Tissues

16.1.2024

Learning outcomes

Recognize the main tissue types, their functions and division within the body

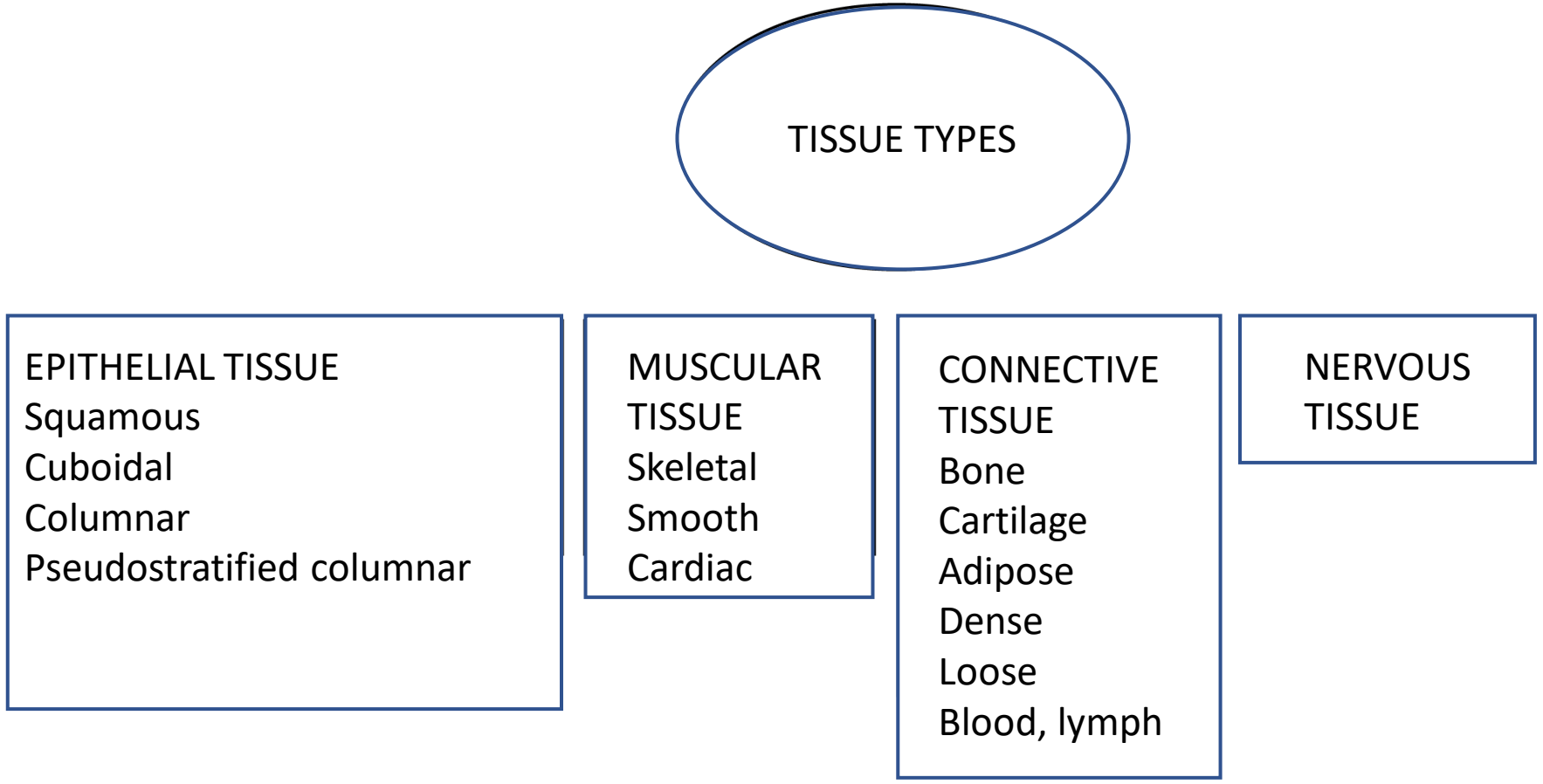
- Epithelial tissue
- Connective tissue
- Nervous tissue
- Muscular tissue

Understand the organization of nervous and muscular tissue in particular

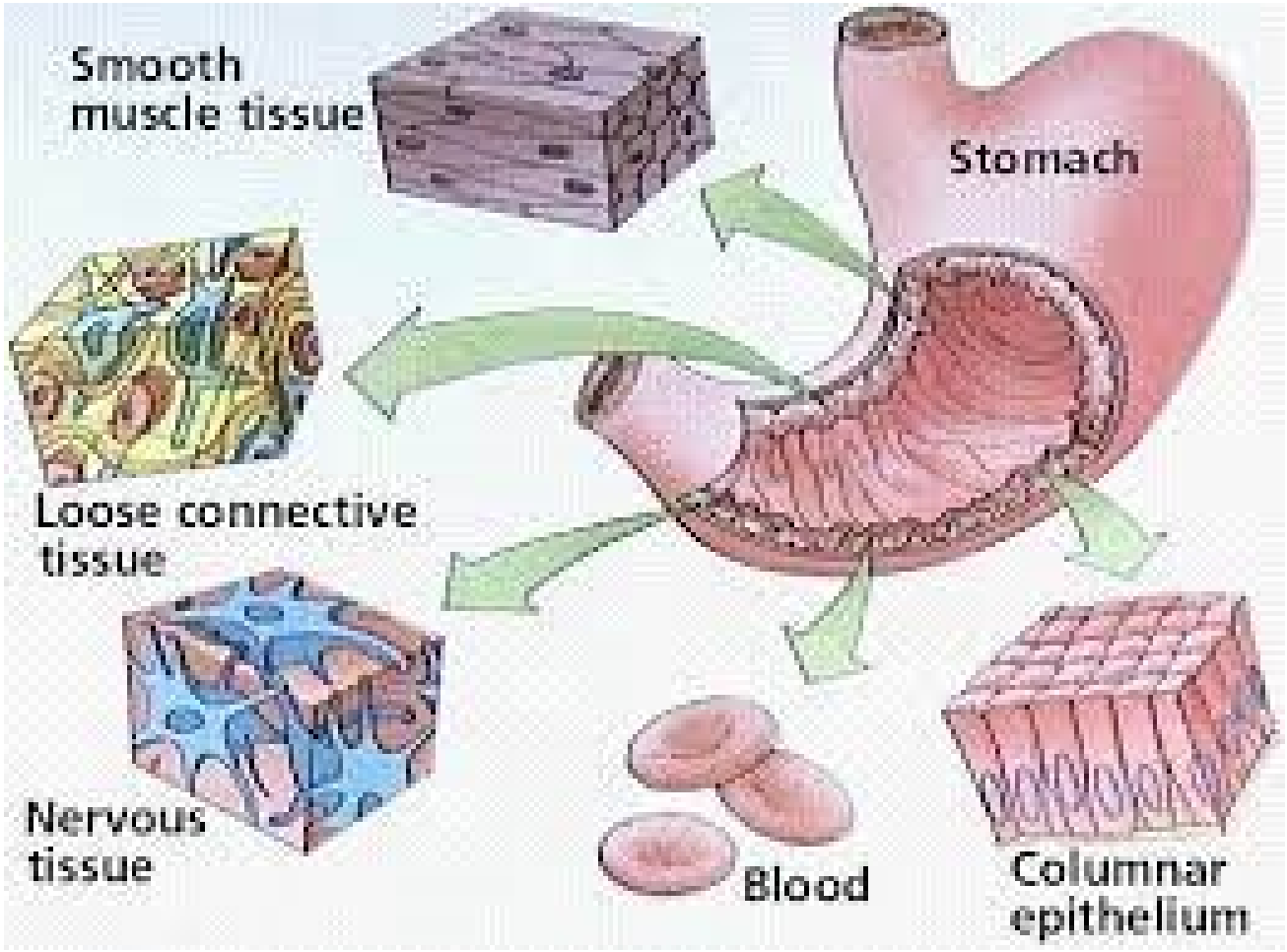
Be able to describe the electrical principles of nervous tissue

Cells that form a particular tissue have similar structure and function

- Histology = study of tissues
- Classified on the basis of cells and extracellular matrix
- Four main types
- Blood and lymph are subcategories of connective tissue



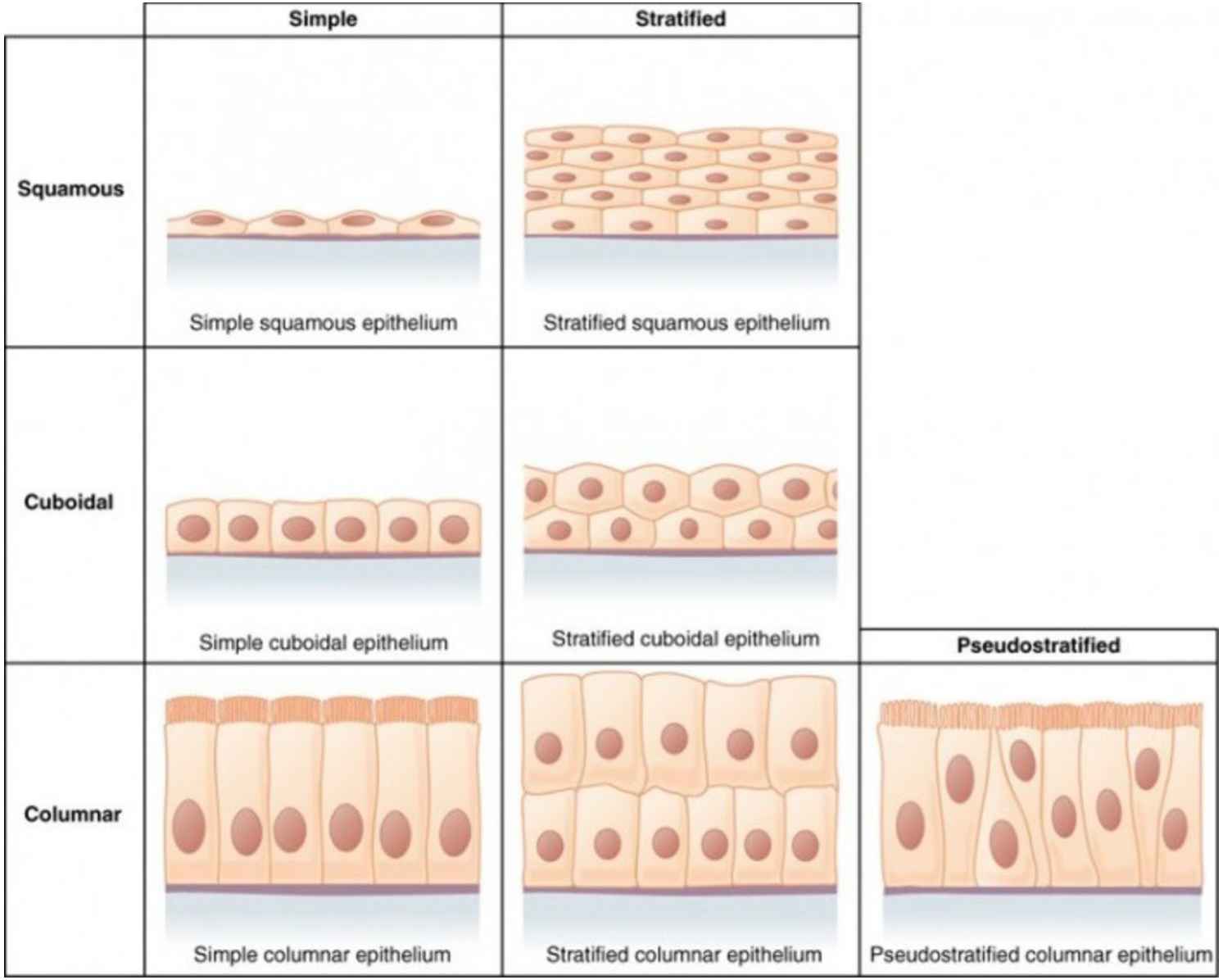
Organs typically contain various tissue types



www2.estrellamountain.edu

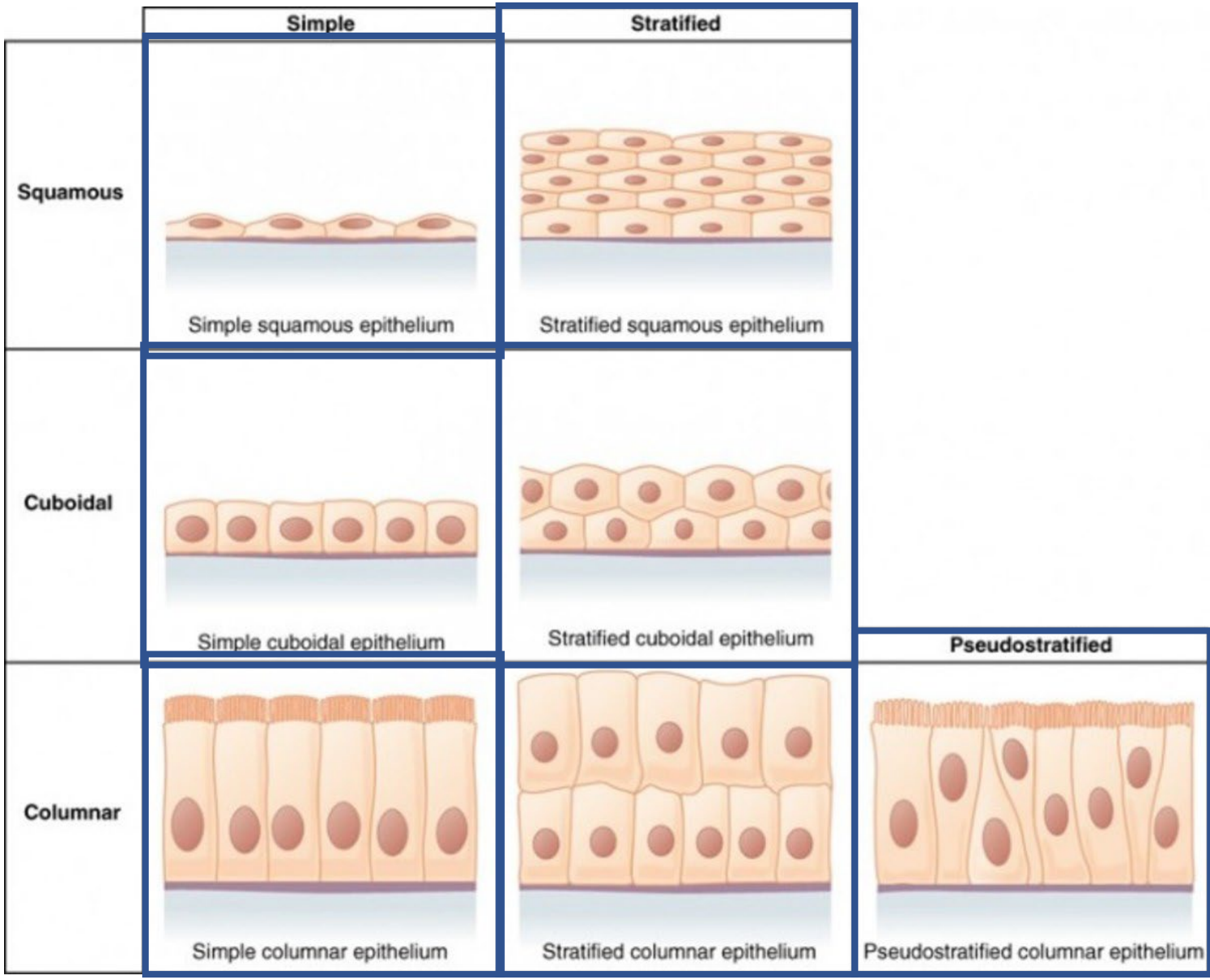
Epithelial tissue

- Skin, mucosa, ducts, sensory receptors, and interior of respiratory, digestive and urinary systems
- Avascular, renews constantly
- Cells closely packed and held together with tight junctions, only little extracellular matrix
- Functions in covering, absorption, secretion, and in receptors
- Thickness varies with function

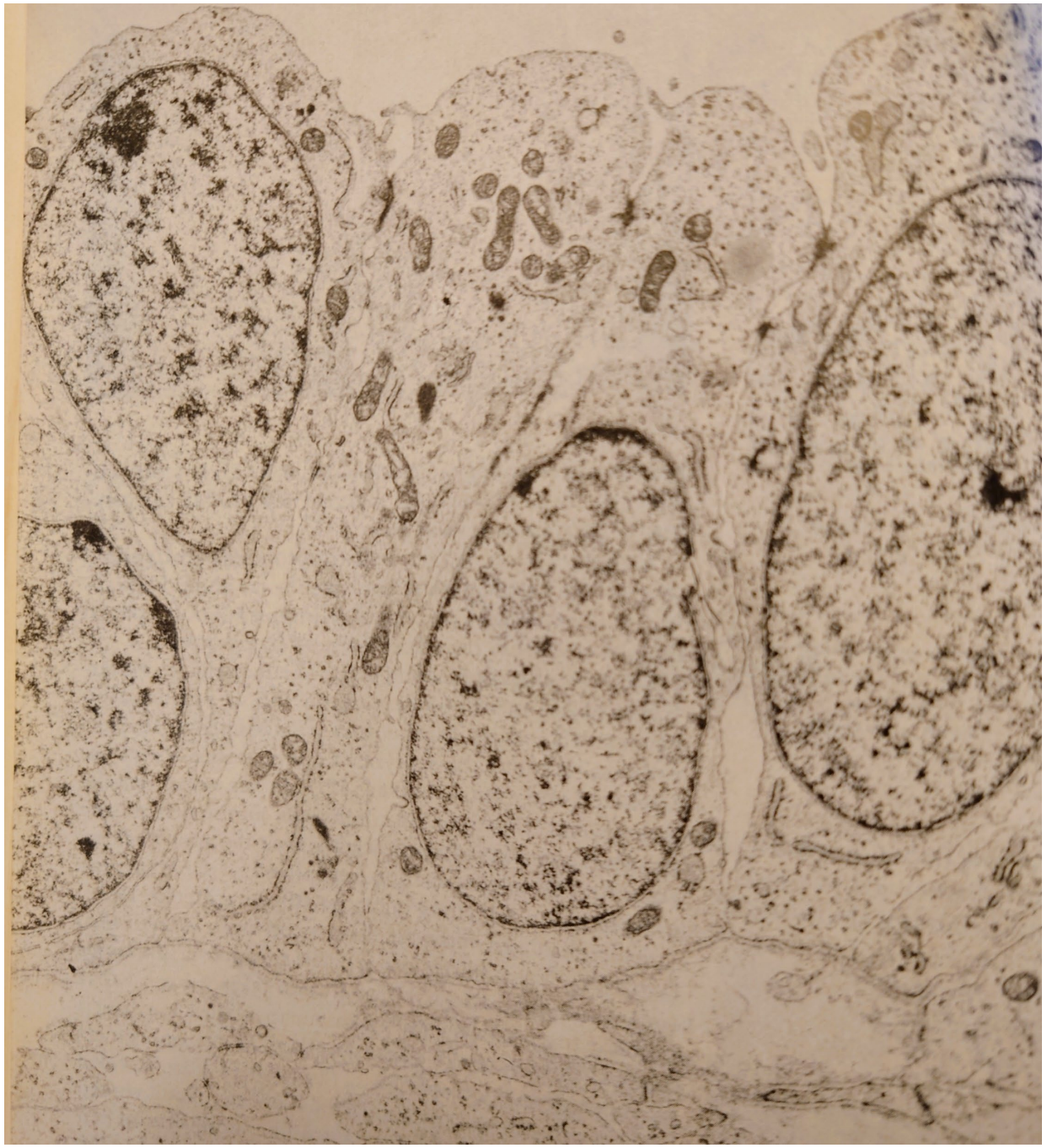


https://images.saymedia-content.com

- *Simple squamous epithelium* in blood vessels (endothelium) ja air sacs in lungs
- *Simple columnar epithelium* lines the gastrointestinal tract from the stomach onwards
- *Ciliated pseudostratified columnar epithelium* resides in the upper respiratory tract
- *Stratified epithelium* in the skin, mouth, esophagus
- *Cuboidal epithelium* in the ducts of glands



