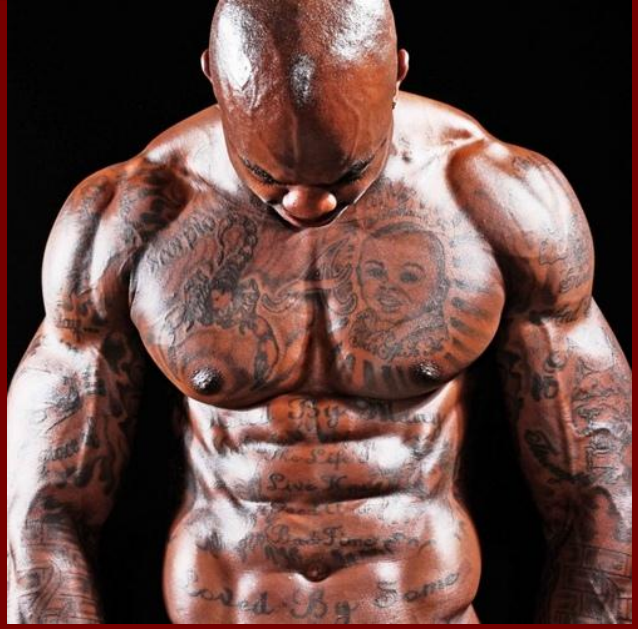
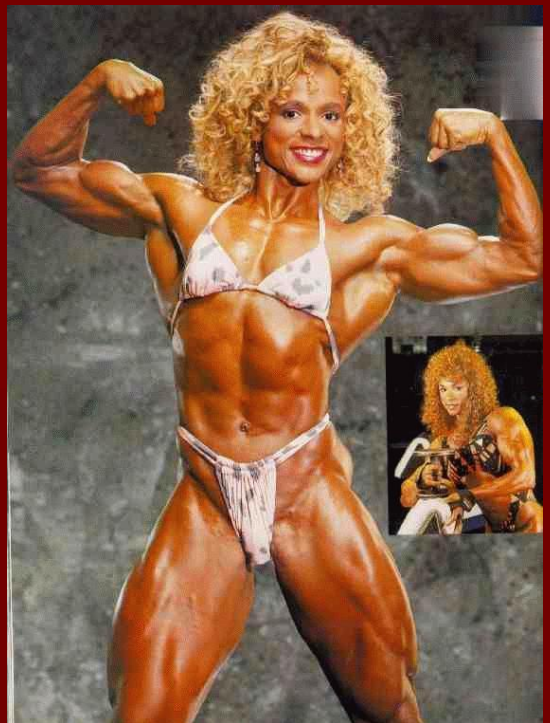
Muscular System



"The Machines of the Body"



Muscle Introduction

- Muscles make up the bulk of the body – about one-third of its weight
- Their ability to contract not only enables the body to move, but also provides the force that pushes substances, such as blood and food, through the body.
- Without the muscular system, none of the other organ systems would be able to function.

Functions of Muscular System

- External and internal body movement
- Maintaining posture
- Stabilizing joints
- Generation of heat (shivering)

Muscle Tissue Types

- Skeletal
- Cardiac
- Smooth

- Differ in structure, function, and location

How are the types the same?

- All muscle cells are elongated – called muscle fibers (thousands depending on muscle)
- Ability of muscle to shorted depends on two type of myofilaments
- Terminology –
  - Myo or mys = muscle
  - Sarco = flesh

Skeletal Muscle

- Body Location = attached to bone or to skin
- Appearance = single, long, cylindrical, multinucleated, **striated**
- Control = voluntary
- Speed of Contraction = slow to fast

Cardiac Muscle

- Body Location = walls of heart
- Appearance = branching chains, uninucleated, **striated**
- Control = involuntary
- Speed of Contraction = slow

Smooth Muscle

- Body Location = walls of hollow organs
- Appearance = single, tapered at each end, uninucleated, **not striated**
- Control = involuntary
- Speed of Contraction = very slow

Different parts of a muscular organ

- belly: bulging part of a muscle
- origin (head): the less moveable attachment (there can be more than one origin)
- insertion: the moveable attachment

