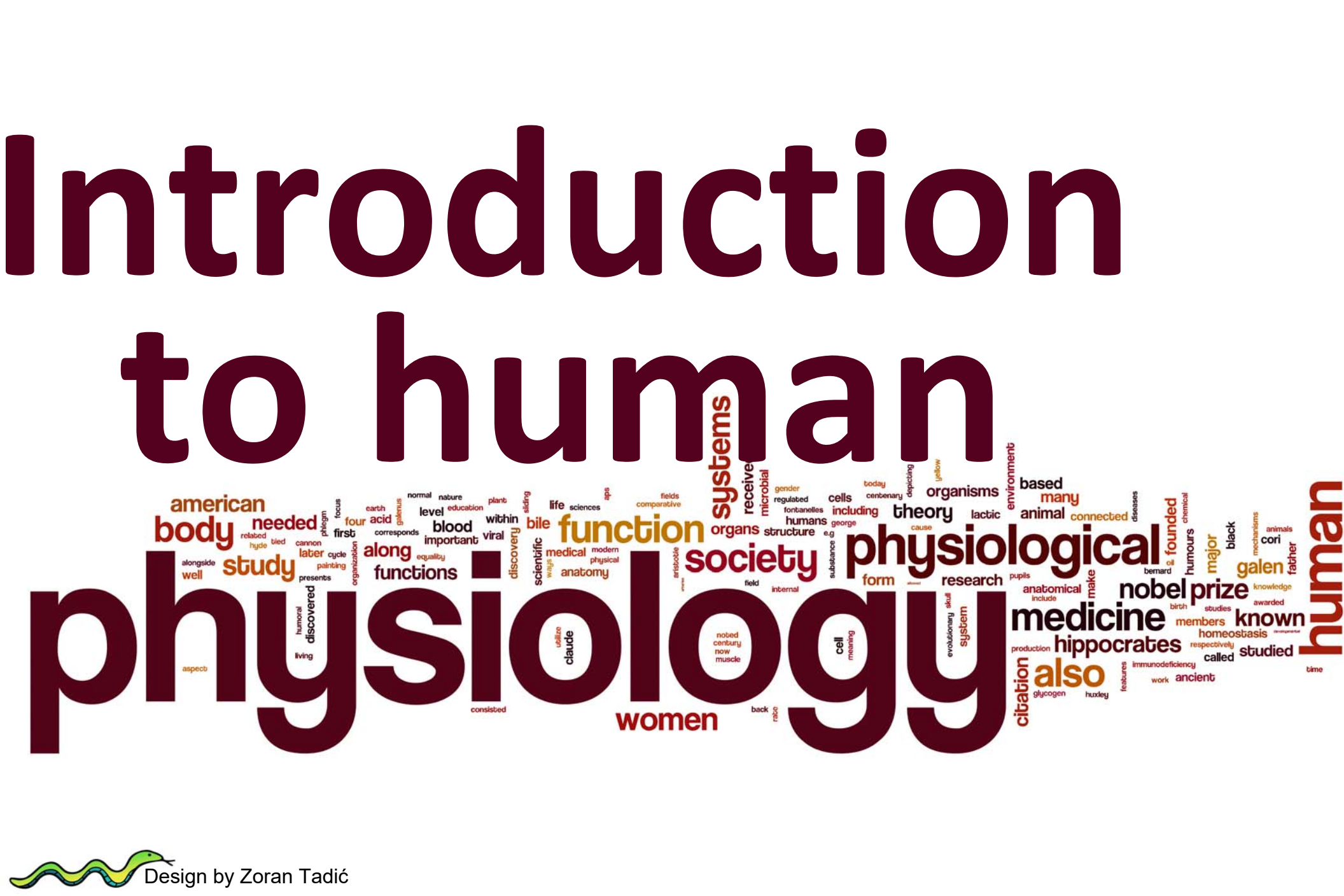
Introduction to human physiology



Design by Zoran Tadić

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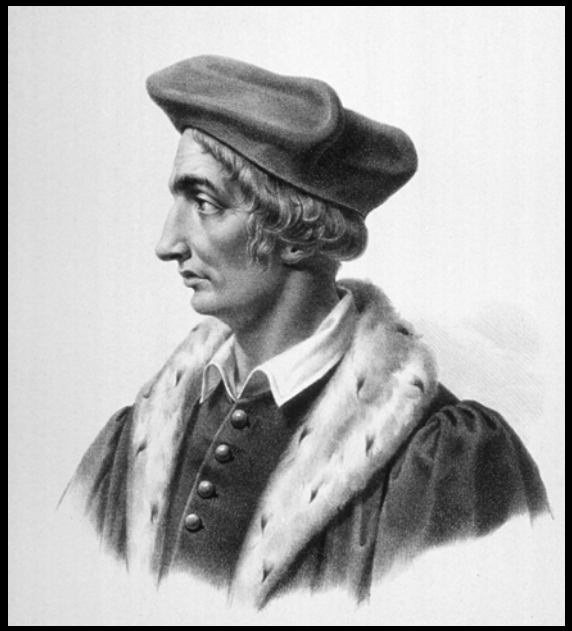
How did it get its name?

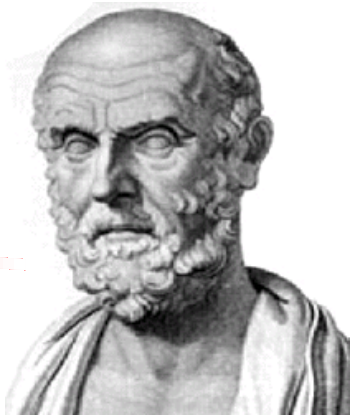
Physiology - *gr.* φύσις (phúsis) = nature, origin + *grč.* λογία (logia) = studies (of)
= *the scientific study of functions & mechanisms in a living system.*



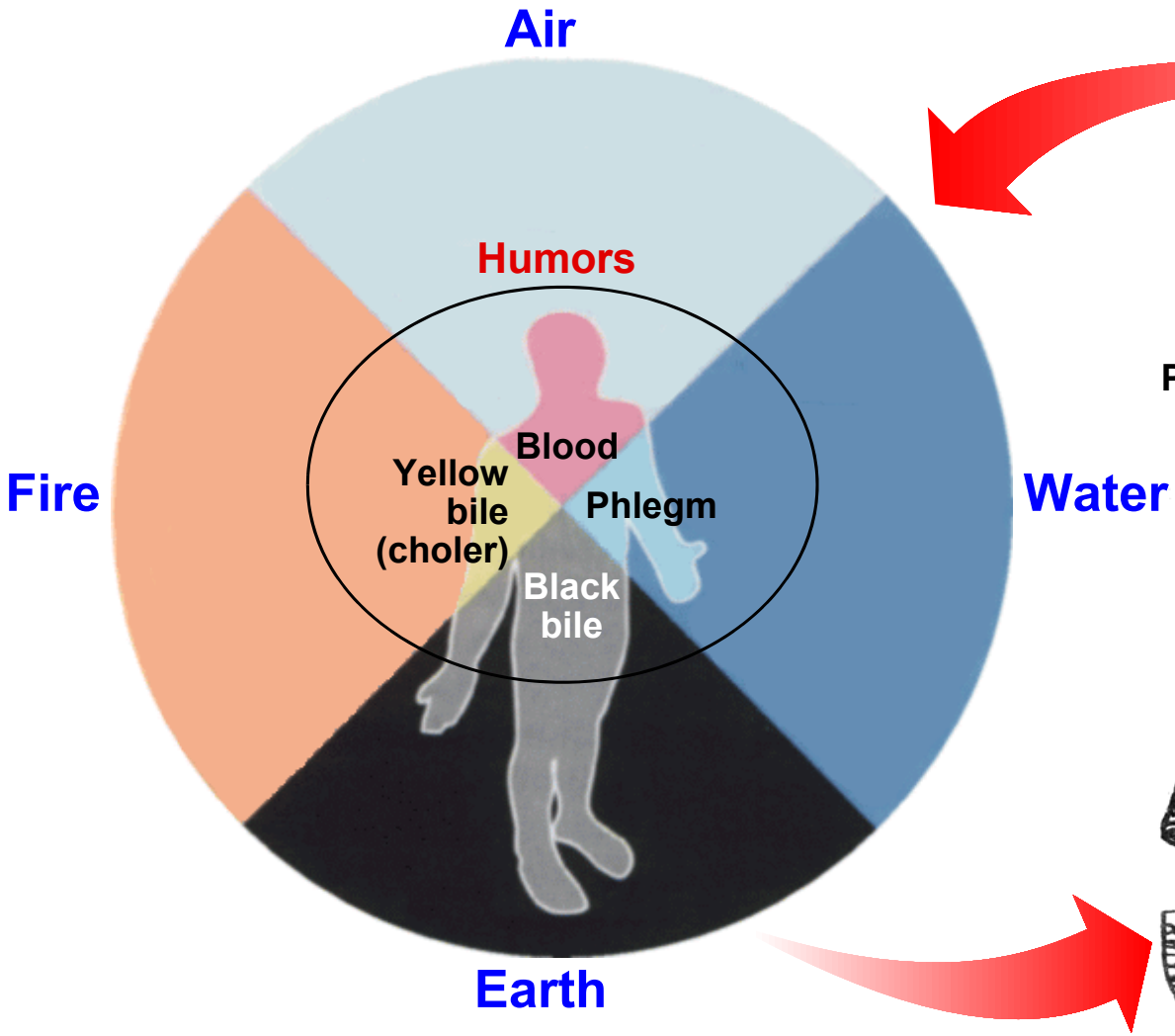
Jean François Fernel
(1497-1558)

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"). 😂

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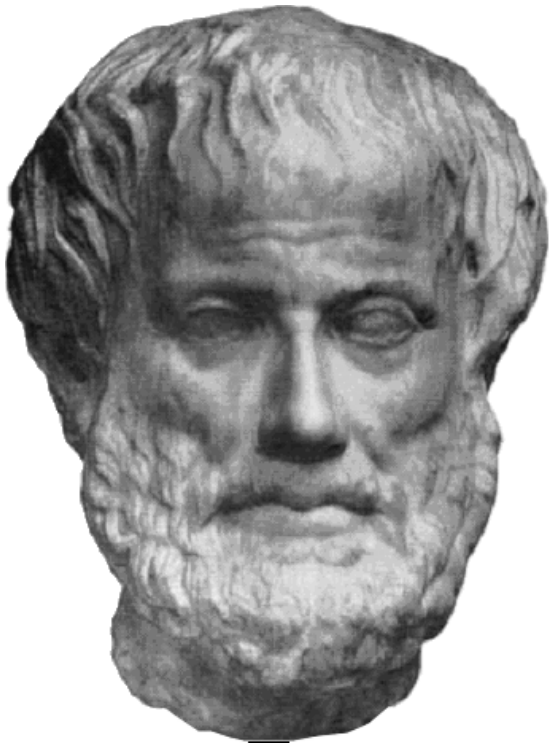
Aristotle and his view on the human body

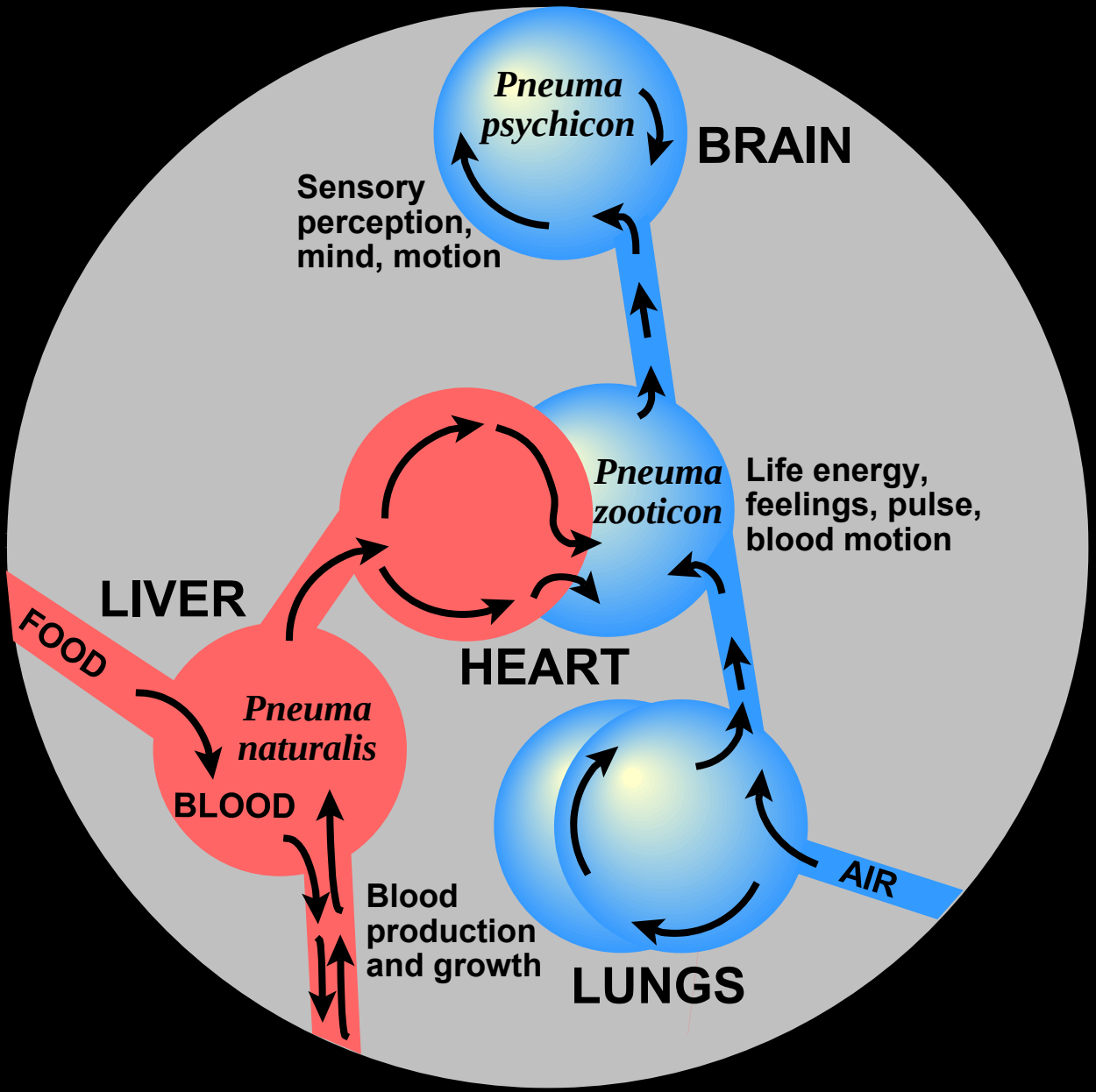


Aristotle
(384-322 BCE)

- **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?**

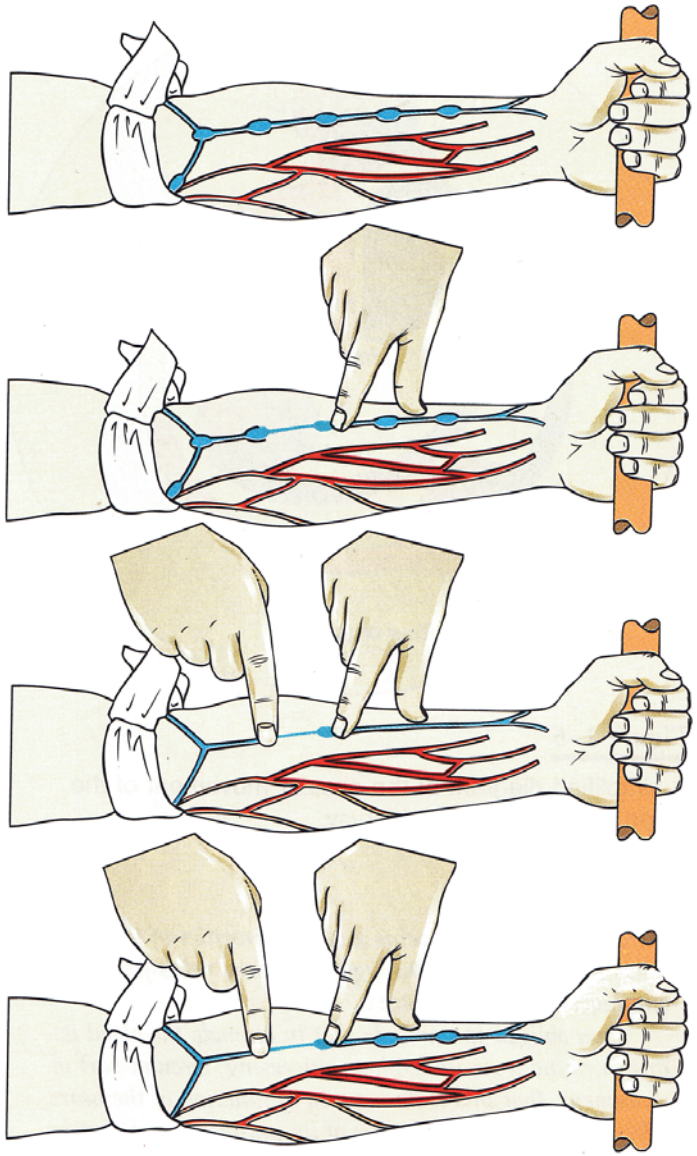
Galen's "pneumatology" or Galenism

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



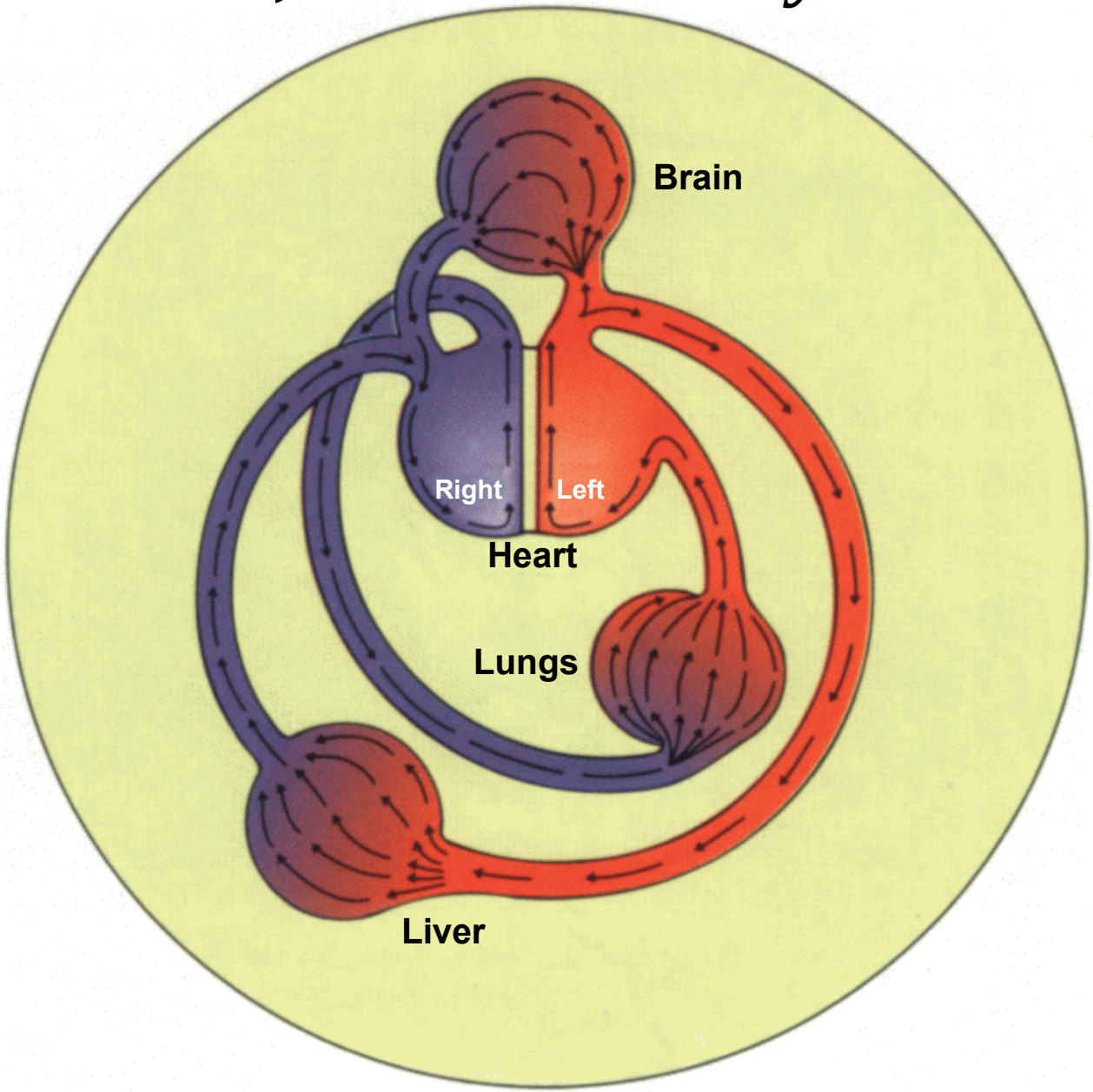
William Harvey and the start of modern physiology

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)

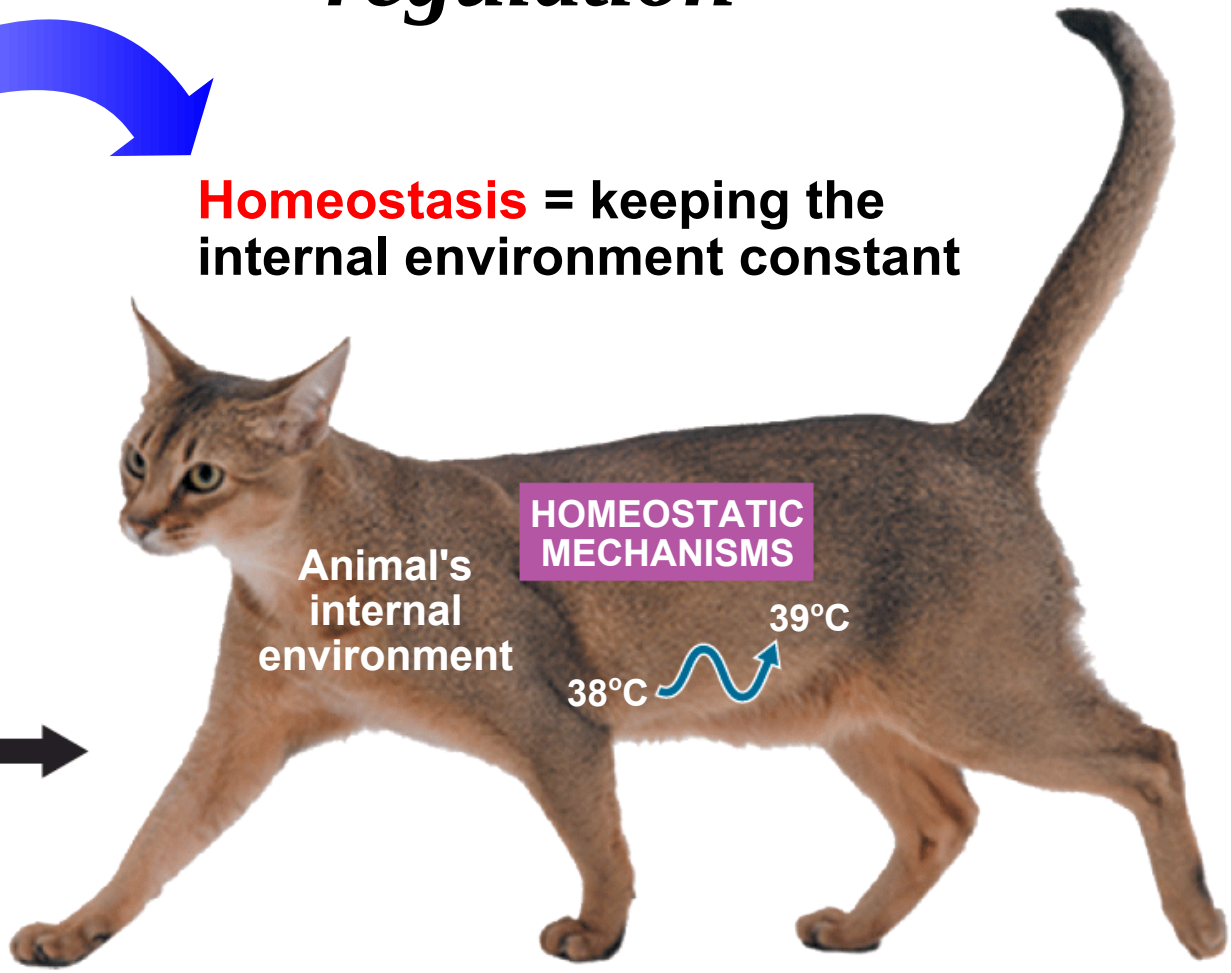
Homeostasis = keeping the internal environment constant

External environment

37°C

4°C

Large external changes



Small internal changes

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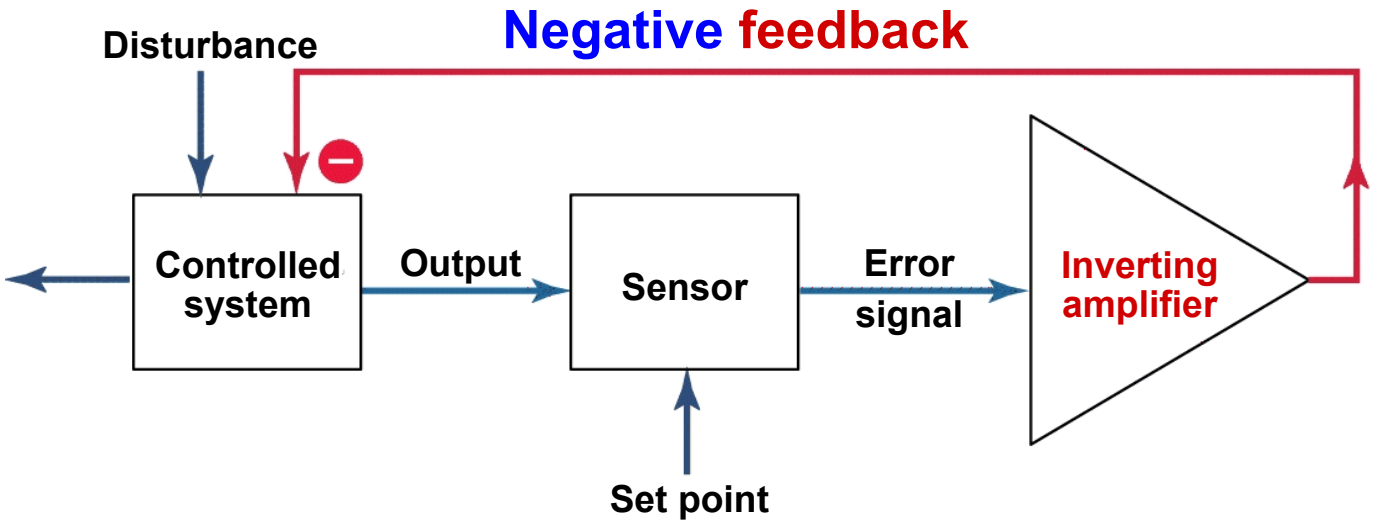
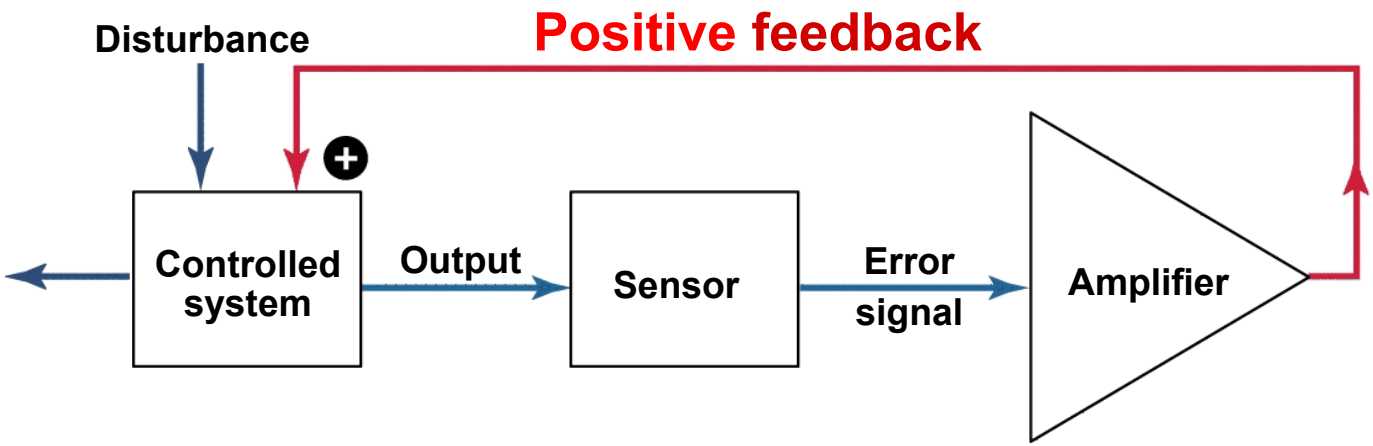
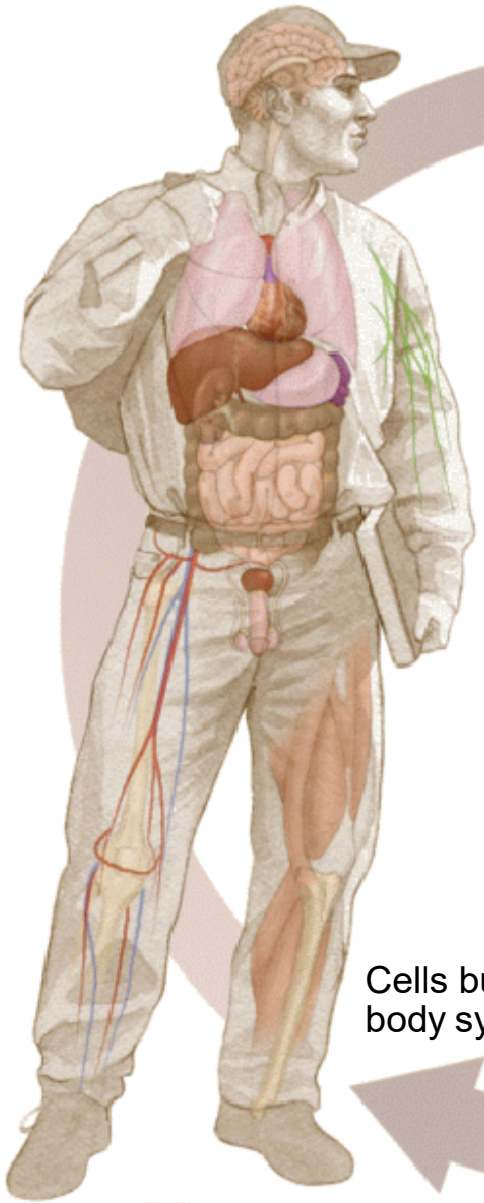
Homerostasis is maintained using negative feedback





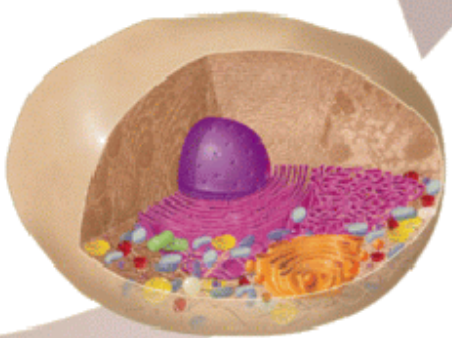
Why is homeostasis important?



Body systems maintain homeostasis

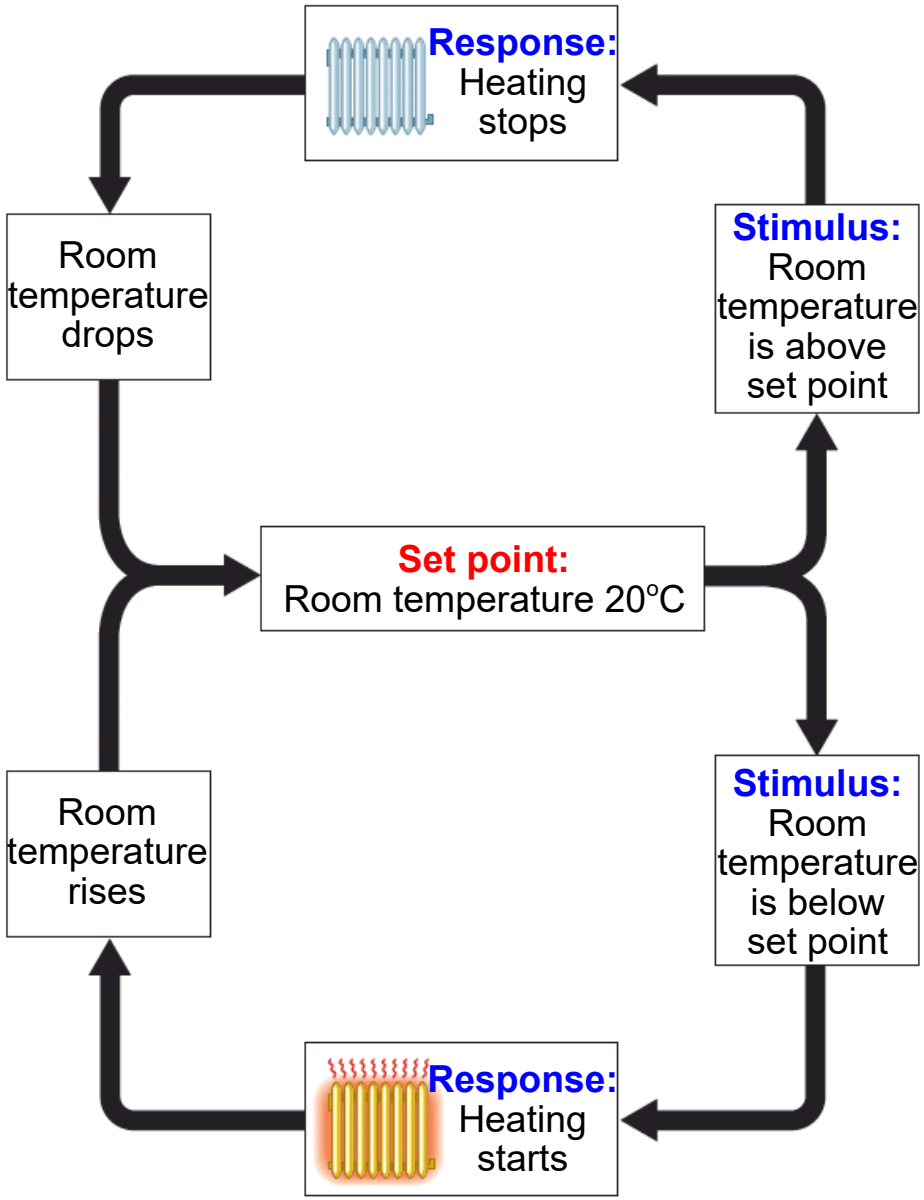
Homeostasis

Homeostasis is essential for cell survival



Cells build body systems

Technical (thermoregulatory) homeostasis



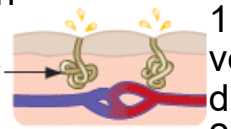
Thermostat (control center) turns heater off

Thermostat (control center) turns heater on

Biological (thermoregulatory) homeostasis

Skin

Sweat gland



Response:
1. Blood vessels dilate
2. Sweat is produced

Control center in brain activates cooling mechanisms

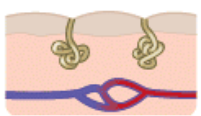
Body temperature drops

Stimulus: Body temperature is above set point

Set point: Body temperature 37°C

Body temperature rises

Stimulus: Body temperature is below set point



Response:
1. Blood vessels constrict
2. Person shivers
3. Metabolic rate increases

Control center in brain activates warming mechanisms

Physiology as one of the foundations of medicine

Kako sam sistematski išao na pregled

Anatomy

↓

Physiology

↓

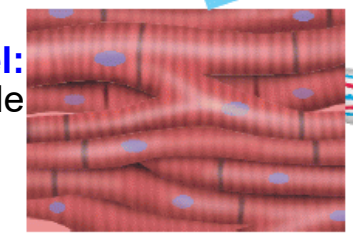
Pathology, Pathophysiology

↓

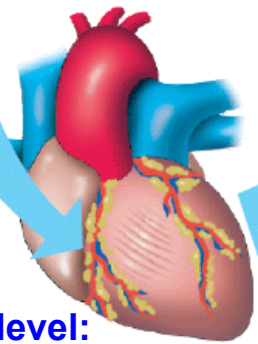
Internal medicine

Physiology as a multilayered science

Cellular level:
Muscle cell



Tissue level:
Cardiac muscle



Organ level:
Heart

Organism level:
Multiple organ systems functioning together

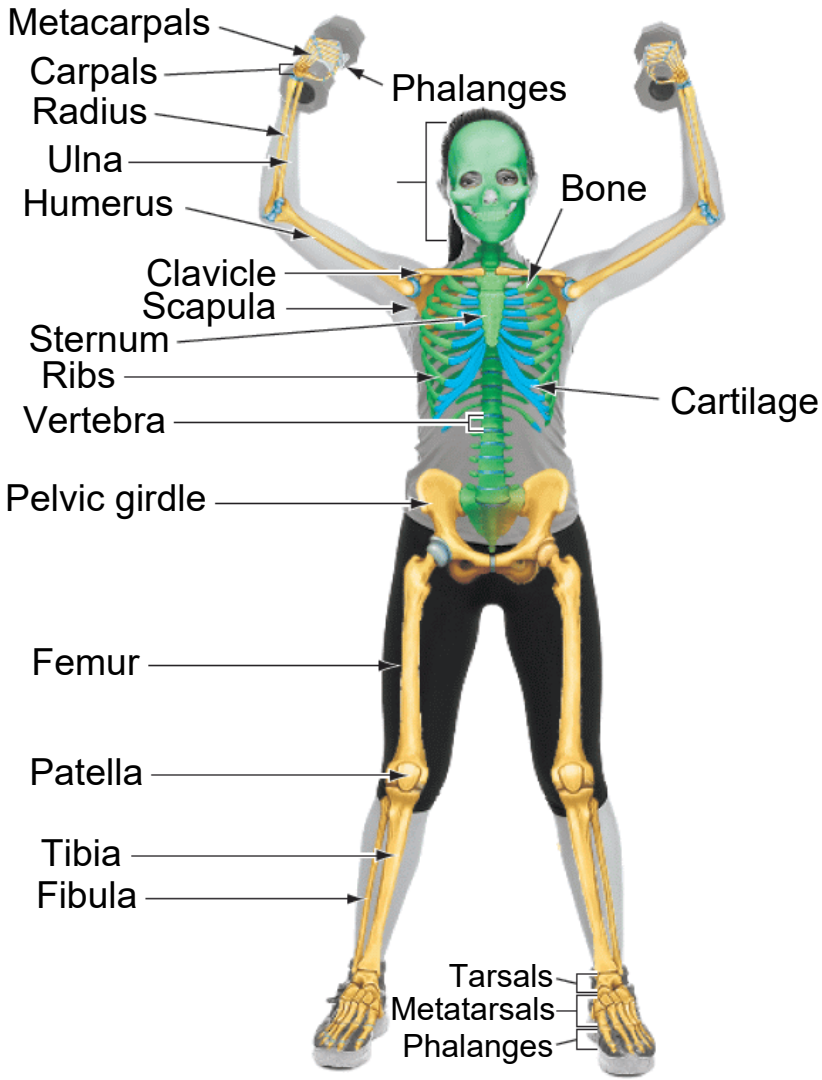
Organ system level:
Circulatory system

Environment

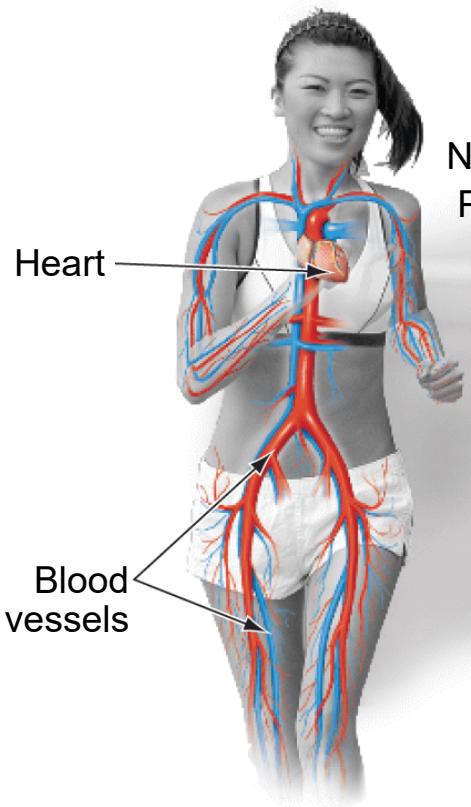
Ecophysiological level:
Physiological interaction of organism and environment

Design by Zoran Tadić

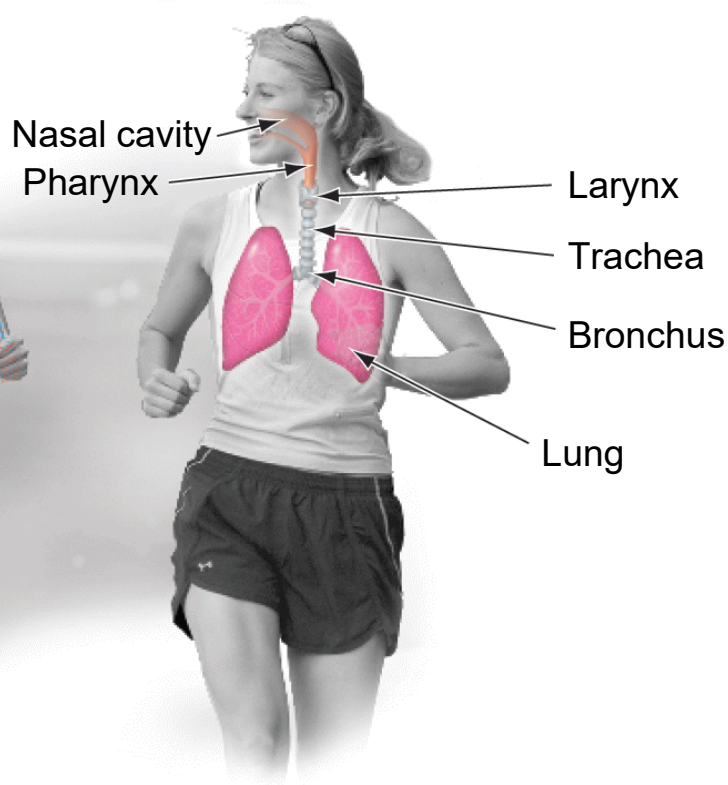
The physiological systems 1



The skeletal system
(supports body and anchors muscles)



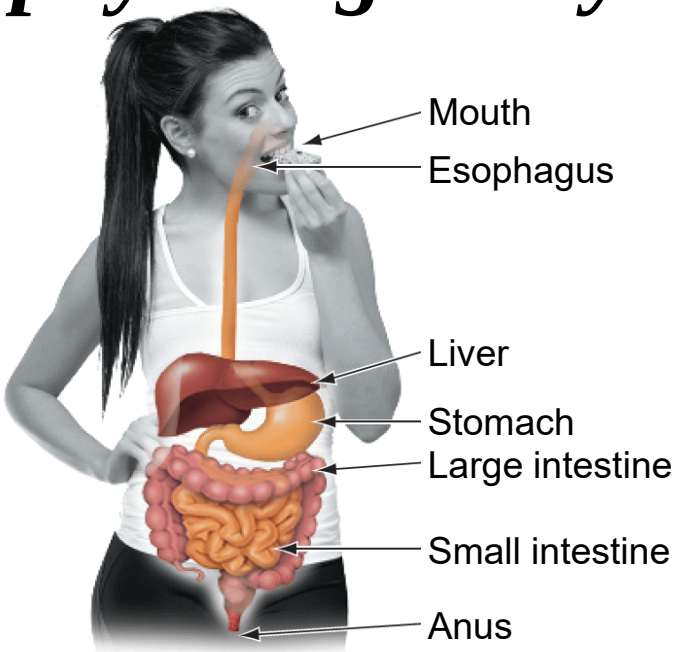
The circulatory system
(transports substances throughout body)



