Muscular-Skeletal Systems and Locomotion

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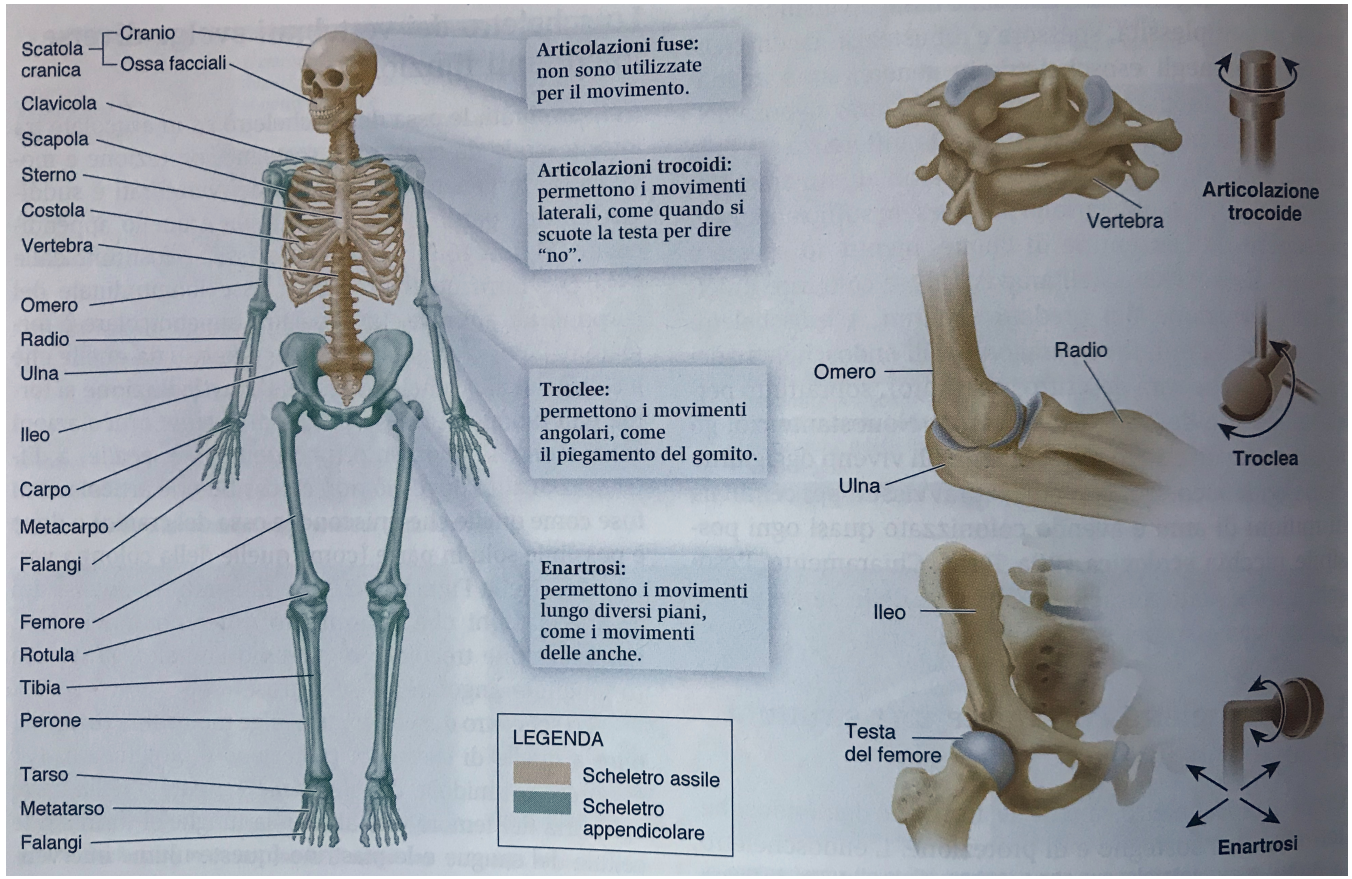
The vertebrate skeleton

Two parts

- **Axial skeleton** – main longitudinal axis
- **Appendicular skeleton** – limb bones and girdles

Joint – formed where two or more bones come together

- Three types that allow movement
  - **Pivot joints**
  - **Hinge joints**
  - **Ball-and-socket joint**
- Others do not
  - **Fused joints** (i.e. skull)



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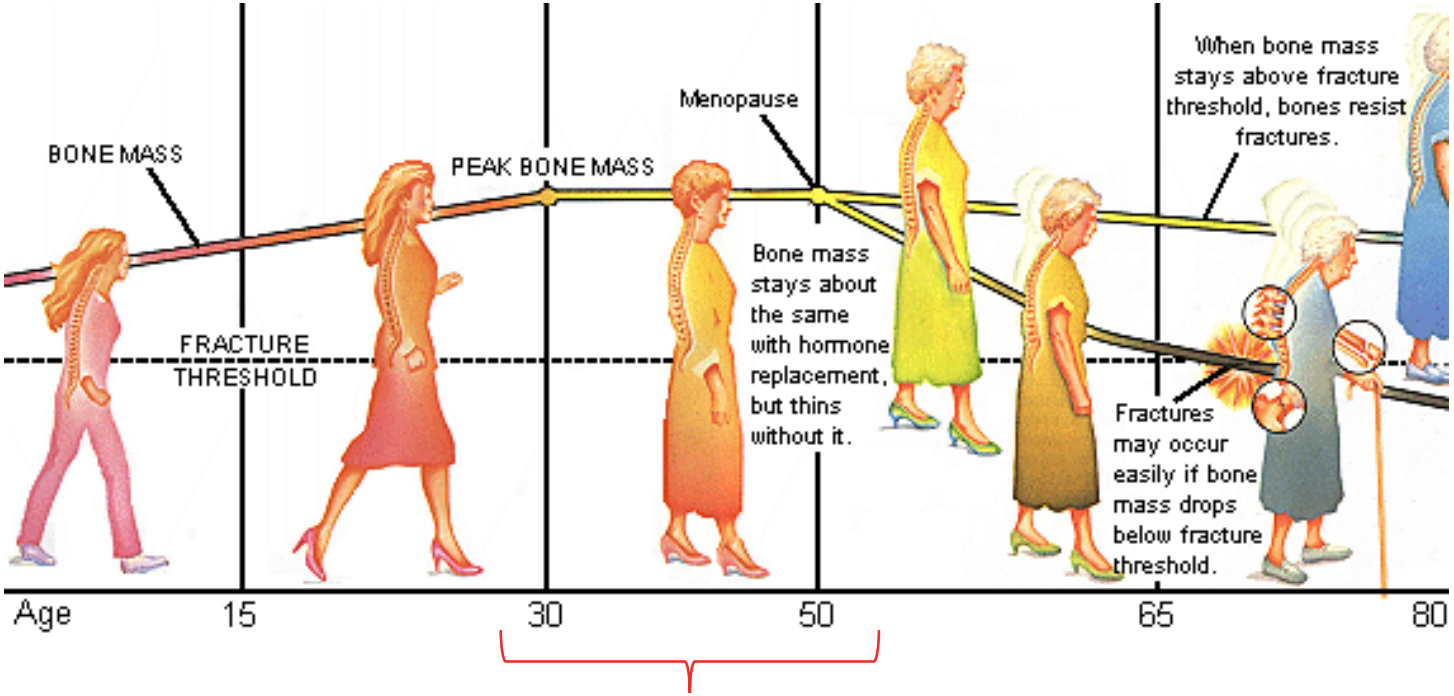
Bone remodeling

- Bone mass is changing during life



Is not static

- **Bones are continuously remodeling** at discrete sites also in absence of injuries

