Lecture 90:

Skeletal Muscle Structure and Function

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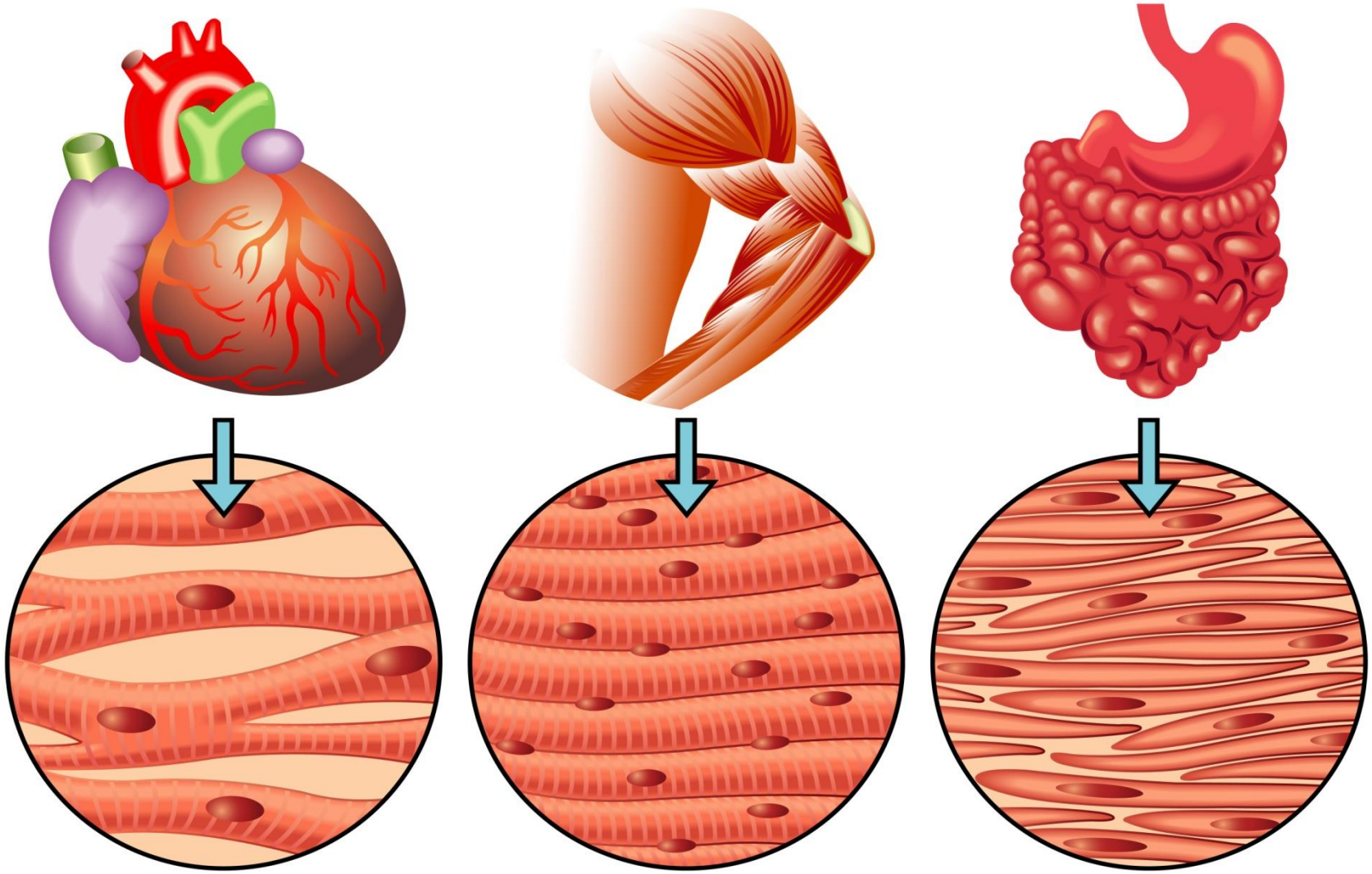
Skeletal Muscle:

- **Human body has about 700 skeletal muscles.**

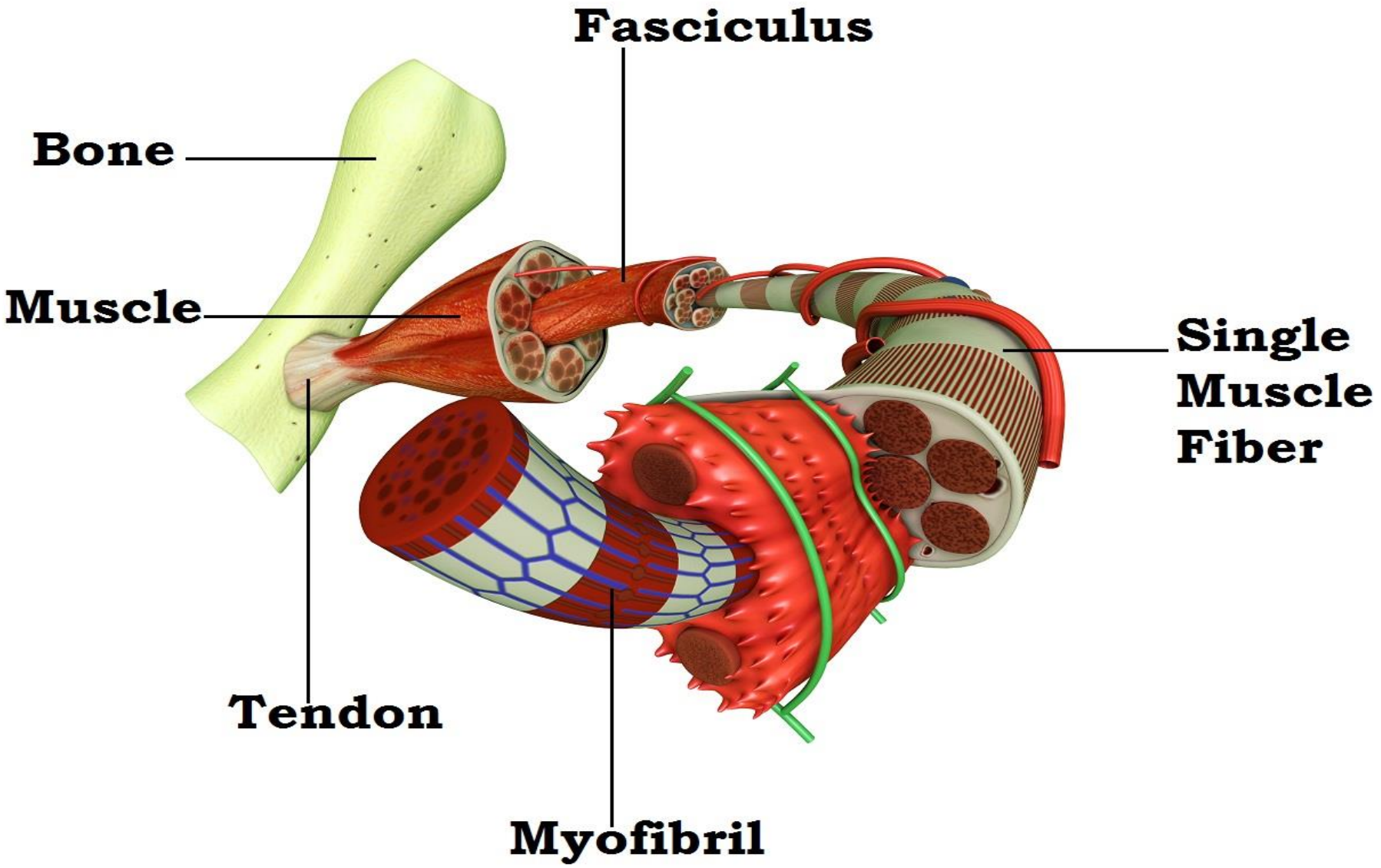
In general, there are 3 types of muscles:

