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International Programme

MUSCULO SKELETAL

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Departemen Fisiologi FK-KMK UGM

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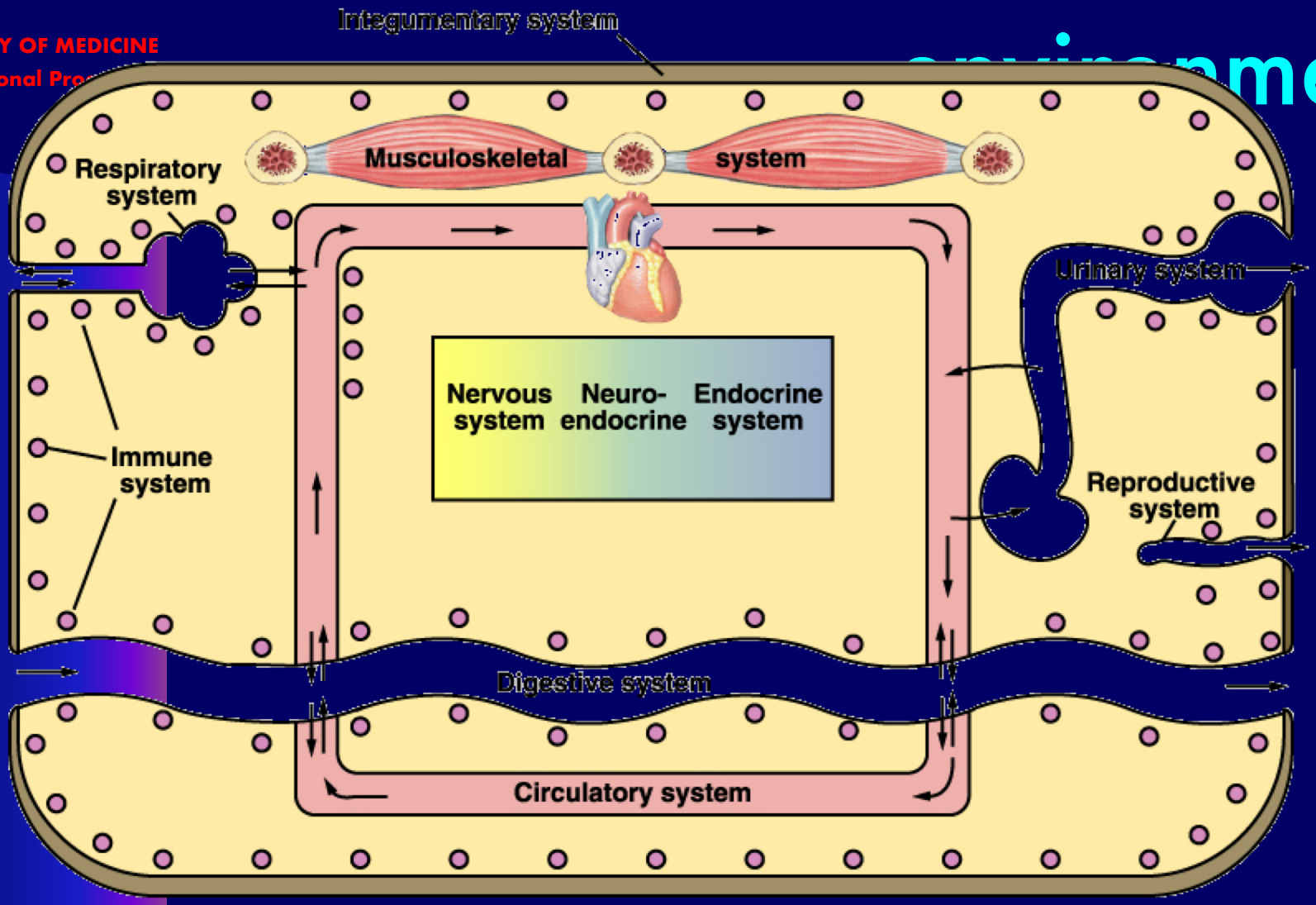
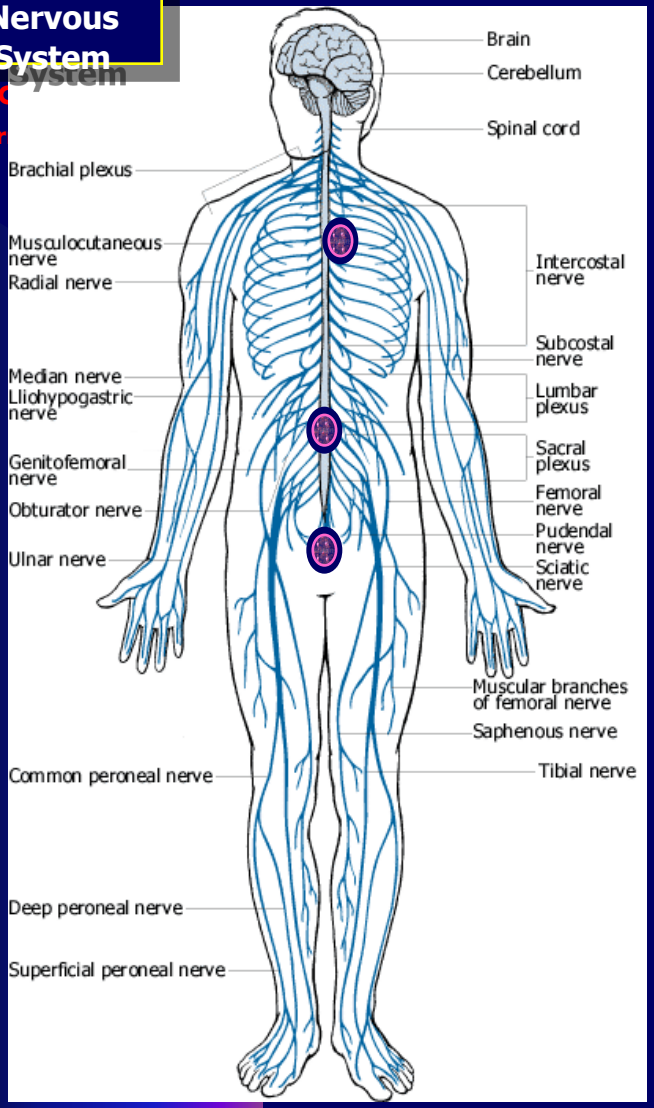
External to Internal environment



..a hint of integration?