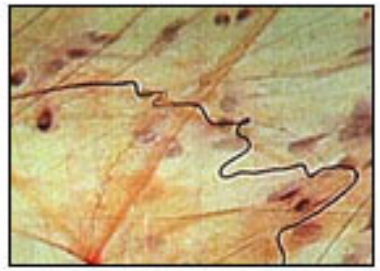
Columnar epithelium
in the stomach

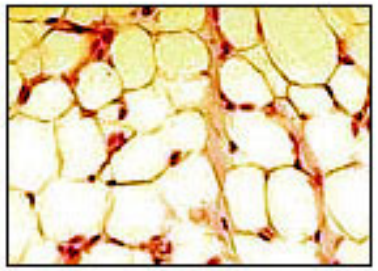


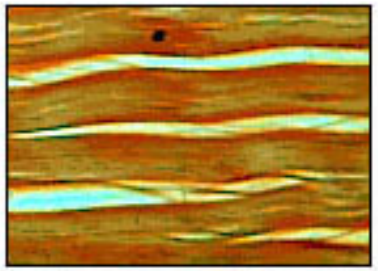
Nienstedt et al. Ihmisen fysiologia ja anatomia

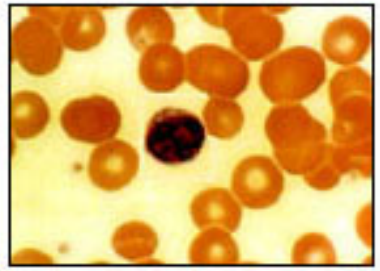
Connective tissue

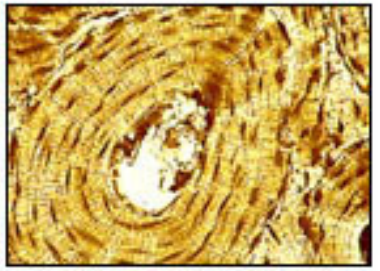
- Four main types: Dense and loose connective tissue, adipose, cartilage, bone
- Common histological features
- Developed from mesenchymal cells
- Extracellular matrix >> cells
- Rich of extracellular matrix protein: collagen, elastic fibers, reticular fibers
- Good vascular support (except for cartilage)

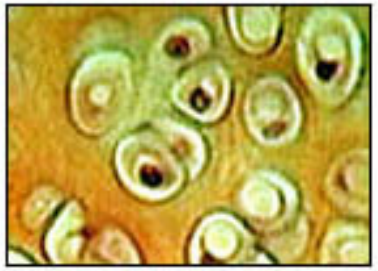

Areolar connective tissue


Adipose tissue


Fibrous connective tissue


Blood


Osseous tissue


Hyaline cartilage

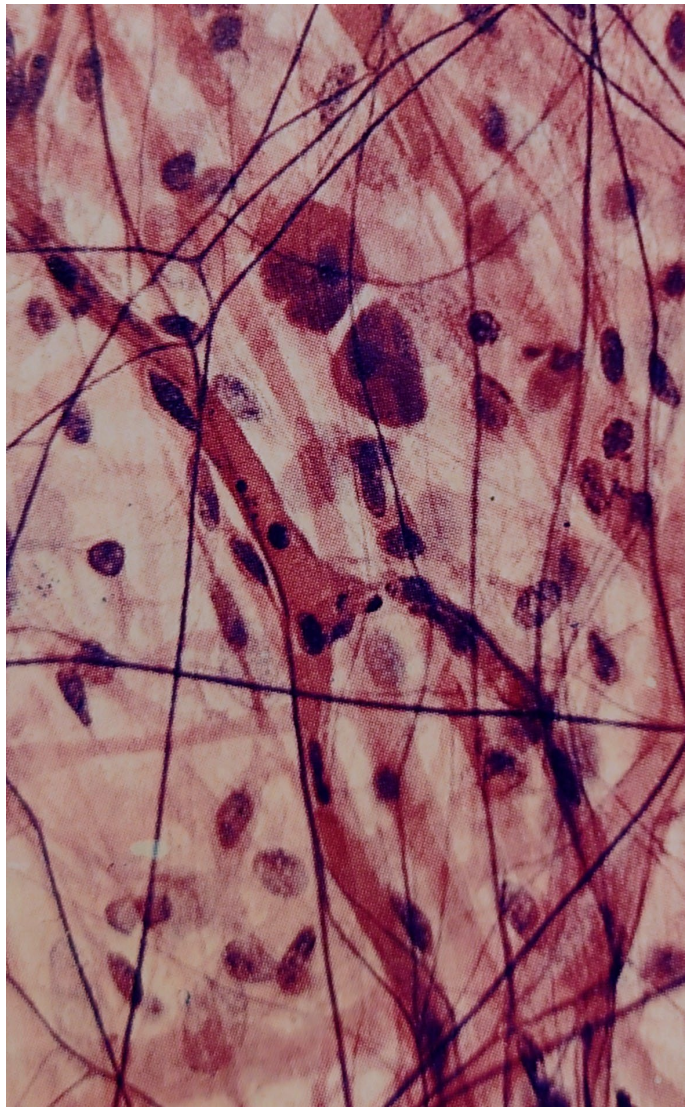
Wikipedia

Collagen

- abundant in skin and tendons
- tensile strength

Elastic fibers

- blood vessels, skin, lung tissue
- allow great stretching



Nienstedt et al. Ihmisen fysiologia ja anatomia

Loose connective tissue

- “everywhere”
- Renews rapidly (scars)

Dense connective tissue

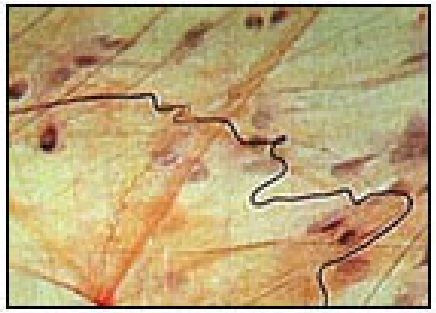
- Tendons, ligaments

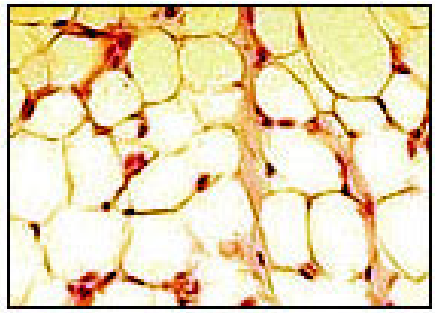
Adipose tissue

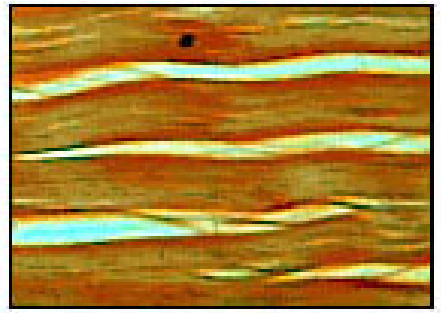
- Abundant under the skin and in omentum

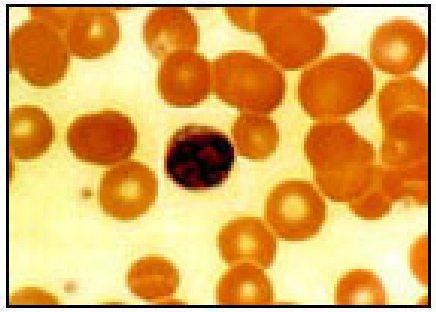
Cartilage

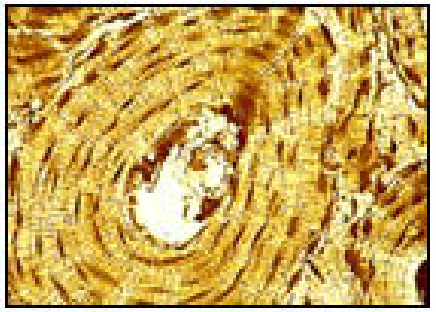
- Strong and tension resistant
- Joints, spine, trachea
- Avascular, no nerve tissue

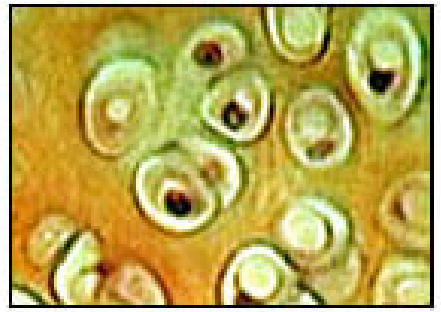

Areolar connective tissue


Adipose tissue


Fibrous connective tissue


Blood

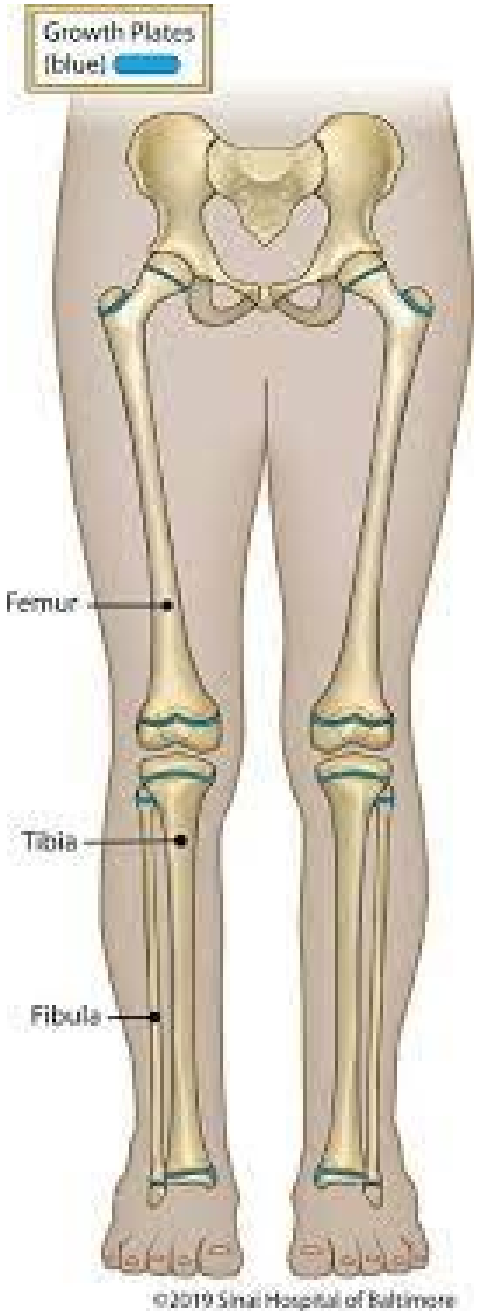

Osseous tissue

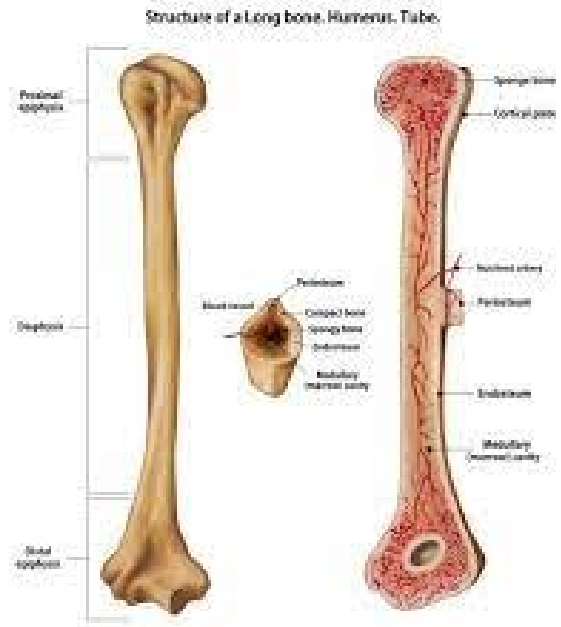

Hyaline cartilage

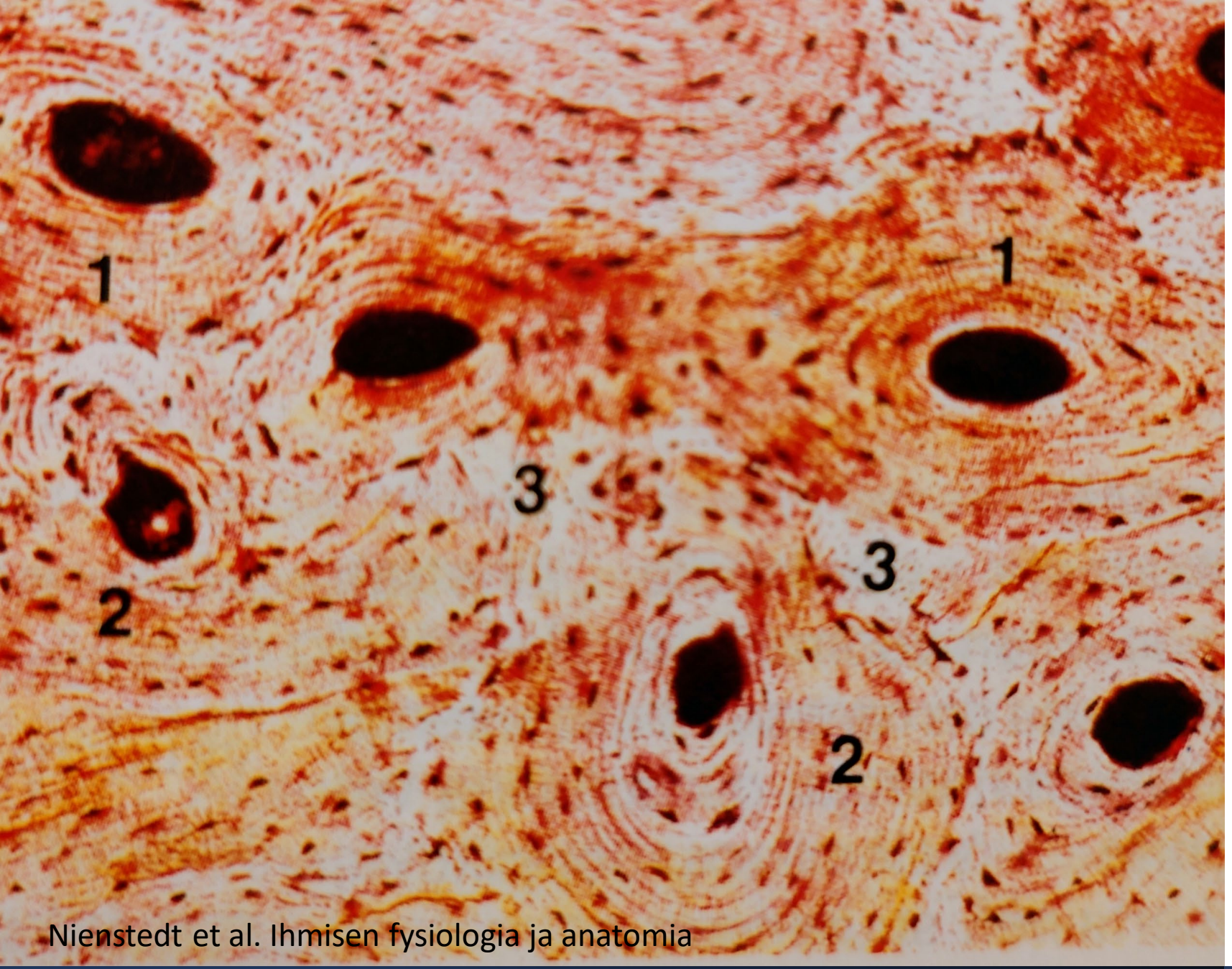
Wikipedia

Bone tissue

- Partly forms directly from the mesenchymal cells (intramembranous ossification)
- More typically first a cartilage model (endochondral ossification)
- Growth plates are the last ones to ossificate
- Production of blood cells in bone marrow







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- Cells are organized around vessels (*osteons*)
- High metabolism: bone resorption and deposition
- Calcium and phosphate storage
- Strong hormonal effects on bone growth and remodelling

Nervous tissue

- Most complicated of the tissue types
- Nerve cells and glial cells
  10^{10} nerve cells in the brain alone

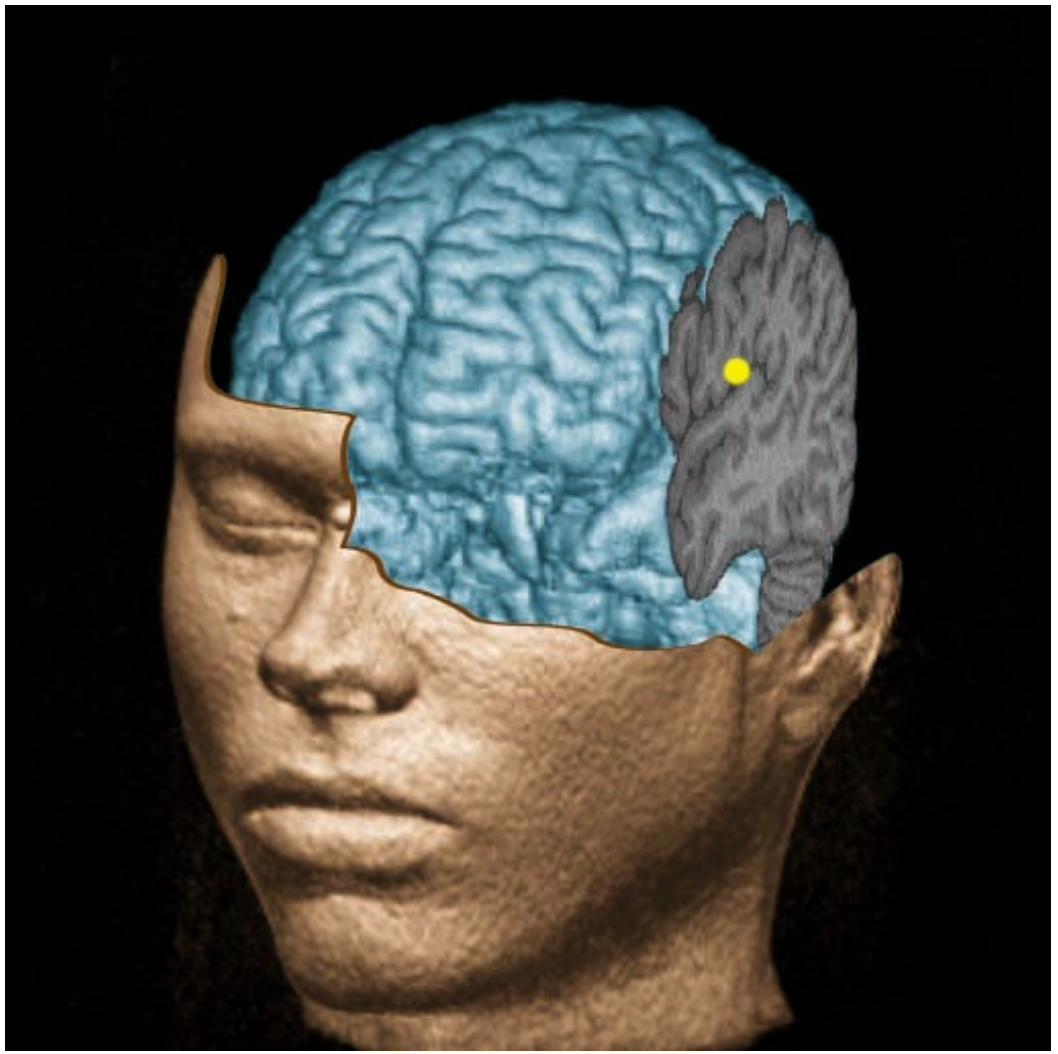
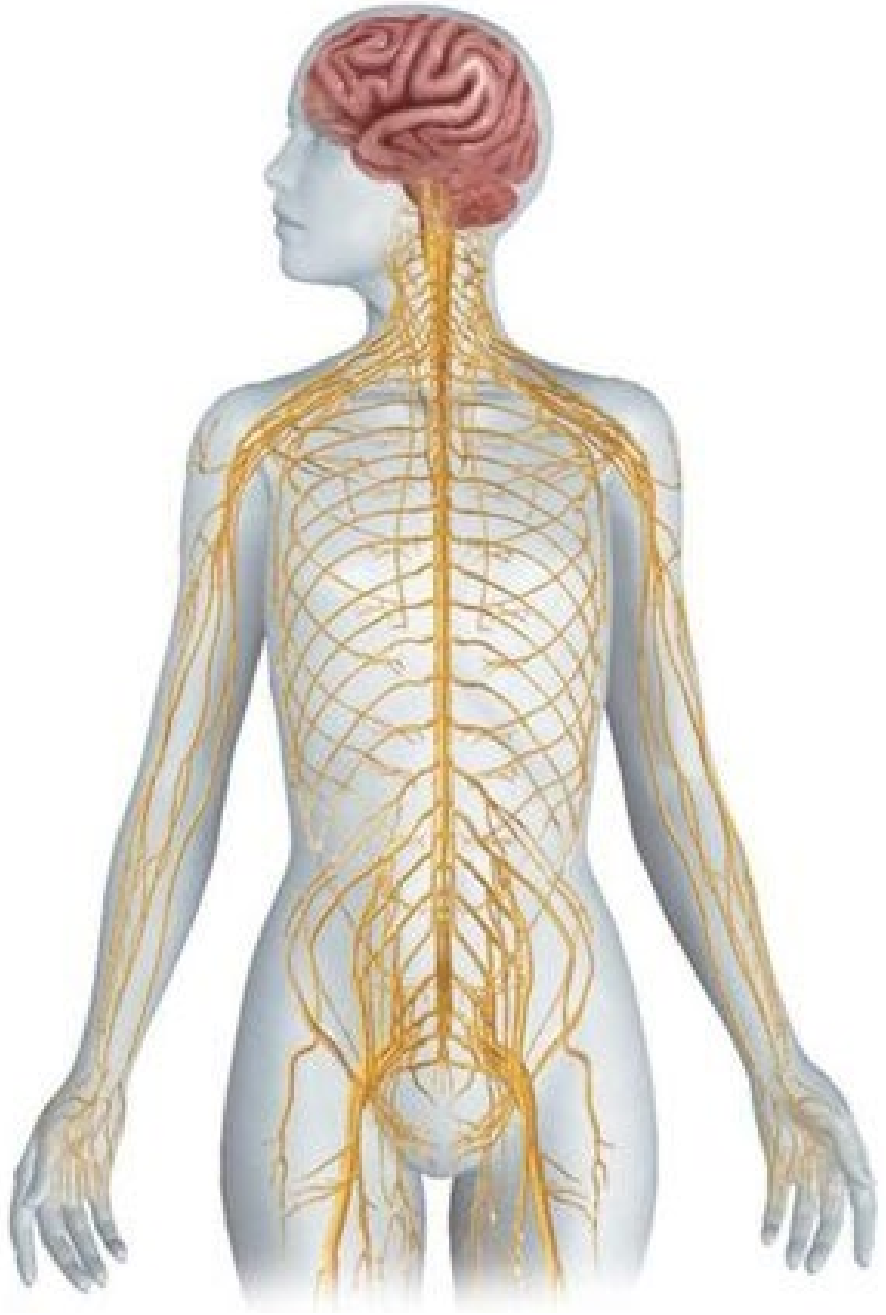


