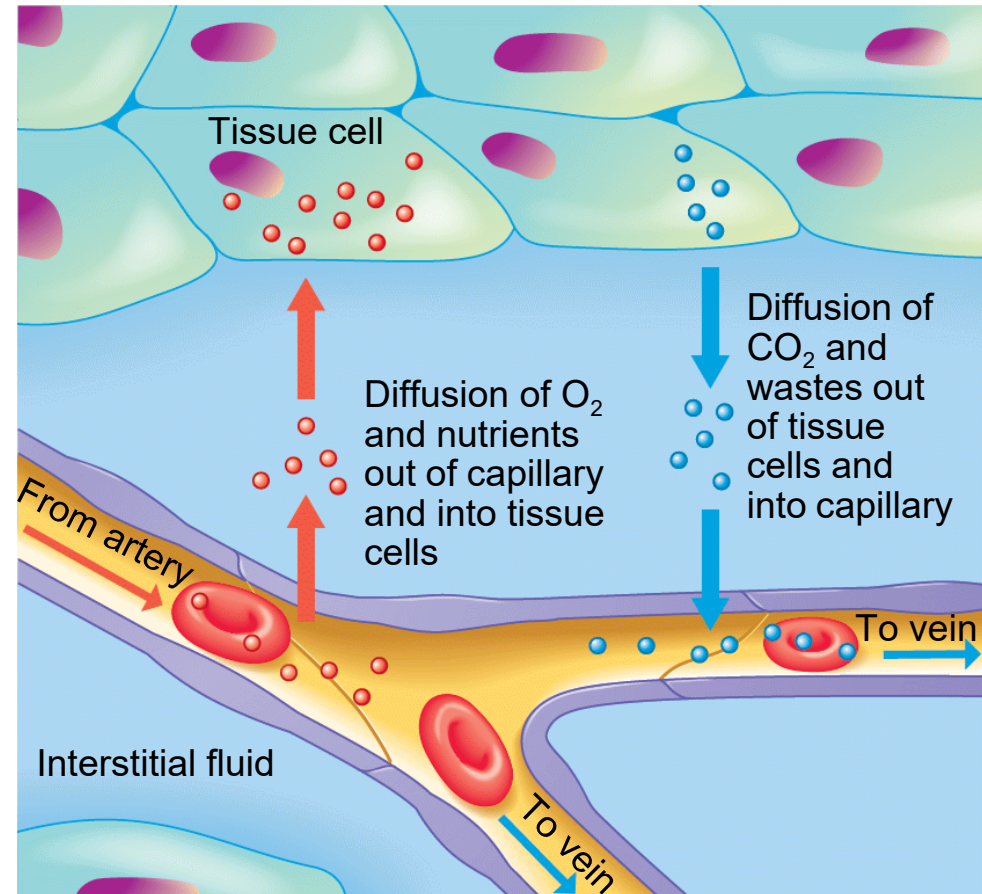
Blood vessels: arteries and veins



Gas, nutrient and waste exchange between tissues and blood



Capillaries. Blood flowing through the circulatory system eventually reaches capillaries, the small vessels where exchange with cells actually takes place.



Chemical exchange. Within the capillary beds, there is local exchange of molecules between the blood and interstitial fluid, which bathes the cells of tissues.

The respiratory system

The diversity of respiratory organs

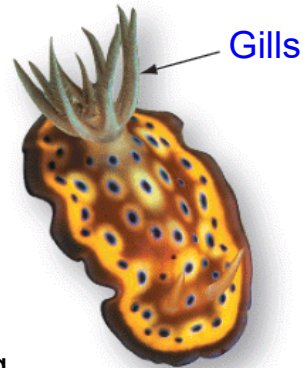
THE DIVERSITY OF RESPIRATORY ORGANS

Skin
(entire body surface)



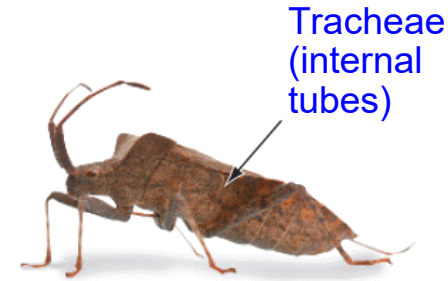
Leech

Gills
(extensions of body surface)



Sea slug

Tracheae
(branching body tubes)