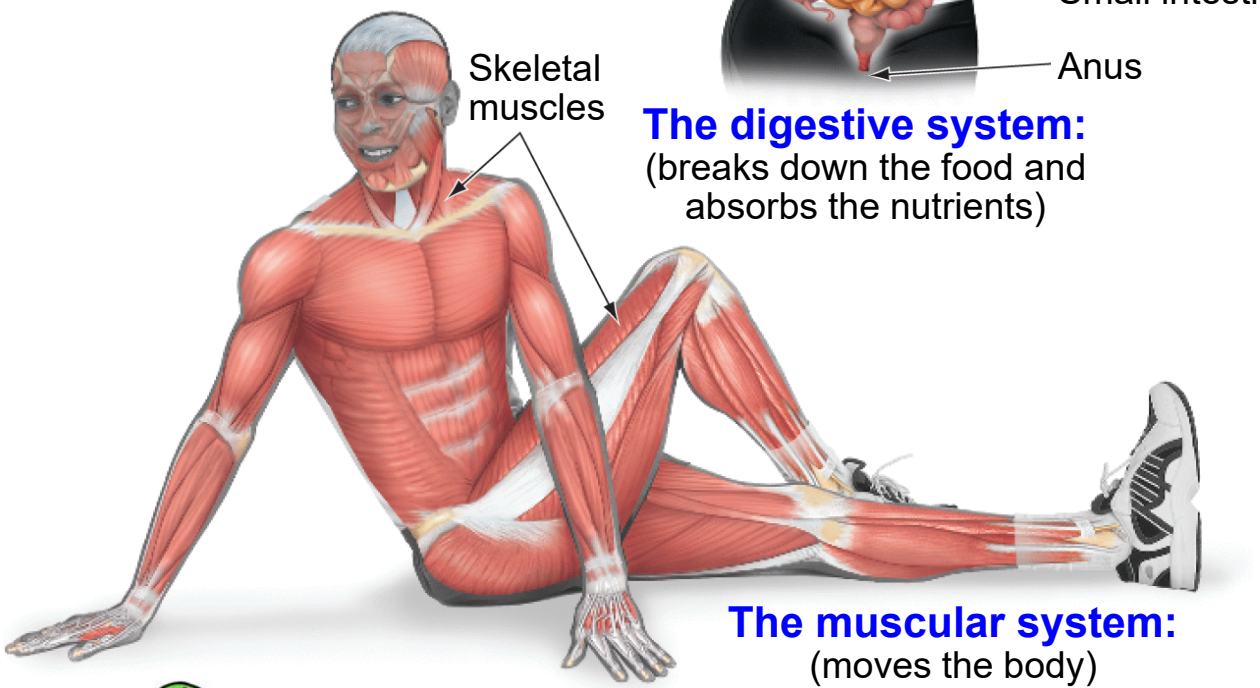
The respiratory system
(exchanges CO_2 and O_2 between blood and air)

Design by Zoran Tadić

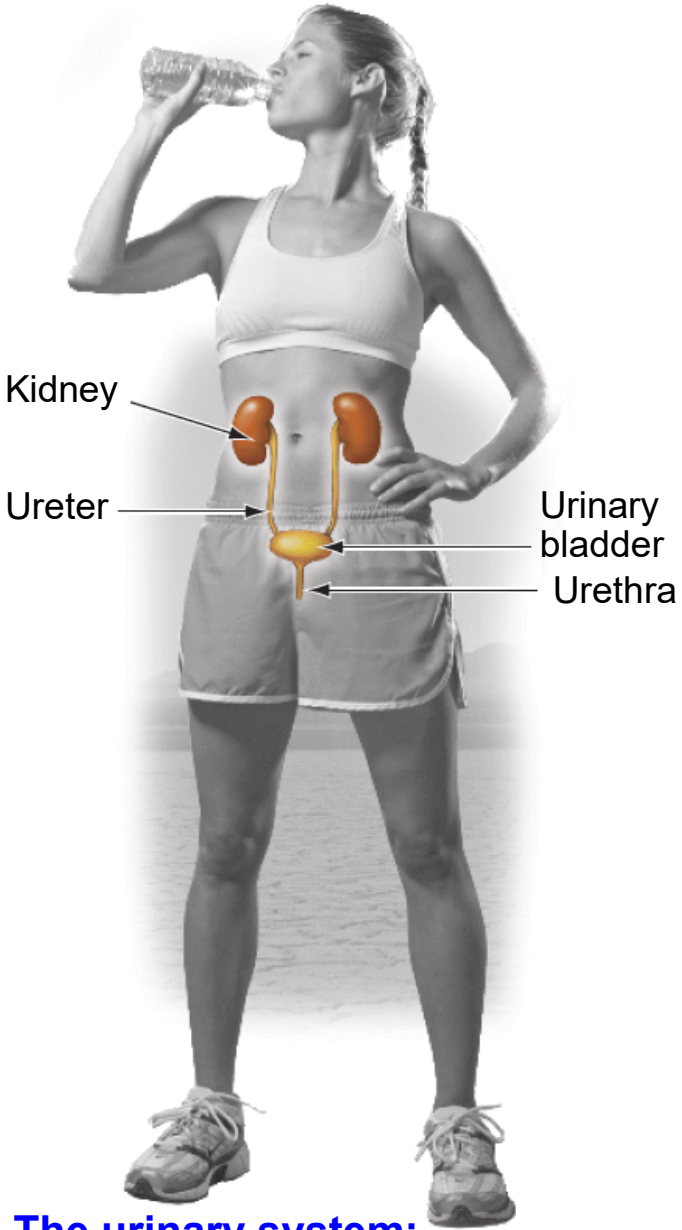
The physiological systems 2



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



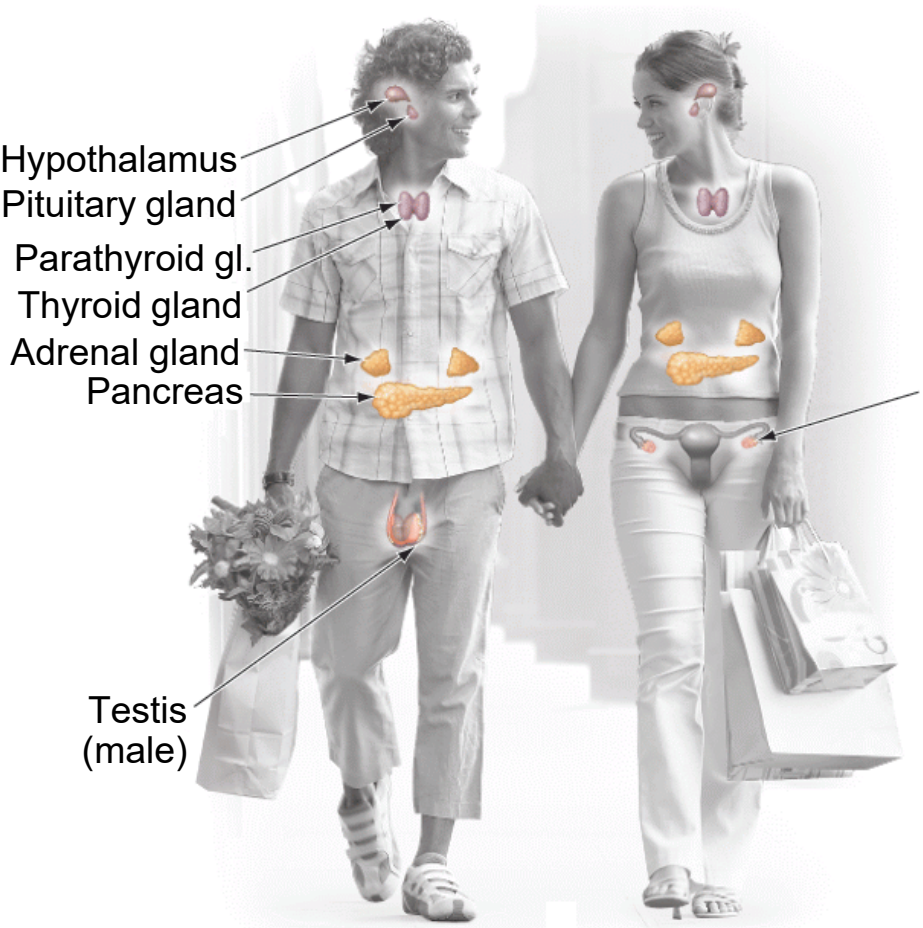
The muscular system:
(moves the body)



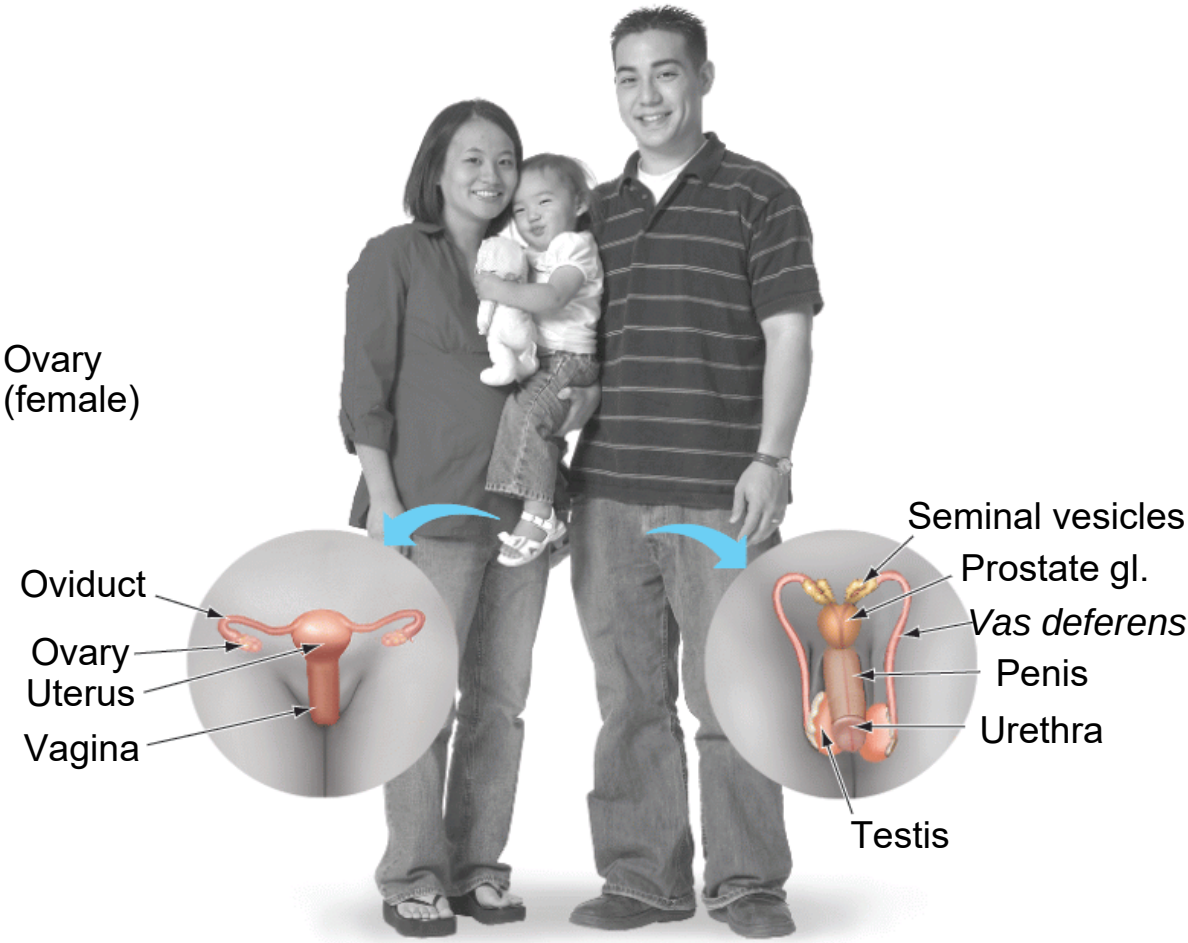
The urinary system:
(rids body of certain wastes)

Design by Zoran Tadić

The physiological systems 3



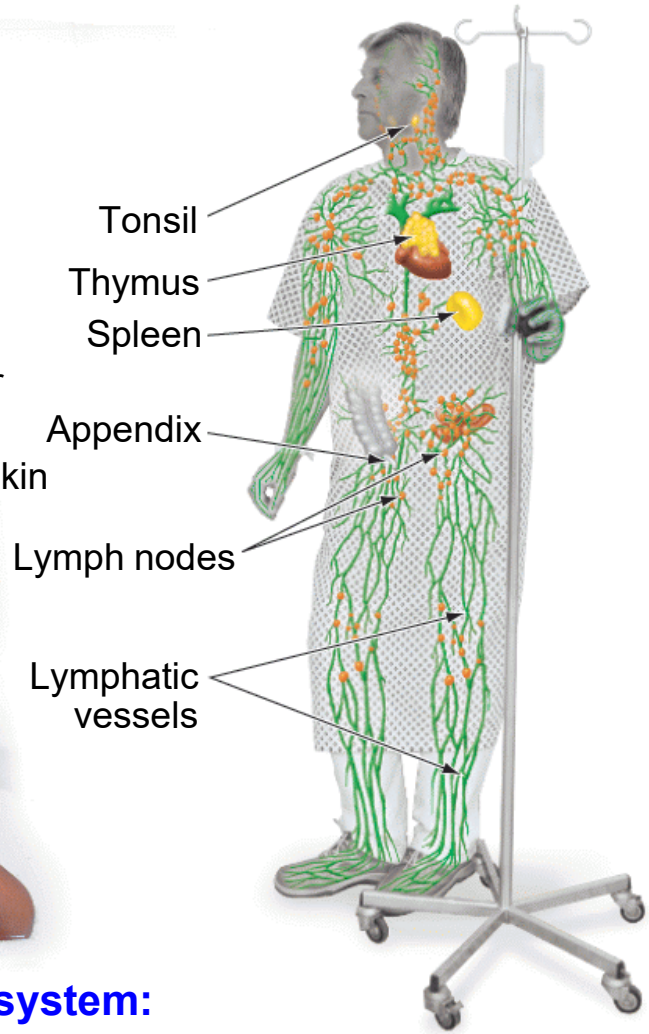
The endocrine system:
(secretes hormones that regulate body processes)



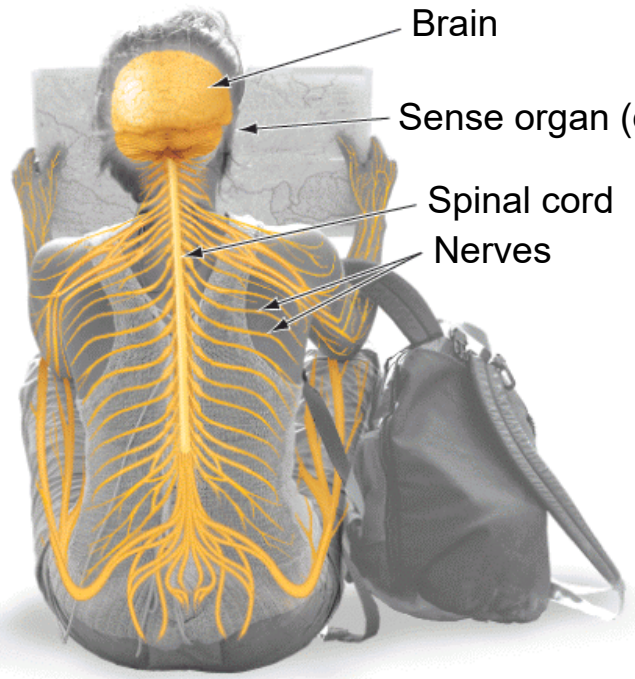
The reproductive system:
(produces gametes and offspring)

The physiological systems 4

The integumentary system:
(protects body)



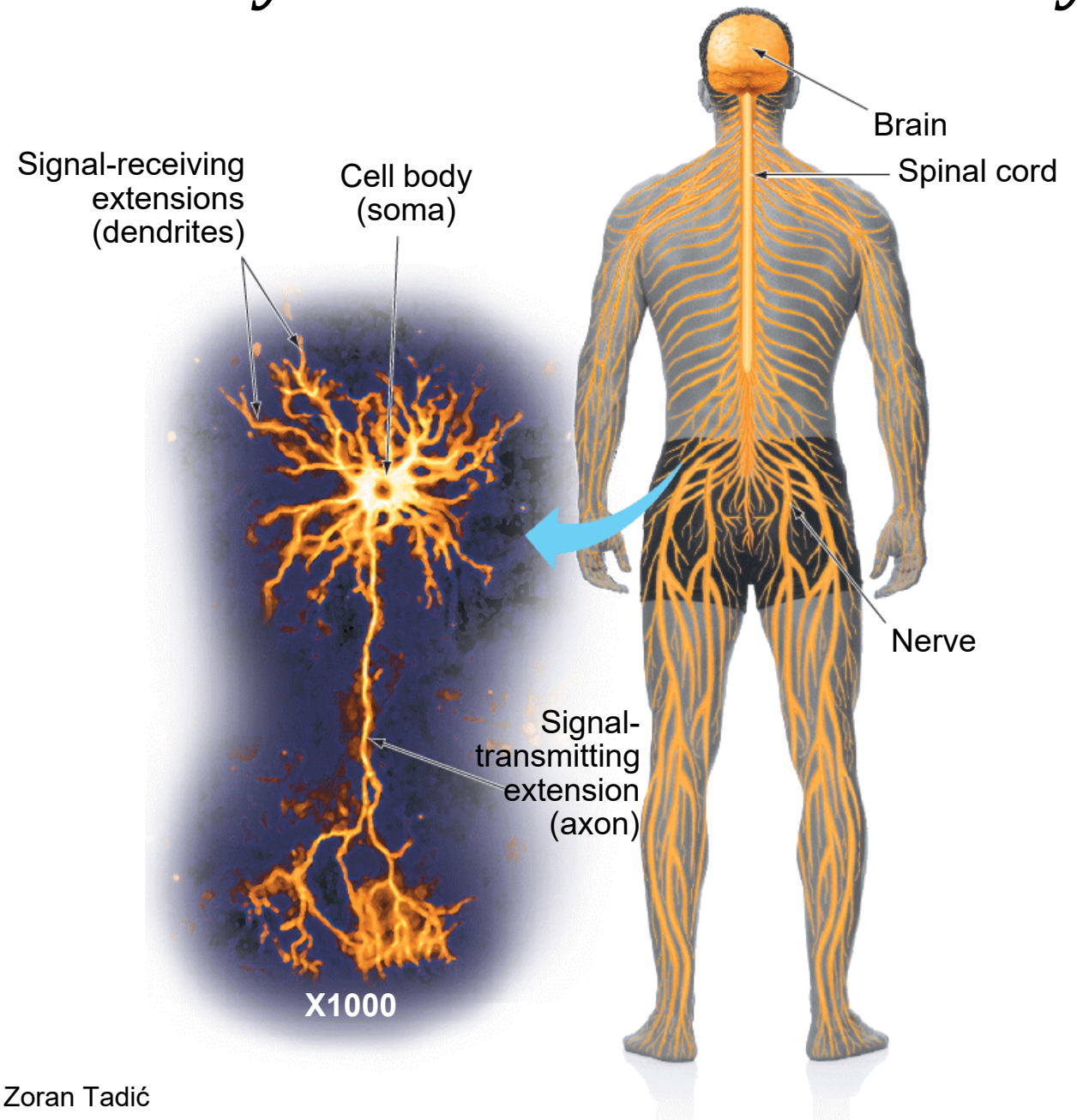
The immune system:
(defends against disease)

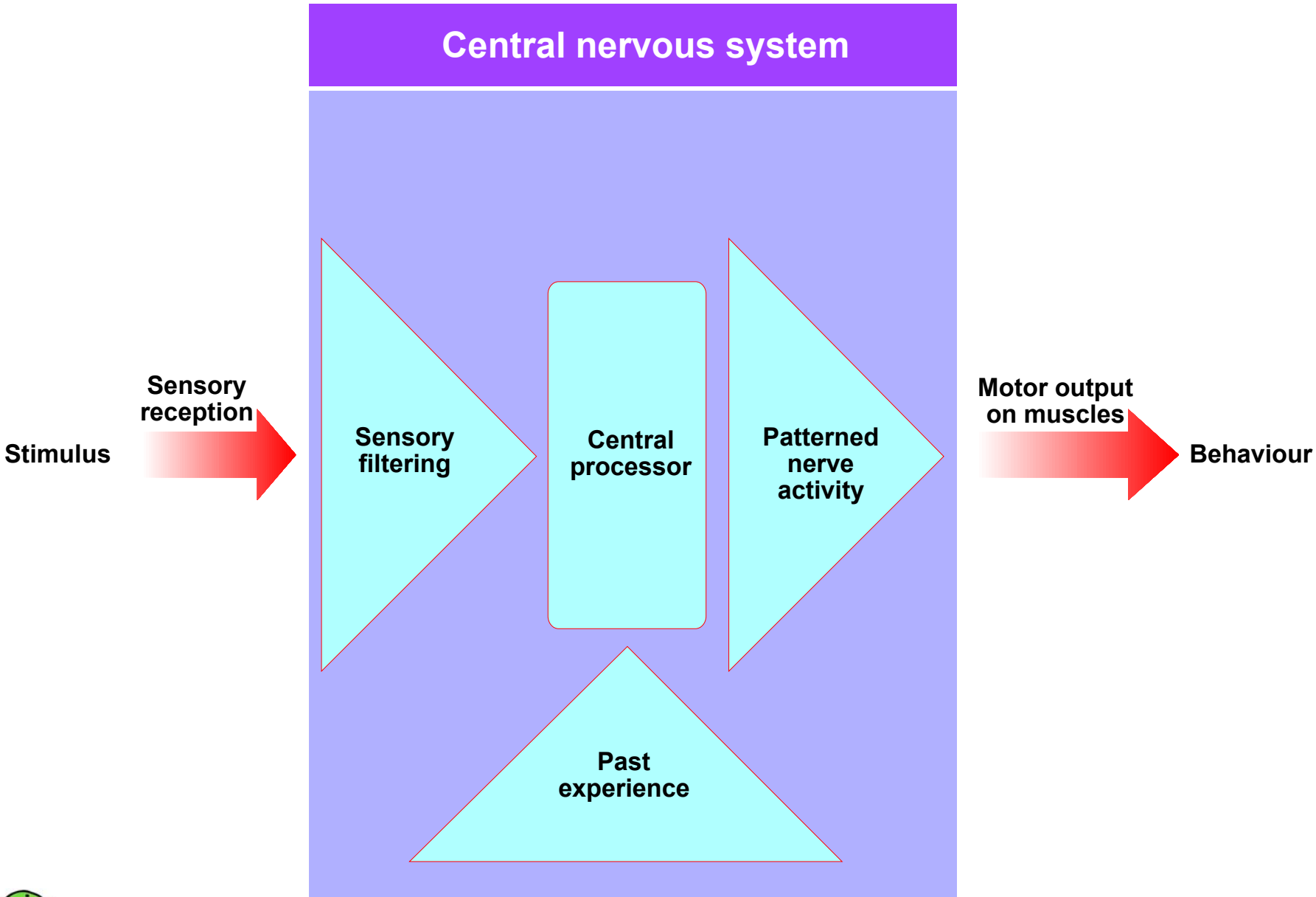


The nervous system:
(processes sensory information and controls responses)

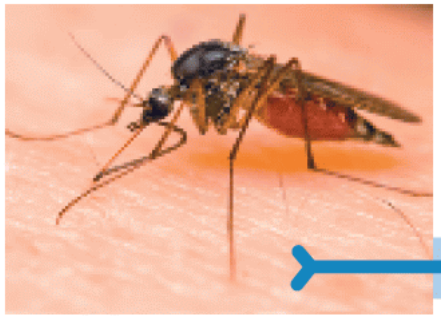
The nervous system

The control system #1: The nervous system





The flow of information through nervous system: An example



Stimulus (in skin)

SENSORY INPUT

Sensory neuron

INTEGRATION

Interneuron

MOTOR OUTPUT

Motor neuron

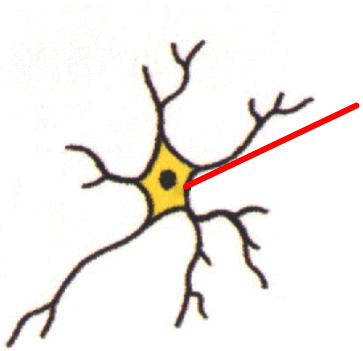
Brain and spinal cord

Response (in skin)

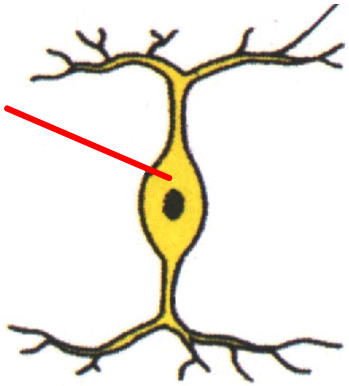
Peripheral nervous system (PNS)

Central nervous system (PNS)

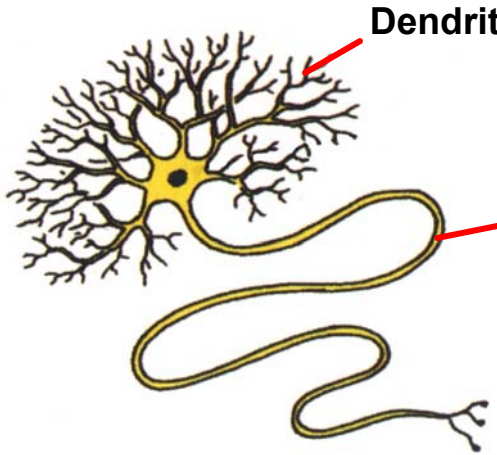
The world of (various) neurons



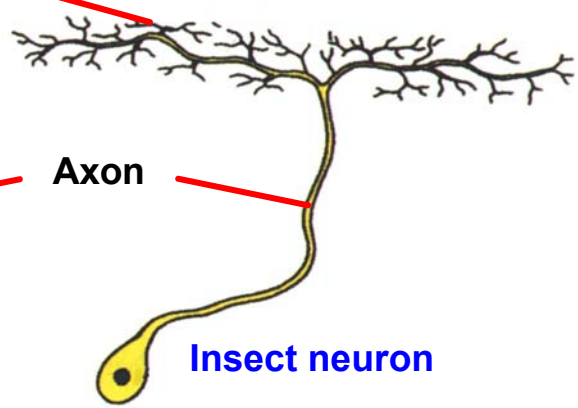
Cell from coelenterate nerve net



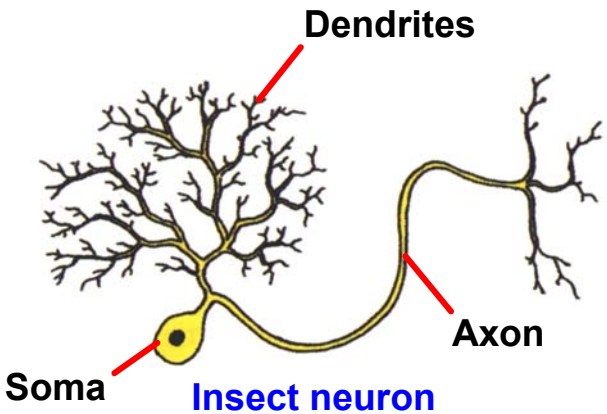
Bipolar cell from vertebrate retina



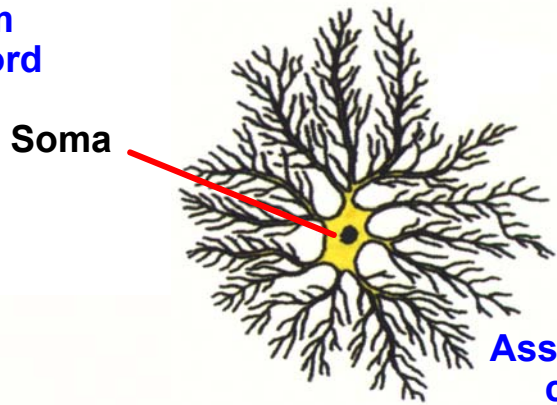
Motor neuron from vertebrate spinal cord



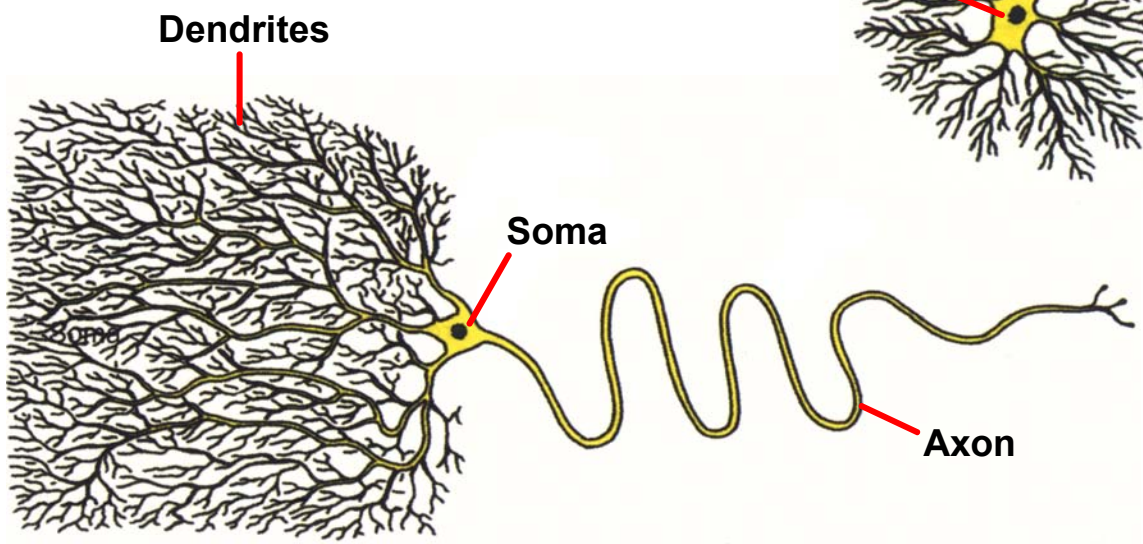
Insect neuron



Insect neuron



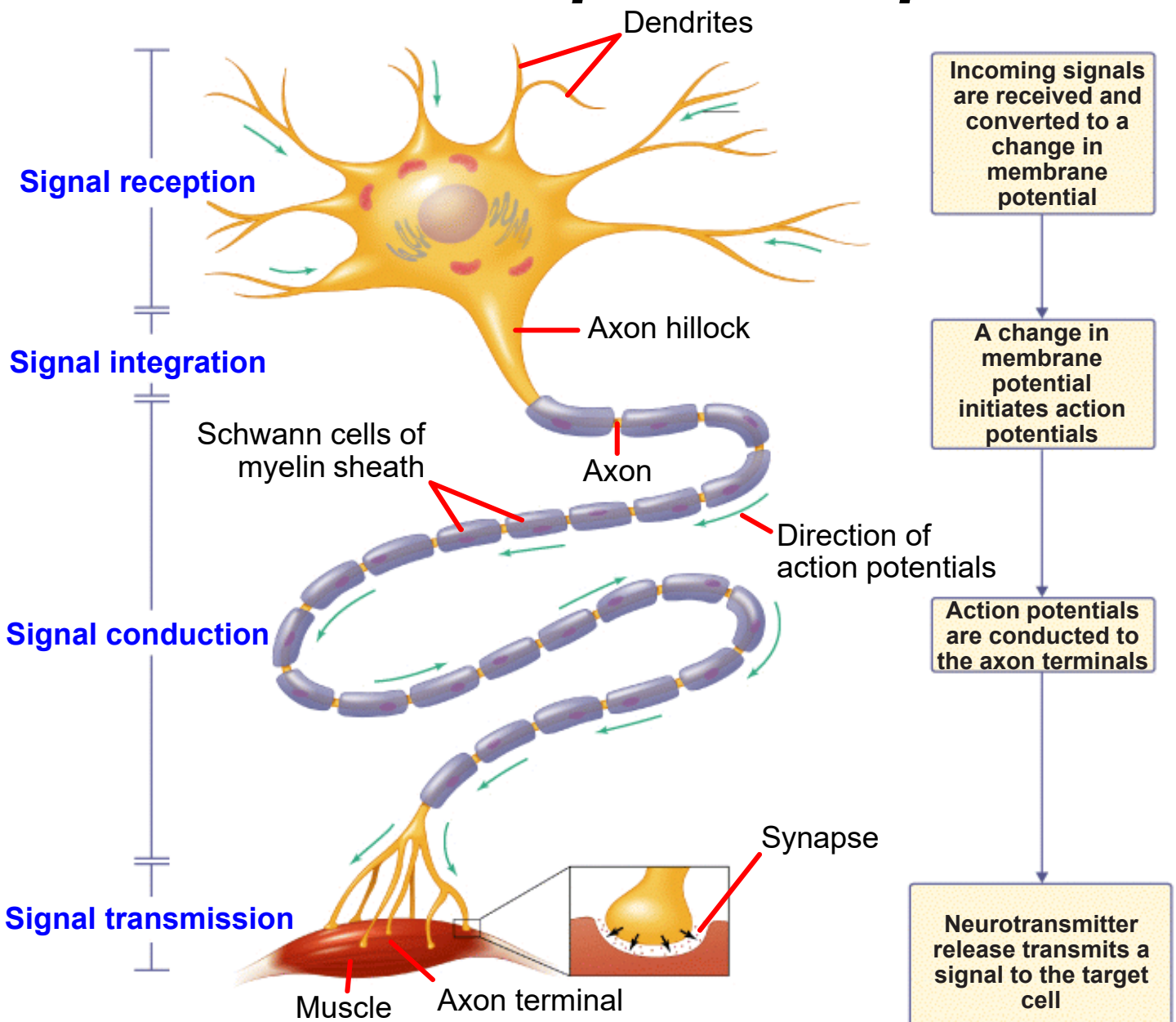
Association cell from mammalian thalamus



Purkinje cell from mammalian cerebellum

Design by Zoran Tadić

The structure and function of a neuron



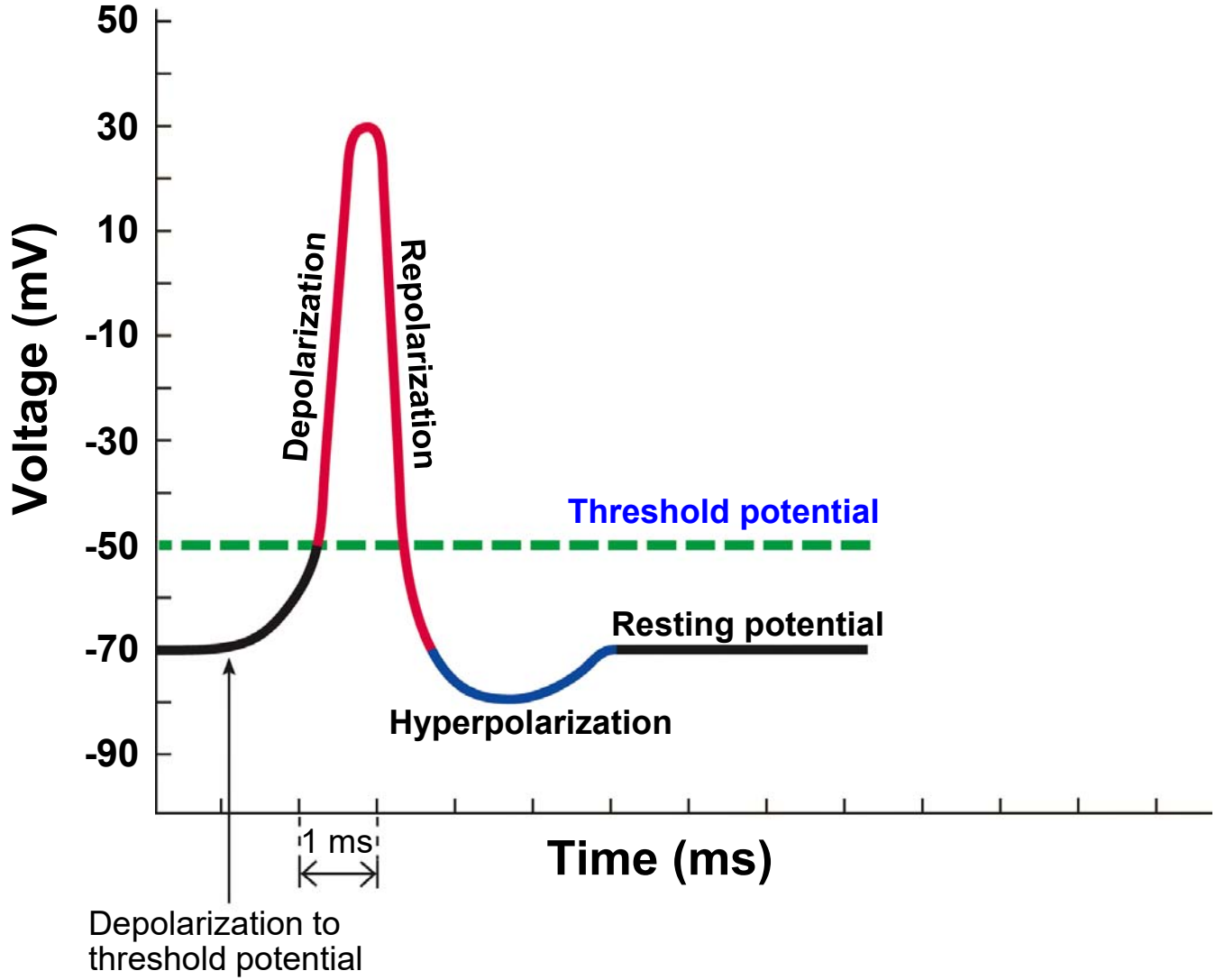
Incoming signals are received and converted to a change in membrane potential

A change in membrane potential initiates action potentials

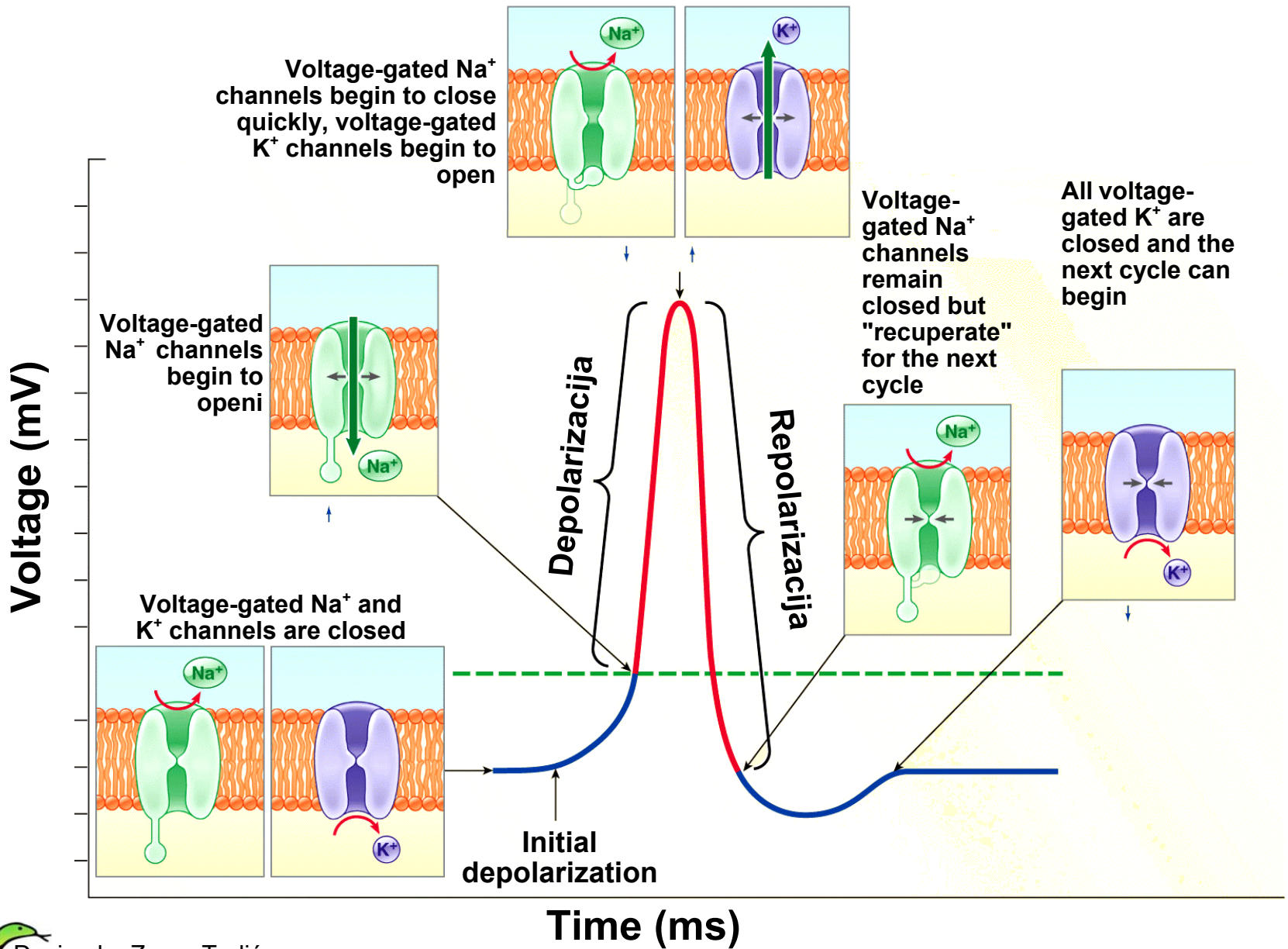
Action potentials are conducted to the axon terminals

Neurotransmitter release transmits a signal to the target cell

The action potential - basic electric phenomenon of the nervous system



How is an action potential generated?