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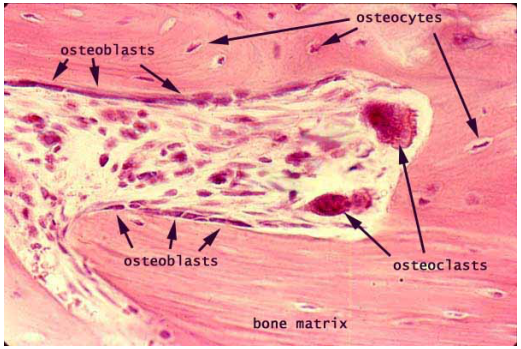
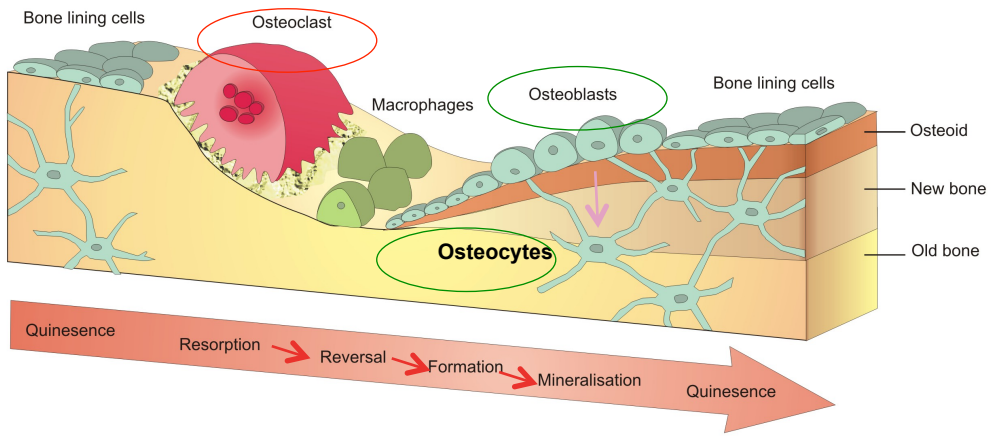
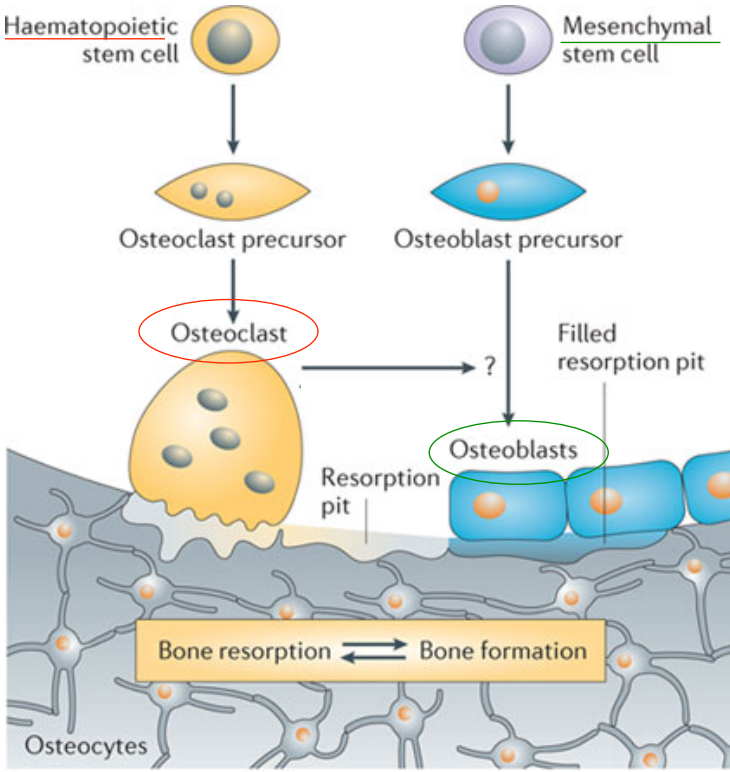
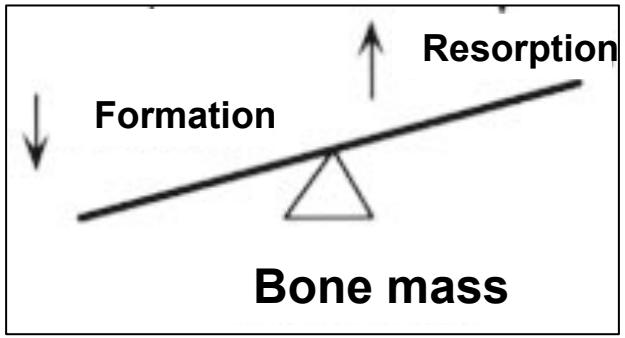
Bone remodeling: the actors







The bone remodelling process.
Bone is continuously remodelled at discrete sites in the skeleton in order to maintain the integrity of the tissue. During this process, old bone is resorbed by osteoclasts and replaced with new osteoid, secreted by osteoblasts. First osteoclasts are activated, and the resorption phase takes approximately 10 days. Following resorption, unclassified macrophage-like cells are found at the remodelling site in the intermediate, or reversal phase. Osteoblast precursors are then recruited , which proliferate and differentiate into mature osteoblasts, before secreting new bone matrix. The matrix then mineralises to generate new bone and this completes the remodelling process. Copyright BTR©



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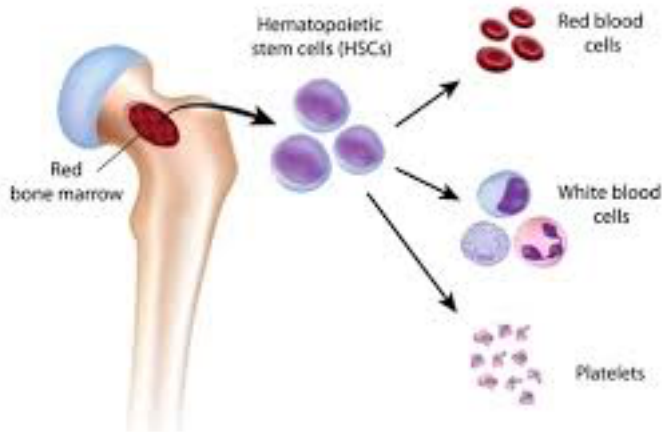
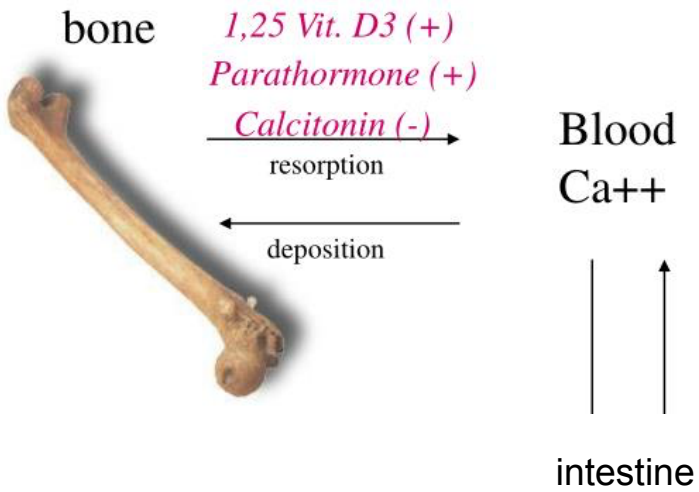
Additional functions of the skeleton

- **Blood cells and platelets** are formed in **bone marrow**

- Ca^{2+} **and** PO_4^{2-} homeostasis achieved in large part through **exchanges between bone and blood**