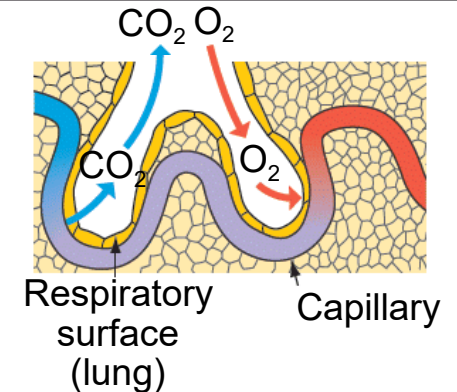
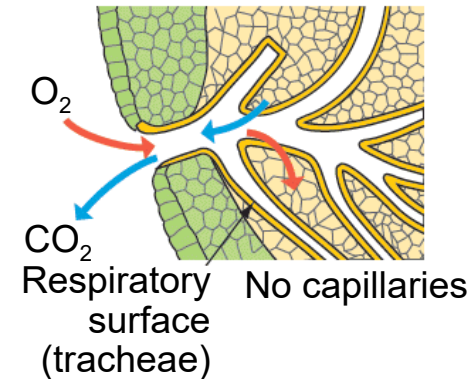
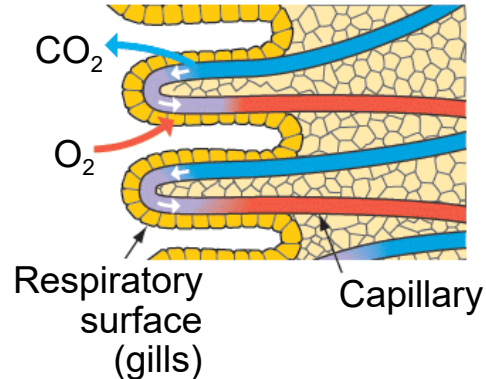
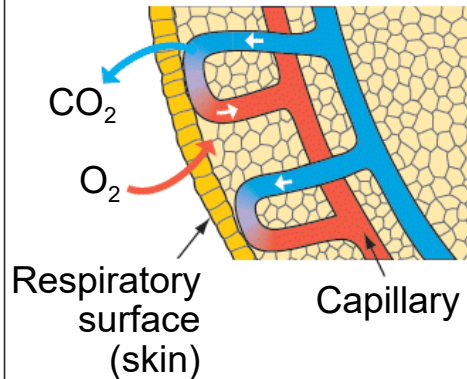


Stinkbug

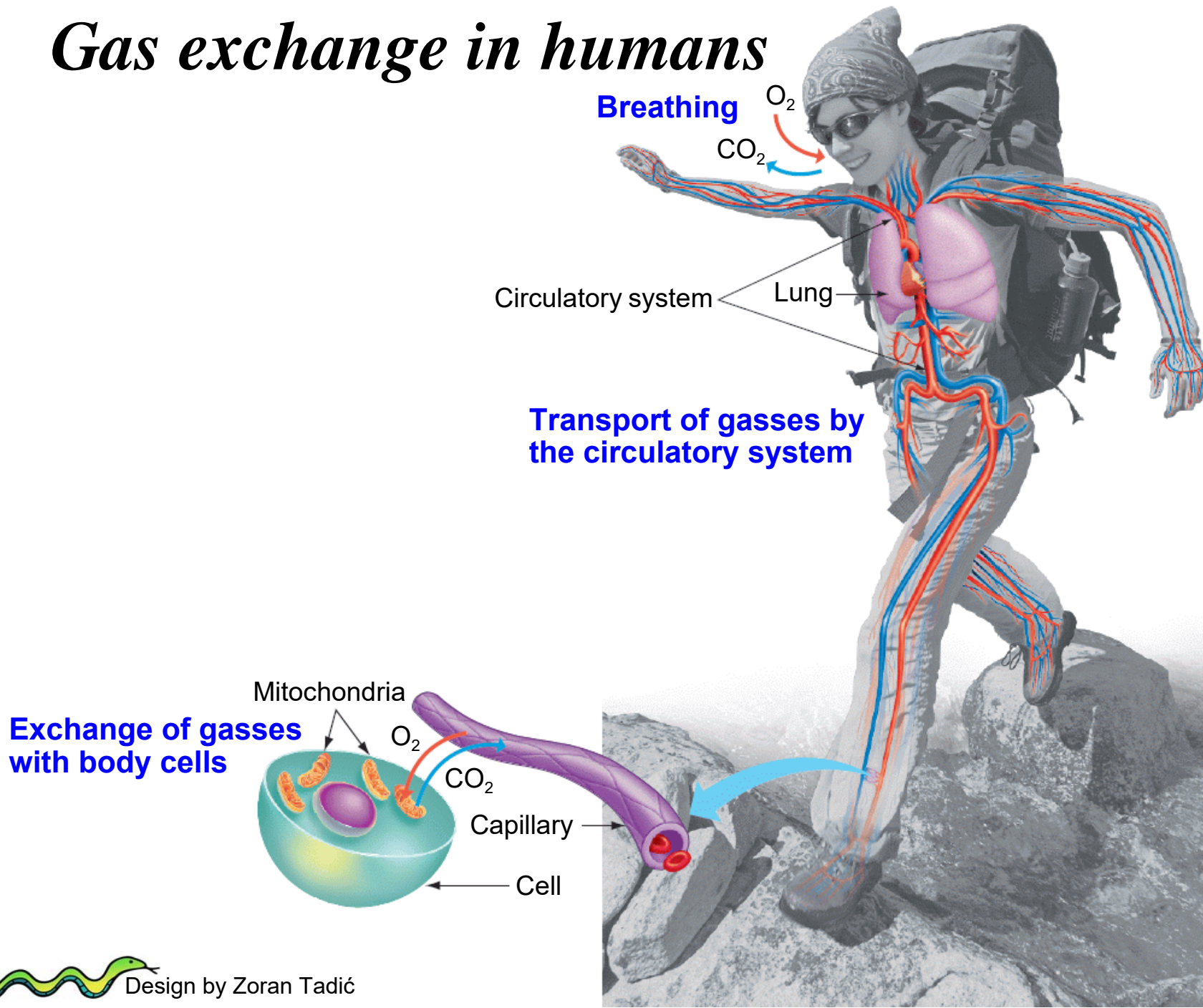
Lungs
(localized internal organs)