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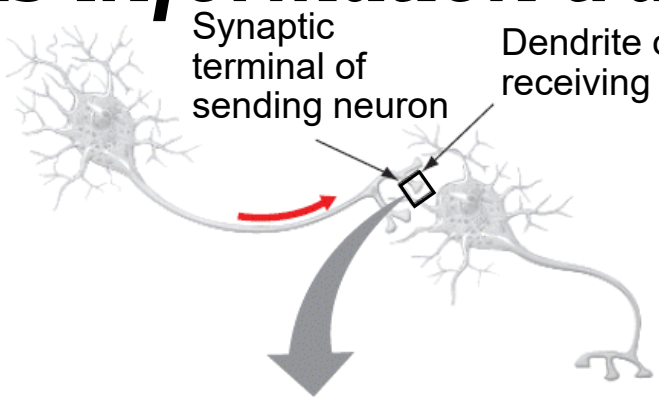
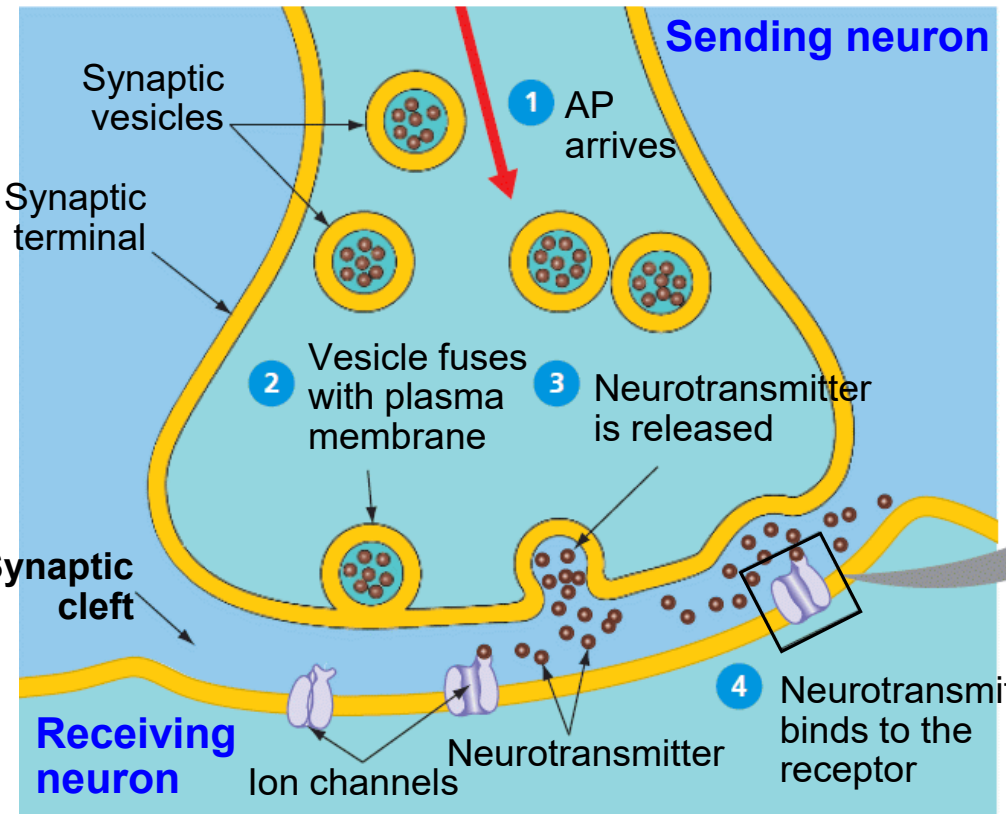
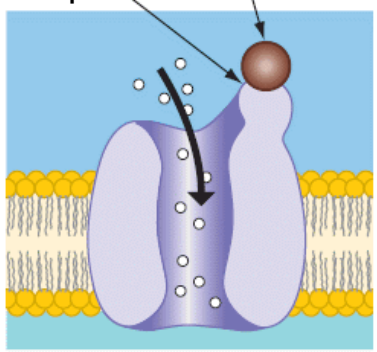
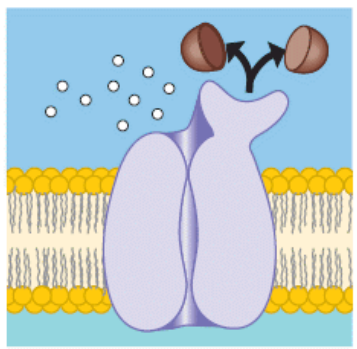
How is information transferred to another neuron?





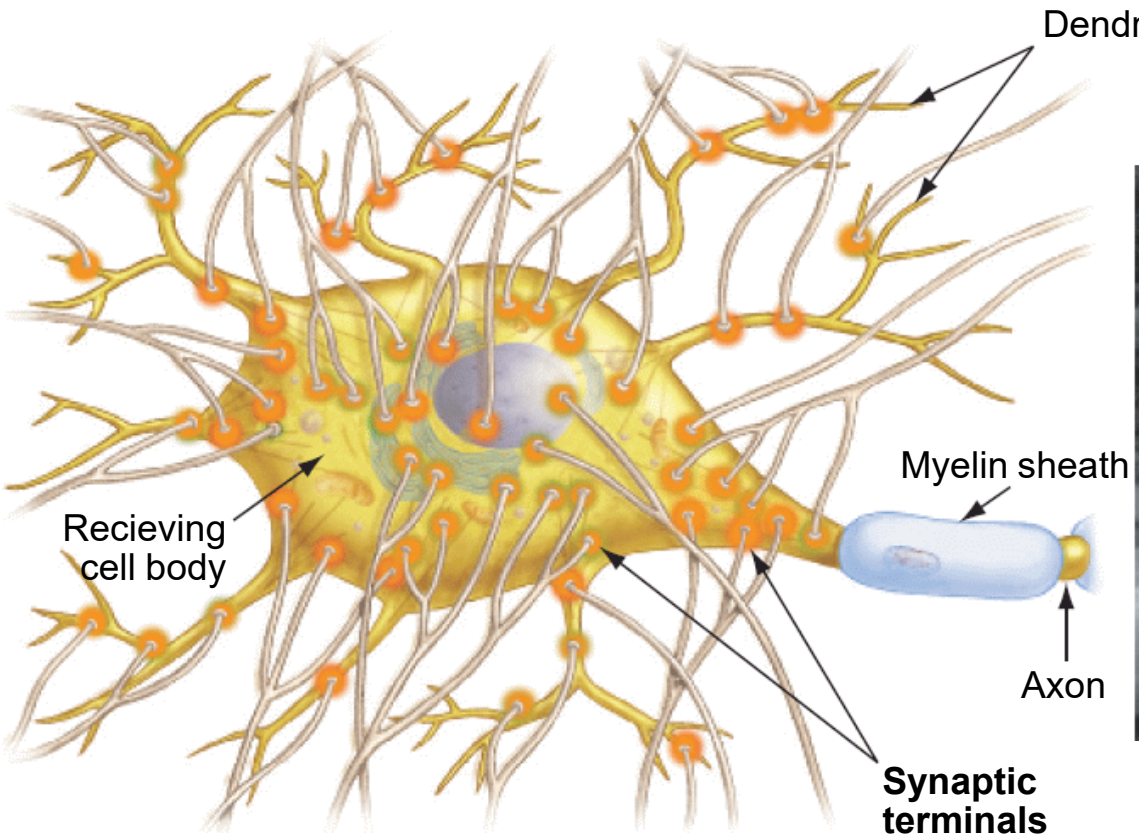


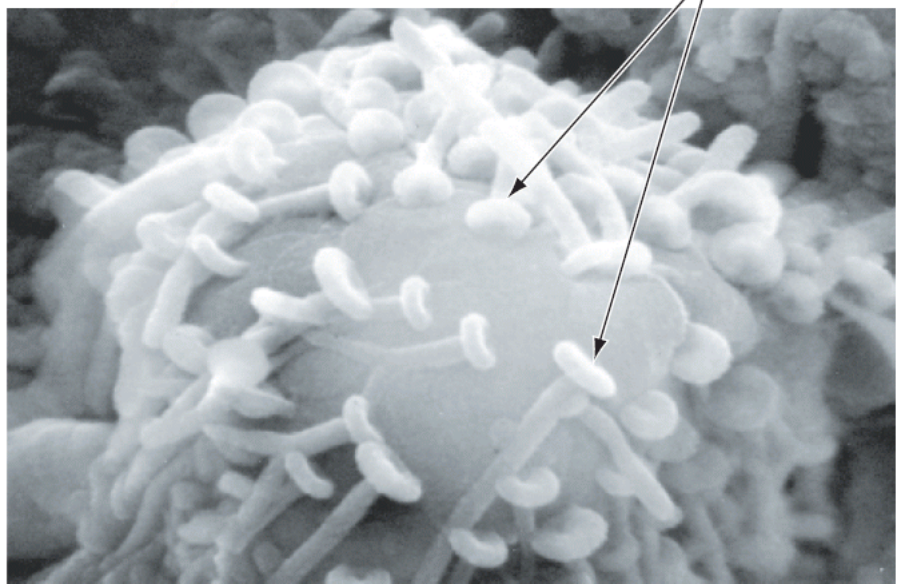
5 Ion channel opens and triggers or inhibits a new action potential



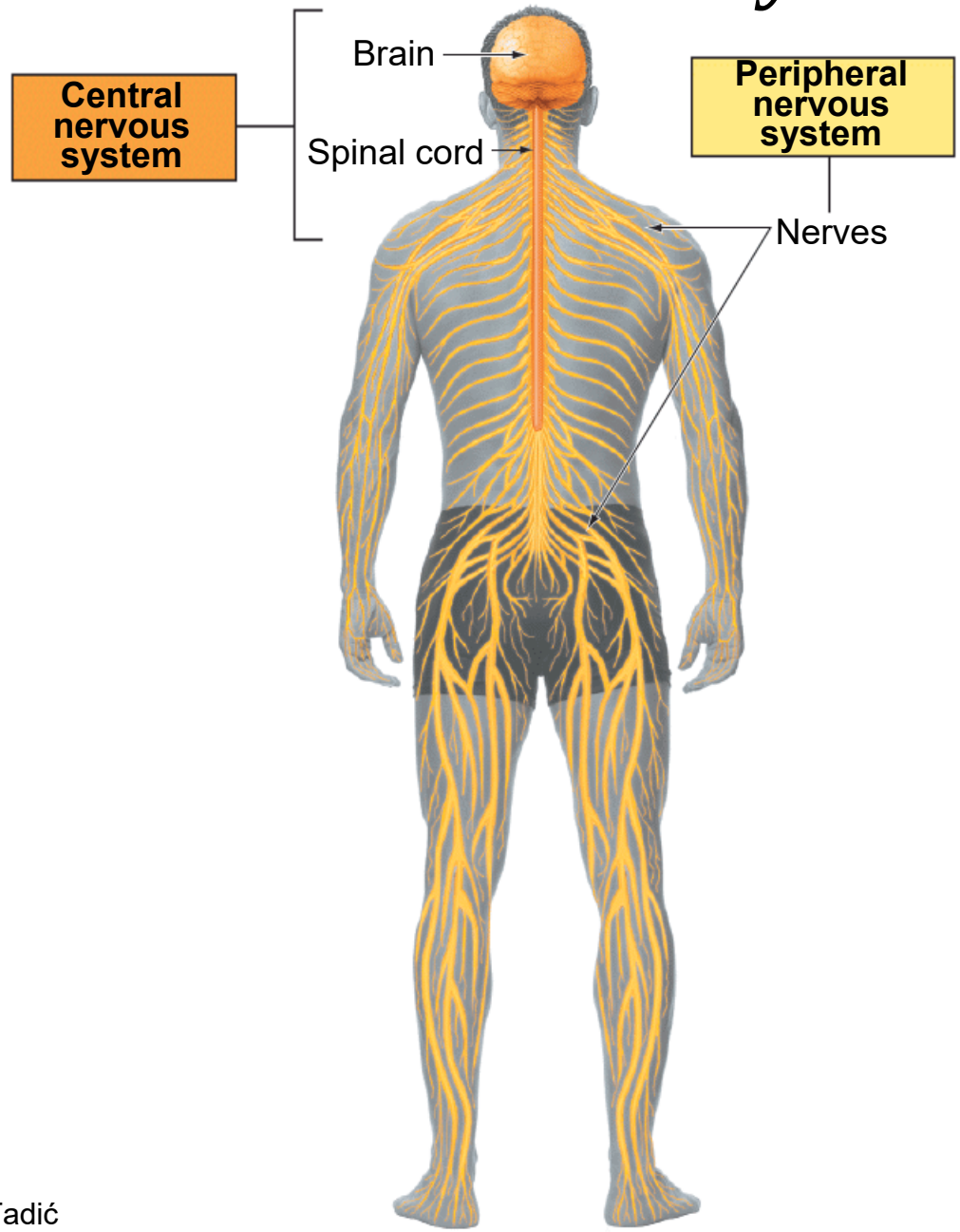
6 Ion channel closes. Neurotransmitter is either broken down, as shown, or transported back into the sending neuron

Multiple synaptic inputs of the neuron

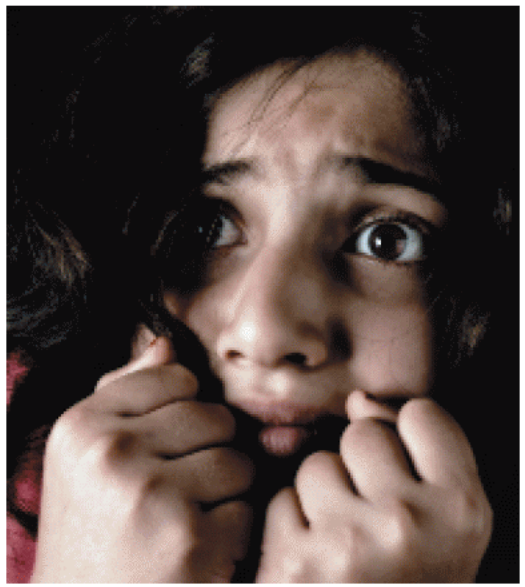




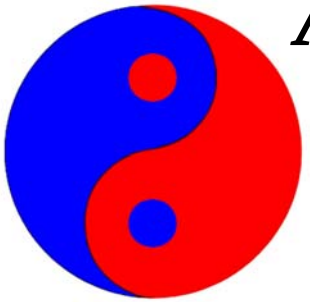
Human nervous system



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"

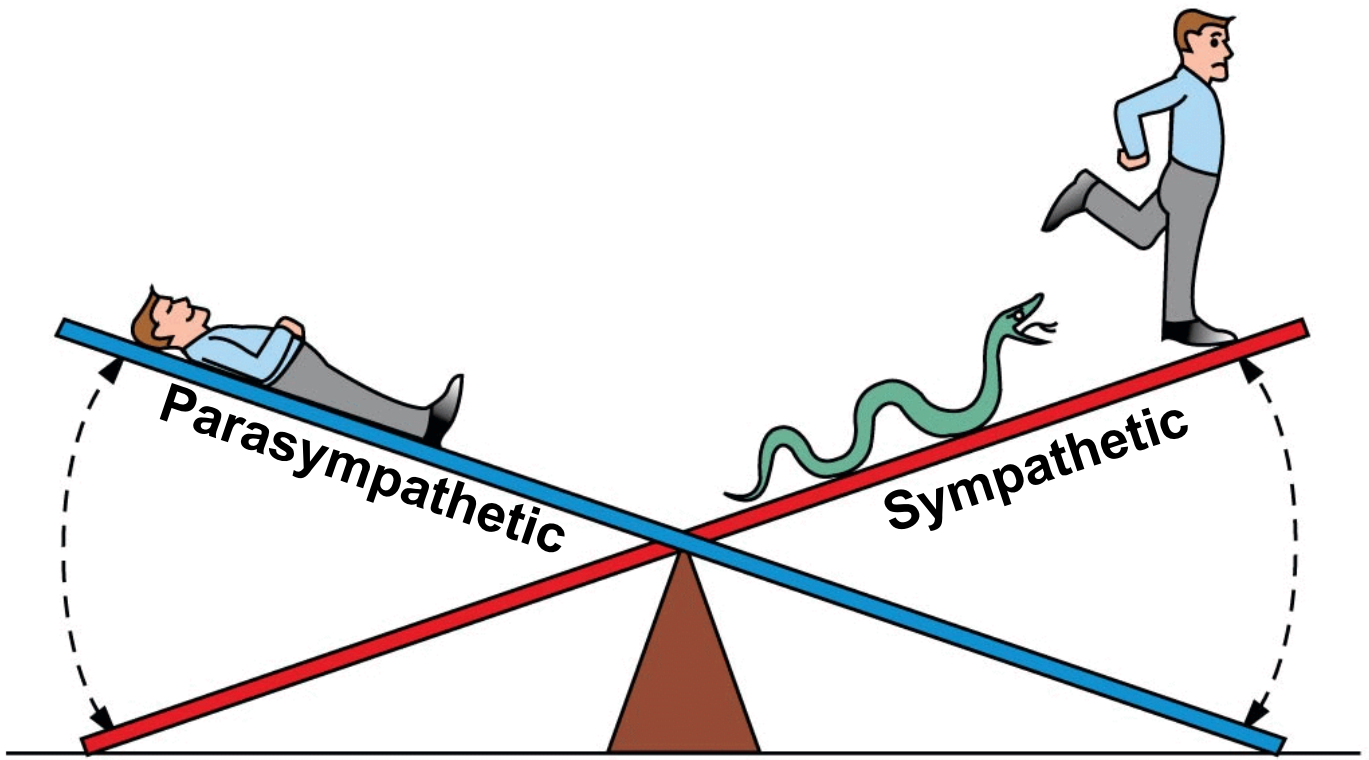
Autonomic nervous system (ANS)



陰陽

yīnyáng

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



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

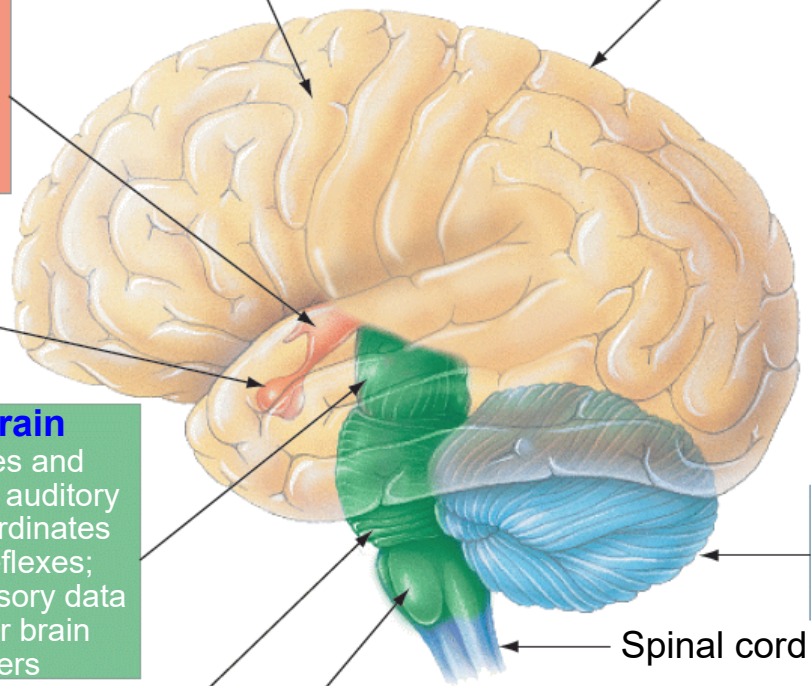
Sympathetic part of the ANS controls "fight or flight" body response

Parts of the brain

Cerebrum
Performs sophisticated integration

Cerebral cortex
Outer layer of the cerebrum: involved in memory, learning, speech, emotions, formulates complex behavioural responses

Hypothalamus
Regulates autonomic nervous system; serves as homeostatic control center; controls pituitary gland, acts as biological clock



Pituitary gland

Brainstem
Consists of midbrain, pons and medulla oblongata; regulates vital functions such as breathing; serves as sensory and motor filter for other parts of the brain

Midbrain
Receives and integrates auditory data; coordinates visual reflexes; sends sensory data to higher brain centers

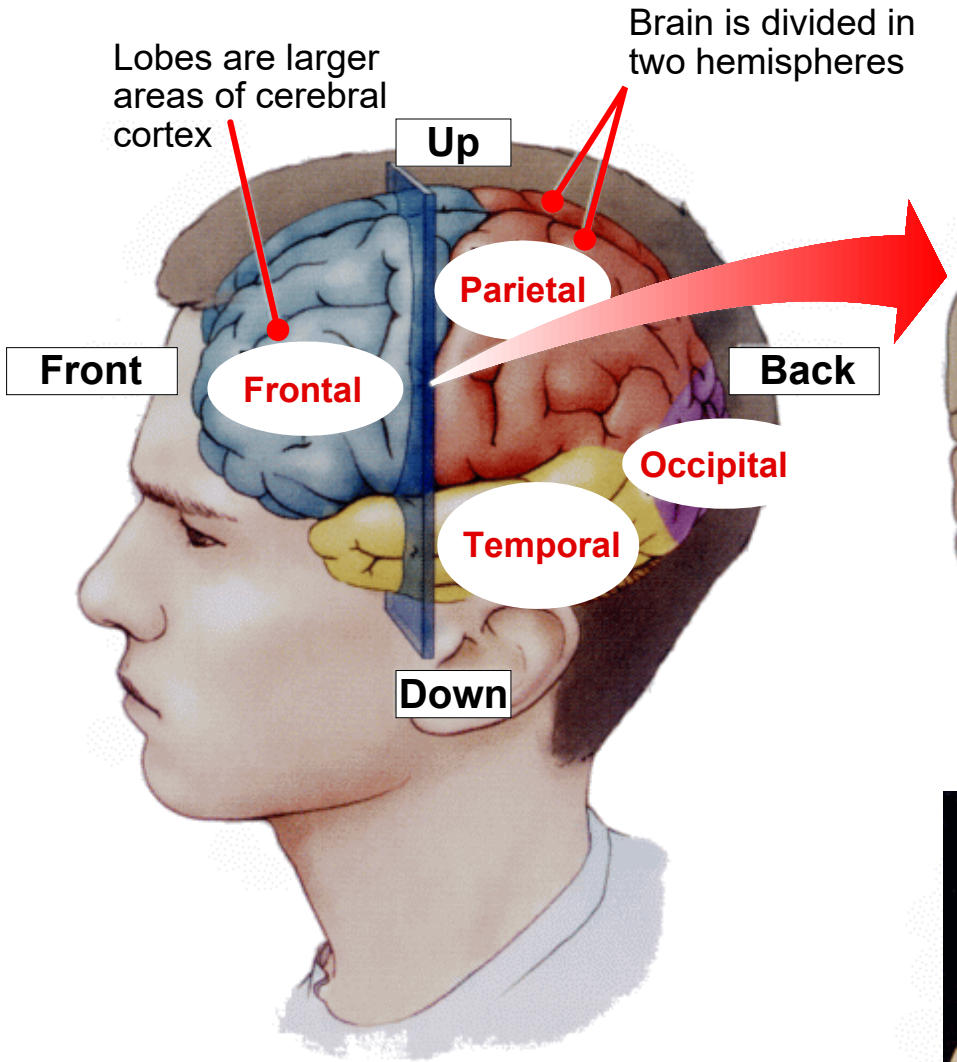
Pons
Controls breathing

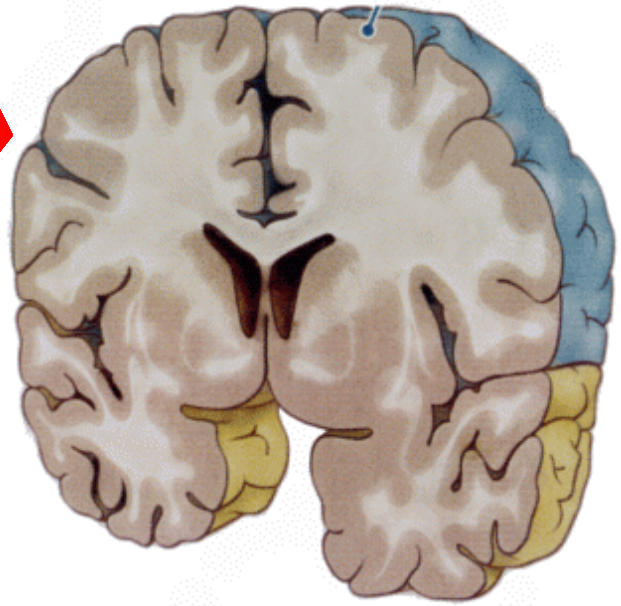
Medulla oblongata
Controls breathing, circulation, swallowing, digestion

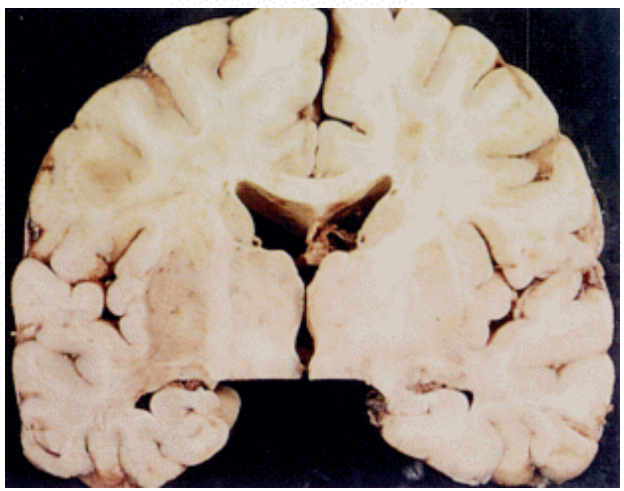
Cerebellum
Controls body movement

Spinal cord

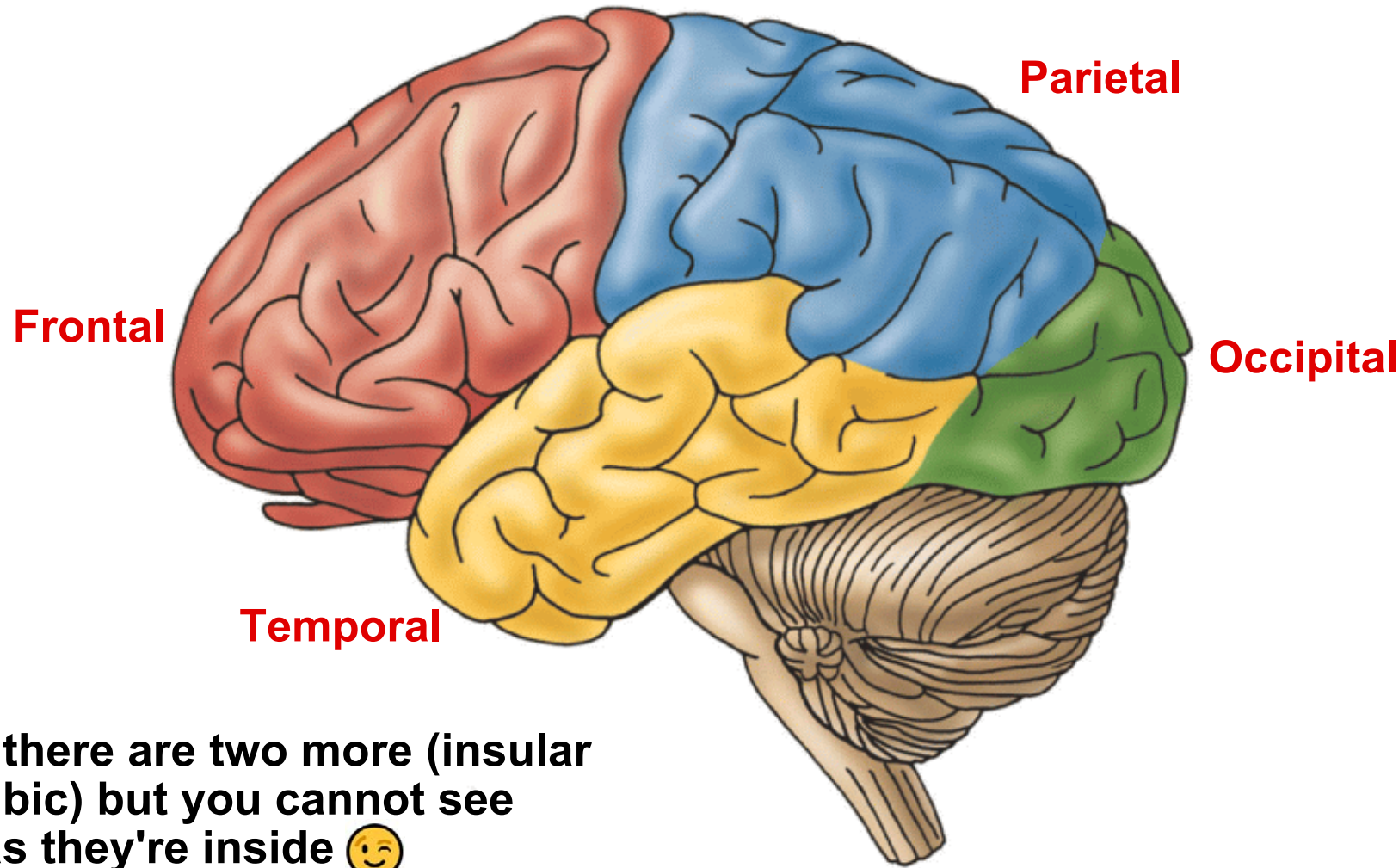
Cerebral hemispheres, lobes and cortex





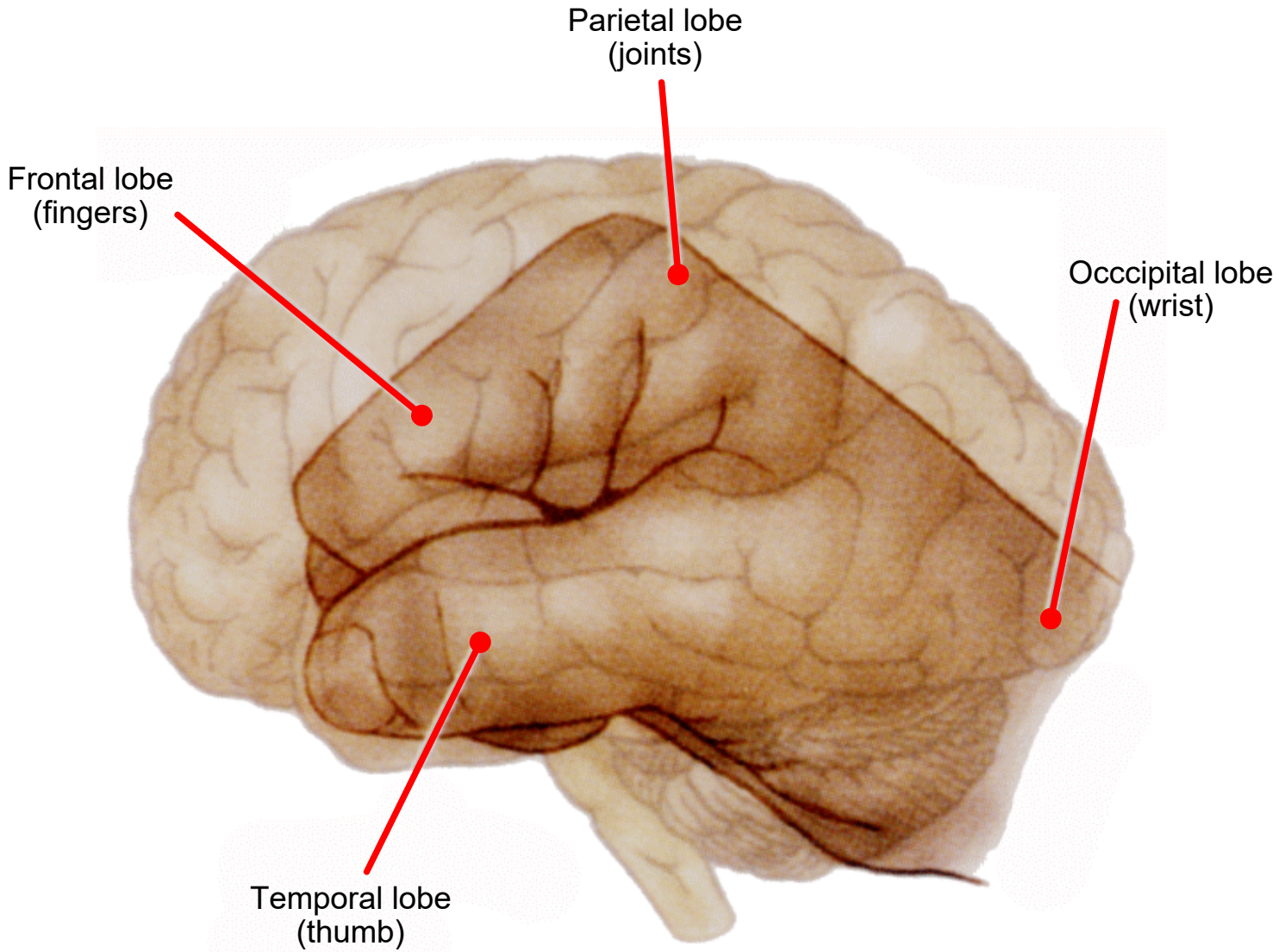


Cerebral lobes. . .

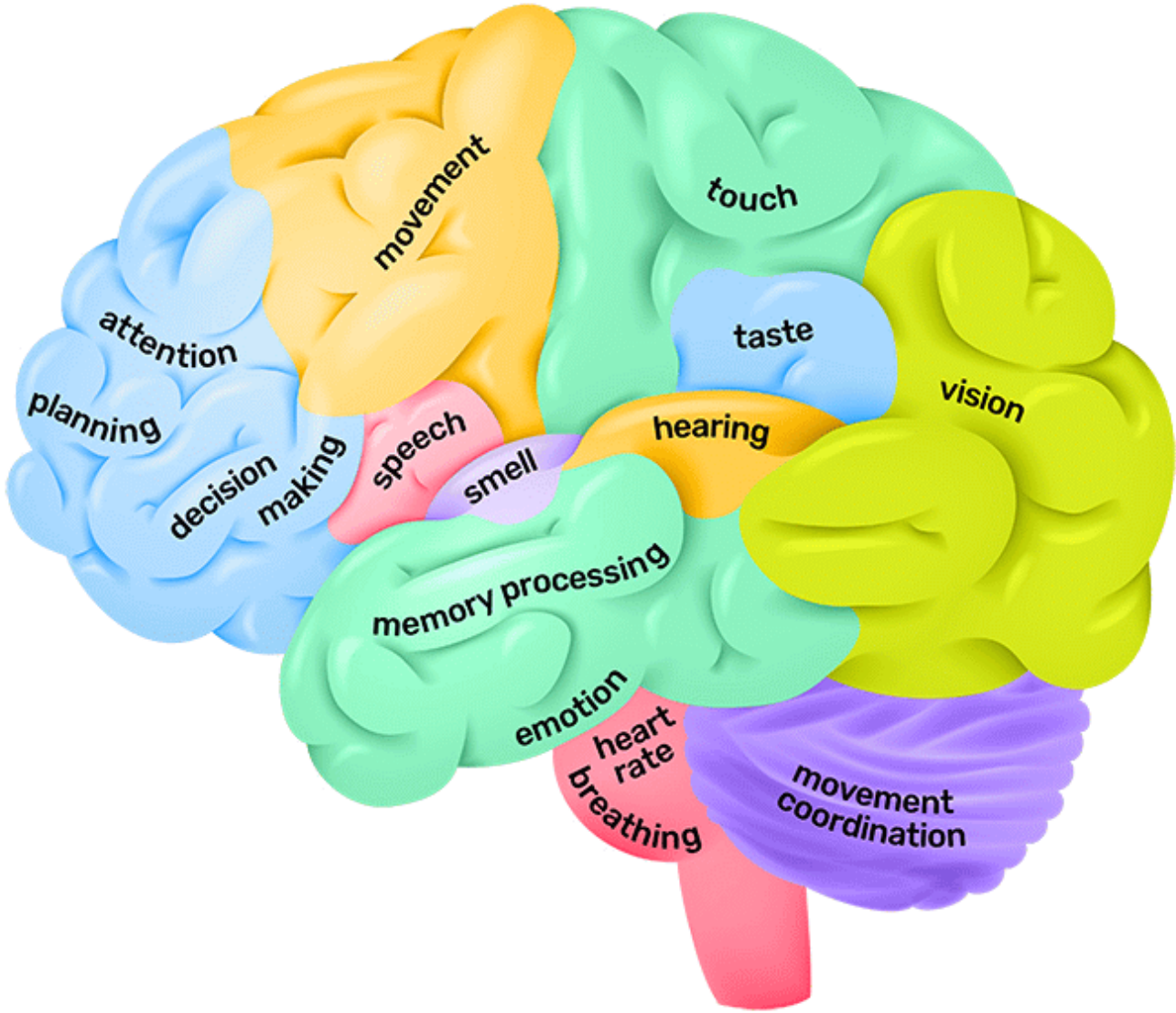


In fact, there are two more (insular and limbic) but you cannot see them, as they're inside 😉

. . .and how to remember them



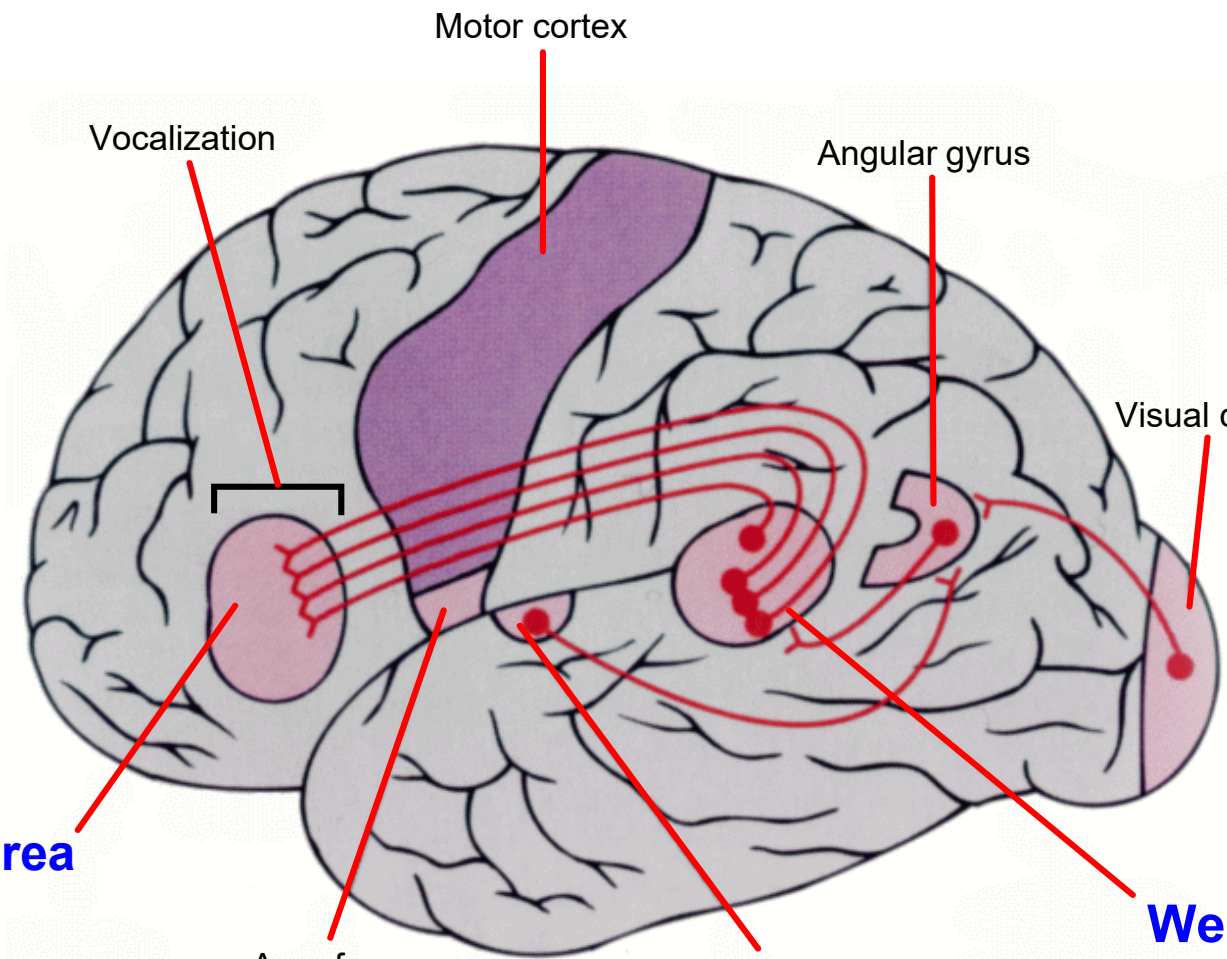
Functional areas of the left cerebral hemisphere



Human language - a higher brain function

Paul Broca
(1824-1880)

Karl Wernicke
(1848-1904)



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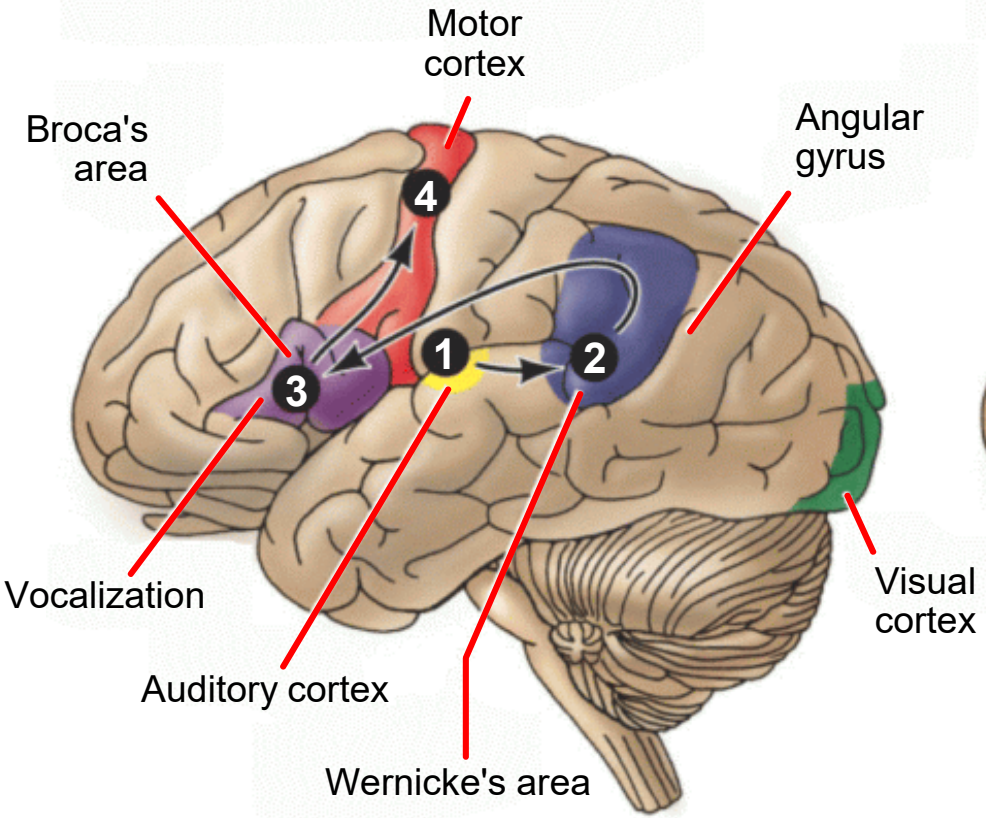
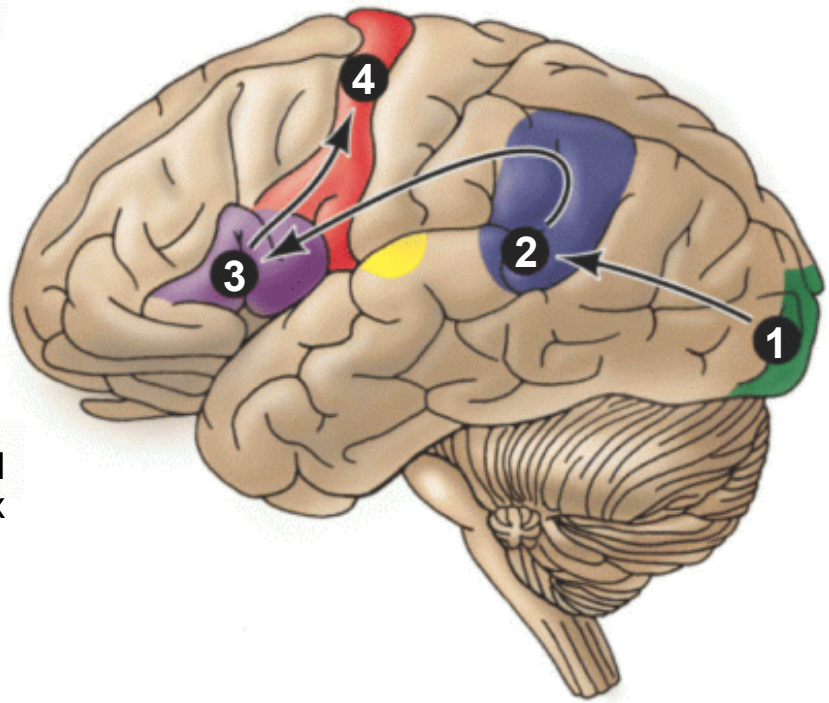
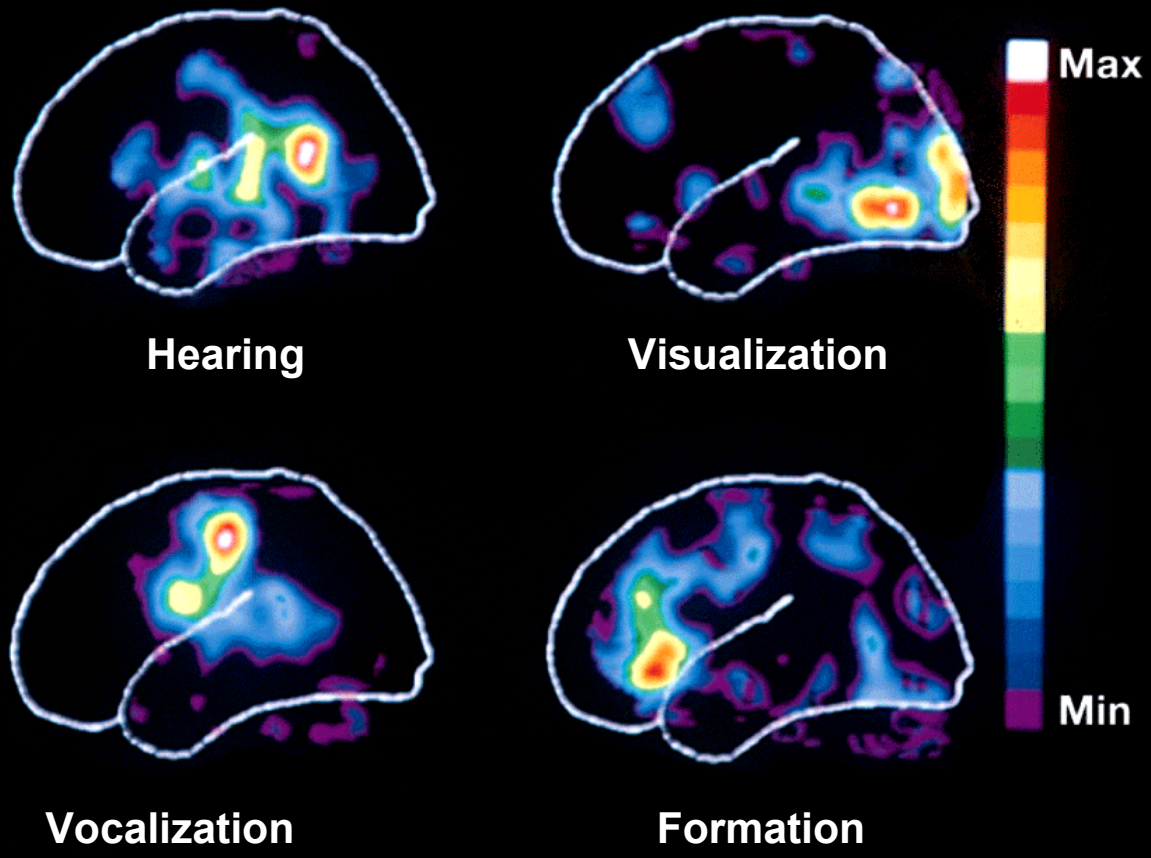
Repeating of the heard word