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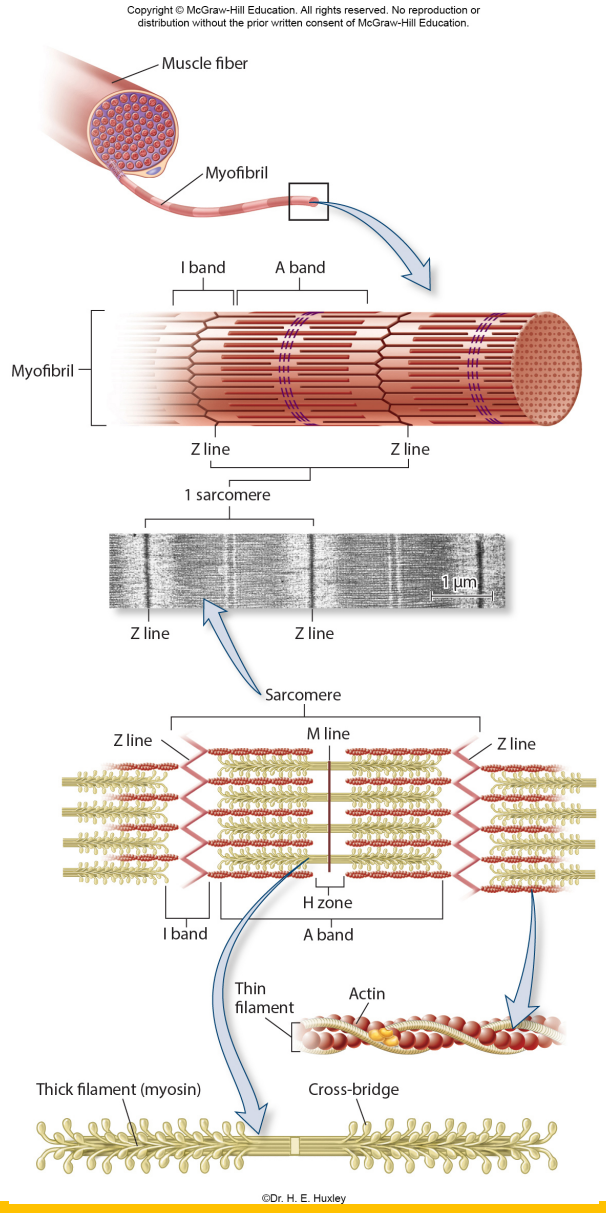
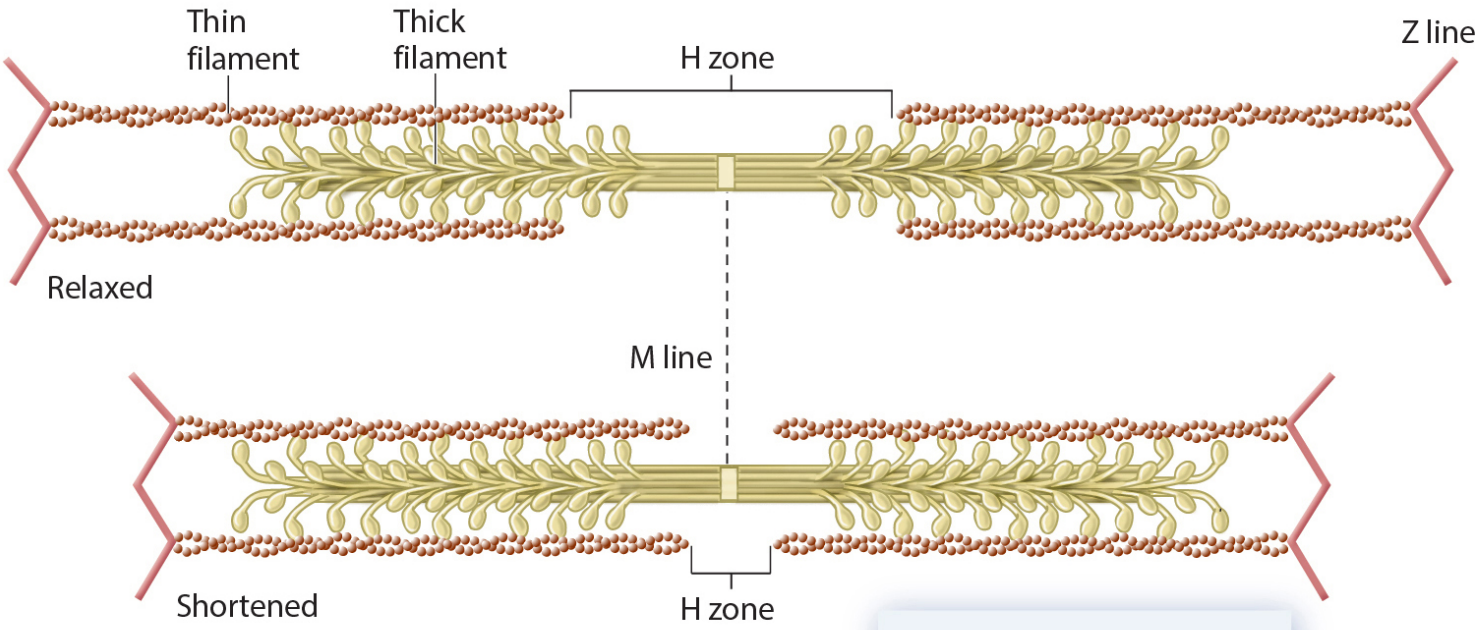
Muscle fibers: contracting apparatus

- **Myofibrils** – cylindrical bundles in muscle fibers
- Each myofibril contains repeating units of filaments (**sarcomeres**)
  - **Thick filaments** – made of **myosin**
  - **Thin filaments** – made of **actin and other proteins**



Sliding filament mechanism

- **Sarcomeres shorten** as **thin filaments slide** past stationary thick filaments
- **Myosin cross-bridges** attach to thin filament and force thin filament toward center of sarcomere
- Cross-bridge **repeats motion** as long as stimulation to contract continues



Successive movements of cross-bridges pull the thin filaments toward the M line.

b) Sliding filament mechanism

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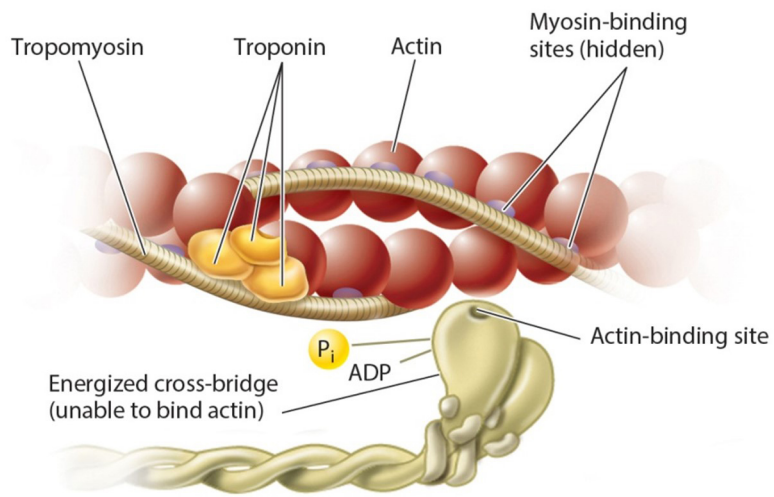
Calcium initiate the process

Tropomyosin

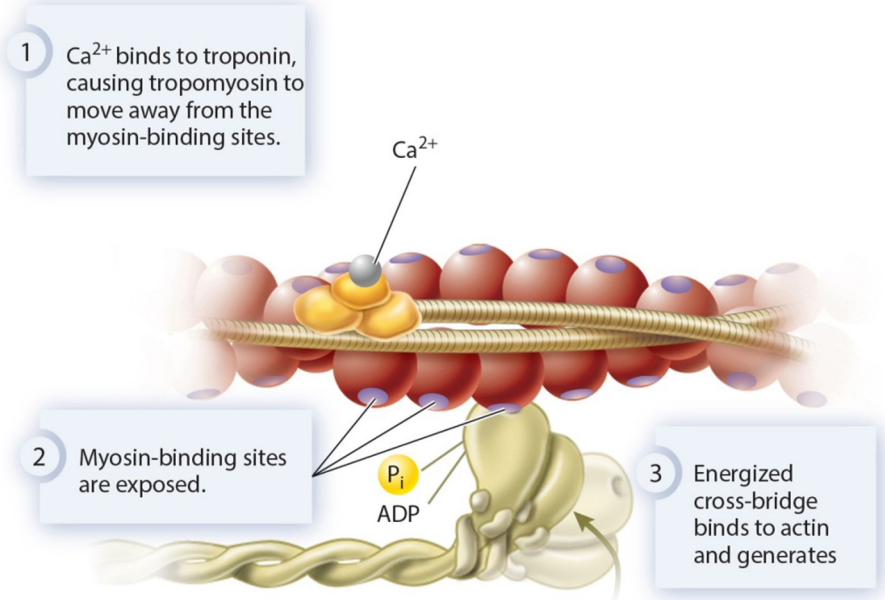
- Composed of two intertwined proteins
- Arranged along length of actin thin filament
- In absence of Ca^{2+}, **covers myosin-binding sites on actin** and prevents cross-bridges' contact with actin