Figure: E. Salli

Central and peripheral nervous system

- Central neurvous system = brain and spinal cord
- Peripheral nervous system = efferent and afferent nerve fibers to and from the muscles and inner organs



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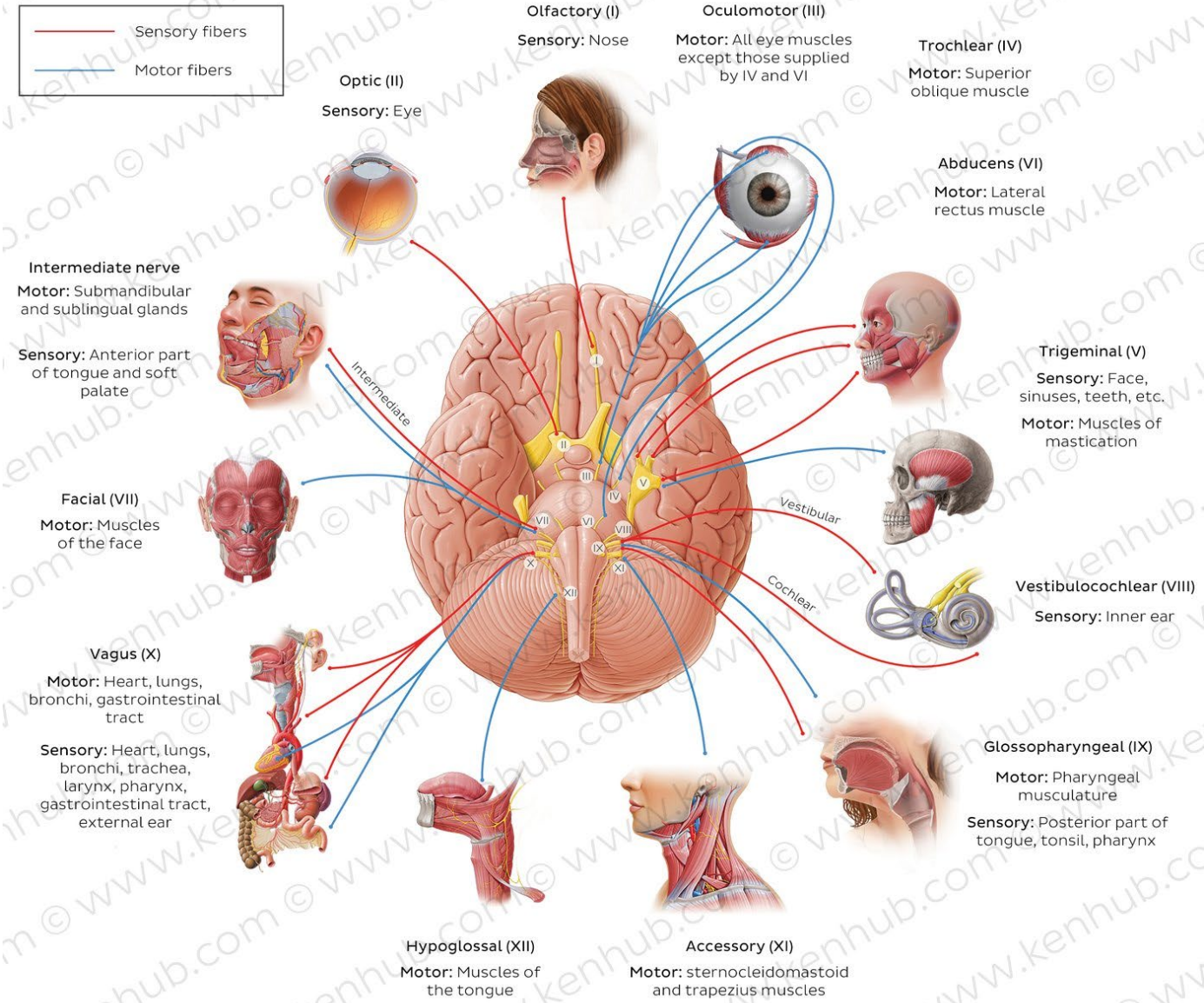
Peripheral nervous system consists of somatic and autonomous nervous systems

- Somatic nervous system =

  12 cranial nerves, 31 spinal nerves



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- Somatic nervous system =
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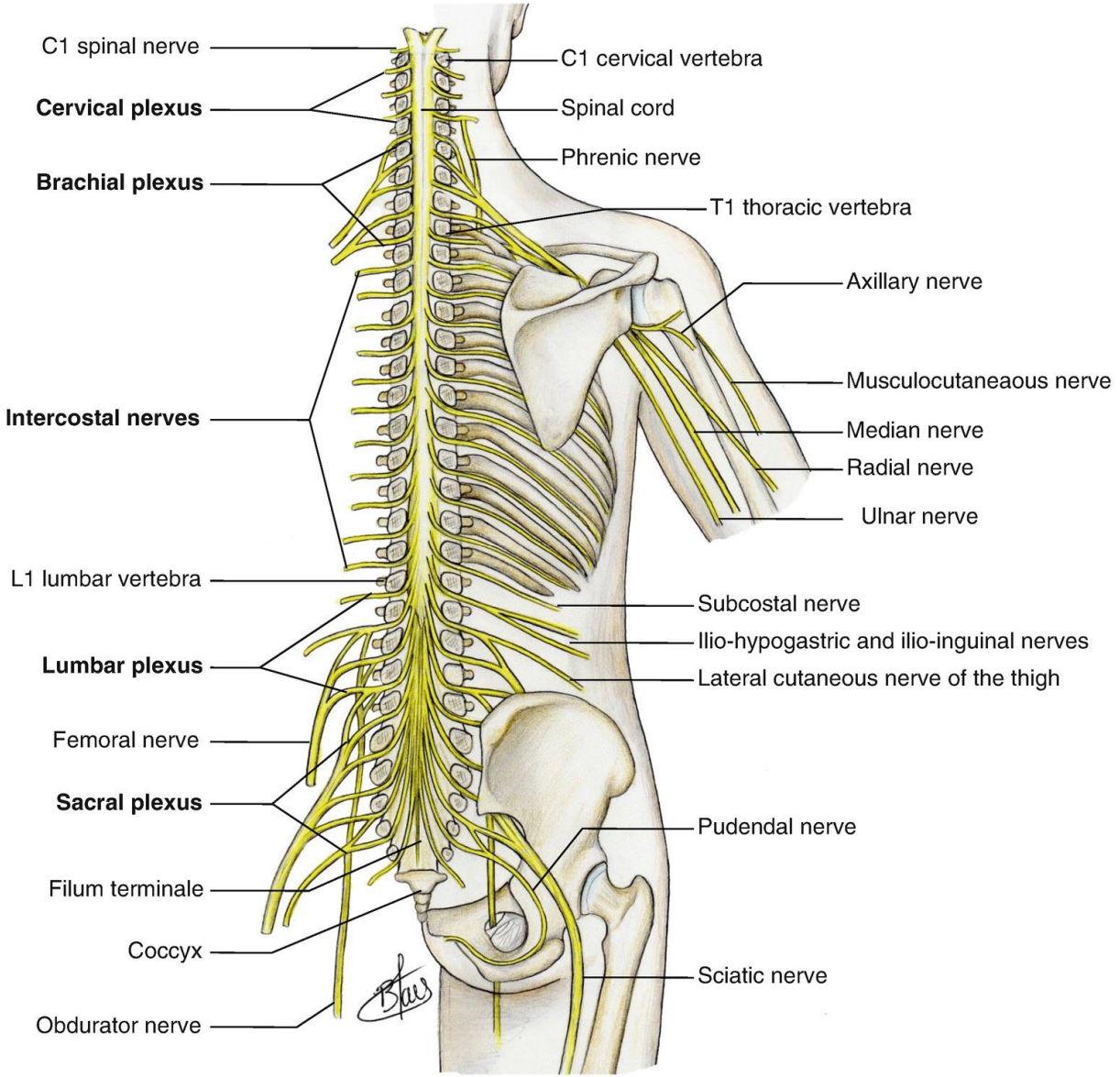

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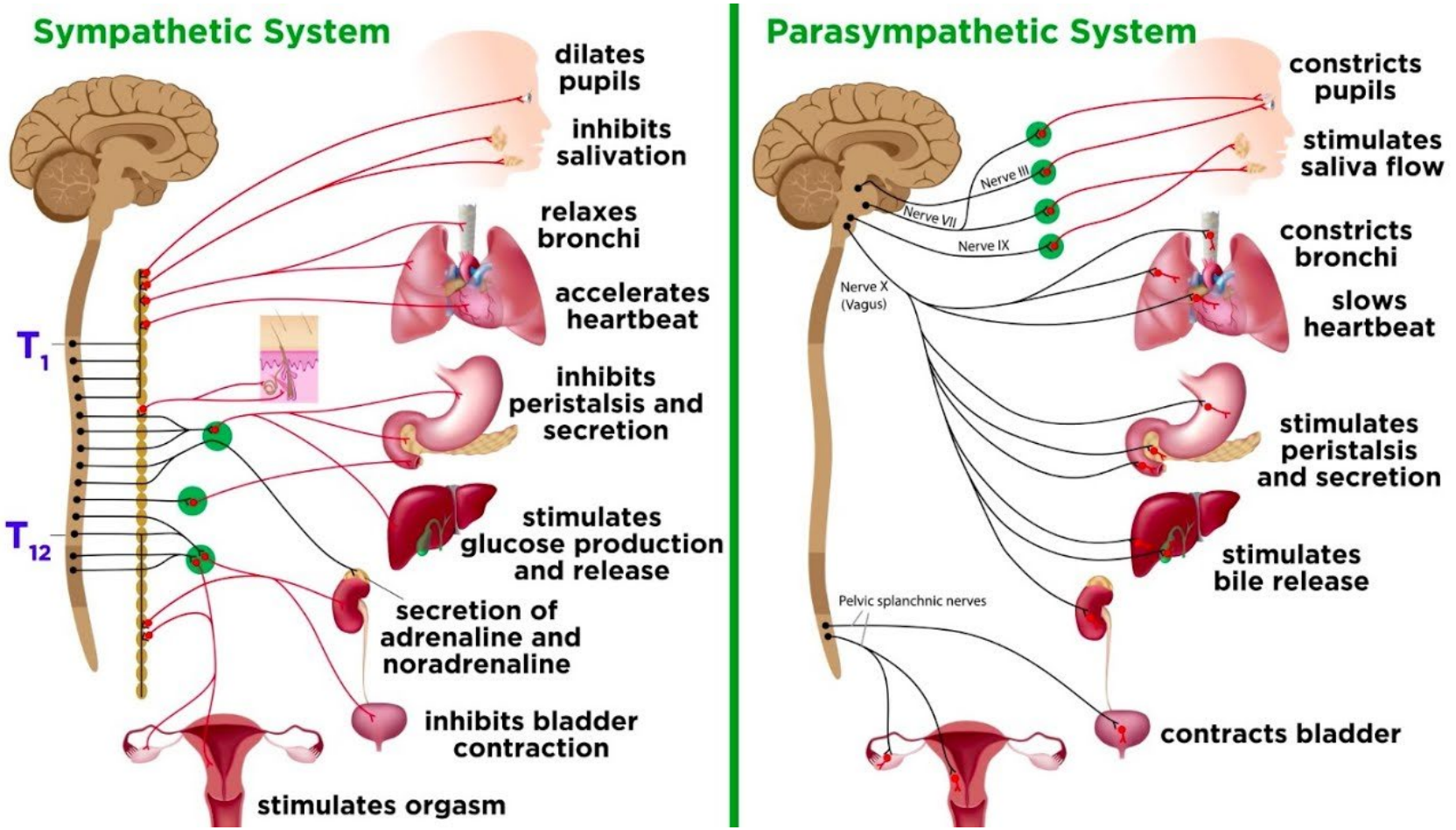
Autonomic nervous system

- Control and information to and from inner organs (*e.g.*, heart, glands, smooth muscles)



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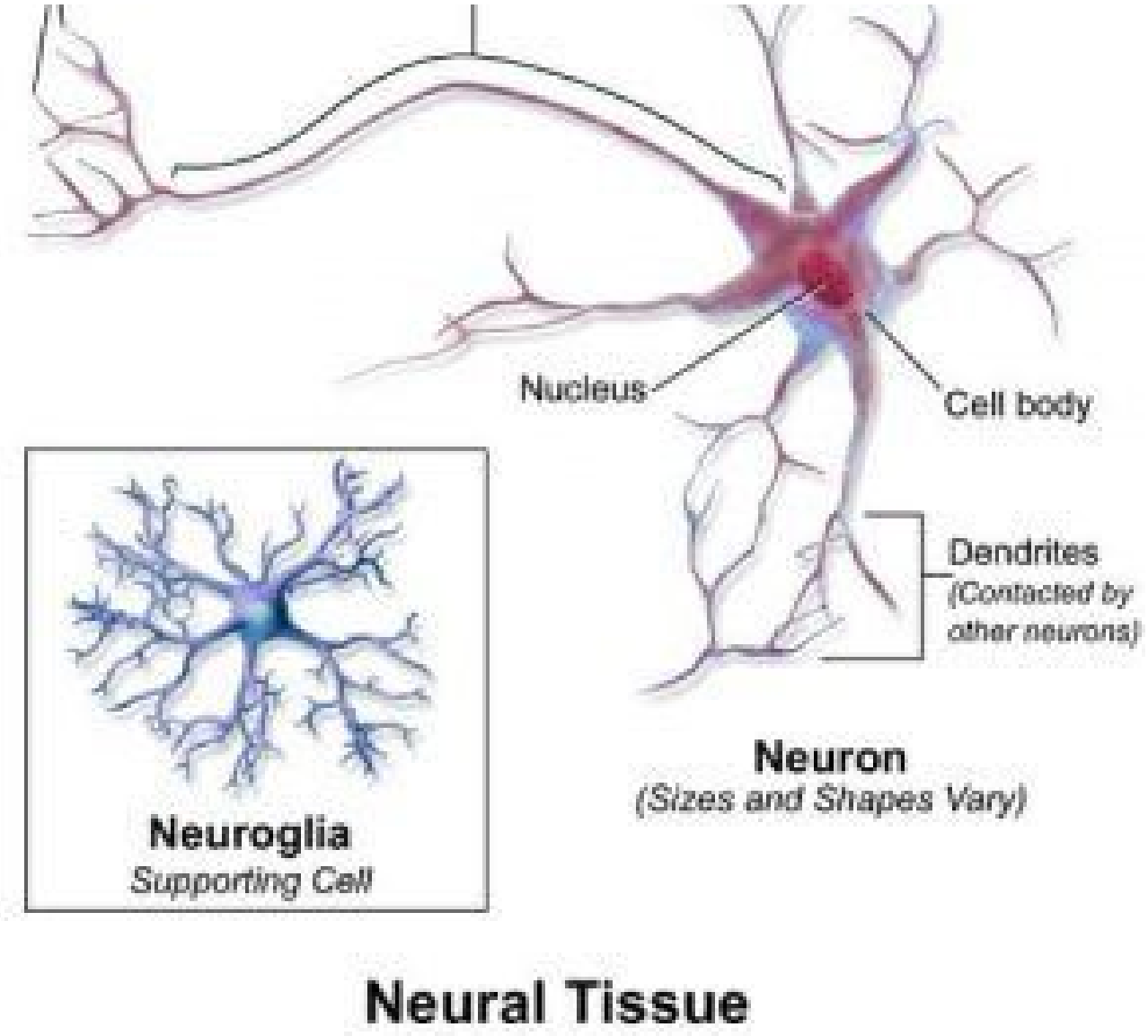
Nervous tissue consists of nerve cells and glial cells



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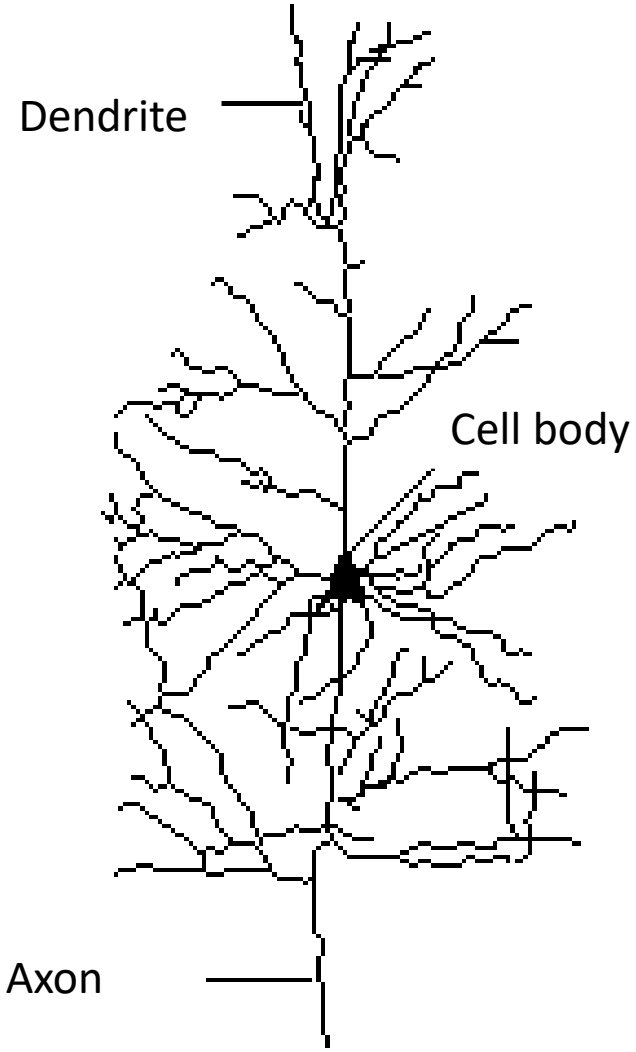
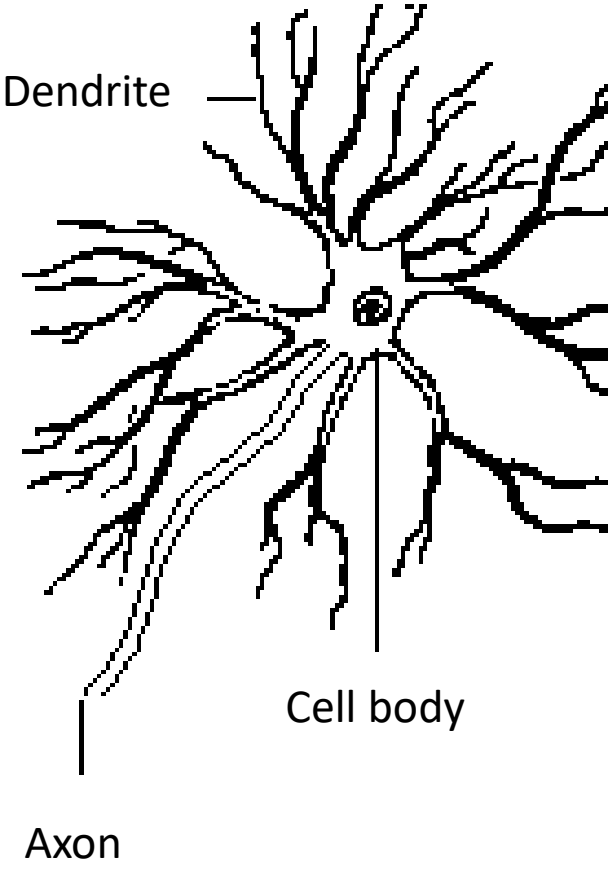
Neuron

