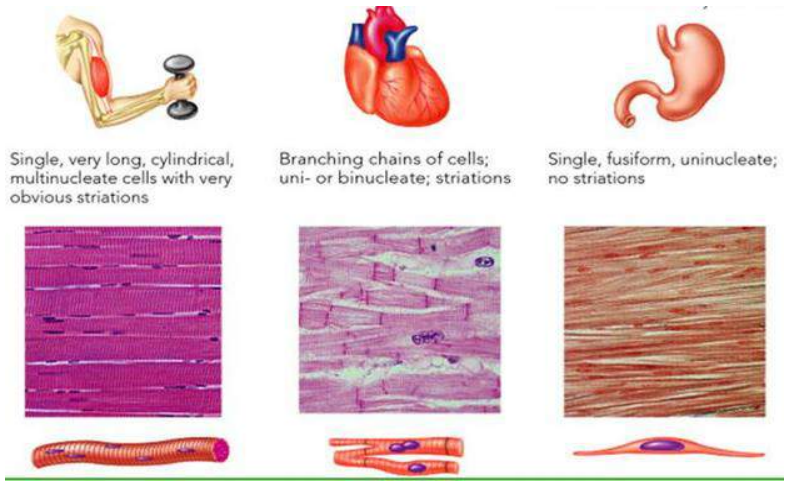
SKELETAL MUSCLE PHYSIOLOGY

PHYSIOLOGY OF SKELETAL MUSCLE

1. INTRODUCTION

- SKM is attached to skeleton and **helps to move the skeleton.**
- **STRIATED** - striped – with alternate light and dark band, when observed under microscope.
- Cylindrical
- Multinucleated
- Working mainly in VOLUNTARY manner: it means its activity can be consciously controlled – with exception of Diaphragm and muscle that maintain stability and posture.
- Capable of performing rapid and powerful contraction and also slow and sustained tonic contraction.



2. DISTRIBUTION

- Mostly in all instances are attached to BONES / OSSEOUS tissue.
- Attached to bones by means of TENDONS - [A densely packed non elastic fibrous connective tissue]
- Innervated with SOMATIC nerves. [pertaining to the body]
- Supported by various connective tissue – the tissue to a thin coat [EPIMYSIUM] cover for small bundles of muscle fibers [PERIMYSIUM] and each smaller bundles covered with delicate aerolar tissue [ENDOMYSIUM].

3. NERVE AND BLOOD SUPPLY

- Supplied with somatic motor neurons
- The axon of somatic nerve branches many times and each branch extending to each muscle fiber.
- Plenty of capillaries. – each muscle fiber is in contact with one/ more capillaries. [to oxygenate , remove heat and metabolic waste produced during contraction].

4. CHEMICAL COMPOSITION OF SKELETAL MUSCLE

- Water – 75%
- Solid – 25% >>> Proteins (20%) , Fat (0.2%), Carbohydrates(1%) , Inorganic salts (1-1.5%), Non Nitrogenous extracts, Nitrogenous extracts .
- Potassium, traces of calcium, sodium, Mg, Fe, chloride, Sulphate.
- Proteins : ACTIN, MYOSIN and their complexes [Tropomysin, Actomyosin] etc.
- Creatinine Phosphate, Xanthine, Hypoxanthine.
- Various Pigments : Myoglobin and Cytochrome.
- Enzymes and co enzymes of Glycolytic cycle.

ULTRA STACTURE OF SKELETAL MUSCLE

Each skeletal muscle is an organ that **consists of various integrated tissues.**