Troponin

- Smaller protein bound to both tropomyosin and actin
- **Binds** Ca^{2+} and **moves tropomyosin off** of **myosin-binding site on actin** – permits cross-bridge cycling to occur
- Removal of Ca^{2+} reverses the process contraction stops



a) Low cytosolic Ca^{2+}, relaxed muscle



b) High cytosolic Ca^{2+}, activated muscle

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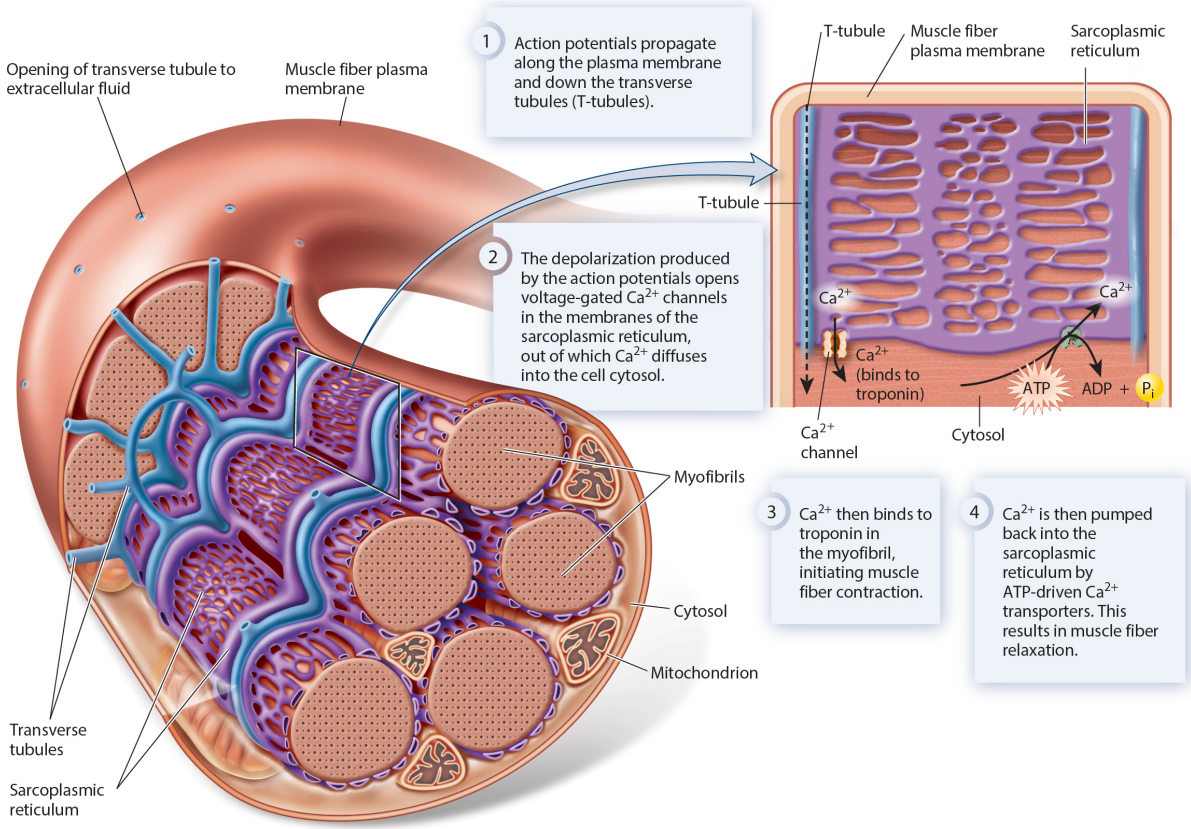
Excitation-contraction coupling

Muscle fibers are capable of propagating **action potentials**

Causes rise in cytosolic Ca^{2+} released from **sarcoplasmic reticulum**

- Transverse or **T-tubules are invaginations of plasma membrane** that **conduct the action potential from the outer surface** of muscle fiber to sarcoplasmic reticulum
- Depolarization **opens sarcoplasmic reticulum Ca channels**
- **Rise of cytoplasmic Ca** triggers contraction
- **Ion pumps return calcium** to the **sarcoplasmic reticulum**, resulting in muscle relaxation



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Neuromuscular junction

- Junction of motor neuron's axon and muscle fiber
- **Axon terminals** containing vesicles of **acetylcholine**
- **ACh receptor on muscle fibers is ligand-gated ion channel**
- Na^+ **flows into muscle cell** leading to depolarization and action potential propagation to T-tubules
- Overstimulation of muscle fiber prevented by **acetylcholinesterase**