The Human Nervous System

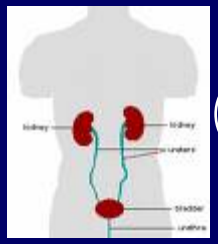
Central Nervous System



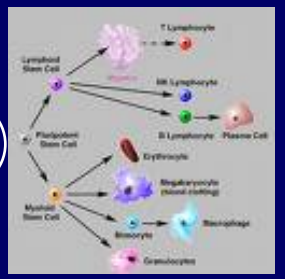
Cardiovascular system

Autonomic Nervous System

Urogenital tract



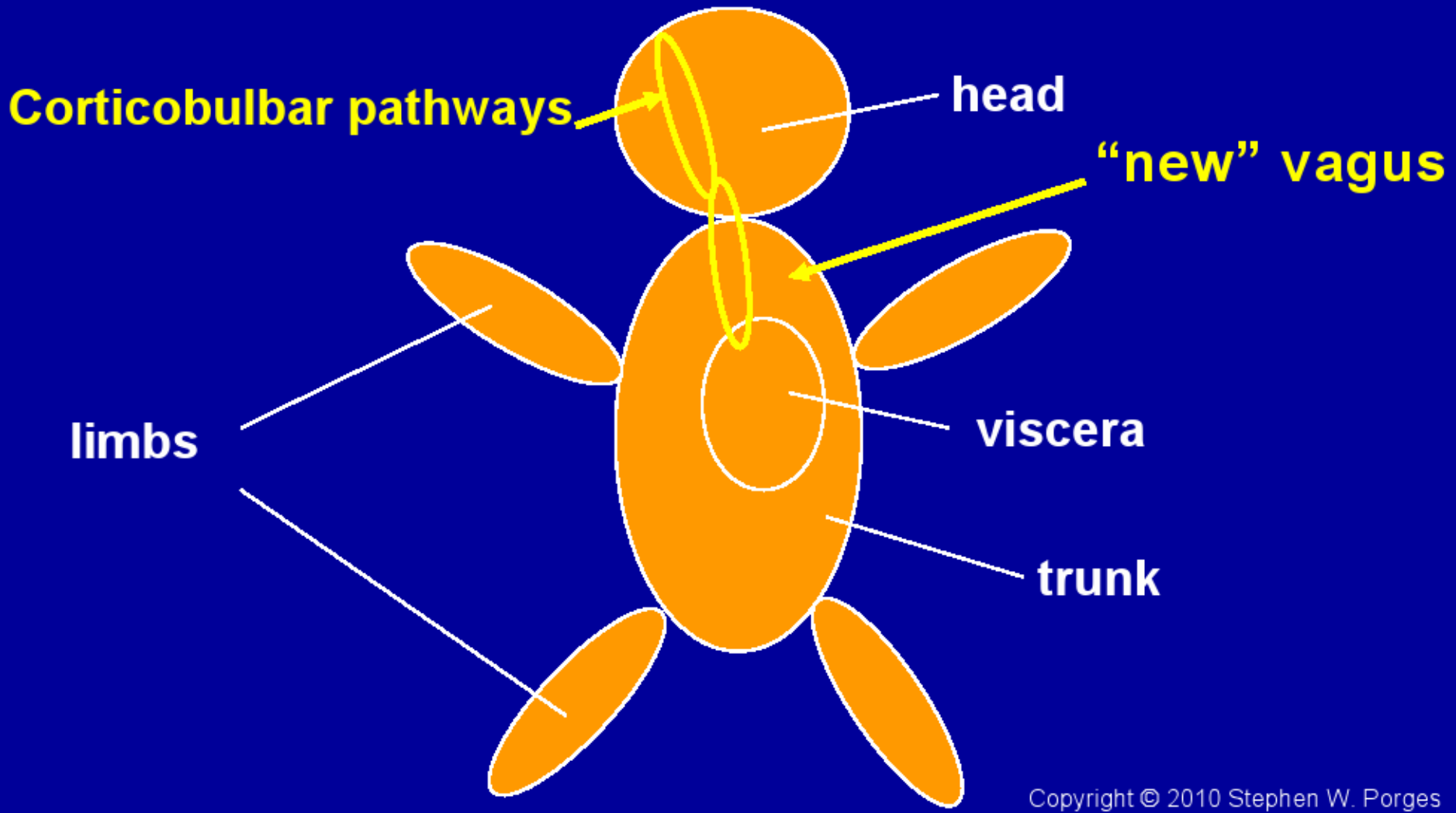
Immune system



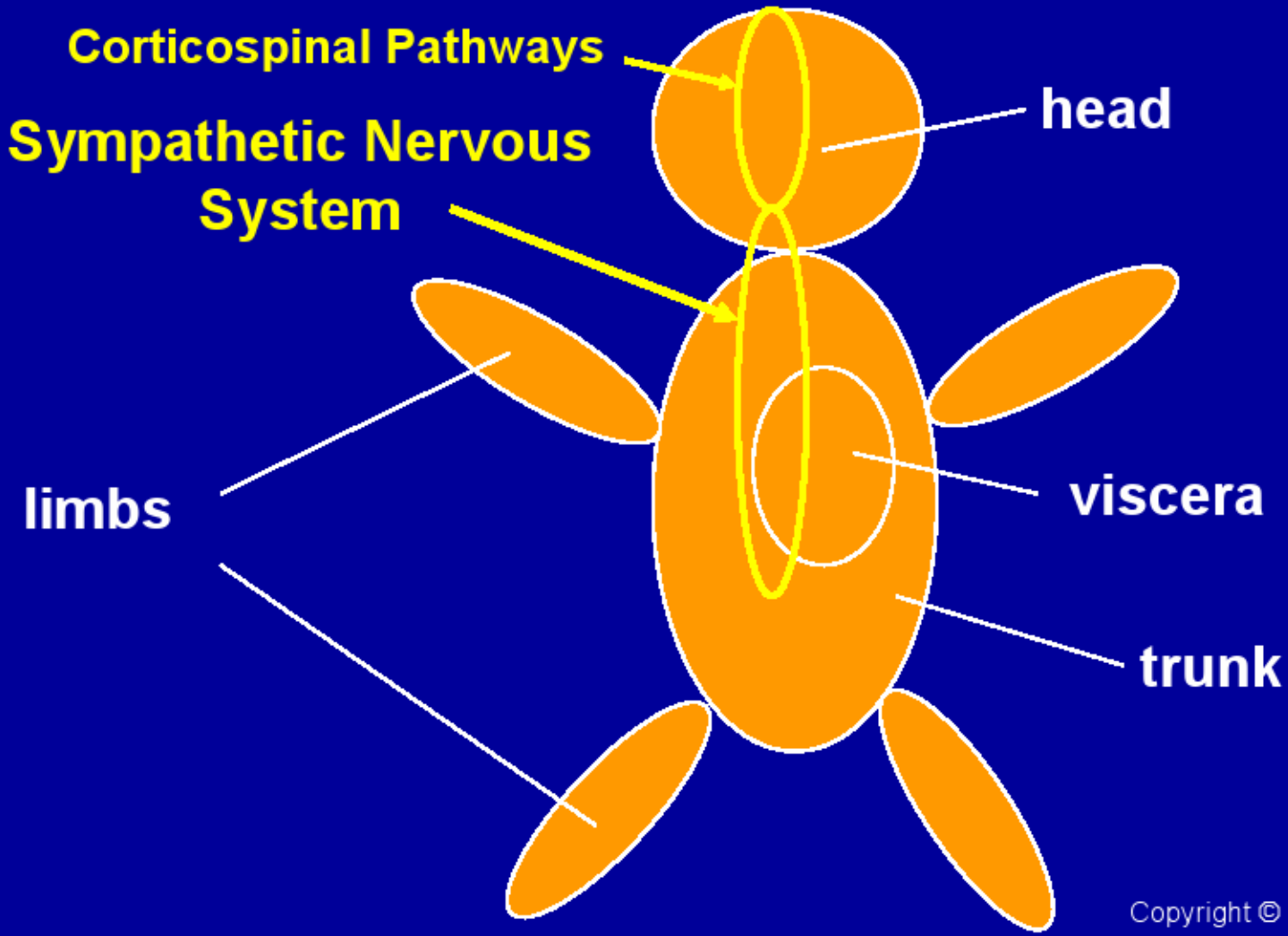
Homeostasis

Gastrointestinal tract

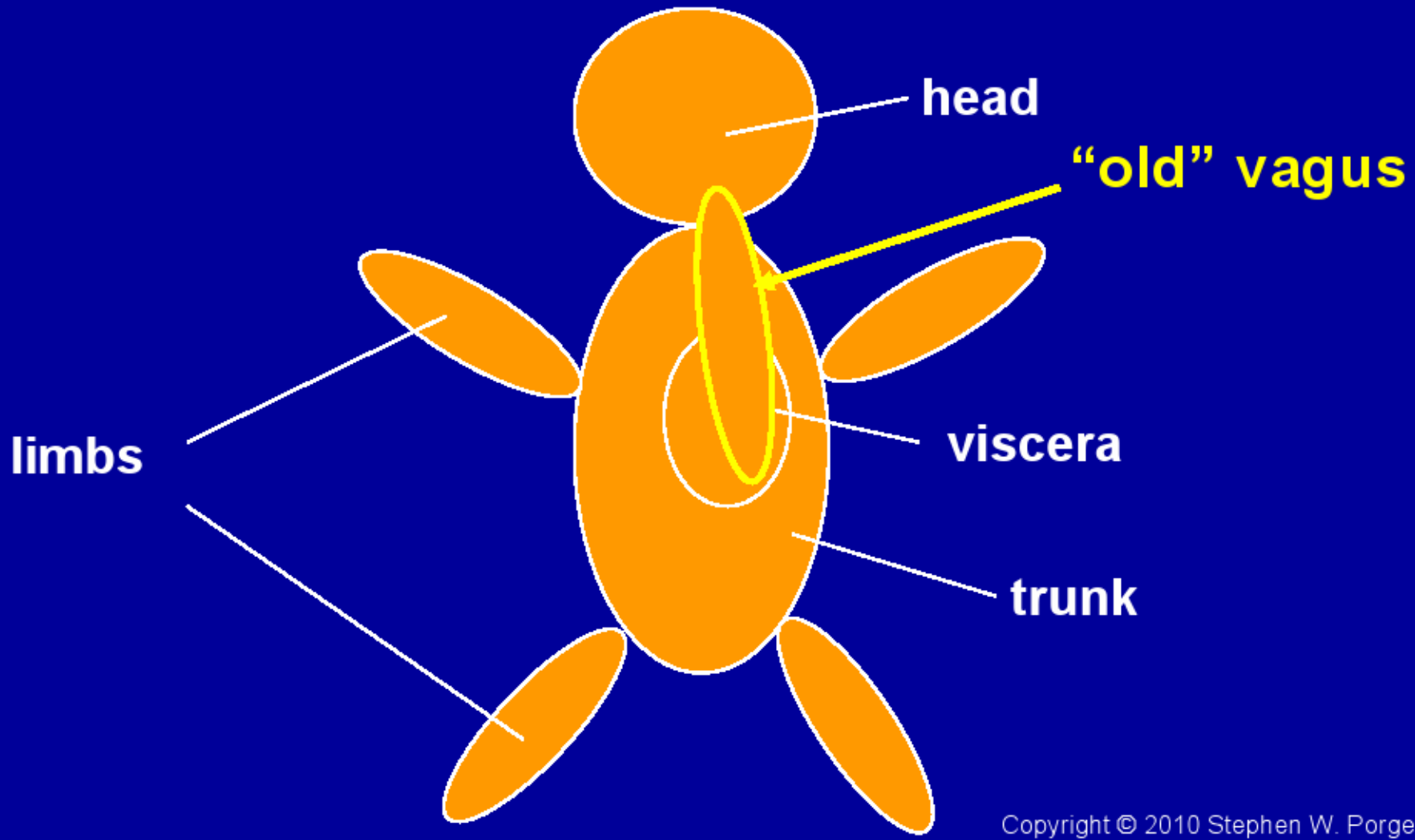
Phylogenetic Organization of the ANS: The Polyvagal Theory



Phylogenetic Organization of the ANS: The Polyvagal Theory



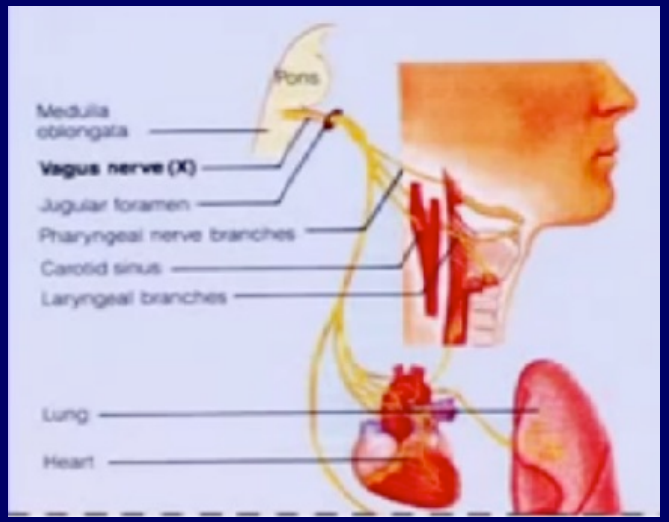
Phylogenetic Organization of the ANS: The Polyvagal Theory