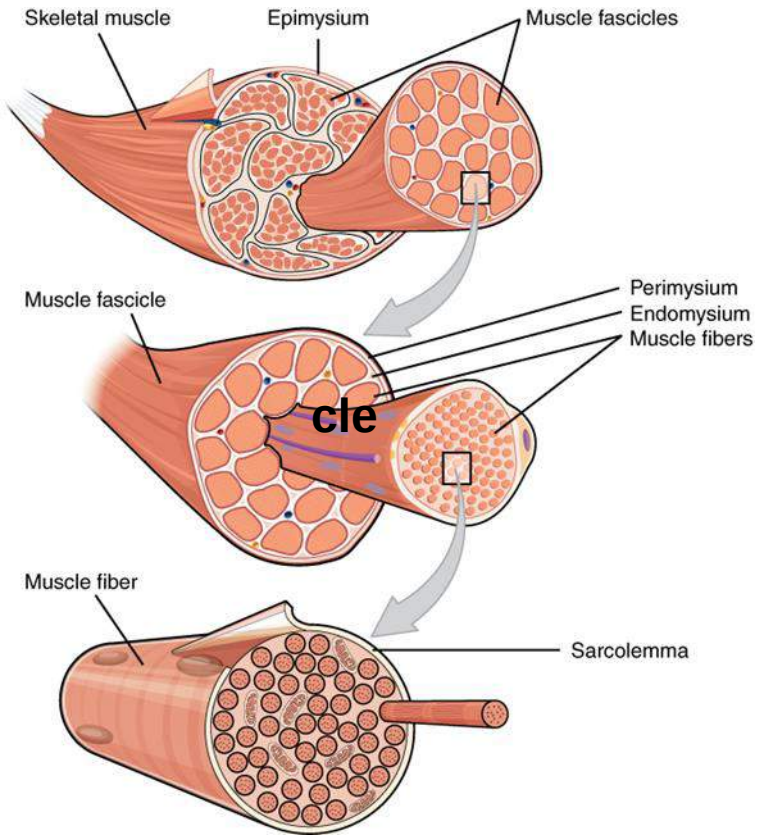
These tissues include the **skeletal muscle fibers, blood vessels, nerve fibers, and connective tissue**.

Each skeletal muscle has **three layers of connective tissue** (called "**mysia**") that enclose it and provide structure to the muscle as a whole, and also **compartmentalize the muscle fibers within the muscle**

Each muscle is wrapped in a sheath of dense, irregular connective tissue called the epimysium, which **allows a muscle to contract and move powerfully** while maintaining its structural integrity. The epimysium **also separates muscle from other tissues and organs in the area**, allowing the muscle to move independently.

Inside each skeletal muscle, **muscle fibers are organized into individual bundles**, each **called a fascicle,** by a **middle layer of connective tissue** called the **perimysium.**