Vocalization of the written word

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

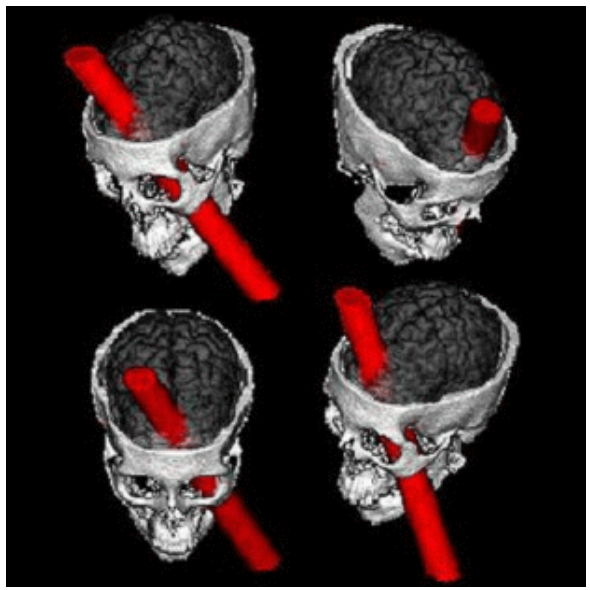


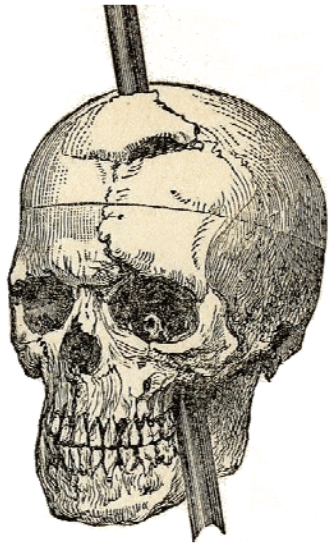
Functions of the frontal lobe

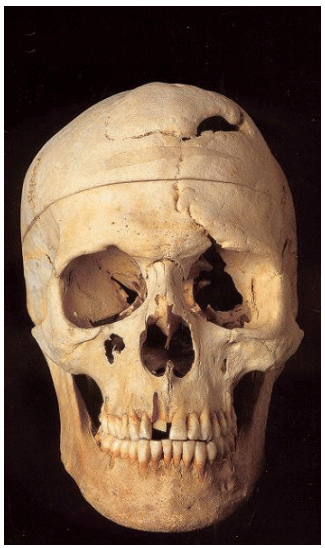
The Nobel Prize for physiology or medicine in 1949

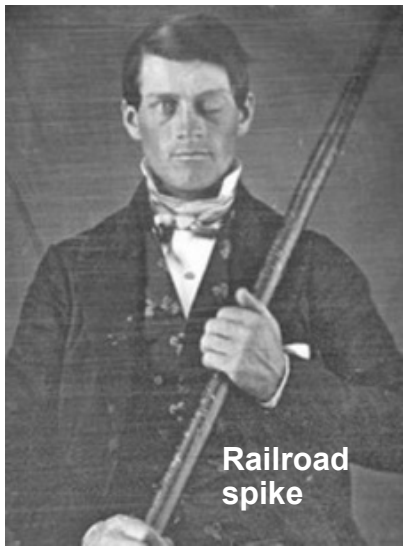
Egas Moniz
(1874-1955)

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



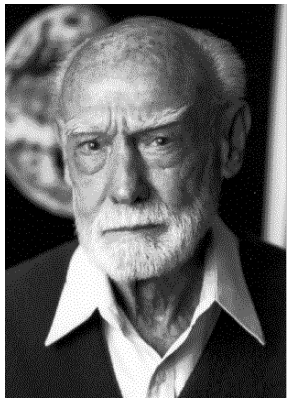






Phineas Gage
(1823-1860)

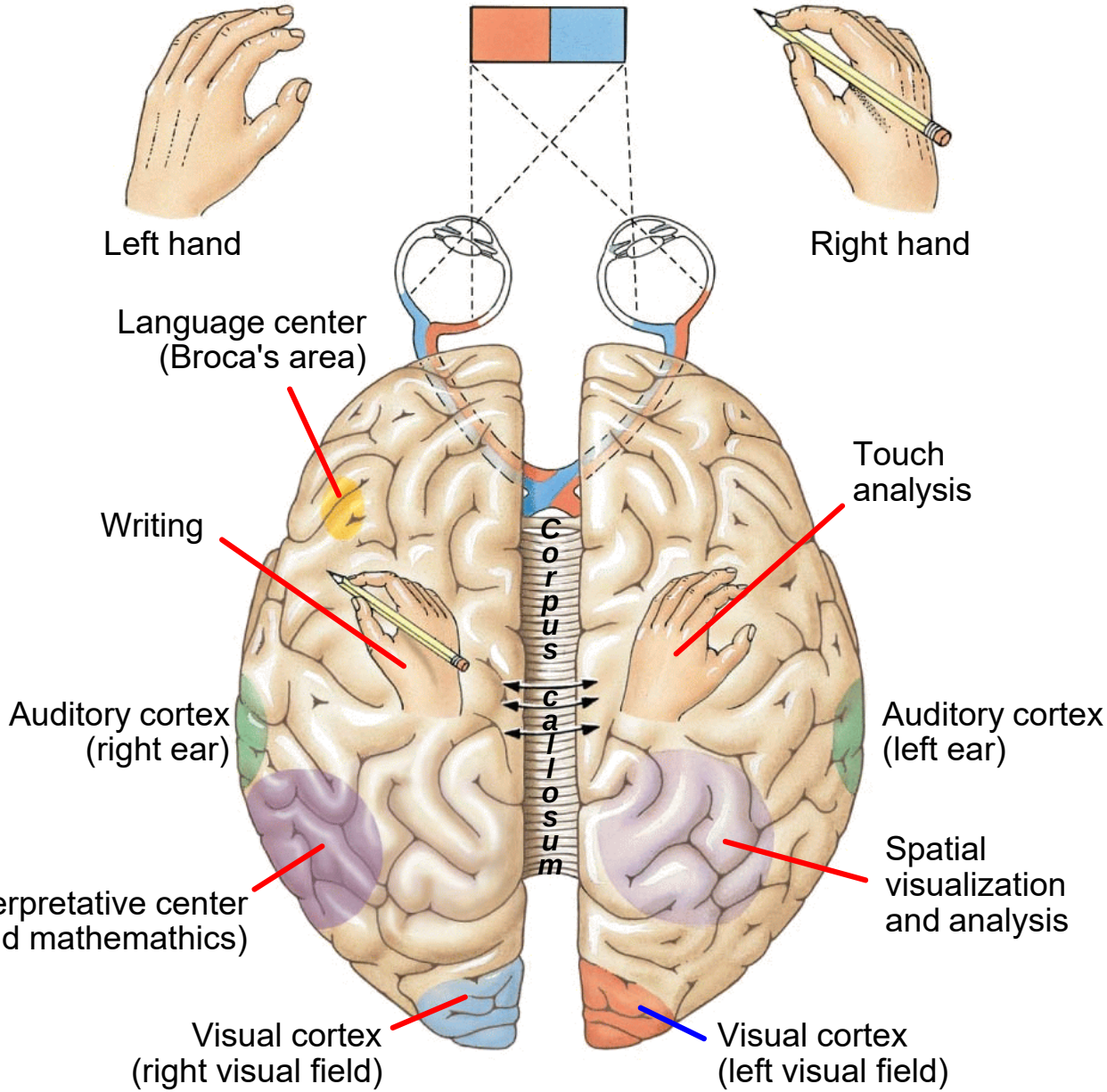
Hemispheres are not functionally symmetrical!



Roger W. Sperry
(1913-1994)

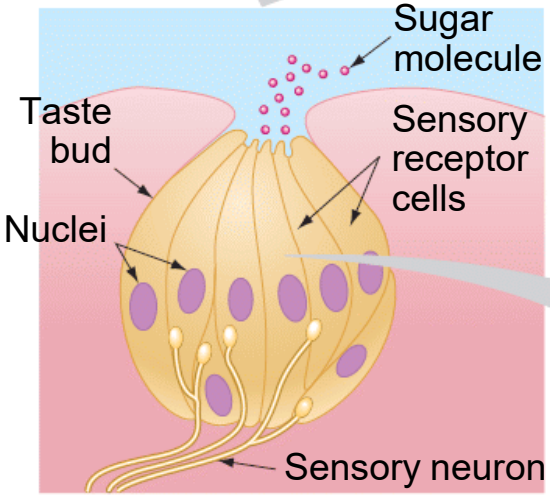
The Nobel Prize for physiology or medicine in 1981

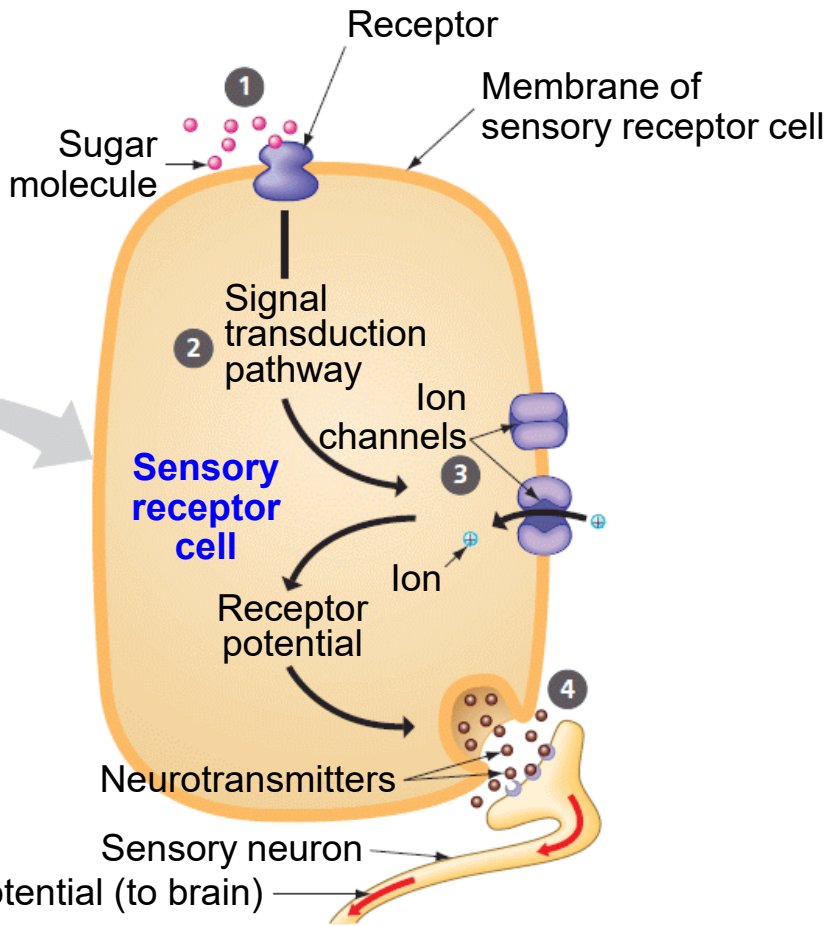
"for his discoveries concerning the functional specialization of the cerebral hemispheres"



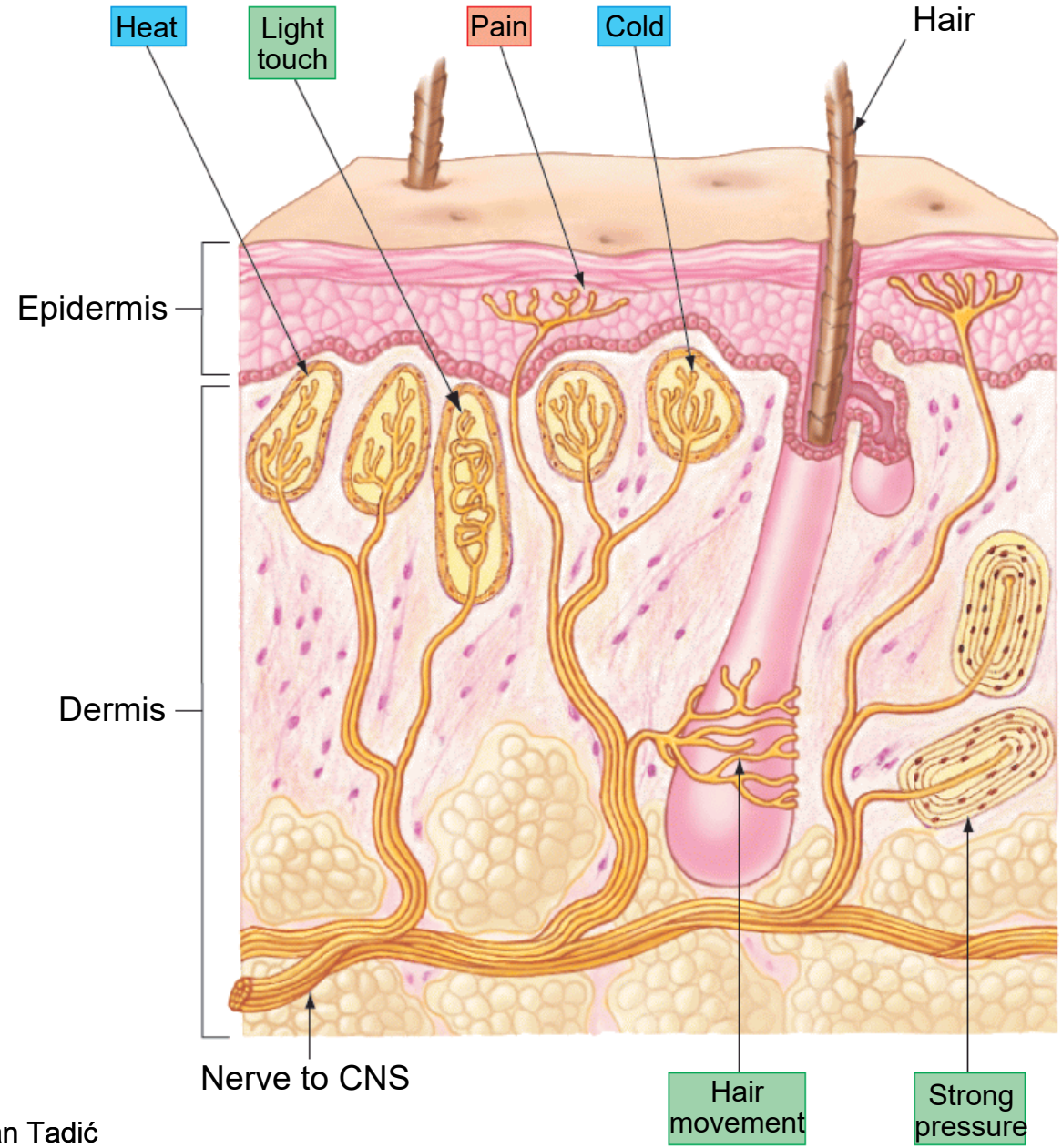
Design by Zoran Tadić

Sensory transduction: An example





Somatosensory receptors in human skin



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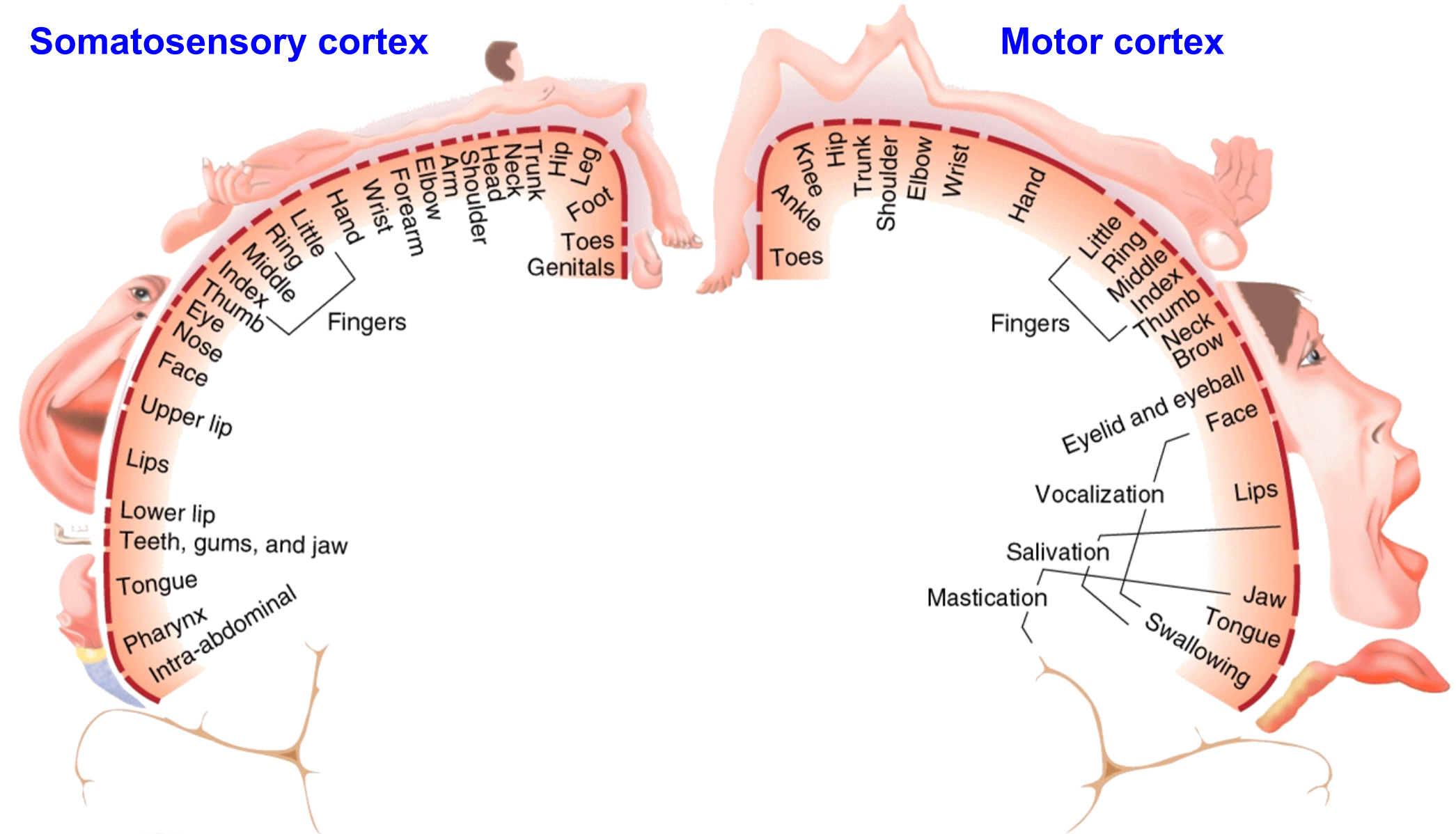
Somatosensory and motor cortical maps



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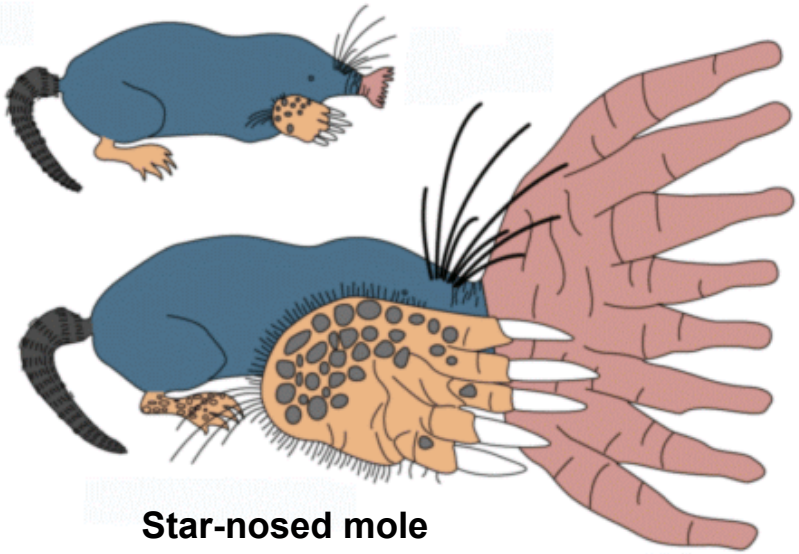
Somatosensory and motor hommunculi

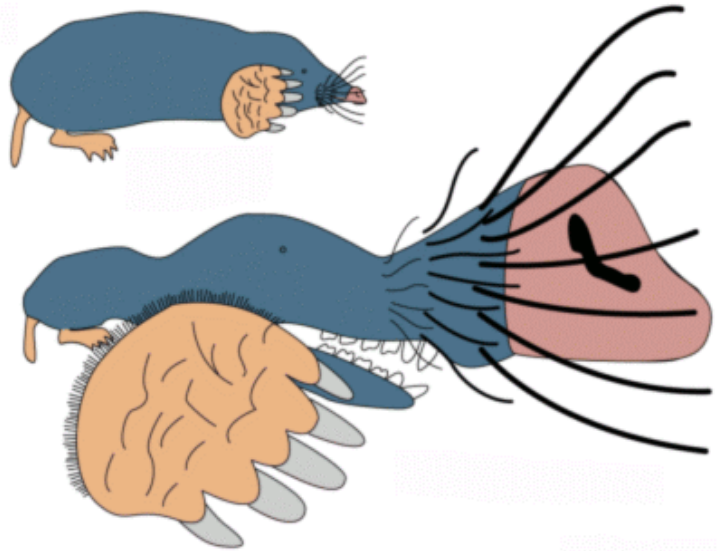
Somatosensory hommunculus

Motor hommunculus

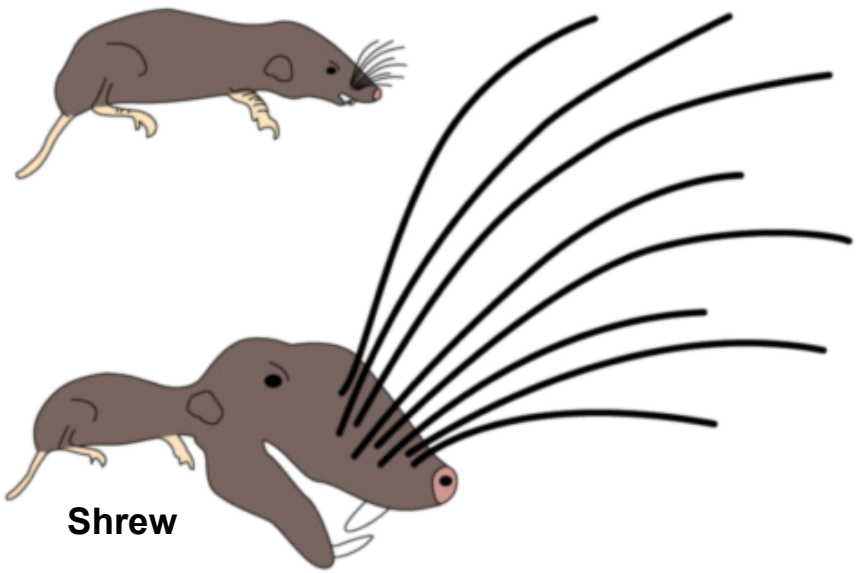
The same applies to the animals!



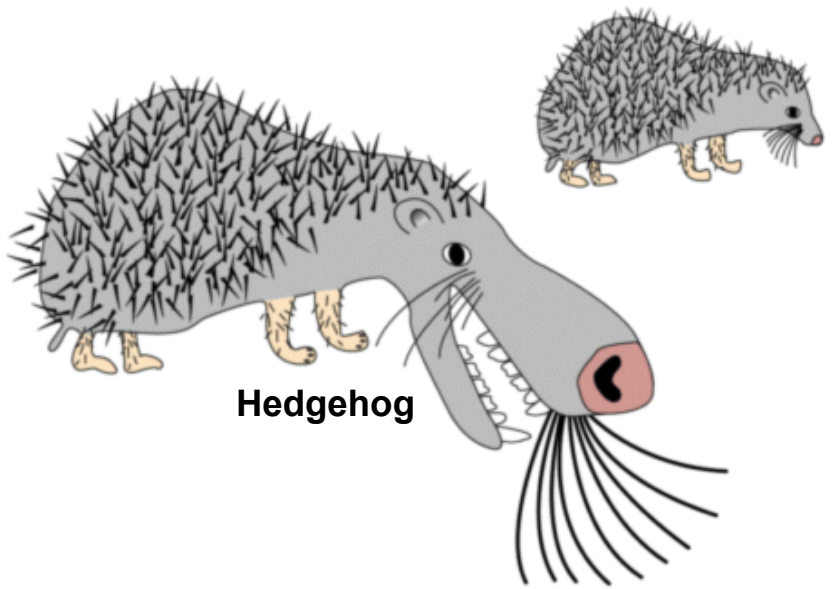
Star-nosed mole



Common mole

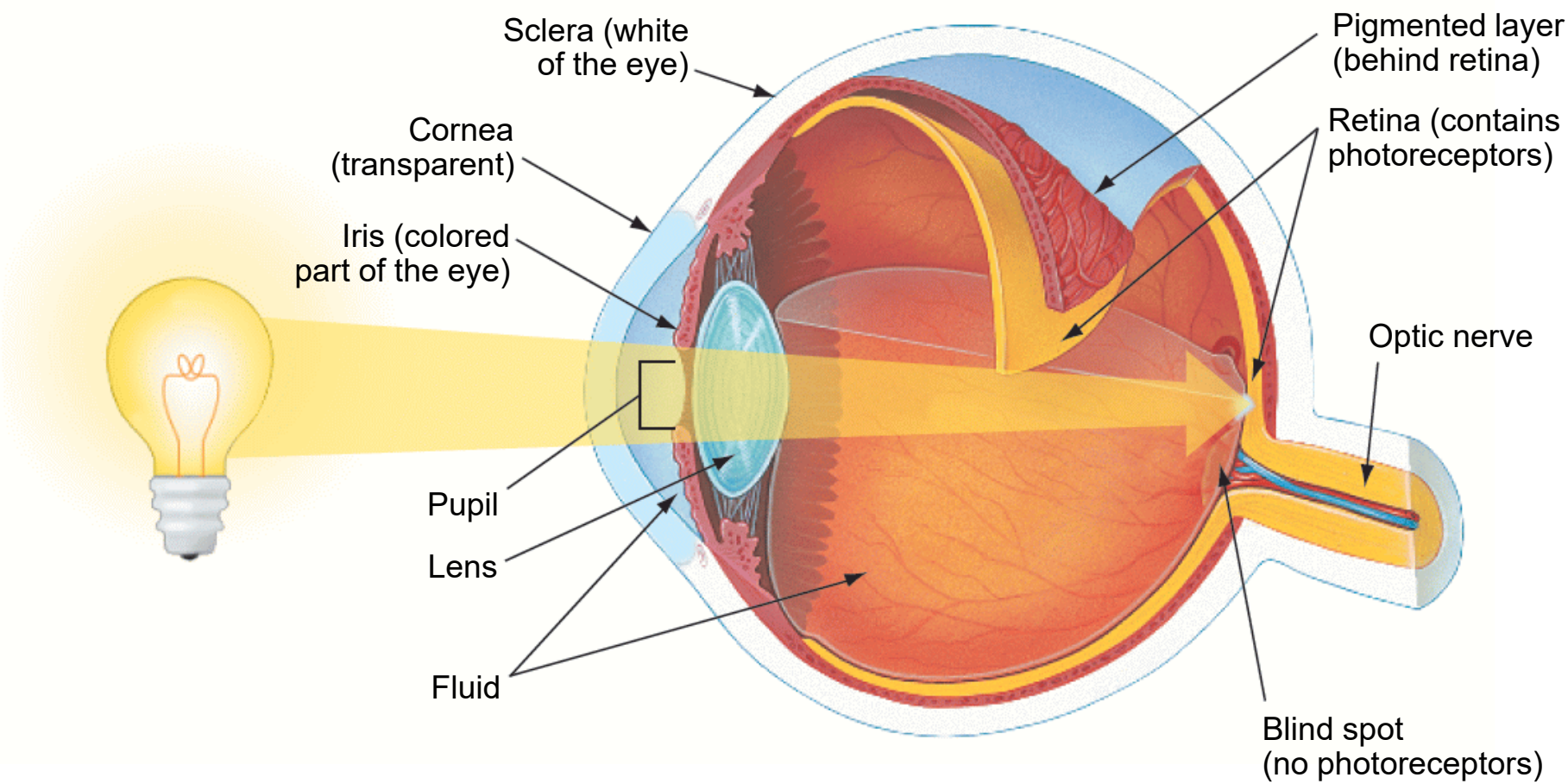


Shrew

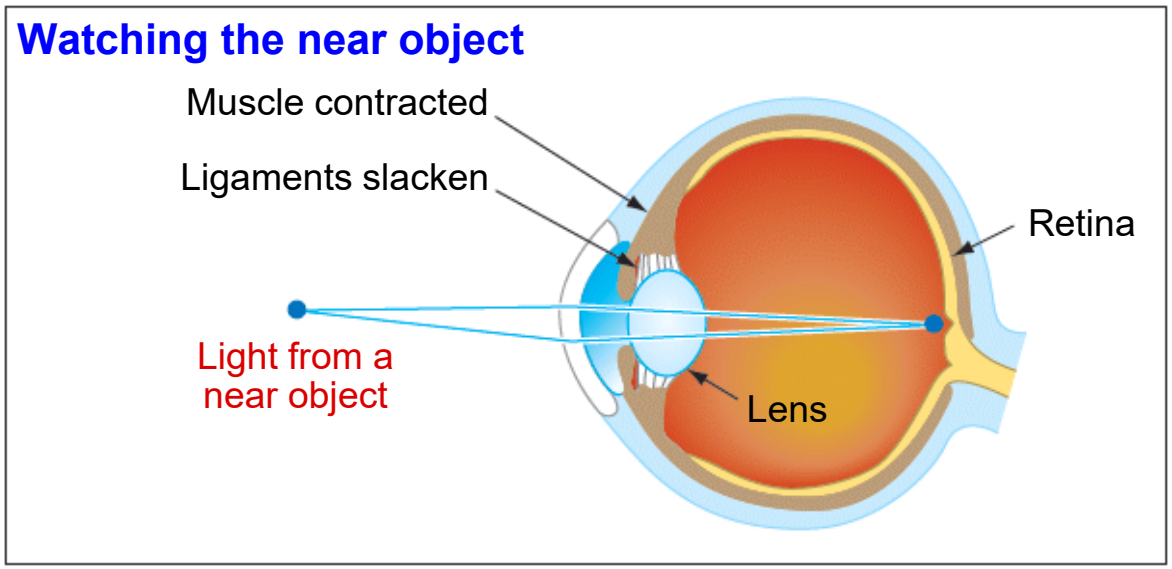


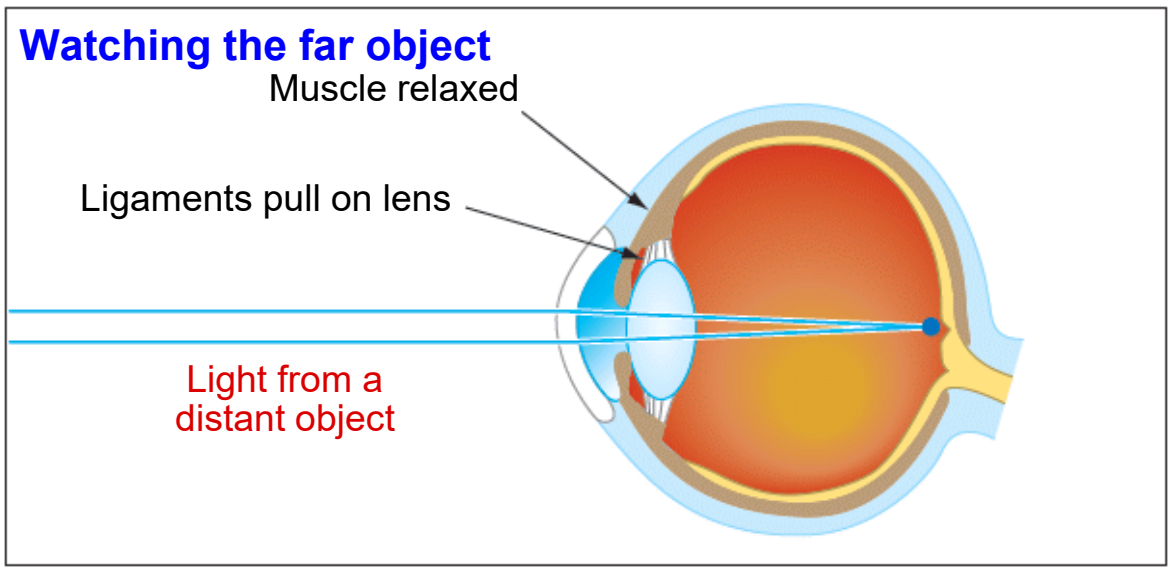
Hedgehog

Light path to the retina

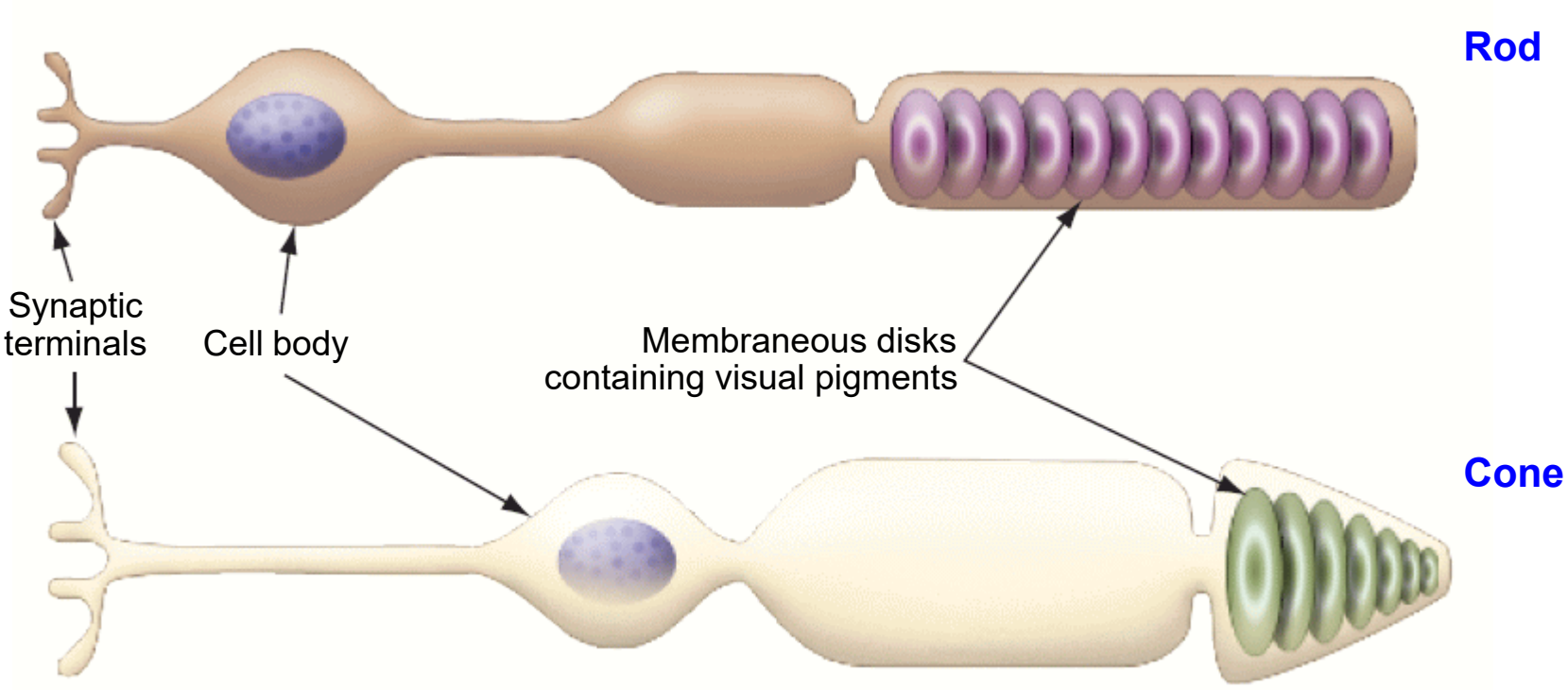


How does the lens focus light?