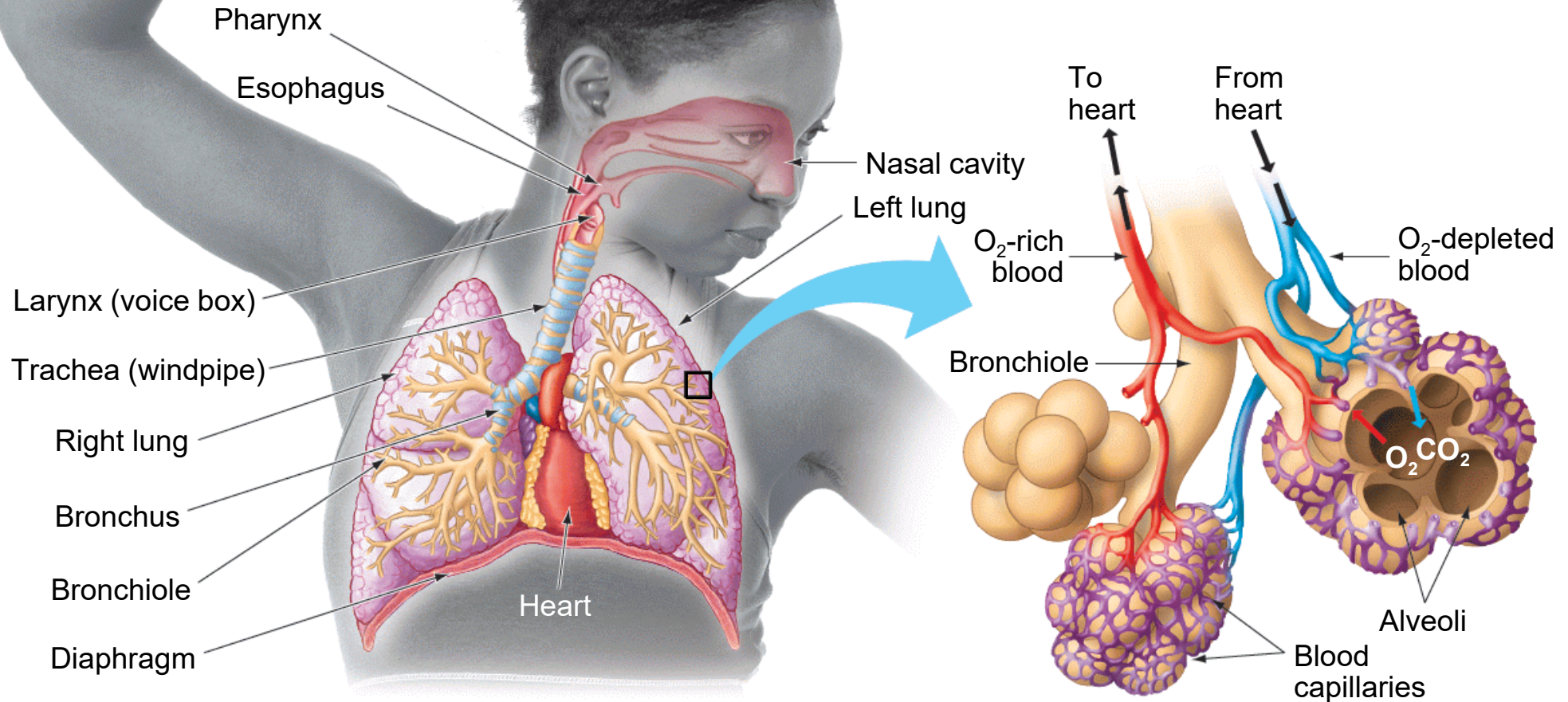
Lungs
Mouse



Gas exchange in humans



Human respiratory system