Types of Body Movements

- Flexion = decrease in joint angle and brings two bones closer together
- Extension = increase in joint angle and brings two bones farther apart
- Pronation = moving from upward facing or anterior to downward facing or posterior
- Supination = moving from posterior position to anterior position
  - Like your holding a cup of soup

- Abduction = moving a limb away from midline of body
- Adduction = moving a limb toward the midline of body

- Circumduction = combination of flexion, extension, adduction, and abduction

- Dorsiflexion = movement of ankle bringing the toes up toward the shin
  - Standing on your heels
- Plantarflexion = movement of ankle causing the toes to point down
  - Standing on your toes

Types of Muscles

- Muscles can’t push, they can only pull as they contract
- Movement is the result of pairs or teams of muscles working together

Types of Muscles

1) Prime Movers – when several muscles are contracting at once, it the muscle that has the major responsibility for causing the movement
2) Antagonists – muscles that oppose or reverse a movement
3) Synergists – help prime movers by making same movement or reduce other unnecessary movements

Muscle Names

- Relative size of muscle – *(gluteus maximus)*
- Location of muscle – named for the bone *(temporalis)*
- Number of origins – *(biceps, triceps, quadrips)*
- Location of muscle's origin and insertion – *(sternocleidomastoid)*
- Shape of muscle – *(deltoid)*
- Action of muscle – *(adductor longus, extensors of wrist)*

Muscle Activity

- With a partner, demonstrate the following movements at different joints in the body.
- Write down what muscles are responsible for each movement

- Neck: flexion and extension
- Shoulder: adduction and abduction
- Elbow: flexion and extension
- Wrist: adduction and abduction
- Knee: flexion and extension
- Ankle: dorsiflexion and plantar flexion

General Skeletal Muscle Structure

- Muscle tissue = Muscle fibers, as well as large amounts of connective tissue, blood vessels, and nerves
- Connective tissue covers and supports each muscle fiber and reinforces the muscle as a whole

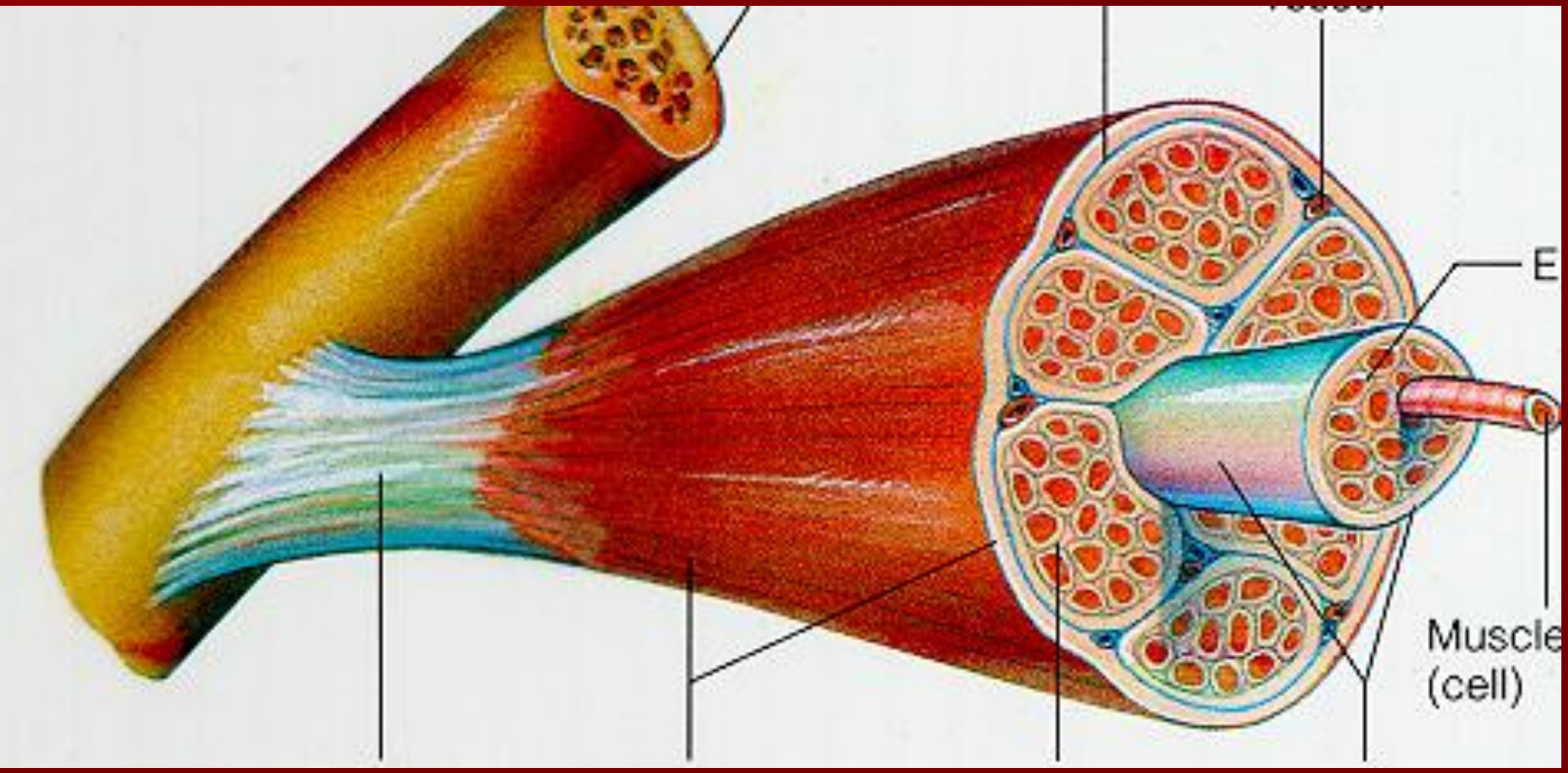
- Health of muscle depends on a sufficient nerve and blood supply. Each skeletal muscle has a nerve ending that controls its activity.

