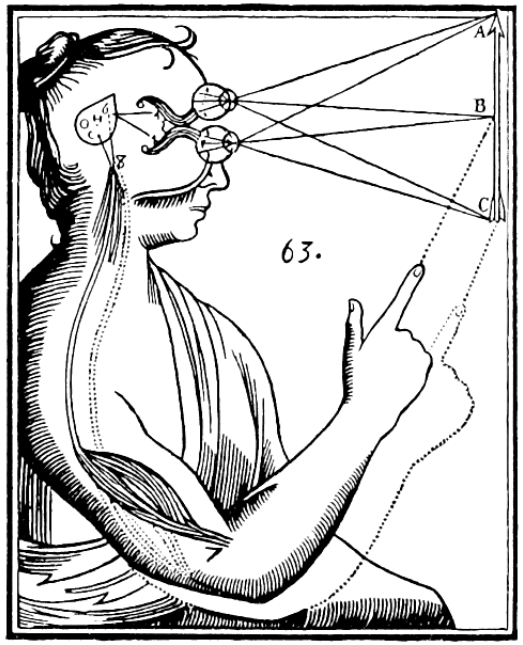
GSSE Physiology

Neurophysiology and muscle physiology

Nick Skladnev

RMO POW



*All images/figures from Ganong's 25th ed. Unless otherwise specified

Structure

Nerves
- Structure + types
- Action potentials
- Neurotransmission

Muscle
- Structure + types
- Conduction
- Output

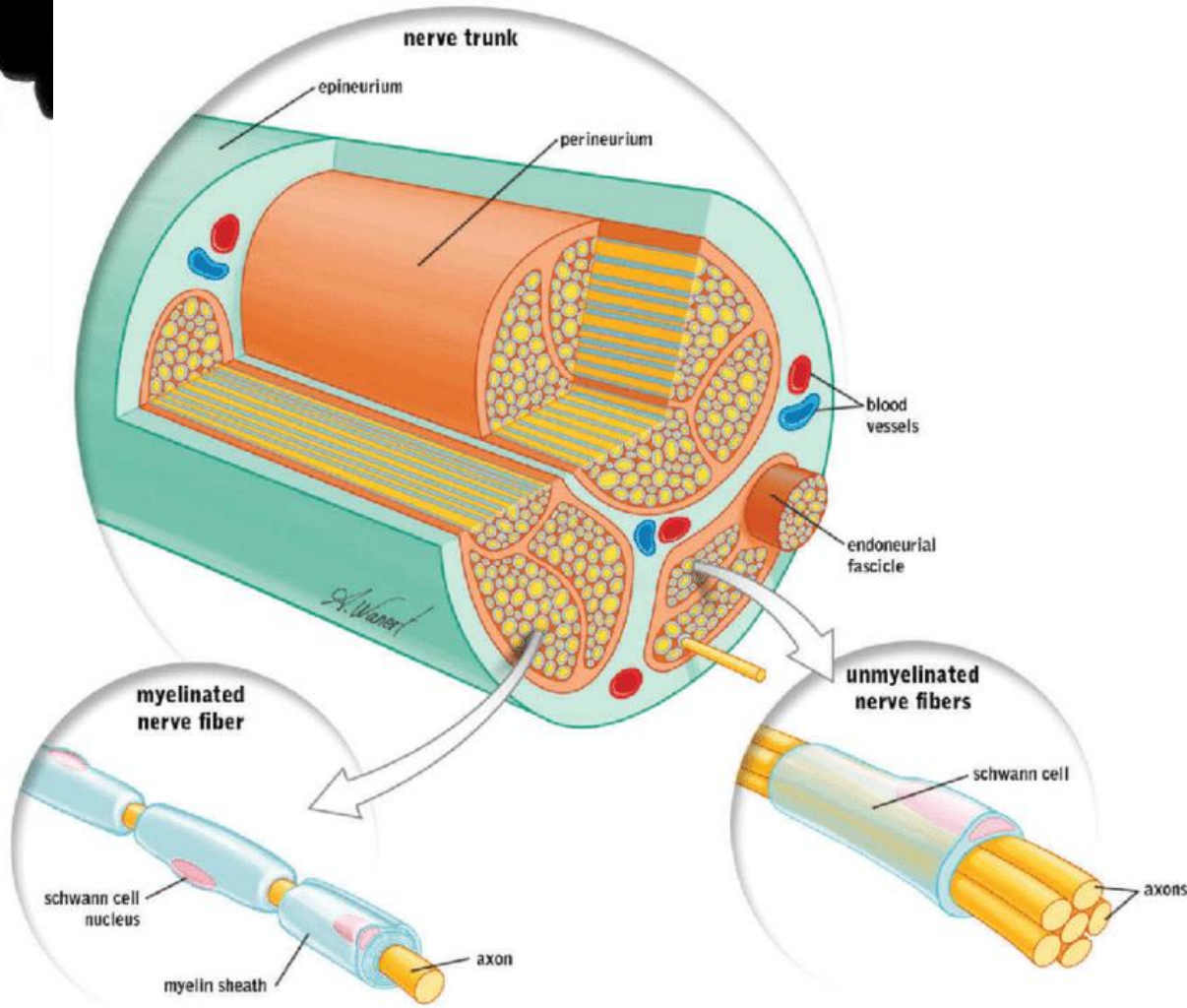
Synthesis
- Principle pathways
- Reflex arcs

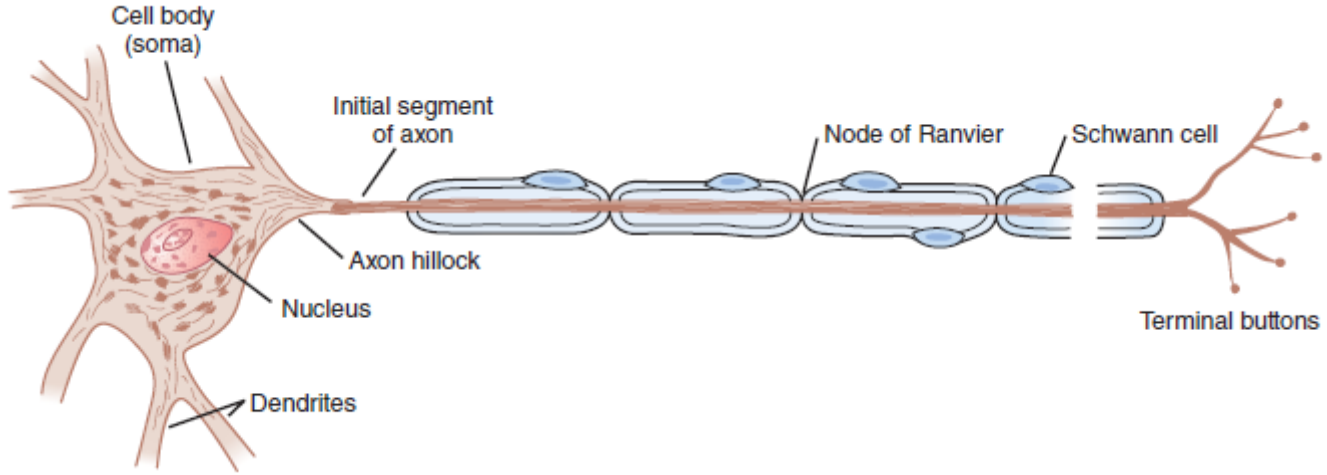
NOT EXHAUSTIVE

Principles > Details

Commit to a few anchor details

Nerve structure




Cell body
(soma)
Initial segment
of axon
Node of Ranvier
Schwann cell
Axon hillock
Nucleus
Terminal buttons
Dendrites

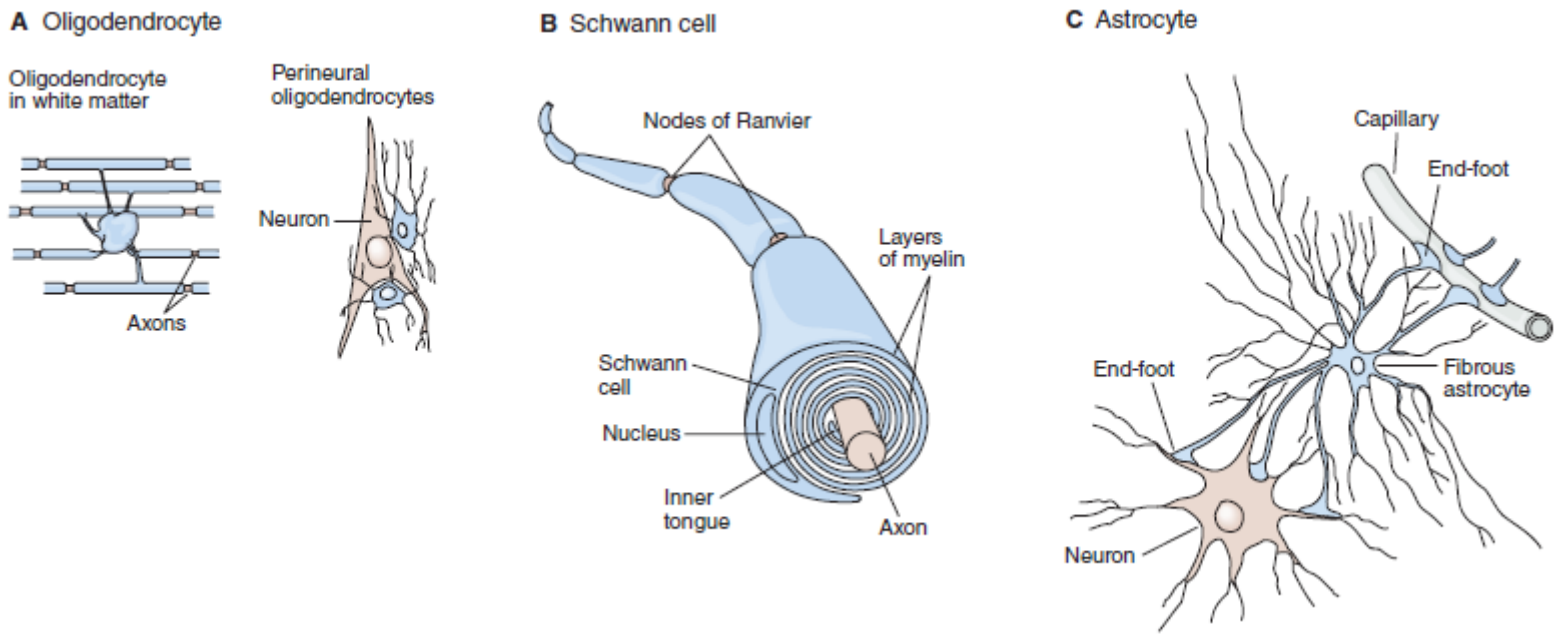

A Oligodendrocyte
Oligodendrocyte
in white matter
Perineural
oligodendrocytes
Neuron
Axons
B Schwann cell
Nodes of Ranvier
Layers
of myelin
Schwann
cell
Nucleus
Inner
tongue
Axon
C Astrocyte
Capillary
End-foot
End-foot
Fibrous
astrocyte
Neuron

TABLE 4–1 Types of mammalian nerve fibers.

Fiber Type	Function	Fiber Diameter (μm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
Aα	Proprioception; somatic motor	12–20	70–120		
Aβ	Touch, pressure	5–12	30–70	0.4–0.5	0.4–1
Aγ	Motor to muscle spindles	3–6	15–30		
Aδ	Pain, temperature	2–5	12–30		
B	Preganglionic autonomic	< 3	3–15	1.2	1.2
C, Dorsal root	Pain, temperature	0.4–1.2	0.5–2	2	2
C, Sympathetic	Postganglionic sympathetic	0.3–1.3	0.7–2.3	2	2

TABLE 4–3 Relative susceptibility of mammalian A, B, and C nerve fibers to conduction block produced by various agents.