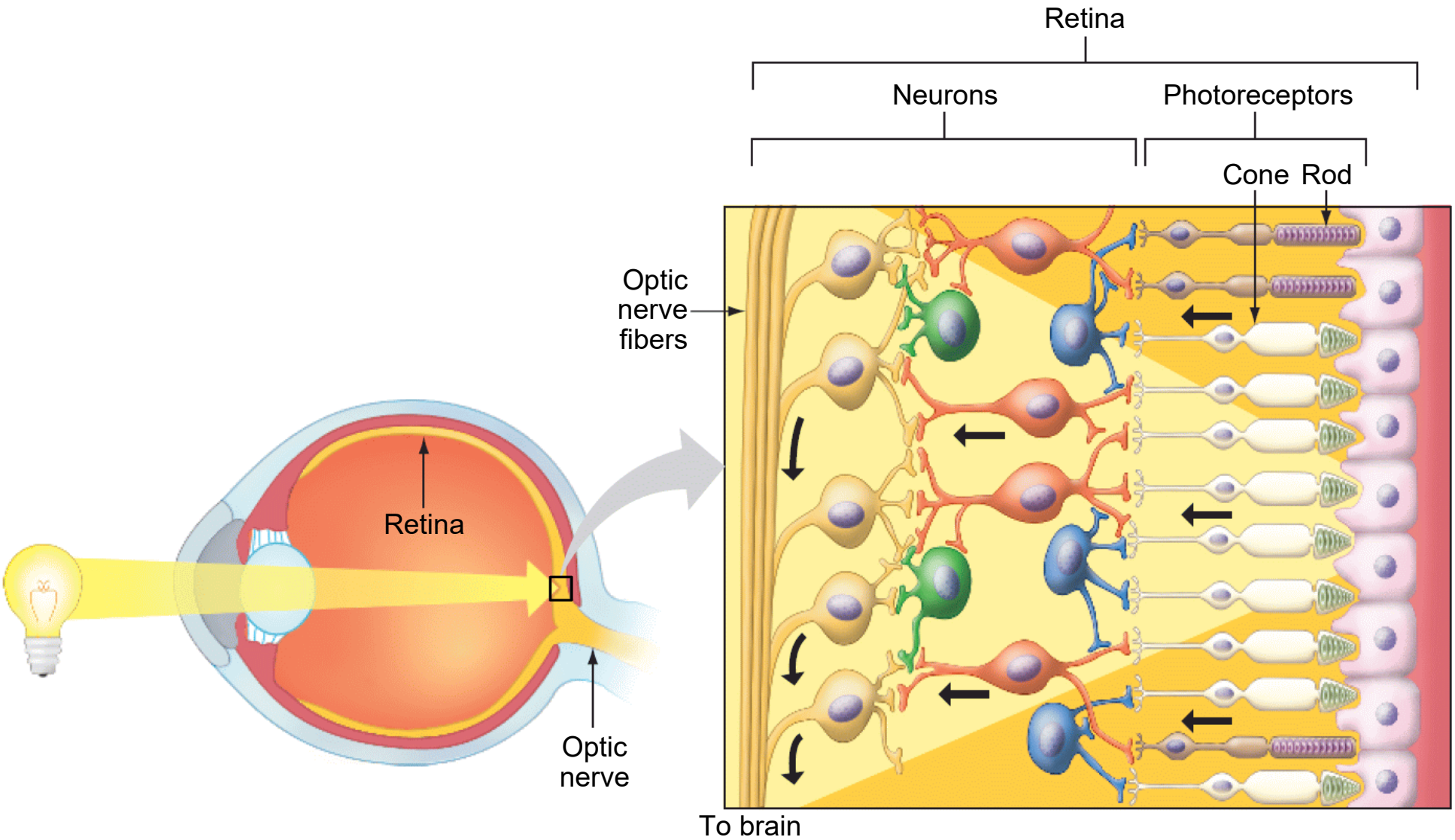




Photoreceptors in human retina

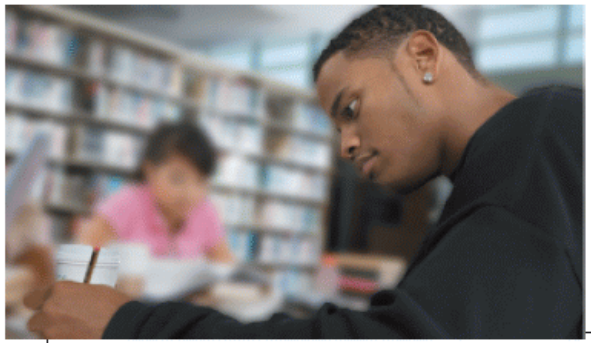


Photoreceptor arrangement in retina

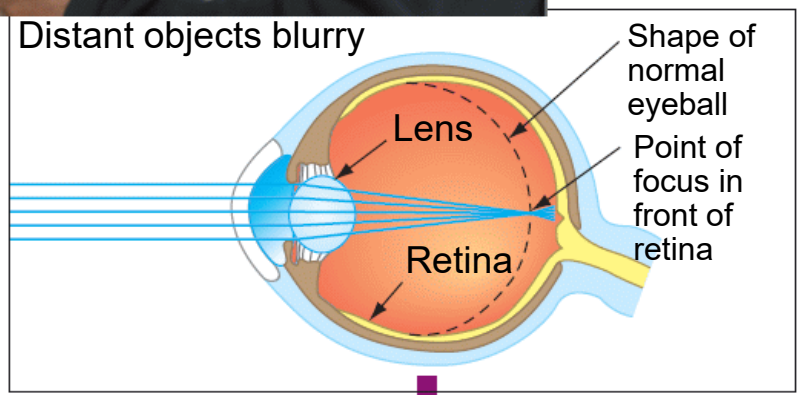


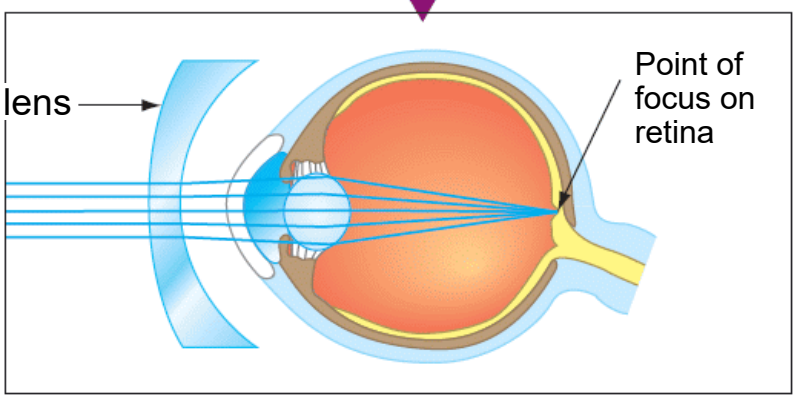
Design by Zoran Tadić

Myopic and hyperopic eye



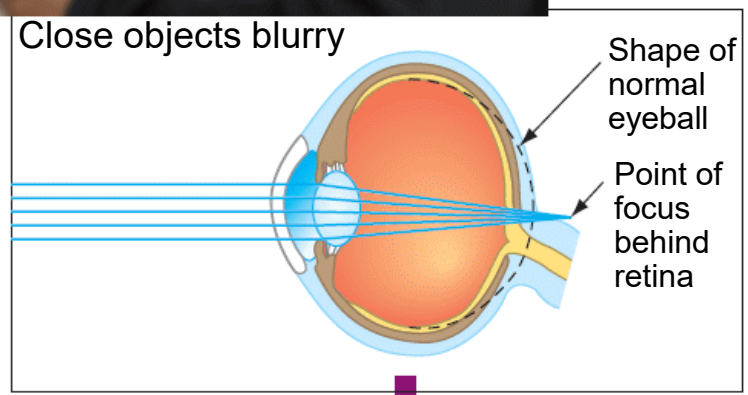
Distant objects blurry

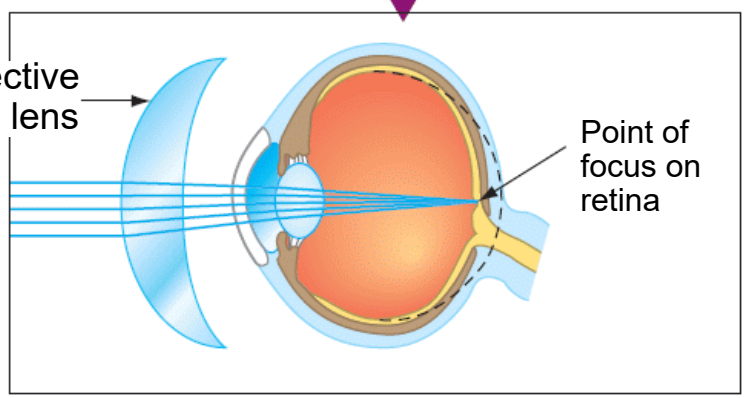




Myopic eye (eyeball too long)

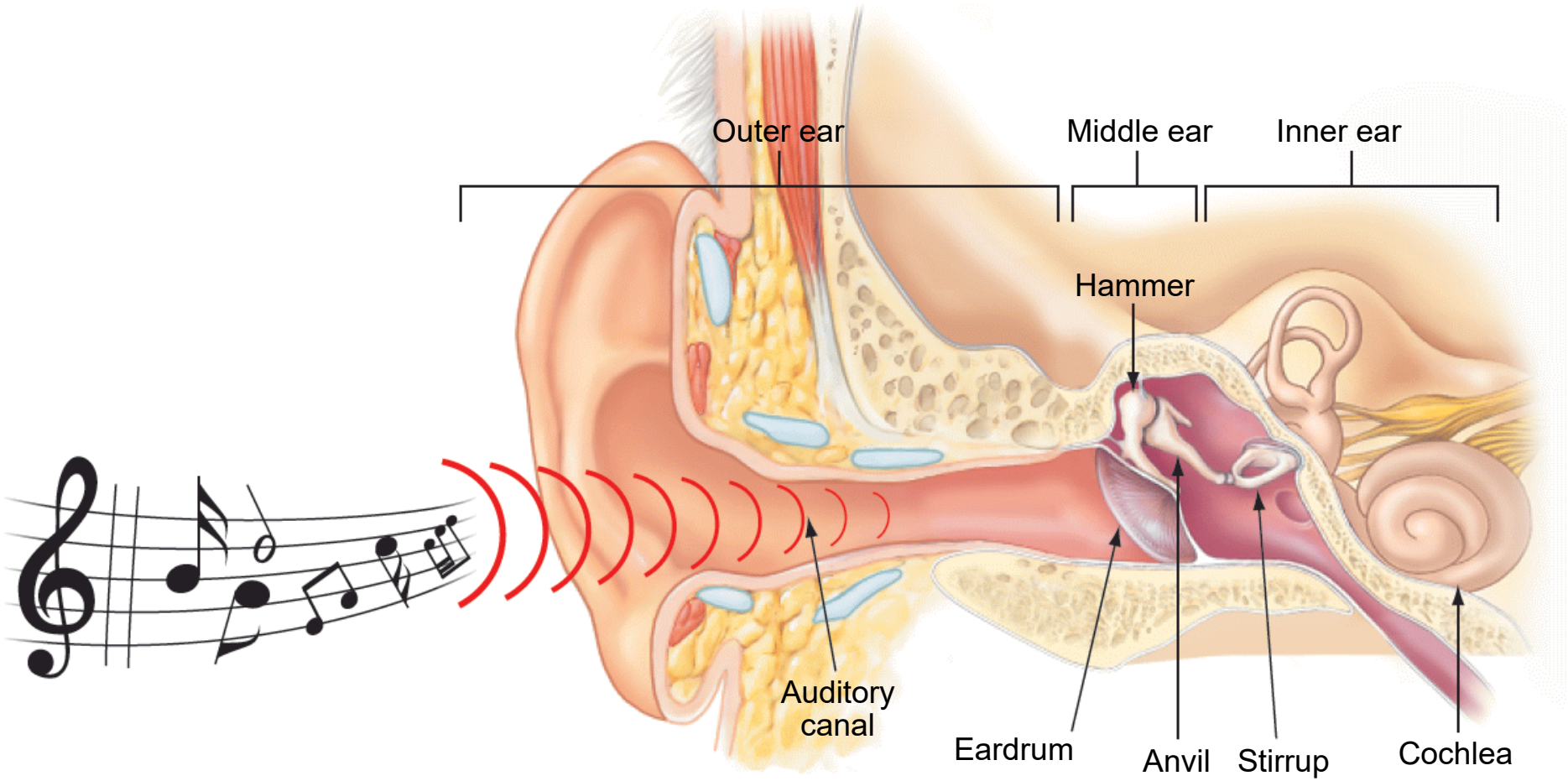
Close objects blurry





Hyperopic eye (eyeball too short)

Pathway of sound to the ear

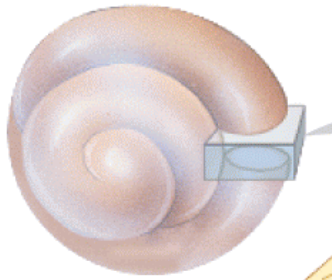


The structure and function of cochlea

The Nobel Prize for physiology or medicine in 1961

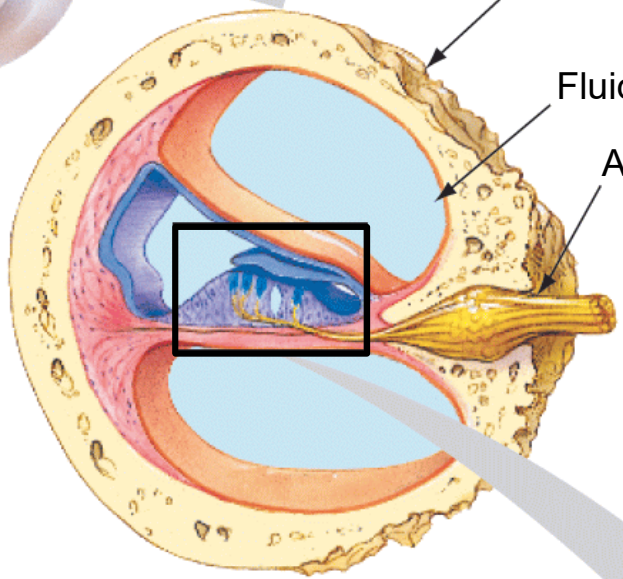
"for his discoveries of the physical mechanism of stimulation within the cochlea"

György Békésy (1899-1972)

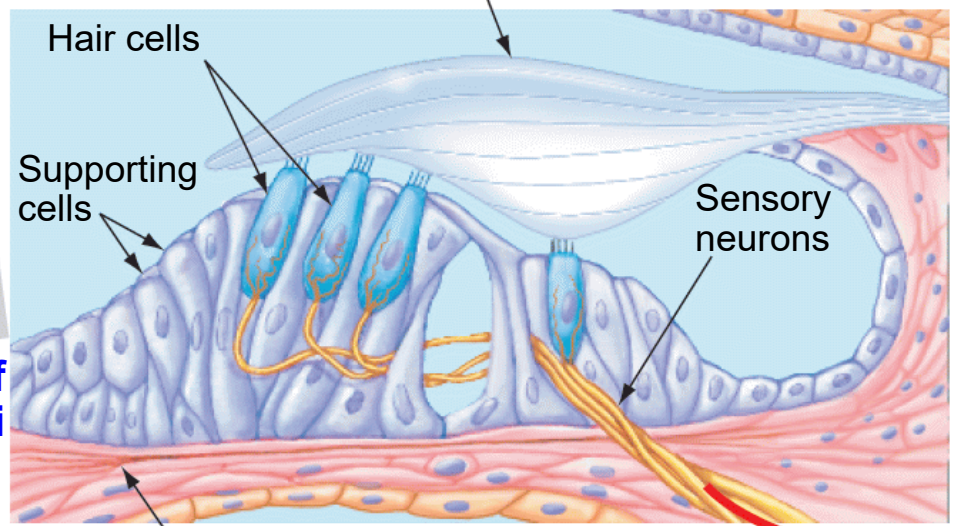


Cochlea

Cross section through cochlea



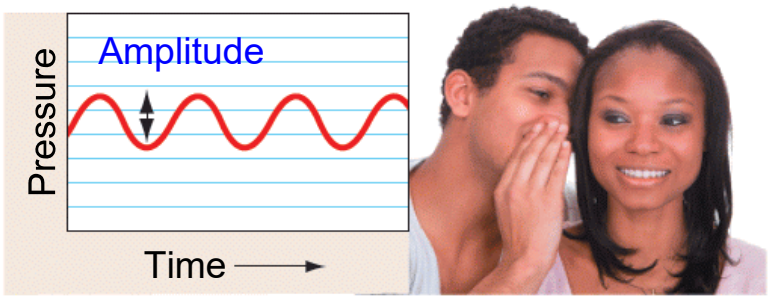
Organ of Corti



Sound characteristics and their coding by cochlea

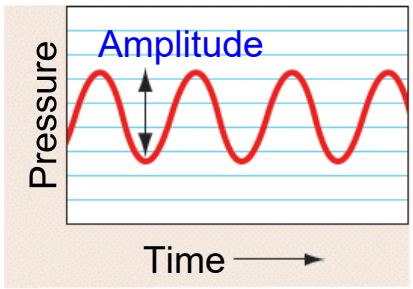
INTENSITY OF SOUND

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.

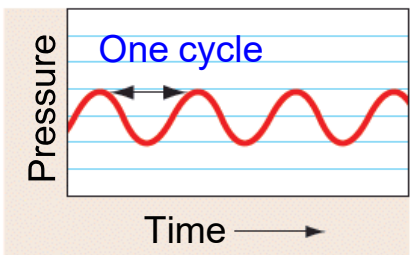
High amplitude = loud sound



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

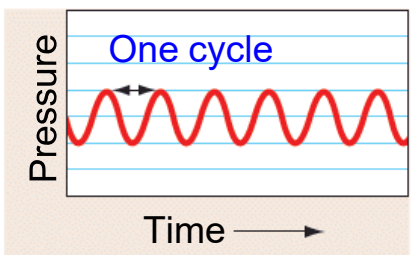
THE PITCH OF SOUND

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

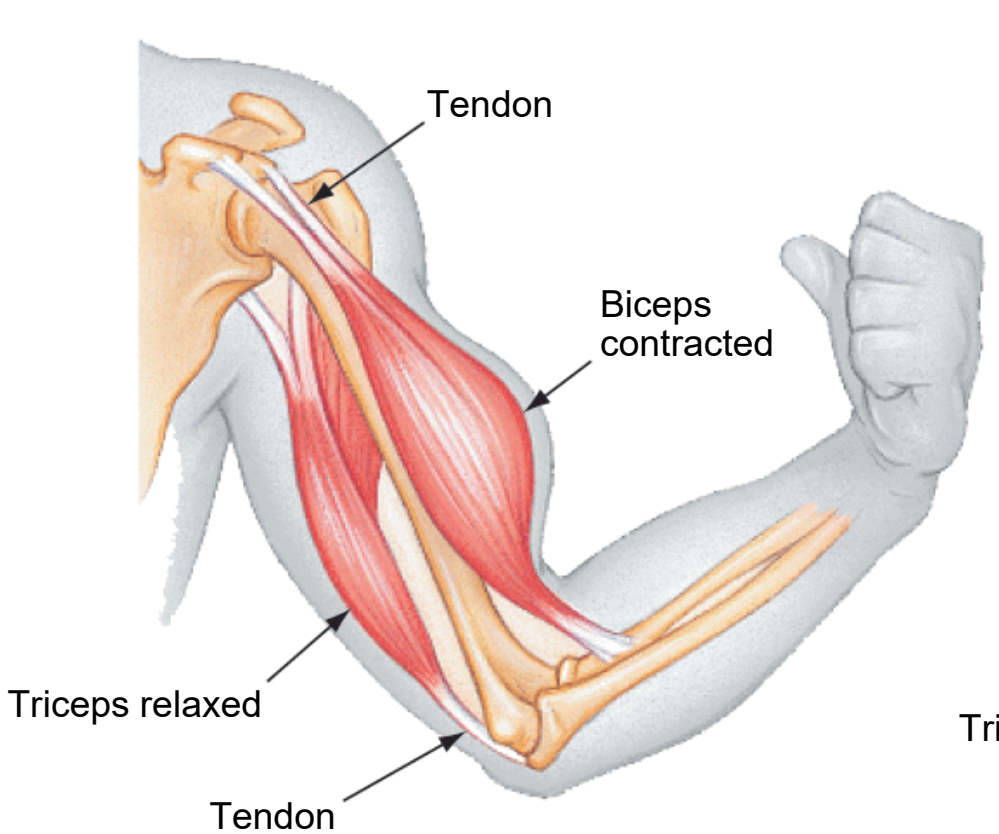


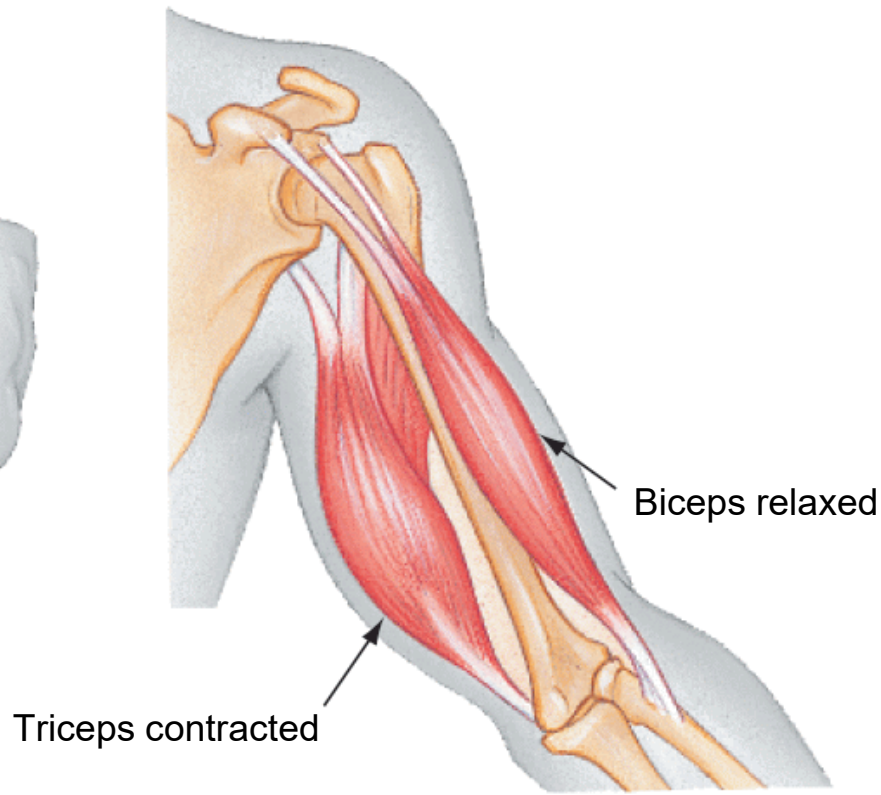
High-frequency sounds cause hair cells at the entrance of the inner ear to vibrate. Action potentials generated in this region of the ear are perceived as high sounds.

Design by Zoran Tadić

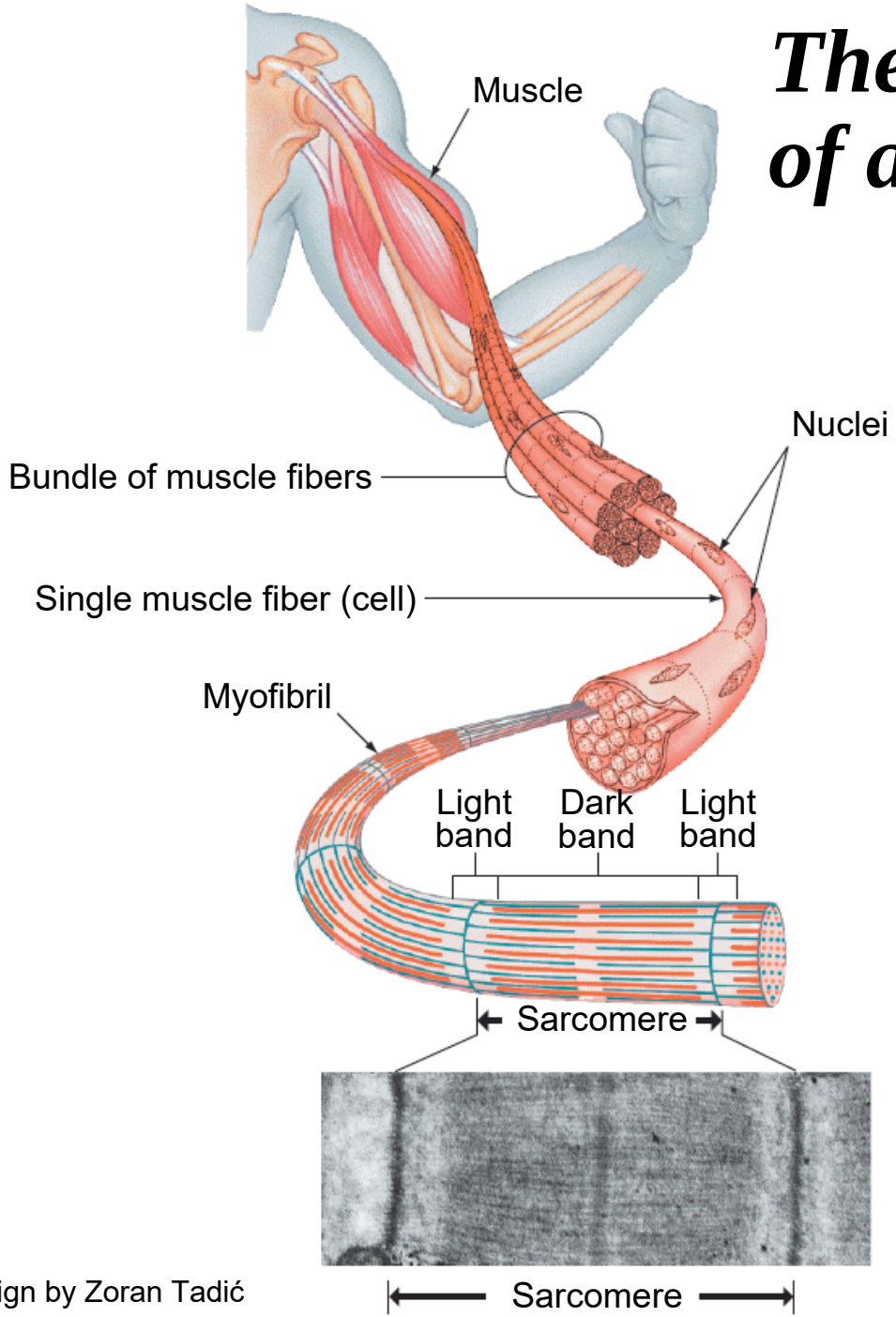
The muscular system

Skeletal muscles are arranged in antagonistic pairs

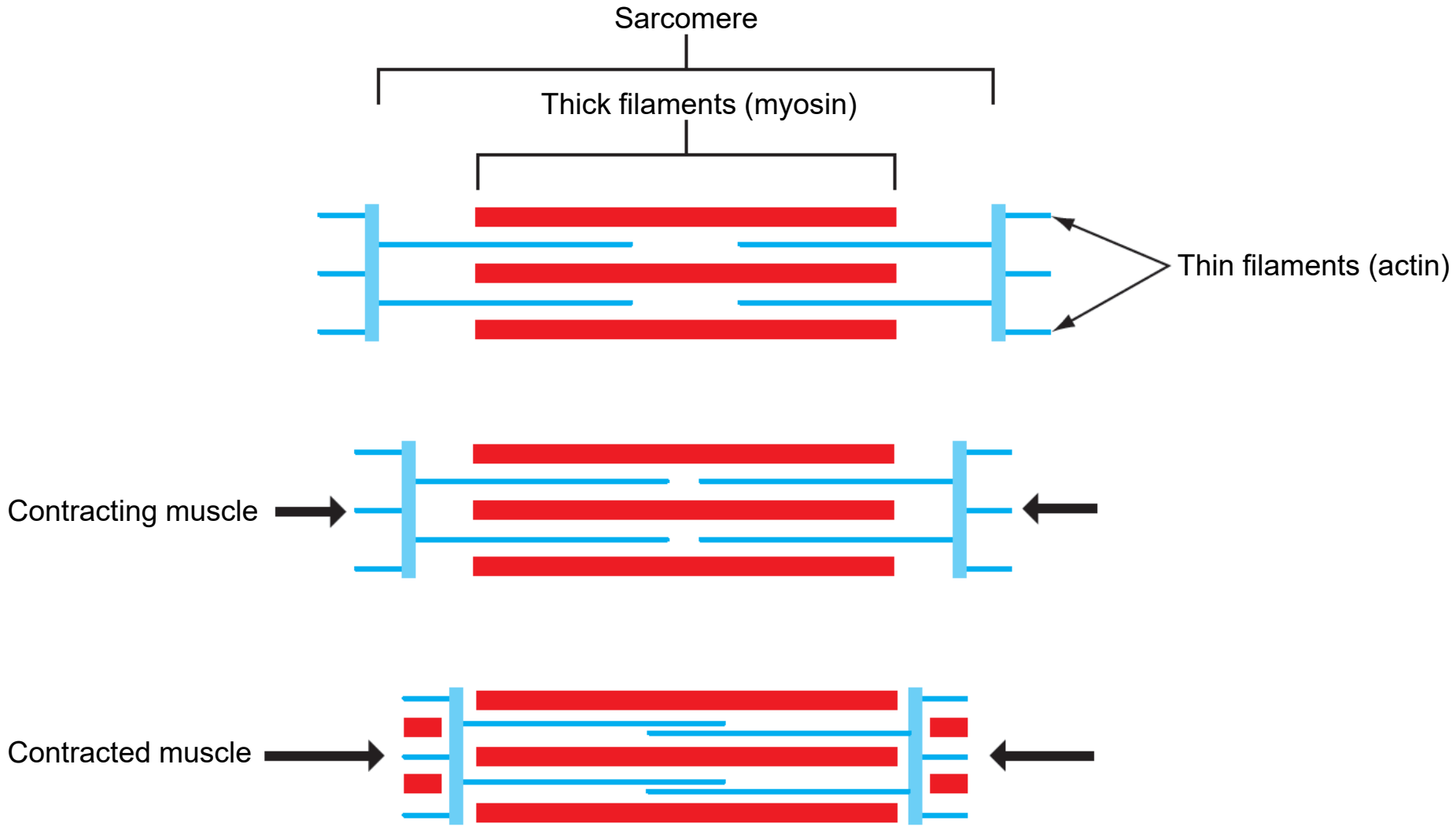




The contraction system of a skeletal muscle

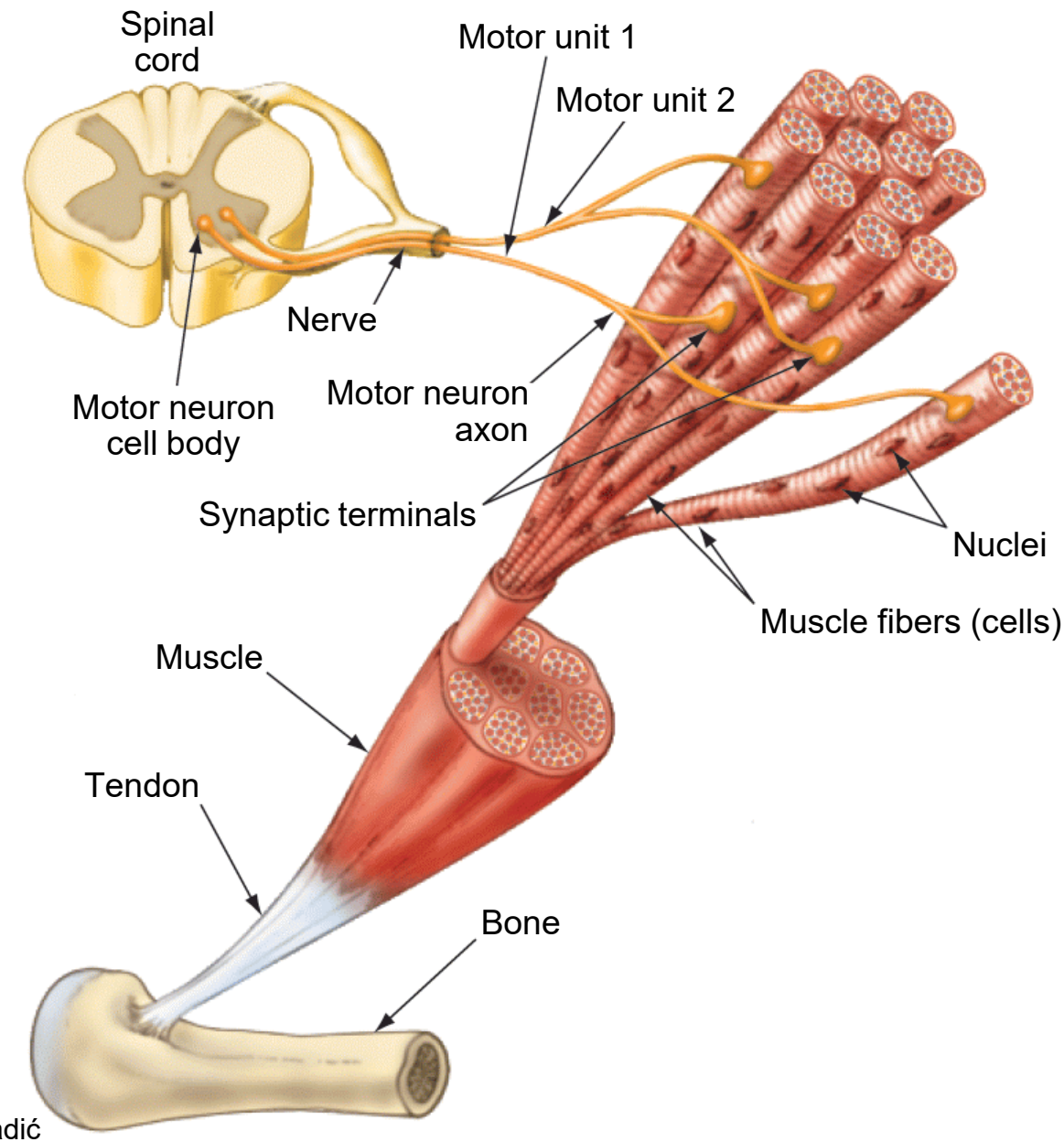


The sliding filaments: actin and myosin



Sarcomeres shorten, but filaments do not!!!

The relationship between motor nerves and muscles



The endocrine system

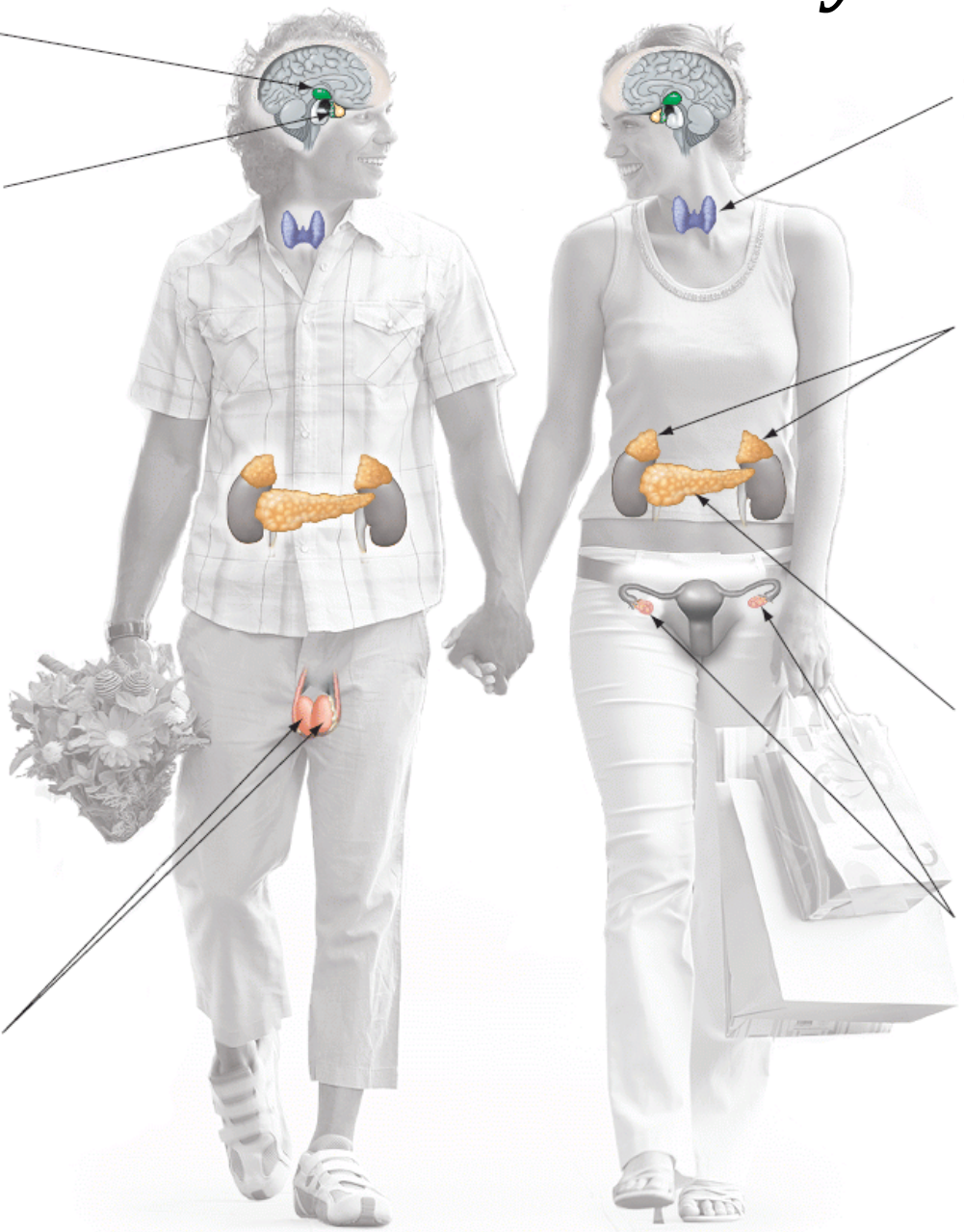
The human endocrine system

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

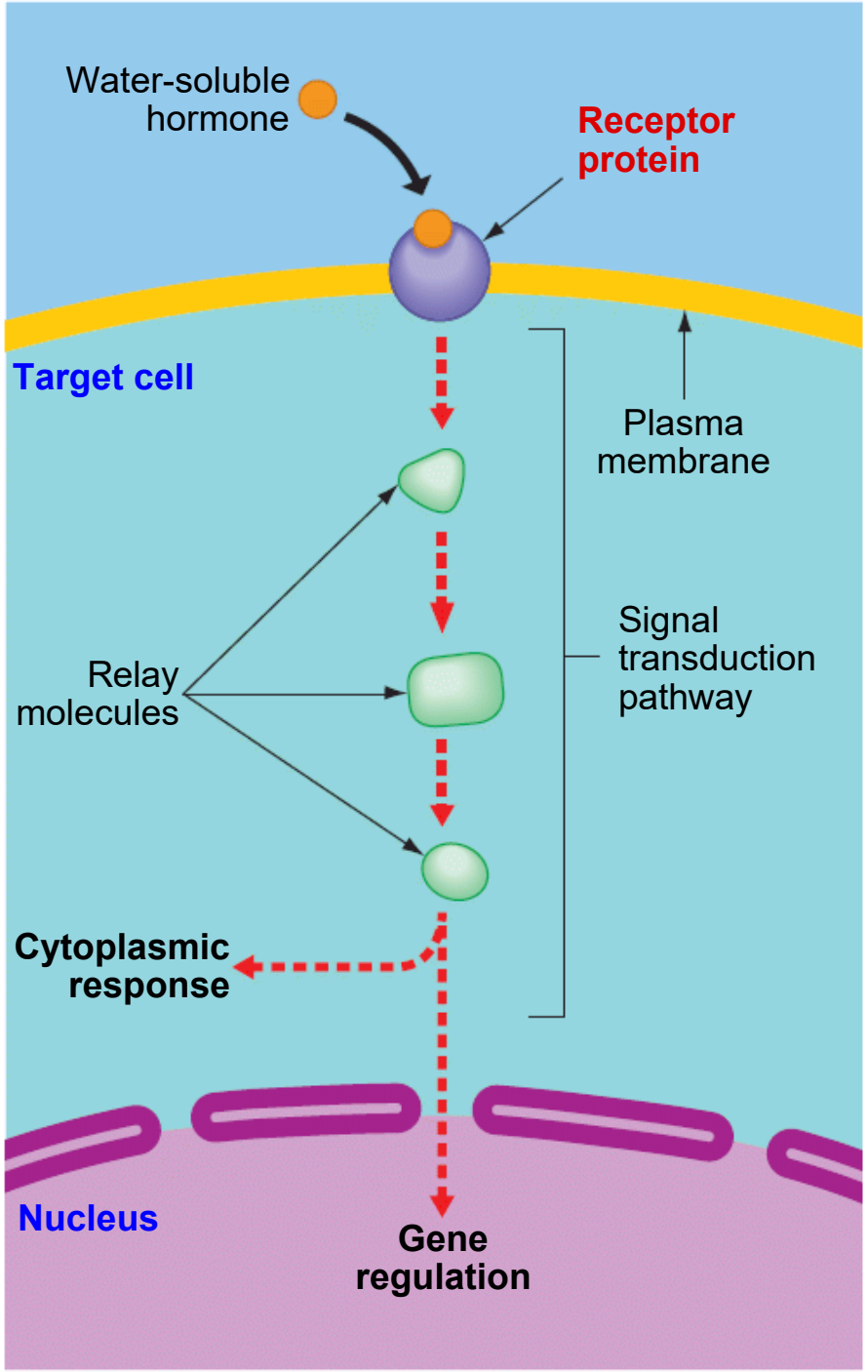
Adrenal glands:
Adrenal medulla
Epinephrine and norepinephrine: Raise blood glucose level; increase metabolic activites; constrict certain blood vessels
Adrenal cortex
Numerous hormones, including
Cortisol: Promotes glucose synthesis

Pancreas:
Insulin: Lowers blood glucose level
Glucagon: Raises blood glucose level

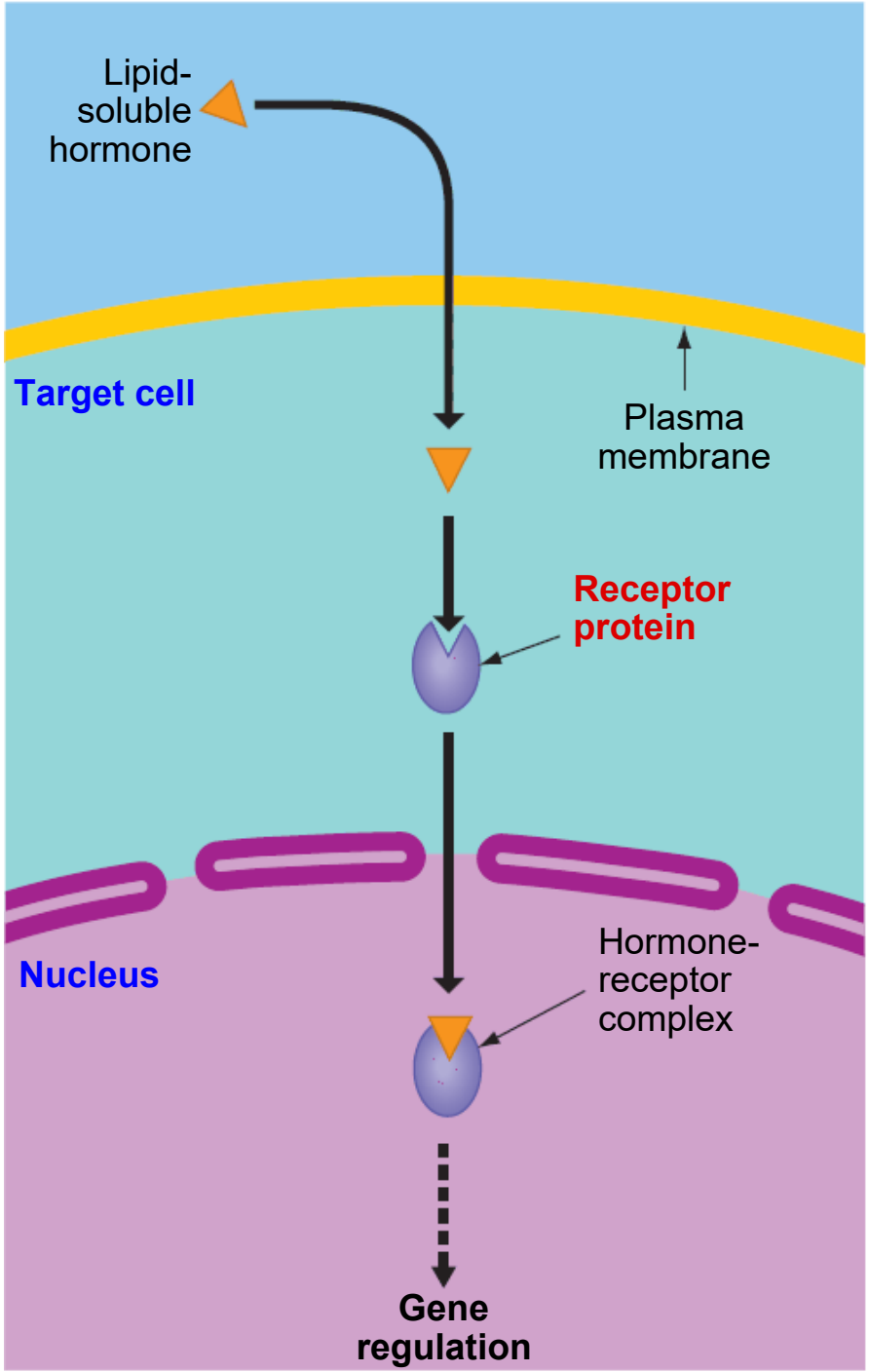
Ovaries (in females):
Estrogens: Stimulate uterine lining growth; promote development and maintenance of female secondary sex characteristics
Progesterone: Promotes uterine lining growth

Design by Zoran Tadić

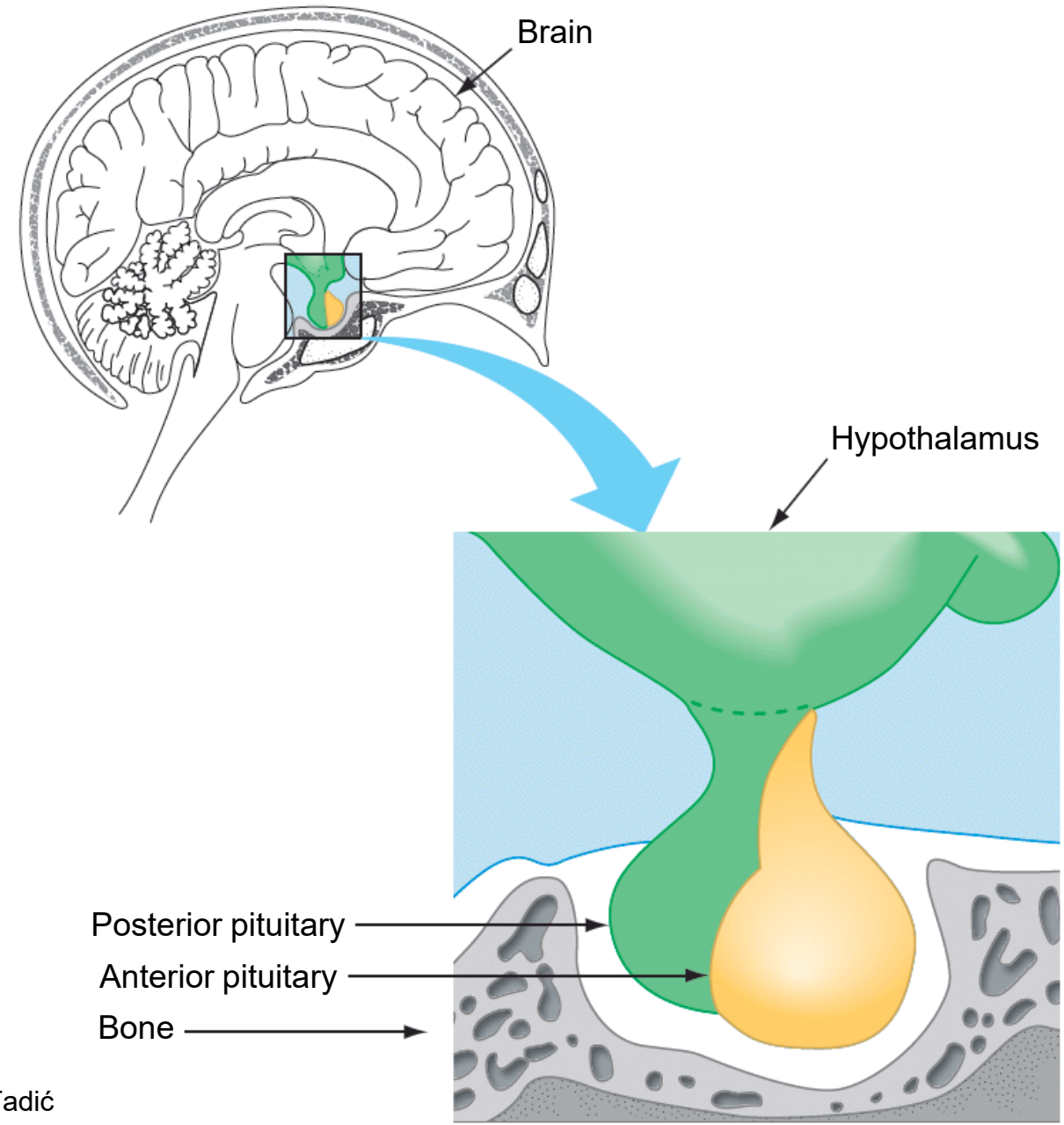
Mechanism of action of water-soluble hormones



Mechanism of action of lipid-soluble hormones



The master axis: Hypothalamus and pituitary gland



How does hypothalamus control pituitary gland?