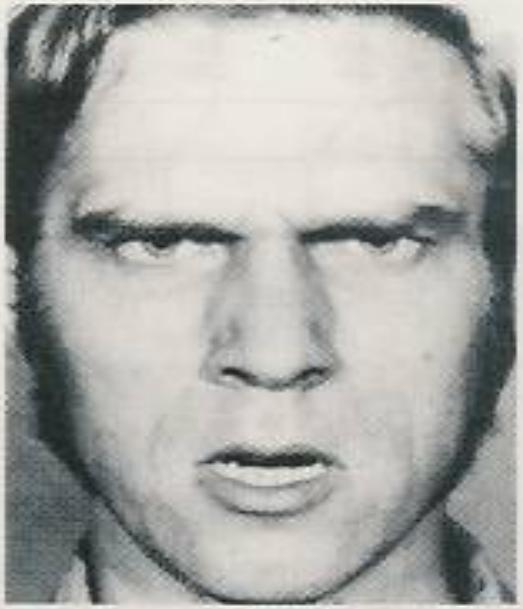
Supra-diaphragmatic vagus

↓

SNS, HPA (stress) Axis

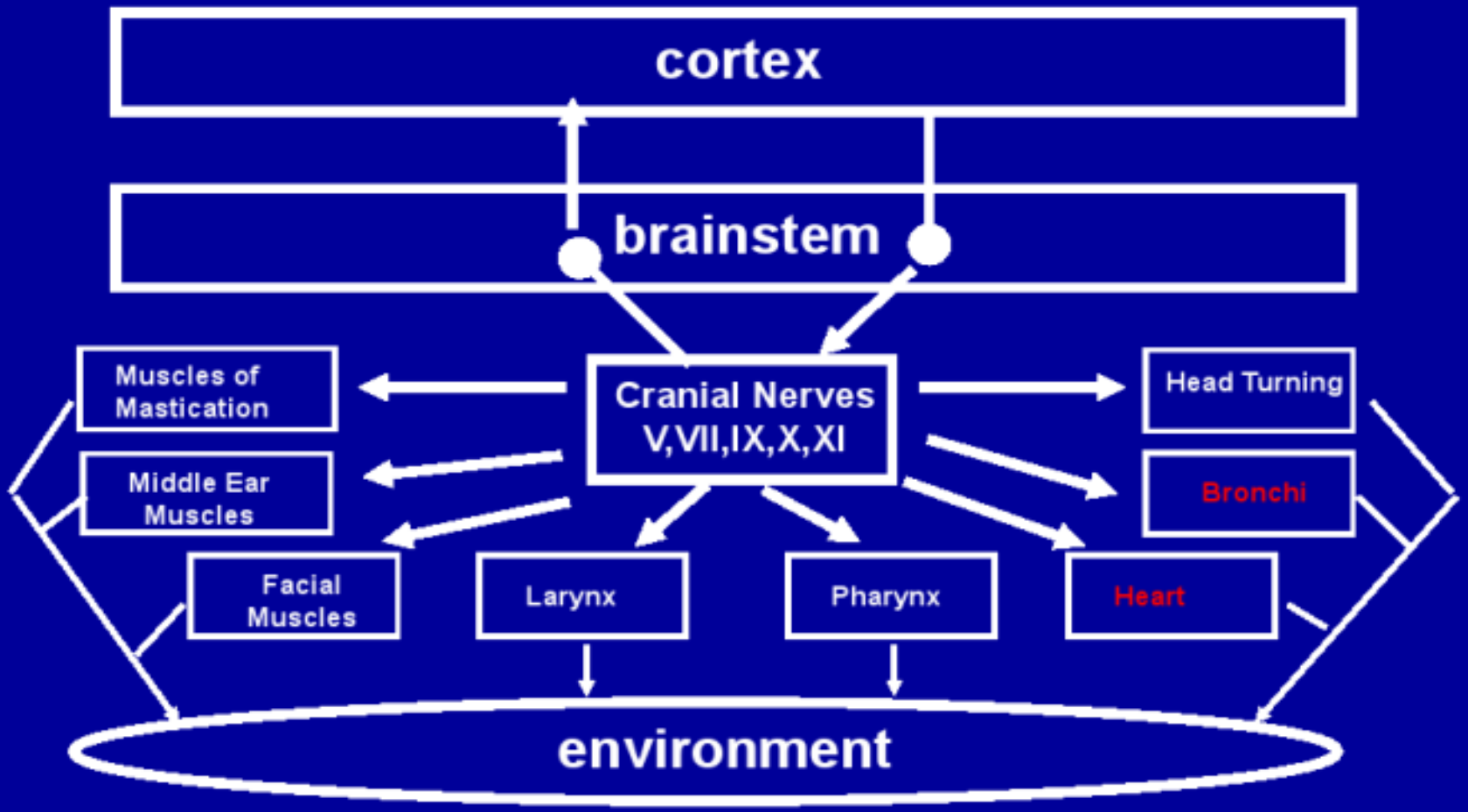


Sympathetic | Parasympathetic



The "*Mammalian*" Vagus and Social Engagement System



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Objective

- **Be able to describe the relevant cellular structures involved in muscle contraction and the events that occur at the cellular level during the production of force by filament interaction**

Control of Contraction

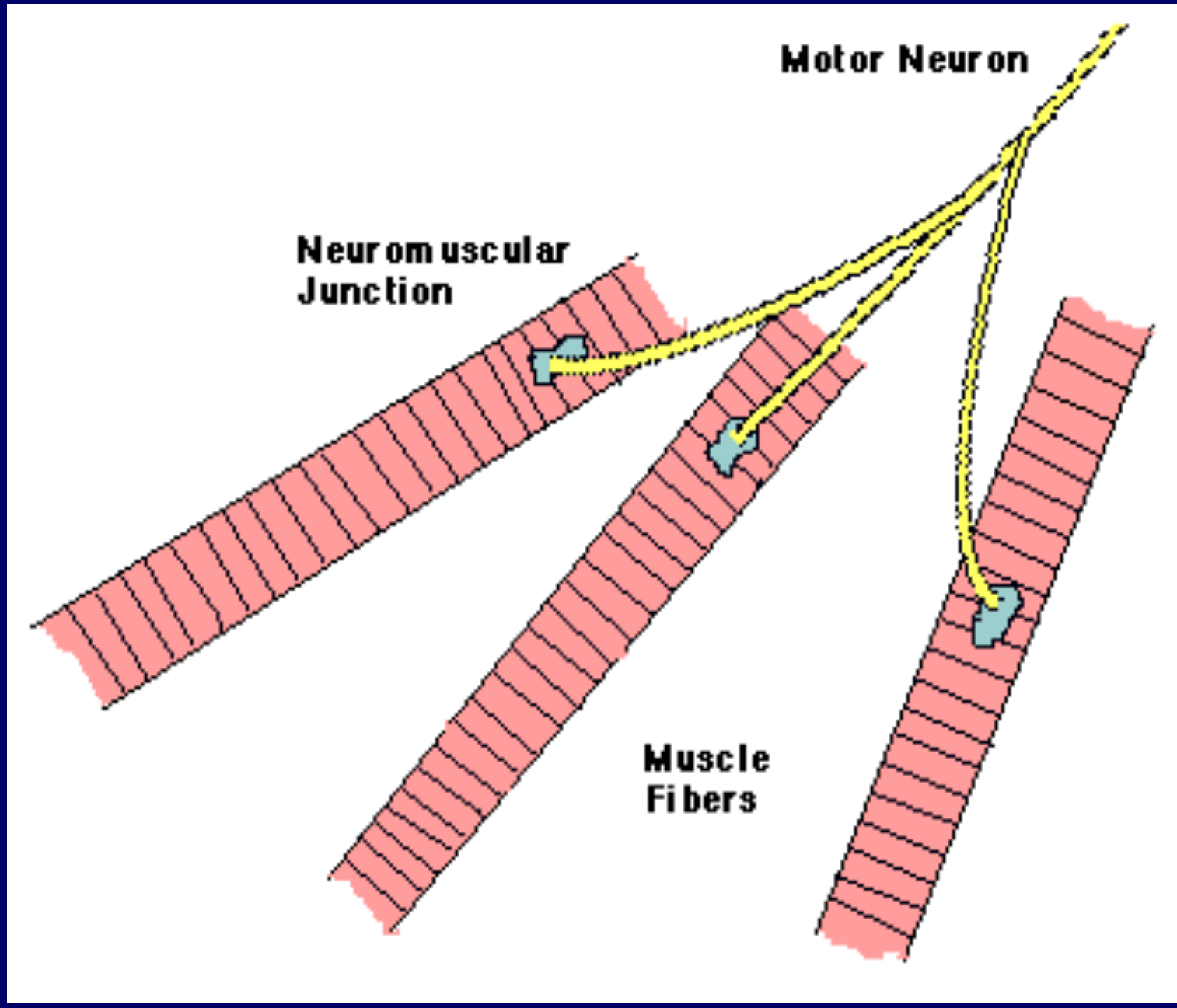
1. **Motor neuron control**
   - **Every muscle cell is contacted by a motor nerve axon or a branch of a motor nerve axon.**