Susceptibility To:	Most Susceptible	Intermediate	Least Susceptible
Hypoxia	B	A	C
Pressure	A	B	C
Local anesthetics	C	B	A

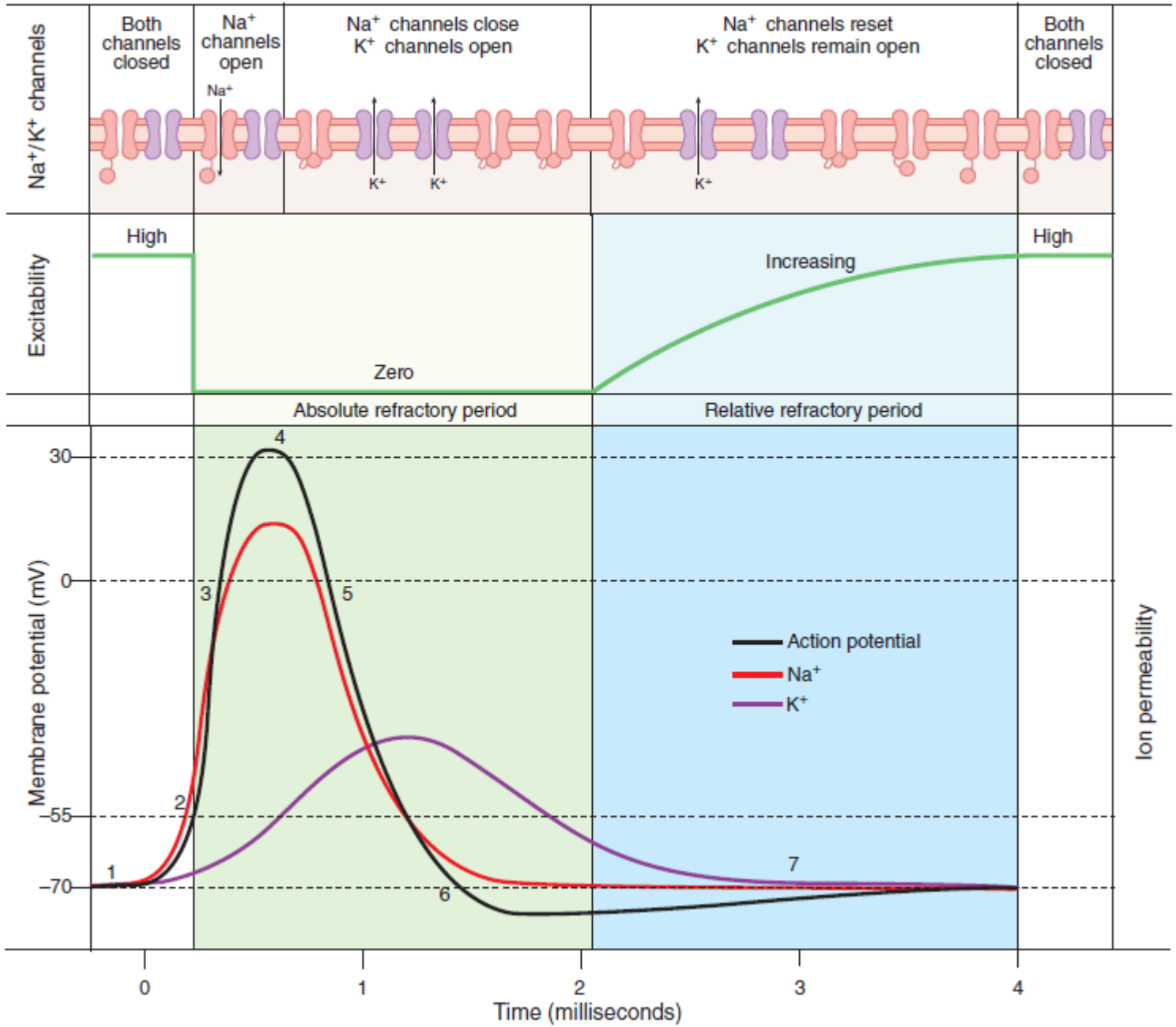
Q – The sensation of painful stimuli

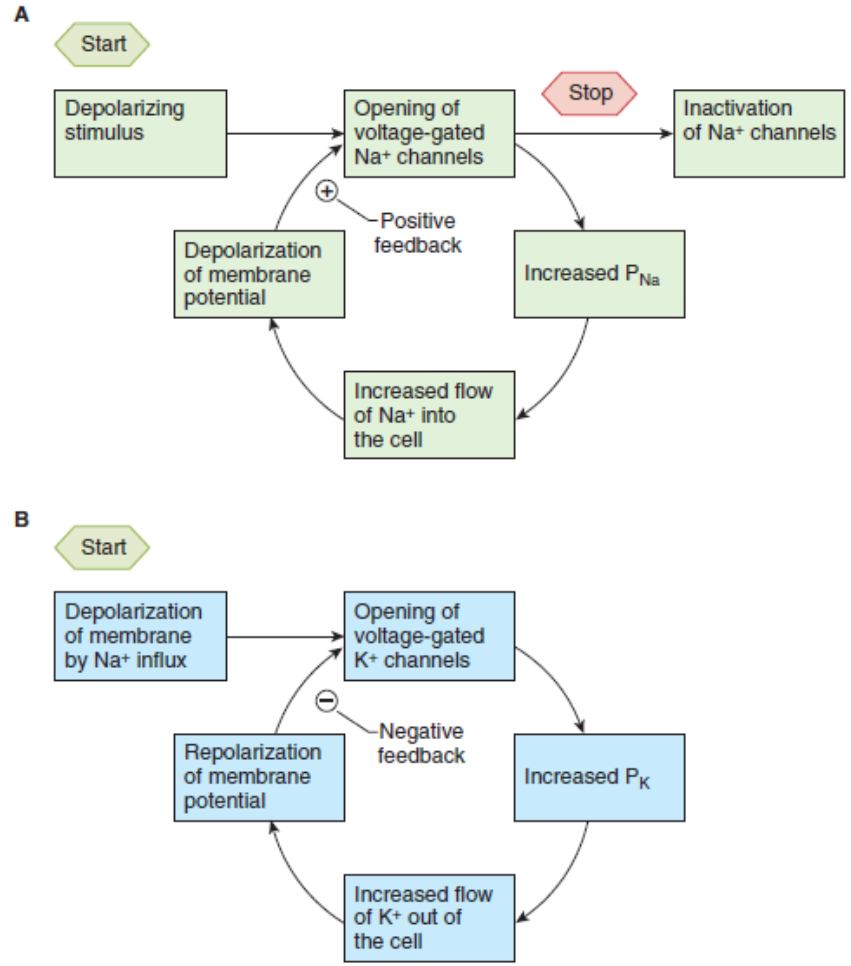
F 1) Is perceived by specific receptors dedicated to its detection

T 2) Is transmitted by two different nerve fibre systems

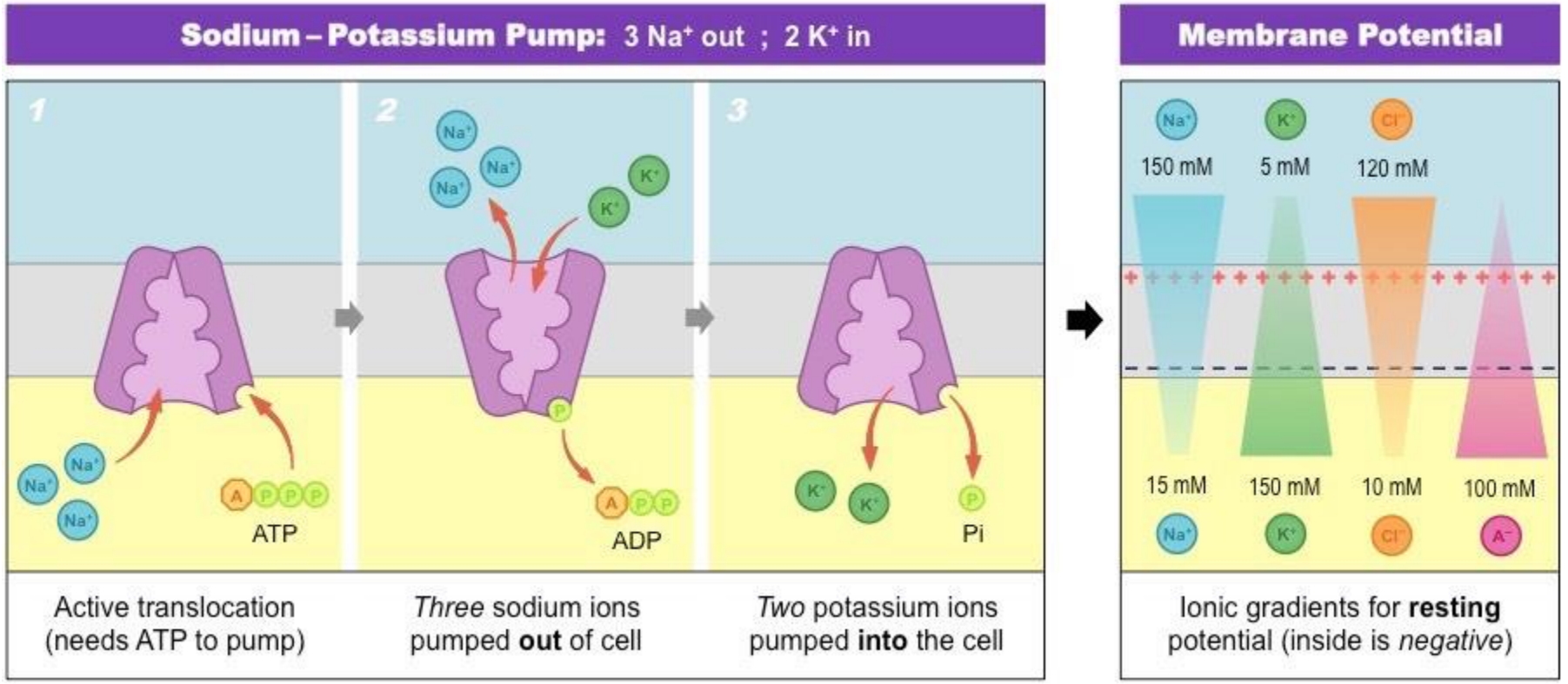
F 3) Travel via descending pathways in the dorsal column of the spinal cord

T 4) Is associated with significant levels of substance P in the substantia gelatinosa


Na+/K+ channels
Both channels closed
Na+ channels open
Na+ channels close K+ channels open
Na+ channels reset K+ channels remain open
Both channels closed
Na+
K+
K+
K+
Excitability
High
Zero
Increasing
High
Absolute refractory period
Relative refractory period
Membrane potential (mV)
30
0
–55
–70
1
2
3
4
5
6
7
Action potential
Na+
K+
Ion permeability
0
1
2
3
4
Time (milliseconds)

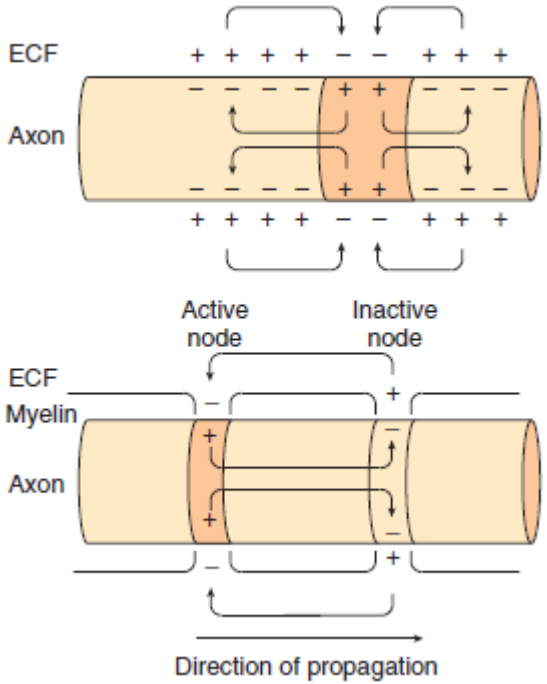

A
Start
Depolarizing stimulus
Opening of voltage-gated Na+ channels
Stop
Inactivation of Na+ channels
Positive feedback
Depolarization of membrane potential
Increased PNa
Increased flow of Na+ into the cell
B
Start
Depolarization of membrane by Na+ influx
Opening of voltage-gated K+ channels
Negative feedback
Repolarization of membrane potential
Increased PK
Increased flow of K+ out of the cell