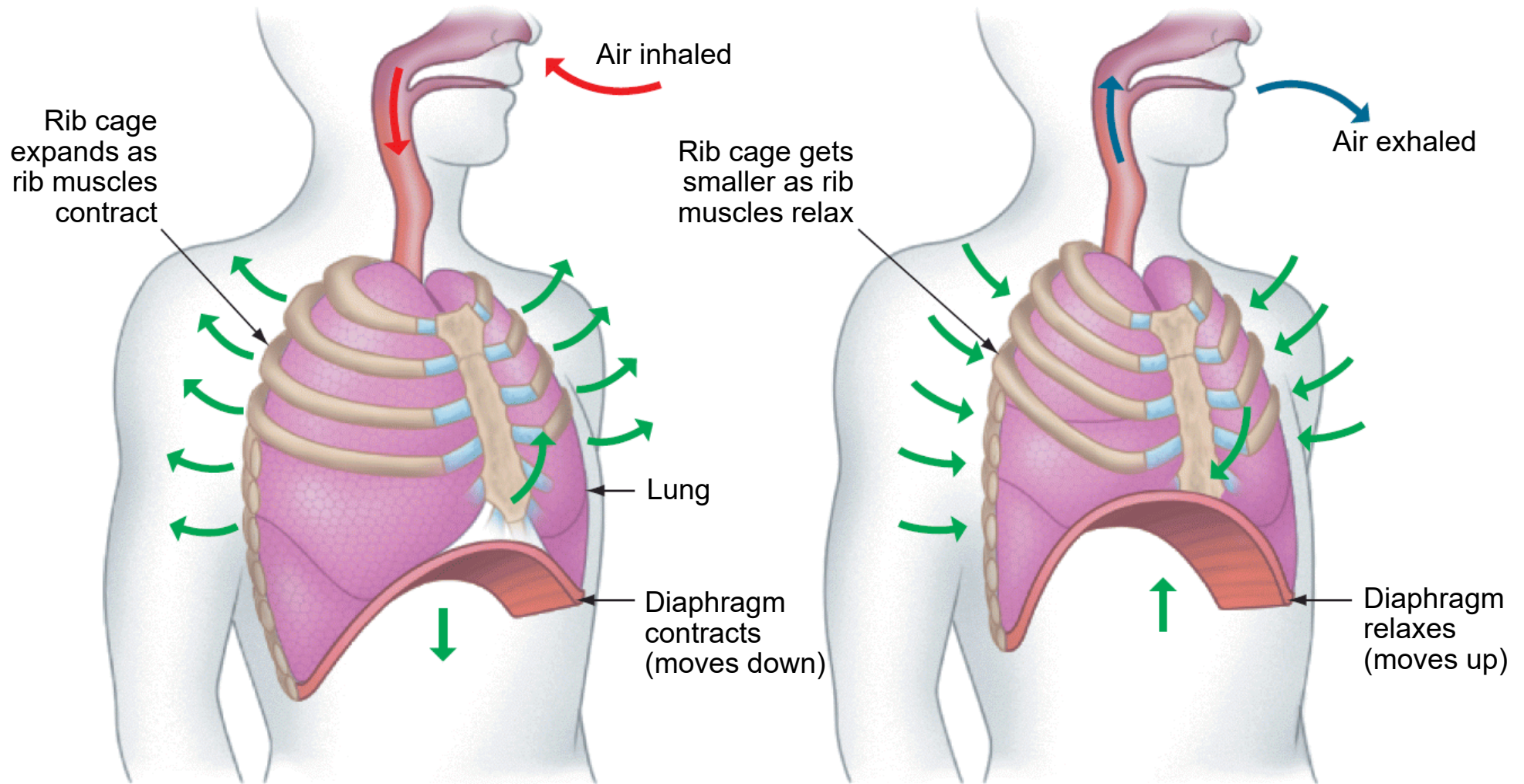


Human respiratory system

Structure of the alveoli



The breathing cycle