- **Skeletal (striated or voluntary) muscle.**
- **Smooth (non – striated or involuntary) muscle**
- **Cardiac muscle (myocardium).**


Cardiac muscle tissue
(Involuntary control)
Skeletal muscle tissue
(Voluntary control)
Smooth muscle tissue
(Involuntary control)

	Skeletal Muscle	Smooth Muscle	Cardiac Muscle
Location	Body wall, arms, legs, head and neck	Esophagus, stomach, intestine, & bladder	Heart
Activity	Strong, phasic, and quick	Weak, rhythmic and slow	Strong, rhythmic, continuous and quick
ATPase activity	High	Low	Intermediate
Sarcomere	Actin and myosin form sarcomeres	Actin and myosin are not organized into sarcomeres	Actin and myosin form sarcomeres
Stimulation	Voluntary by the somatic nervous system	Involuntary by autonomic nervous system	Involuntary by autonomic nervous system

Skeletal Muscle Structure:



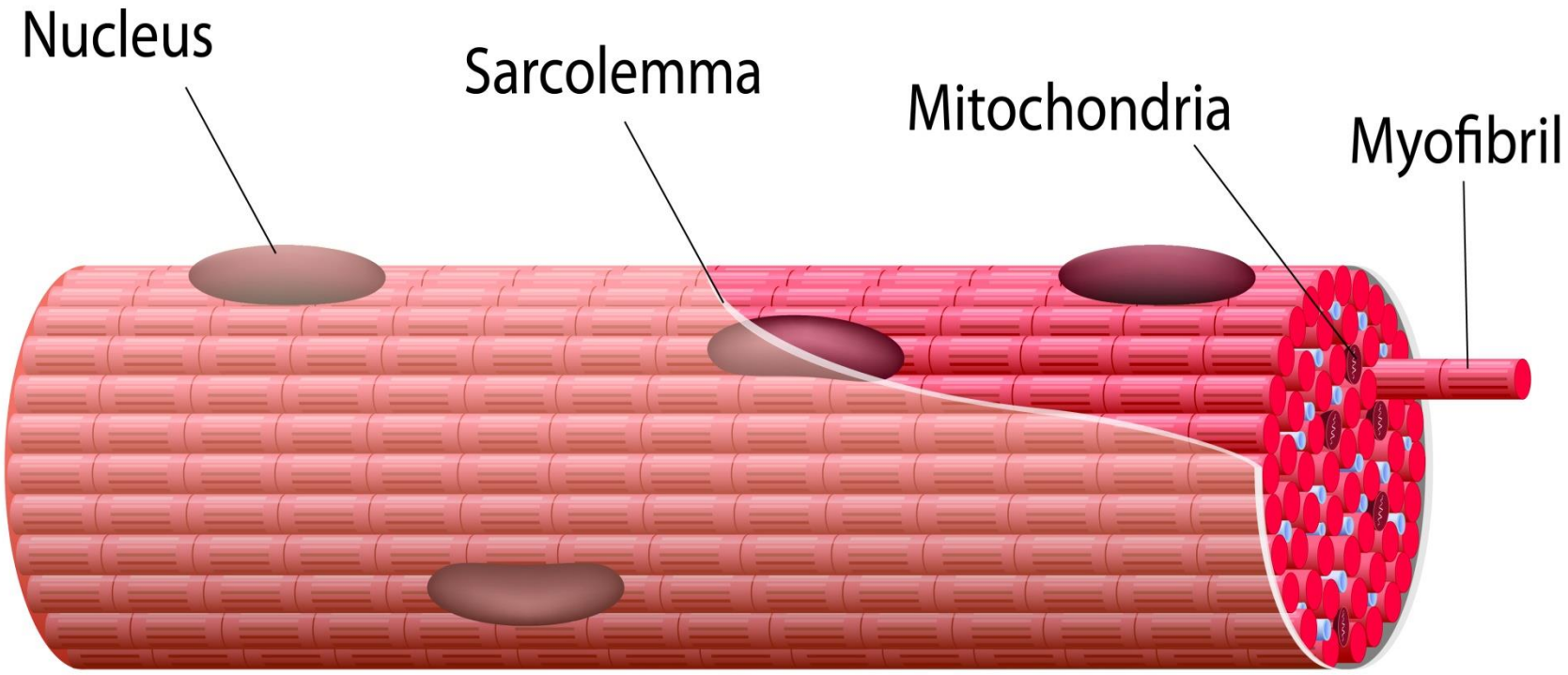
Muscle Fiber:

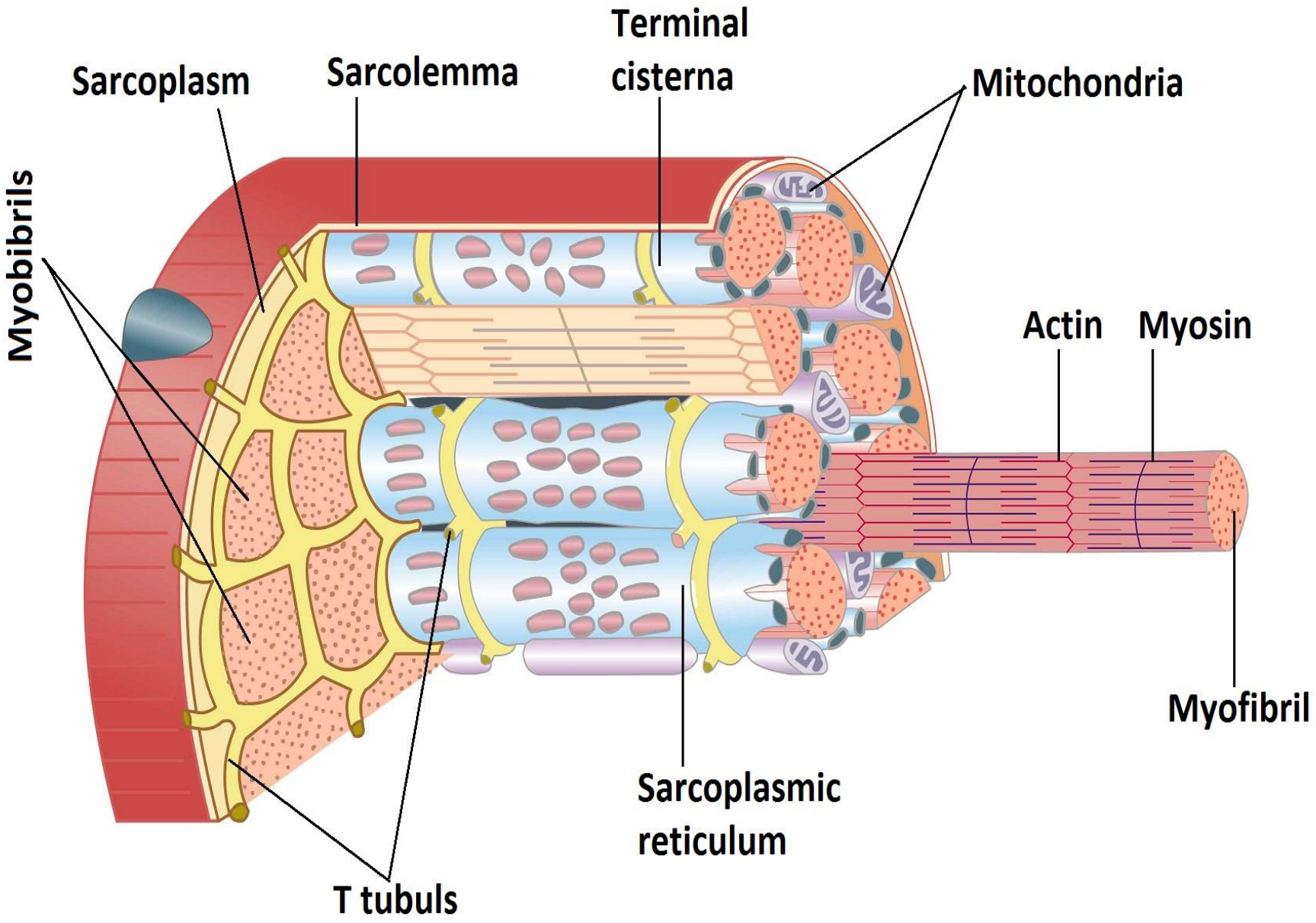
- **A skeletal muscle has been made of contractible bundles named fiber.**
- **Each fiber is a multinucleated cell that has its own cell membrane named sarcolemma.**
- **The length of fiber varies from a few millimeters in the eye muscles to about 30 cm in the large muscles of the leg.**