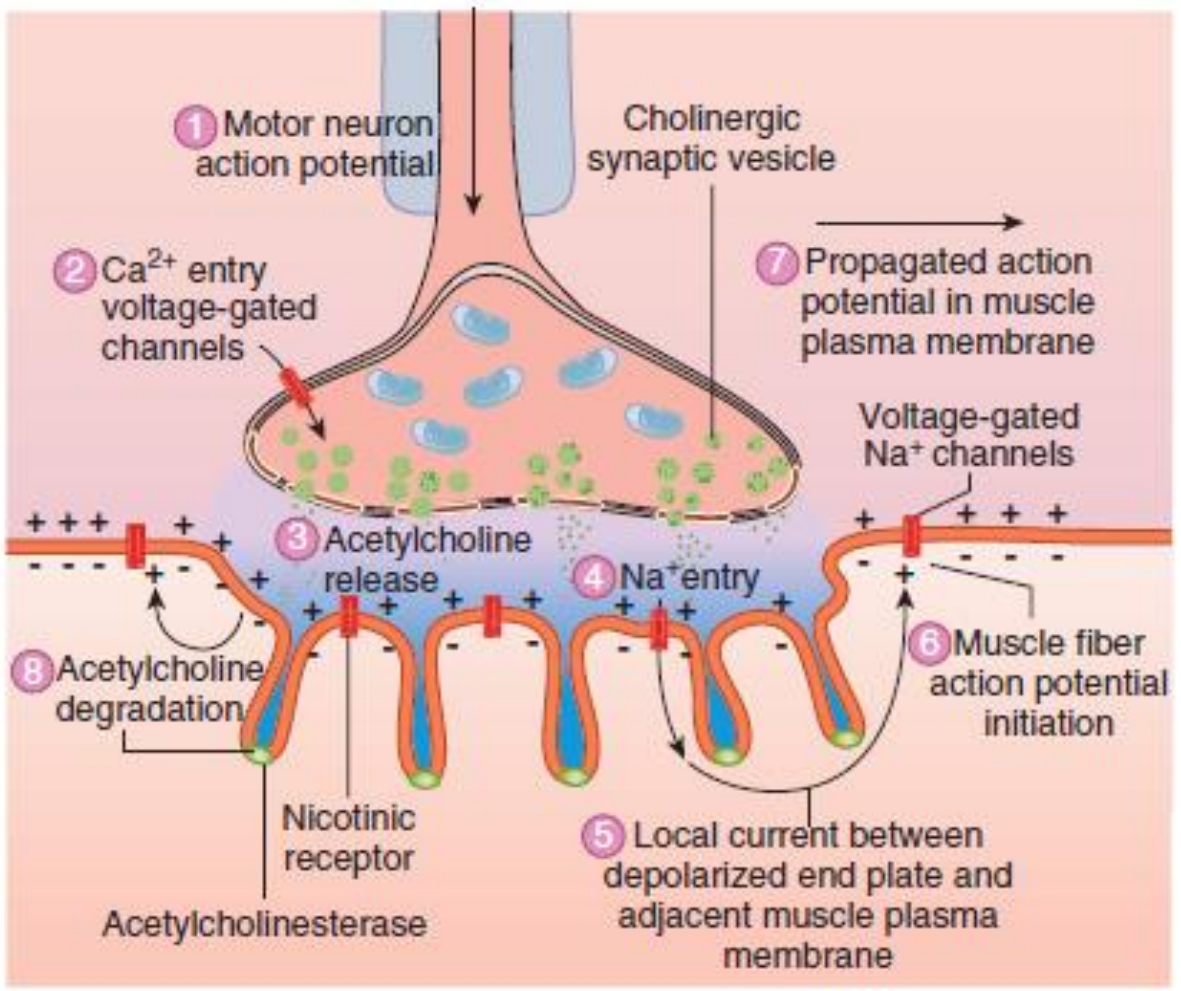
Na/K-ATPase



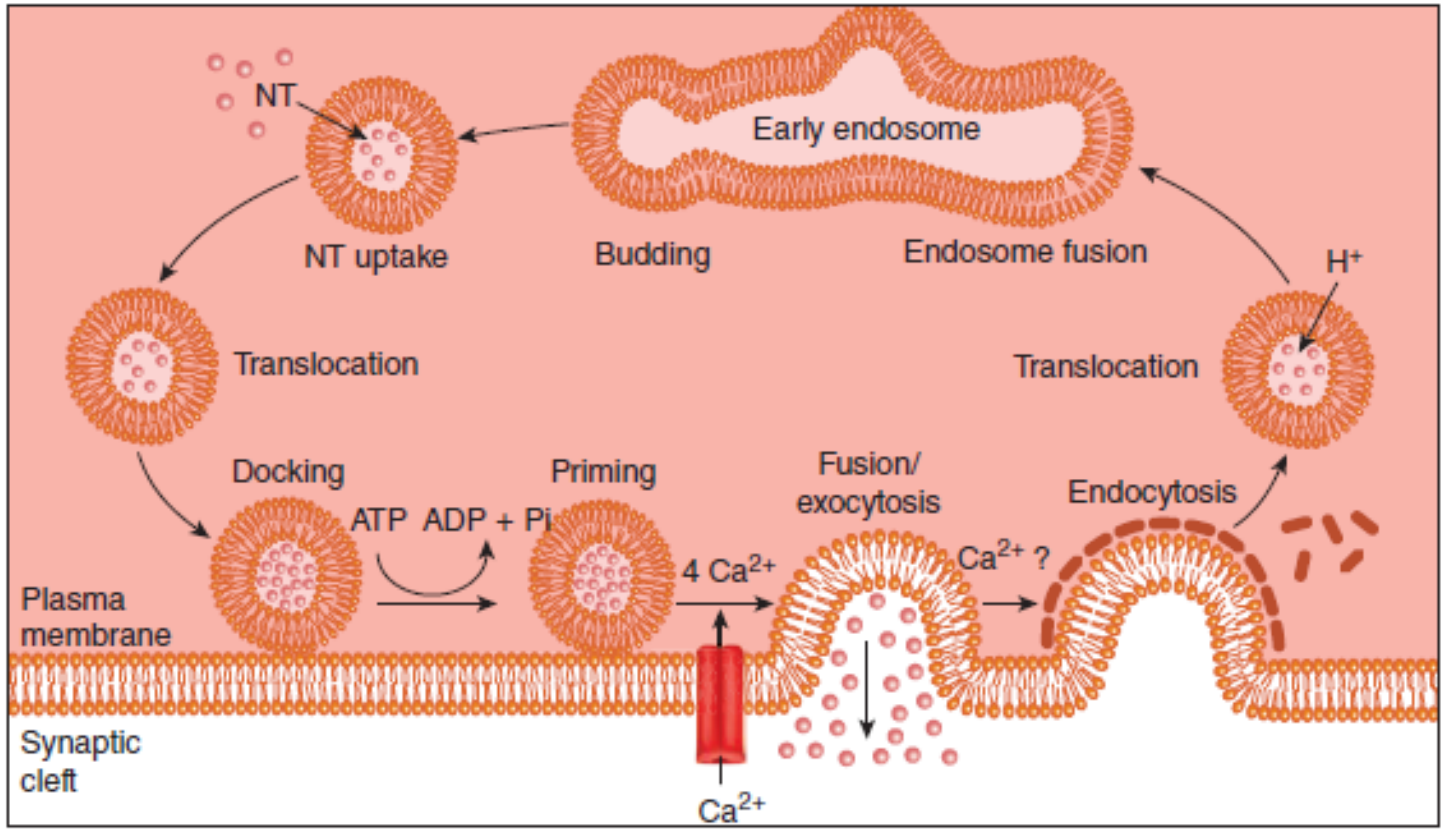
https://ib.bioninja.com.au/standard-level/topic-6-human-physiology/65-neurons-and-synapses/resting-potential.html

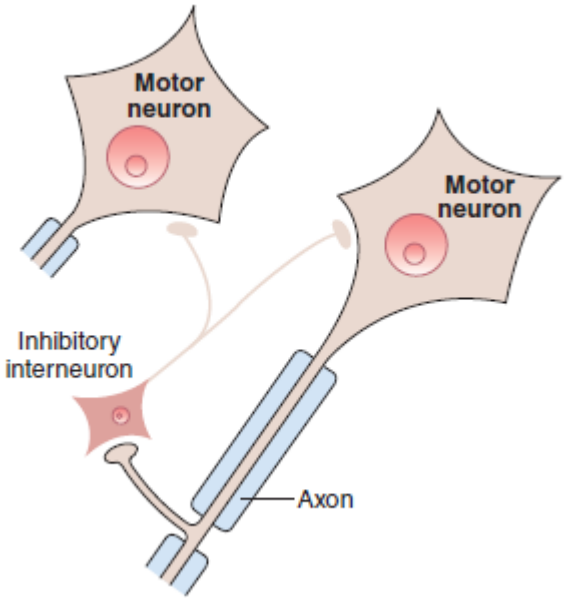
Transmission





- Saltatory conduction
- Axoplasmic flow
- Neurotrophins
- Vesicles





- Types of junction
- Release + recycling
- EPSP + IPSP
- Renshaw Cells

Q - During the relatively refractory period of the action spike in a single squid axon, the intensity of the stimulus required to elicit another spike is.

A) Unchanged
B) Reduced
C) Unchanged, but produces a smaller spike
D) Increased
E) Unchanged, but produces a larger spike

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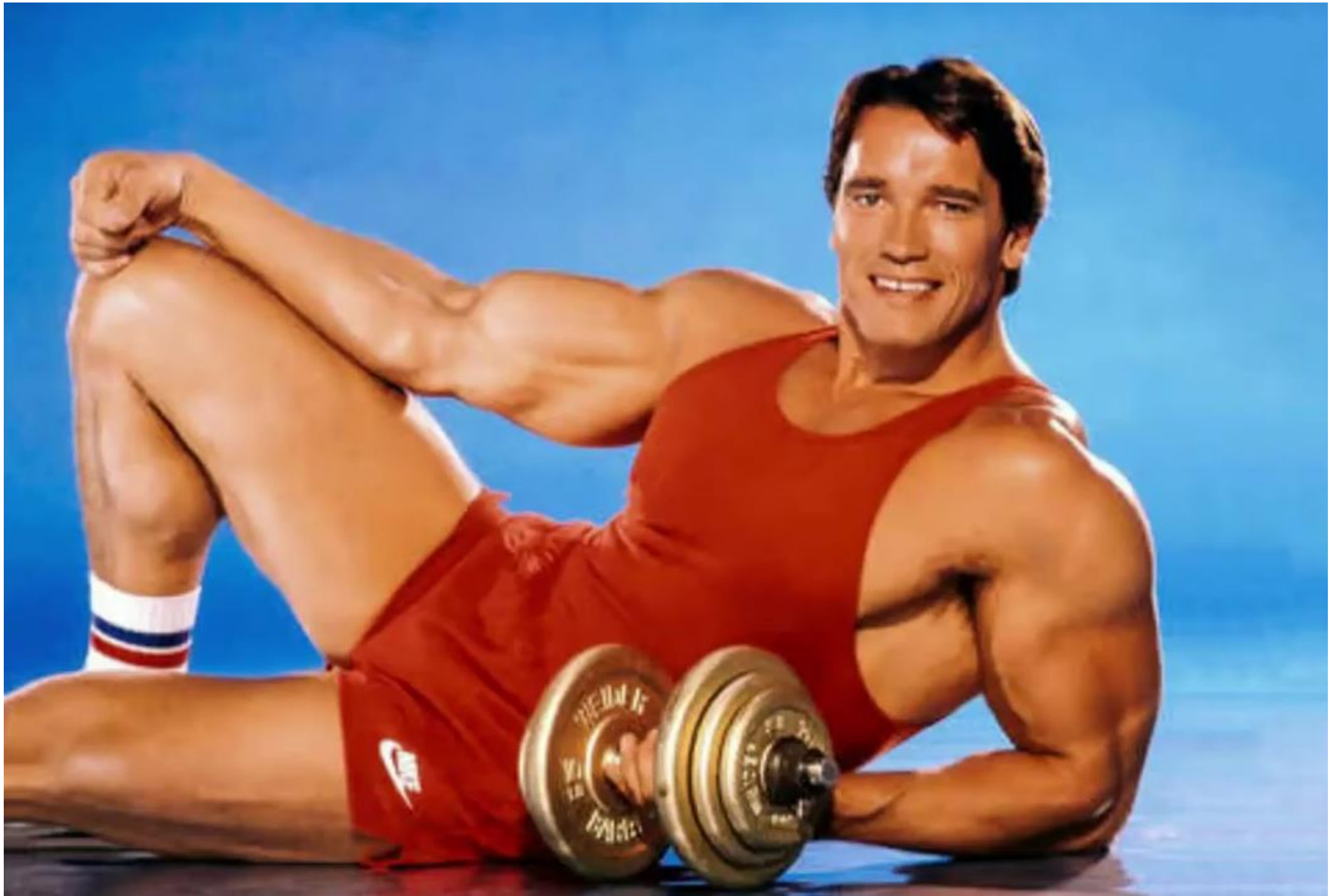
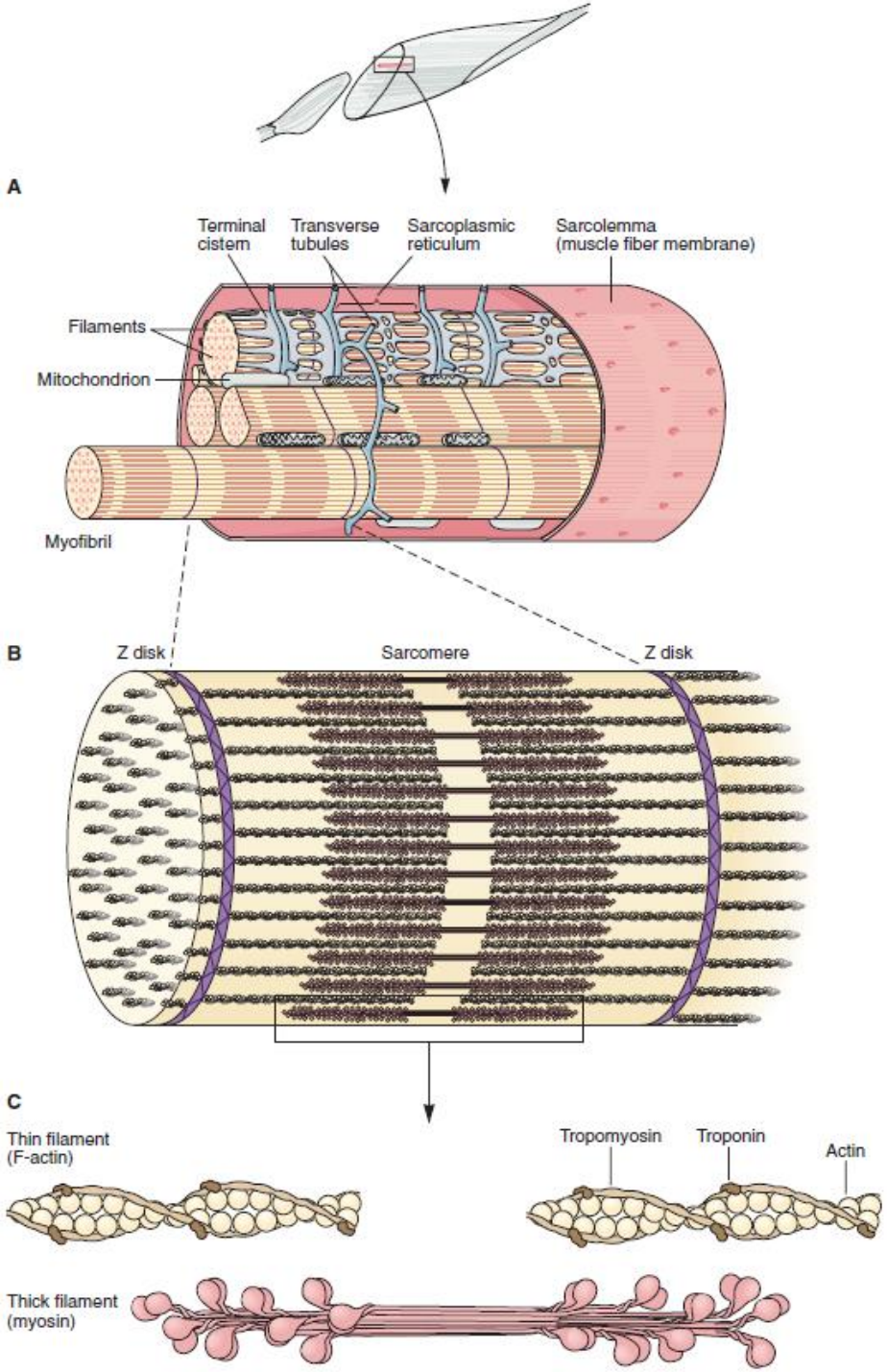
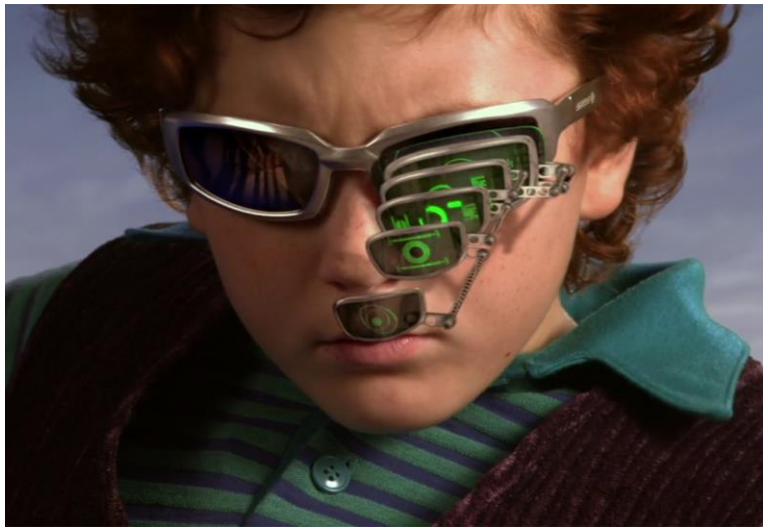