- Active muscles use a lot of energy and require a continuous supply of oxygen and nutrients
  - supplied by arteries
  - muscles produce large amounts of metabolic waste that must be removed by veins

Organization of Skeletal Muscle

- Fascia – fibrous connective tissue under the hypodermis that surrounds functional groups of the muscle
- Single muscles are surrounded by tough, dense connective **epimysium** - which extends and merges with the **tendon** (epi = upon) (myo = muscle)
- Tendon attaches to **periosteum** (covers bone)
- Epimysium surrounds many **fascicles** (bundles)

- A single fascicle is surrounded by **perimysium** (collagenic) (peri = around).
- A fascicle contains **endomysium** (areolar tissue) and **muscle fibers** (muscle cells).
- **Endomysium** surrounds muscle fibers (cells)
- Muscle fibers are long cylindrical cells containing **myofilaments**
- Myofilaments are proteins which are part of the functional contractile unit of skeletal muscle, known as the **sarcomere**


E
Muscle
(cell)

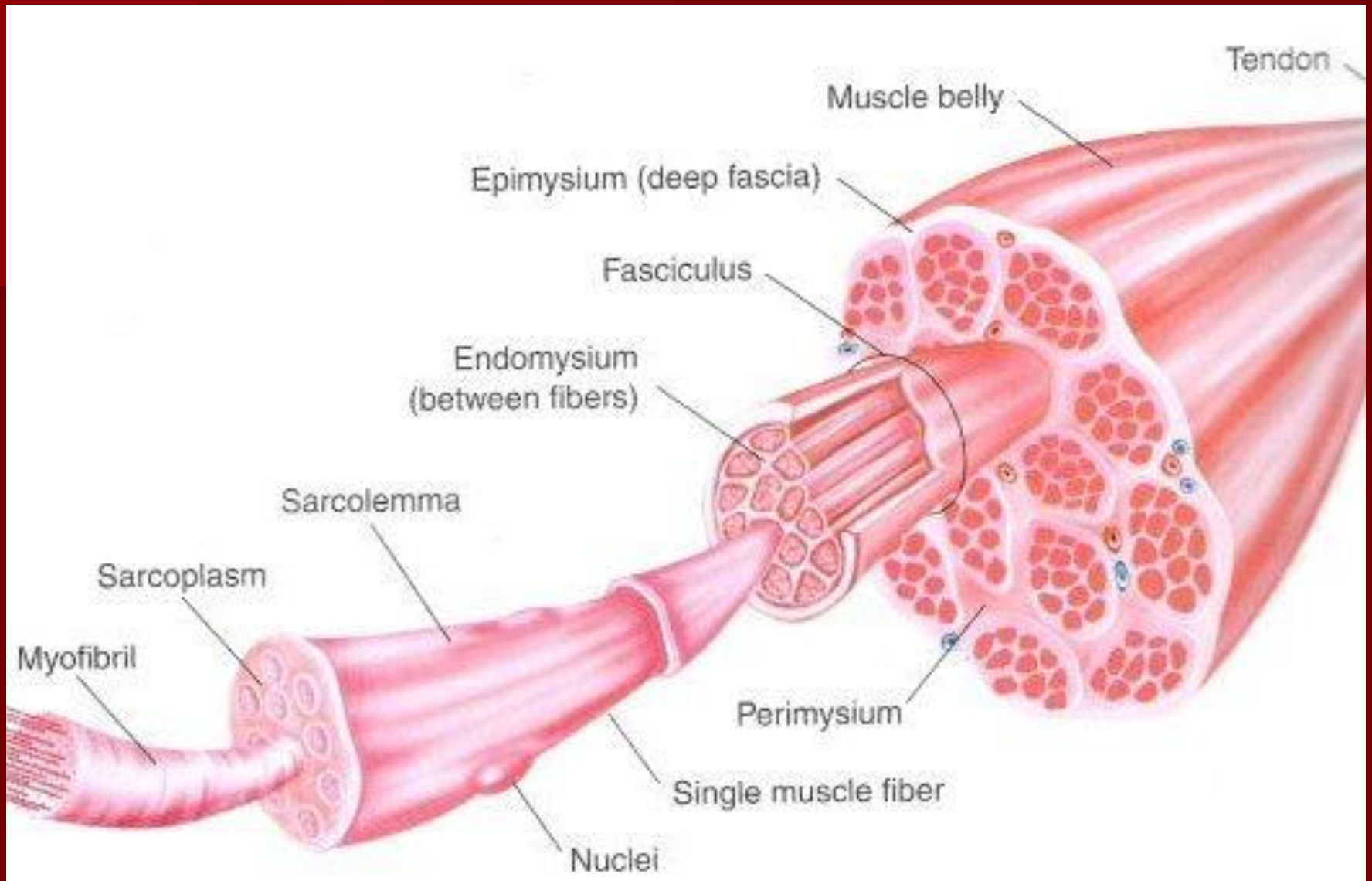
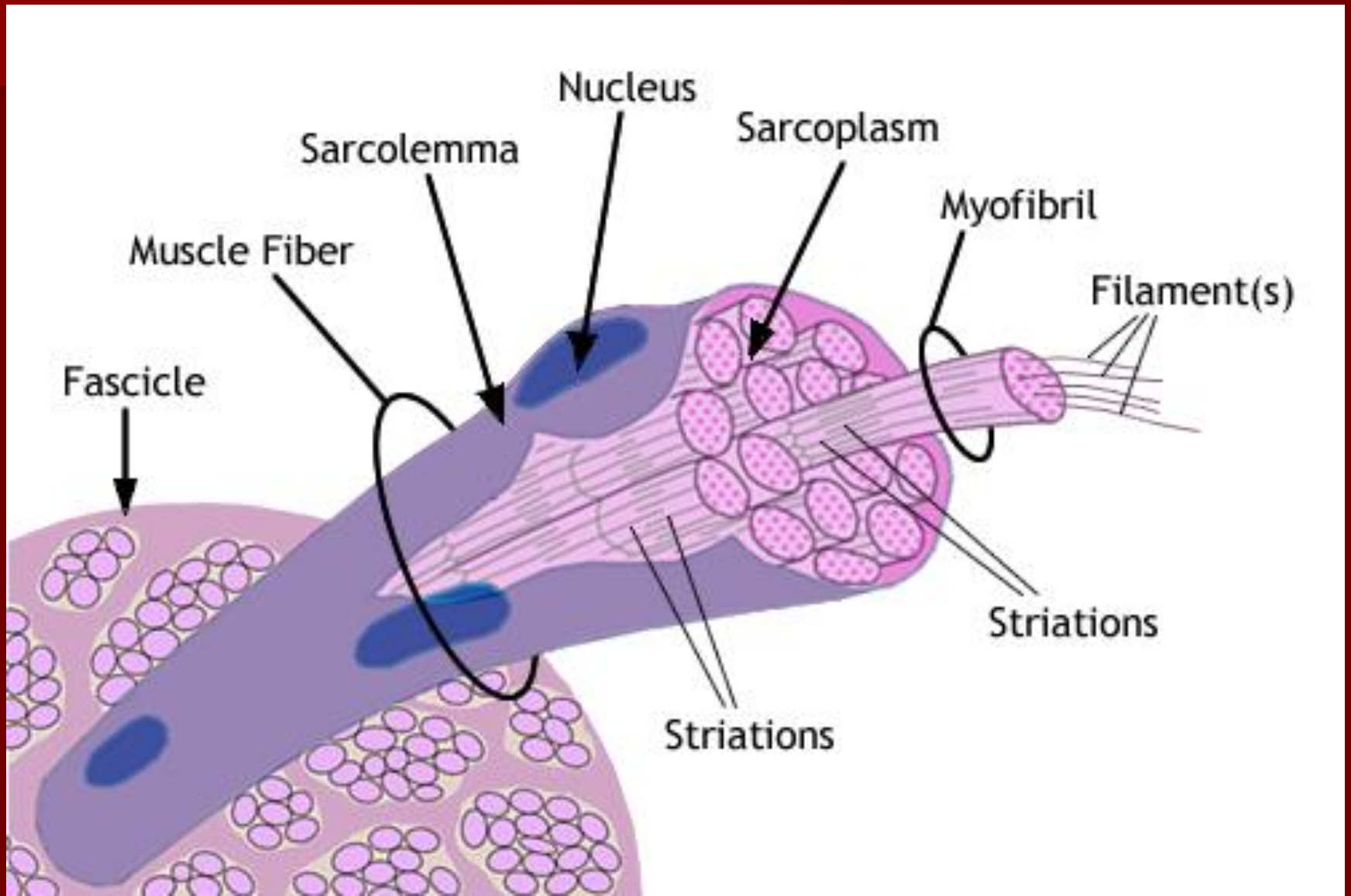