Inhalation

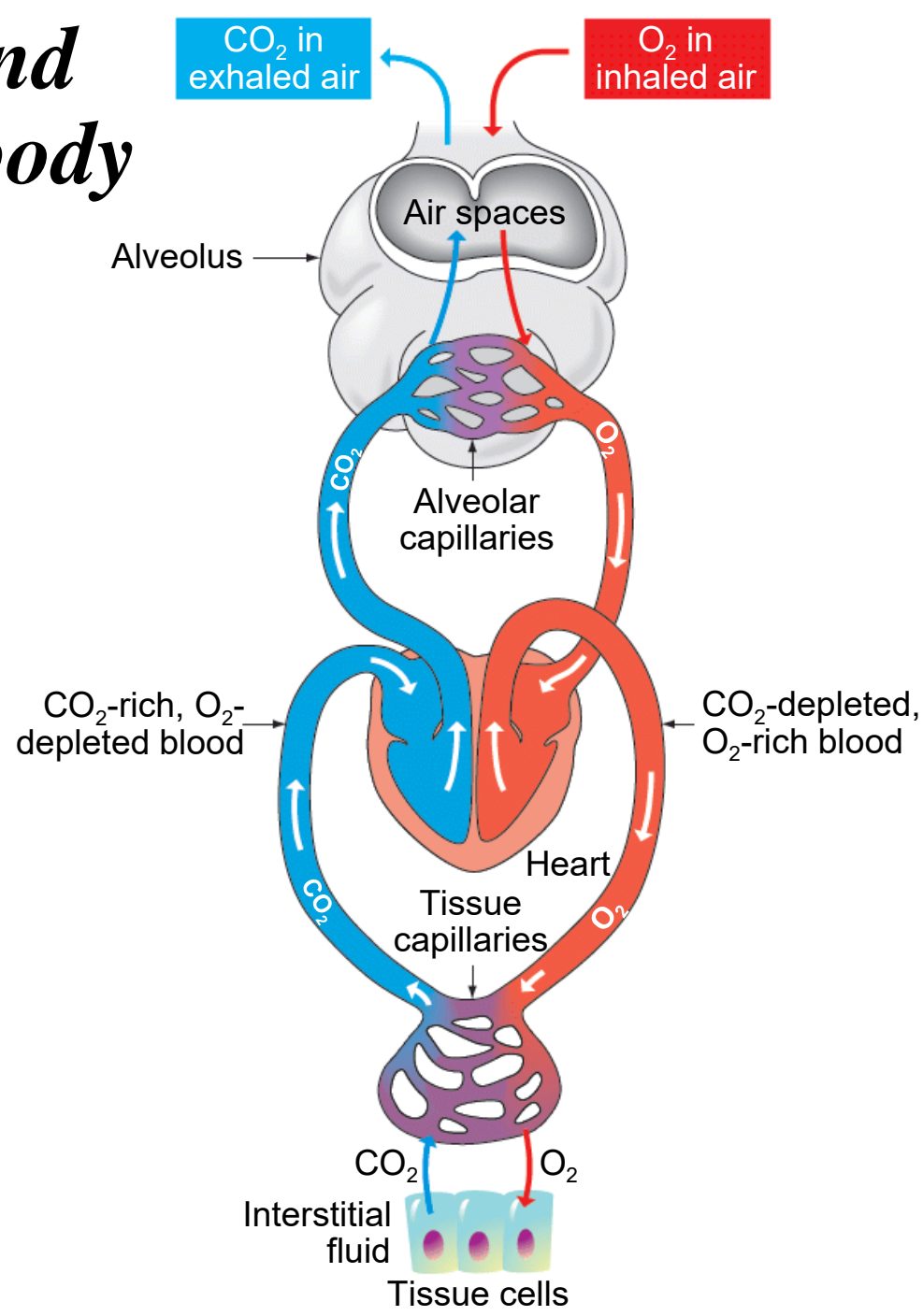
(Air pressure is higher in atmosphere than in lungs)