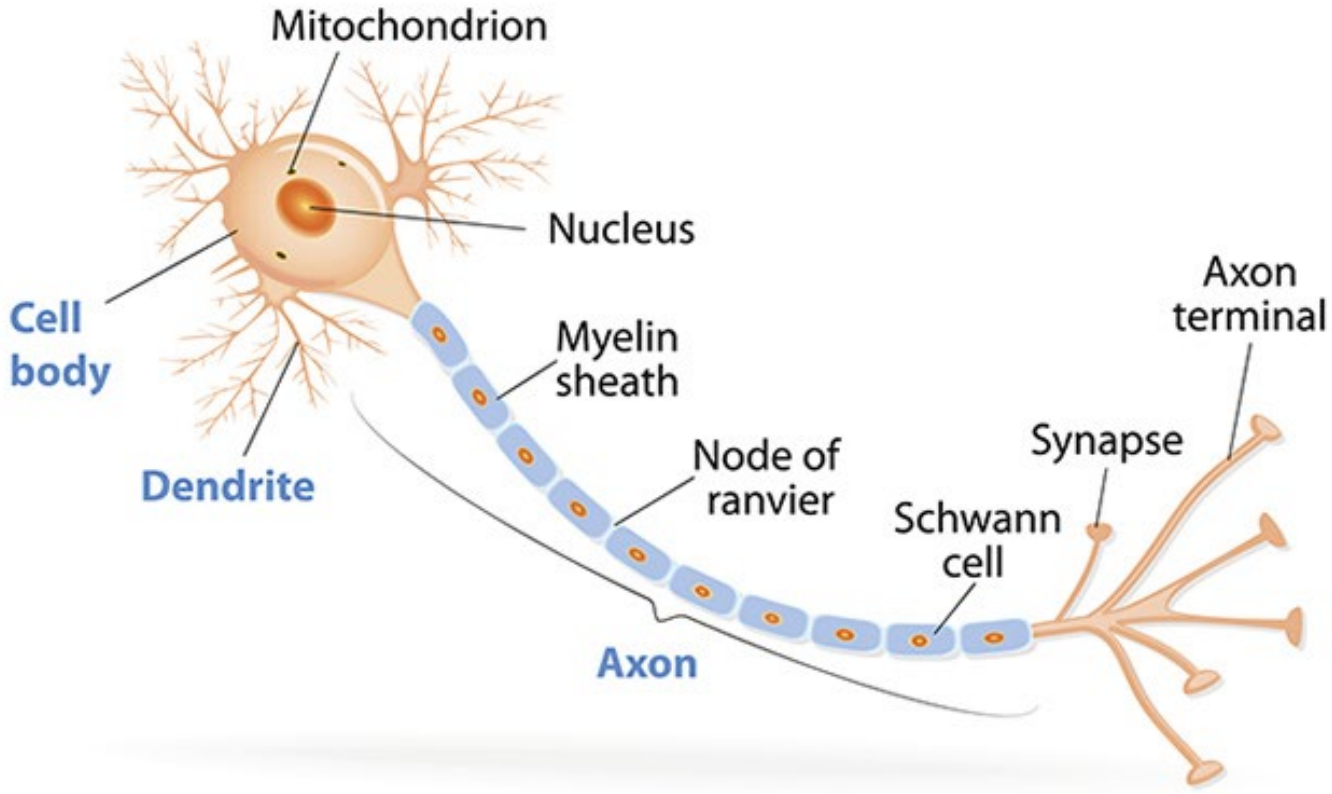
- **Dendrites** receive input from other neurons
- **Cell body** includes the nucleus and the other cell organnelles
- **Axon** propagates nerve impulses towards other neurons





R. Ilmoniemi

- Axons divide to branches in their end
- Propagating axon potential travels usually ~1 m/s, in a myelinated cell > 100 m/s
- **synapse** = connection to the next neuron
- **neuromuscular junction** = nerve fiber connects to a muscle fiber



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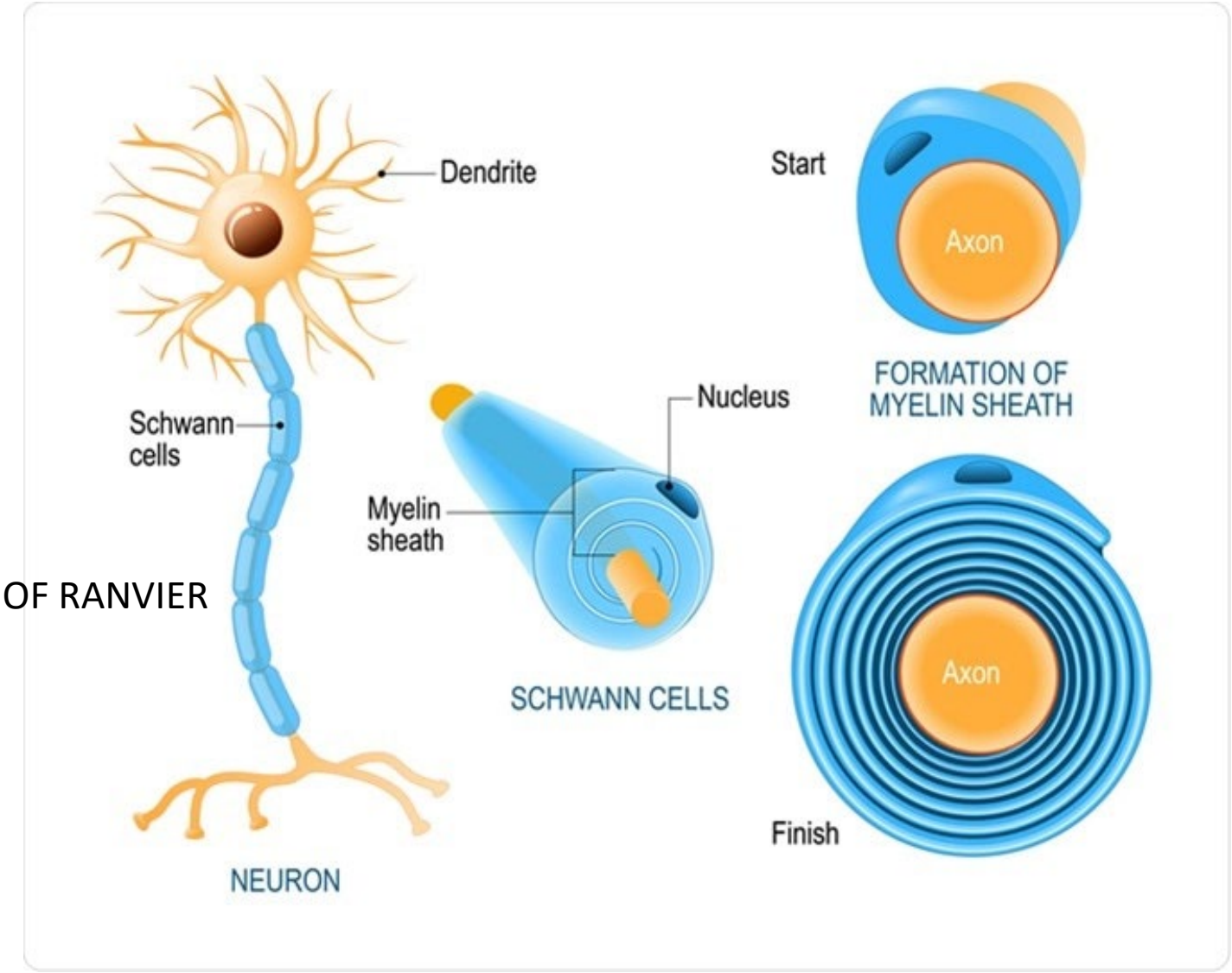
Glia cells

- In peripheral nervous system, Schwann cells form myelin around the axons
- Node of Ranvier
- In central nervous system: oligodendrocytes, astrocytes, microglias



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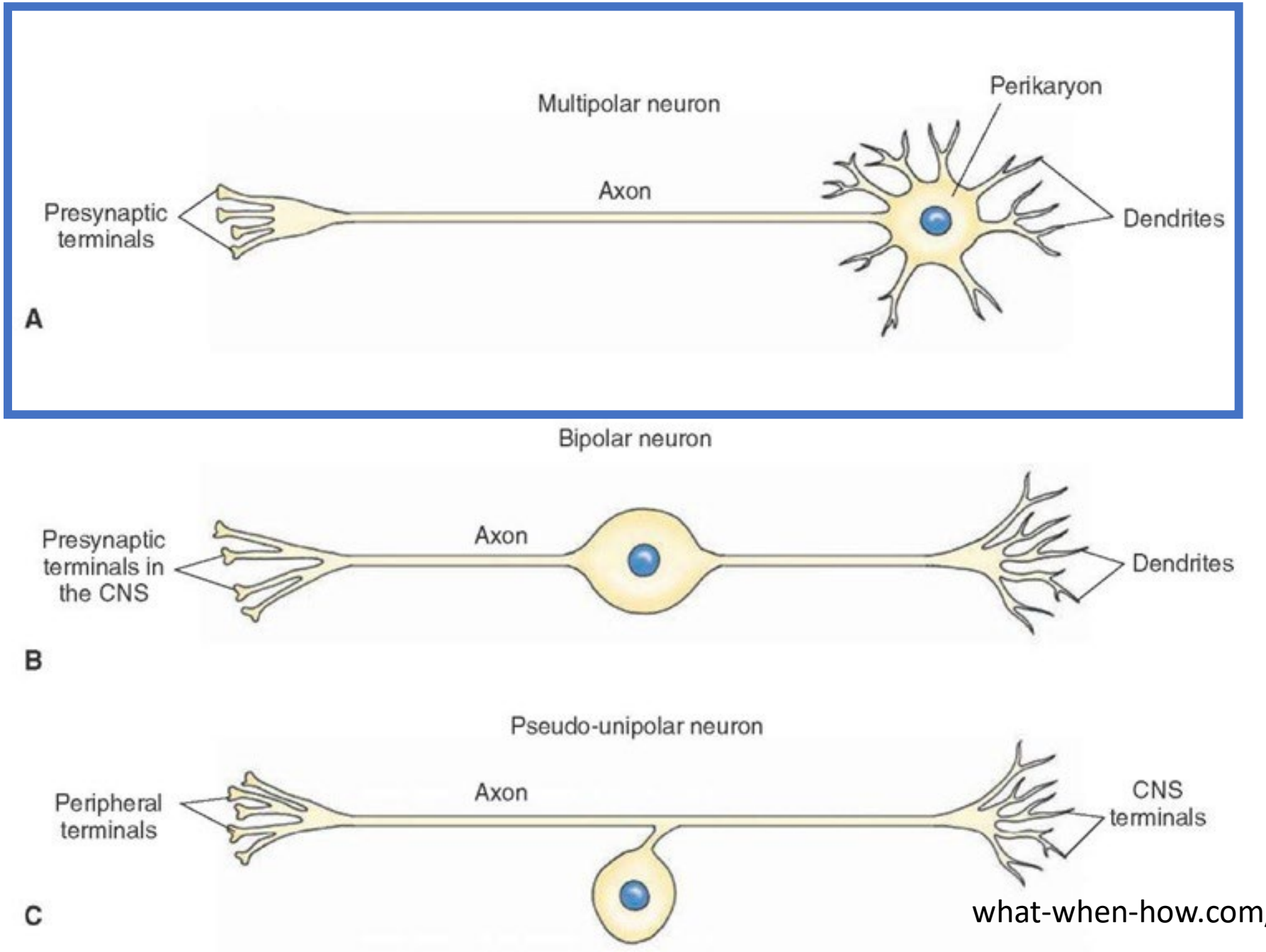
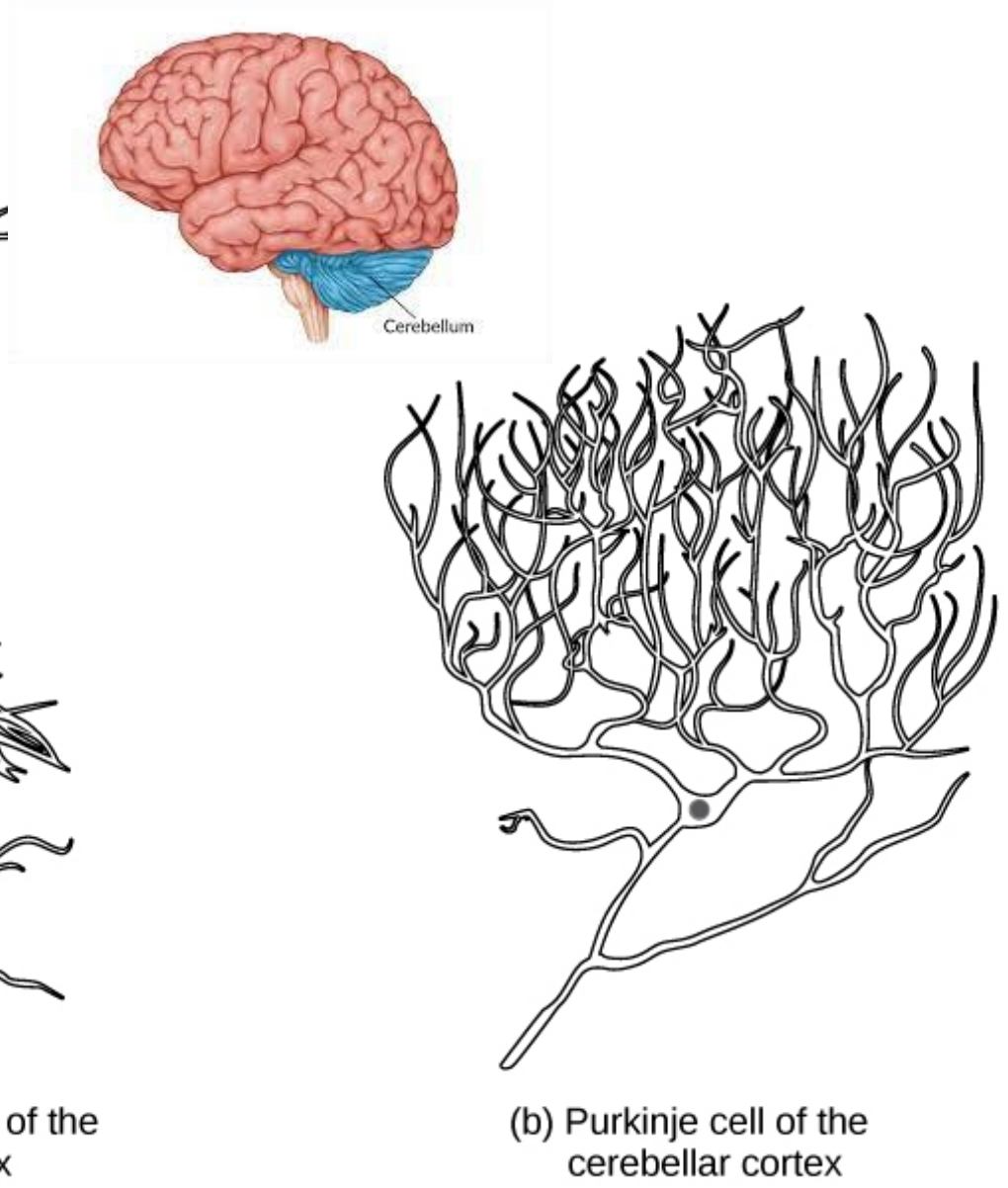
Structural and functional division among nerve cells



what-when-how.com

Structural and functional division among nerve cells

- Pyramidal cells at the cerebral cortex
- Purkinje cells in the cerebellum



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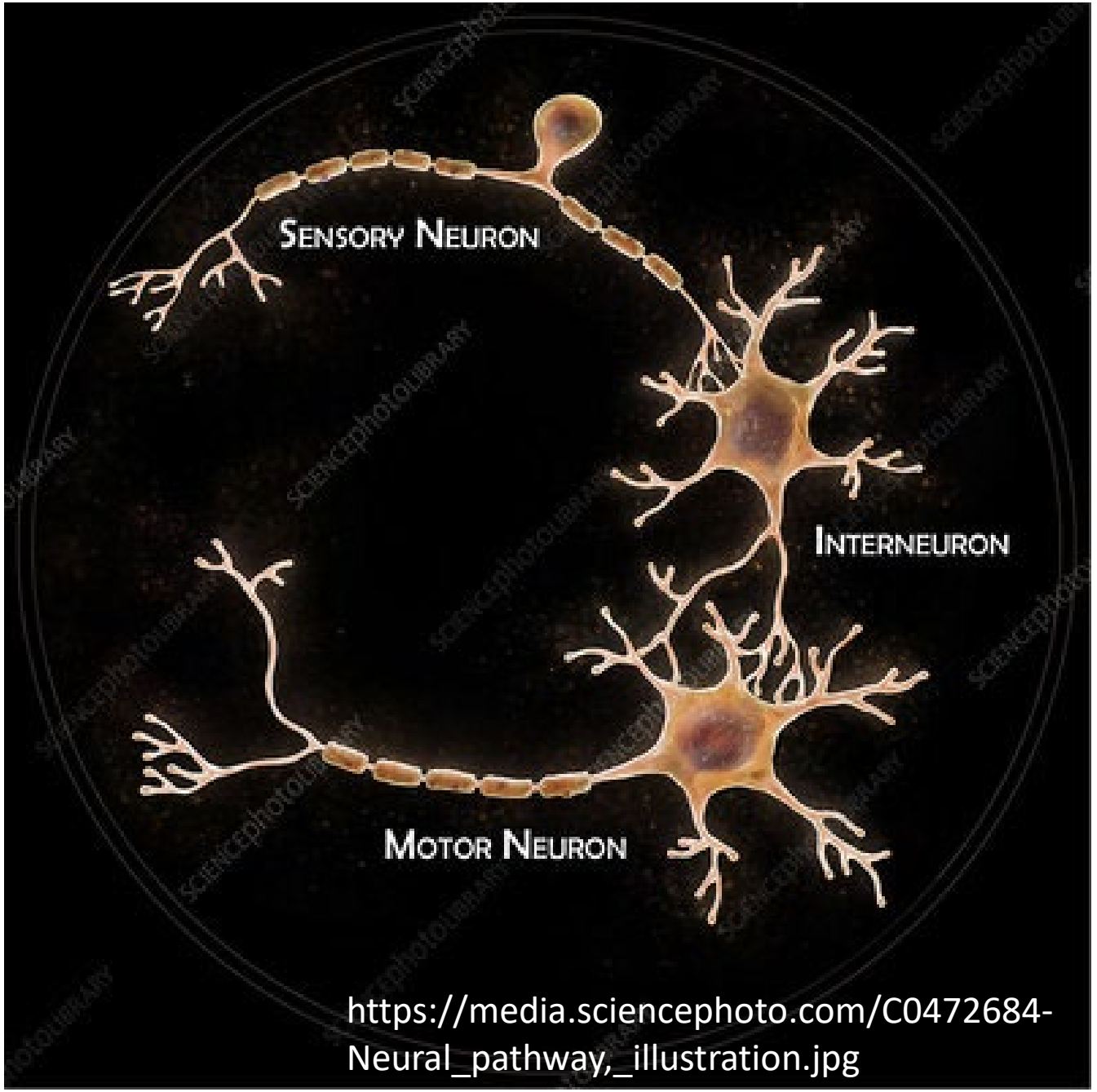
Structural and **functional** division among nerve cells