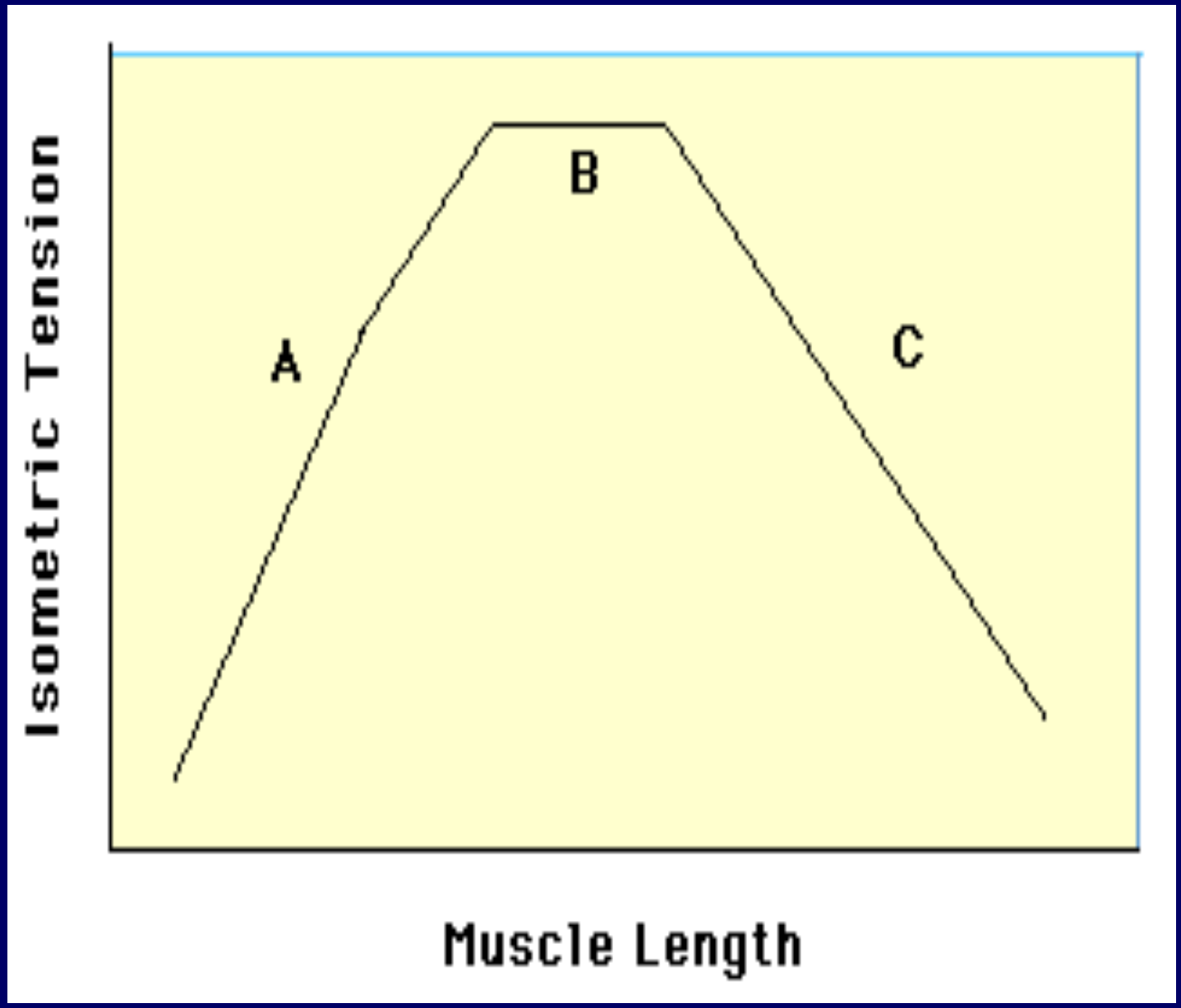
     Action pot. In axon → release of Ach from axon terminal →stimulation of muscle fiber

how rapidly the nervous system is stimulating them; motor unit= single motor neuron and all the muscle fibers

(cells) that it forms junctions with.

Recruitment of more motor units results in greater tension development)


Motor Neuron
Neuromuscular Junction
Muscle Fibers


Isometric Tension
A
B
C
Muscle Length

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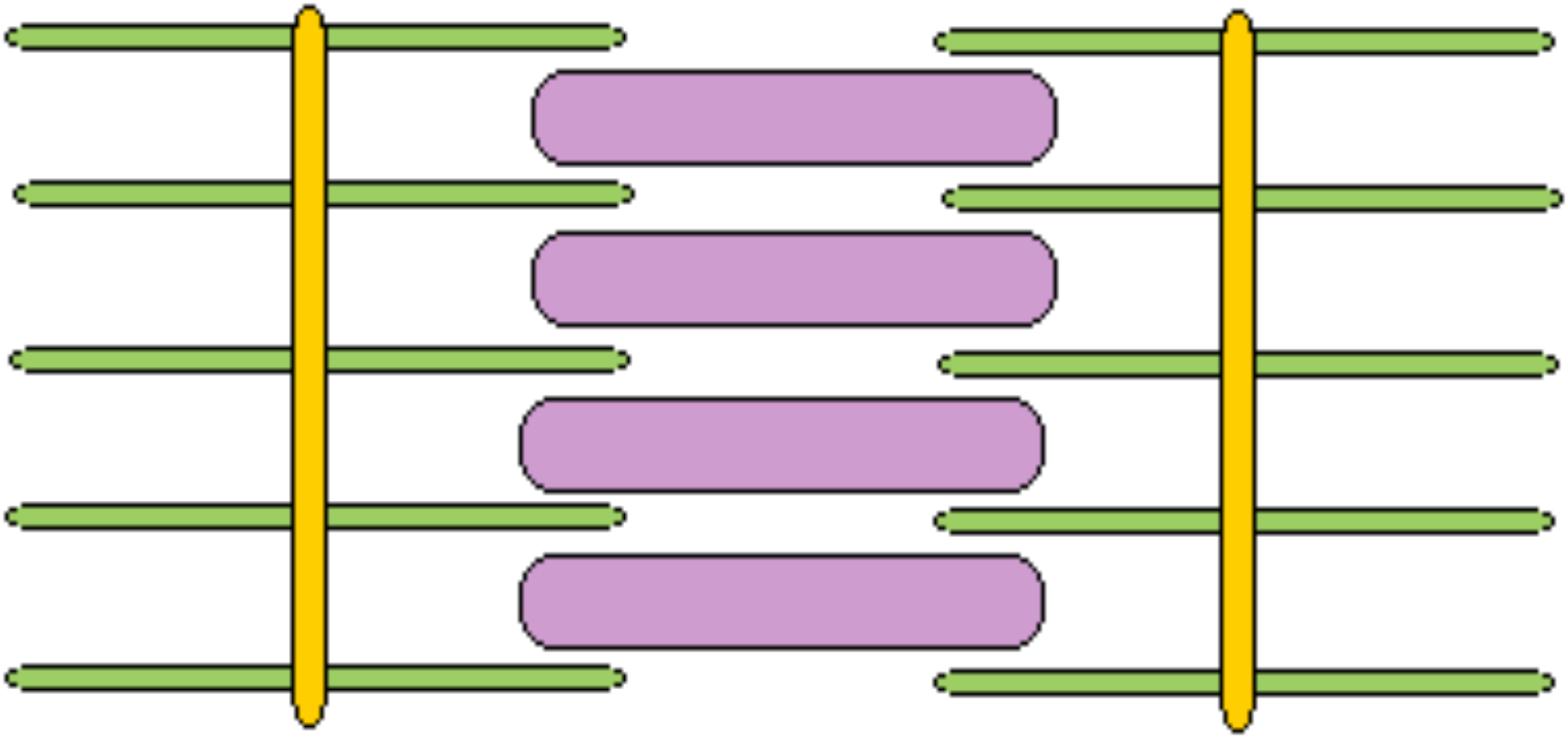
This figure corresponds to point C on the graph. The muscle is stretched to a point where there is very little overlap between actin and myosin. The isometric tension will be low.