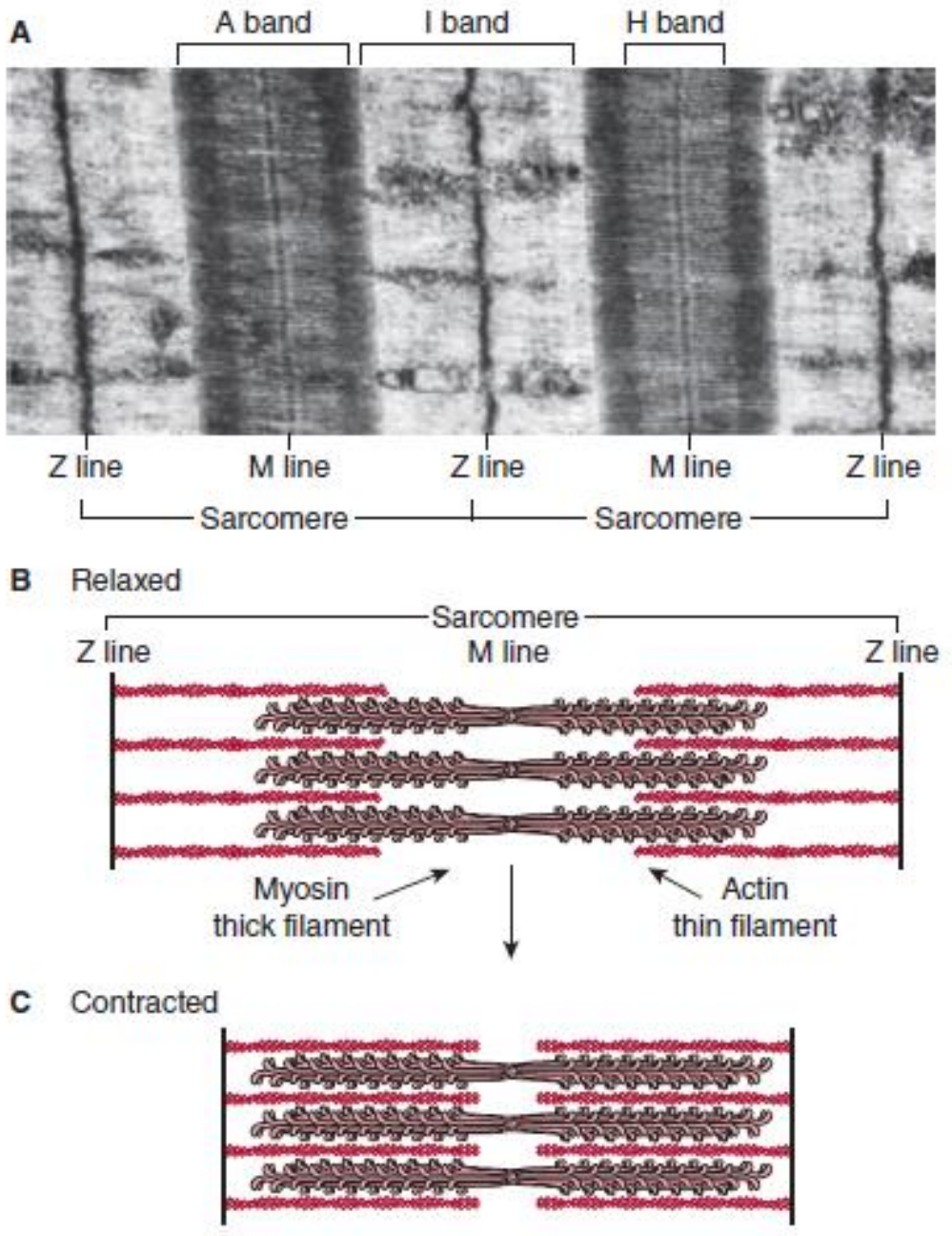
Structure

- Myosin II
- Actin
- Tropomyosin
- Troponin (I, T, C)
- Others (Actinin, Desmin, Titin)





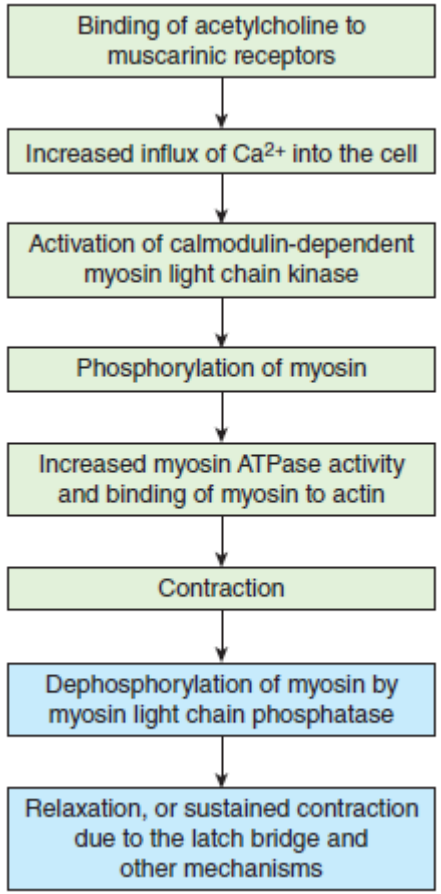
- Thick = A
- Thin = A->I
- Relaxed w/ no thin overlap = H
- Myosin polarity = M

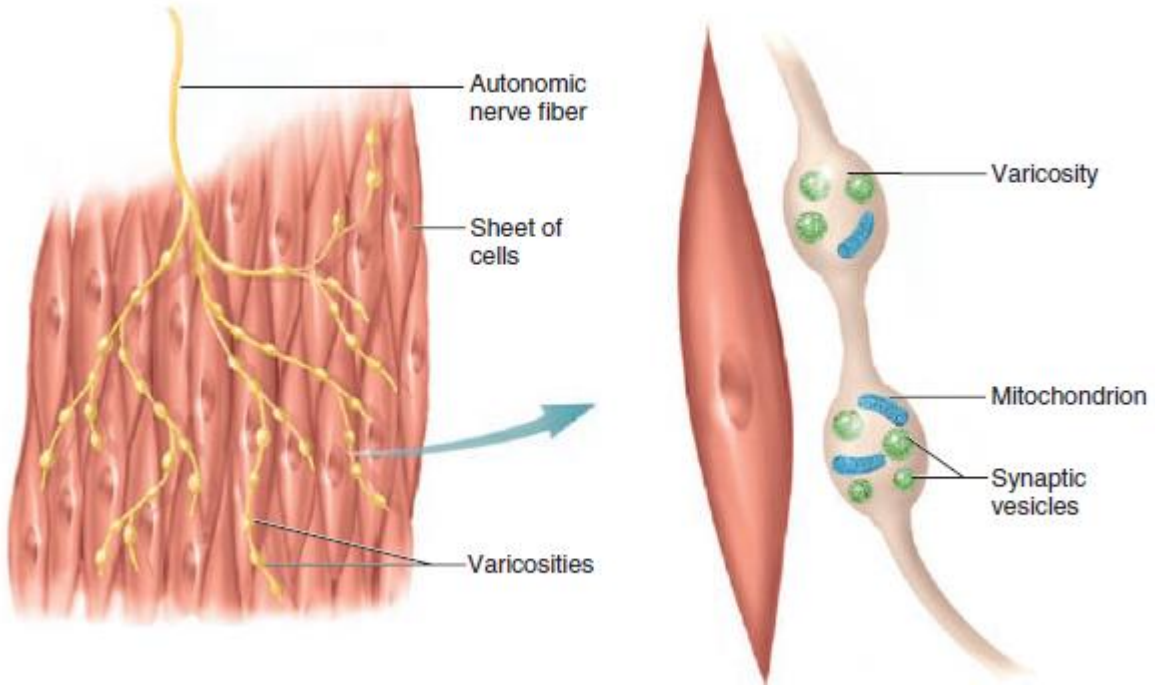


Types + differences

	Skeletal muscle	Cardiac muscle	Smooth muscle
Cells (fibers)	Long tube-shaped, multinucleated cells, aligned with nearby cells	Long, branching cells with single nuclei aligned with nearby cells	Spindle-shaped cells, with single nuclei packed closely
Striations	Yes	Yes	No
Location of nuclei	Periphery of cell	Center of cell	Center of cell
T tubules	Part of triads at A-I junction	Part of dyads at Z disc	No T tubules
Sarcoplasmic reticulum	Abundant with two terminal cisterns in the triads	Less abundant with one terminal cistern per sarcomere in dyads	No distinctive organization
Distinctive structural features	Highly organized sarcomeres & triads	Intercalated discs with adhesion & gap junctions	Gap junctions, caveolae, & dense bodies
Contraction mechanism(s)	Ca^{2+} binding to troponin C exposes myosin binding site on actin	Similar to skeletal muscle	Ca^{2+} binds calmodulin, triggers MLCK mediated phosphorylation of myosin & actin binding
Connective tissue	Endomysium, perimysium, & epimysium	Endomysium, subendocardial, & subpericardial	Endomysium and less organized CT sheaths
Locations	Skeletal muscle, tongue, upper esophagus, eyes	Heart	Blood vessels and walls of most organs
Innervation	Motor for voluntary movement	Autonomic for involuntary pumping of blood	Autonomic for involuntary movement
Growth/renewal	Hypertrophy, limited renewal involving satellite cells	Hypertrophy, little/no renewal	Hypertrophy and hyperplasia/ mitosis