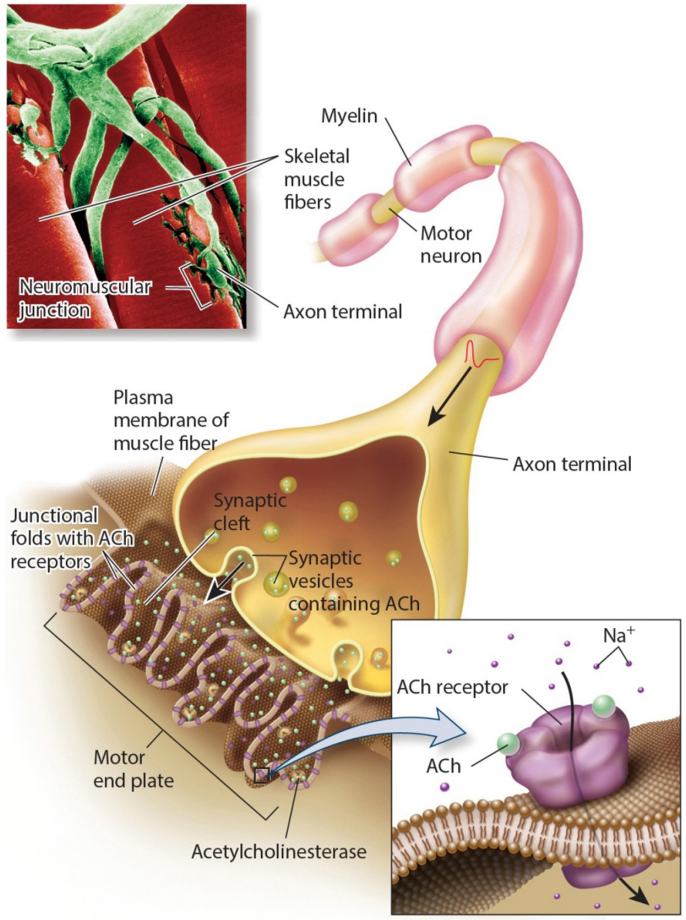

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Table 45.1

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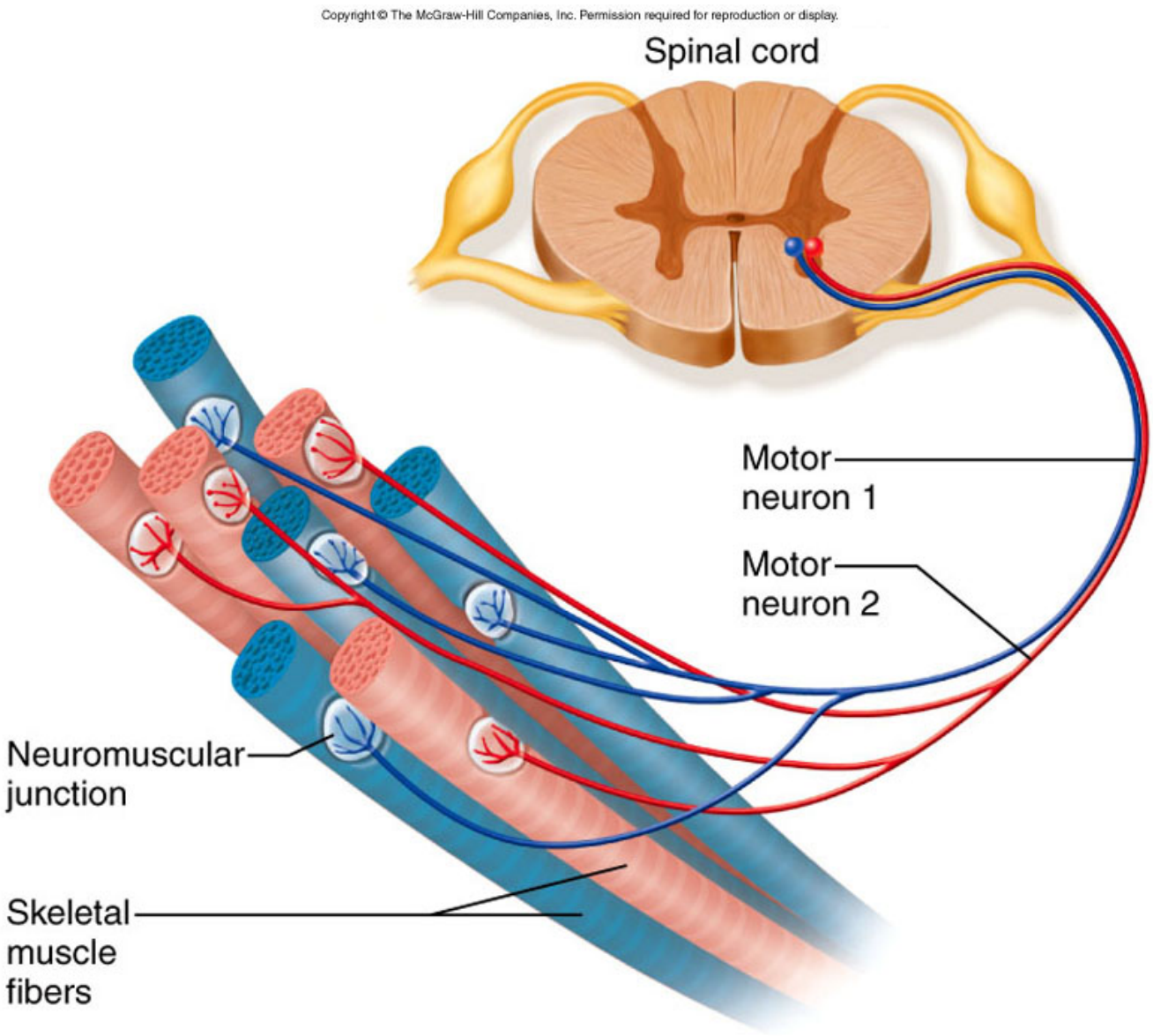
Table 45.1 Characteristics of the Three Types of Skeletal Muscle Fibers

	Slow-oxidative	Fast-oxidative	Fast-glycolytic
Primary source of ATP production	Oxidative phosphorylation	Oxidative phosphorylation	Glycolysis
Mitochondria	Many	Many	Few
Blood supply	High	High	Moderate
Myoglobin content	High (red)	High (red)	Low (white)
Rate of fatigue	Slow	Intermediate	Fast
Myosin ATPase activity	Low	High	High
Rate of contraction	Slow	Fast	Fast

Motor units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Spinal cord
Motor neuron 1
Motor neuron 2
Neuromuscular junction
Skeletal muscle fibers

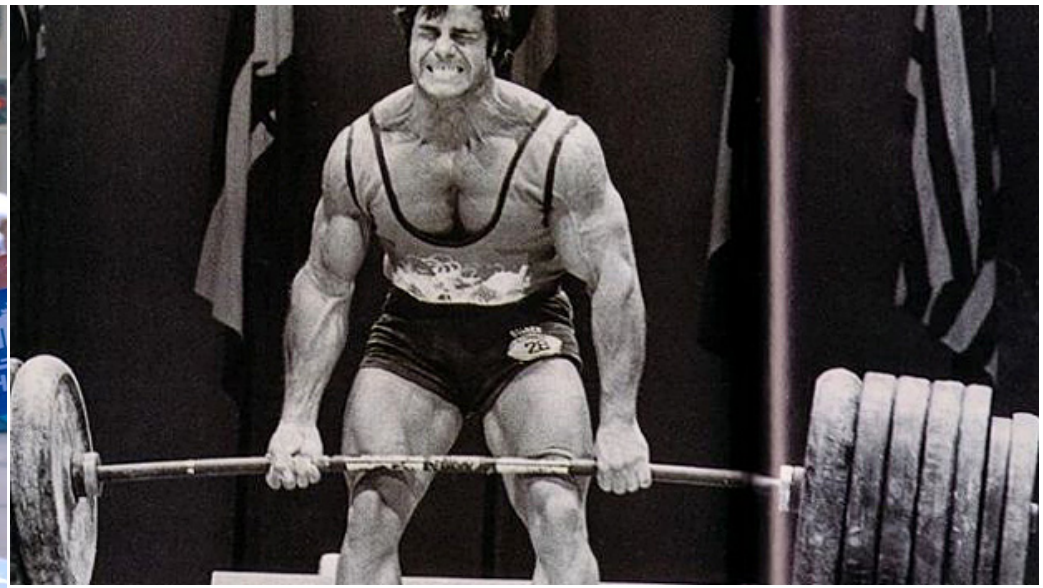
Exercise

Increased amounts of exercise can produce an **increase in the size of muscle fibers** and their capacity for ATP production

Adaptive response depends **on type of exercise**:

- **Aerobic exercise** increases **number of mitochondria** and **blood vessels** surrounding fibers