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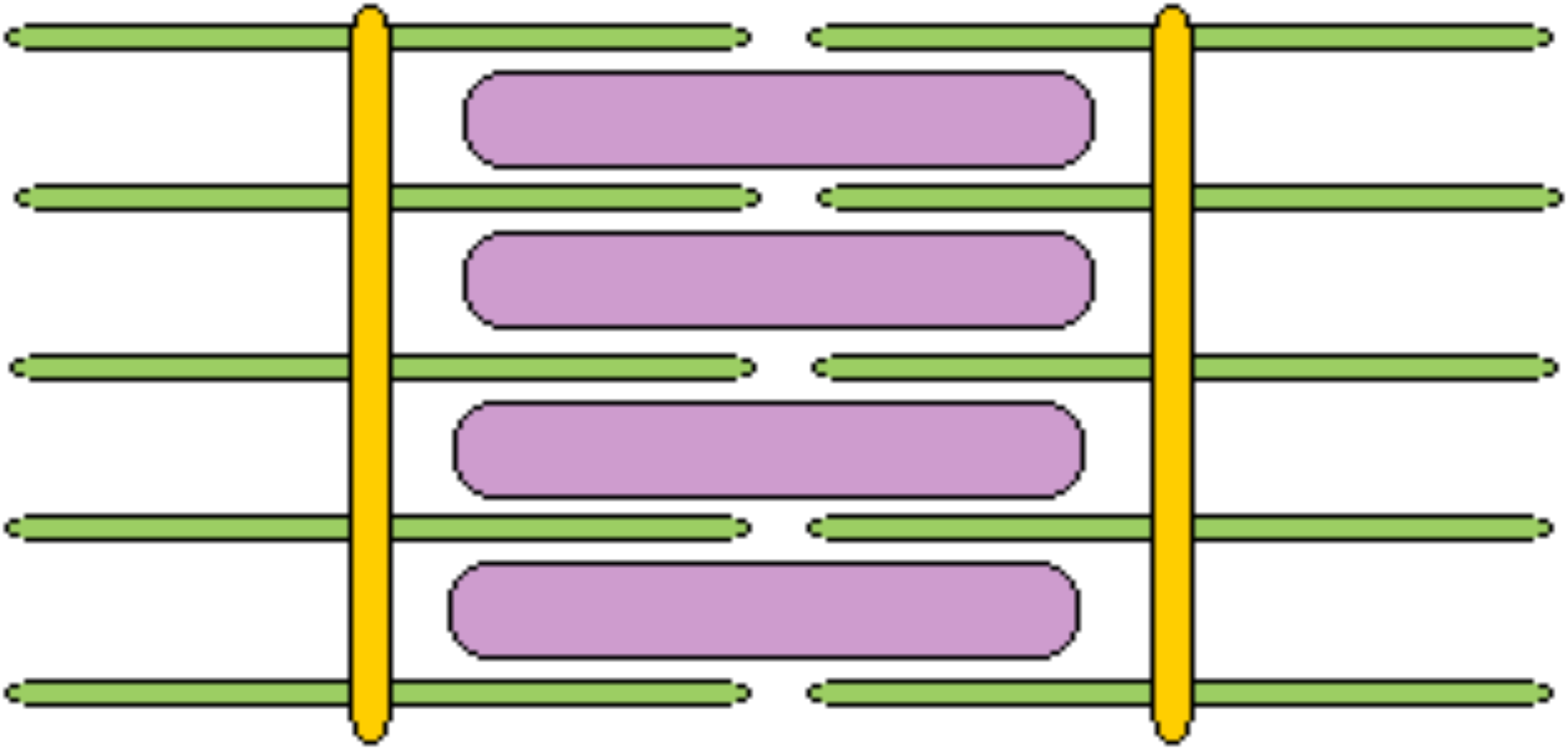
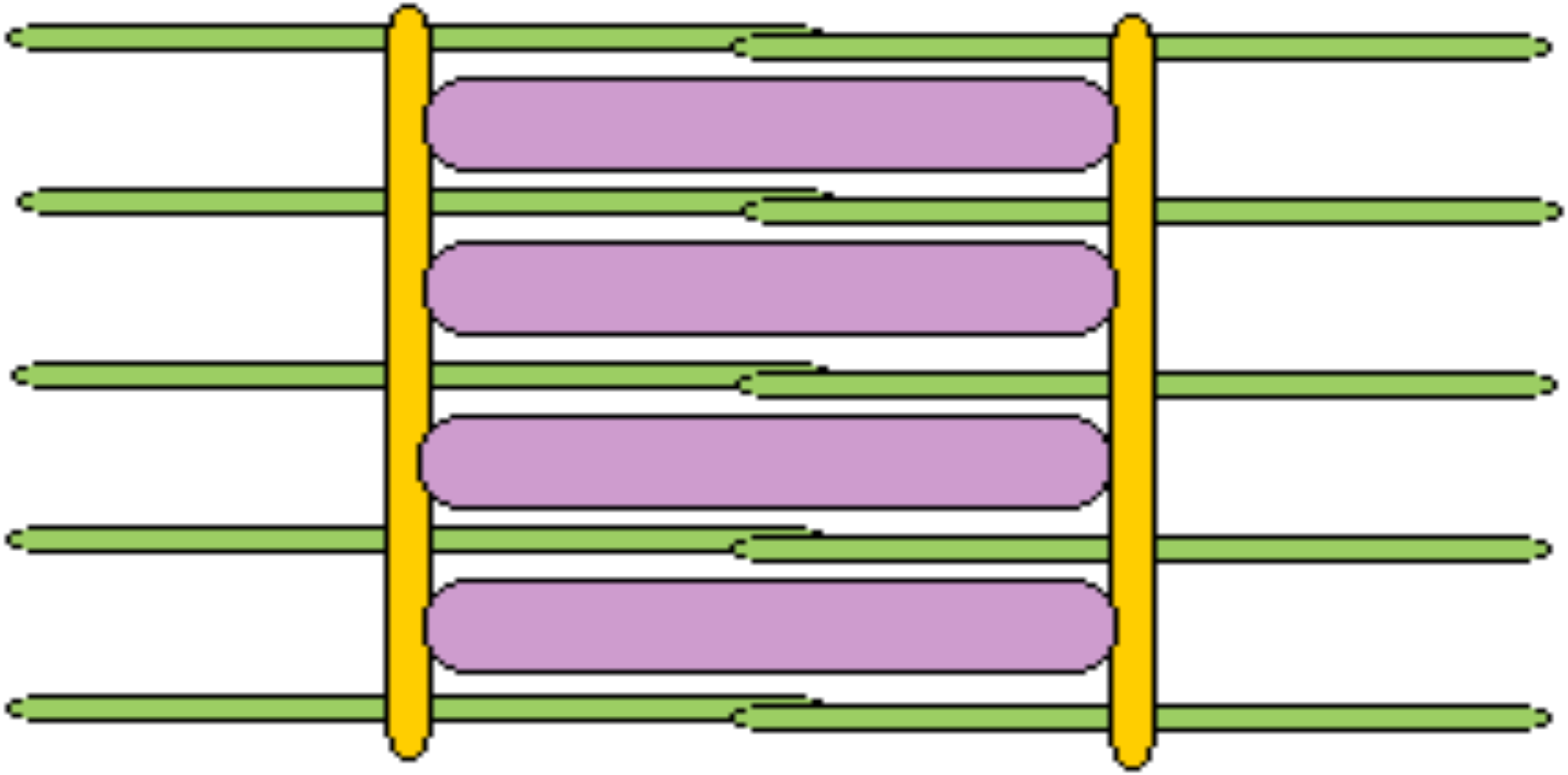
At point B on the graph there is considerable overlap between actin and myosin. There are many active cross bridges, so the isometric tension will be high.



At point A there is a lot of overlap between actin and myosin, but the actin filaments are pushing on each other. This distorts the filaments, weakening the cross bridges.



2. Muscle action potential → invades SR

- The membrane of the muscle fiber is electrically excitable just like a nerve cell axon. Ach causes the muscle fiber to depolarize and this triggers an all-or-none MAP which is conducted along the full length of the muscle fiber and which invades the membranes of the sarcoplasmic reticulum

3. Calcium released into cytoplasm, Complexes with troponin → tropomyosin changes shape
4. Tropomyosin moves, uncovers binding site on actin → cross-bridges form, filaments slide

5. Calcium removed → fiber relaxes

The SR membrane has an active pump that pulls Ca back into the chambers of the SR. This lowers the intracellular Ca ion concentration, troponin again binds tightly to tropomysin, tropomyosin again covers binding sites on actin filaments. Cross bridges can no longer form and muscle relaxes (sarcomeres return to rest length)

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Muscle tension, strength, fatigue

1. Muscle tension = total force developed by cross bridge activation. Isometric contraction occurs when the muscle is stimulated but not allowed to shorten (constant length).
- Strength of contraction (depends on muscle size, how many cells are contracting

Muscle twitch, tetanus

- Whole muscle stimulated by brief electrical shock → record isometric tension, relaxation over time. Repeated shocks cause “staircase” tension development.
- Tetanus = large contraction due to rapid, repeated stimulation so that twitches run together

Fatigue

- Maintained tetanic contraction leads to eventual decline in tension = fatigue.
- Some muscles fatigue rapidly, but also recover rapidly.
- Other muscles fatigue more slowly, but take much longer to recover.
- Regular exercise can make muscles more resistant to fatigue by increasing blood supply and number of mitochondria

Sliding-filament model of sarcomere shortening

1. Arrangement of thick and thin filament: In each sarcomere two sets of actin filaments extend partway toward the center. The myosin filaments are arranged such that they partially overlap the actin filaments. Myosin heads on each side point away from the center of the sarcomer

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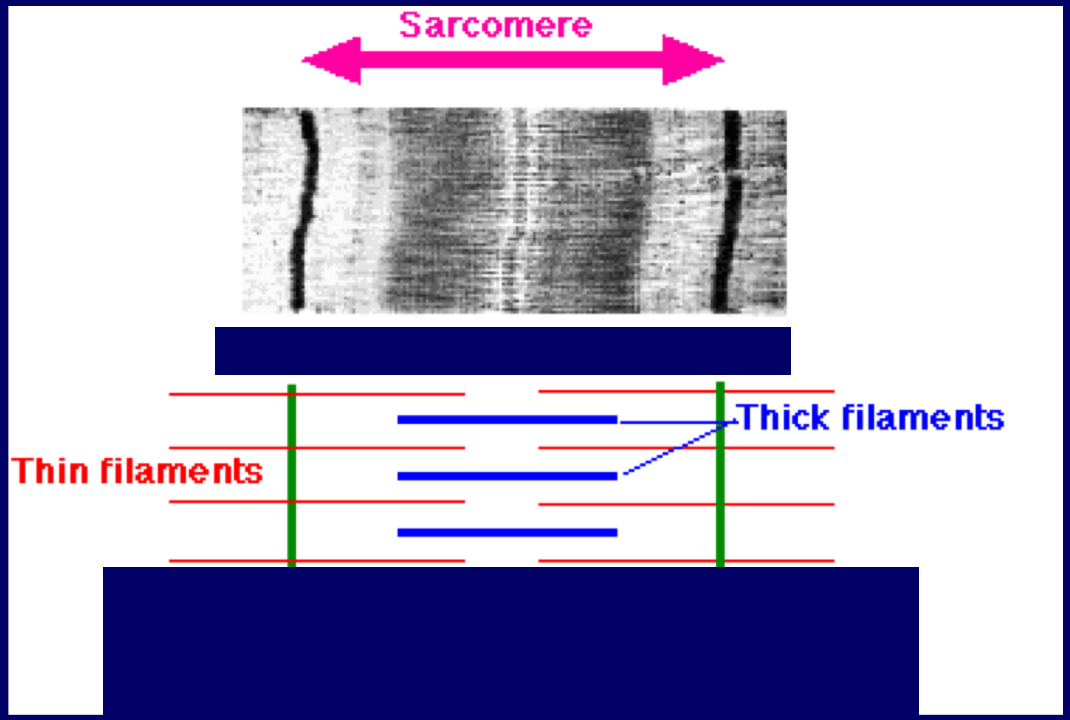
Muscle Structure

- **Basic functional unit of the muscle is the** sarcomere
- **Sarcomere is composed of thick filaments of myosin and thin filaments of actin**



2. During contraction, the interaction of myosin heads with the actin filaments pulls the thin filaments toward the center of the sarcomere. The actin and myosin filaments slide past each other.

3. Cross-bridges = attachment between myosin heads and binding sites on actin filaments

4. When a muscle cell is stimulated, myosin heads are energized by ATP. They attach to adjacent actin filaments, and tilt in a short “power stroke” toward the center of the sarcomere. Each power stroke requires an ATP. With many power strokes in rapid succession, the actin filaments are made to slide past the myosin filaments.

Test Weight of Load

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- Test the weight by lifting a corner of the object.
- If it is too heavy or if the object is an odd shape, STOP!