Smooth muscle differences

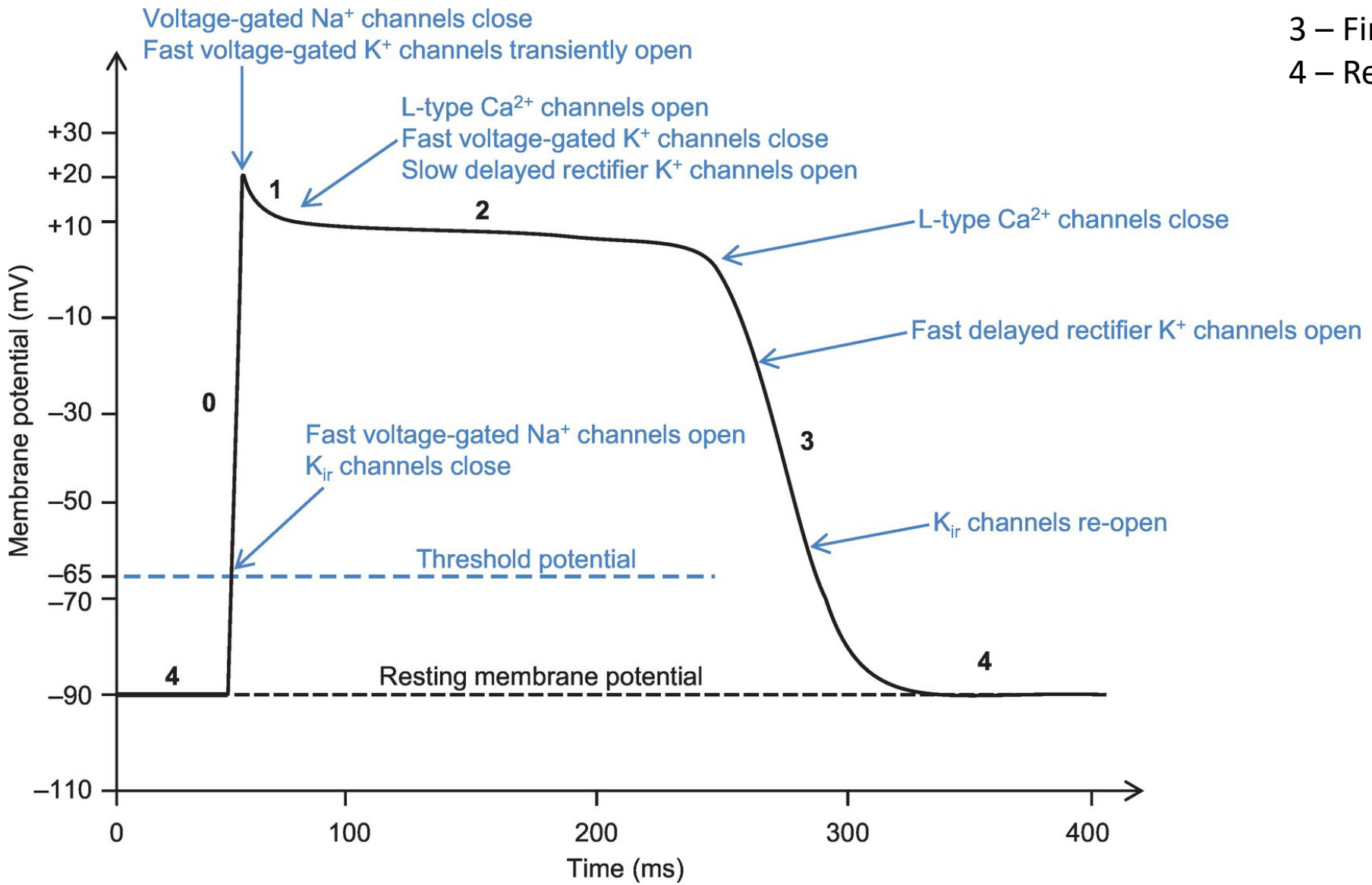




- Unitary vs Multiunit
- No troponin
- Calmodulin
- Nerve supply

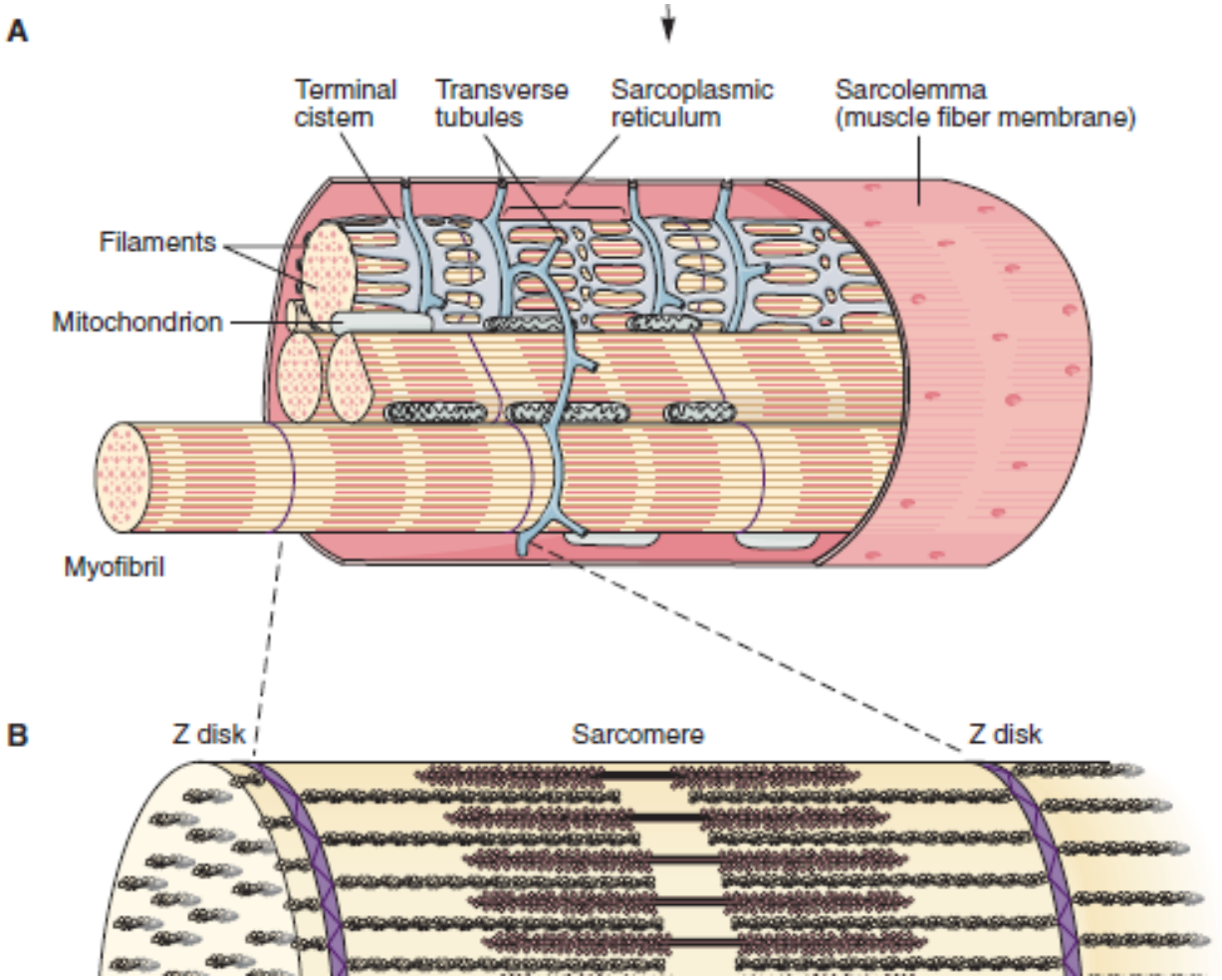
Cardiac AP

0 – Rapid depolarisation
1 – Early rapid repolarisation
2 – Plateau
3 – Final rapid repolarisation
4 – Resting membrane pot



https://www.cambridge.org/core/books/basic-physiology-for-anaesthetists/cardiac-muscle/E905B203766065D5A2857A2F78234CDA

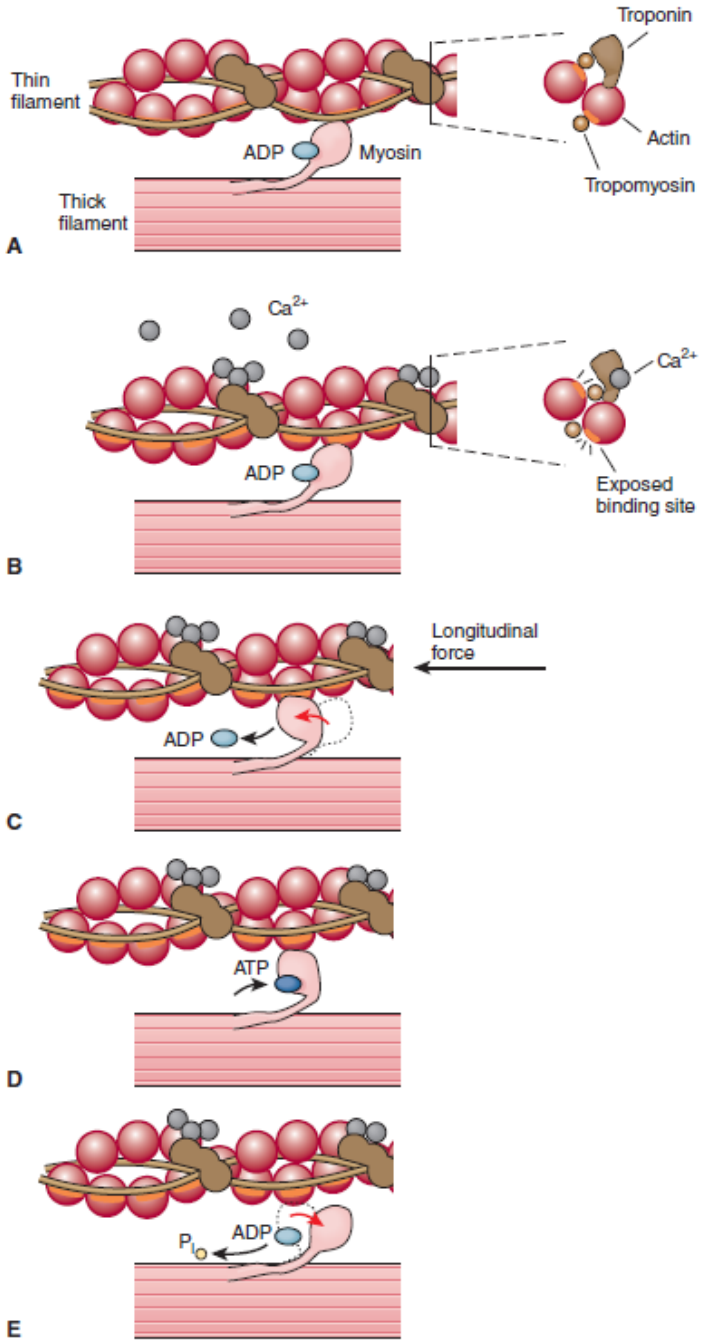
Muscle action



- AP + twitch (duration, slow vs fast)
- Sarcolemma, T tubules, Terminal cisterns (AI jxn)
- DHPR (Ca)
- Sarcoplasmic Reticulum RyR (++Ca)
- SERCA
- ATP dependent

Steps in contraction[a]

- Discharge of motor neuron
- Release of transmitter (acetylcholine) at motor endplate
- Binding of acetylcholine to nicotinic acetylcholine receptors
- Increased Na^+ and K^+ conductance in endplate membrane
- Generation of endplate potential
- Generation of action potential in muscle fibers
- Inward spread of depolarization along T tubules
- Release of Ca^{2+} from terminal cisterns of sarcoplasmic reticulum and diffusion to thick and thin filaments
- Binding of Ca^{2+} to troponin C, uncovering myosin-binding sites on actin
- Formation of cross-linkages between actin and myosin and sliding of thin on thick filaments, producing movement



Steps in relaxation

- Ca^{2+} pumped back into sarcoplasmic reticulum
- Release of Ca^{2+} from troponin
- Cessation of interaction between actin and myosin

- Actin-myosin interactions
- Trop I (+ADP)
- 10nm steps
- Rigor mortis

Q – In skeletal muscle

A. phosphocreatine is the initial energy source for contraction

B. Ca\p2\p+ initiates contraction by binding to tropomyosin

C. transverse tubules (T tubules) release Ca\p2\p+ in the vicinity of the myofibrils in contraction

D. the Z lines move closer together in contraction

E. Ca\p2\p+ passively diffuses back into the sarcoplasmic reticulum in relaxation

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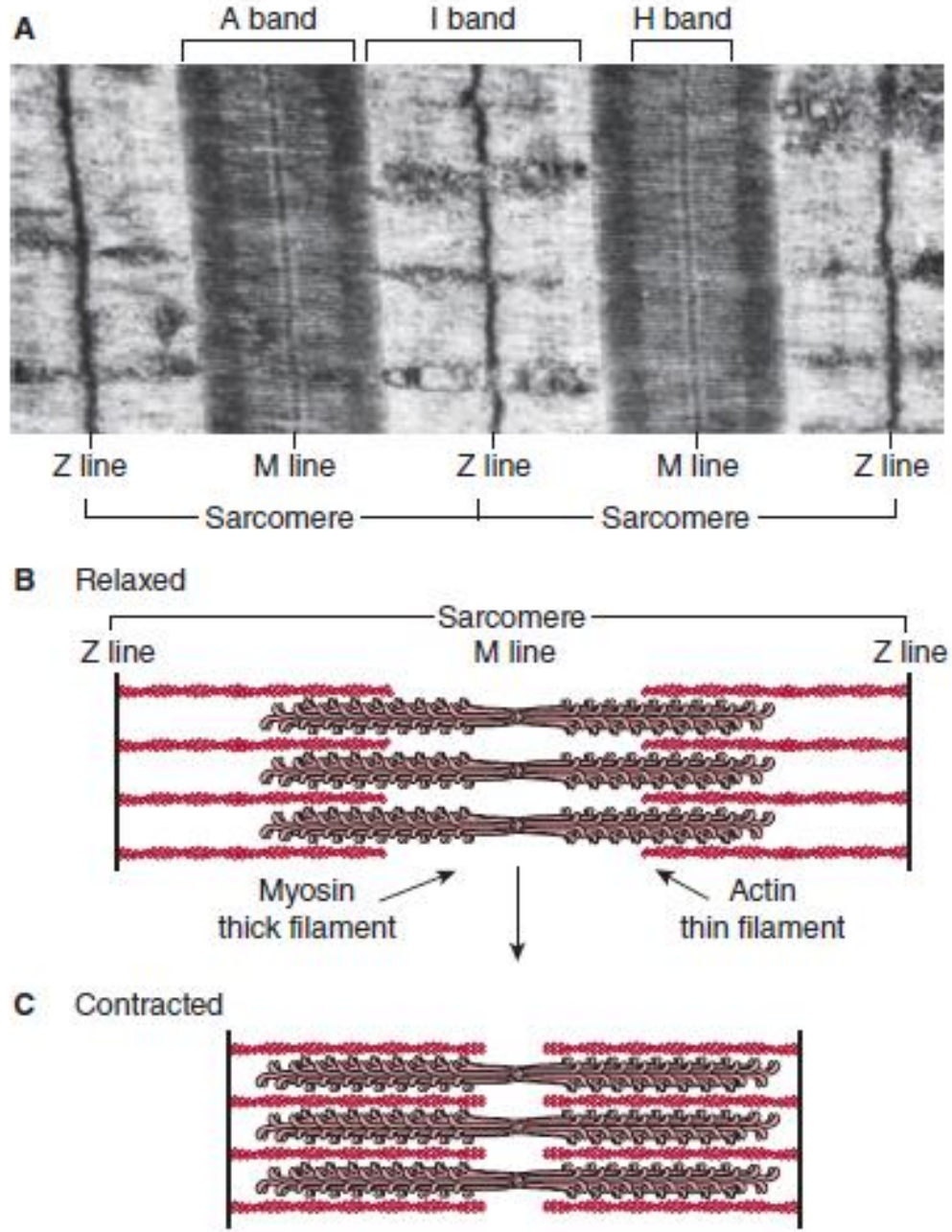