Resistance/strength exercise increases **size of fibers**



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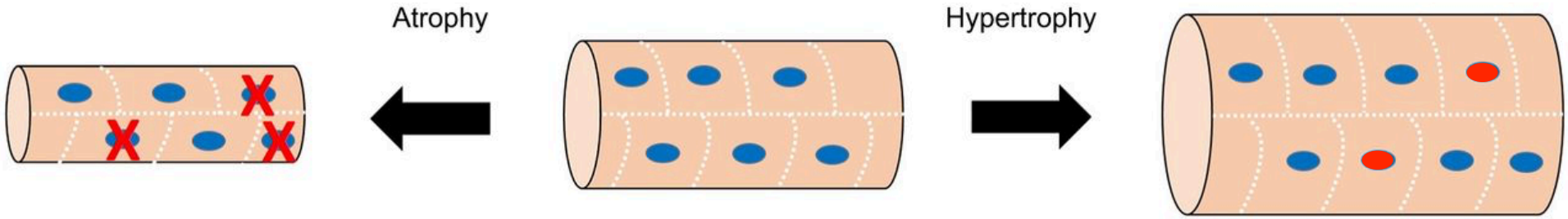
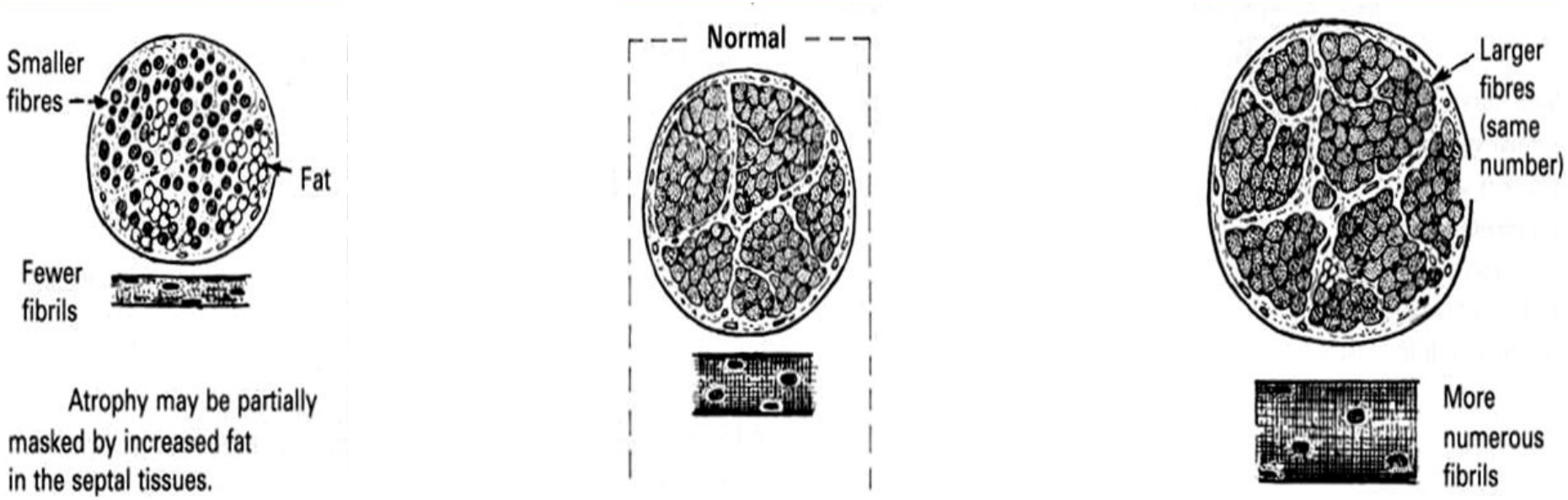
Skeletal muscle remodeling



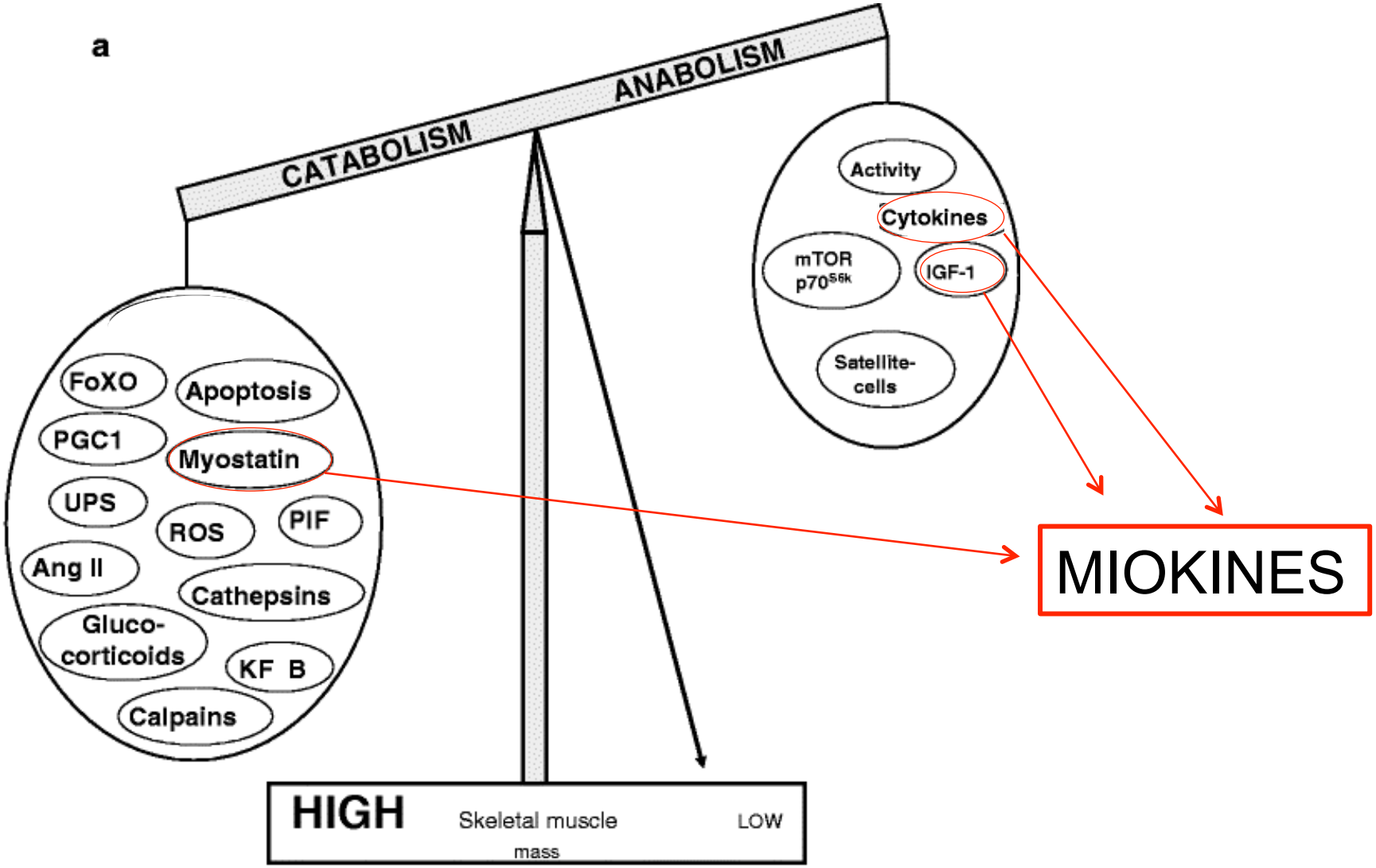
Reilly 2016

- Loss of myonuclei (apoptosis)
- Myofibre CSA ↓
- Myofibrillar proteins ↓

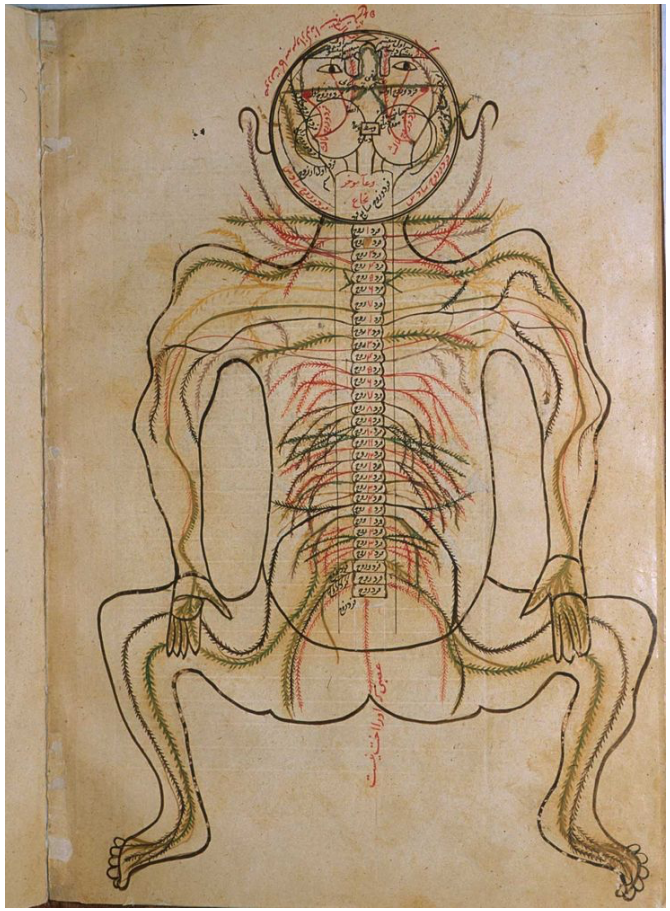
- Addition of myonuclei
- Myofibre CSA ↑
- Myofibrillar proteins ↑