Energy for contraction

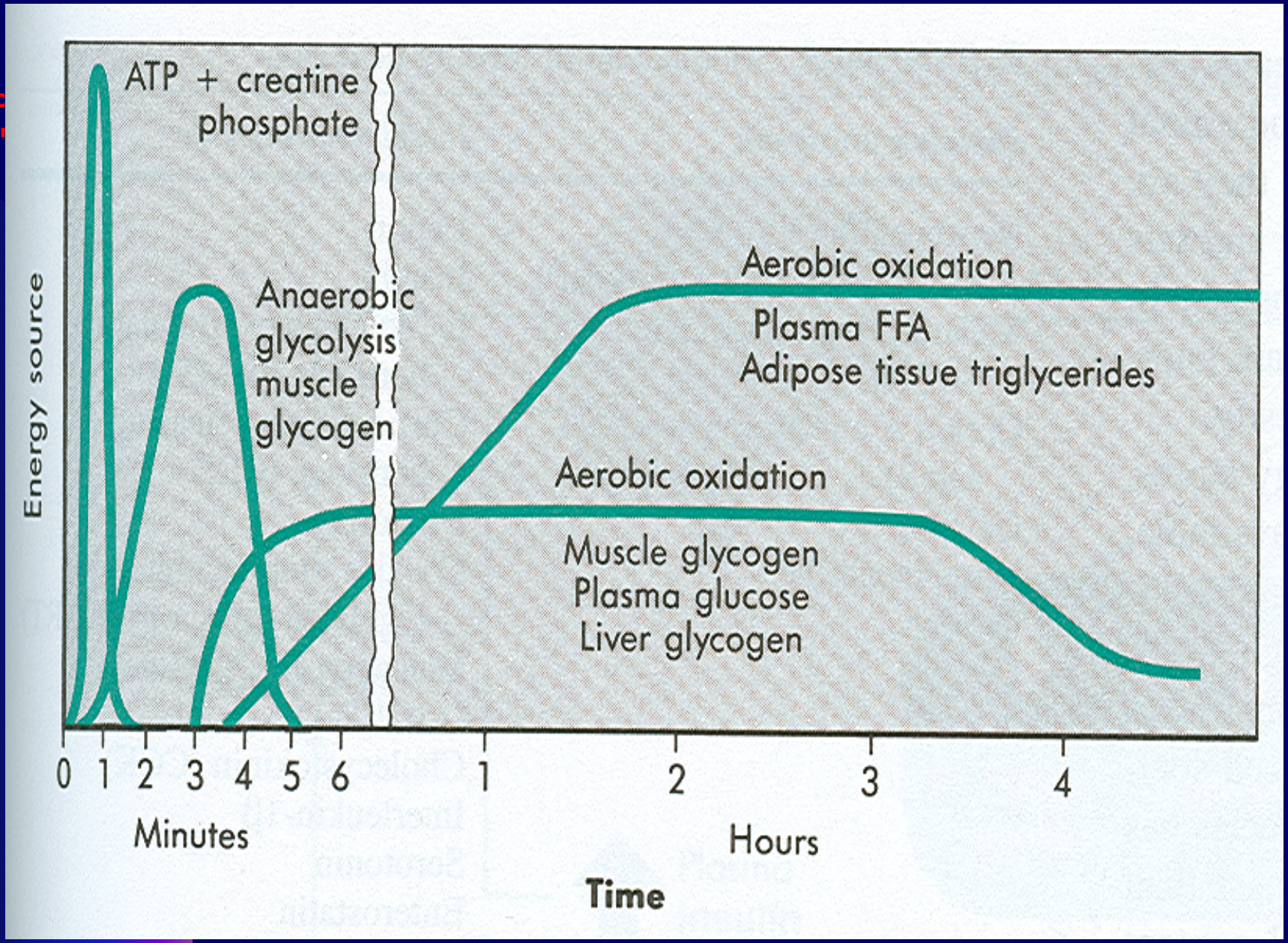
1. Creatine phosphate dephosphoryla tion = Fast regeneration of ATP from ADP and Pi
2. Glycogen →glucose. Aerobic respiration provides most of the ATP needed during moderate exercise
3. Blood glucose and Fatty acids →Fuel for aerobic respiration when muscle glycogen exhausted

4. Fermentation (anaerobic metabolism)
→When respiratory and circulatory systems cannot deliver enough oxygen to sustain muscle contraction during vigorous exercise, glycolysis supplies ATP and produces lactic acid (lactate) from the breakdown of glucose.

- Recall that the net yield is 2 ATP per glucose mulecule instead of 34-36.

Lactic acid rapidly builds up in cell.

Metabolic adaptations during exercise (Fig. 40-12)



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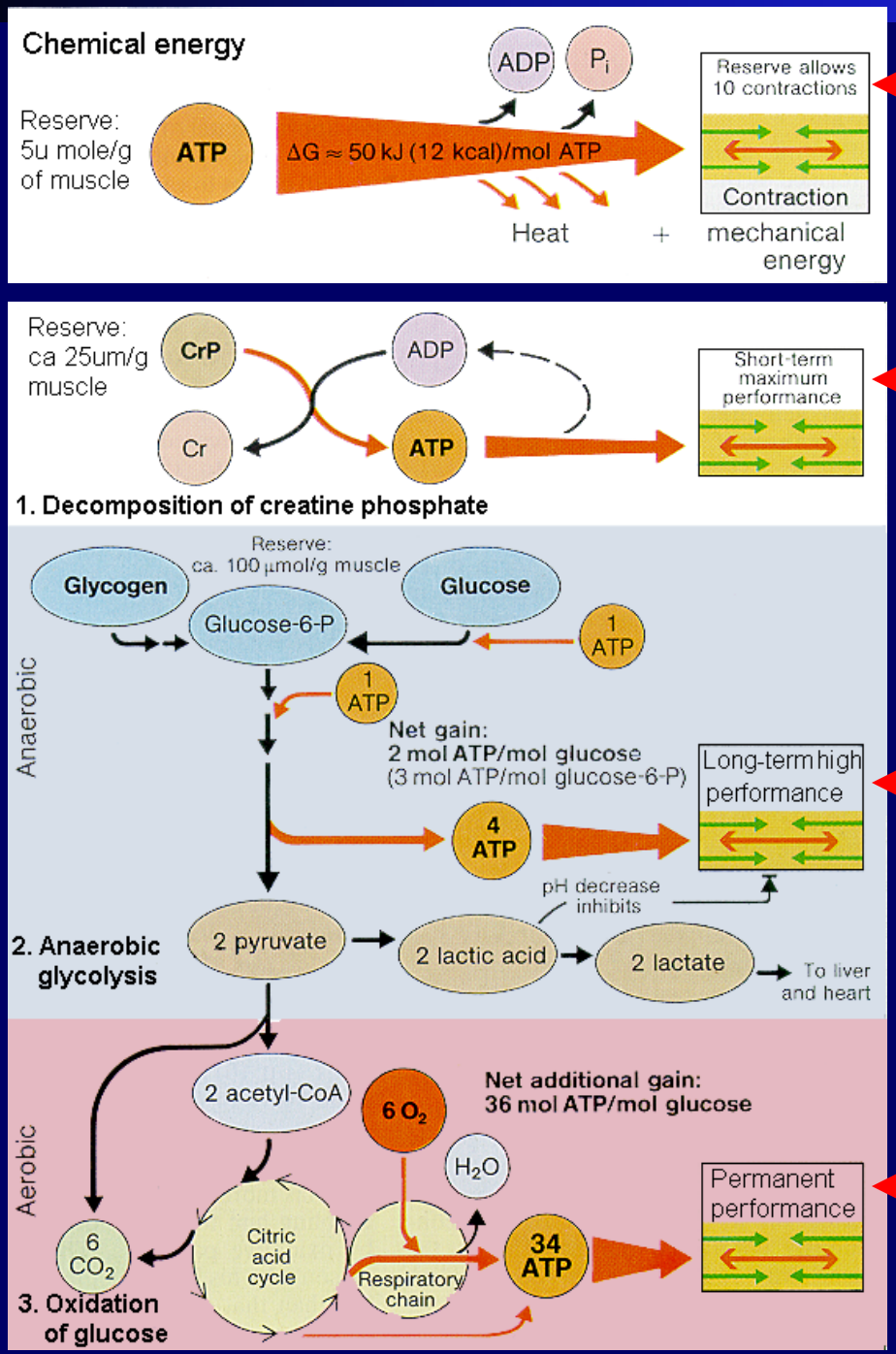