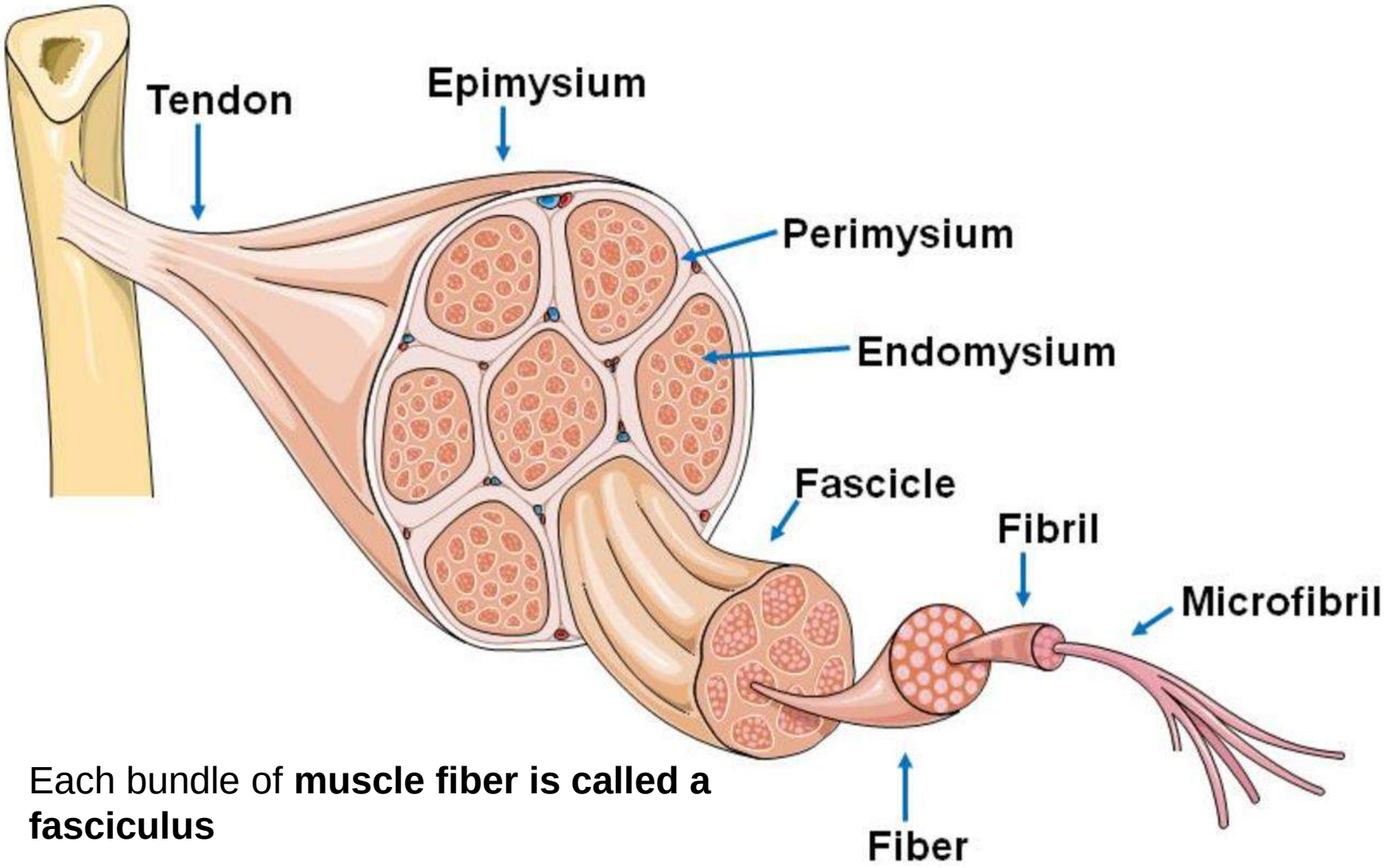
ULTRA STACTURE OF SKELETAL MUSCLE



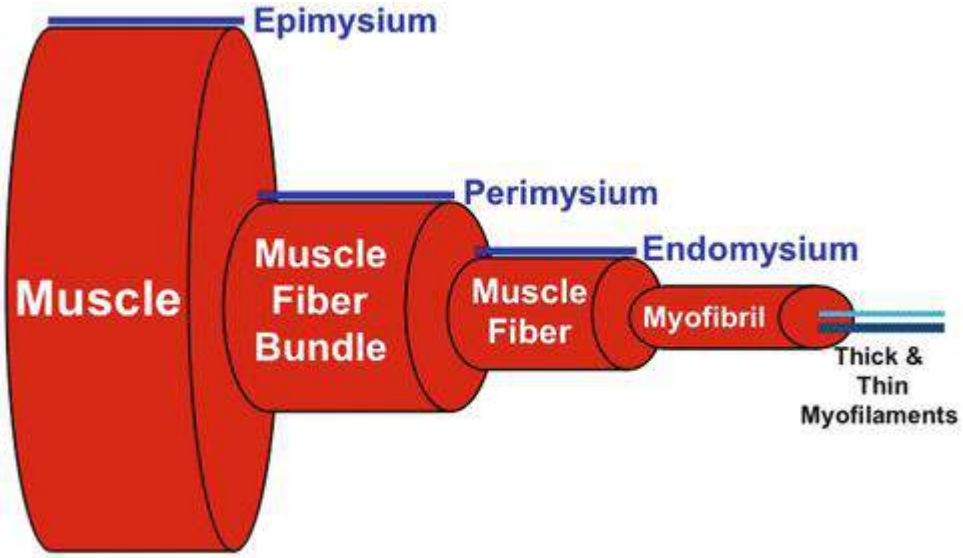
Inside each fascicle, each muscle fiber is encased in a thin connective tissue layer of collagen and reticular fibers called the endomysium.