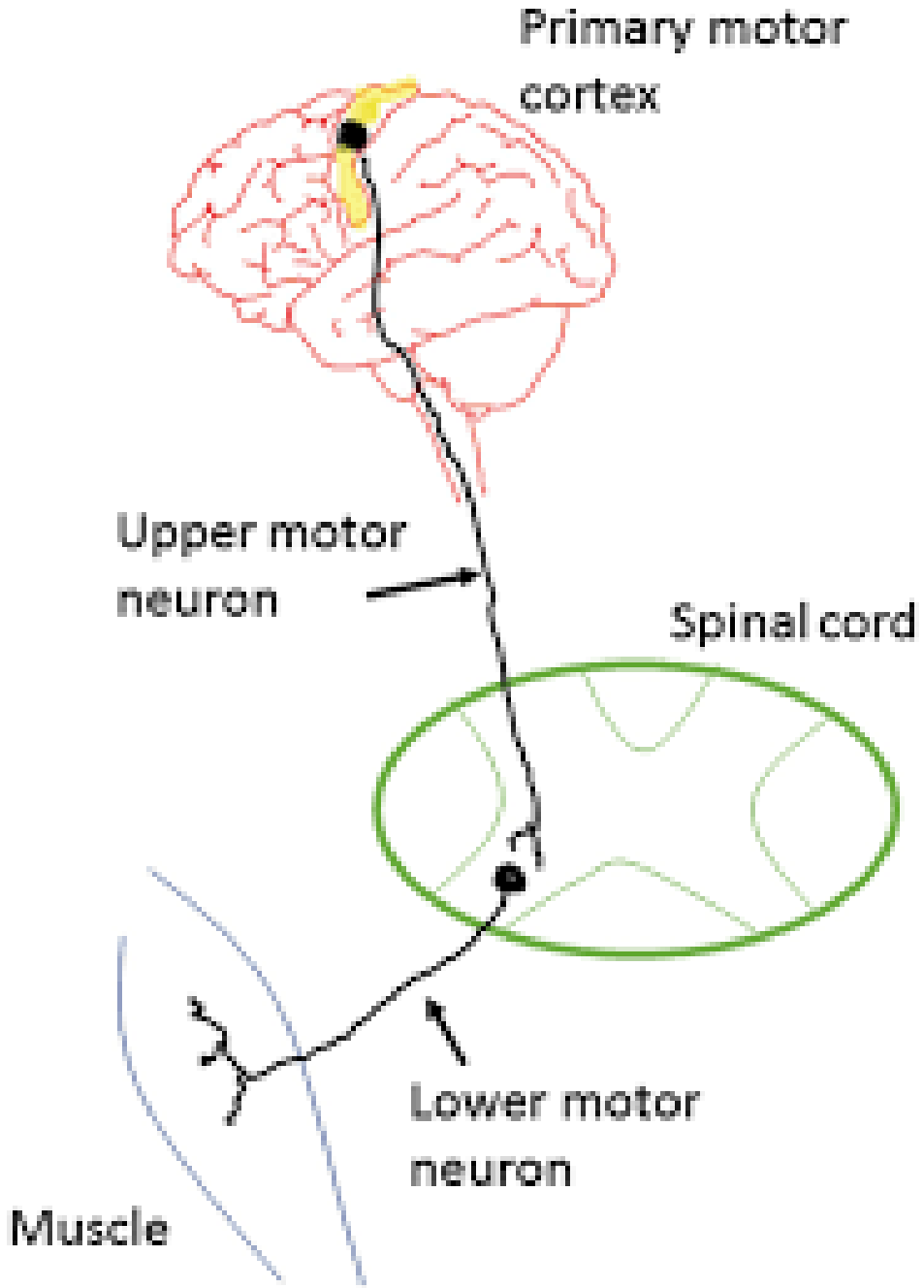
- **Sensory neurons**
- Motor neurons
- Interneurons



https://media.sciencephoto.com/C0472684-Neural_pathway,_illustration.jpg

Structural and **functional** division among nerve cells

- Sensory neurons
- **Motor neurons: upper and lower**
- Interneurons



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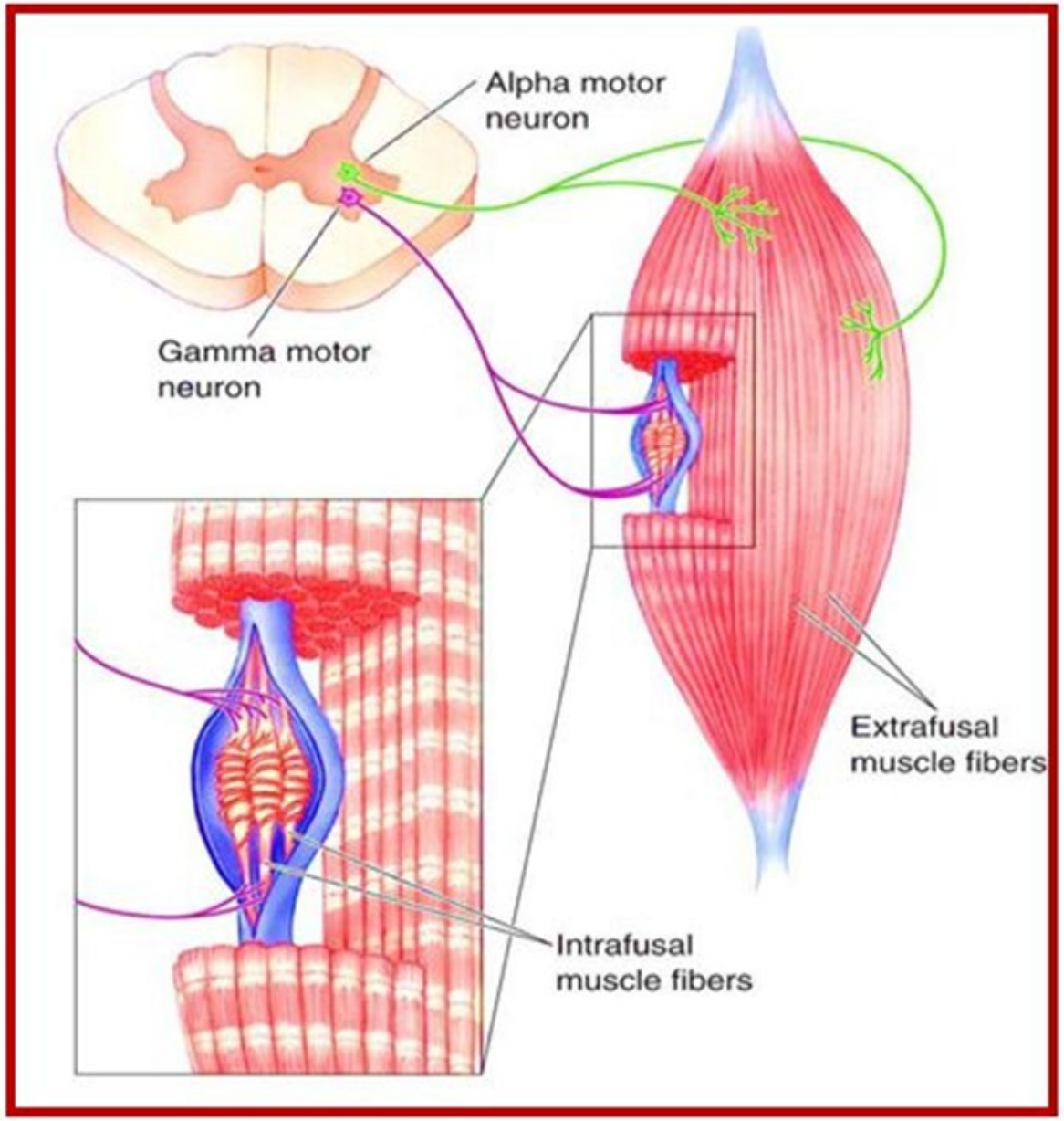
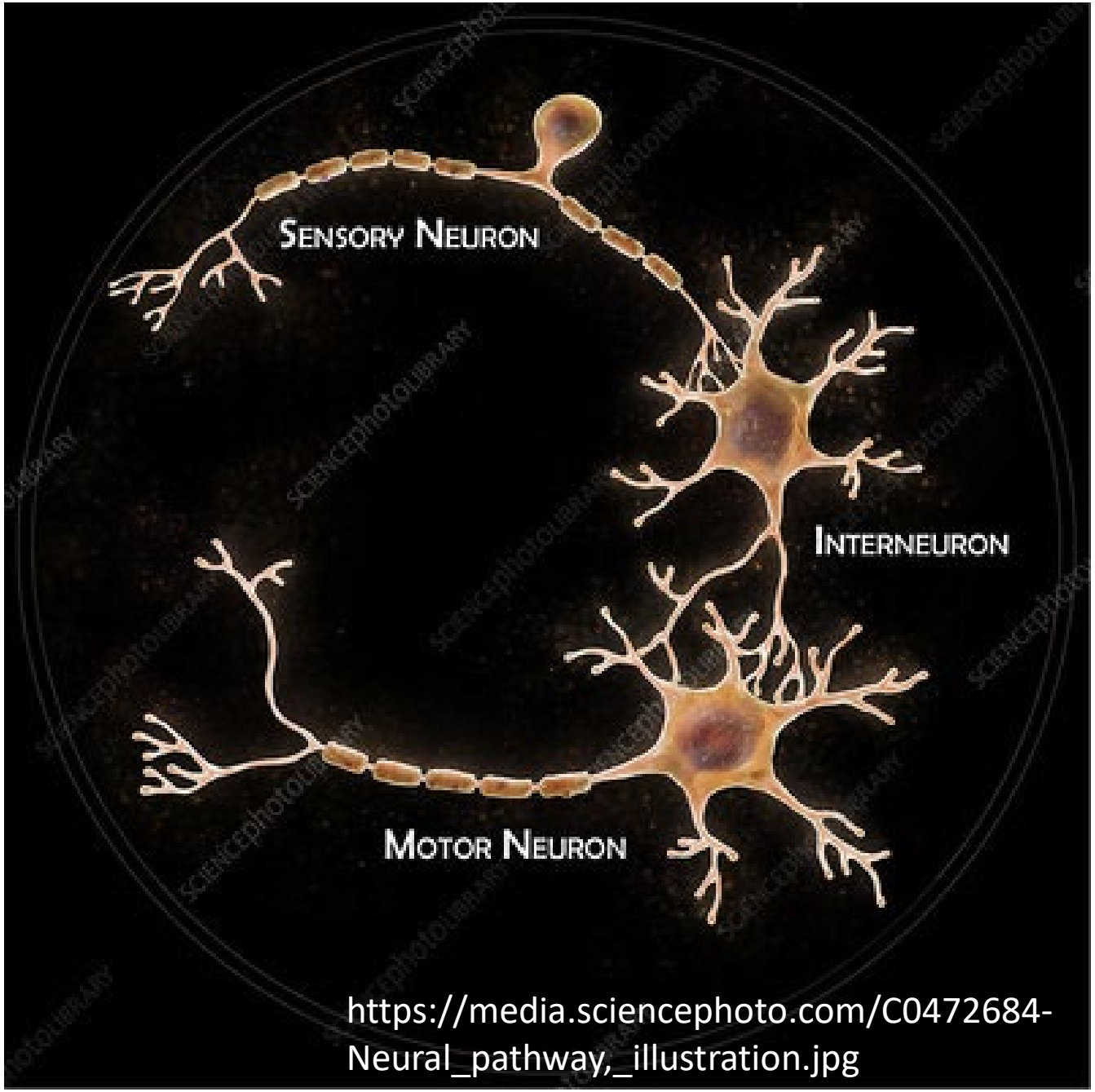
Different types of motor neurons



F. Netter

Structural and **functional** division among nerve cells

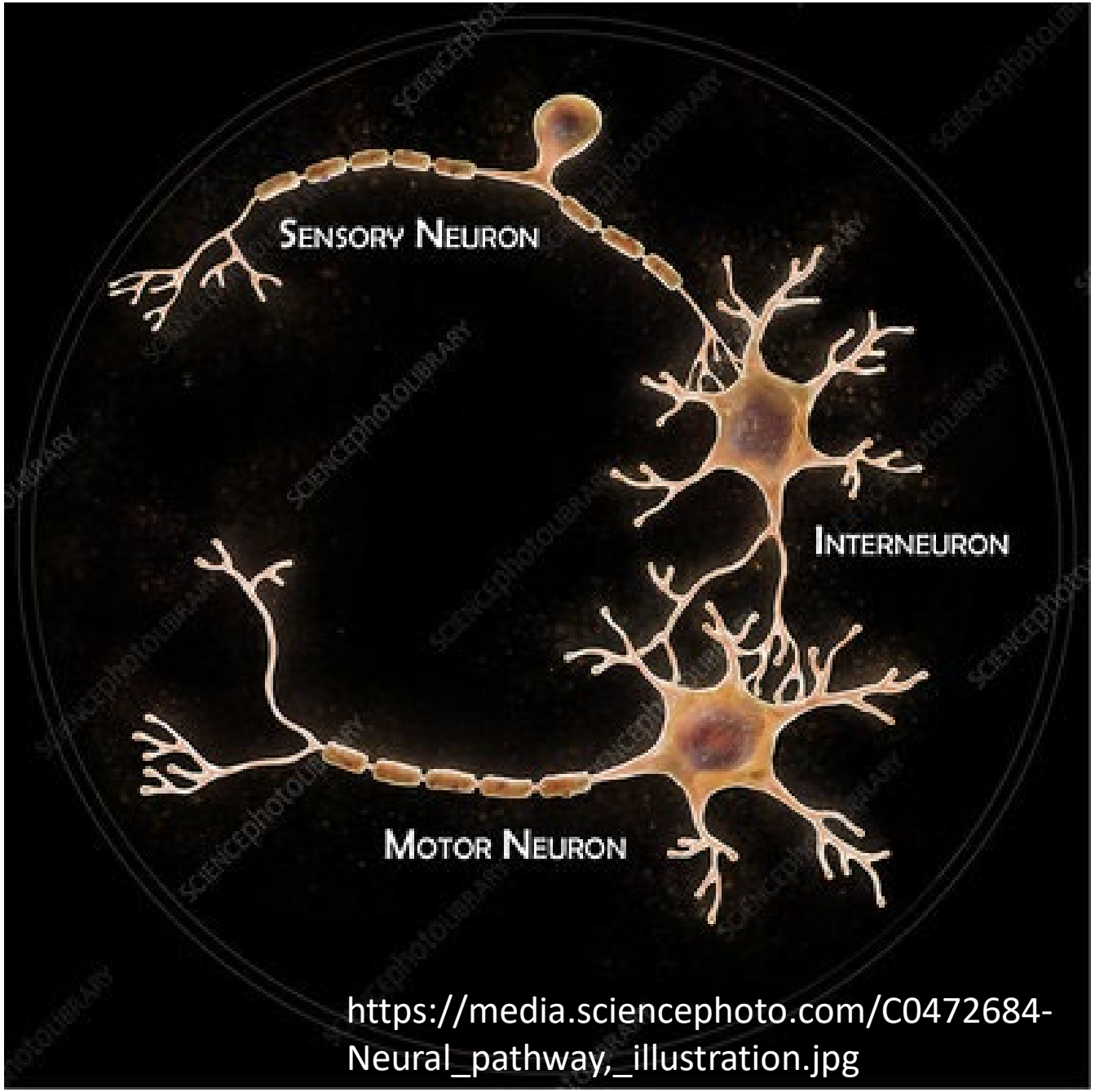
- Sensory neurons
- Motor neurons
- **Interneurons**



https://media.sciencephoto.com/C0472684-Neural_pathway,_illustration.jpg

Structural and **functional** division among nerve cells

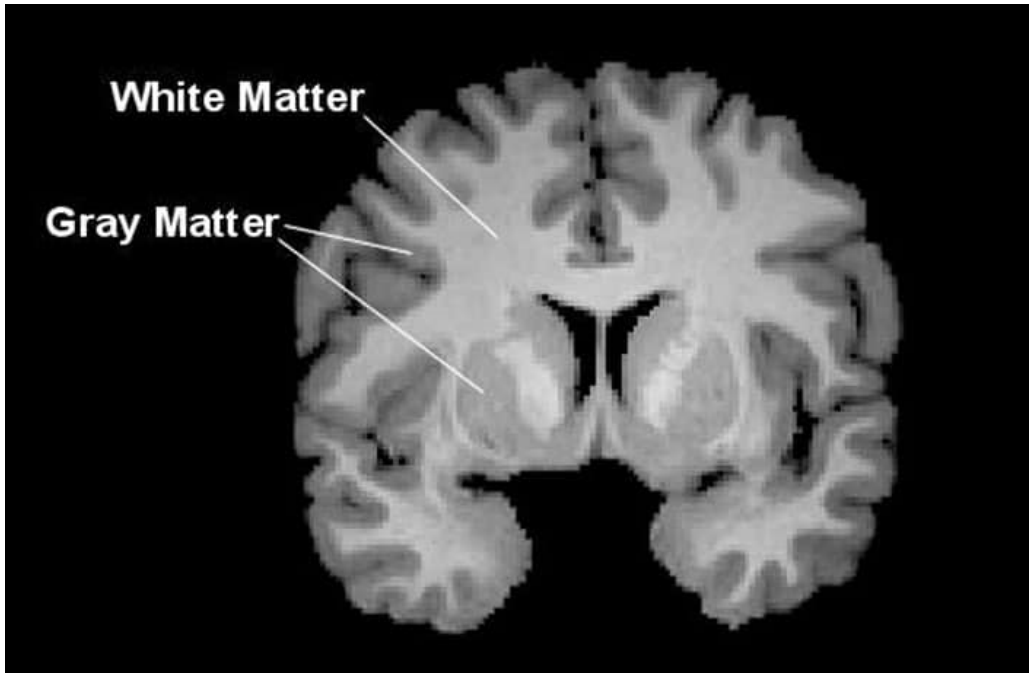
- Sensory neurons
- Motor neurons
- Interneurons



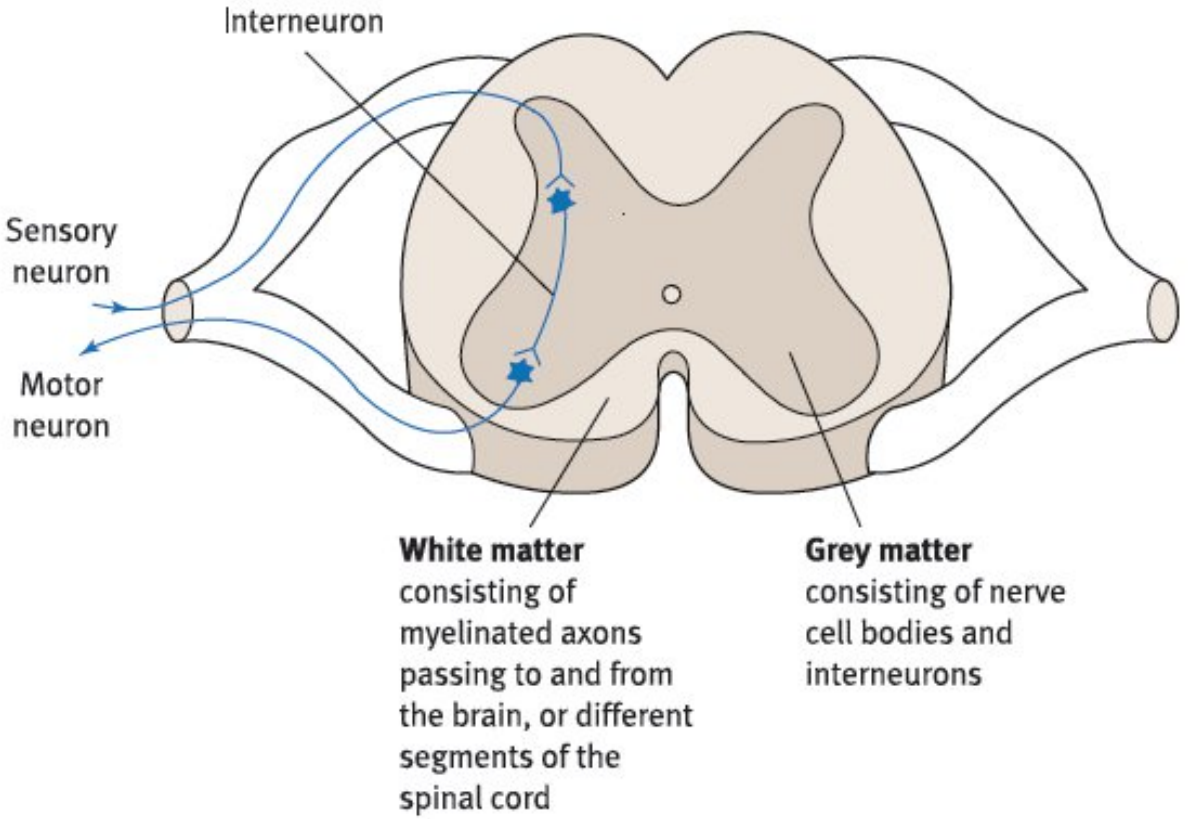
https://media.sciencephoto.com/C0472684-Neural_pathway,_illustration.jpg