A
A band
I band
H band
Z line
M line
Z line
M line
Z line
Sarcomere
Sarcomere
B Relaxed
Sarcomere
Z line
M line
Z line
Myosin
thick filament
Actin
thin filament
C Contracted

Q -Events in contraction of skeletal muscle include

T 1: release of acetylcholine at motor end plate

F 2: binding of acetylcholine to muscarinic receptors

T 3: binding of Ca2+ to troponin C thus uncovering myosin binding sites on actin

F 4: inward spread of depolarization along sarcoplasmic reticulum

Q – In smooth muscle

T 1) Calmodulin is the regulatory calcium binding protein

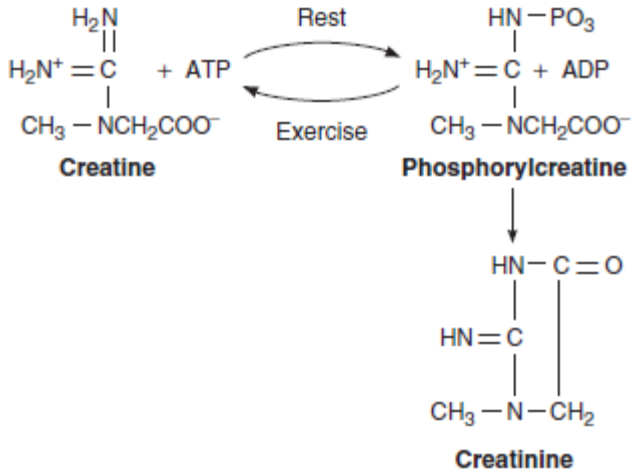
F 2) The T tubules transmit the action potentials

T 3) The calcium pump is slow acting in comparison with the calcium pump in skeletal muscle

F 4) Both sarcoplasmic reticulum and T tubules release Ca/p2+ to initiate contraction

Energy

- Macro sources depend on tissue
- Glucose
- Glycogen
- Creatine



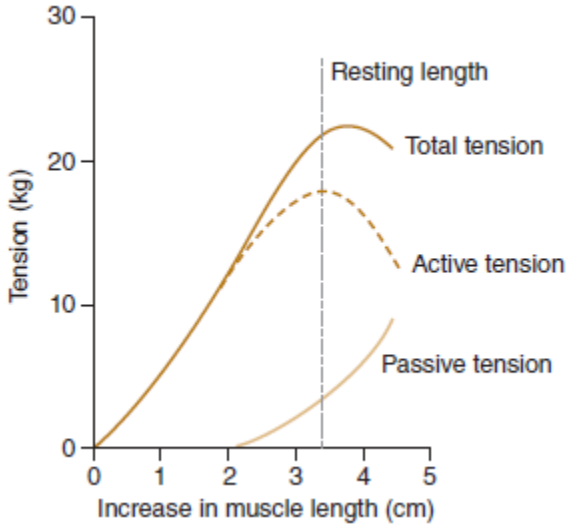
Energy in phosphate bond:
$ATP + H_2O \rightarrow ADP + H_3PO_4 + 7.3$ kcal

ATP "storage" in muscle via creatine:
Phosphorylcreatine + ADP ⇌ Creatine + ATP

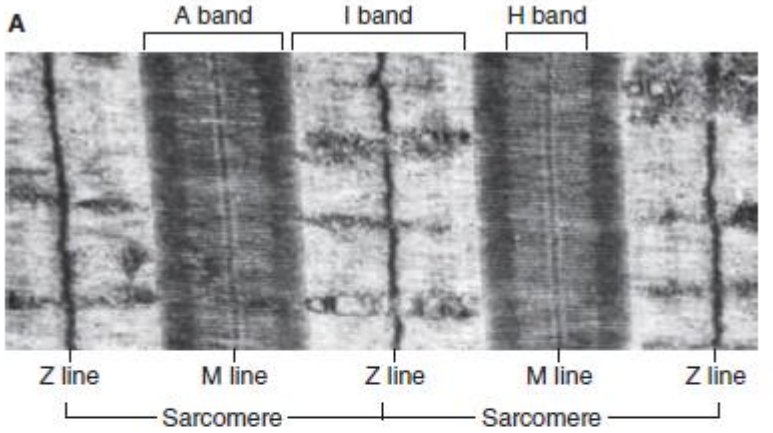
Anaerobic pathway:
Glucose + 2 ATP ⟶ 2 Lactic acid + 4 ATP
(or glycogen + 1 ATP)

Aerobic pathway:
Glucose + 2 ATP ⟶ $6\ CO_2 + 6\ H_2O$ + 40 ATP
(or glycogen + 1 ATP)

FFA ⟶ $CO_2 + H_2O$ + ATP



Work = Force x Distance



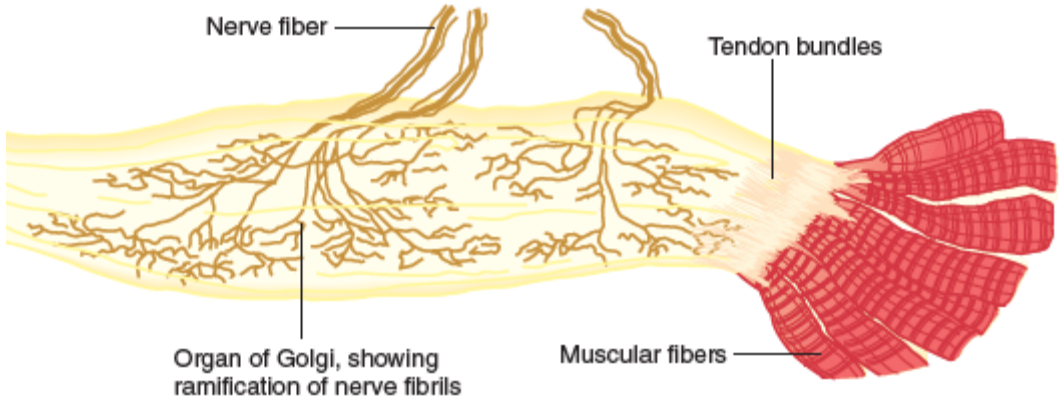
- Isometric/Isotonic
- Length-Tension (sliding filament)
- Starlings Law
- Output (Heat + Work)
- Motor unit

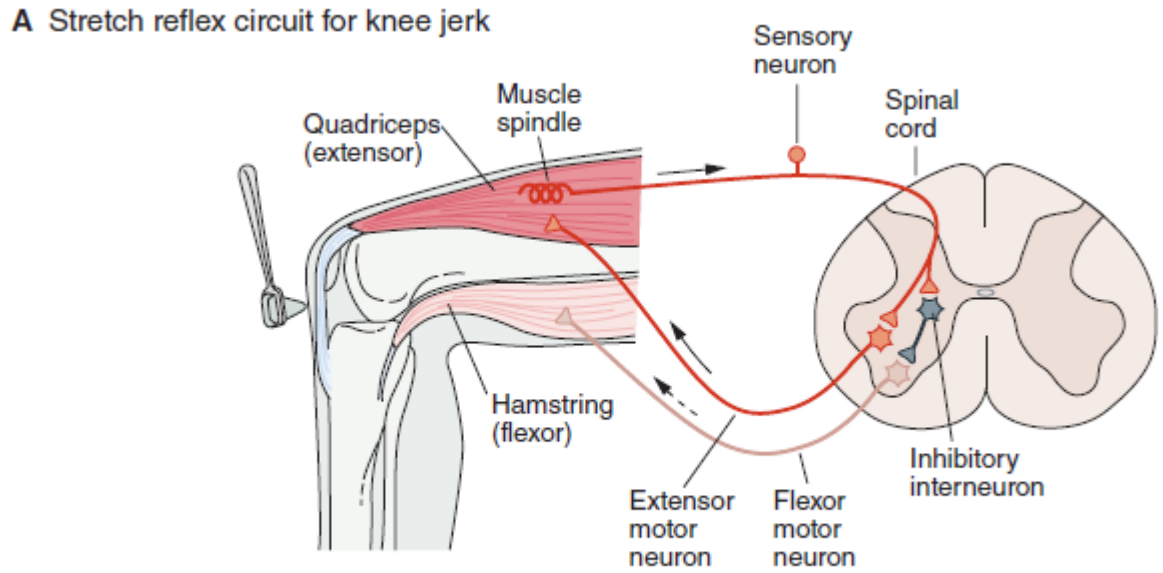
TABLE 5–2 Classification of fiber types in skeletal muscles.

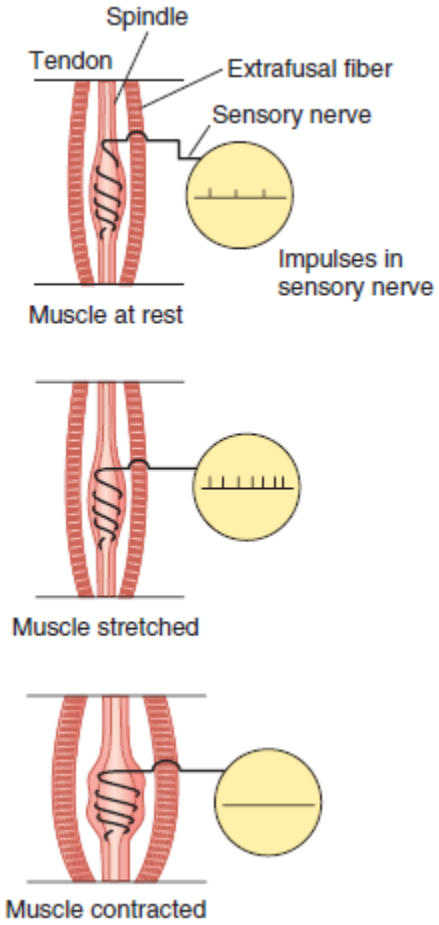
	Type 1	Type IIA	Type IIB
Other names	Slow, Oxidative (SO)	Fast, Oxidative, Glycolytic (FOG)	Fast, Glycolytic (FG)
Color	Red	Red	White
Myosin ATPase activity	Slow	Fast	Fast
Ca^{2+}-pumping capacity of sarcoplasmic reticulum	Moderate	High	High
Diameter	Small	Large	Large
Glycolytic capacity	Moderate	High	High
Oxidative capacity	High	Moderate	Low
Associated Motor Unit Type	Slow (S)	Fast Resistant to Fatigue (FR)	Fast Fatigable (FF)
Membrane potential = –90 mV			

Reflex arcs

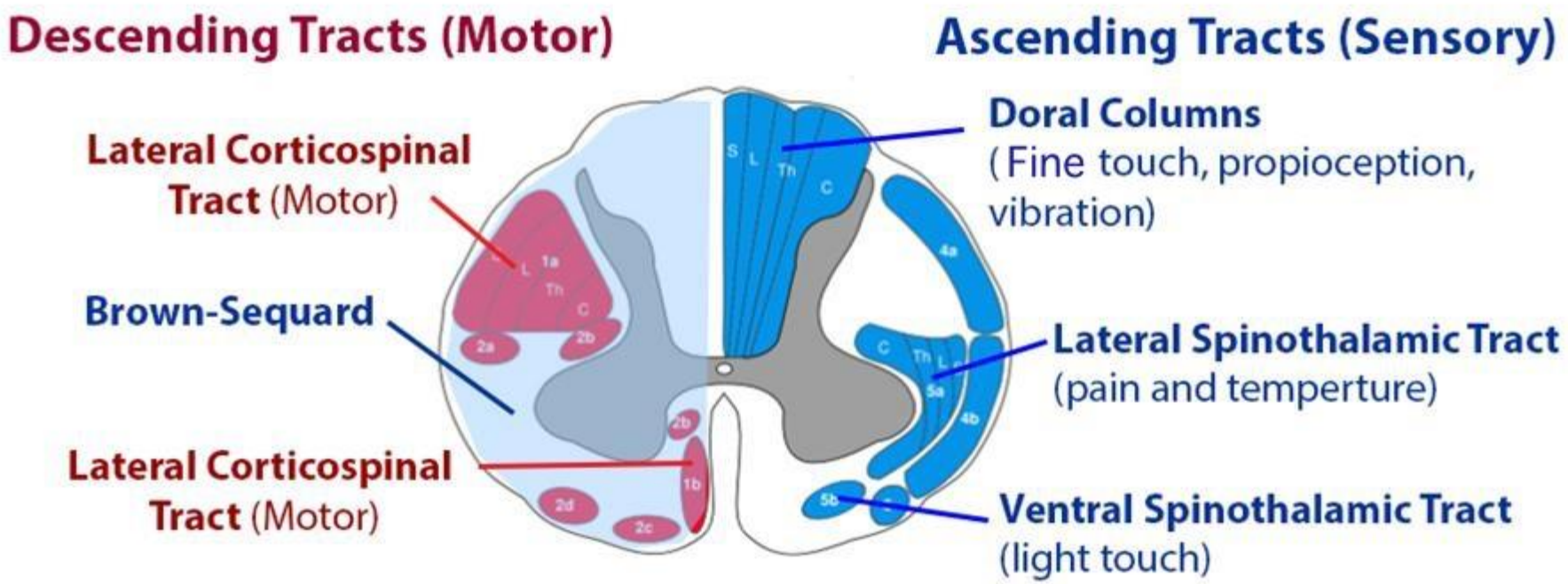
- Alpha MN (LMN) = motor unit
- Gamma MN (LMN) = Spindles
- Spindles (muscle stretch)
- GTO (tendon stretch)