Myokines modulate catabolism and anabolism



Peripheral Nervous System (PNS)
and
Autonomic nervous system (ANS)



Anatomical illustration of the nervous system
by Mansour Ibn-Ilyas, ca. 1400

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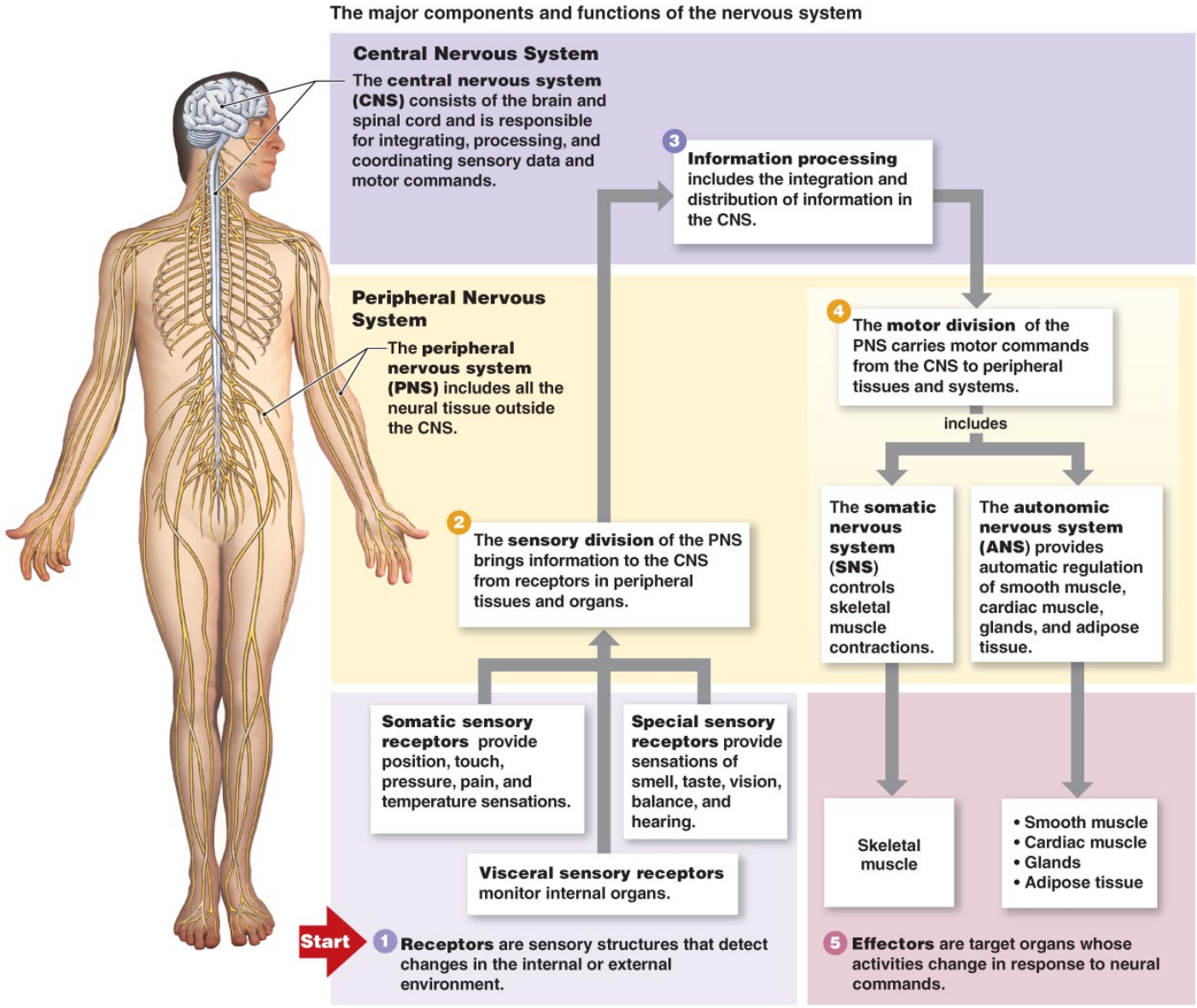
Sensory and Motor/Effector Divisions of the PNS



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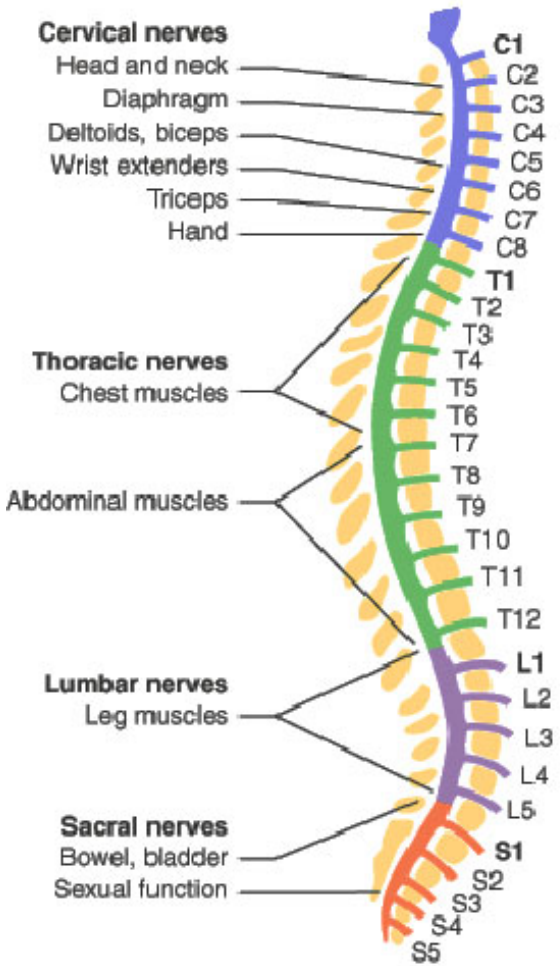
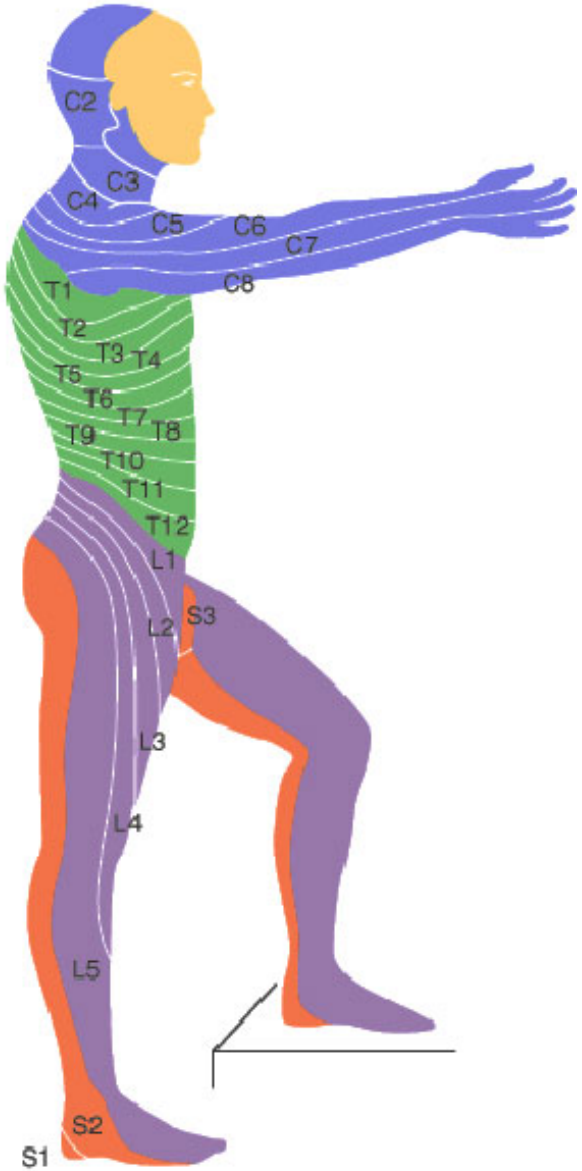
Segmental distribution of Spinal Innervation