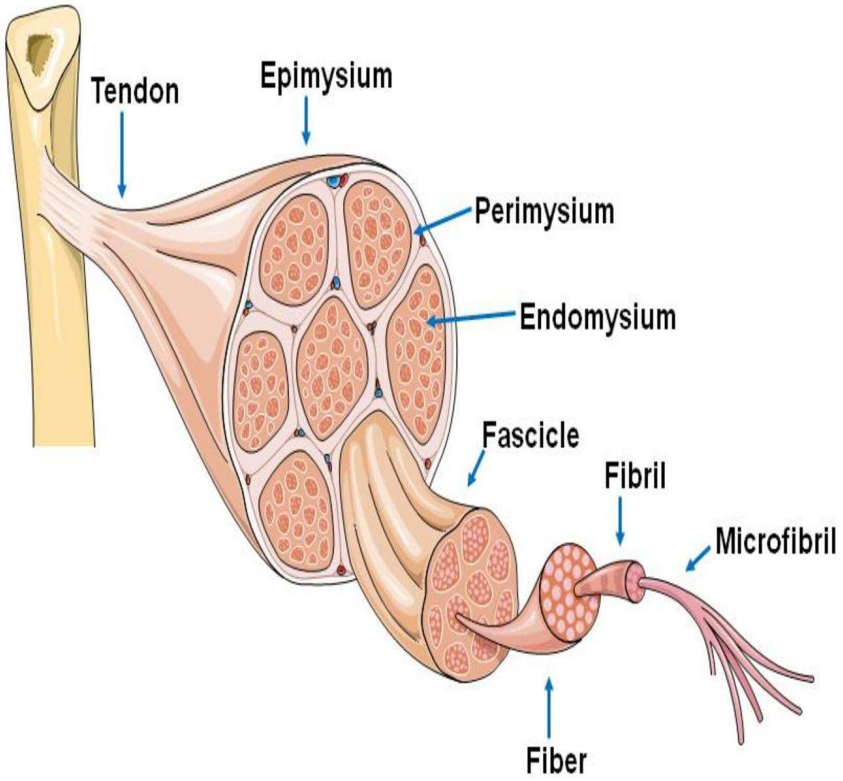
The endomysium contains the extracellular fluid and are vascularized.

ULTRA STACTURE OF SKELETAL MUSCLE



Each bundle of **muscle fiber is called a fasciculus**





Every skeletal muscle is also richly vascularized for nourishment, oxygen delivery, and waste removal. In addition, every muscle fiber in a skeletal muscle is **supplied by the axon branch of a somatic motor neuron, which signals the fiber to contract.**

Unlike cardiac and smooth muscle, the **only way to functionally contract a skeletal muscle is through signaling from the nervous system**.

ULTRA STACTURE OF SKELETAL MUSCLE

SKELETAL MUSCLE FIBERS

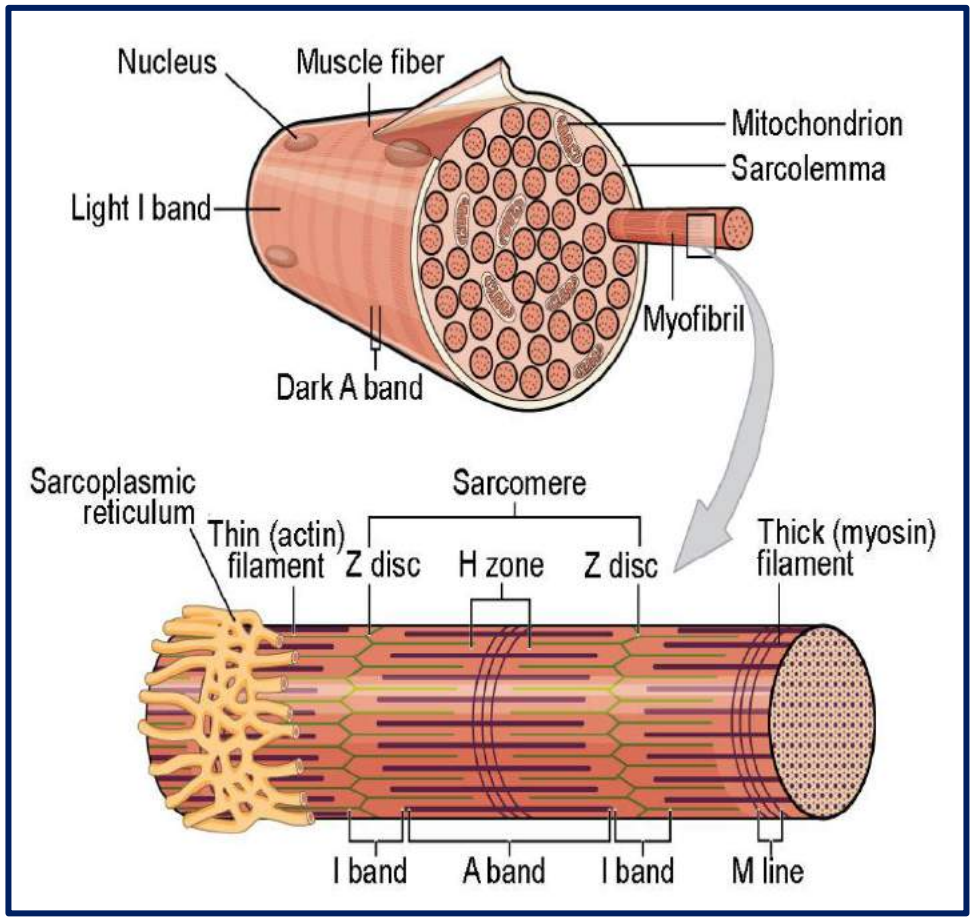
Because **skeletal muscle cells are long and cylindrical, they are commonly referred to as muscle fibers**.