- **Each muscle fiber is packed with myofibrils, which are composed of sarcomeres.**

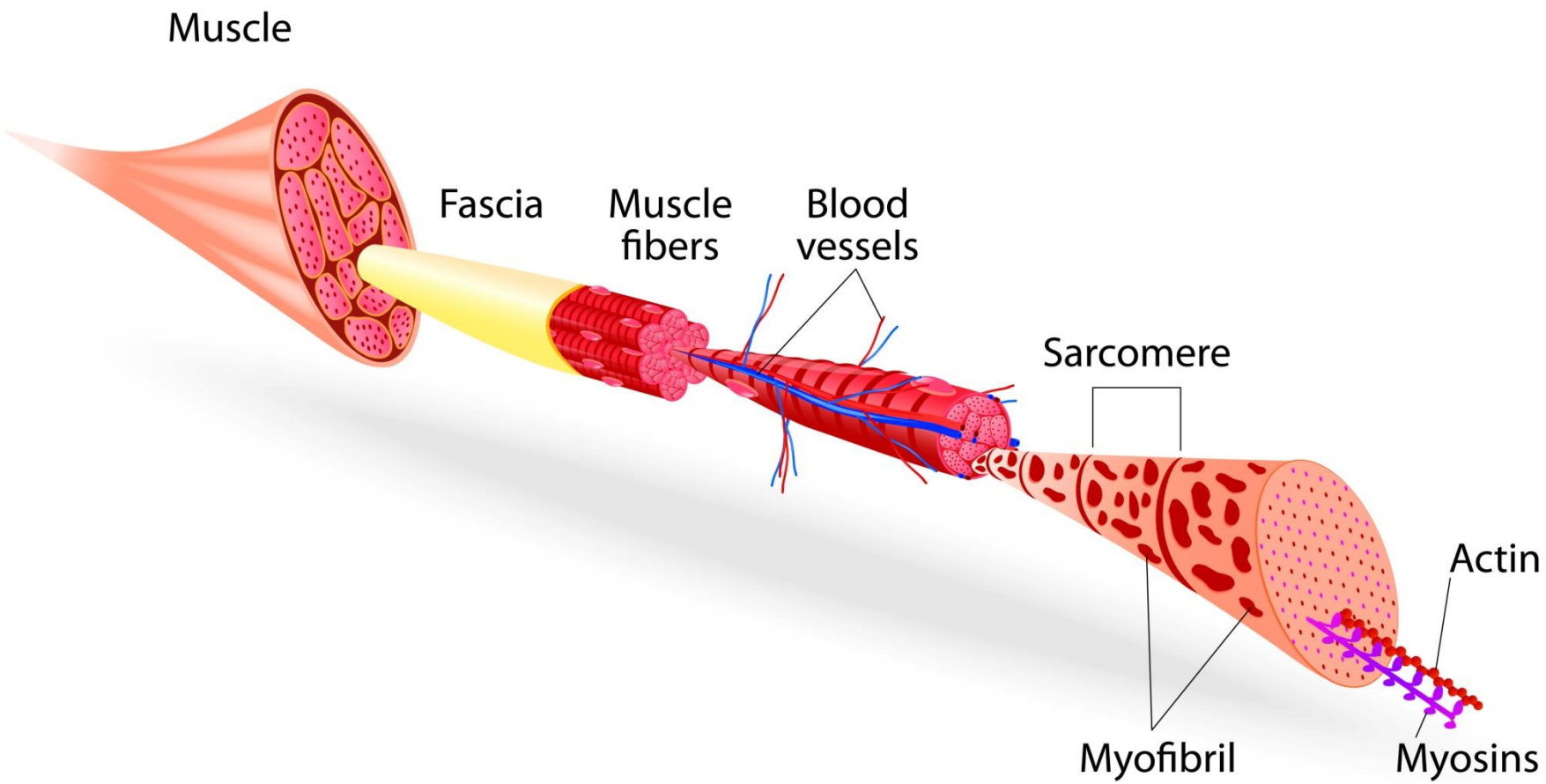
- **Sarcomere is the functional unit of muscle and is composed of actin and myosin, the filamentous proteins.**