Nervous tissue consists of grey and white matter

- Grey matter = neurons
- White matter = glia cells



www.psypost.org/



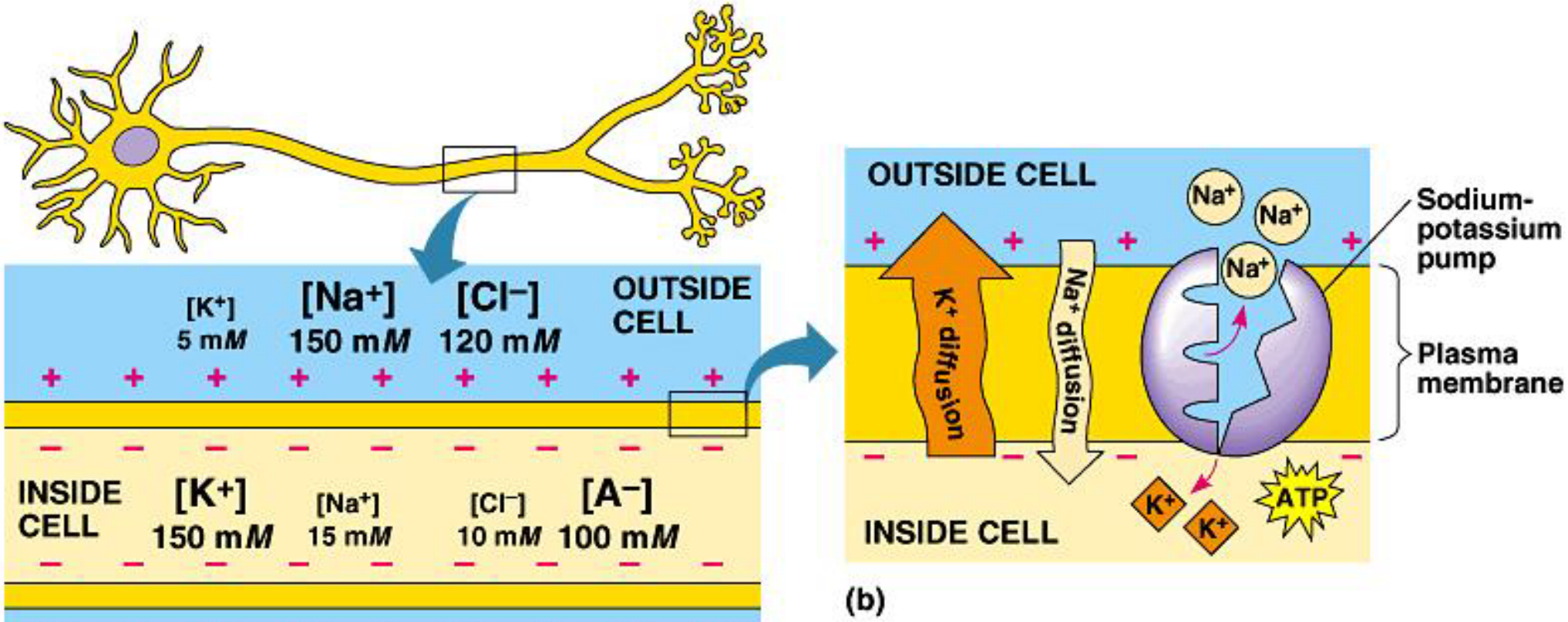
quora.com/Neurology-What-is-white-matter-and-grey-matter-in-spinal-cord-and-the-brain

In the cerebral cortex, the grey matter consists of 6 layers

Wikimedia

Jones 1981

Membrane potential



Membrane potential appr. -70 mV

- Na^+-K^+ pumps
- K^+ "leaks" outside cells
- Intracellular anions do not follow K^+-ions

Action potential

- Potential change that spreads along the cell membrane in nerve and muscle cells

- The permeability of ion channels in the cell membrane changes due to
  - ➢ pressure
  - ➢ transmitter
- Excitative change → Na^+ ions enter the cell
- Inhibitory change → Cl^- ions enter the cell

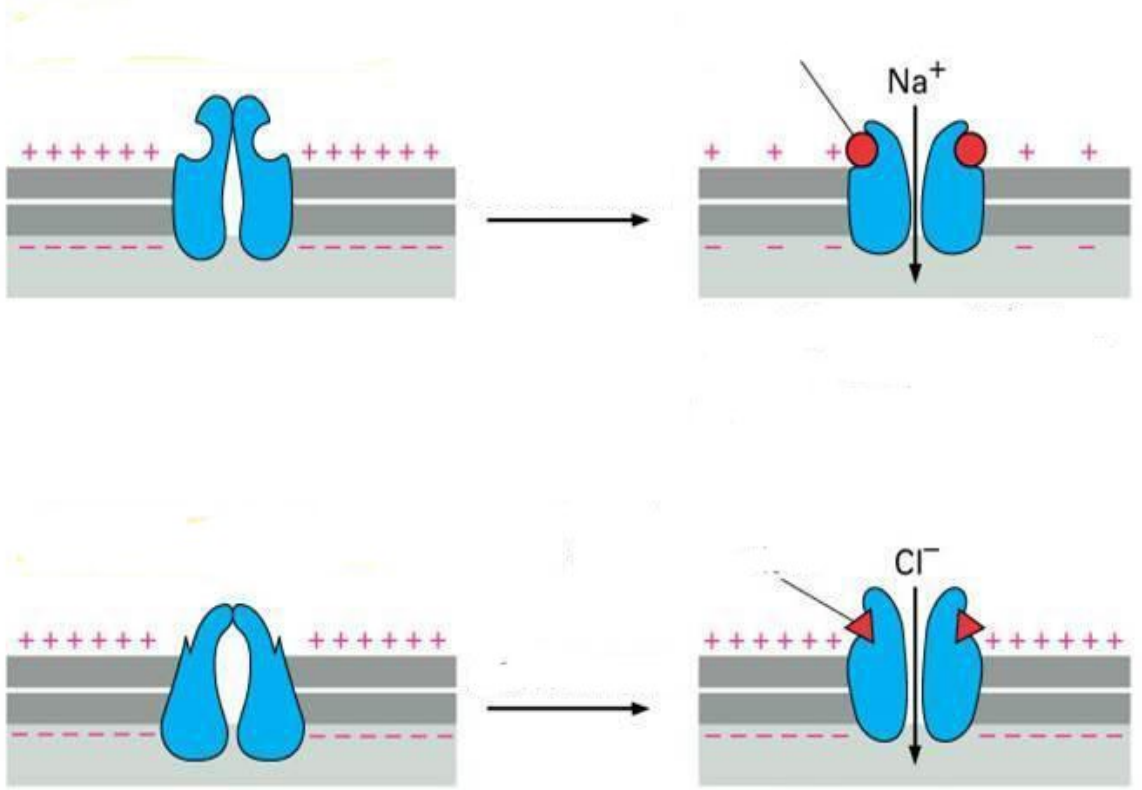
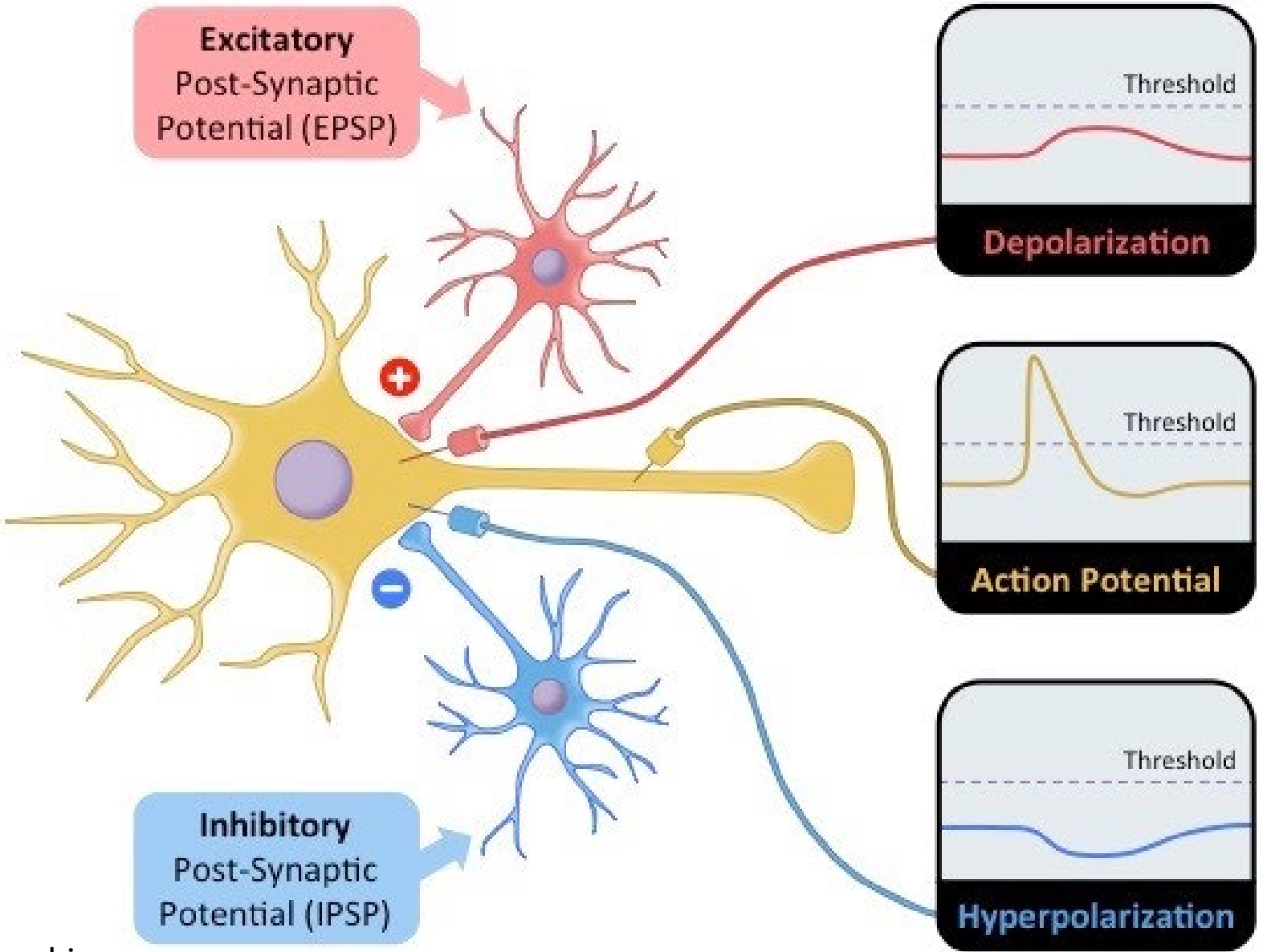


Figure 12-43 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Axon hillock sums up signals



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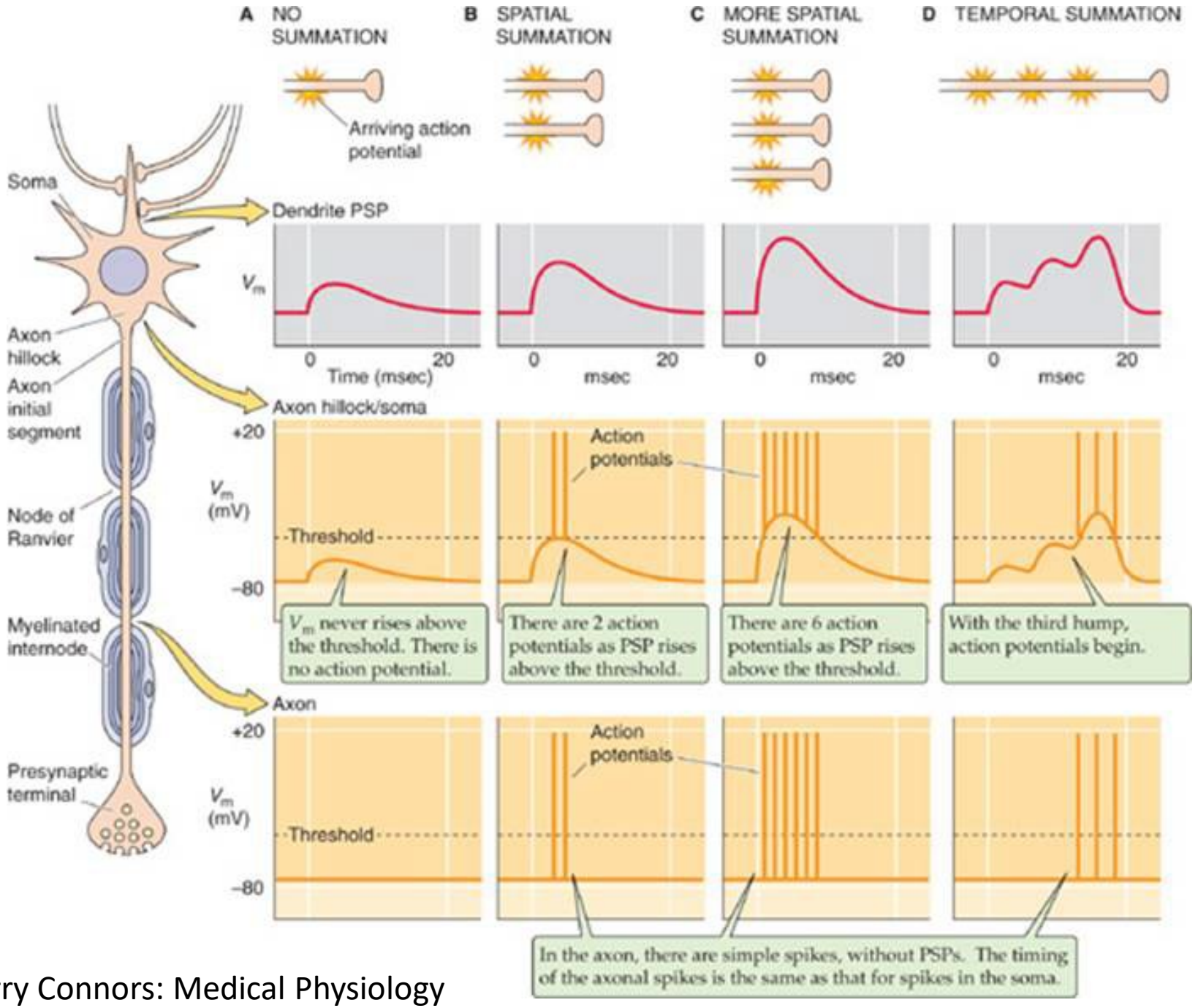
An action potential occurs if the combination of graded potentials exceeds a threshold

"All or nothing":
Axon hillock initiates the action potential

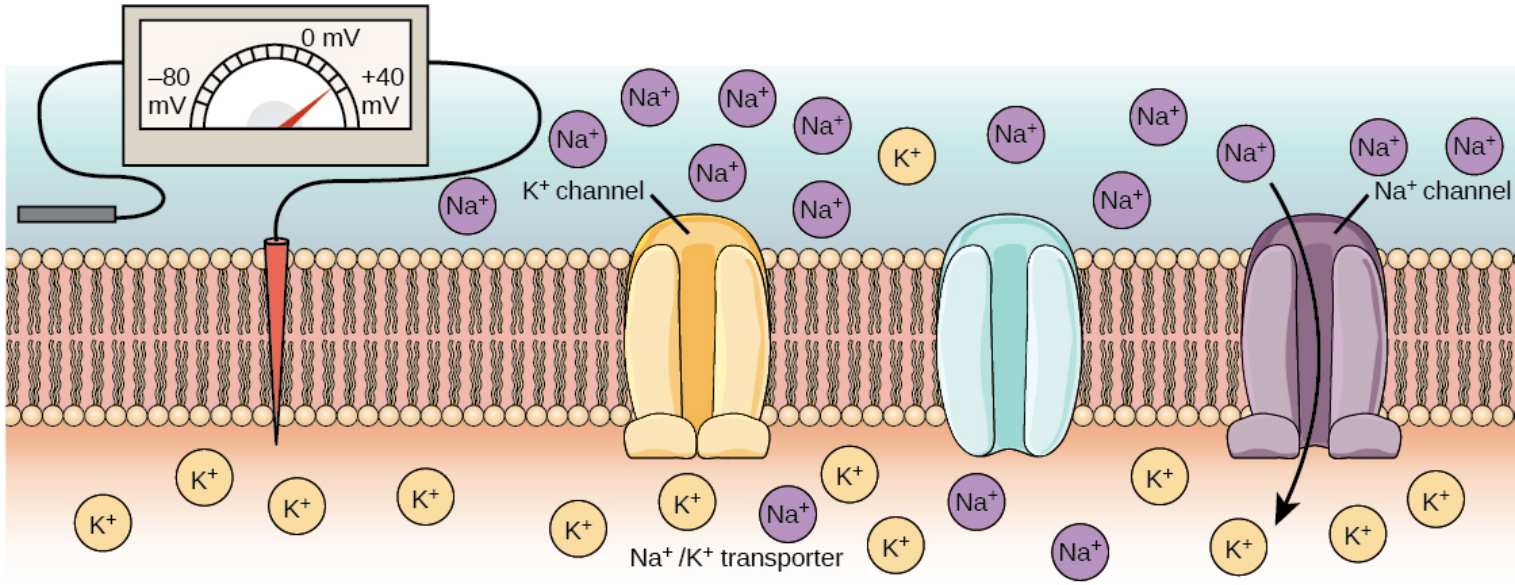


Barry Connors: Medical Physiology

- Depolarisation is followed by repolarization as K^+ channels open and Na^+ channels close
- Time scale appr. 1 ms

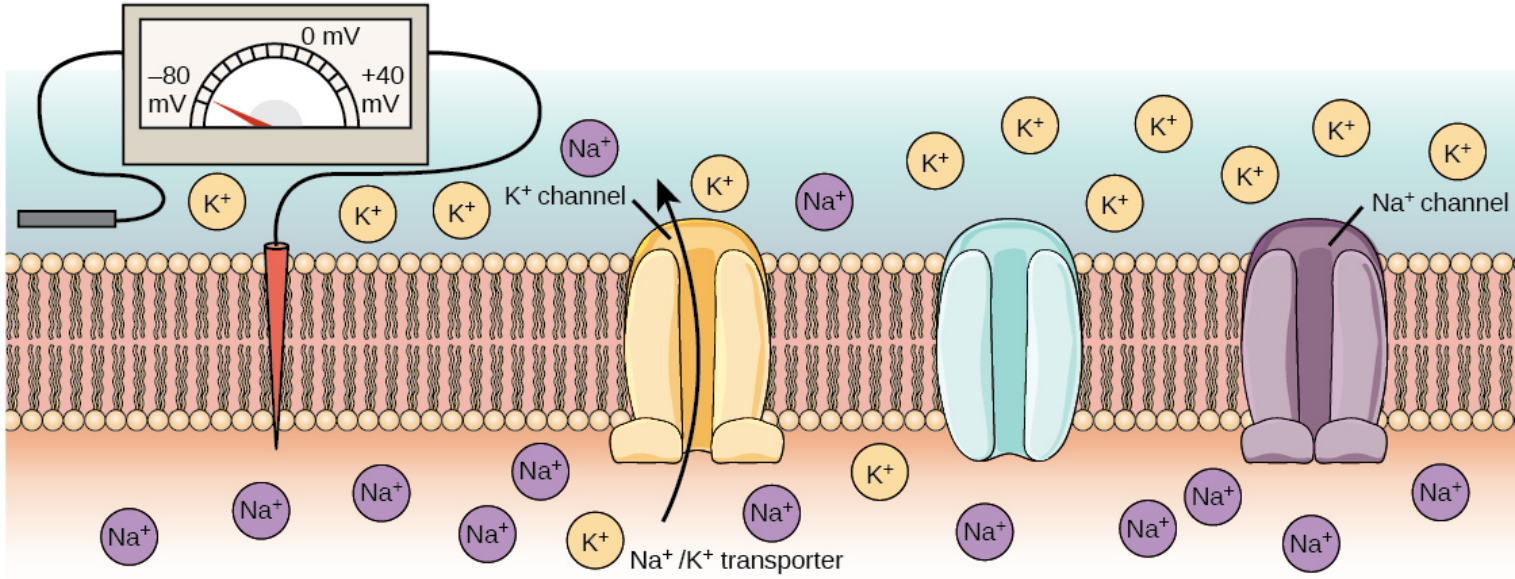
cnx.org/contents/How-Neurons-Communicate