Information flow

Hypothalamus

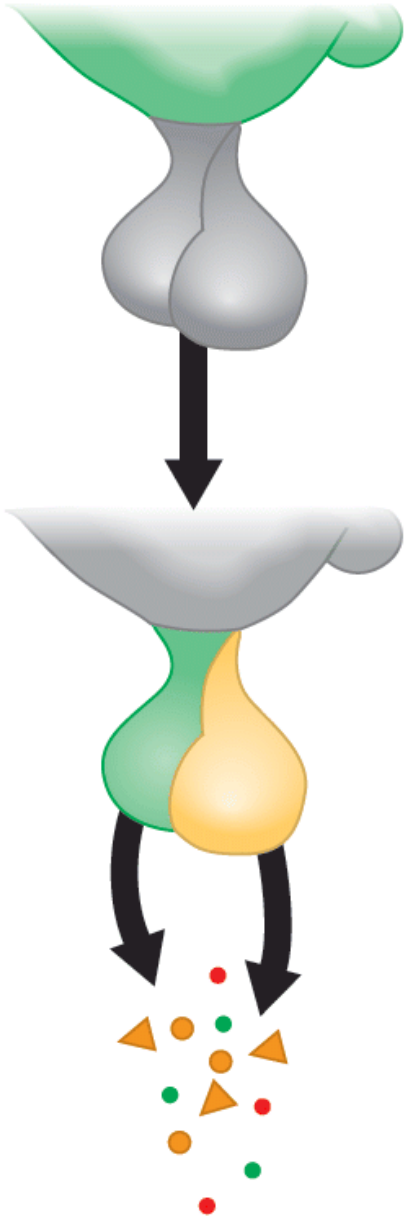
Information from nerves about internal conditions and the external environment is received by the hypothalamus.

Pituitary gland

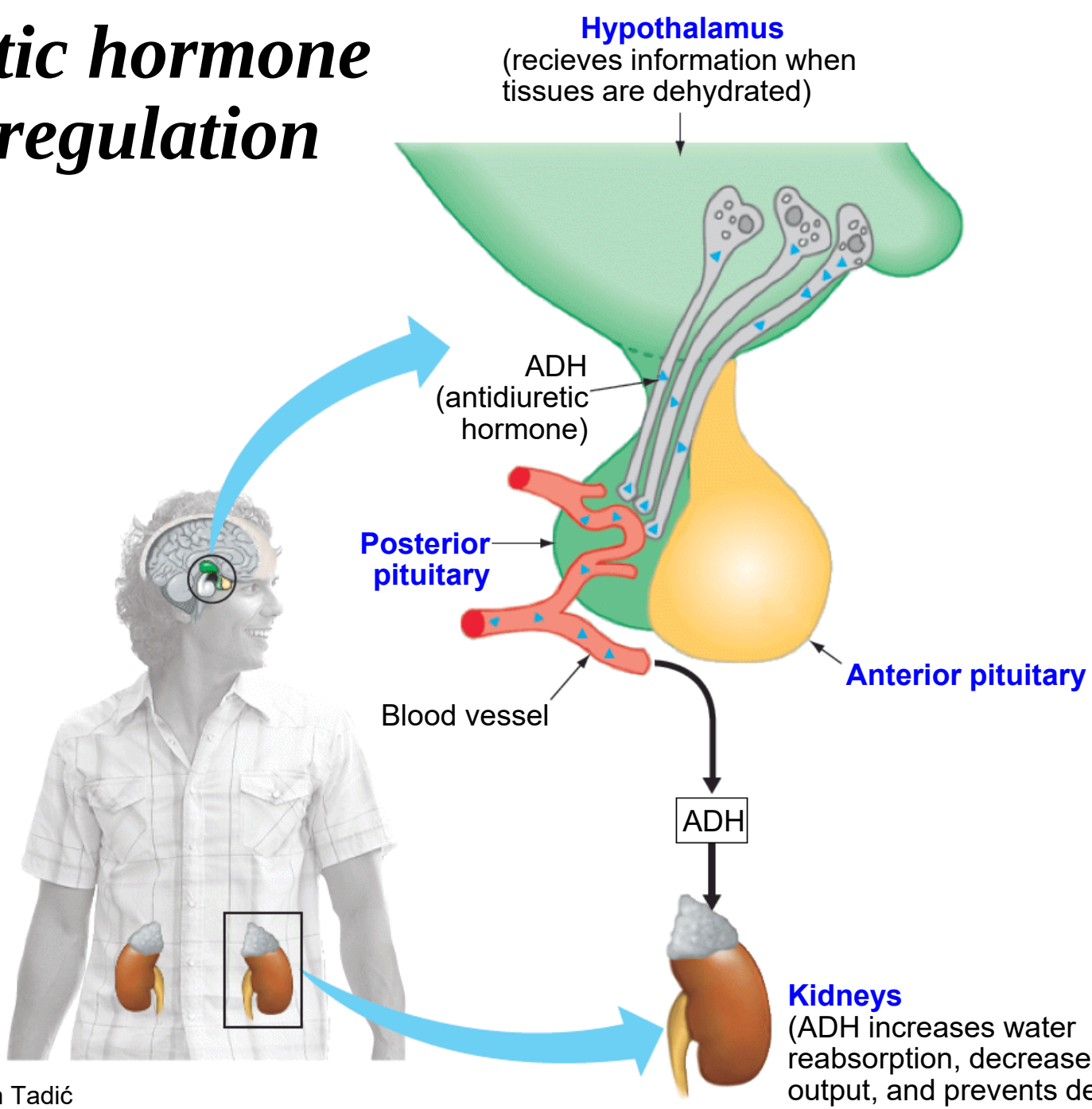
The hypothalamus sends signals to the anterior lobe of the pituitary gland.

Hormones

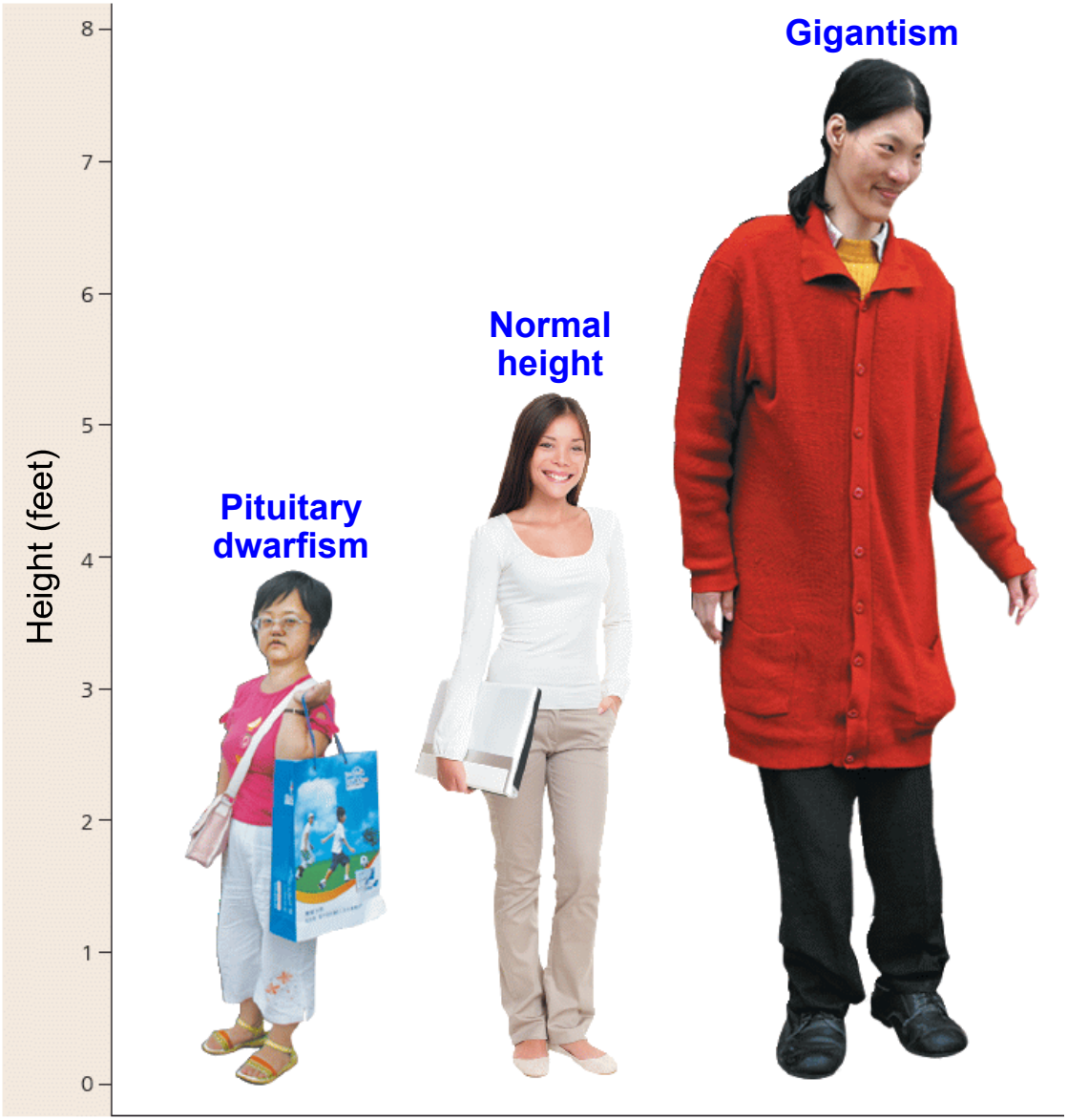
The pituitary gland secretes hormones that affect body functions.



Antidiuretic hormone and osmoregulation



Growth hormone (HGH) secretion during childhood



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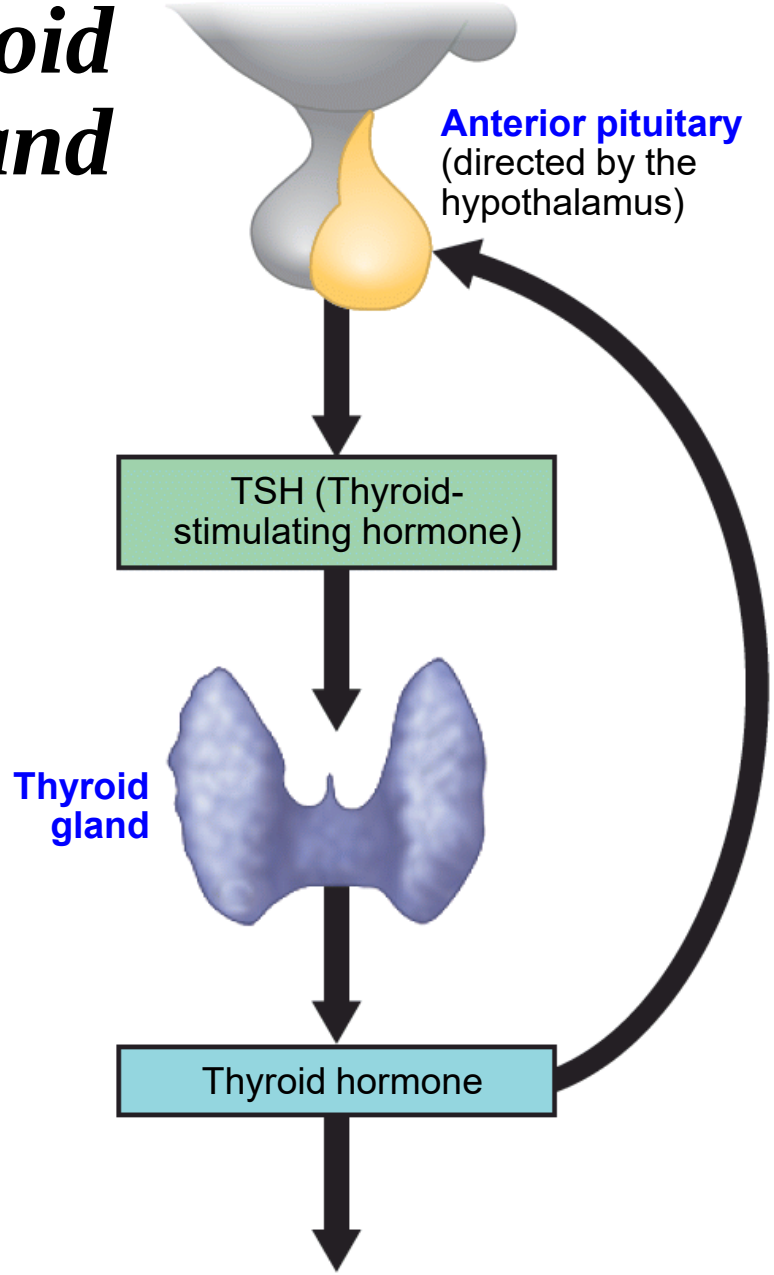
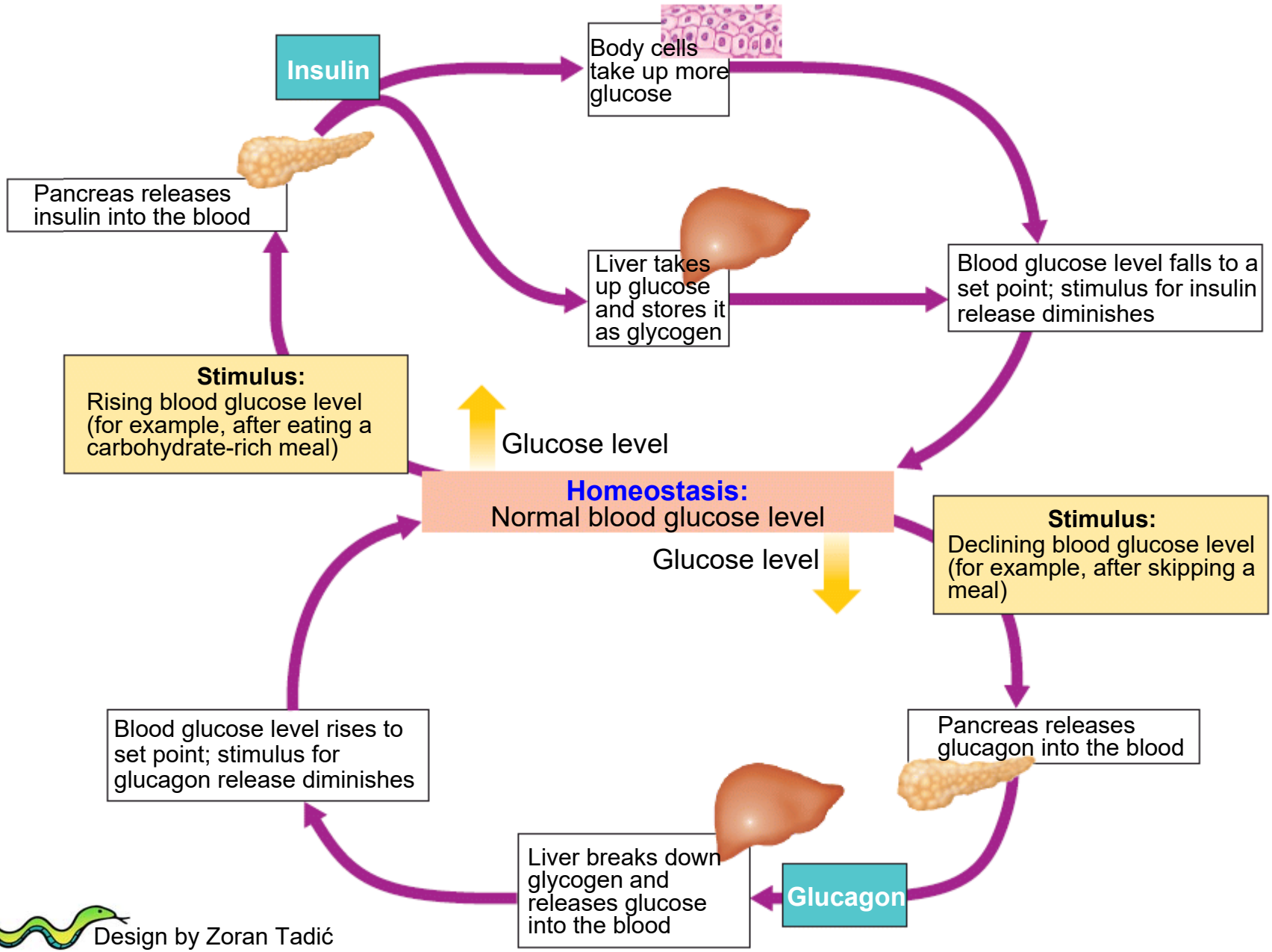
Function of the thyroid gland



Regulation of glucose in the blood



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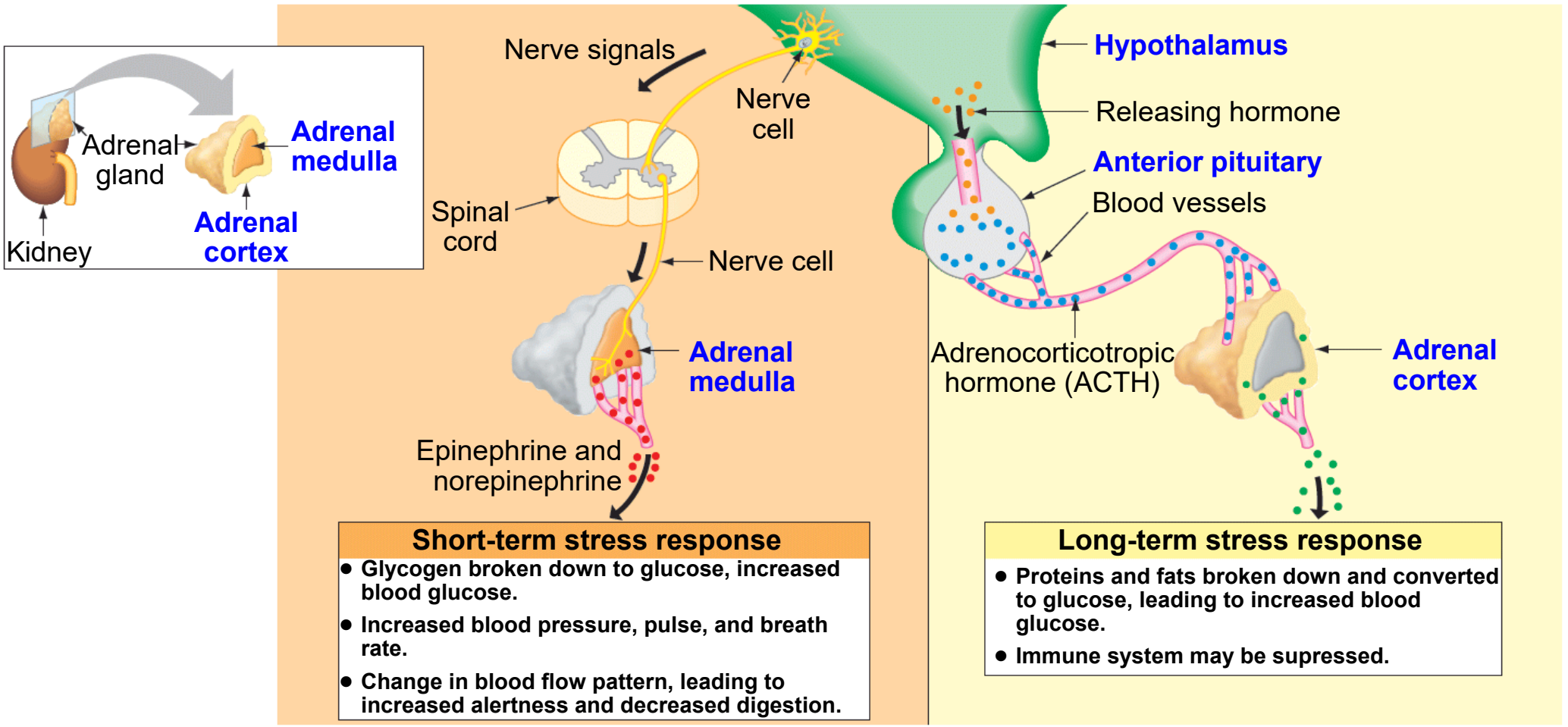
How does adrenal gland regulate stress response?



Short-term stress response

- Glycogen broken down to glucose, increased blood glucose.
- Increased blood pressure, pulse, and breath rate.
- Change in blood flow pattern, leading to increased alertness and decreased digestion.

Long-term stress response

- Proteins and fats broken down and converted to glucose, leading to increased blood glucose.
- Immune system may be supressed.

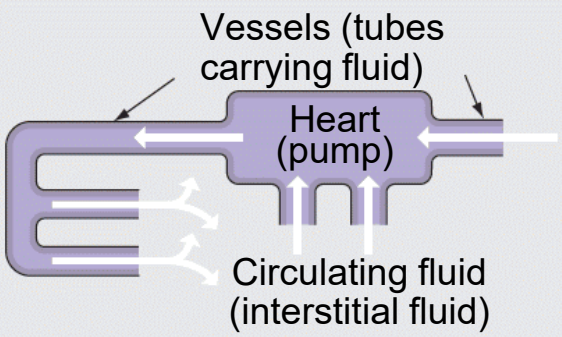
The circulatory system

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.



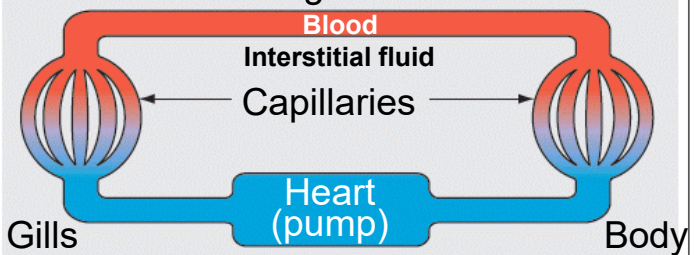
Molluscs, arthropods

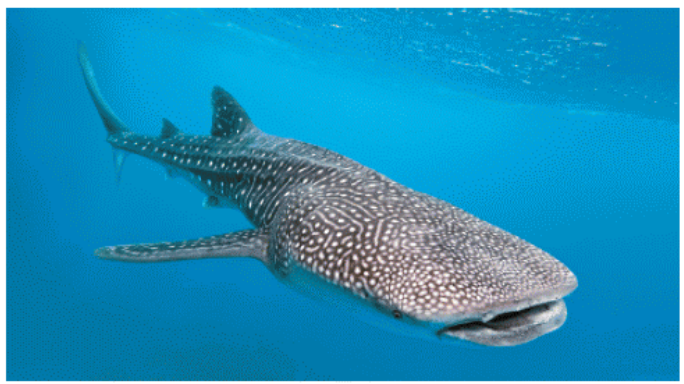
Closed circulatory system

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.

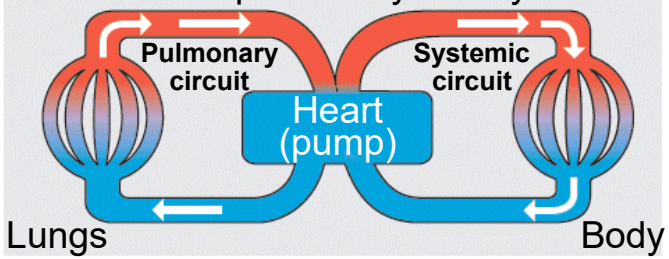




Bony fishes, rays, sharks

Double circulation system

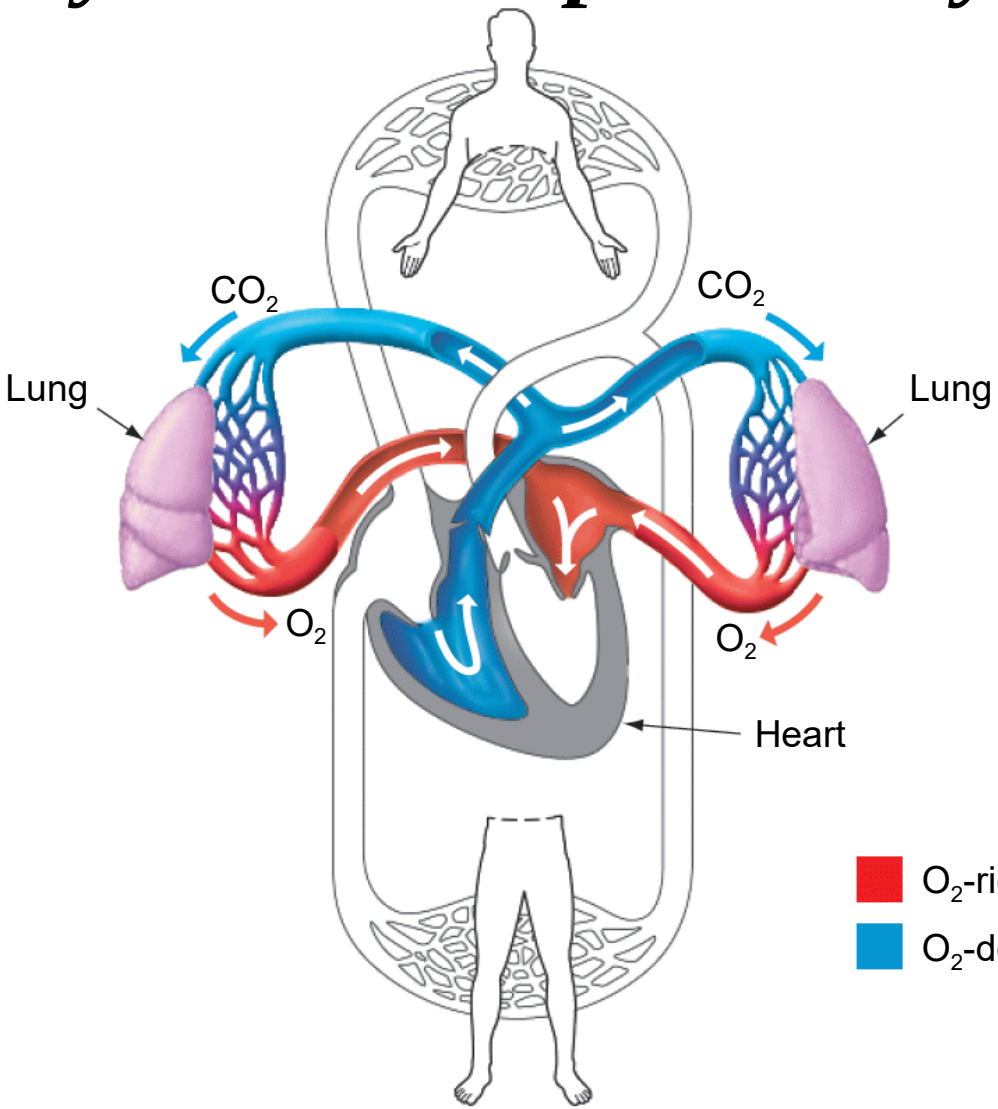
Blood flows through the heart in two circuits: pulmonary and systemic

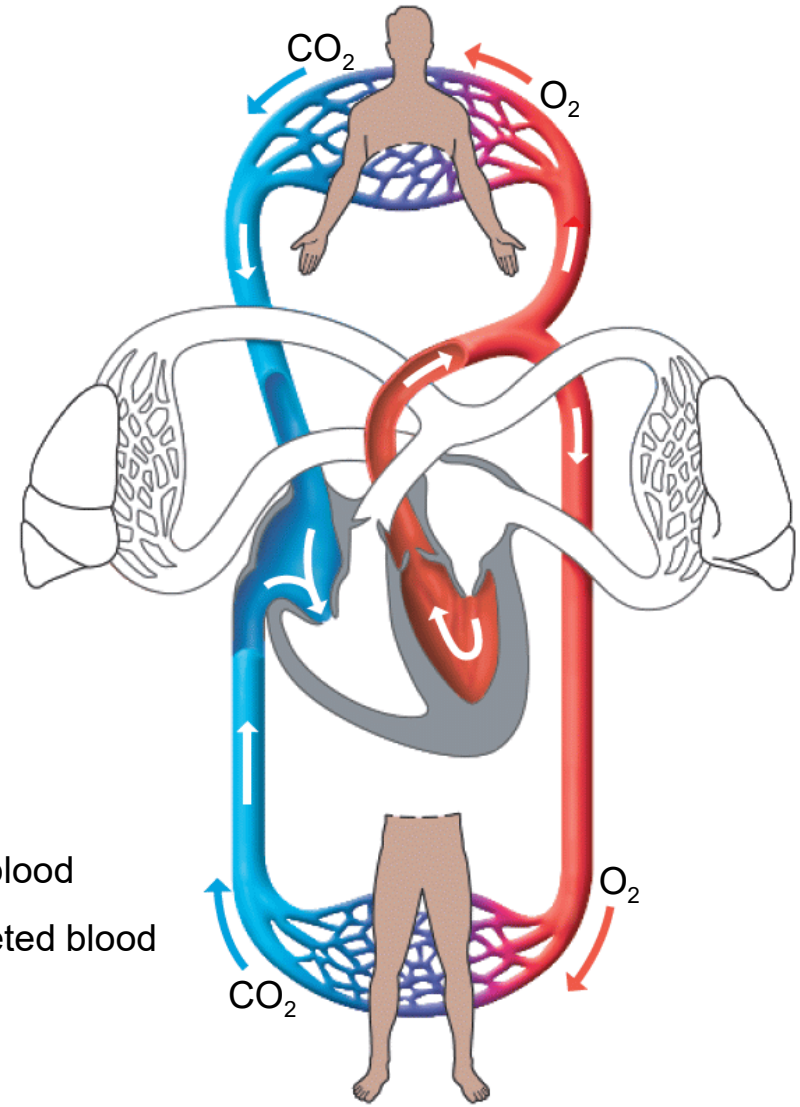


Amphibians, reptiles, birds, mammals

Design by Zoran Tadić

Systemic and pulmonary circuits: different roles





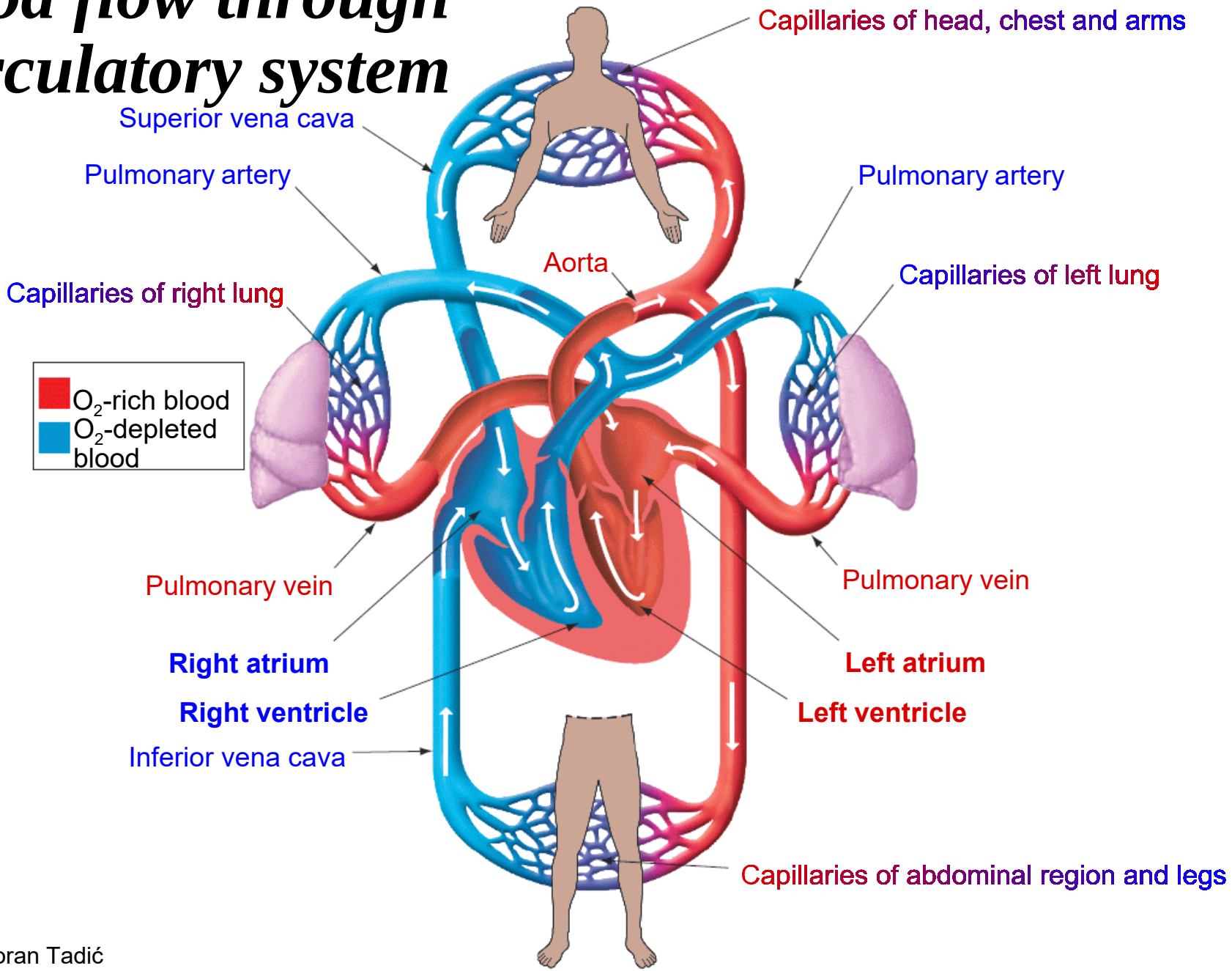
O_2-rich blood

O_2-depleted blood

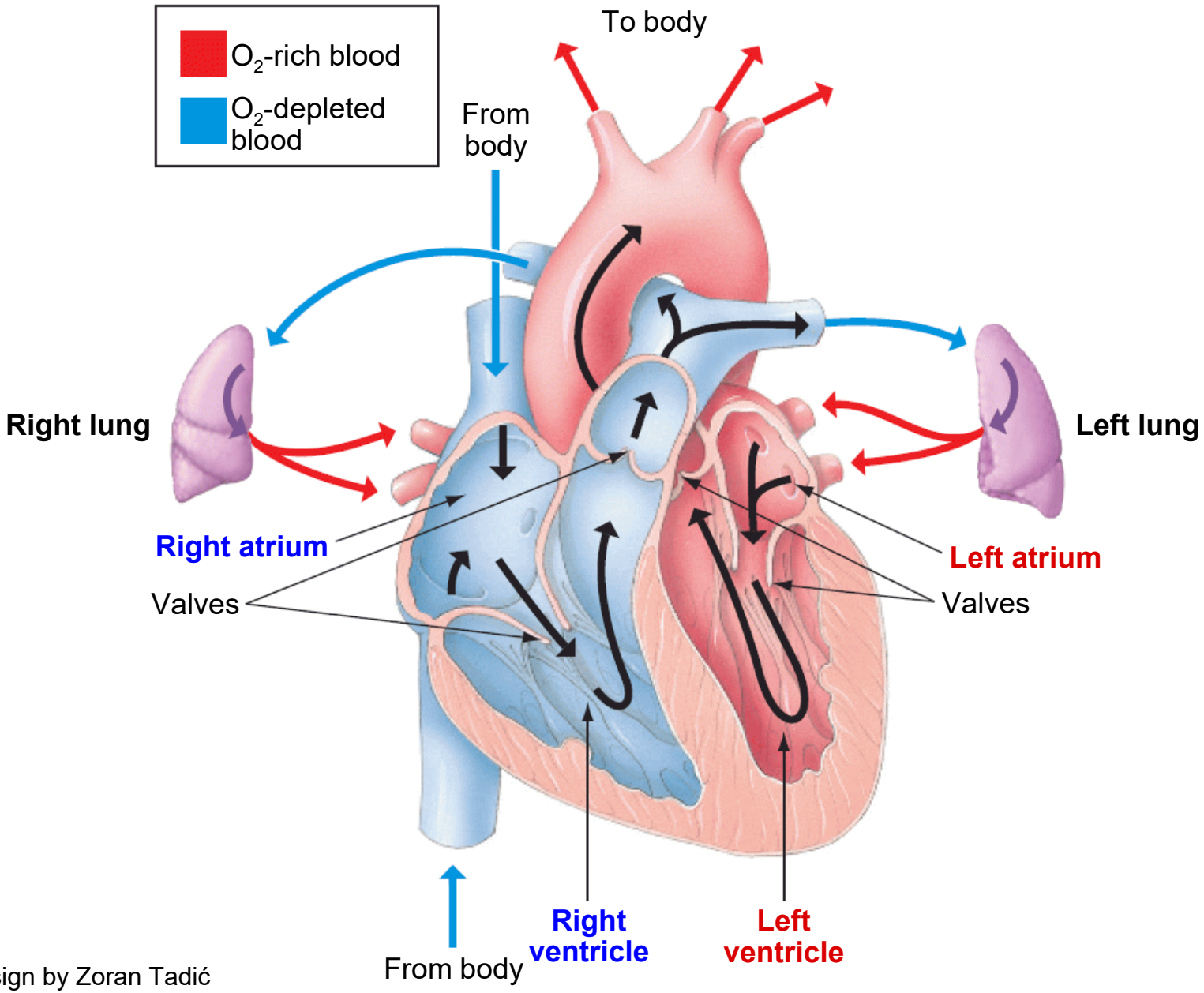
Pulmonary circuit: In organisms with double circulation, the pulmonary circuit transports blood between the heart and lungs.