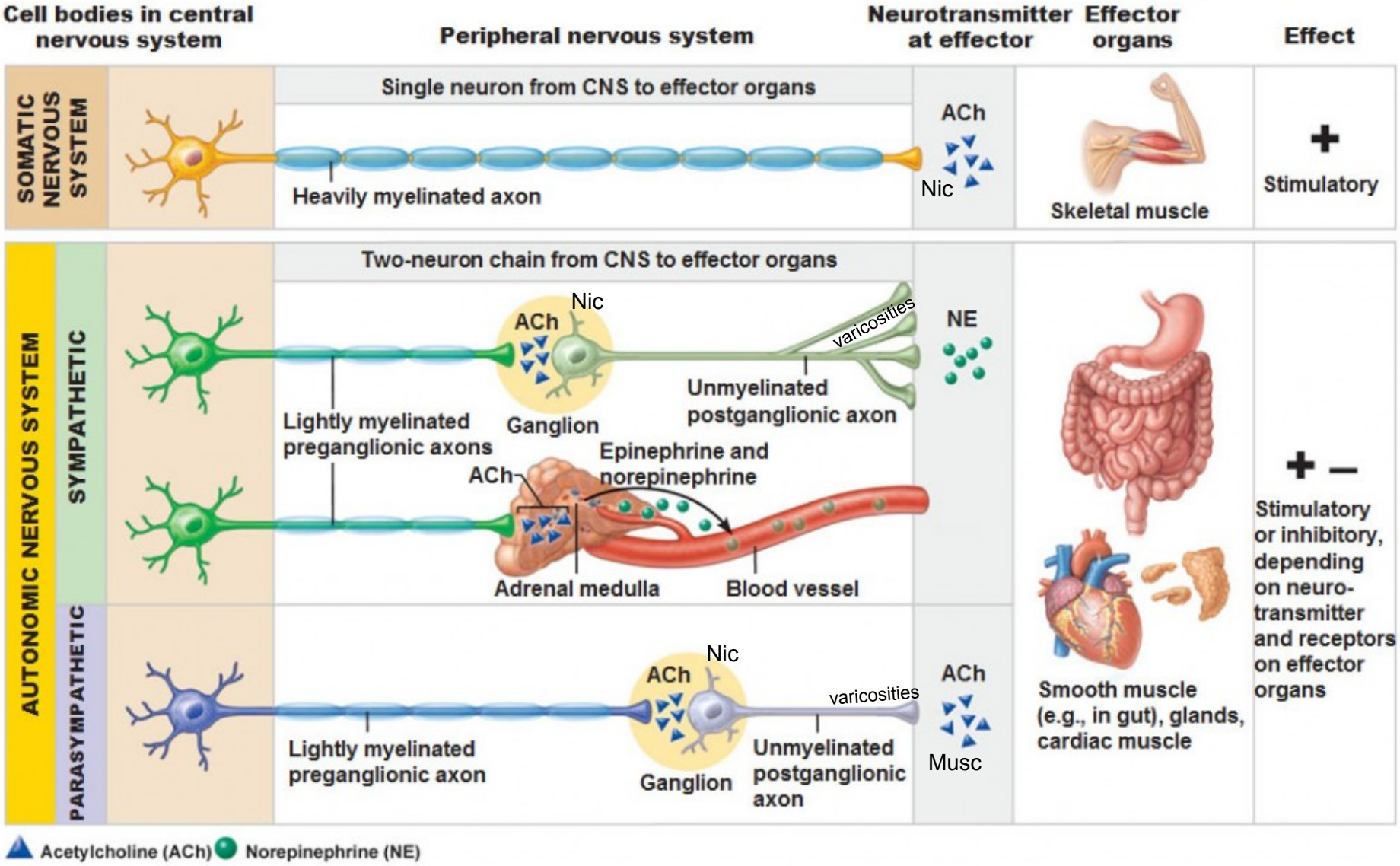
Dermatome is the **strip of skin** supplied by an **individual spinal nerve**

Borders are not sharp: **successive nerves partially overlap in the same segments**





Comparison of Autonomic and Somatic Motor System



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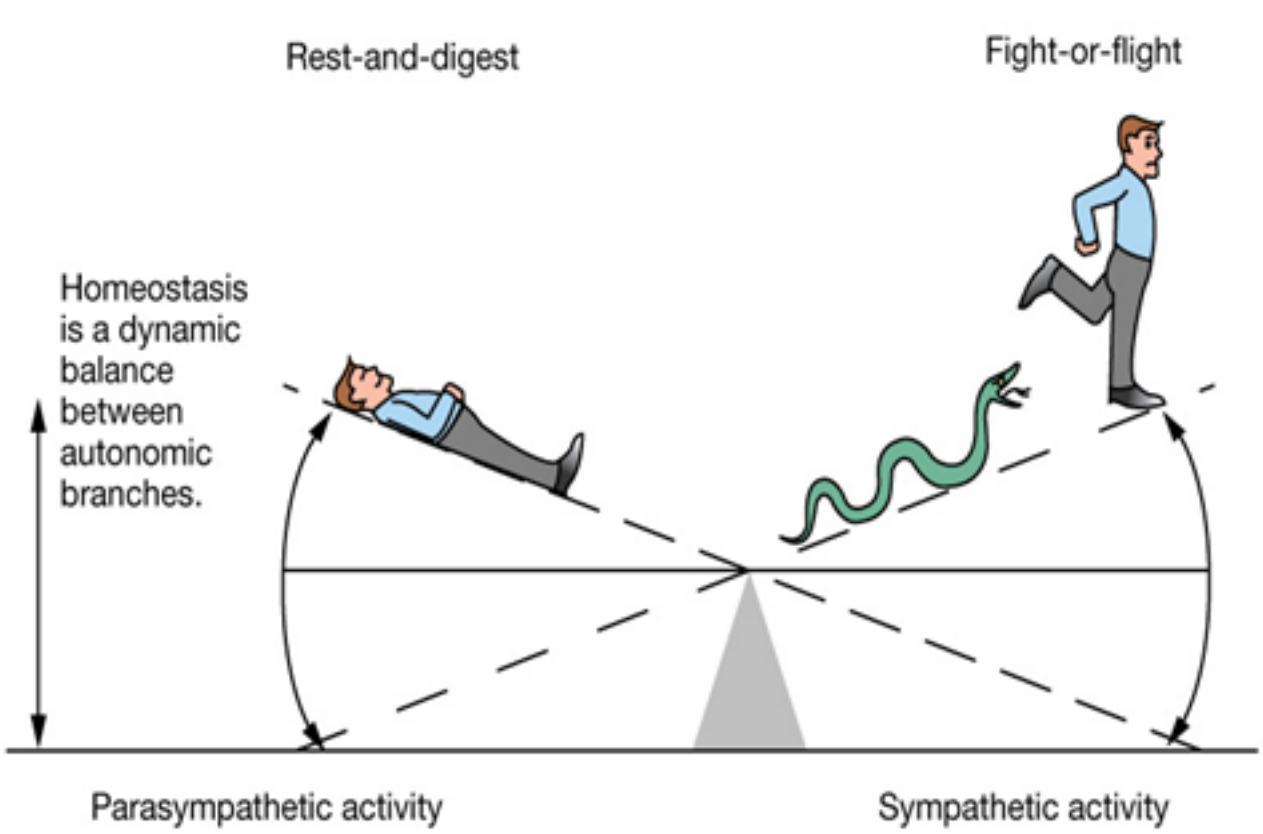
Fight-or-Flight response and Homeostasis

A different contribution from the different components is required when the **homeostasis** of the organism is **challenged** by **external factors** or **functional demand**

Also the fight-or-flight response **may be seen** as related to **homeostasis**