(b) Depolarization



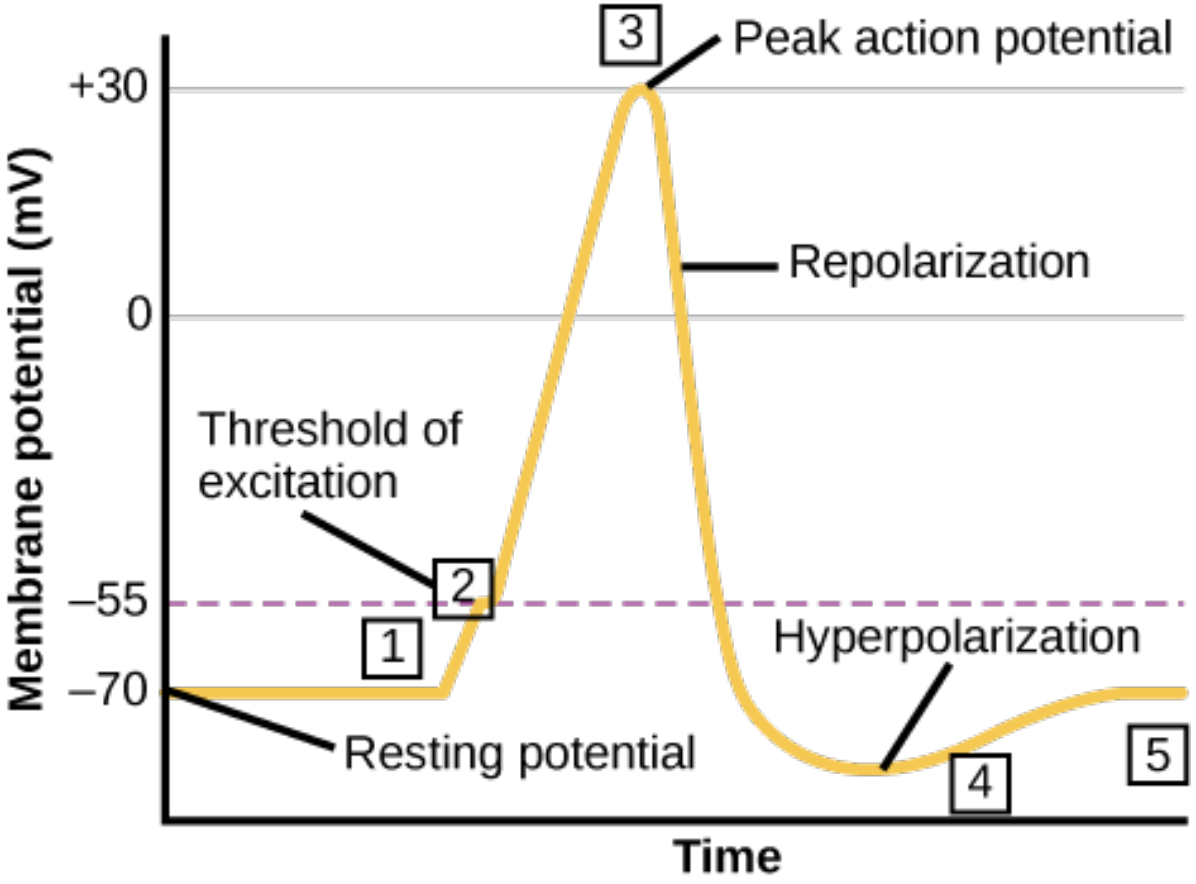
In response to a depolarization, some Na^+ channels open, allowing Na^+ ions to enter the cell. The membrane starts to depolarize (the charge across the membrane lessens). If the threshold of excitation is reached, all the Na^+ channels open.

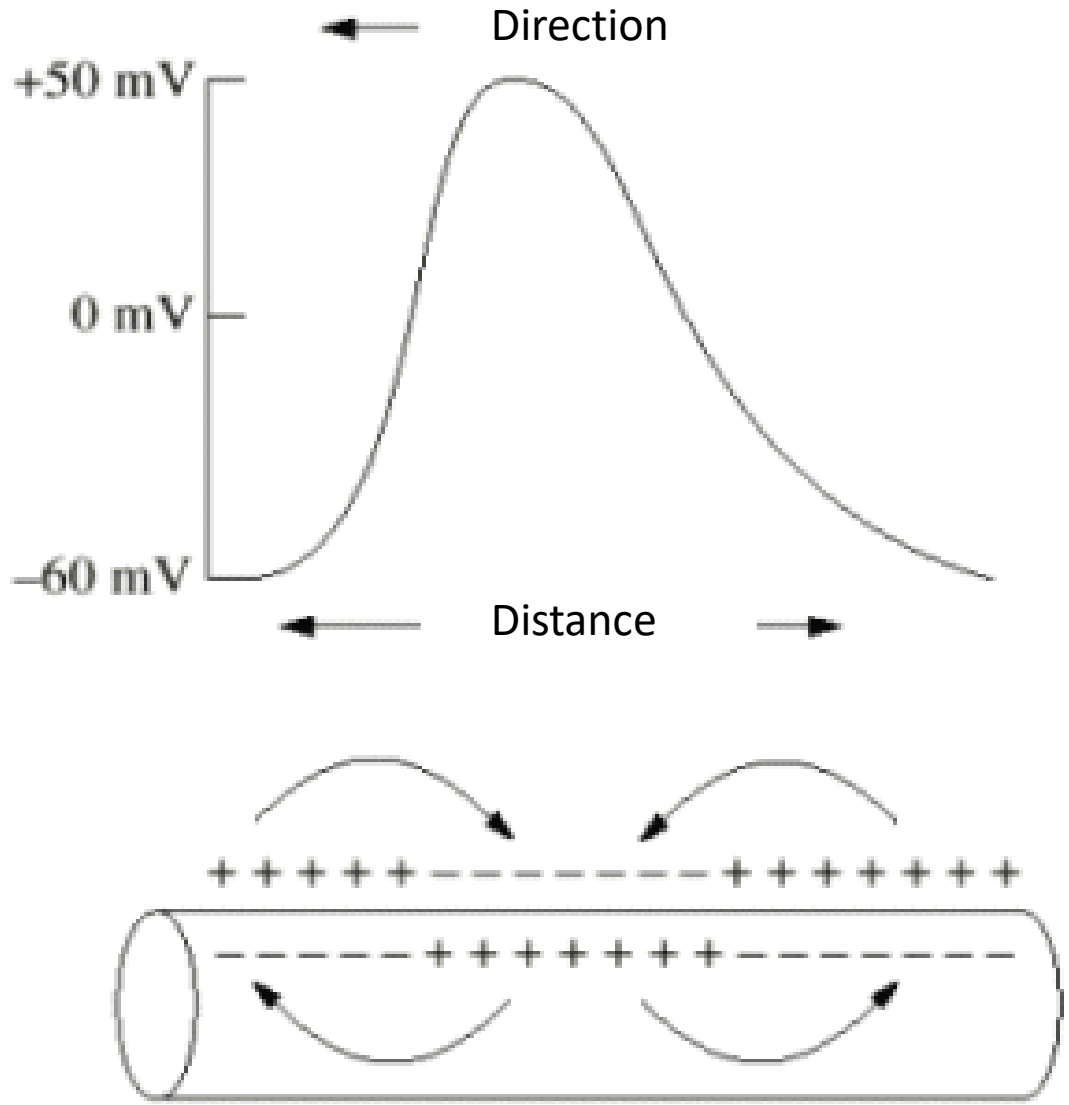
(c) Hyperpolarization



At the peak action potential, Na^+ channels close while K^+ channels open. K^+ leaves the cell, and the membrane eventually becomes hyperpolarized.

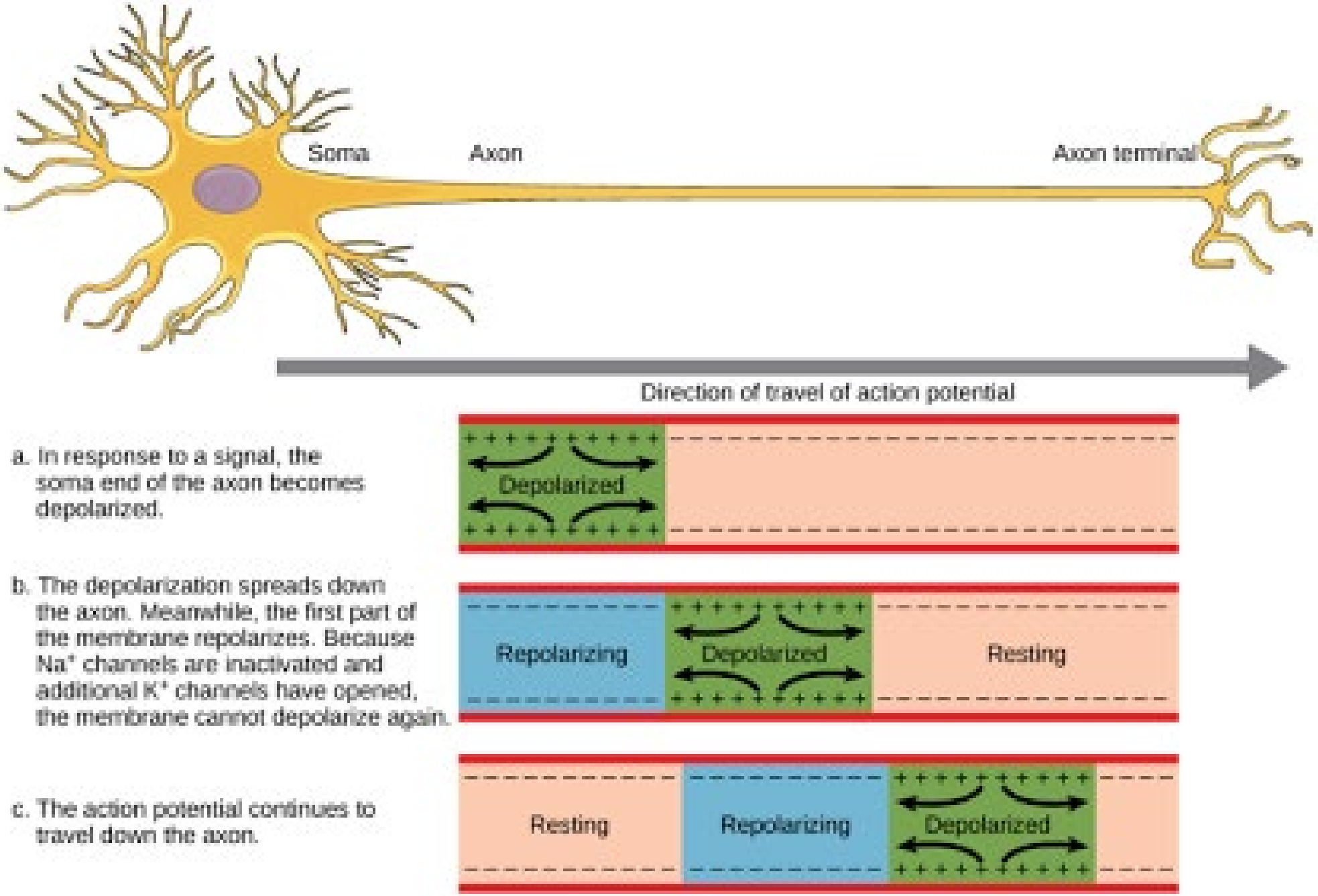
Repolarisation is followed by hyperpolarisation





cnx.org/contents/How-Neurons-Communicate

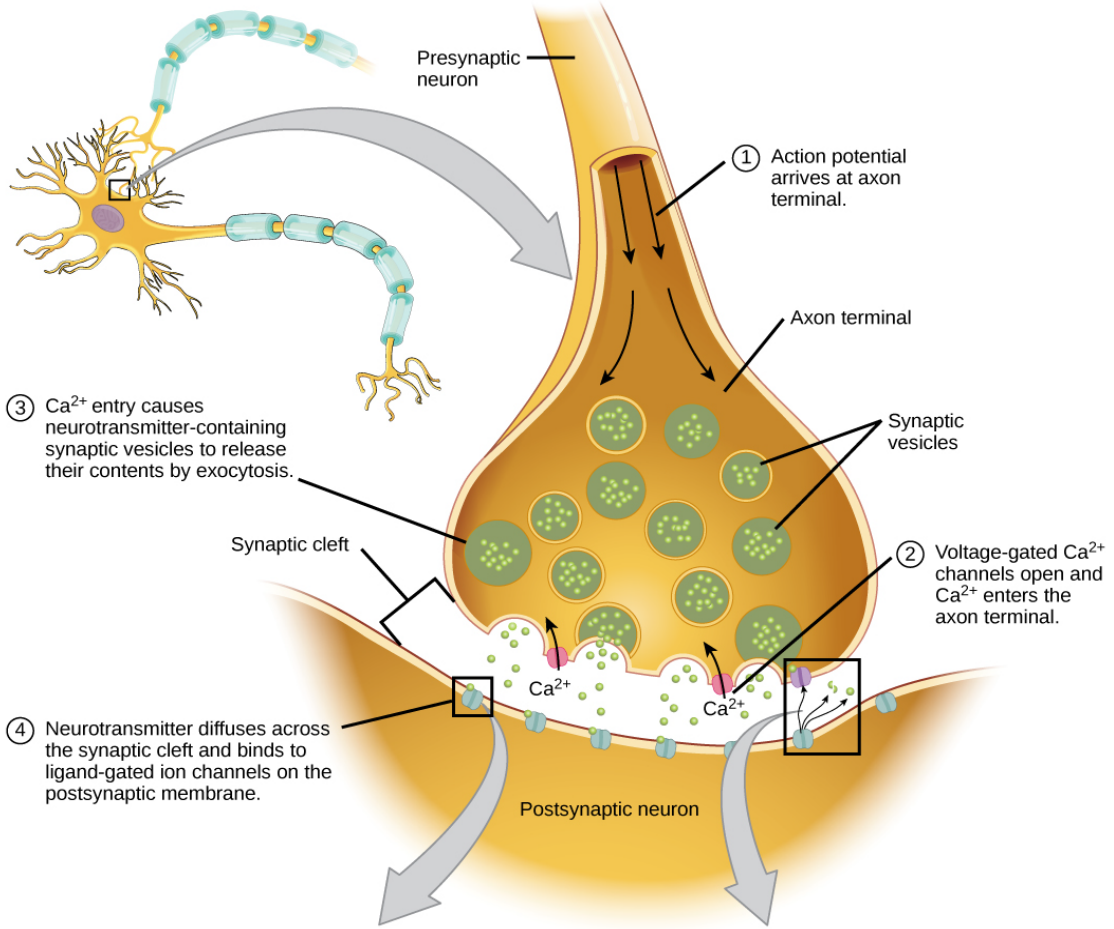
R. Ilmoniemi/U. Hollström

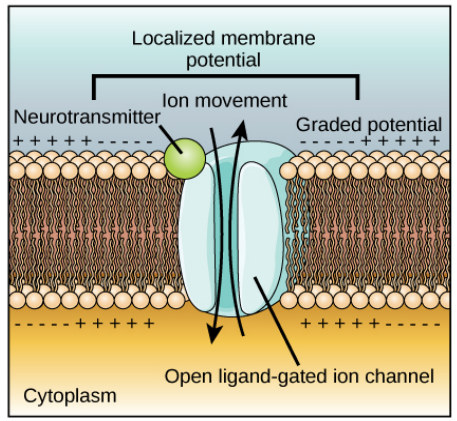


cnx.org/contents/How-Neurons-Communicate

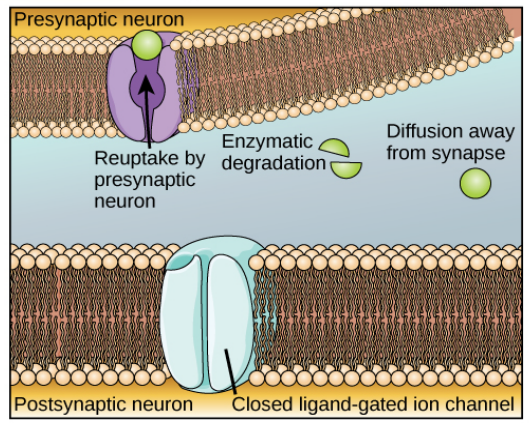
Synaptic transmission

- Neurotransmitter synthesized presynaptically
- When relased into synaptic cleft, it reacts with the postsynaptic receptors





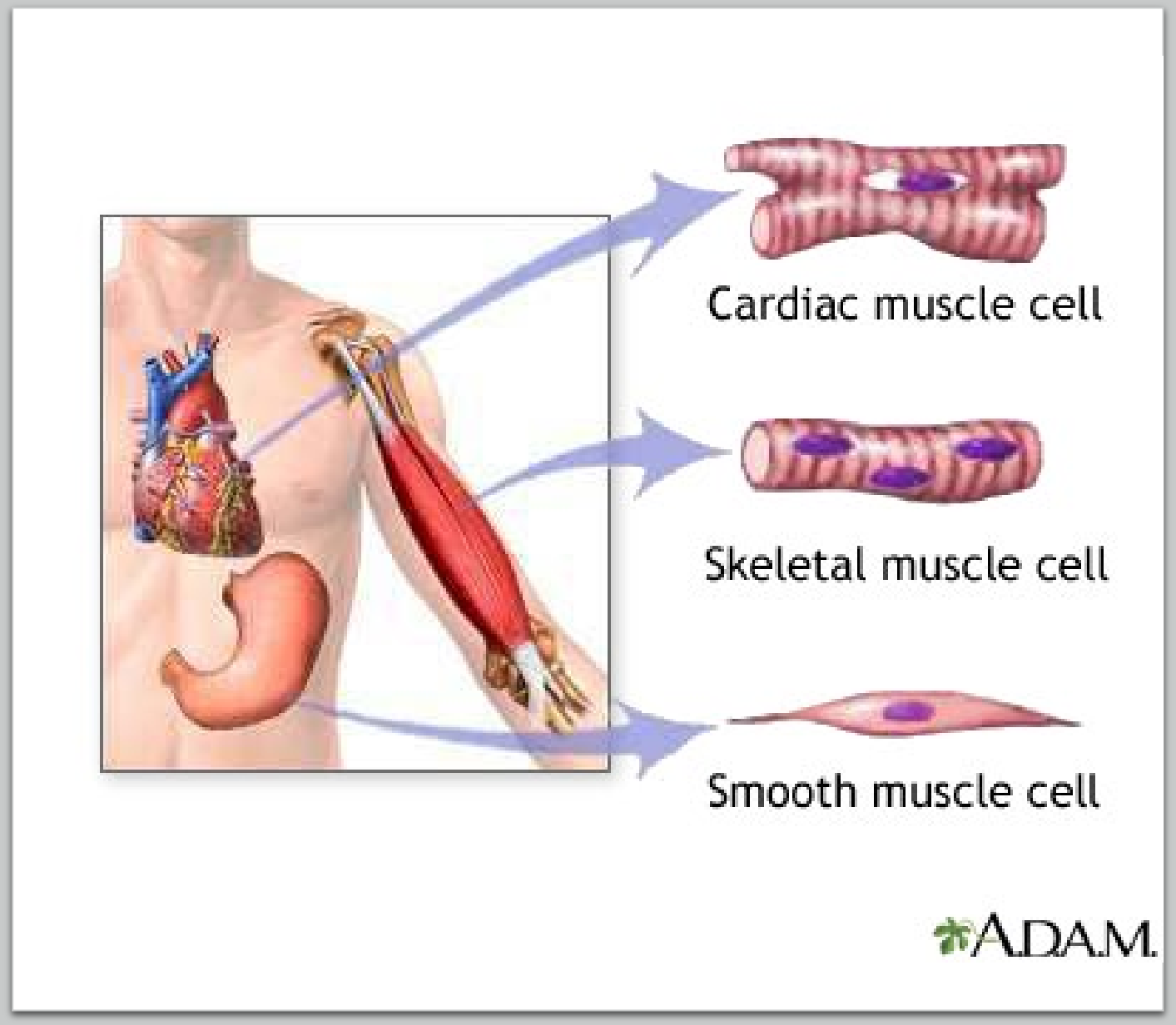
5 Binding of neurotransmitter opens ligand-gated ion channels, resulting in graded potentials.



6 Reuptake by the presynapic neuron, enzymatic degradation, and diffusion reduce neurotransmitter levels, terminating the signal.