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

Blood flow through circulatory system



Blood flow through human heart



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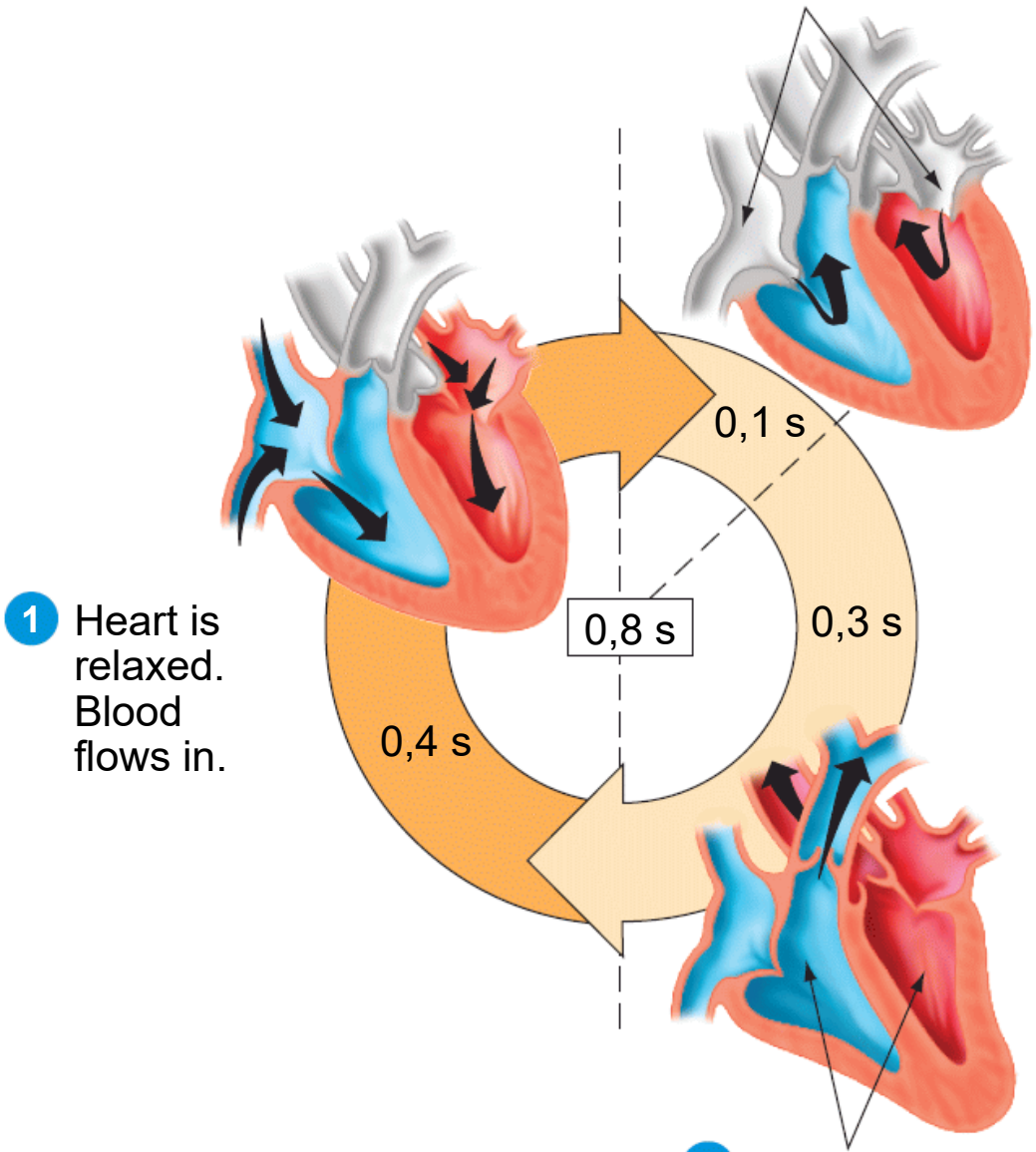
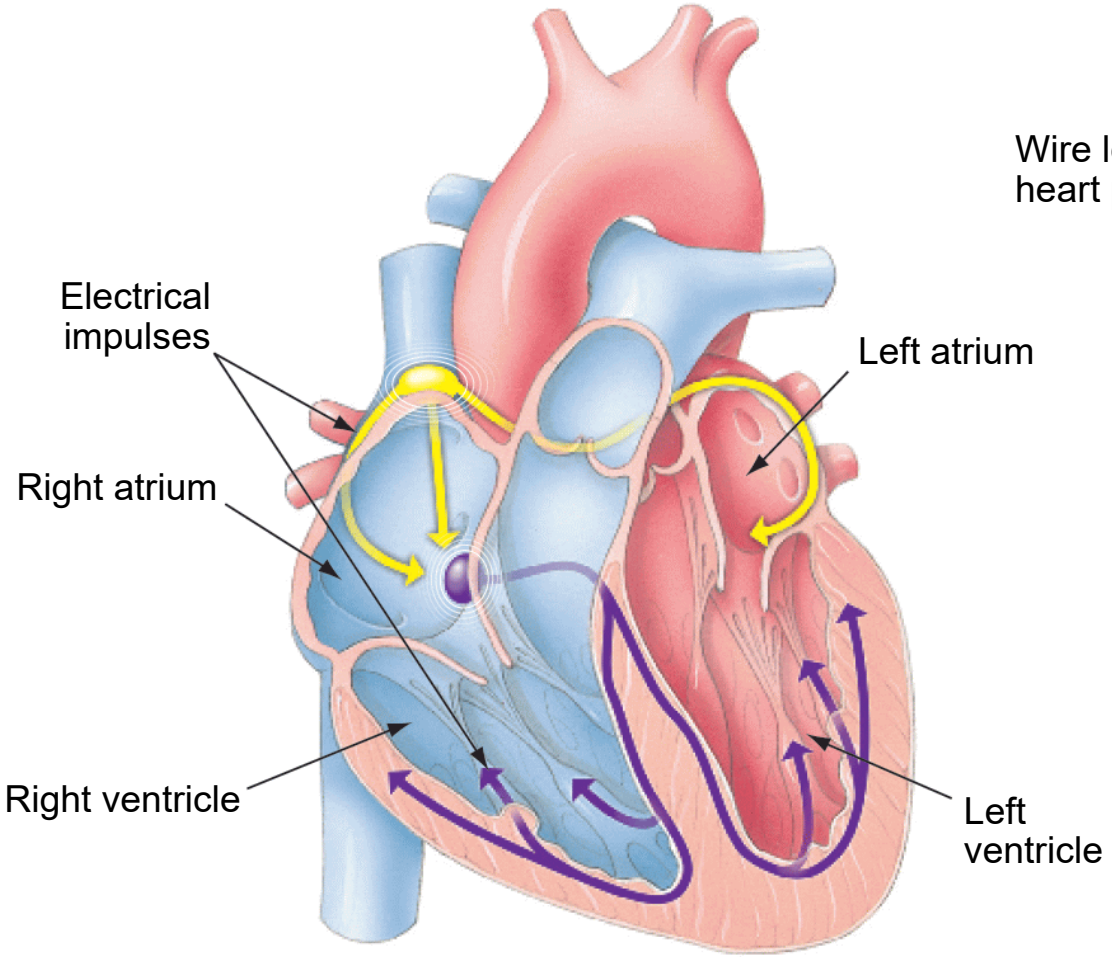
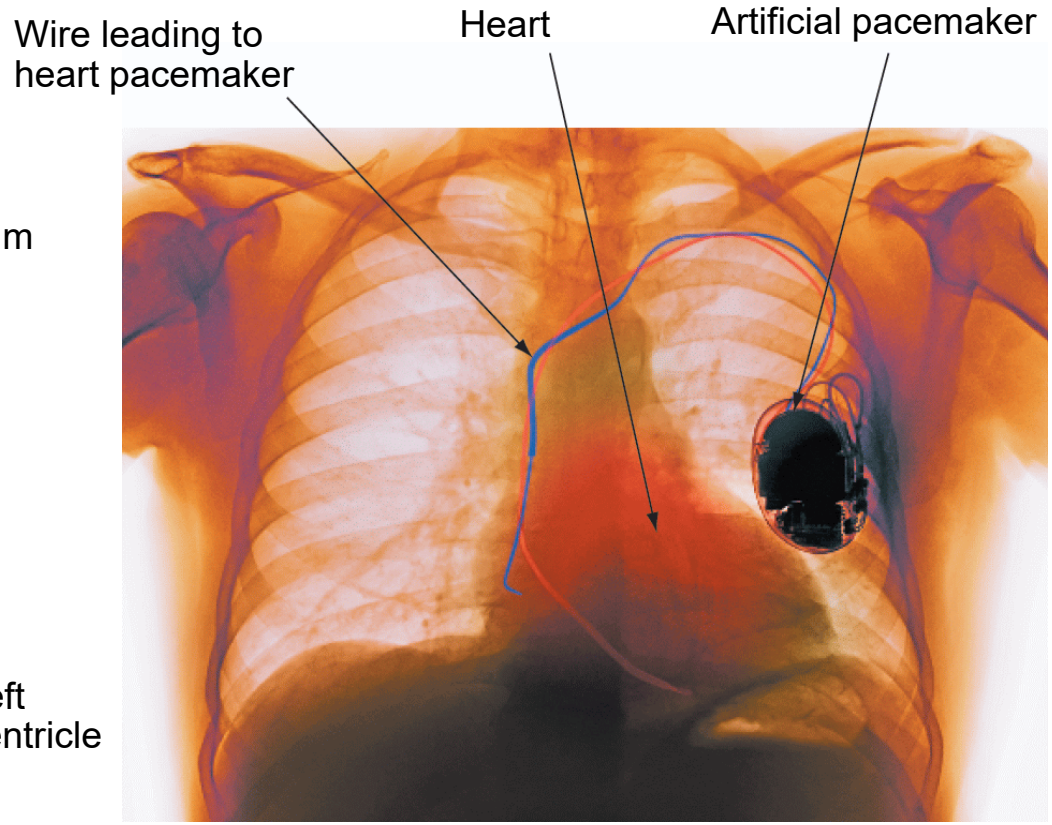
The cardiac cycle



Natural and artificial pacemaker

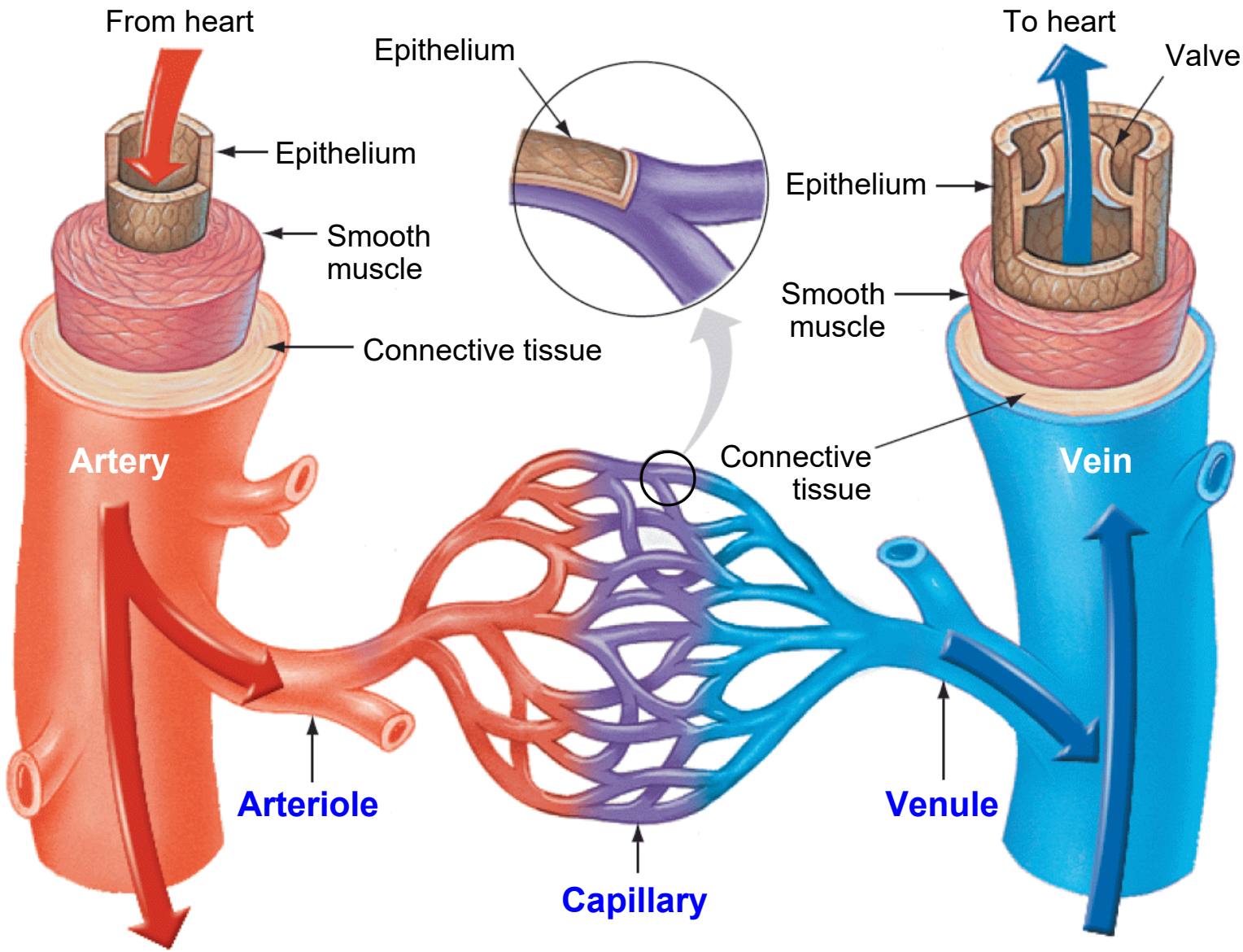




The heart's natural pacemaker. The pacemaker is located in the right atrium. Electrical impulses spread through the heart, first to the atria (shown in yellow arrows), then to the ventricles (purple arrows).

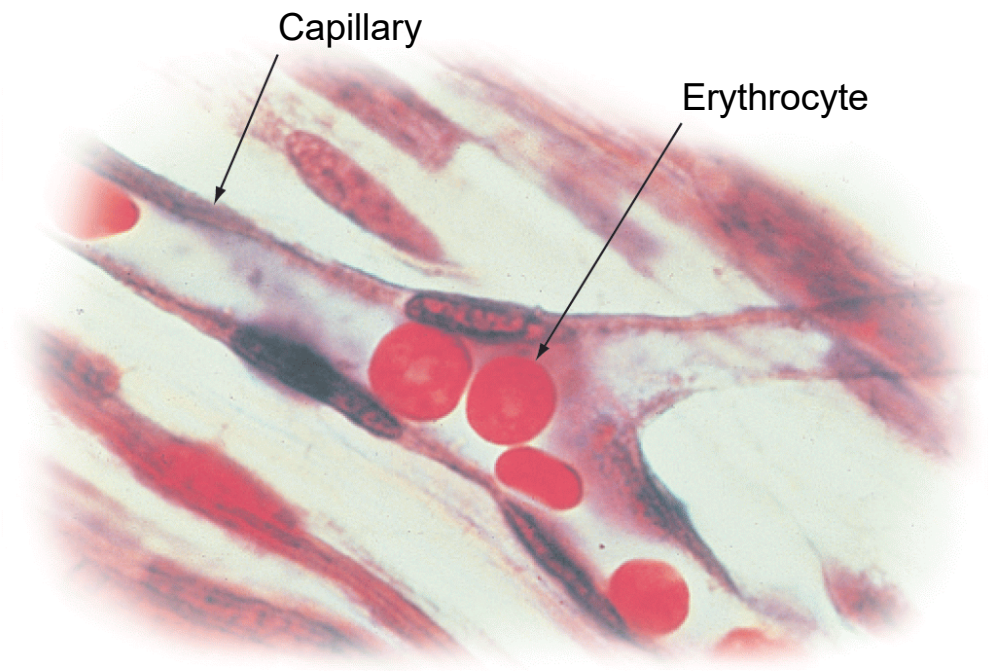
An artificial pacemaker. A small electronic device surgically implanted into cardiac muscle or (as shown here) the chest cavity and connected to the heart's pacemaker by a wire can help maintain proper electrical rhythms in a defective heart.

Blood vessels: arteries and veins

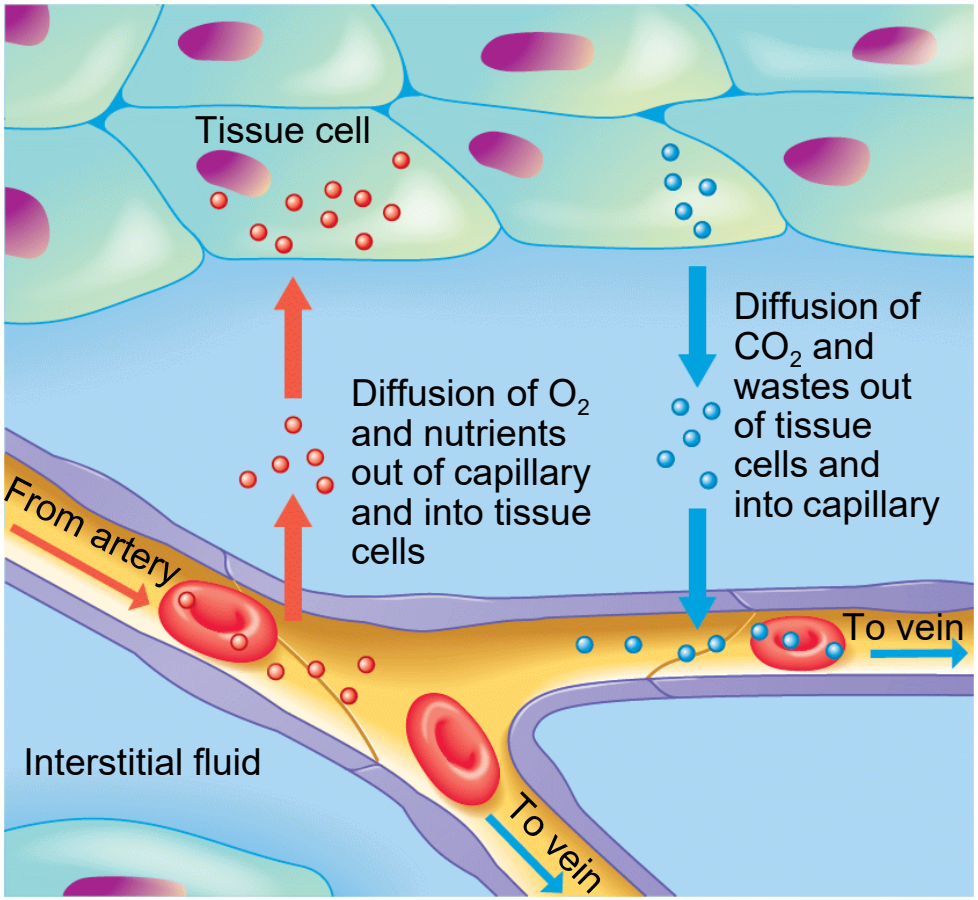


Design by Zoran Tadić

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.

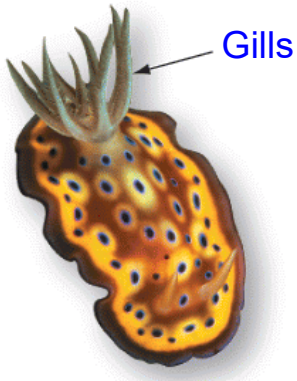
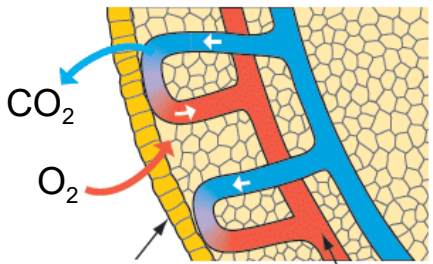
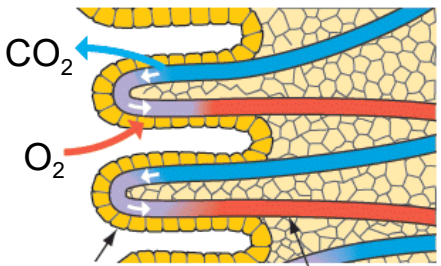
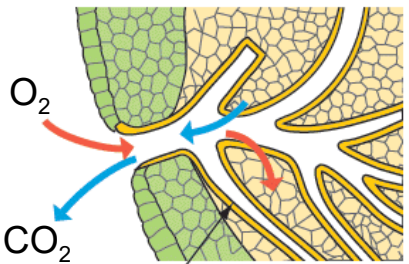
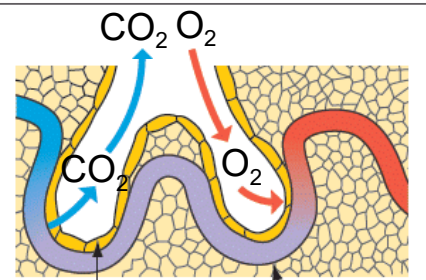


Chemical exchange. Within the capillary beds, there is local exchange of molecules between the blood and interstitial fluid, which bathes the cells of tissues.

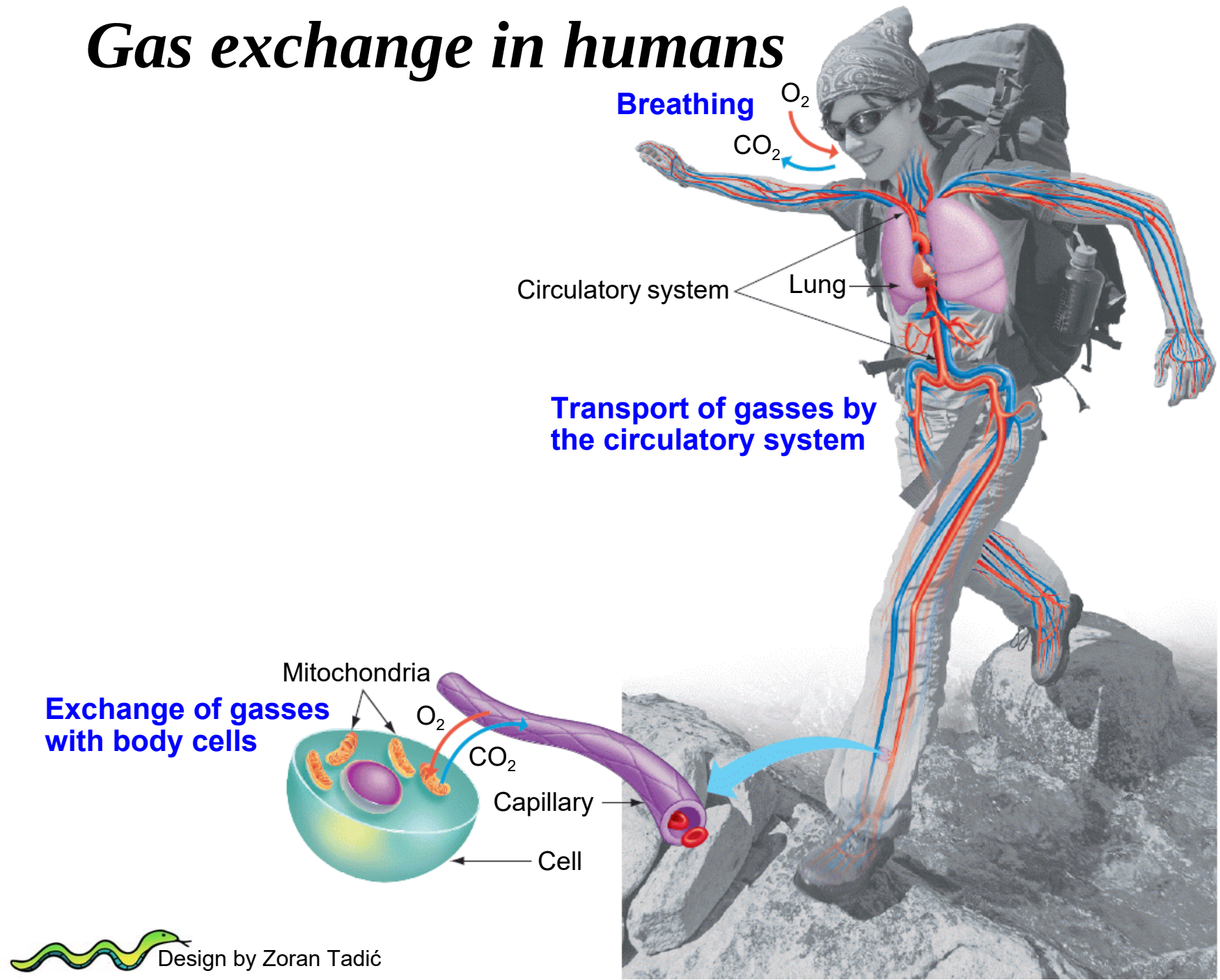
The respiratory system

The diversity of respiratory organs

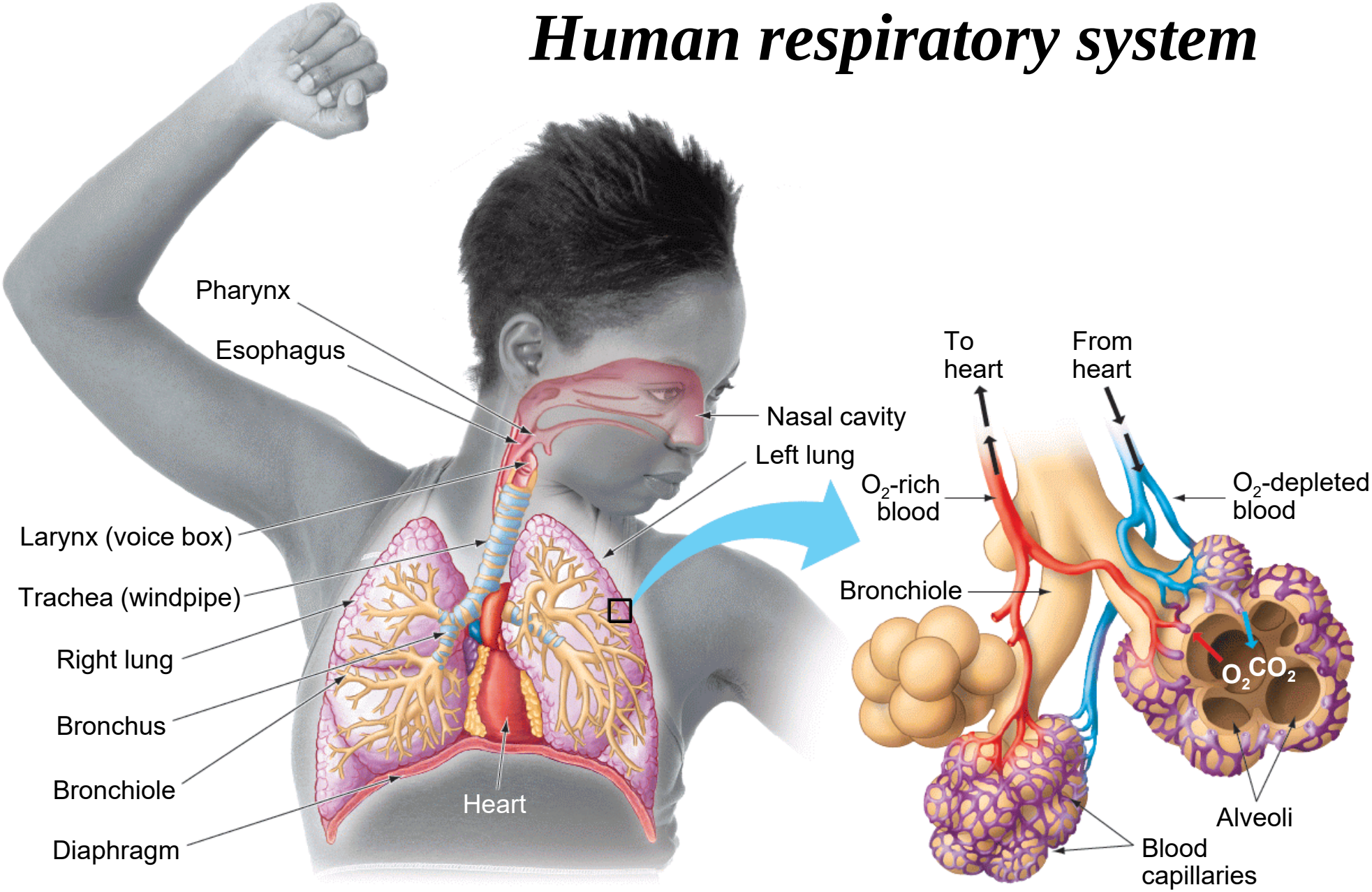
THE DIVERSITY OF RESPIRATORY ORGANS

Skin (entire body surface)	**Gills** (extensions of body surface)	**Tracheae** (branching body tubes)	**Lungs** (localized internal organs)
 Leech	 Sea slug	 Stinkbug	 Mouse
			

Gas exchange in humans



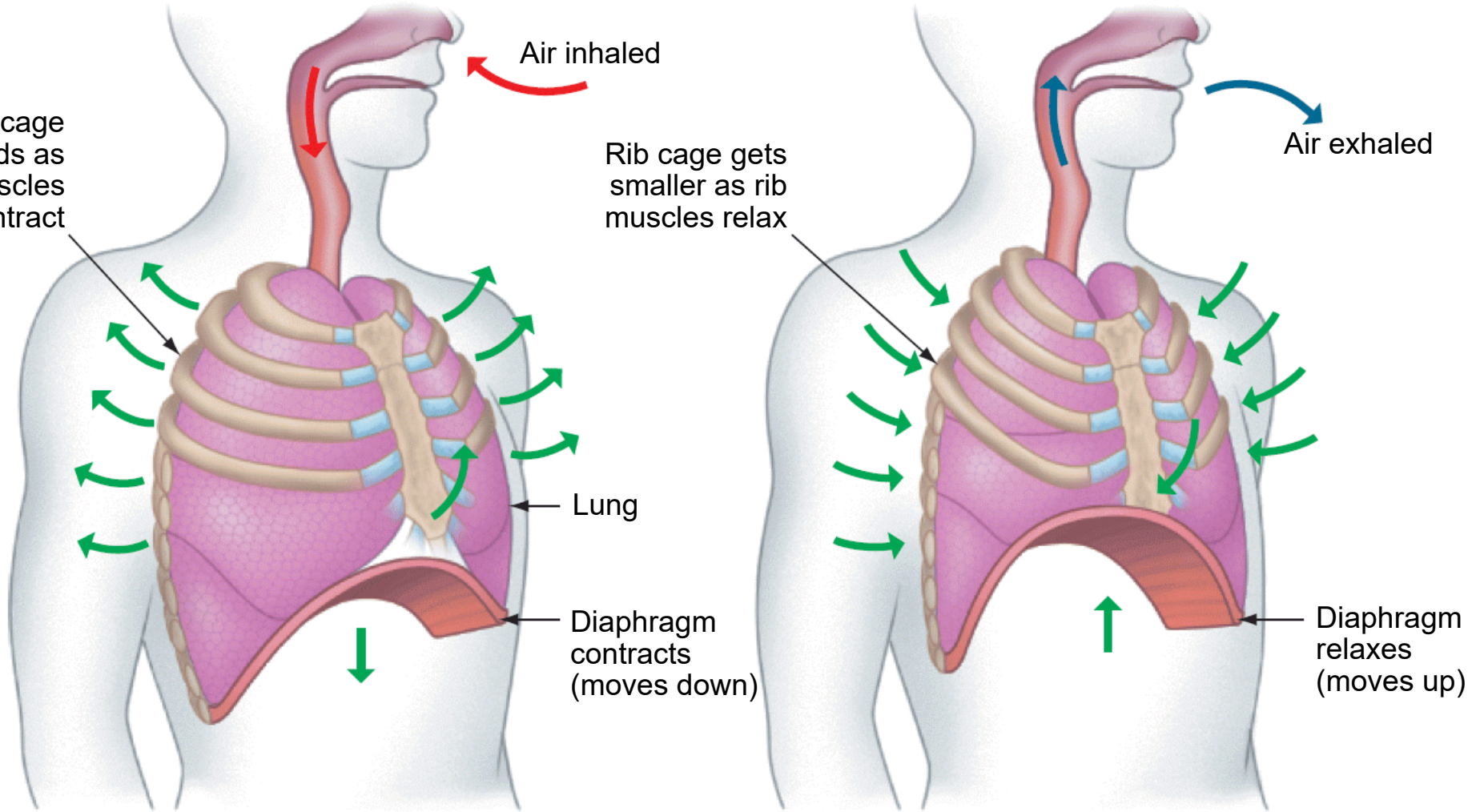
Human respiratory system



Human respiratory system **Structure of the alveoli**

Design by Zoran Tadić

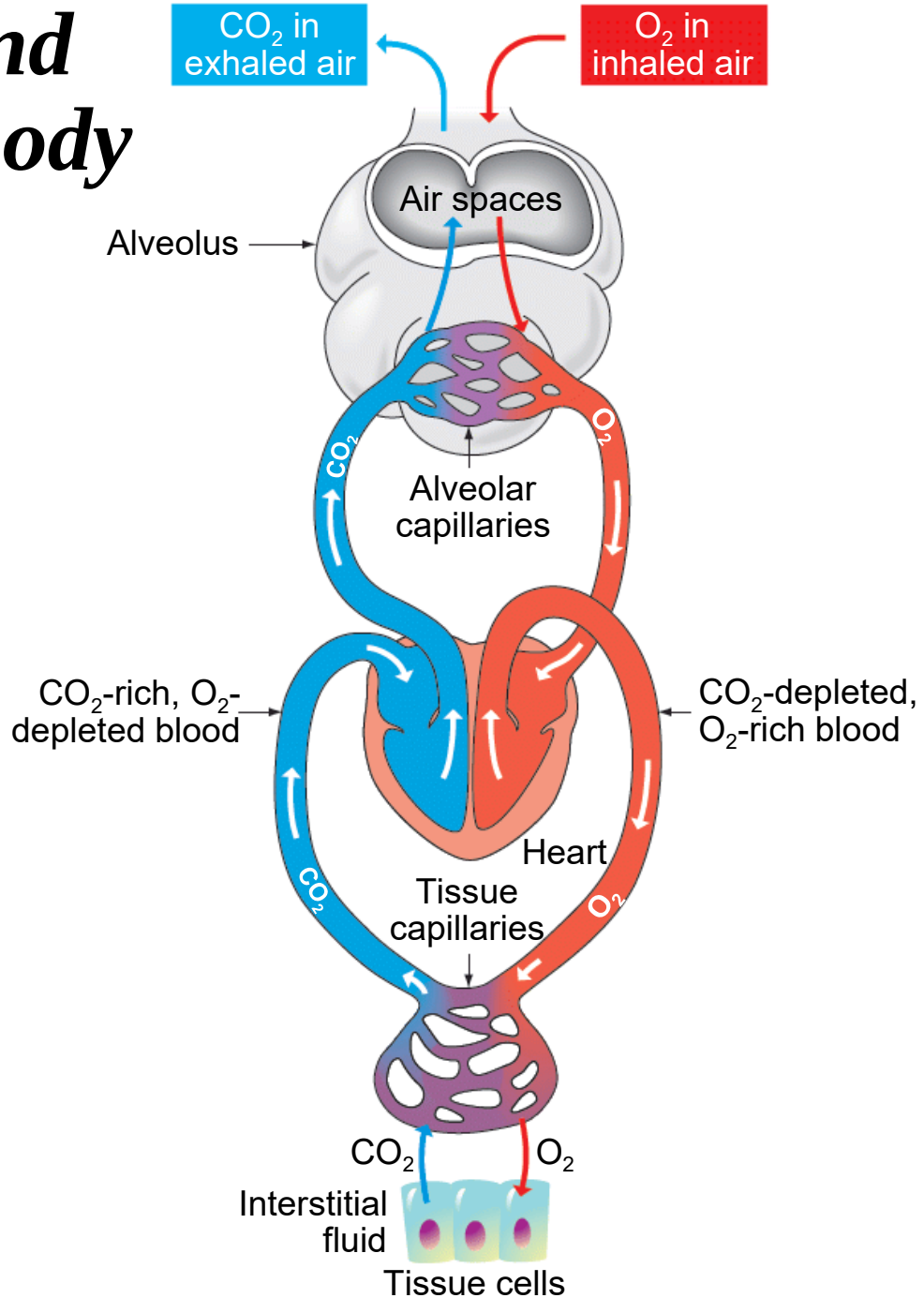
The breathing cycle



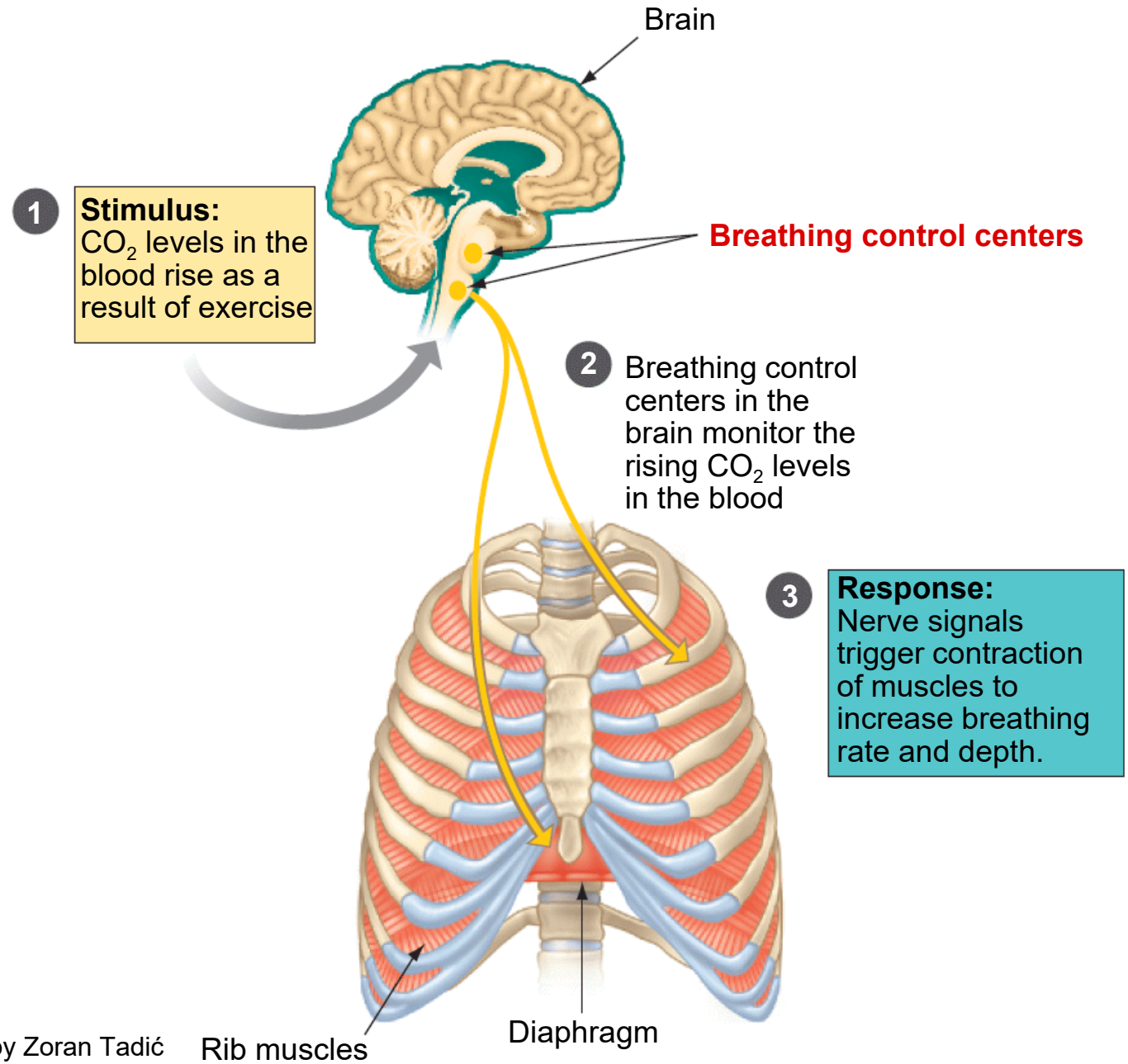
Inhalation
(Air pressure is higher in atmosphere than in lungs)

Exhalation
(Air pressure is lower in atmosphere than in lungs)

Gas transport and exchange in the body

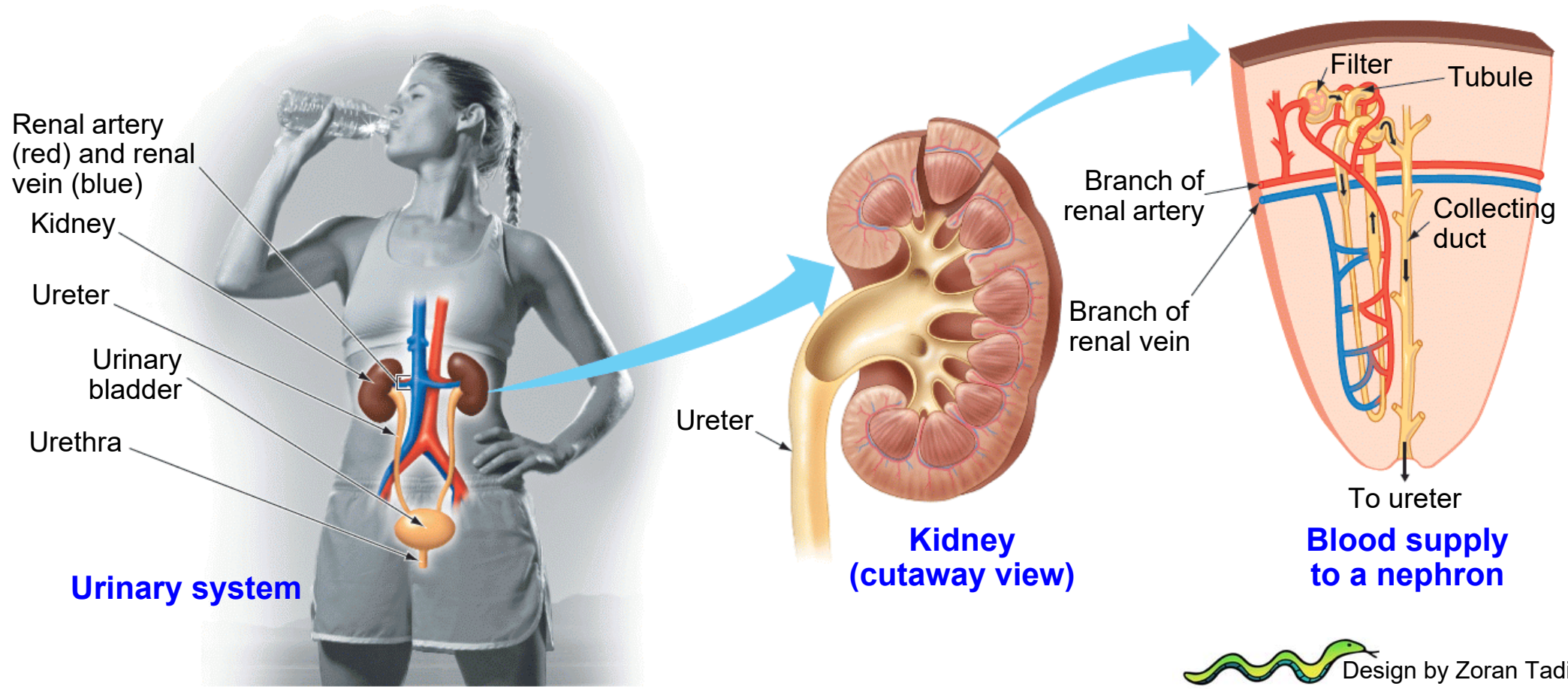


Neural centers that control breathing



The urinary system

Kidneys - important osmoregulatory organs



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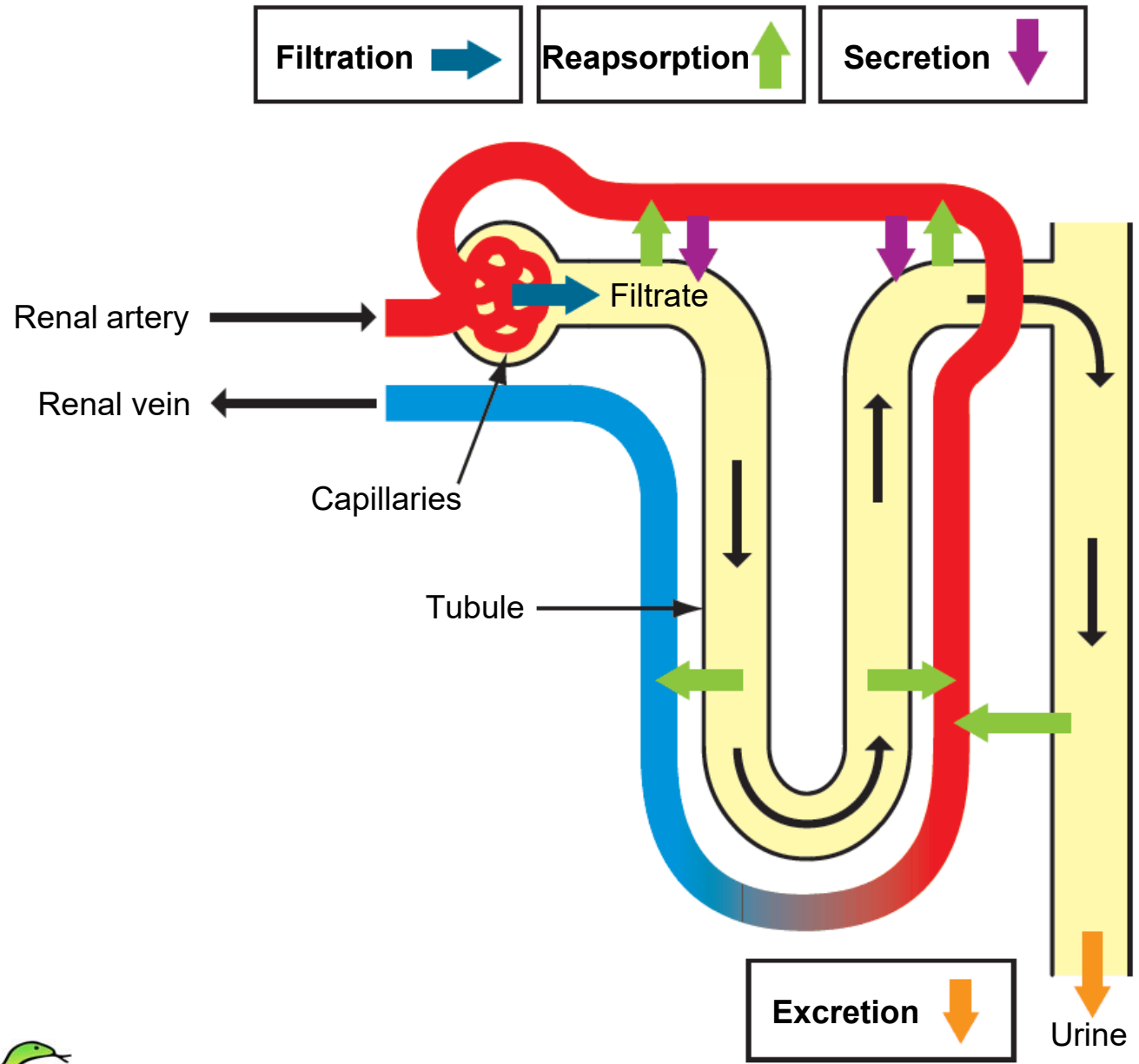
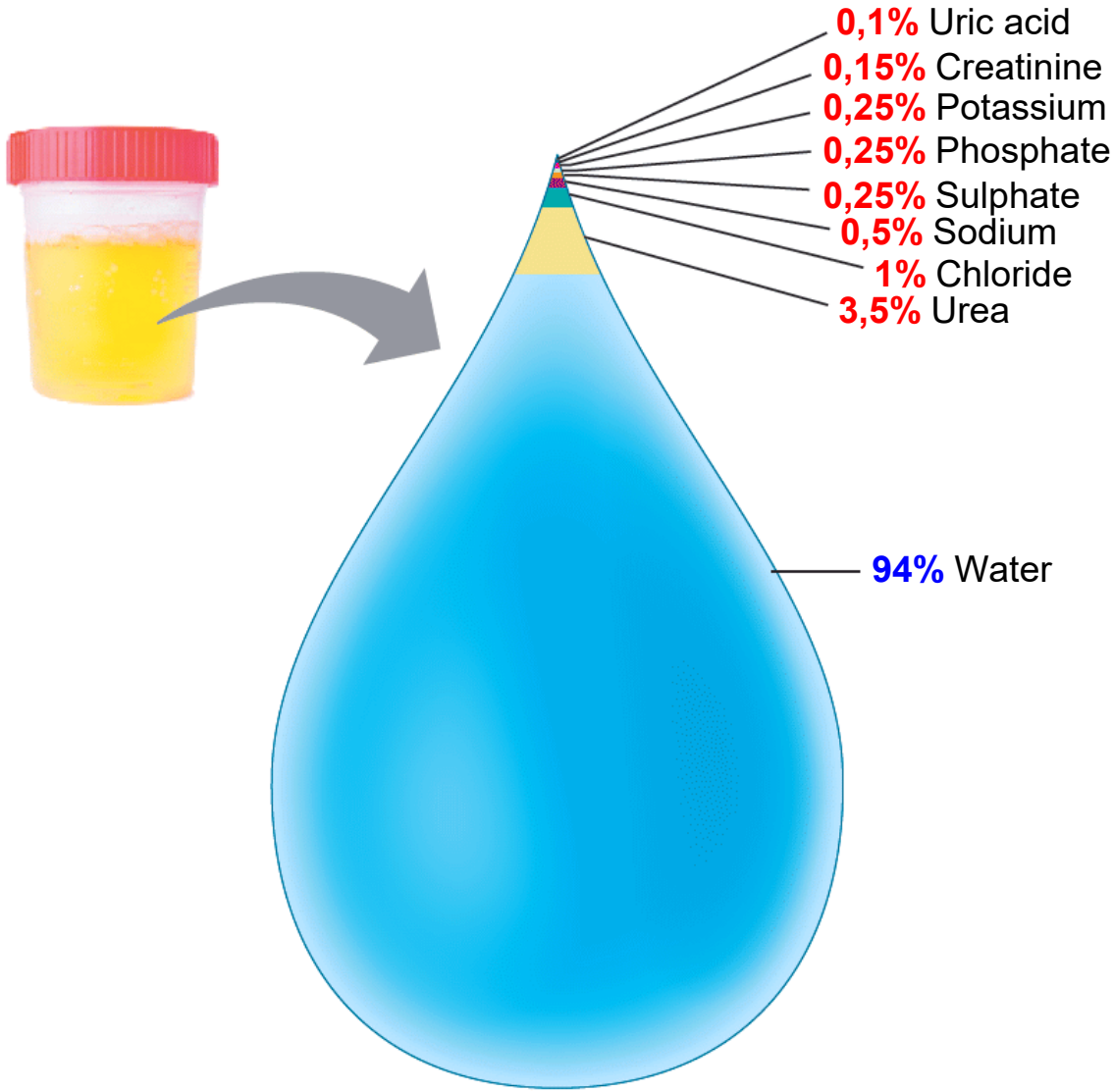
Diuresis - the formation of urine