Figure 1: Muscle belly split into various component parts (from Essentials of Strength Training & Conditioning, National Strength & Conditioning Association)

Microscopic Anatomy of Muscle

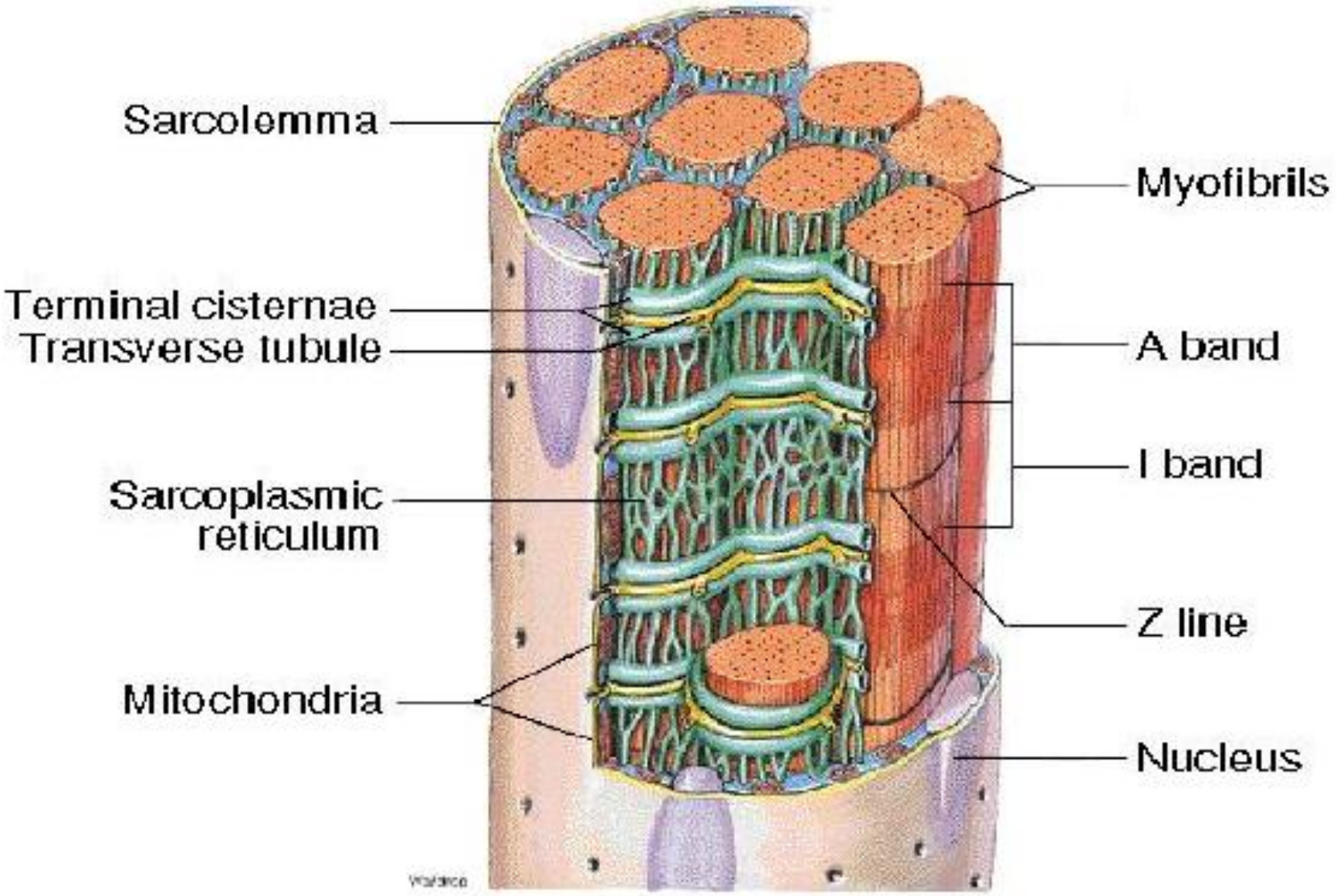


Parts of Muscle Fiber

- Many Nuclei
- Cell membrane = sarcolemma
- Myofibrils
- Cytoplasm
- Mitochondria
- Sarcoplasmic reticulum
- Transverse tubules – T tubes

- Myofibrils contain light and dark bands depending on where the actin and myosin are located