Exhalation

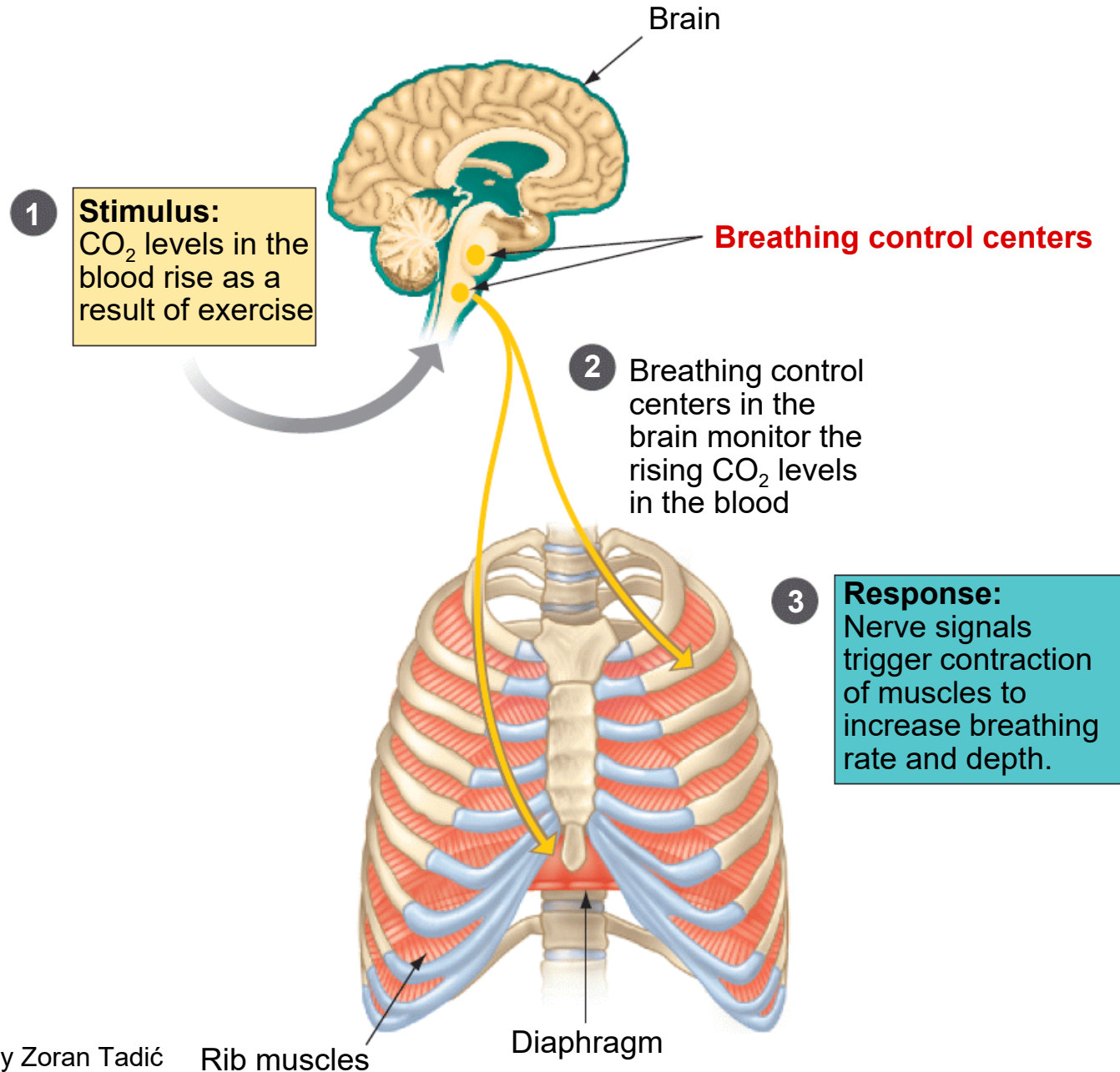
(Air pressure is lower in atmosphere than in lungs)