10 contractions

50 contractions

400 contractions

Unlimited

Lumbar BMD of Different Athletic Groups

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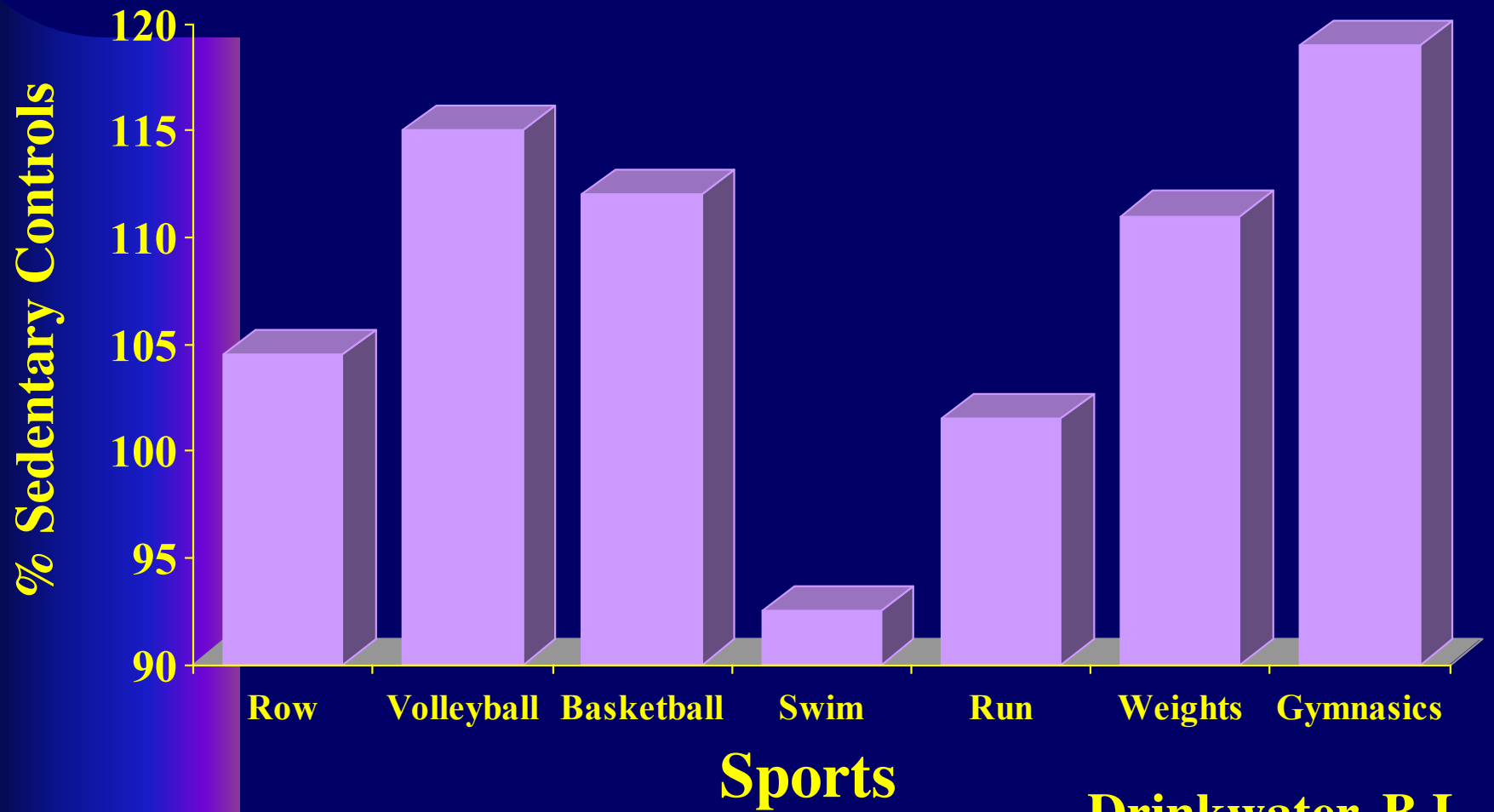
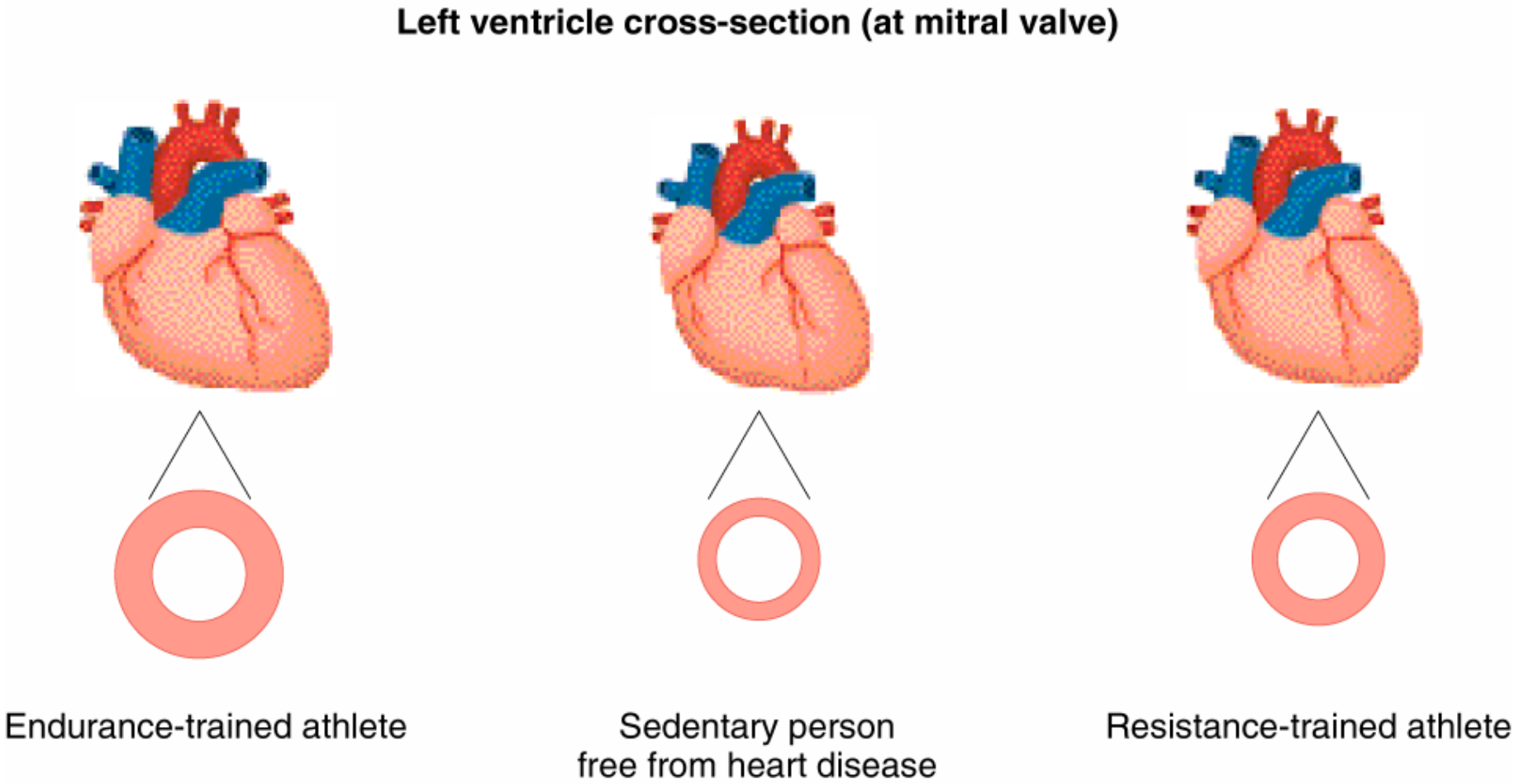