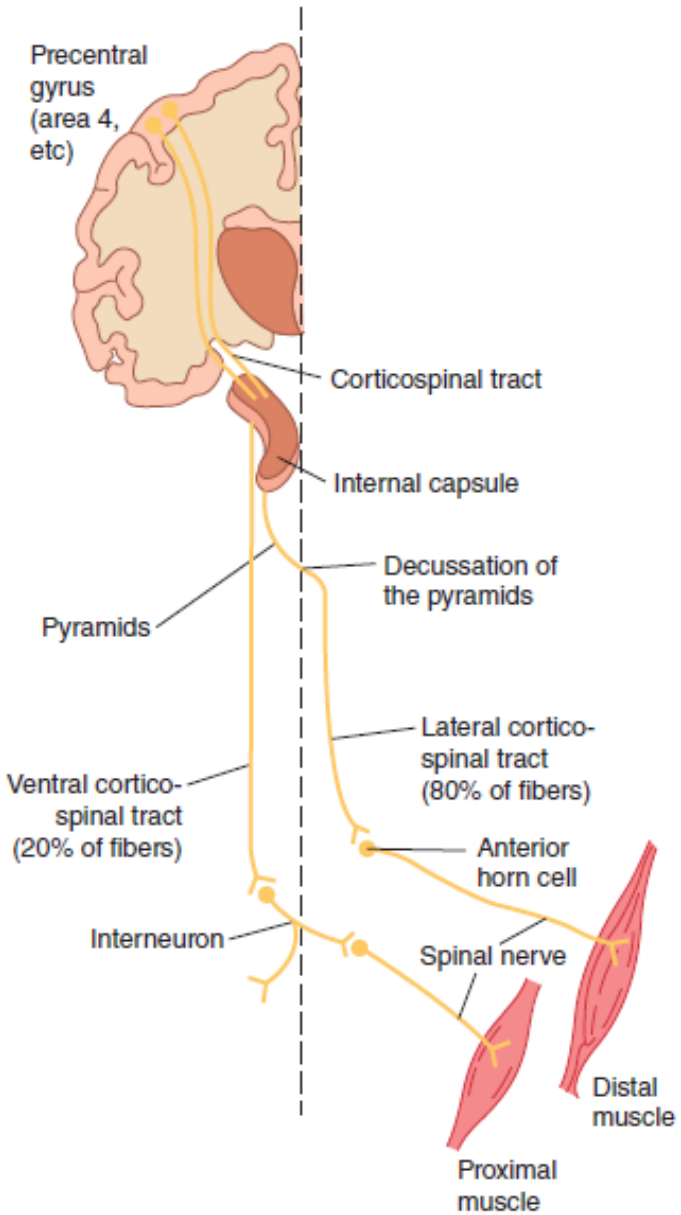


Principle Motor + Sensory pathways

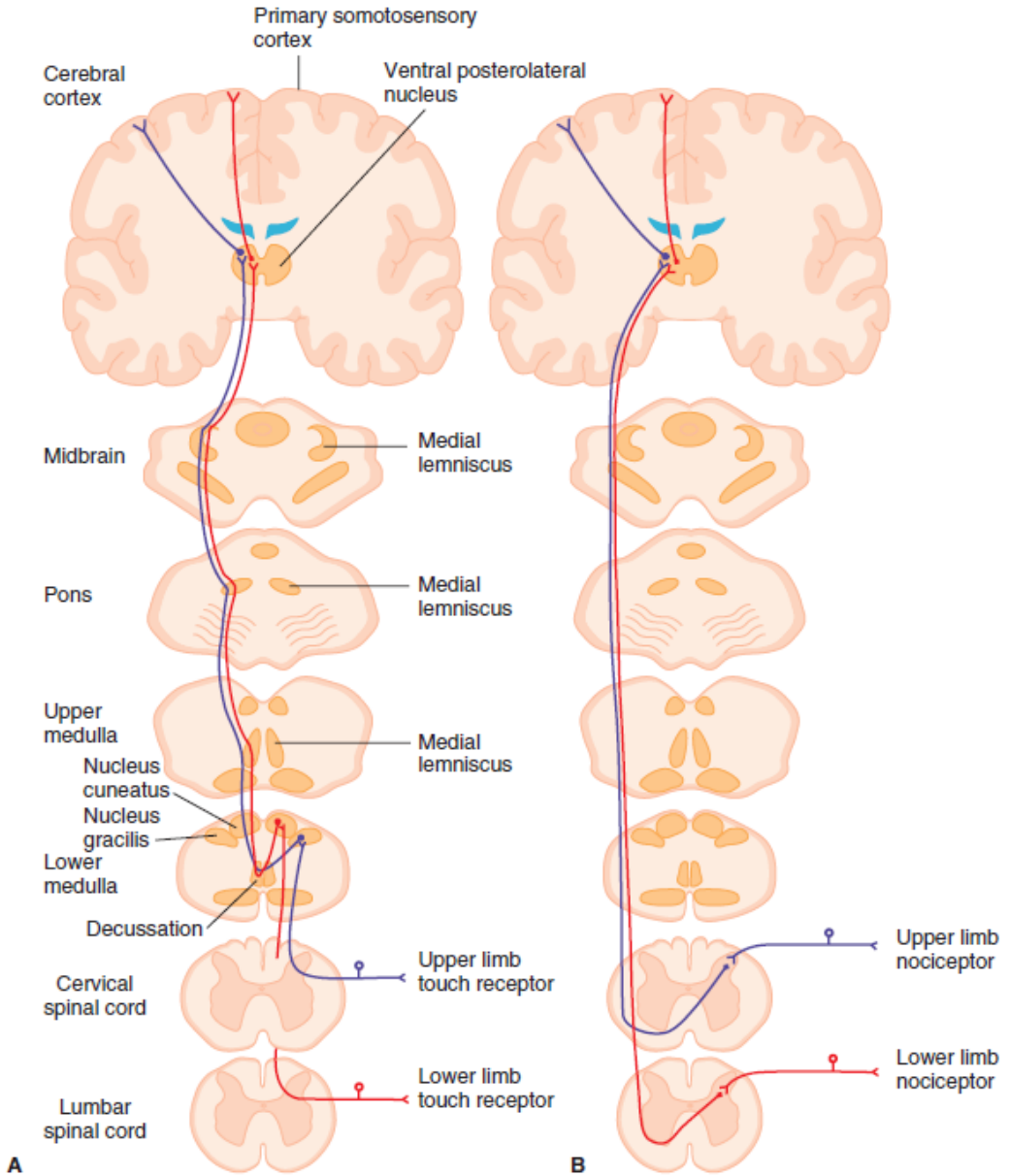


Orthobullets

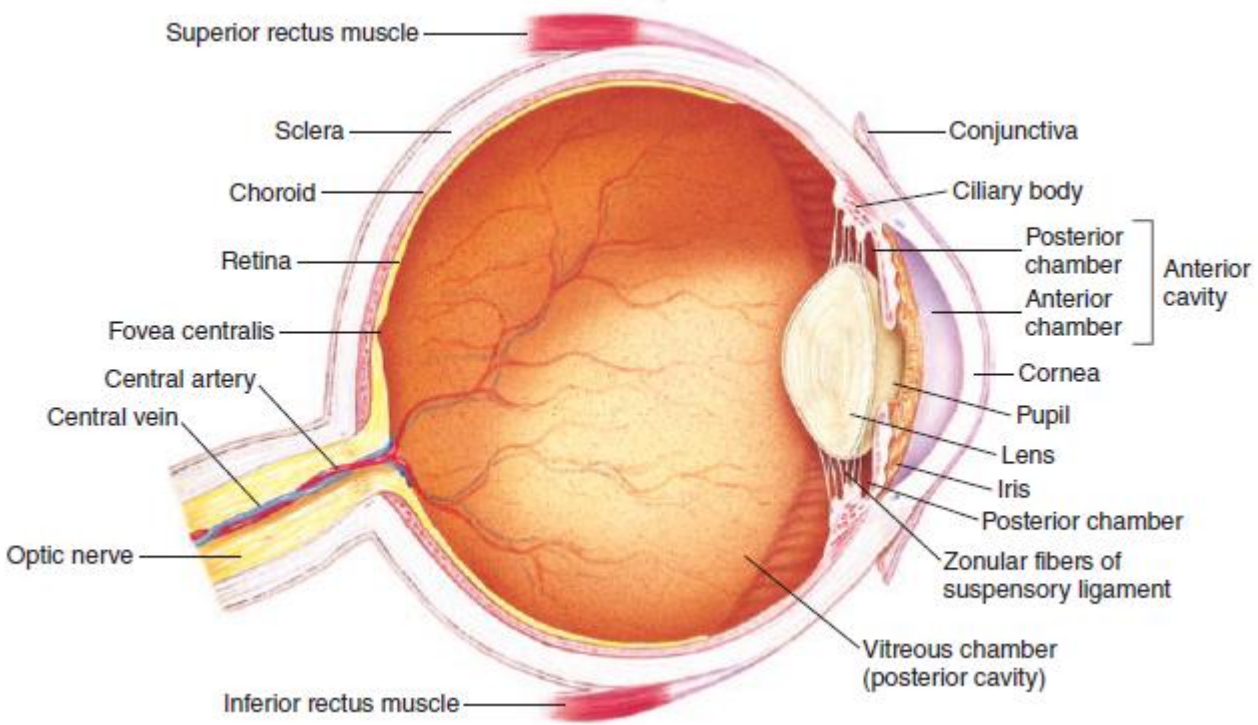
MOTOR

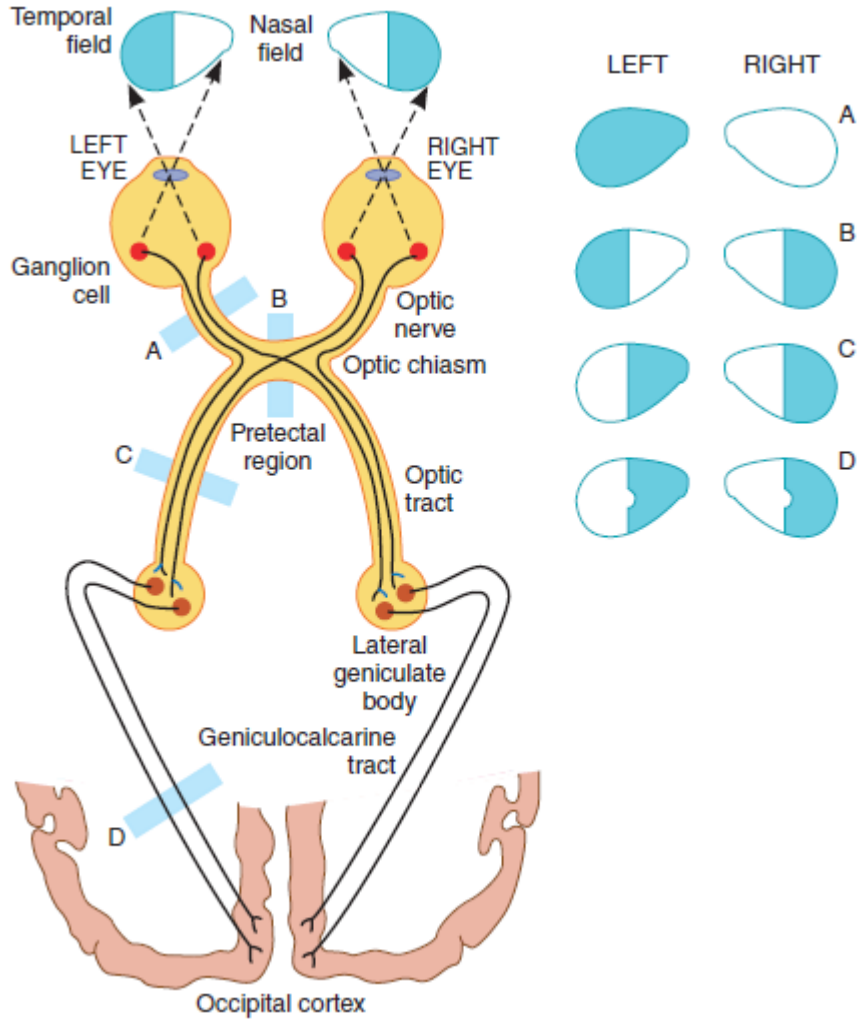


SENSORY

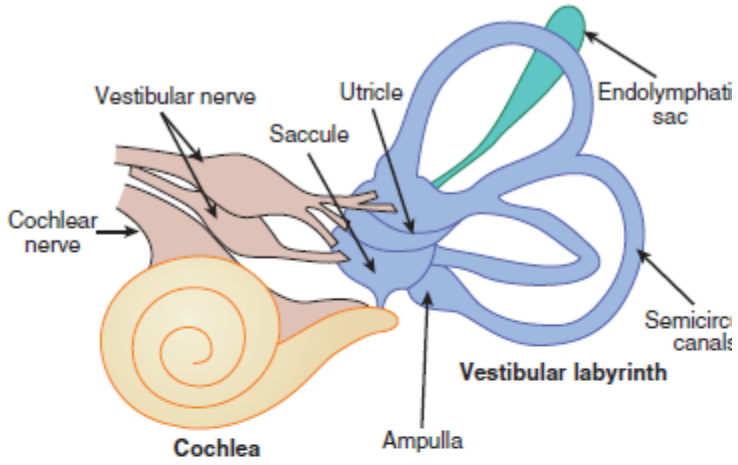


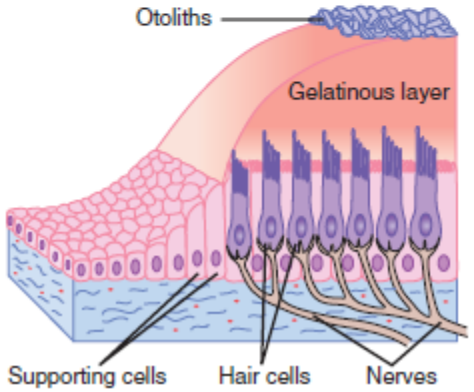
VISION

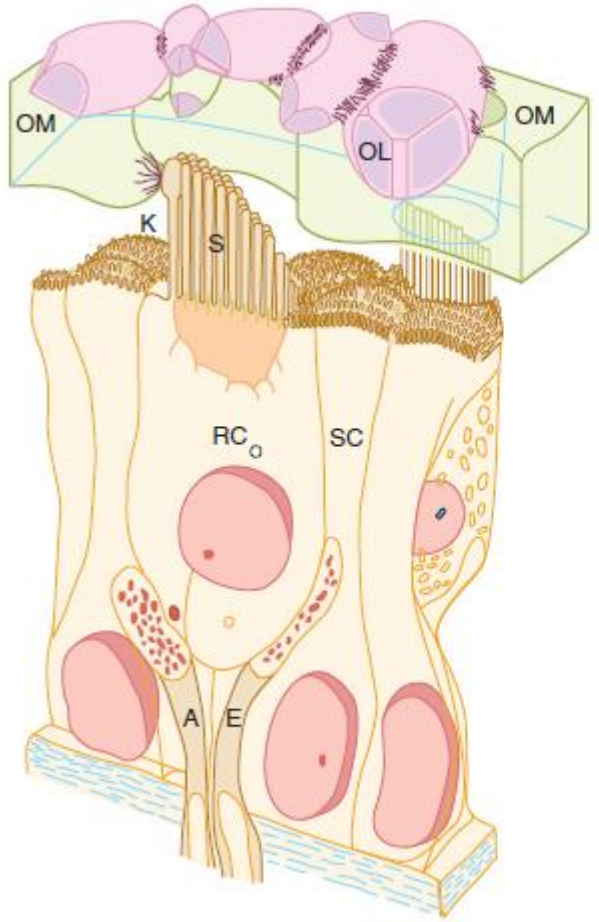

Superior rectus muscle
Sclera
Choroid
Retina
Fovea centralis
Central artery
Central vein
Optic nerve
Inferior rectus muscle
Conjunctiva
Ciliary body
Posterior chamber
Anterior chamber
Anterior cavity
Cornea
Pupil
Lens
Iris
Posterior chamber
Zonular fibers of suspensory ligament
Vitreous chamber (posterior cavity)

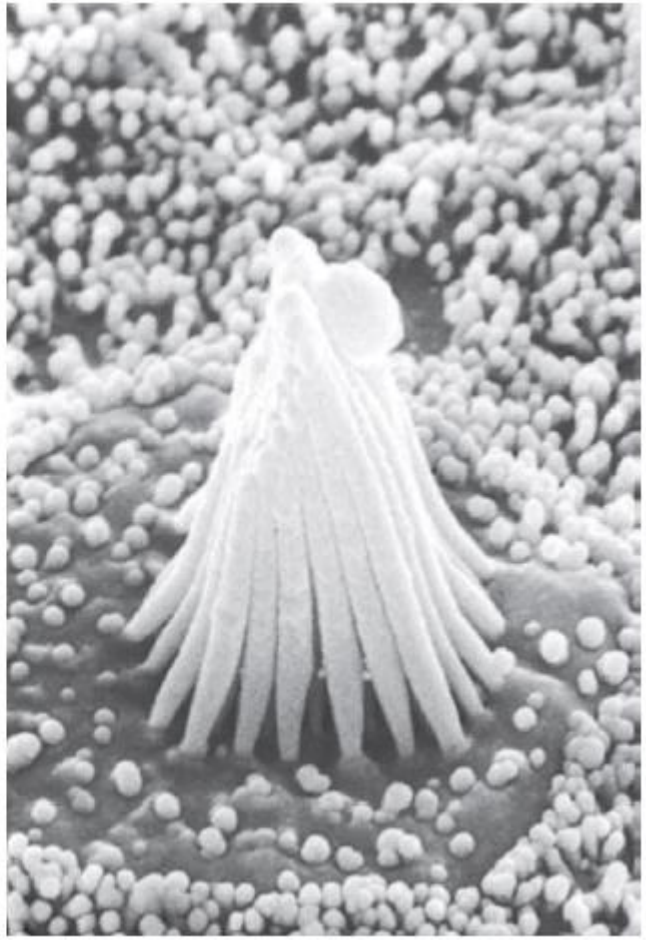

Temporal field
Nasal field
LEFT EYE
RIGHT EYE
Ganglion cell
A
B
C
D
Optic nerve