MUSCLE FIBER

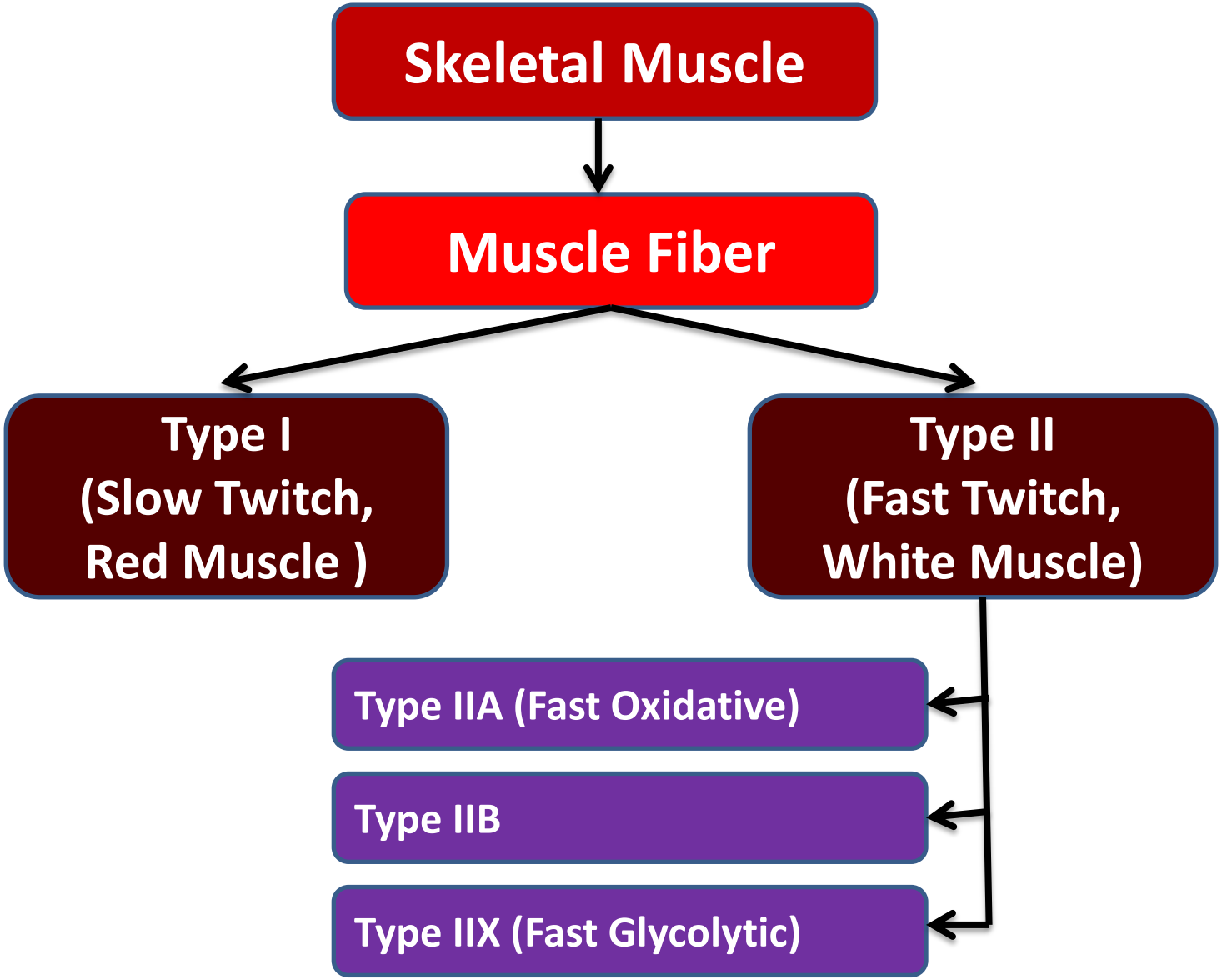



Sarcoplasm
Sarcolemma
Terminal cisterna
Mitochondria
Myobibrils
Actin
Myosin
Myofibril
Sarcoplasmic reticulum
T tubuls

Structure of skeletal muscle



Types of Fiber:



	Type I	Type IIA	Type IIX
Aerobic activity	High	Intermediate	Low
Anaerobic activity	Low	Intermediate	High
Capillary density	High	High	Low
Myoglobin content	High	Low	Low
Mitochondrial density	High	Intermediate	Low
Speed of contraction	Slow	Fast	Fast
Force of contraction	Low	Intermediate	High
Fatigue resistance	High	Intermediate	Low

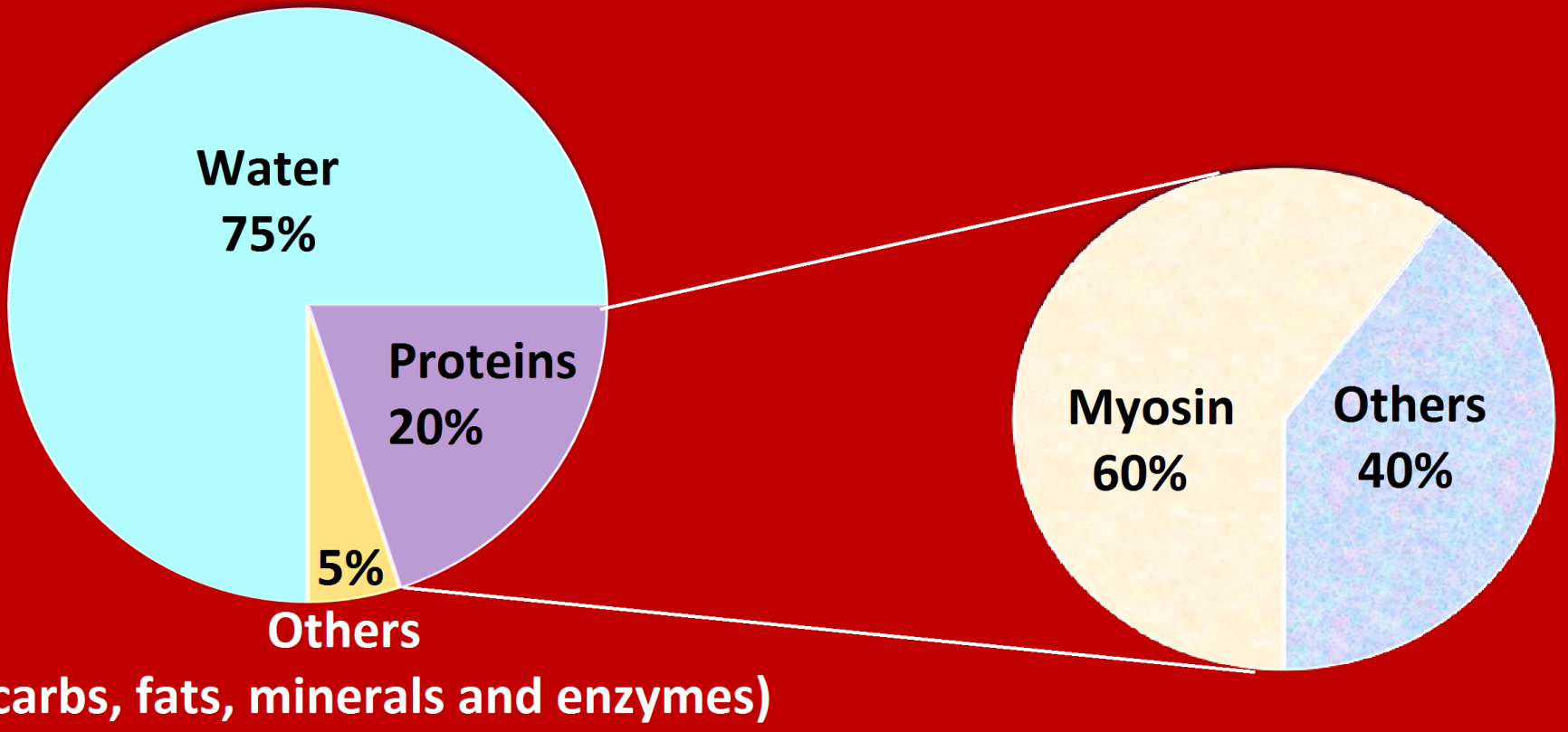
Chemical Composition of Muscle:

Skeletal muscles are composed of:

- **75% water**
- **20% proteins (actin, myosin, and tropomyosin)**
- **5% others:**

- **Enzymes**
- **Minerals (calcium, magnesium, sodium, potassium, phosphorus and chloride)**
- **Lactate**
- **Carbohydrates**
- **Fats**

Your Muscles Are Made Of:



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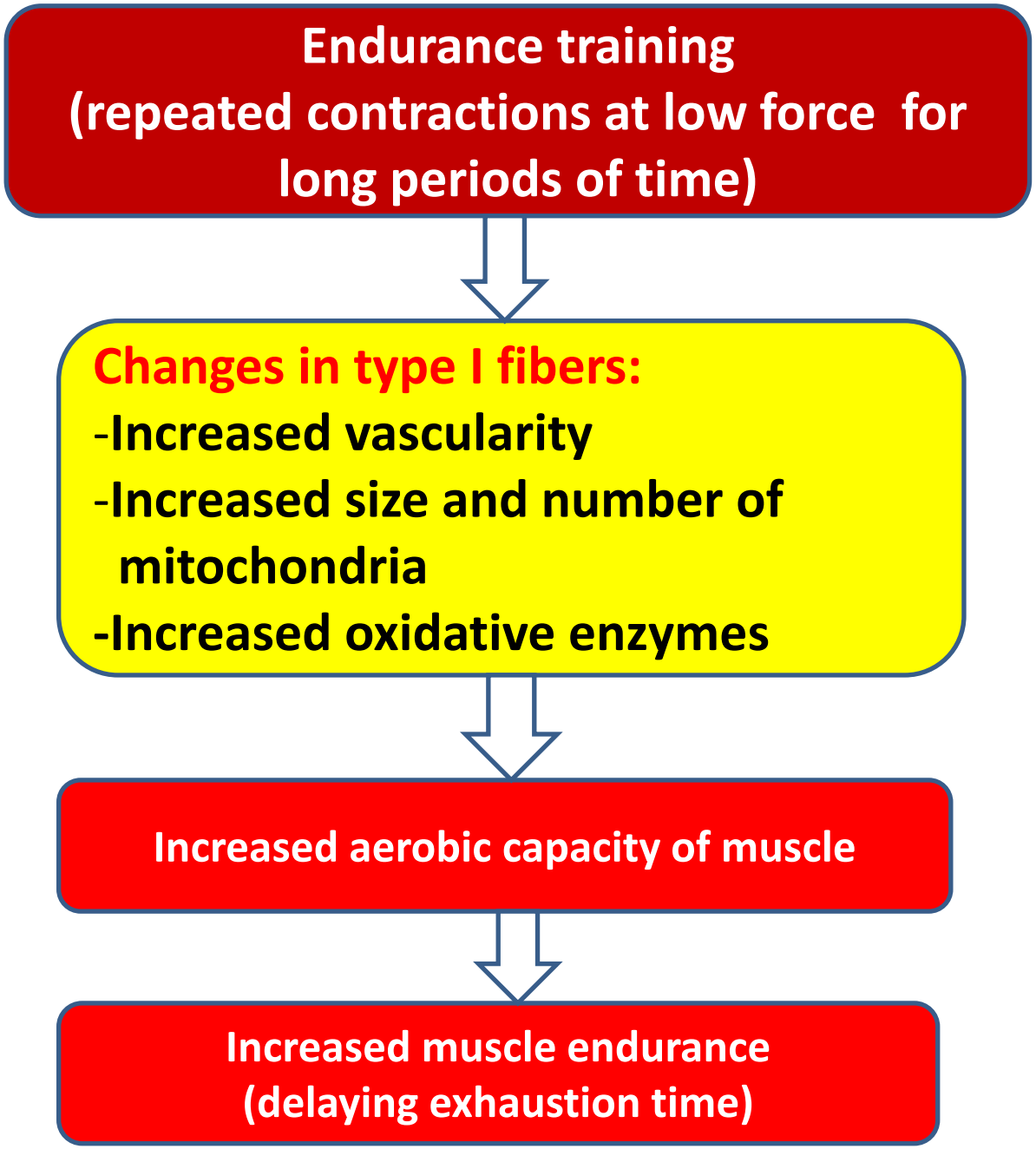
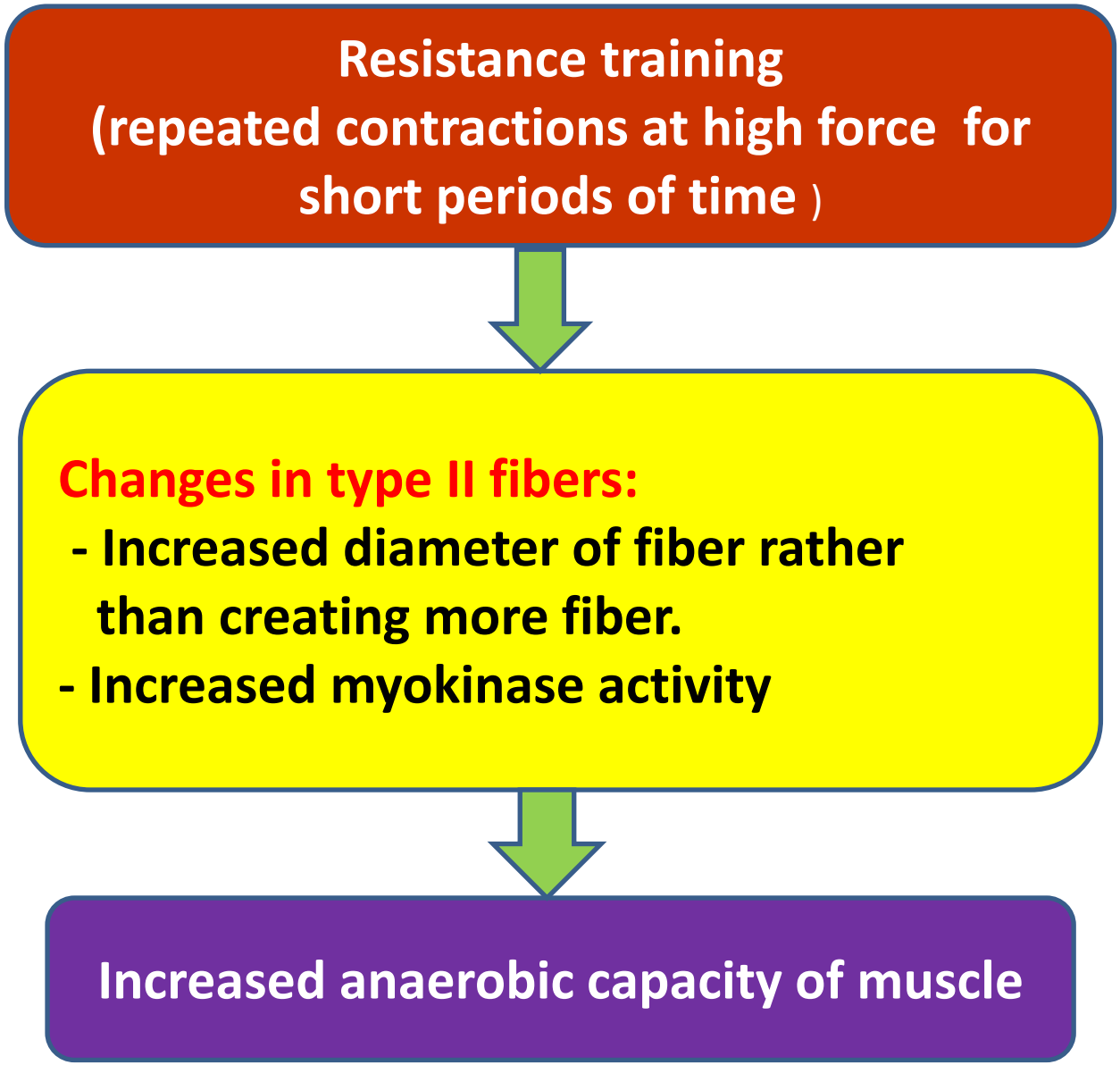
Dominant Muscle Fiber:

- **The relative proportions of type I and II fibers at birth is mainly controlled by genetic programming.**
- **Changes in gene expression in response to mechanical loading would have an impact on fiber dominancy and body type.**
- **Let`s see how muscle fibers respond to mode of exercise:**


Endurance training
(repeated contractions at low force for long periods of time)
Changes in type I fibers:
-Increased vascularity
-Increased size and number of mitochondria
-Increased oxidative enzymes
Increased aerobic capacity of muscle
Increased muscle endurance
(delaying exhaustion time)


Resistance training
(repeated contractions at high force for short periods of time)
Changes in type II fibers:
- Increased diameter of fiber rather than creating more fiber.
- Increased myokinase activity
Increased anaerobic capacity of muscle

Fibers Type II Dominancy:

- **Fast twitch fibers rely on anaerobic system.**
- **They have key roles in sports that require sudden changes of pace or stop-and-go such as soccer, basketball, wrestling, hockey, tennis, volleyball etc.**
- **They are low in myoglobin and mitochondria, which gives them whitish appearance.**