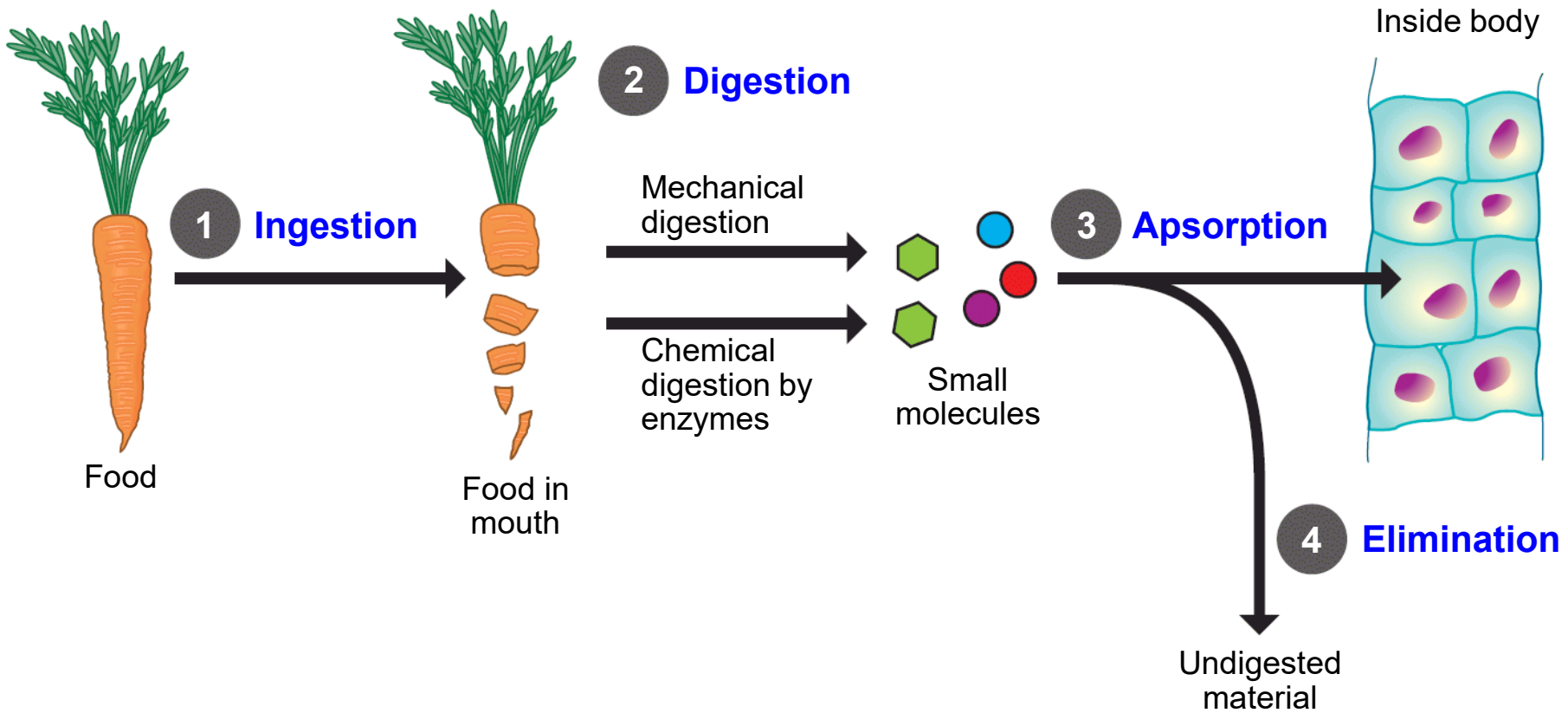


Composition of human urine



The digestive system

Four stages of digestion

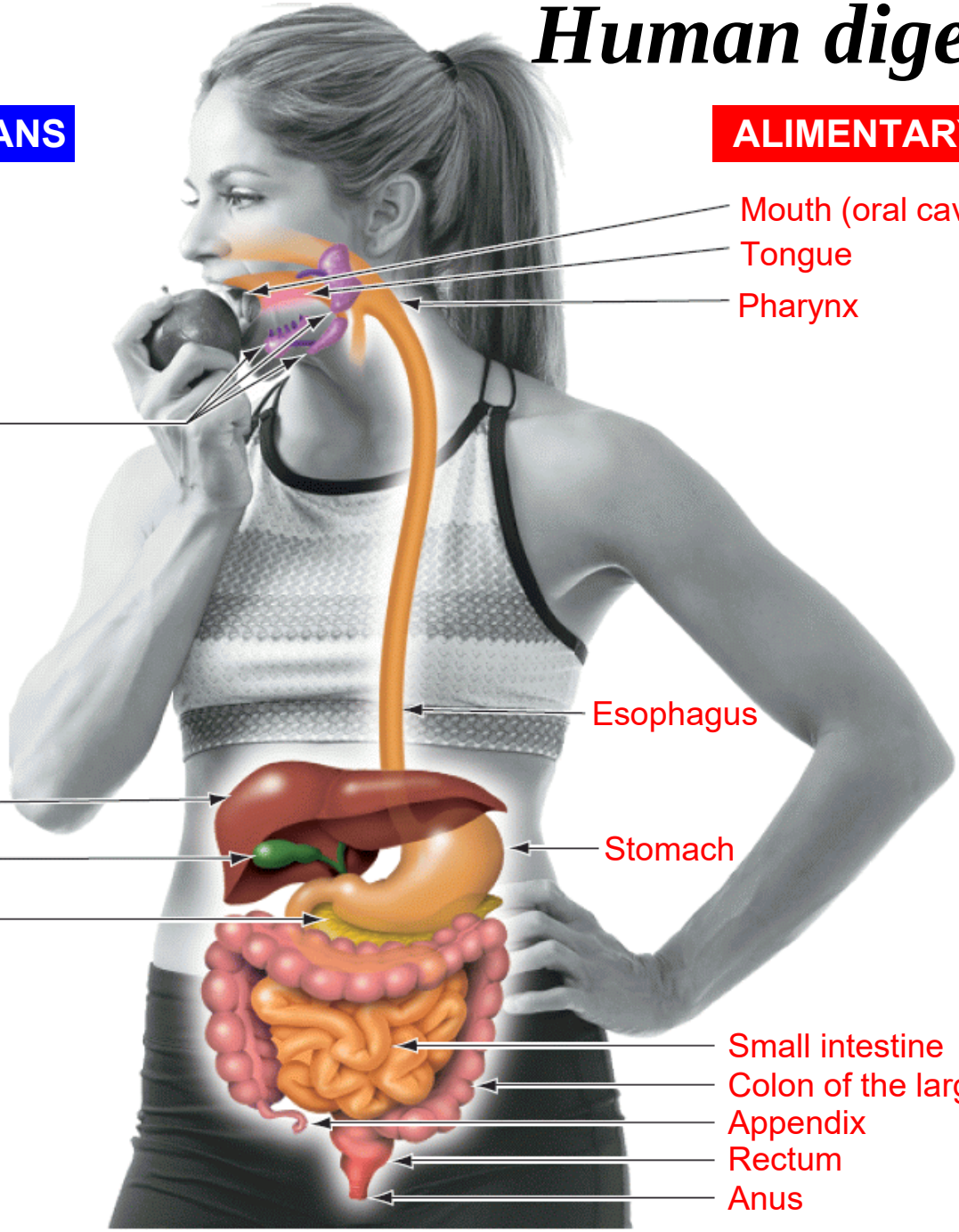


Diversity of animal diets

ANIMAL DIETS		
Herbivore (mainly eats plants and/or algae)	**Carnivore** (mainly eats animals)	**Omnivore** (regularly eats animals as well as plants)
		

Design by Zoran Tadić

Human digestive system



ACCESSORY ORGANS

Salivary glands

Liver

Gallbladder

Pancreas

ALIMENTARY CANAL

Mouth (oral cavity)

Tongue

Pharynx

Esophagus

Stomach

Small intestine

Colon of the large intestine

Appendix

Rectum

Anus

Design by Zoran Tadić

Overview of digestive processes in humans

Ingestion:
Food into mouth

Digestion:

Mechanical:

Chewing in mouth

Churning in stomach

Chemical:

Saliva in mouth

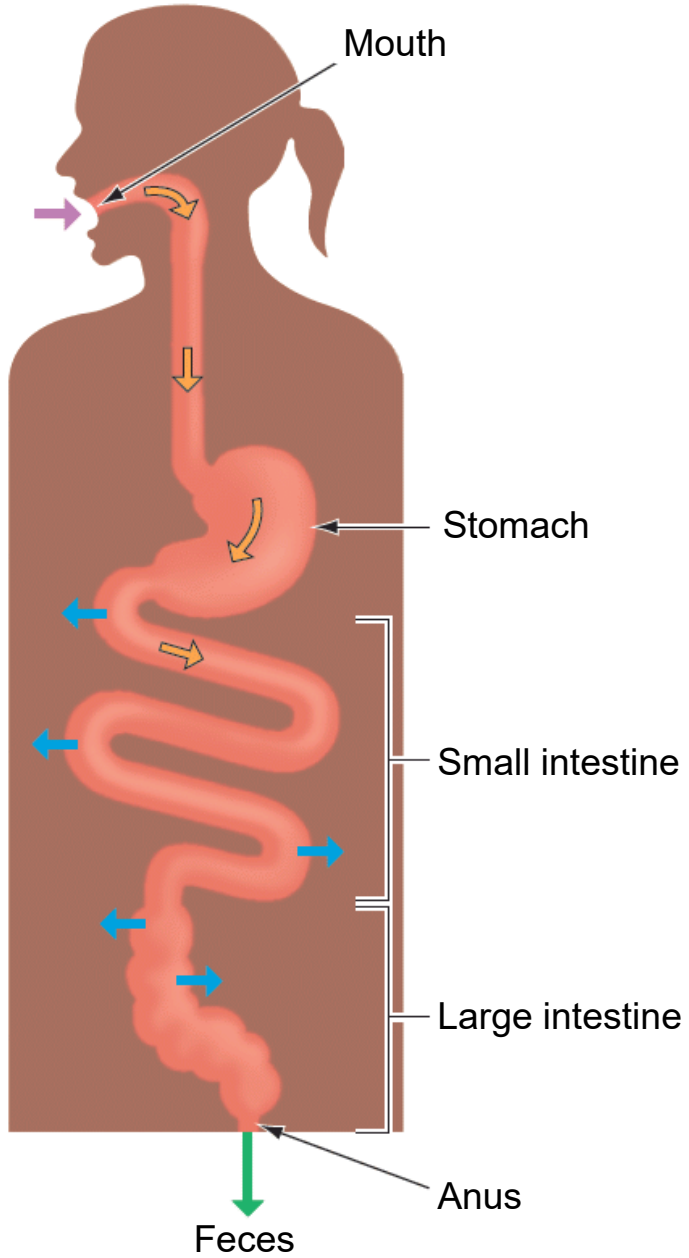
Pepsin and acid in stomach

Enzymes in small intestine

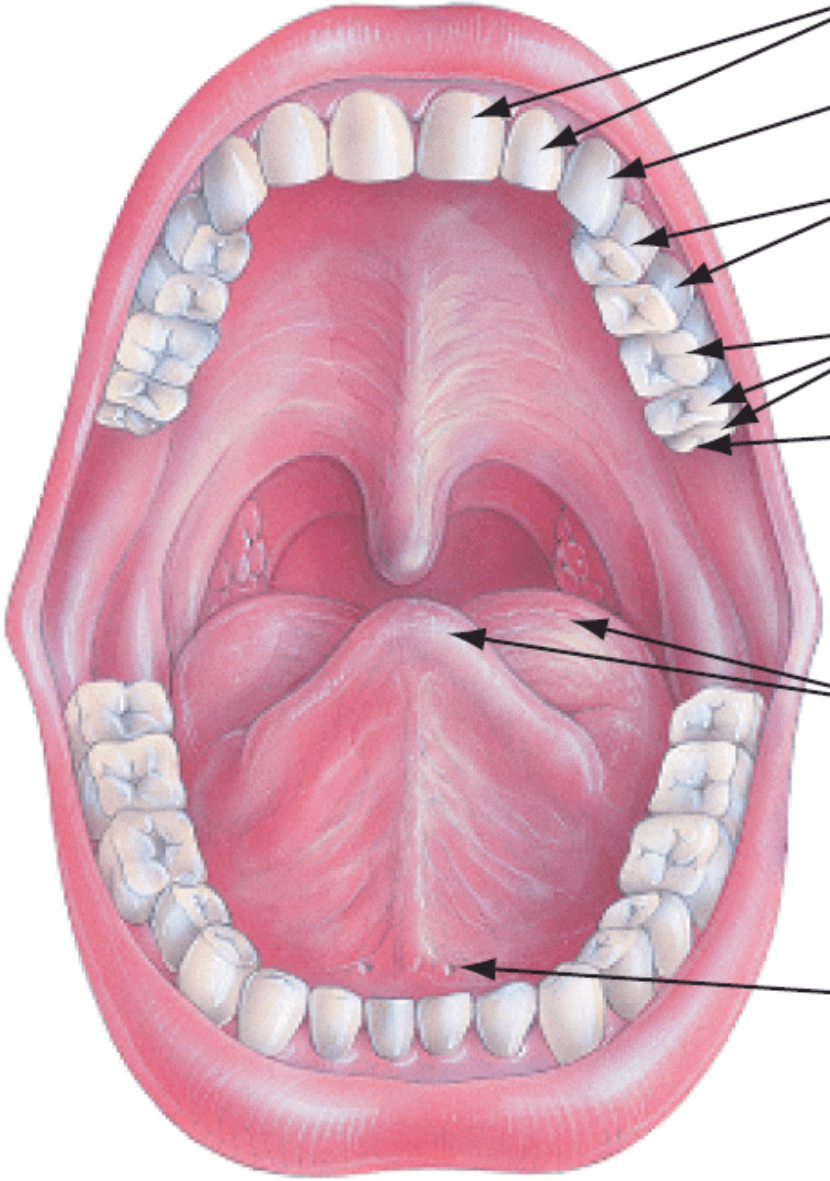
Apsorption:
Nutrients and water in small intestine

Water in large intestine

Elimination:
Feces formed in large intestine and eliminated through anus



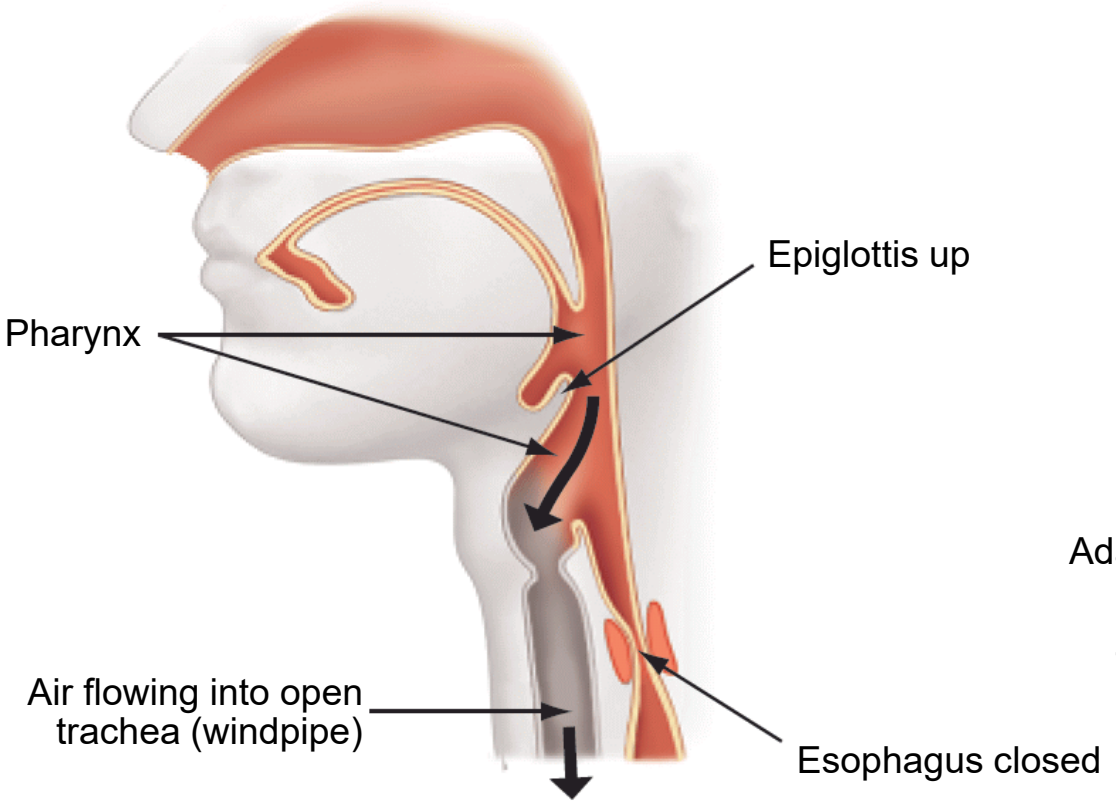
Human teeth



Incisors
Canine
Premolars
Molars
Wisdom tooth
Teeth
Tongue
Opening of a salivary gland duct

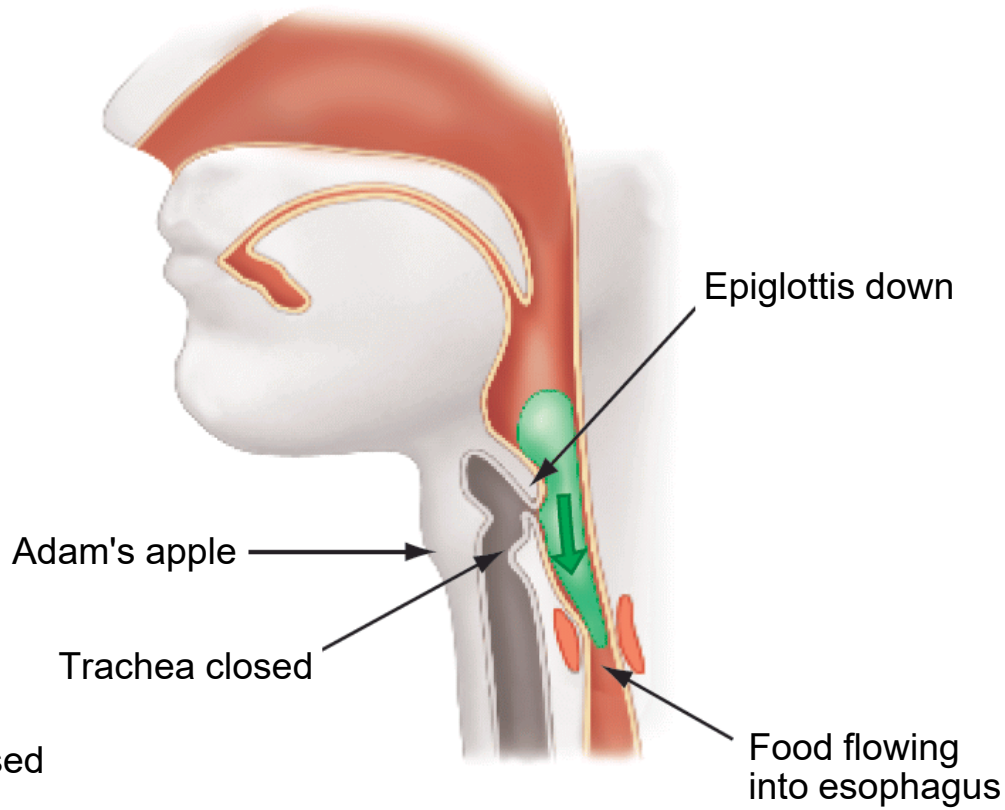
Epiglottis controls pharynx during swallowing

BREATHING



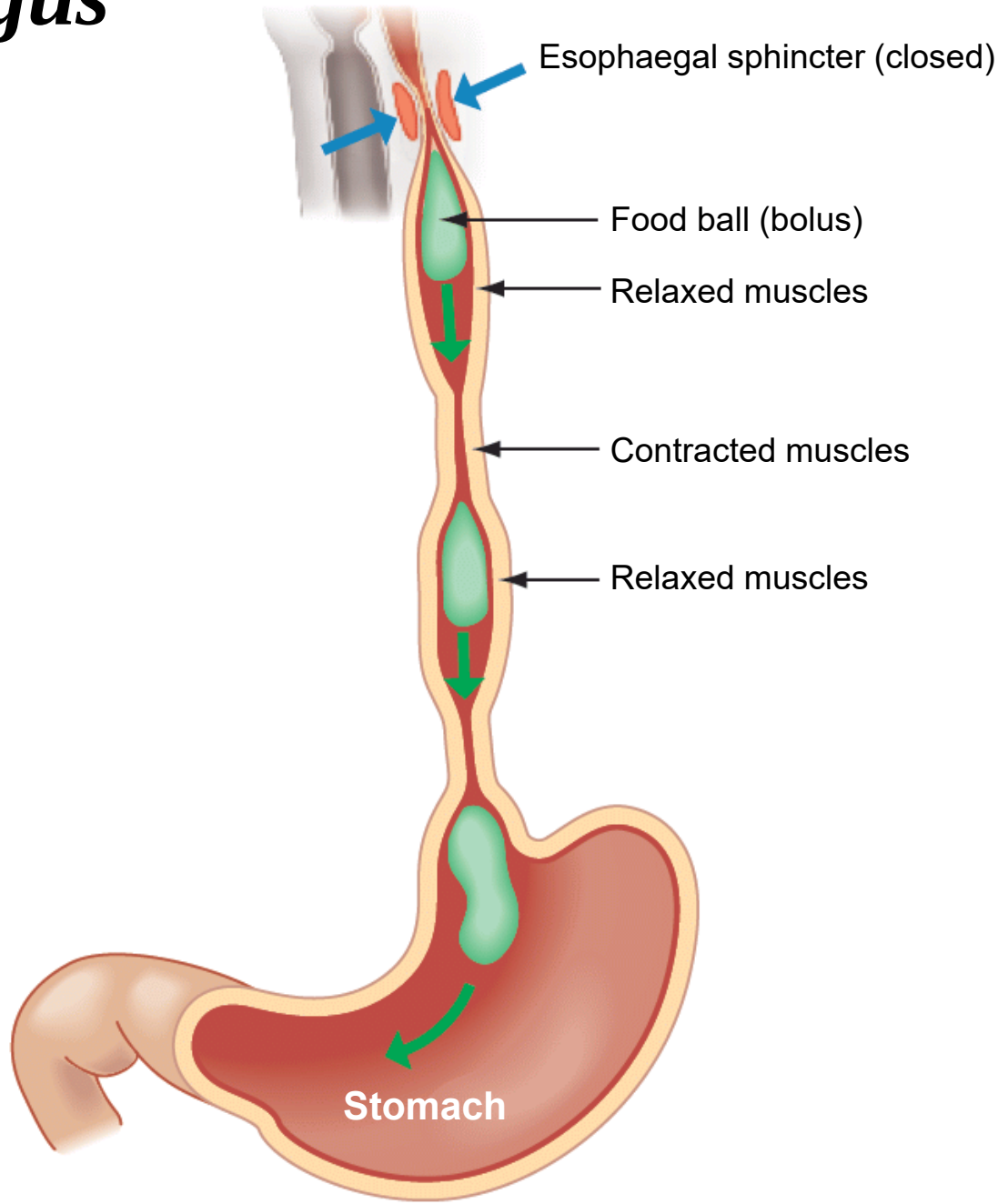
When you're not swallowing food or drink, air travels freely through the trachea (black arrows).The esophagus is closed.

SWALLOWING

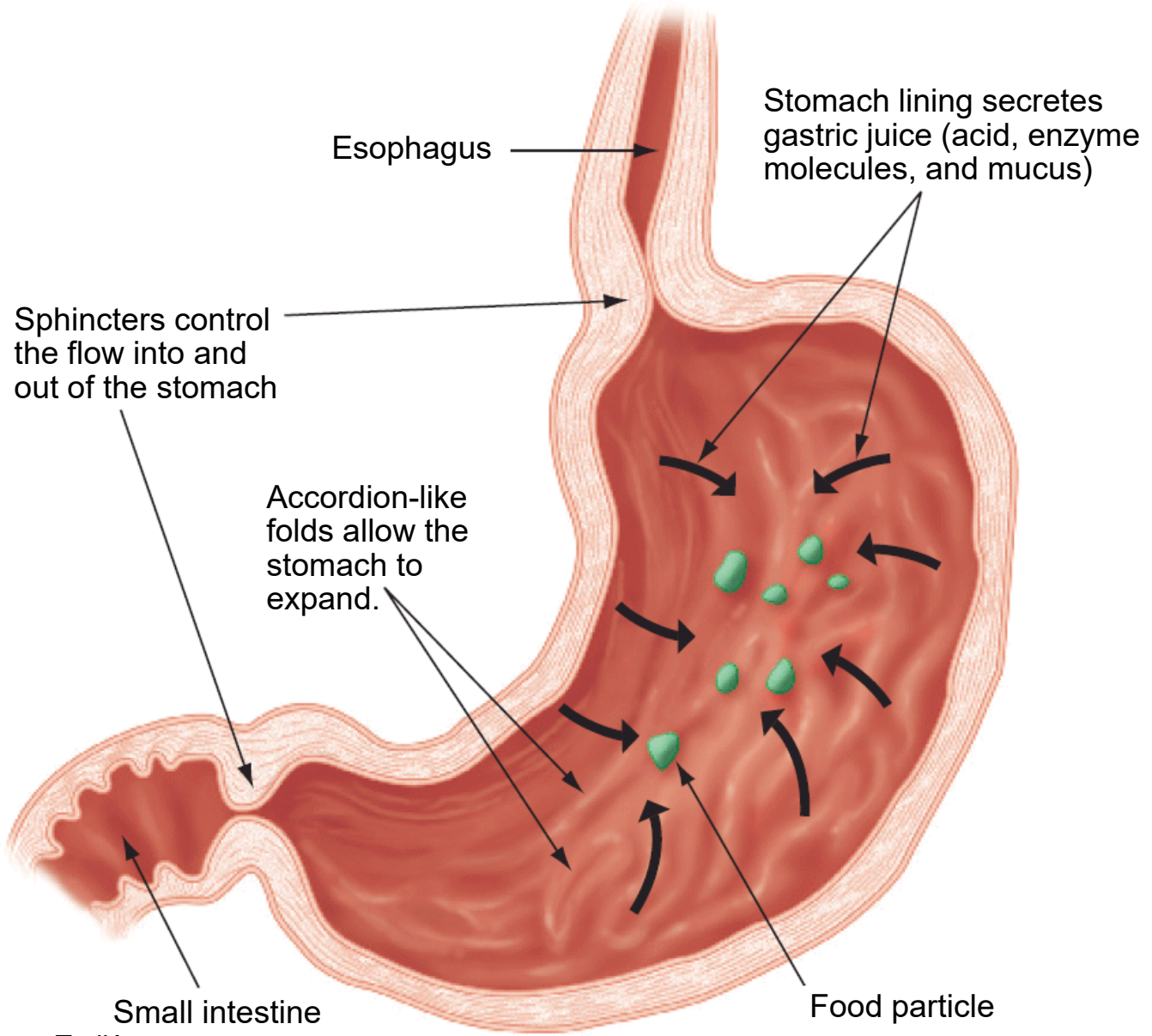


When the food reaches the back of the mouth, a swallowing reflex is triggered. The top of the trachea rises against the epiglottis, closing the air passage, while the esophagus opens. Food travels down the esophagus (green arrow).

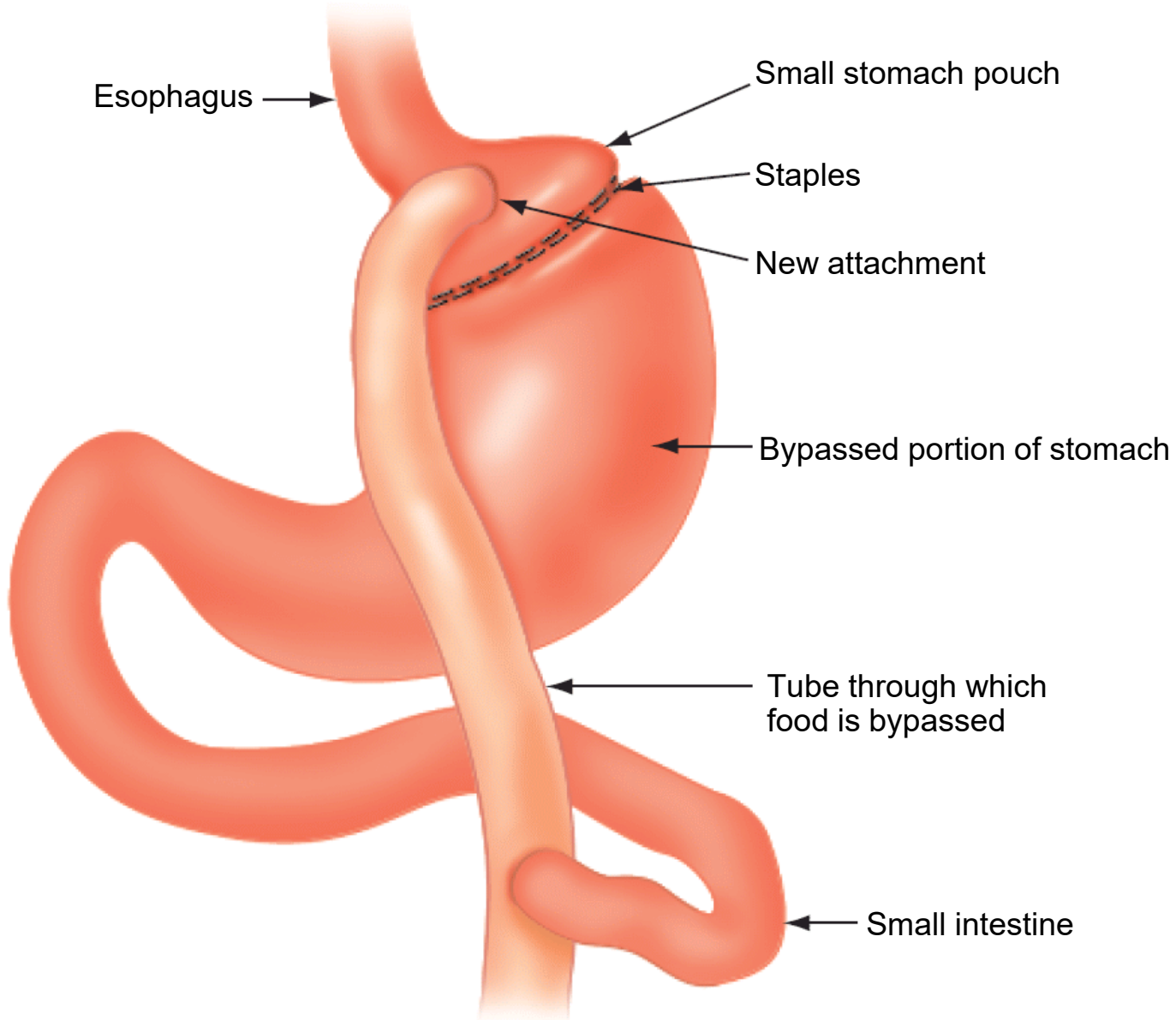
Peristalsis of esophagus



Human stomach



If you think you're too fat, you can always do this!



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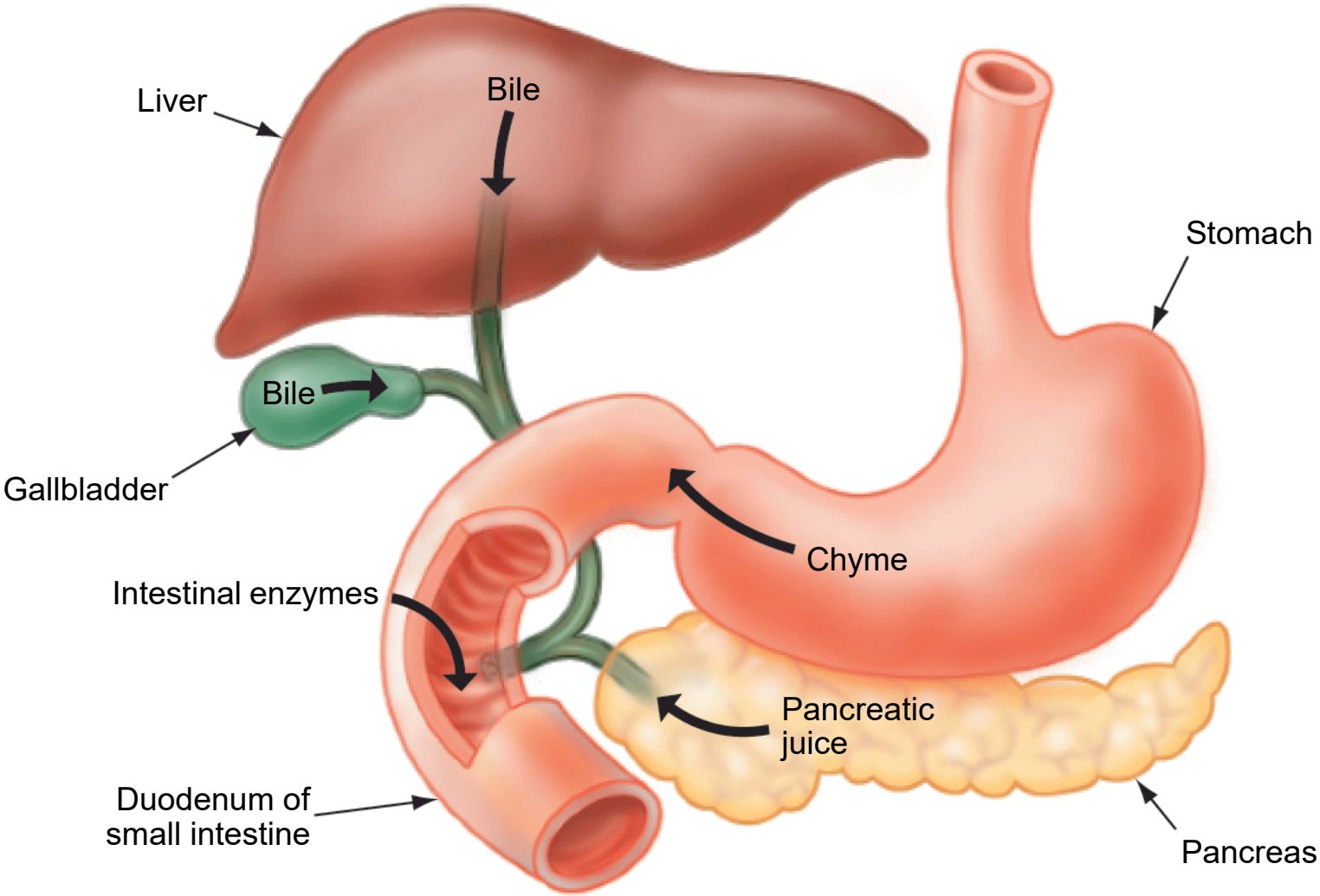
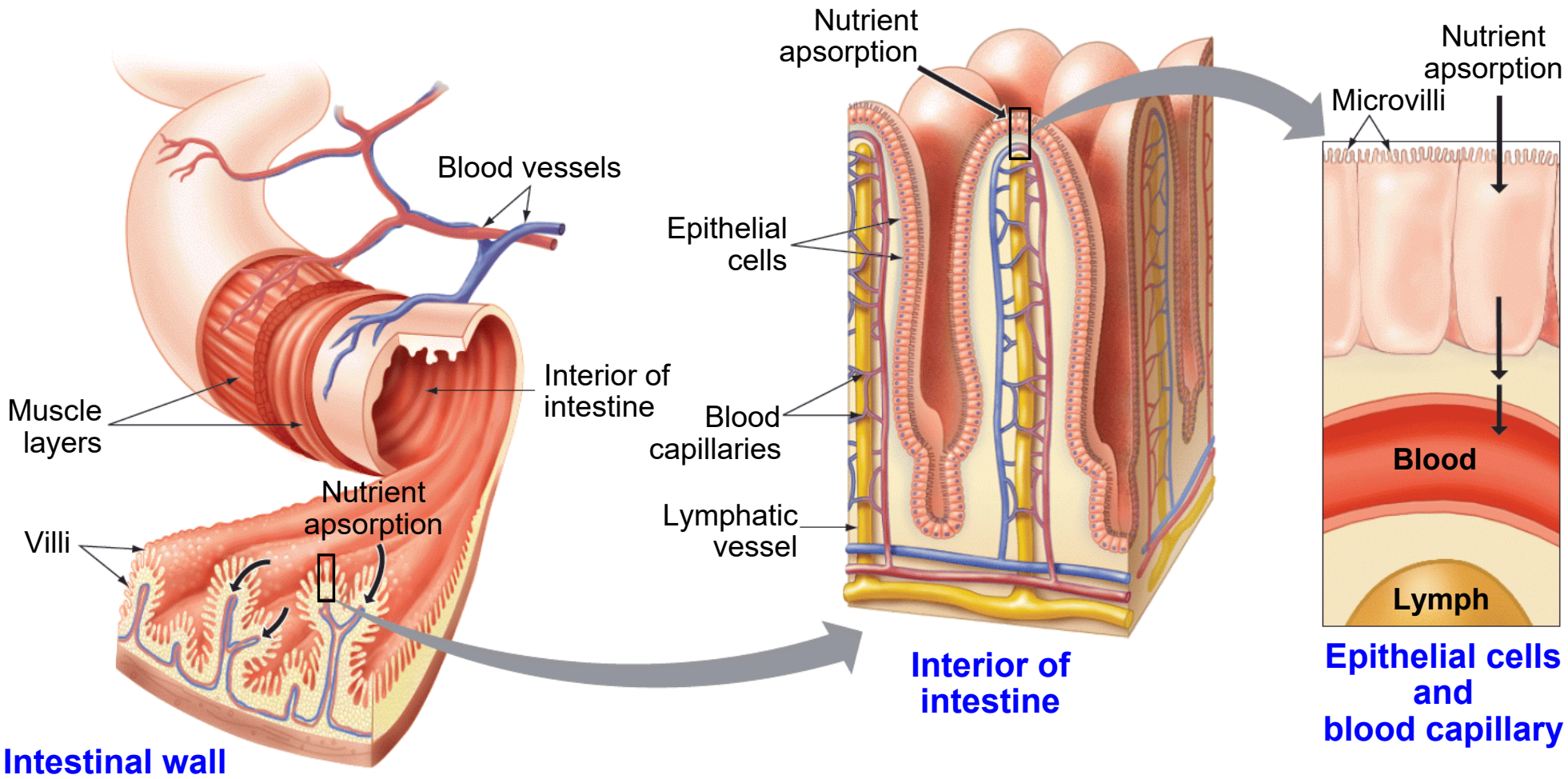
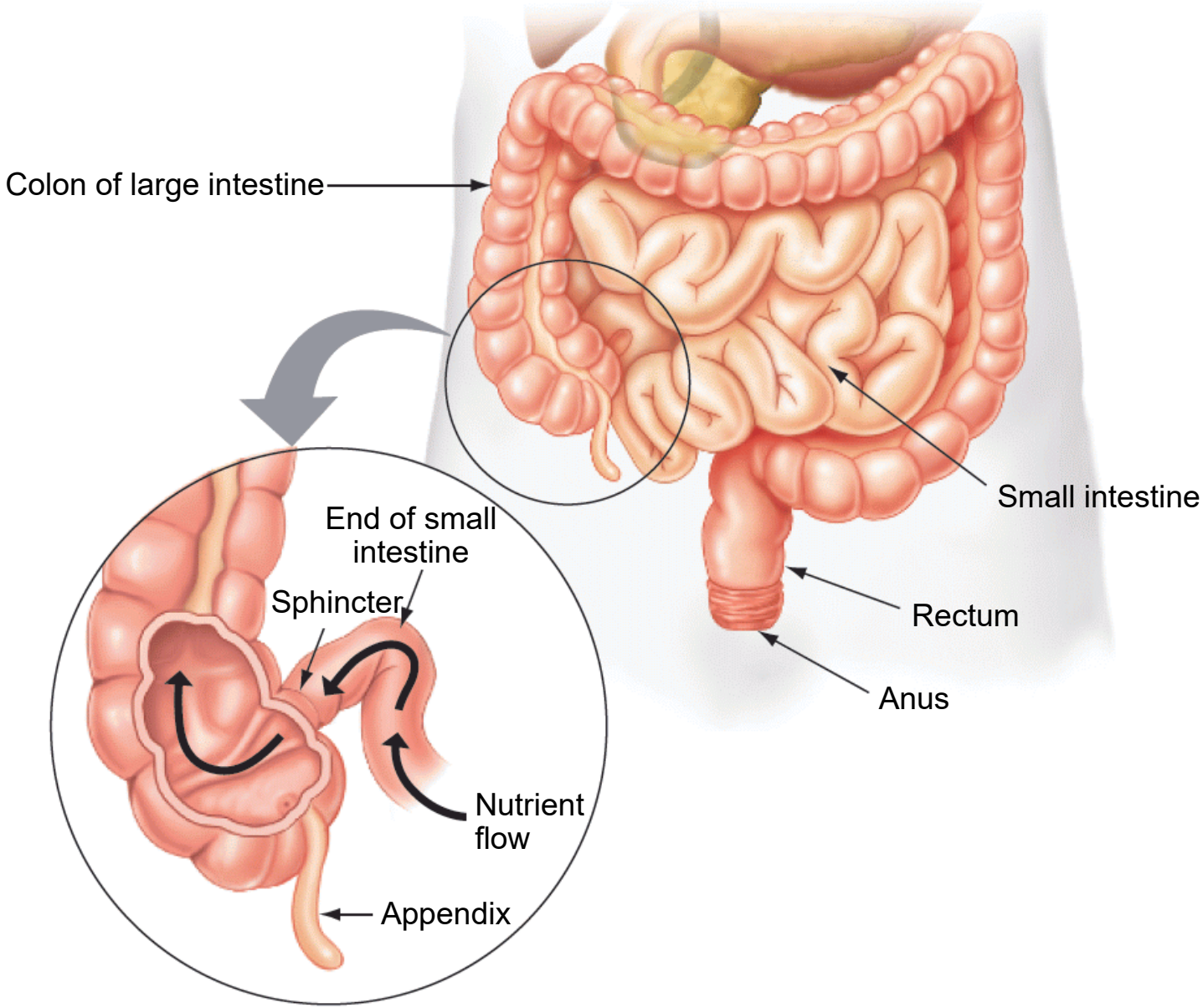
Digestion in duodenum



Small intestine - the place of nutrient apsorption



Large intestine - the place of water apsorption



THE END (of the kangaroo)