Drinkwater, B.L. (19

LEFT VENTRICULAR HYPERTROPHY



Gains in the Beginning of a Program

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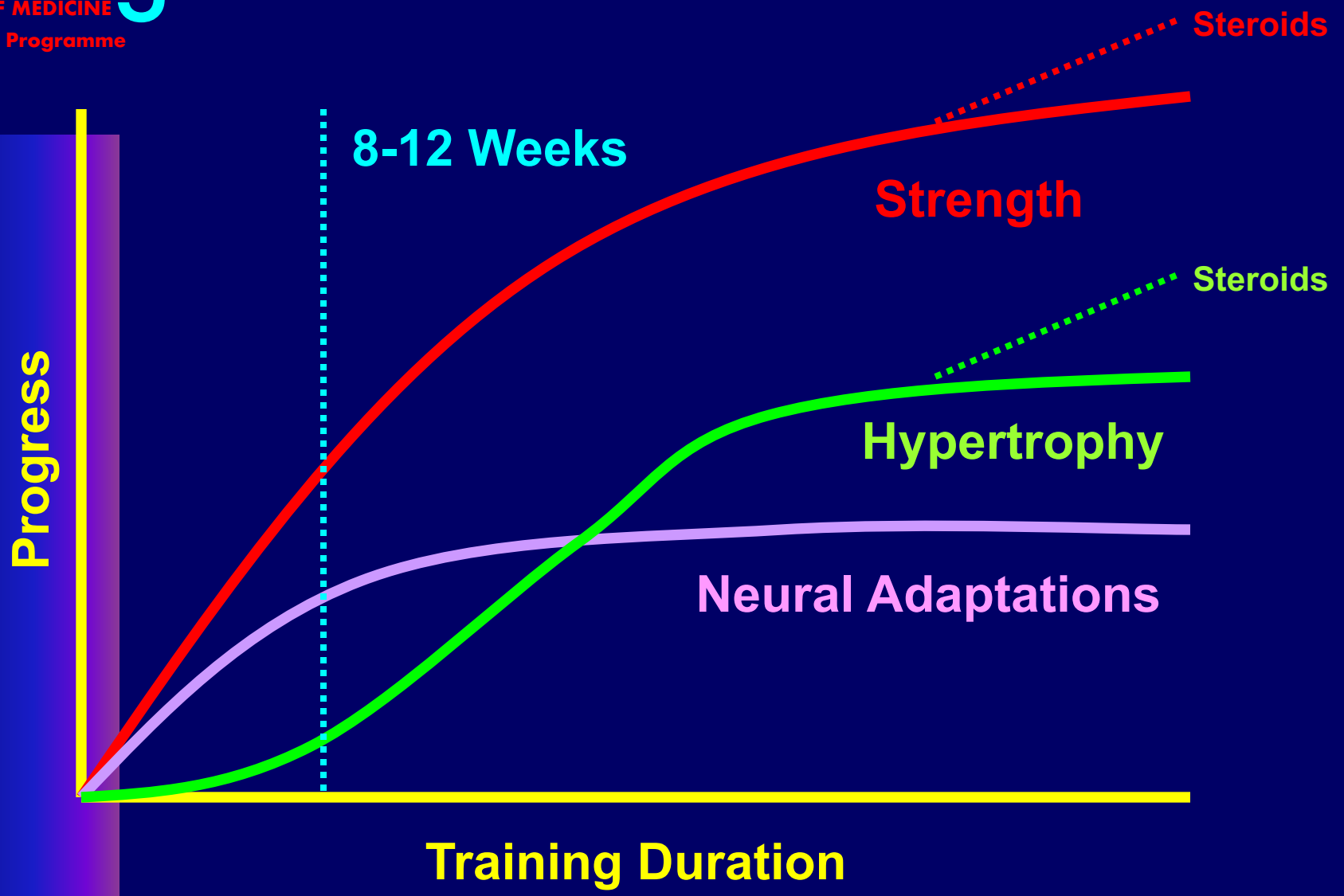
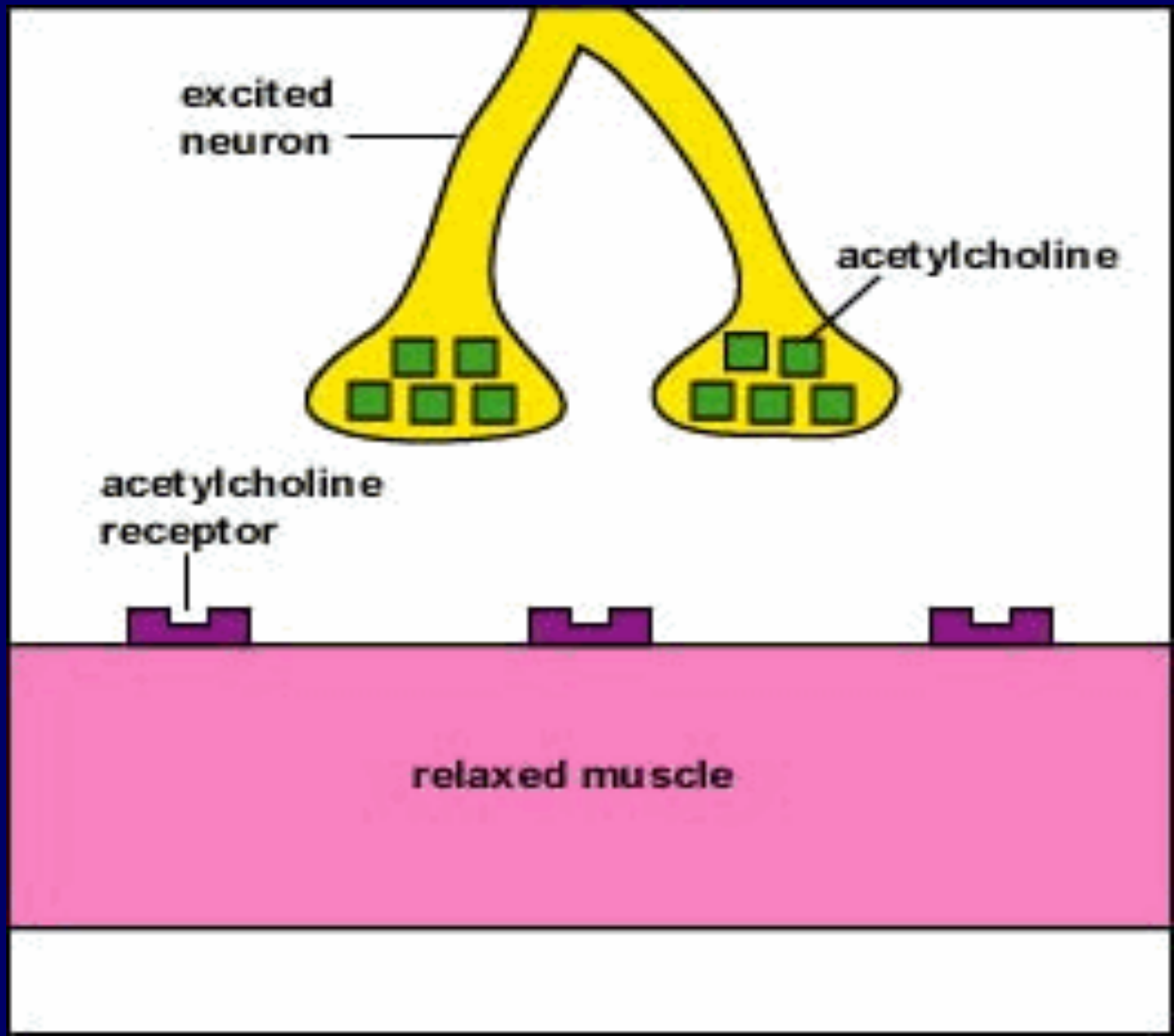
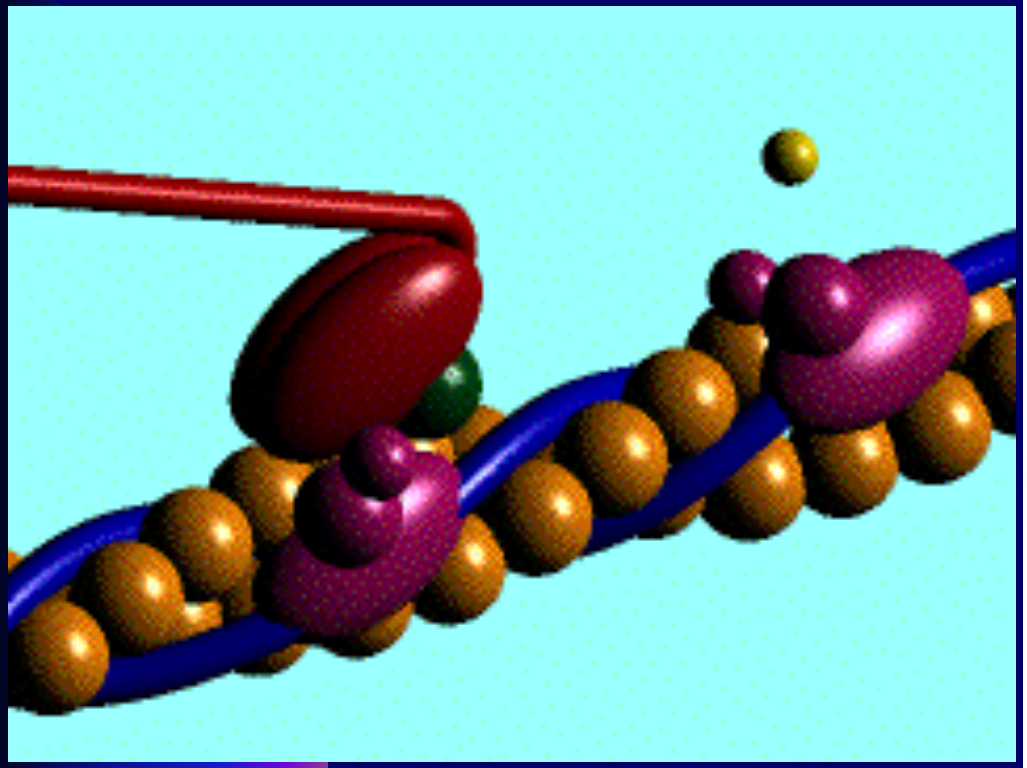



Colgate
SCOTT

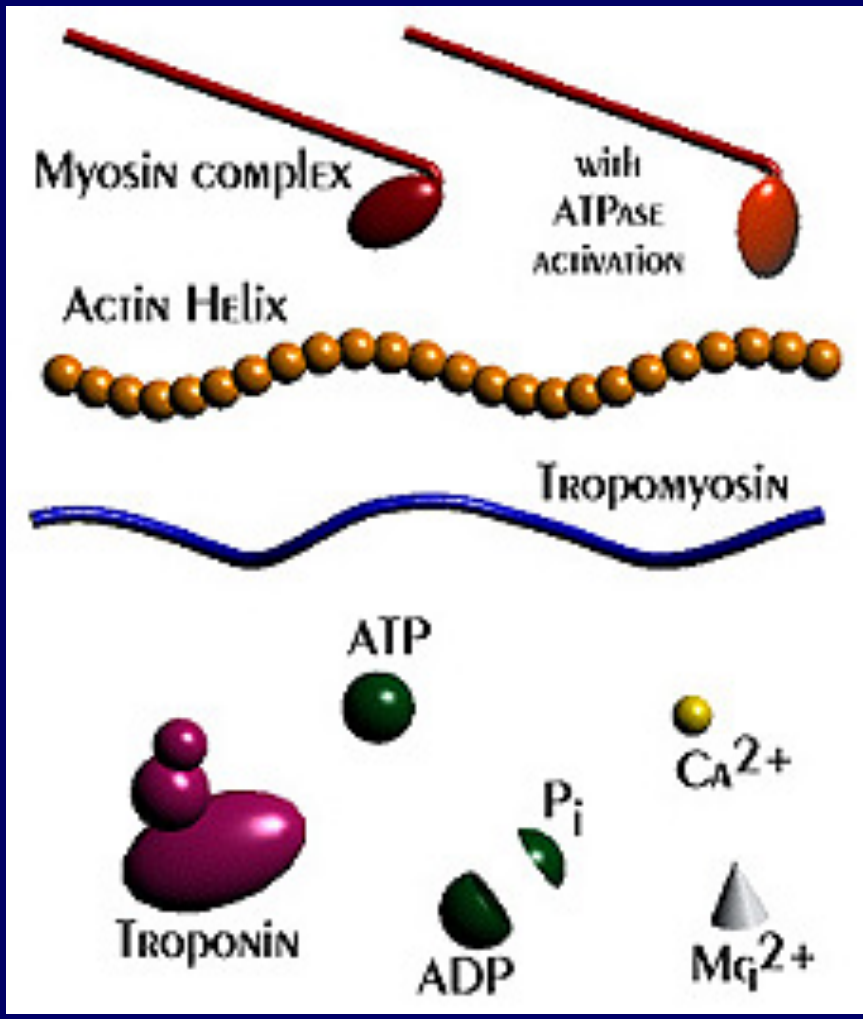
ATLET SEPAK BOLA


excited
neuron
acetylcholine
acetylcholine
receptor
relaxed muscle

Cross-bridge Cycle



This animation by Mike Geeves, Laboratory of Molecular Biology in the UK and the Cambridge Institute for Medical Research



Two Basic Types of Contraction Are Isotonic and Isometric

- In an isotonic contraction the muscle shortens, keeping a constant tension
- In an isometric contraction the muscle does not shortens and tension builds up
- Most real contraction are mixtures of the 2 types

- **A Single Nerve Impulse Produce a Muscle Twitch**
  - Single stimuli usually release enough ACh in the NMJs of the motor unit to produce action potentials in the muscle membranes
  - This will cause the muscle to contract after a short delay

- Order of events. Ach release → muscle action potential → Ca release → contraction
- A simple twitch gives only 20-30% of the maximum tension possible-the muscle starts to relax before the maximum is reached

- **Muscle Contraction Can Summate to Produce More Force**
  - If a second stimulus is given before a muscle relaxes the muscle will shorten further, building up more tension than a simple twitch- this is called summation
  - If many stimuli are given very close together the muscle will go into a smooth continuous contraction called tetanus

- **Another Way to Increase the Force of Contraction is to Recruit More Motor Units**
  - **Each muscle is made up of tens of thousands of motor units**
  - **Force generated by a muscle can be increased by firing more and more motor units**

- **Different Types of Skeletal Muscle Fibers Specialize for Endurance or Speed**
  - **Muscle cells (fibers) specialize for their type of activity**
    - **Atheletes have fiber types that match their activities**

- Endurance fibers (type I)
  - Have many mitochondria-the mitochondria give these fibers a red appearance because one of the mitochondrial enzymes contains Fe
  - Also contain a red pigment called myoglobin which stores O2
  - Contract slowly but resist fatigue

- **Fast twitch fibers (type II)**
  - Fibers specialized for fast contractions are white-they contain few mitochondria
  - Relying on glycolysis to supply energy (glycolysis is faster than respiration)
  - Contract rapidly but fatigue quickly

- Fiber type is mostly genetically determined, but some experiments have shown conversion of one fiber type into another


THANK YOU