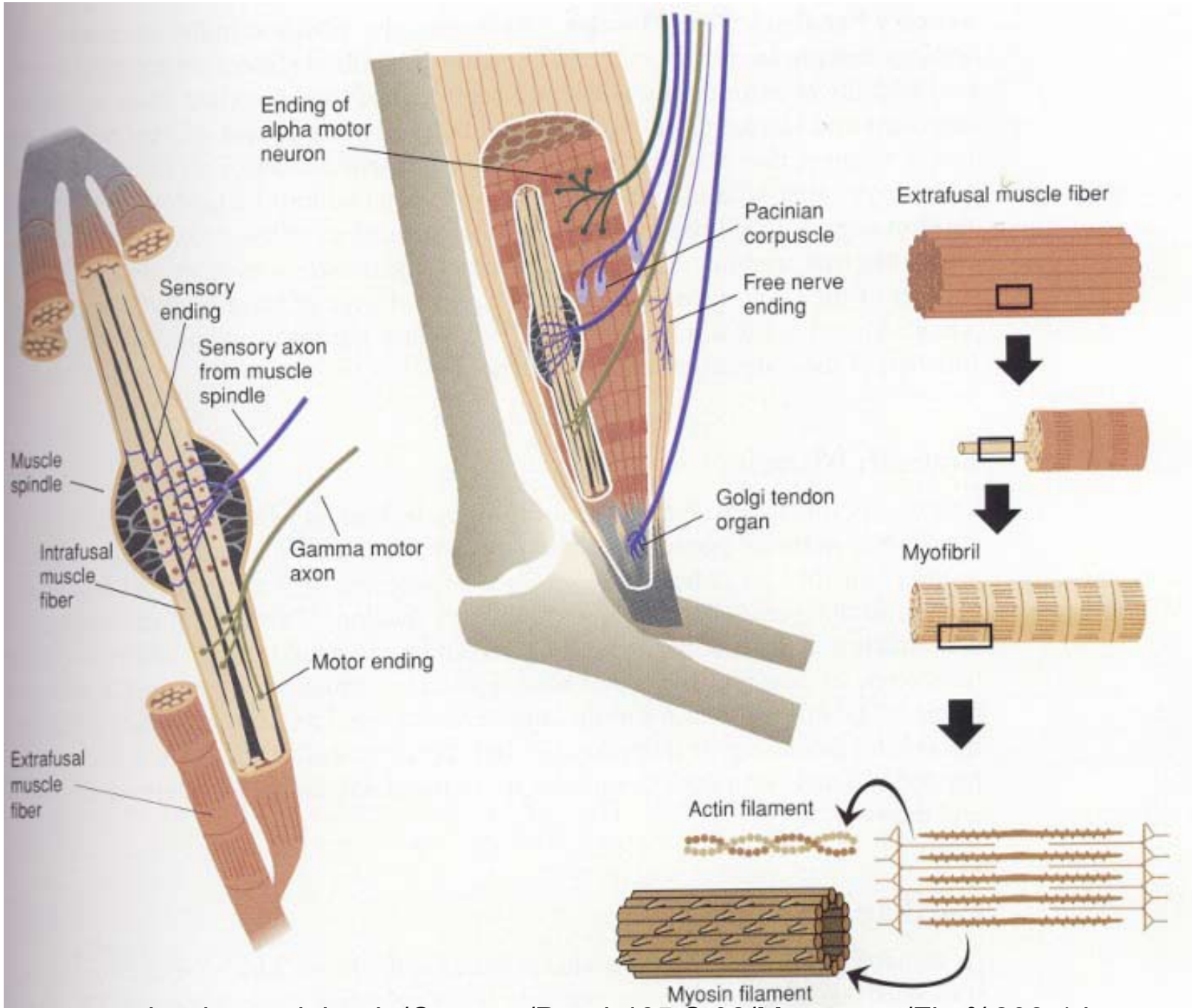
Muscle tissue

- Ability to contract
- 40-50% of human weight
- Muscle cell = muscle fiber
- Three types



Skeletal muscle

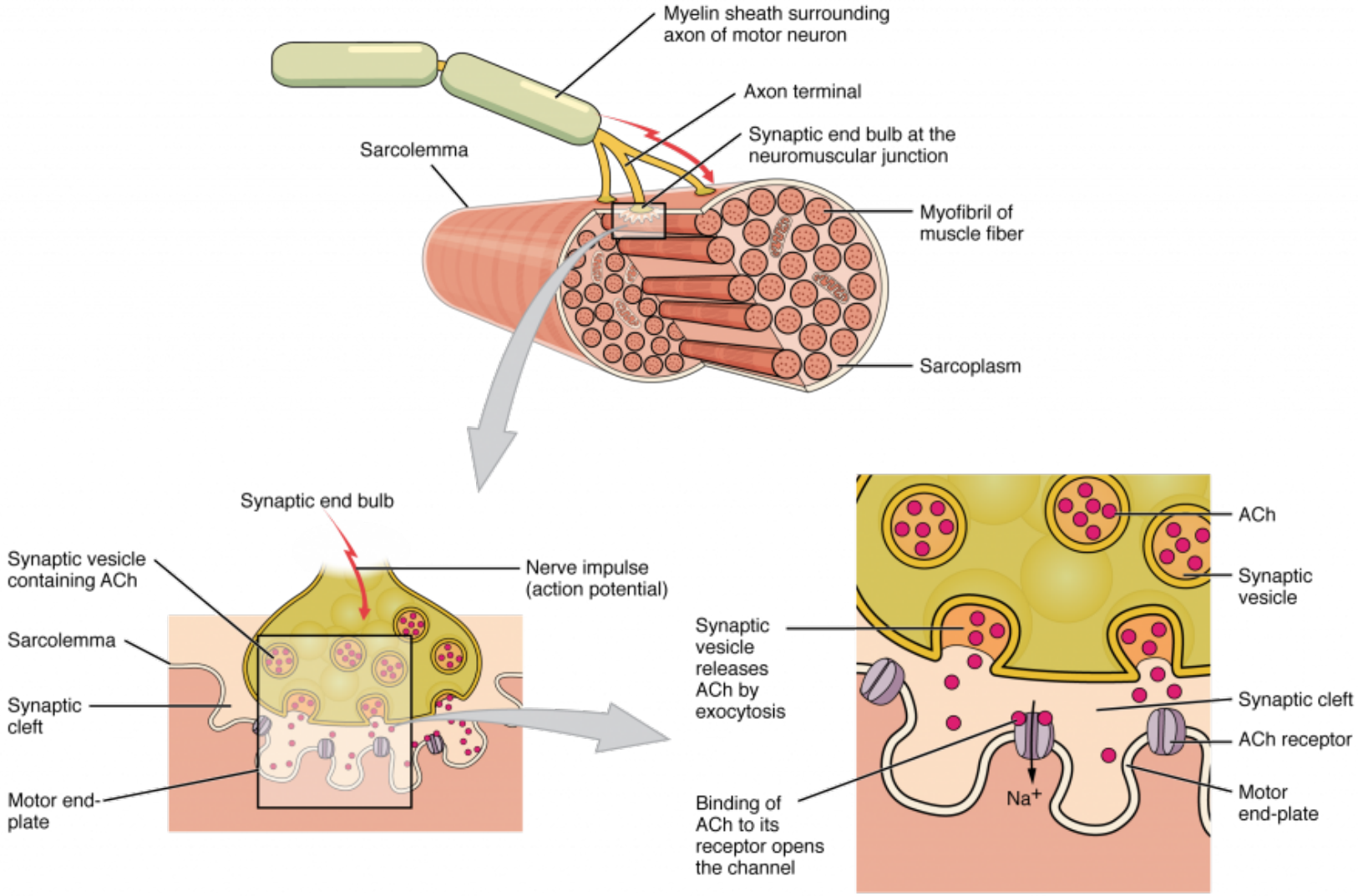
- Voluntary
- Usually attached to skeleton
- Cell length 5-50 mm, diameter 10-100 um
- Hundreds of nuclei per cell
- (myo)fibril – (myo)filament
- Actin and myosin filaments



nawrot.psych.ndsu.nodak.edu/Courses/Psych465.S.02/Movement/Fig.%208-1.jpg

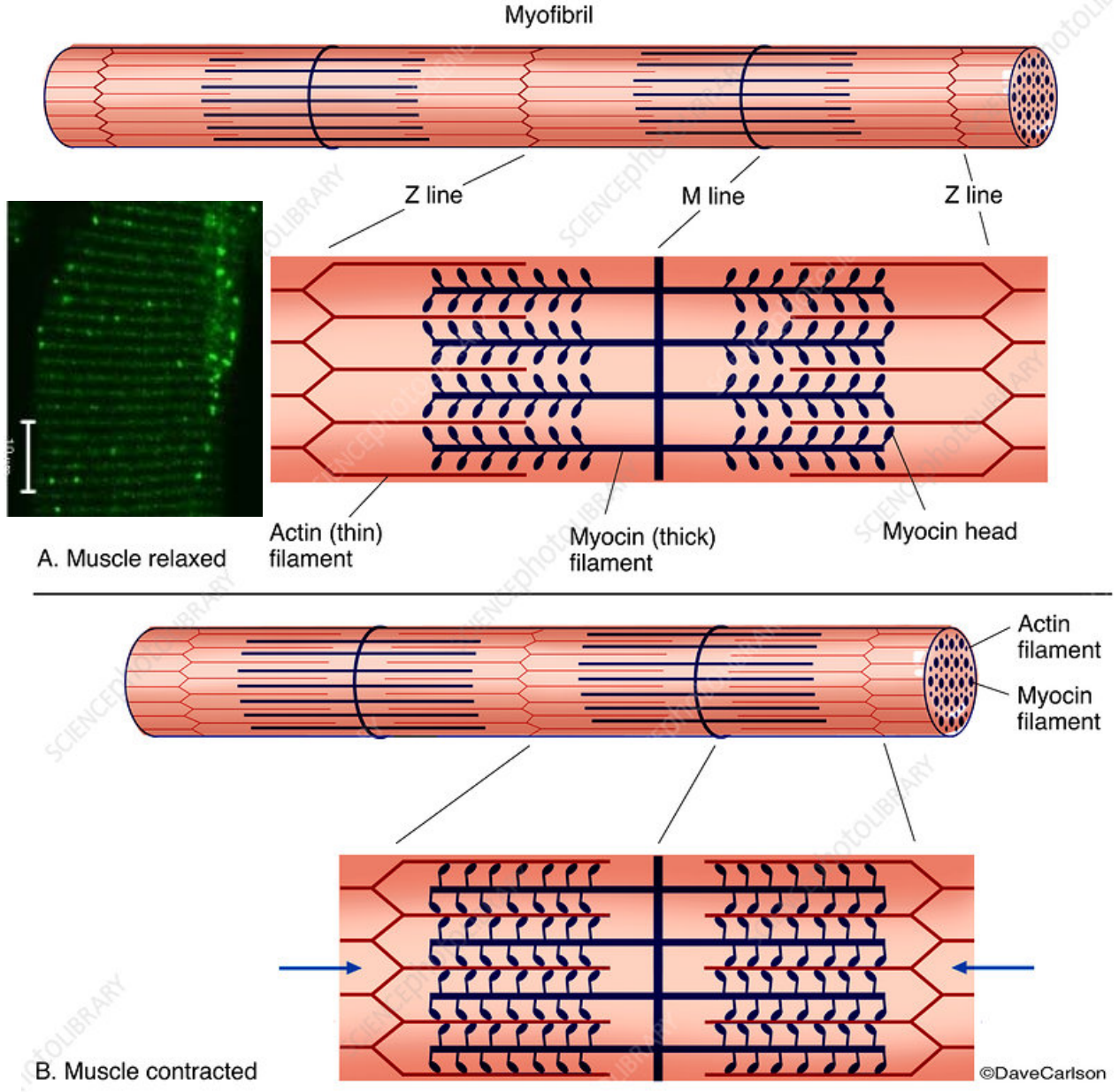
Muscle contraction

- Neuromuscular junction
- Each axon is connected with tens to hundreds of muscle cells (*motor unit*)
- *Motor end plate* at the end of the axon
- Each action potential results in depolarization in a muscle cell



https://open.oregonstate.education/aandp/chapter/10-3-muscle-fiber-excitation-contraction-and-relaxation/

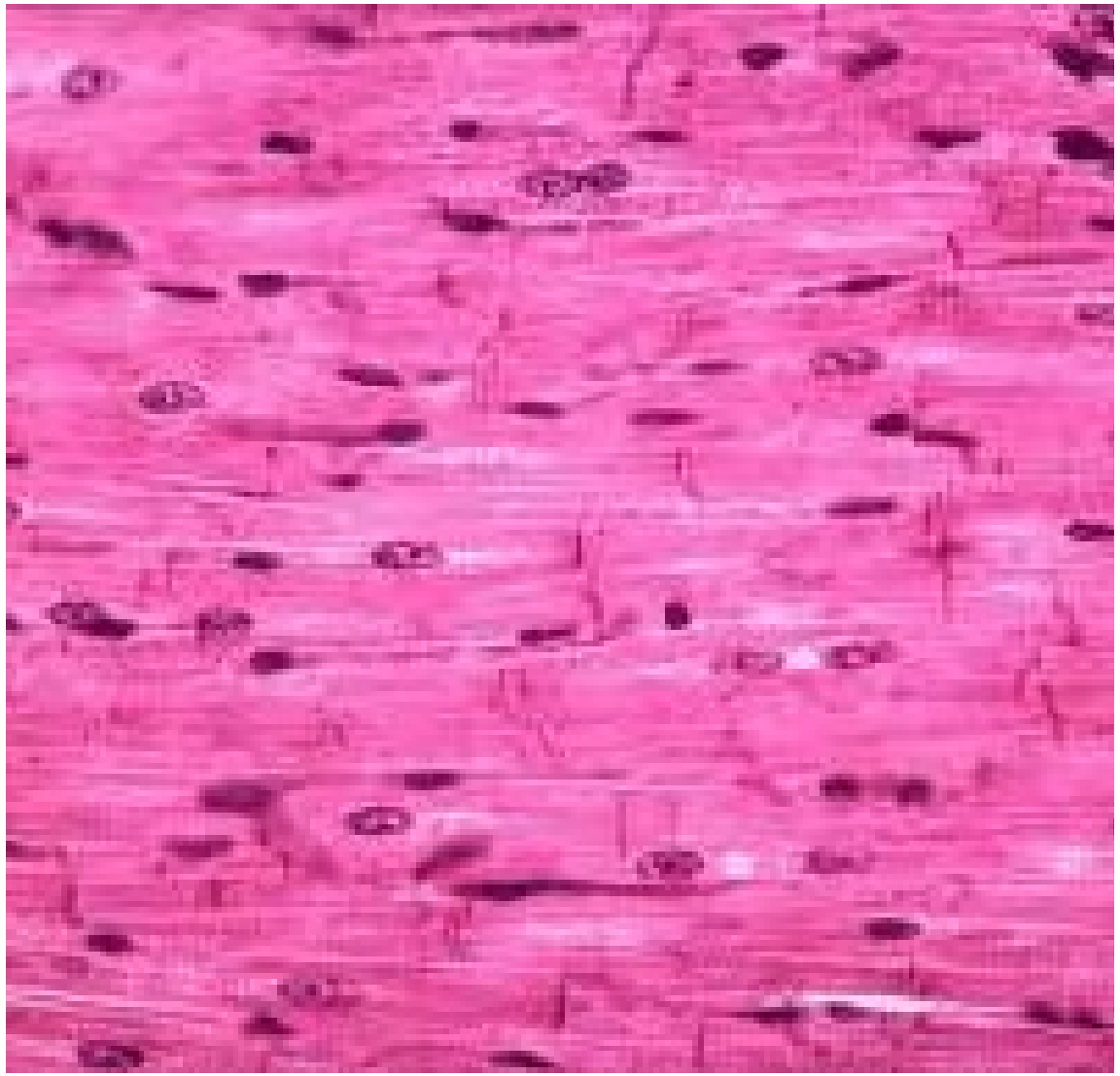
- Action potential propagates into the cell via *sarcolemma* (cell membrane)
- Ca^{2+} ions are released from the sarcoplasmic reticulum
- Actin and myosin filaments slide to interact
- Duration of each muscle contraction is tens of ms, *vs.* the rapid depolarization wave in nerve cells



solunetti.fi/fi/histologia/endoplastinen_kalvosto/

Smooth muscle

- Involuntary
- In the walls of, *e.g.,* vessels, intestines, airways to lungs
- Cell length 0.02-0.5 mm, diameter 3-10 um
- One nucleus per cell
- Non-organized actine and myocin filaments → weaker contractions



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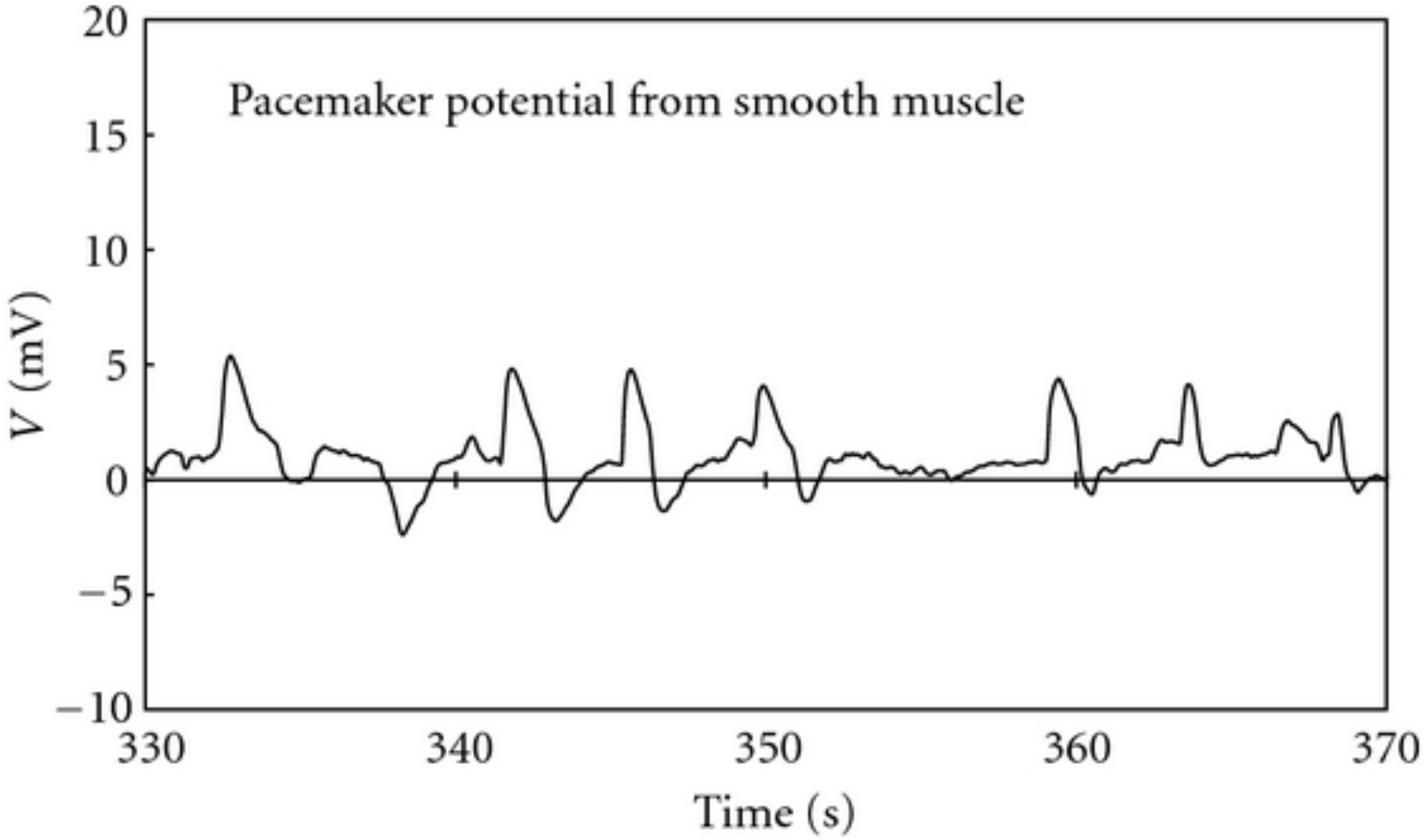
Smooth muscle cells have pacemaker potential

- At particular areas, the resting potential idles spontaneously and can start action potential
- Impulse can directly spread to near-by cells via gap junctions
- Innervation via autonomic nervous system



Cho et al. 2012

Cardiac muscle

- Involuntary
- Abundant of mitochondria and capillaries
- Branched structure, connect to each other via intercalated discs
- No renewal potential
- Both pacemaker cells and innervation via autonomic nervous system
- Impulse spreads directly to near-by cells
- Long repolarization → tetanic muscle contraction impossible

bigstock.com

Comparison of muscle cell types: Summary

MUSCLE CELL	CELL SIZE	NUCLEUS	STRIPES	INNER-VATION	AUTO-MATISM	DIRECT IMPULSE CONDUC-TION	VOLUN-TARY	DENERVATION	EFFECT OF HORMONES
SKELETAL	large	many	+	somatic	-	-	+	atrophy	+/-
SMOOTH	normal	one	-	autonom.	+/-	+/-	-	works still	+++
CARDIAC	normal	one	+	autonom.	+	+	-	works still	+