- Myofibrils = chains of tiny contractile units called **sarcomeres**

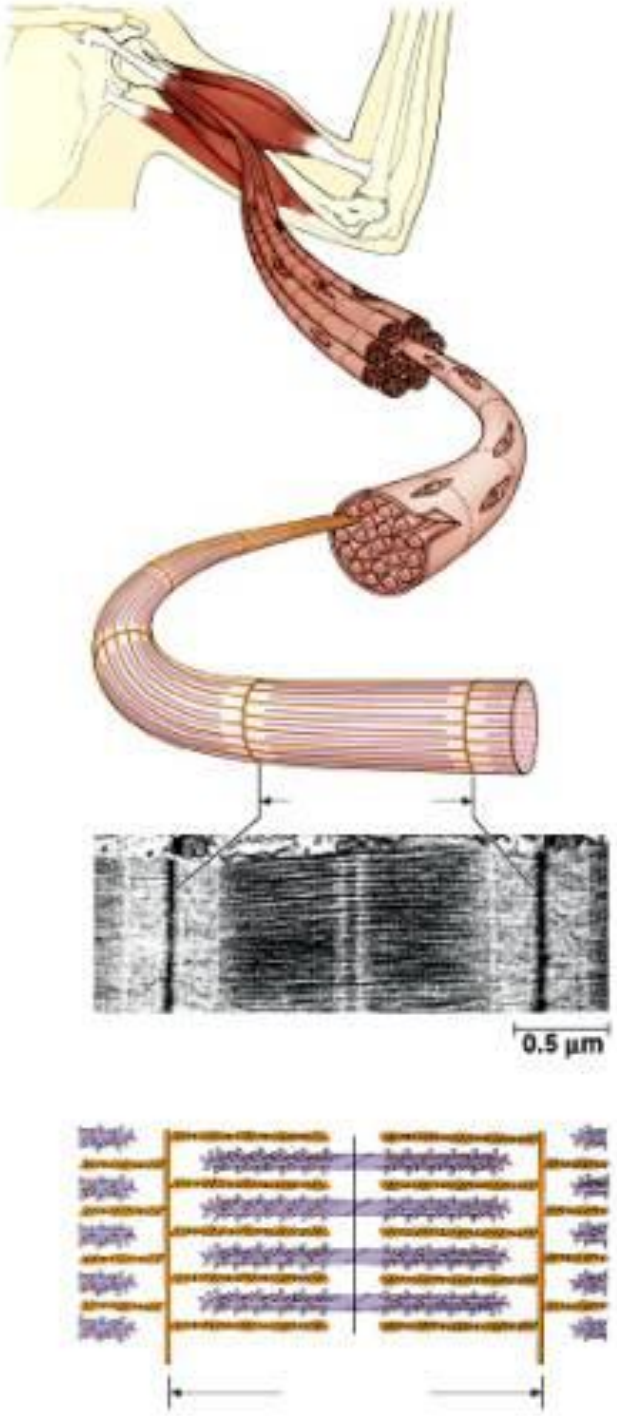

Sarcolemma
Terminal cisternae
Transverse tubule
Sarcoplasmic reticulum
Mitochondria
Myofibrils
A band
I band
Z line
Nucleus

TWO Types of Protein Filaments

Thick ones and Thin ones:

- THICK FILAMENTS are made up of a PROTEIN called **MYOSIN**
- THIN FILAMENTS are made of a PROTEIN called **ACTIN**

- Myosin and Actin Filaments are arranged to form overlapping patterns
- Theses are responsible for the Light and Dark Bands that can be seen in Skeletal Muscle (Striated Appearance)



Sarcomere – tiny contractile units

- The structural and functional unit of skeletal muscle

- Actin is surrounded by the T-and-T system (troponin and tropomyosin)
- Myosin has extensions called heads, which can attach at actin binding sites reference points of a sarcomere

Zones of Sarcomere

- Z-line: the terminating end of a sarcomere (middle of one I-band)
- I-band (light): contains actin only
- A-band (dark): contains actin and myosin
- H-zone: contains myosin only

Muscle Physiology

Muscles are able to contract because of irritability and contractility (ability to shorten)

Steps to Muscle Contraction

1) Electrical impulse starts in spinal cord, travels down axon of motor neuron to the axonal terminal – caused by depolarization, Na in

2) Electrical impulse reaches the neuromuscular junction and the neurotransmitter Acetylcholine (ACh) is released from the vesicles of the neuron into the synaptic cleft

3) Acetylcholine binds to a protein and temporarily causes the sarcolemma to be permeable to Na+ and Na+ rushes into the muscle fiber

4) Upset in Na+ levels generates an action potential that doesn't stop until it travels the length of the cell membrane

Sliding Filament Theory

5) Meanwhile, the action potential causes Ca+ to be released from the sarcoplasmic reticulum and binds to the T and T system of actin

6) Ca+ causes the proteins to move, which exposes the binding sites for the heads of the myosin

7) Myosin heads attach to actin and pivot which shortens the sarcomere. Heads release and reattach causing more shortening. This process requires ATP.

8) Myosin never completely lets go of the actin, which causes the actin not to lengthen in between pivots of the myosin heads.

9) Ca+ and electrical impulse will cause the shortening of the muscle fibers and contract the muscle.