Gas transport and exchange in the body

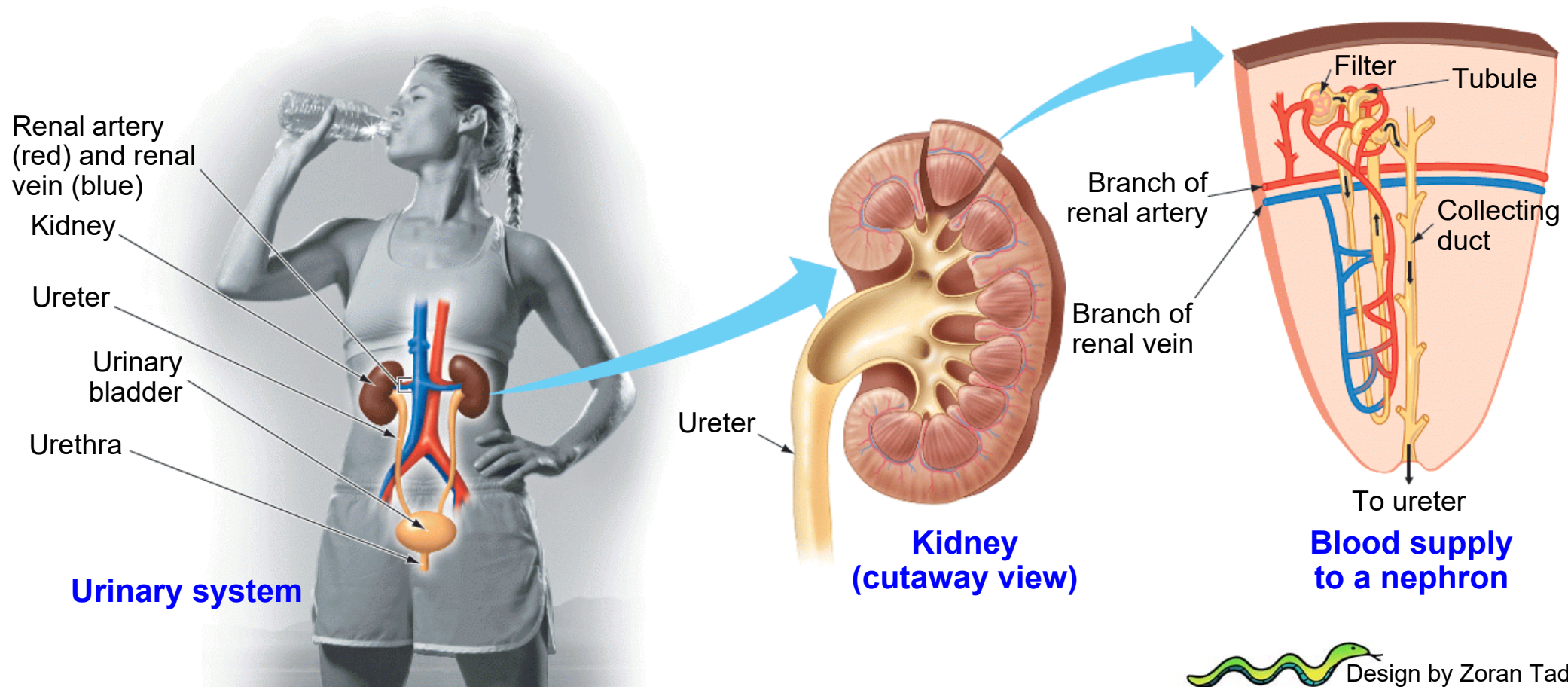


Neural centers that control breathing

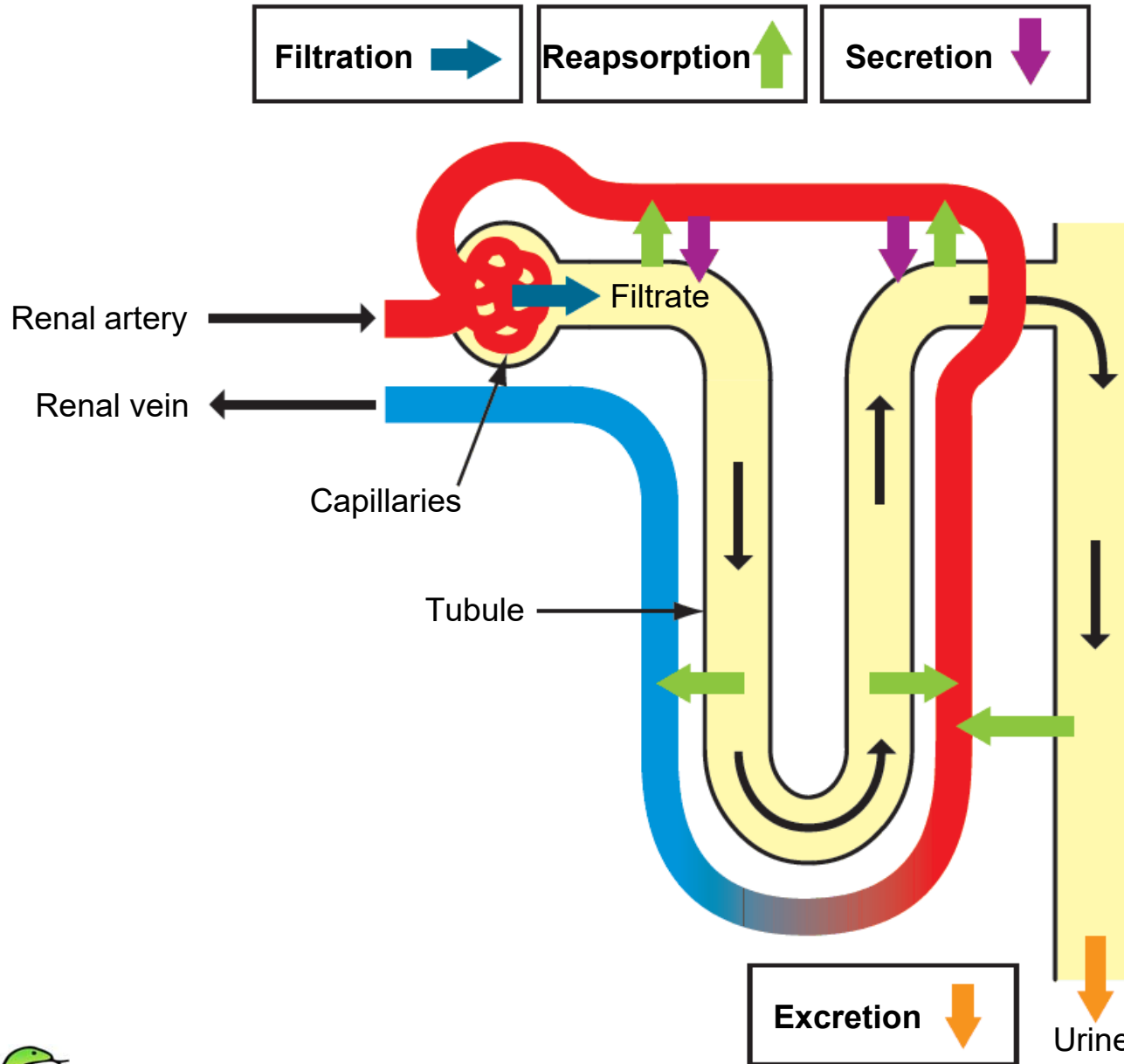


The urinary system