Fibers Type I Dominancy:

- **Slow twitch fibers rely on aerobic energy systems.**
- **They have key roles in endurance sports such as marathon, long distance running and swimming, cycling etc.**
- **They are rich in mitochondria, myoglobin and iron-containing cytochromes, which gives them reddish appearance.**

Impact of Immobility on Muscles:

- **Physical inactivity causes muscle mass reduction by decreasing the rate of protein synthesis.**

If a muscle is immobilized in a shortened position:

- **The proportion of collagen increases (compared to contractile proteins).**
- **The muscle gets stiffened and less extensile.**

Complete Immobilization of the Leg

Decreased Protein Synthesis

Loss of Type I Fiber

Atrophy of the Muscles

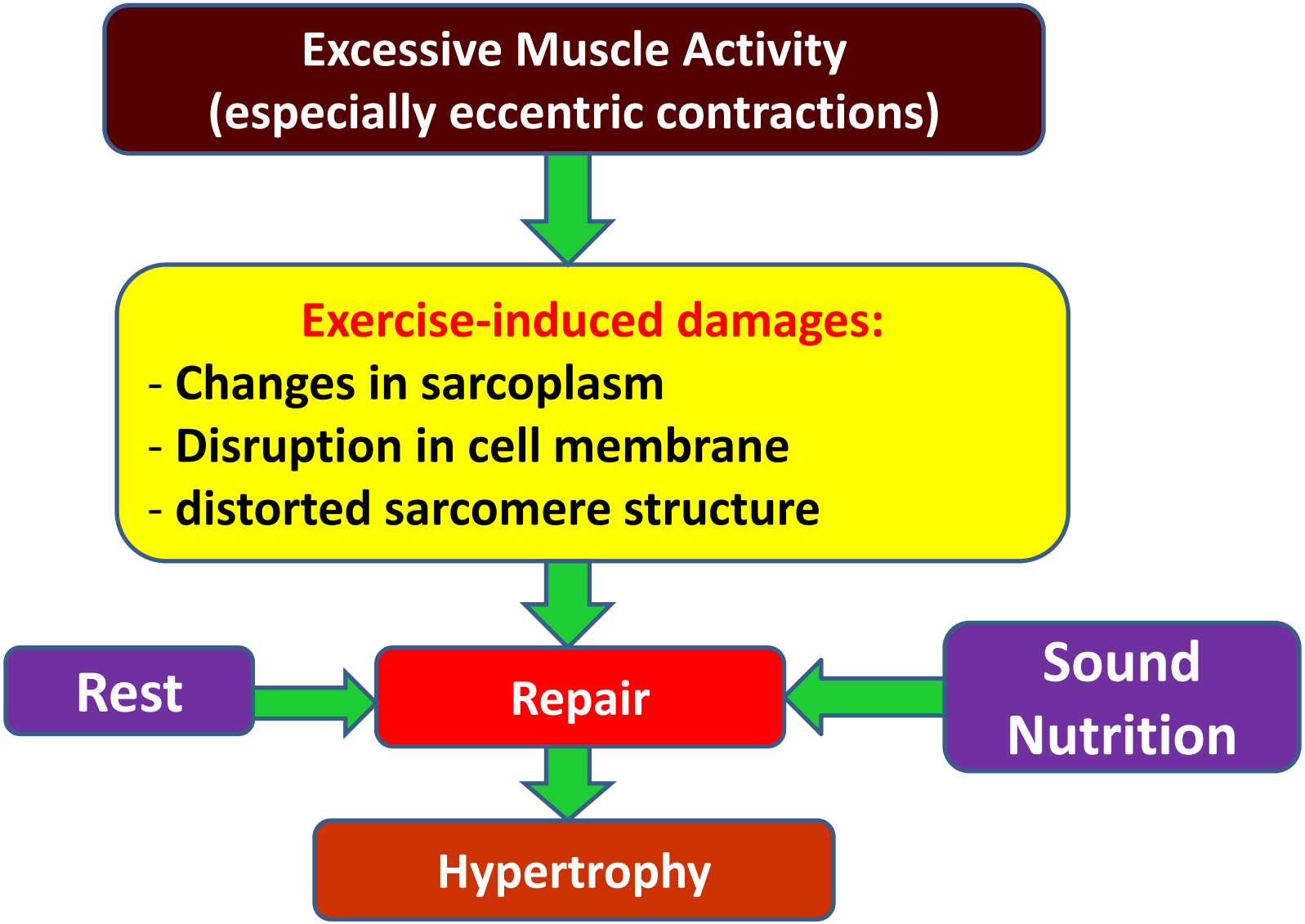
(*a reduction of 20% of muscle in 8 weeks*)

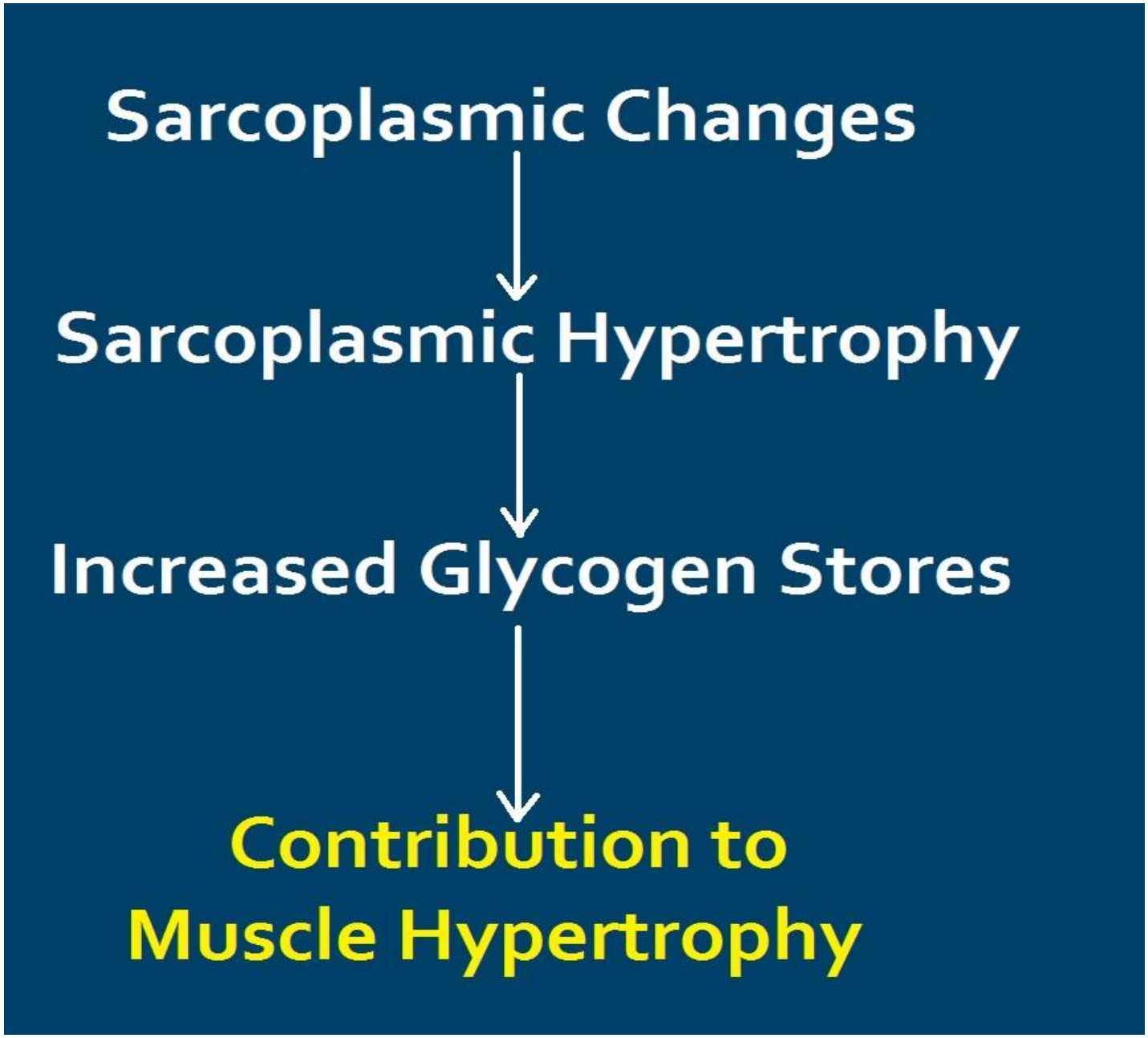
Muscle Growth and Hypertrophy:

- **Studies by using radioactive tracer show that muscle lengthening occurs mainly by adding new sarcomeres to the fiber at the junction of muscle and tendon.**

- **What is the exact mechanism of hypertrophy? It is controversial .**

Possible Mechanism of Hypertrophy:




Sarcoplasmic Changes
Sarcoplasmic Hypertrophy
Increased Glycogen Stores
Contribution to
Muscle Hypertrophy

Energy Systems and Sources for Muscles:

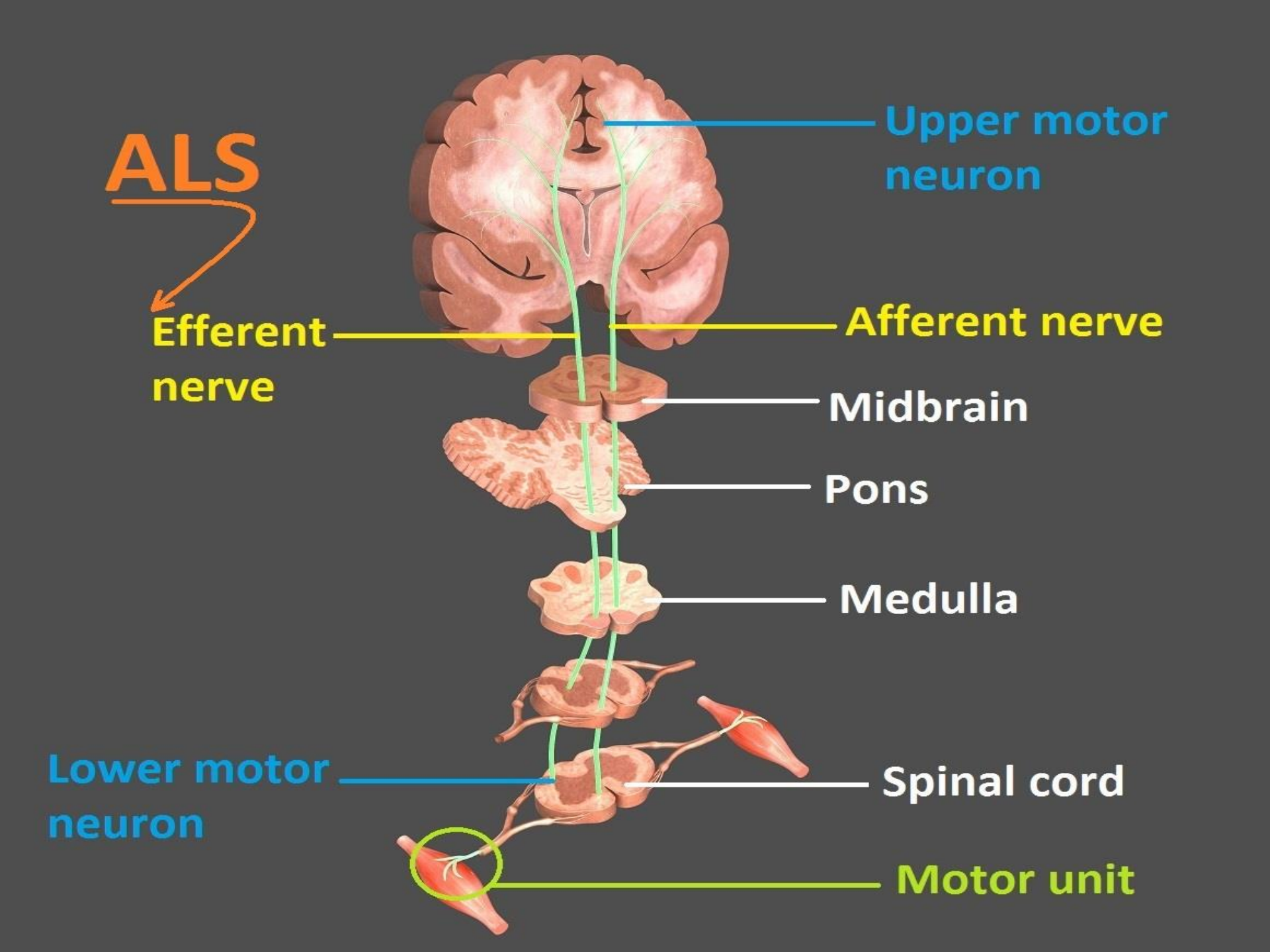
	Fiber Type I	Fiber Type IIA	Fiber Type IIX
Aerobic	High	Medium	Low
Anaerobic	Low	Medium	High
Main fuel	Triglyceride	Glycogen, Creatine phosphate	Glycogen, Creatine phosphate

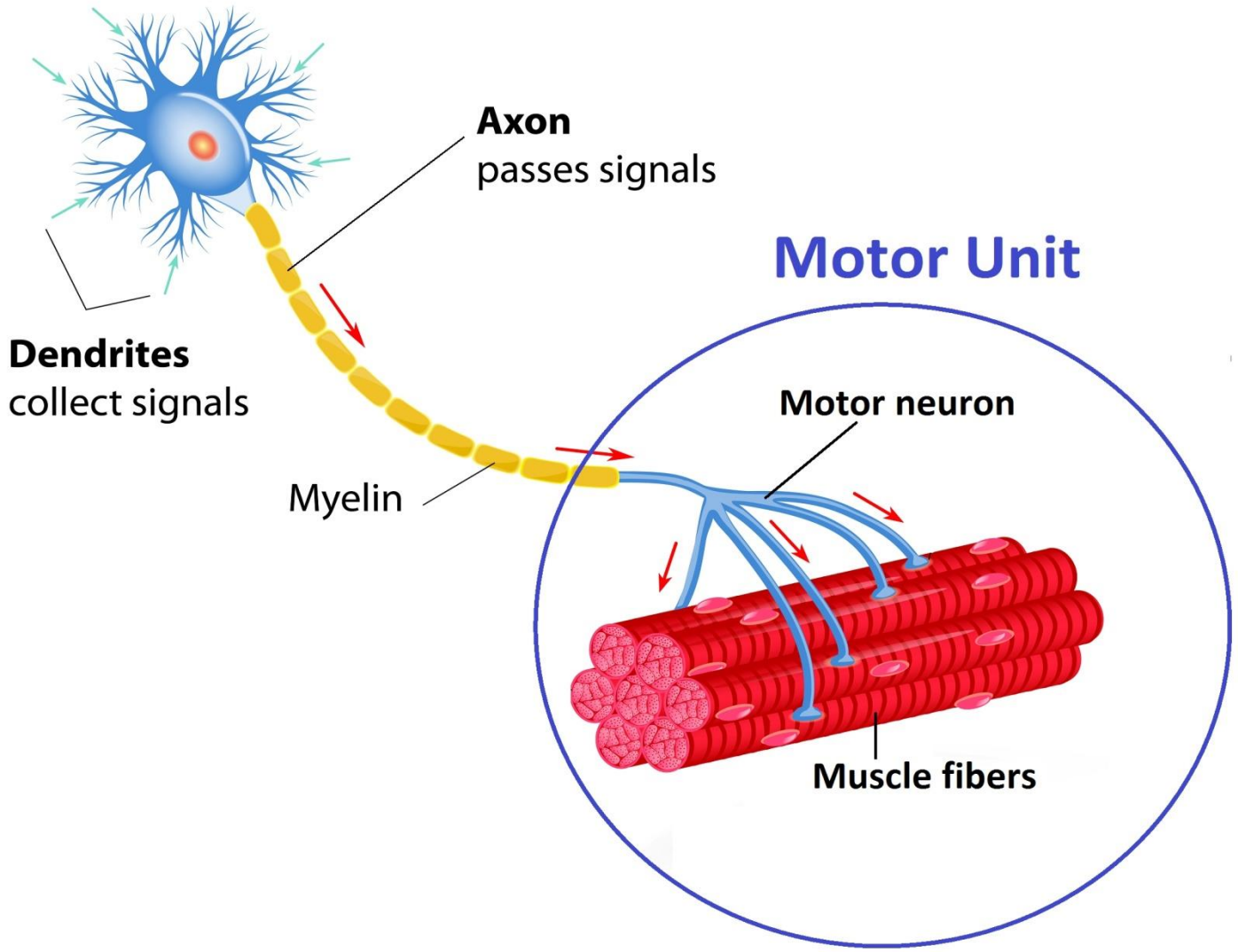
Neuromuscular Control:

- **The muscles and their movements are controlled by somatic nerves.**
- **Each muscle fiber is innervated by a single motor neuron.**
- **The neurons that control motor function are called "*motoneurons* or *alpha motoneurons*".**

Motor Unit:

- **A motor unit consists of one motor neuron and the group of muscle fibers it innervates.**
- **It is the functional unit of movement.**
- **The motor neurons that supply motor units are located at the ventral horn of the spinal cord and are called "*lower motor neurons (LMNs)".***
- **LMNs are controlled by motor neurons from the cerebral cortex, which are called "*upper motor neurons (UMNs)*".**


ALS
Upper motor neuron
Efferent nerve
Afferent nerve
Midbrain
Pons
Medulla
Lower motor neuron
Spinal cord
Motor unit


Axon
passes signals
Motor Unit
Dendrites
collect signals
Motor neuron
Myelin
Muscle fibers

- **How many fibers can be innervated by one motor neuron?**

- **It depends on the movement function of a muscle. It could be from as low as 10 muscle fibers in the eyes muscles to over 2000 muscle fibers in large muscle groups.**

- **The synapse between LMNS and the muscle fibers of a motor unit is called "*neuromuscular junction*".**

Muscle Contraction and Movement:

- **Muscle contraction is the force and tension generated within the muscle and is initiated by physiologic changes and neurotransmitters at the neuromuscular junction.**

Types of Muscle Contraction:

- **Isometric contraction.**
- **Isotonic contraction.**
- **Concentric contraction.**
- **Eccentric contraction.**

Isometric contraction:

- **It is a contraction in which the muscle generates active tension without changing its length, such as trying to lift your car!**

- **In this type of contraction, the active tension is less than the load, and the load cannot be lifted or moved.**

Isotonic contraction:

- **It is a contraction in which the muscle generates active tension equals to the load.**

- **In this type of contraction, the tension remains stable but the muscle gets shorter, causing the load to be lifted or moved at the end.**

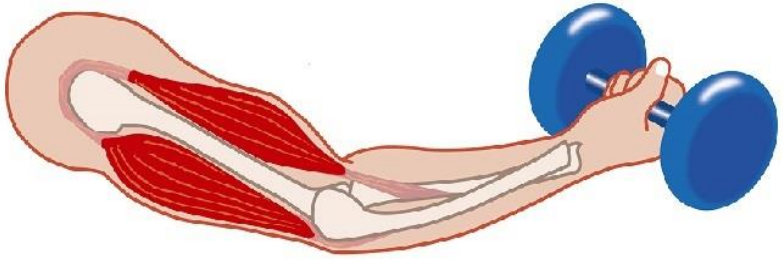
Concentric contraction:

- **It is a contraction in which the muscle tension is sufficient to overcome the load, and the muscle gets shortened as it contracts.**

Eccentric contraction:

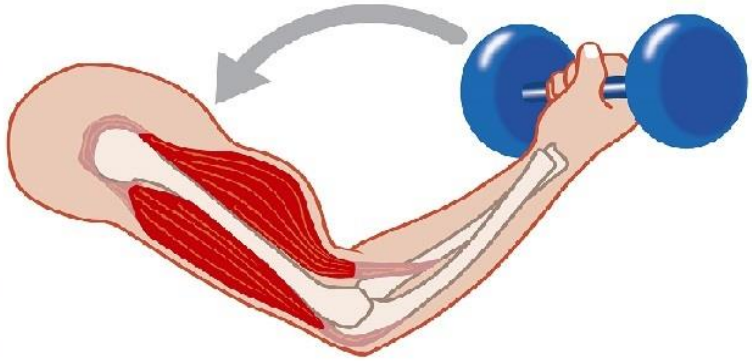
- **It is a contraction in which the tension generated by the muscle cannot overcome the load on the muscle and the muscle gets lengthened as it contracts.**

Isometric Contraction



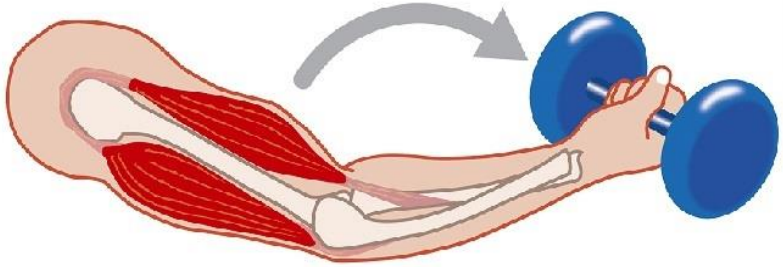
The muscle contracts, but does not shorten or lengthen.

Concentric Contraction



The muscle contracts and shortens.

Eccentric Contraction



The muscle contracts and lengthens.

- **Eccentric contraction stimulates muscle growth more than concentric contraction, as exercise-induced muscle damage is greater during lengthening contractions.**

Coordinated muscle movement require the action of two or more muscle groups:

- **Agonists: the muscle groups that promote a movement.**
- **Antagonists: the muscle groups that oppose a movement.**
- **Synergists: the muscle groups that assist the agonist muscles by stabilizing a joint or contributing additional fore to the movement.**

Tendon and Ligament:

Tendon:

- **The connective tissue that attaches muscle to bone. It generally transmits tensile force in one direction only.**

Ligament:

- **The connective tissue that attaches bone to bone. It must resist the separation of bones in more than one direction.**

Structure and Composition:

- **70% water.**
- **30% solid mass:**

- **Collagen 92% (mainly collagen type I)**
- **Elastin 3%**
- **Proteoglycans 4%**
- **Inorganic compounds 1%**

Ligaments are higher in elastin and lower in collagen.

Homework:

- **1) Describe the different types of muscle contractions.**

- **2) Describe as to how muscular hypertrophy happens.**