Optic chiasm
Pretectal region
Optic tract
Lateral geniculate body
Geniculocalcarine tract
Occipital cortex
LEFT
RIGHT
A
B
C
D

HEARING + BALANCE









Q- The firing of motoneurons

T 1: can be inhibited by nerve terminals which release glycine

T 2: can be inhibited by nerve terminals which release gamma-aminobutyric acid

T 3: is subject to supraspinal control

T 4: is subject to negative feed-back control by means of Renshaw cells

Q - Below a hemisection of the spinal cord

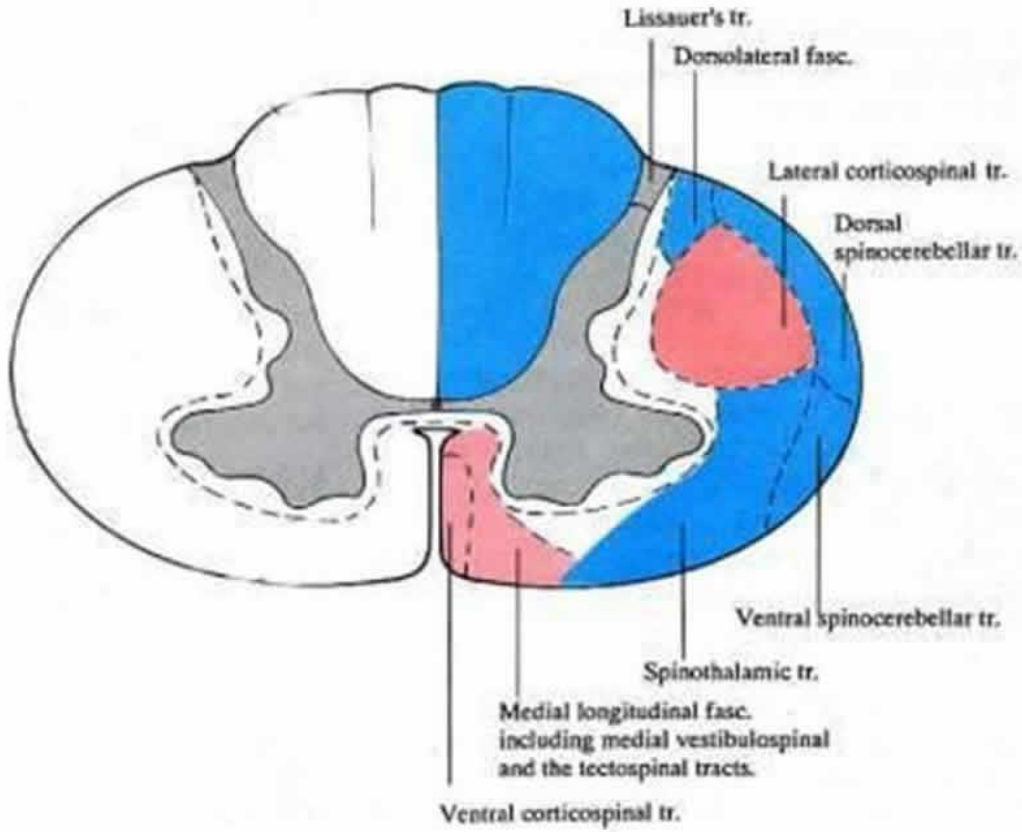
T 1: paralysis is ipsilateral

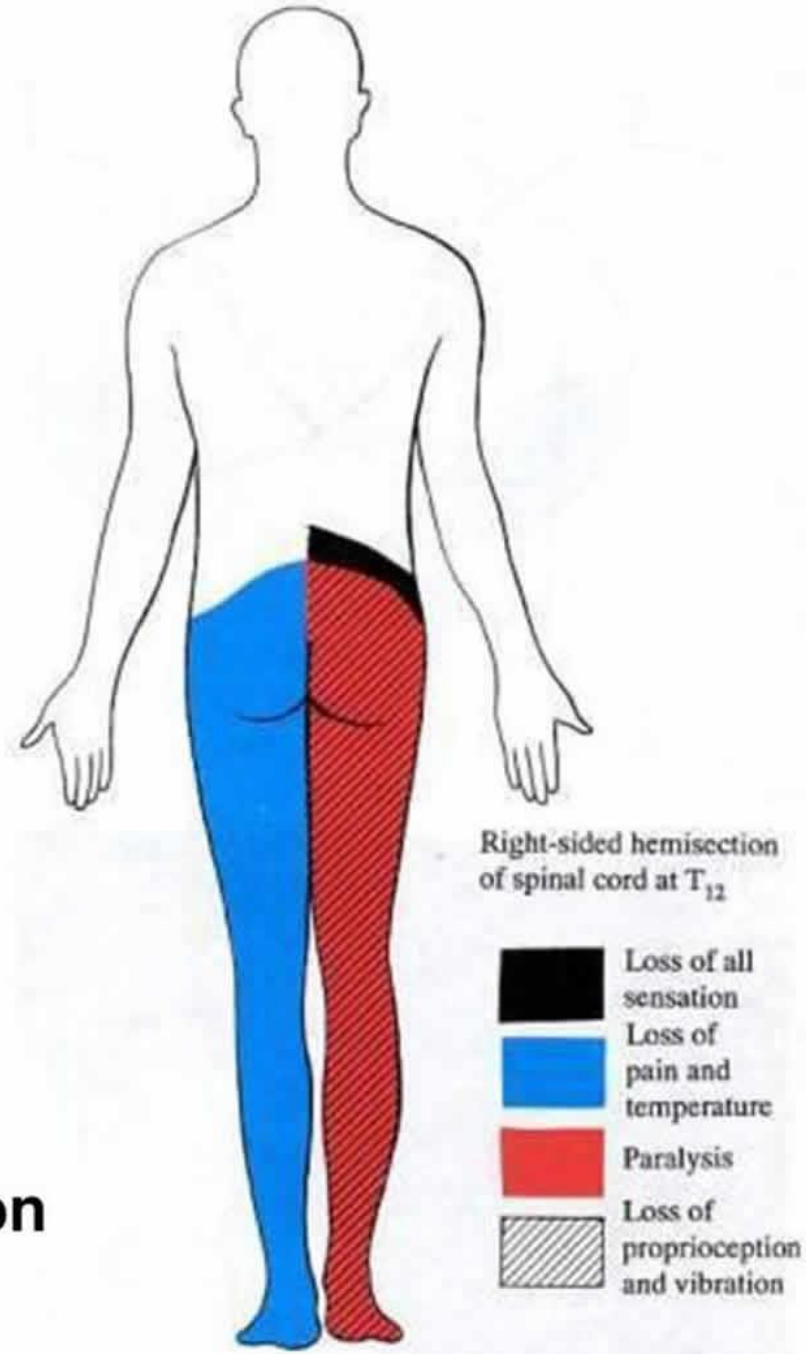
T 2: loss of proprioception and vibration sense is ipsilateral

T 3: analgesia is contralateral

F 4: thermal anaesthesia is ipsilateral

Brown-Sequard Syndrome





Right-sided Hemisection of spinal cord at T12.