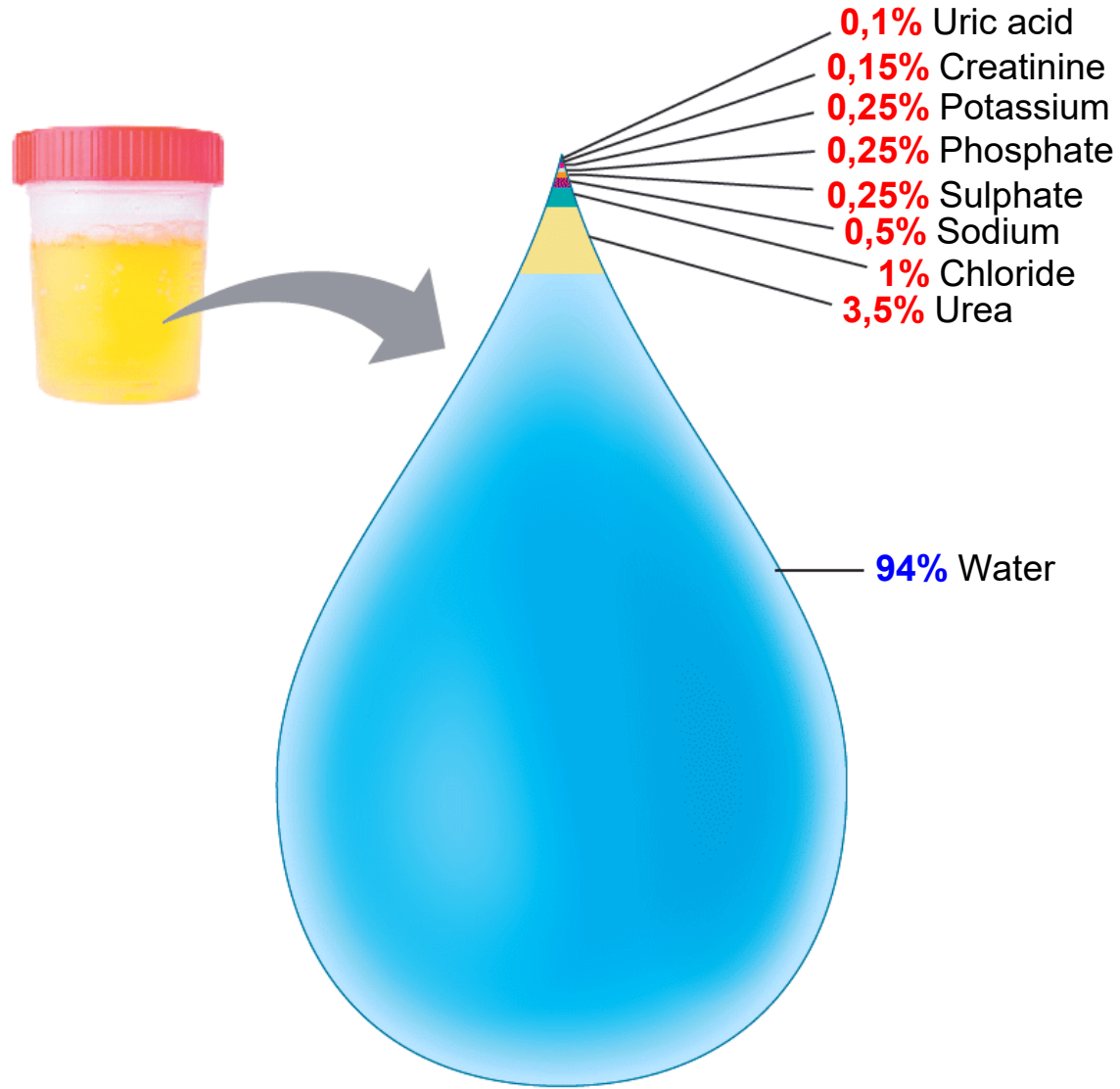
Kidneys - important osmoregulatory organs



Diuresis - the formation of urine



Composition of human urine



THE END (of the kangaroo)