Muscle Relaxation

- Acetylcholine is broken down by enzymes as soon as action potential has passed. Single electrical impulse causes only one contraction.
- Sarcoplasmic reticulum begins to pump Ca+ back into its sacs
- As Ca+ is stripped from the T and T system on the actin, the proteins get returned to their original positions
- Myosin heads can't bind to sites on actin anymore
- Thick and thin filaments are no longer attached, and slide past one another and back to original resting length

Graded Response

- "All or None" Law – muscle cell will contract to its fullest when adequately stimulated
  - Never partially contracts

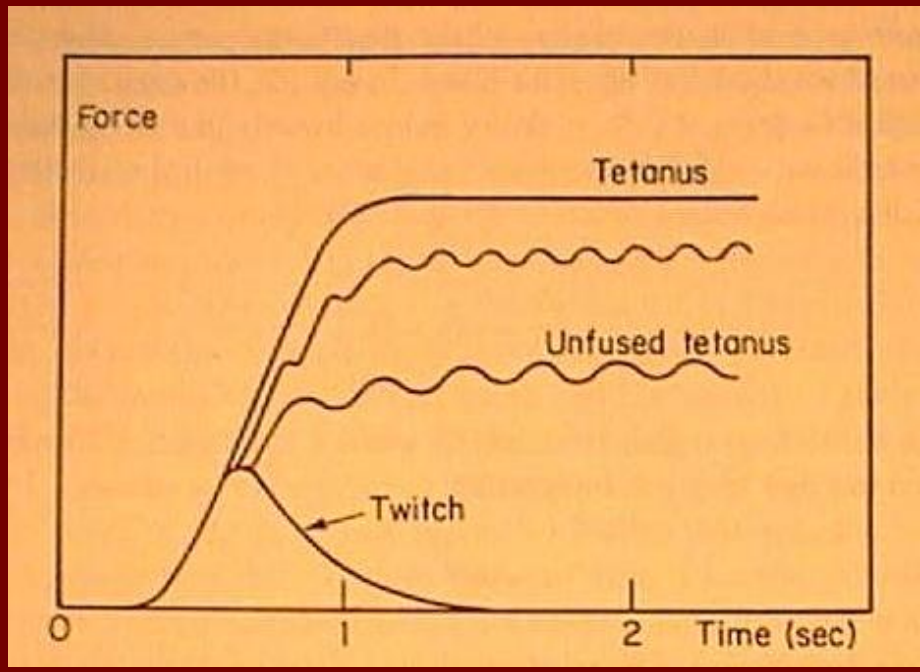
- Graded Response – degrees of shortening
  1) Changing speed of muscle contraction
  2) Changing number of muscle cells being stimulated

Muscle Response to Increasingly Rapid Stimulation

- Complete tetanas –

get very rapid stimuli, so rapid the muscle cells don't have time to relax between stimuli

  - Stronger and smoother contractions



- Muscle Twitches – single, brief, jerky contraction

Muscle Response to Stronger Stimuli

- When a few muscle cells are stimulated = contraction is slight

- When all muscle cells are stimulated = contraction is strong

"The same hand that soothes can deliver a stinging slap"

Energy for Muscle Contractions

- Need ATP to cause contractions – body only stores 4 to 6 seconds worth
- So, out body has to regenerate the ATP
- Our body does this by three pathways:

1)Direct phosphorylation of ADP by creatine phosphate

- CP + ADP → Creatine + ATP

- Creatine Monohydrate- natural supplement that helps your body make more ATP which delays the development of lactic acid as you workout

2) Aerobic Respiration – needs O_2

- Glucose + O_2 → H_2O + CO_2 + ATP
- Glycolysis → Krebs Cycle → Electron Transport Chain → Makes 38 ATP

– first pathway the body uses, but it is slow

3) Anaerobic glycolysis and lactic acid formation – does not need O2

- Glycolysis → No O2 → Lactic Acid → Makes 2 ATP

- working muscles requiring more nutrients that the body has to offer
- produces less ATP per glucose, but can last for 20 to 30 sec of strenuous activity
- drawbacks: use up glucose and accumulates lactic acid (muscle fatigue and soreness)