Skeletal muscle fibers can be **quite large for human cells, with diameters up to 100 µm and lengths up to 30 cm (11.8 in) in the Sartorius of the upper leg.**

Multiple nuclei mean multiple copies of genes, permitting the production of the large amounts of proteins and enzymes needed for muscle contraction.

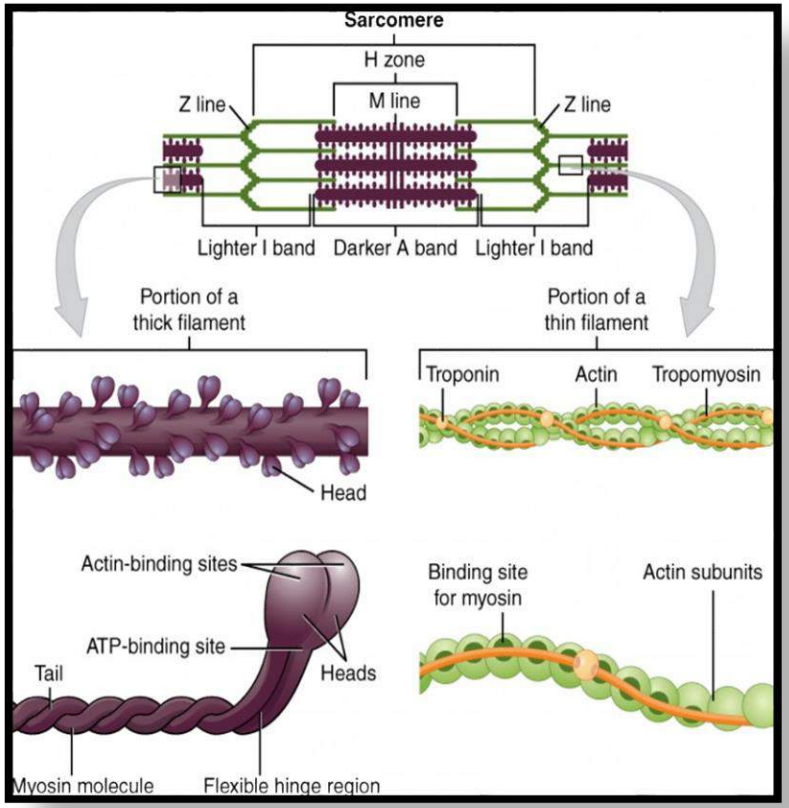
The **plasma membrane of muscle fibers is called the sarcolemma**, the **cytoplasm is referred to as sarcoplasm,** and the specialized **smooth endoplasmic reticulum**, which stores, releases, and retrieves calcium ions (Ca++) is called the **sarcoplasmic reticulum** (SR) (Figure 2).

The functional unit of a **skeletal muscle fiber is the sarcomere**, a **highly organized arrangement of the contractile myofilaments: actin (thin filament) and myosin (thick filament), along with other support proteins.**



THE SARCOMERE

The sarcomere is the **functional unit of the muscle fiber.**



THE SARCOMERE

The sarcomere is the **functional unit of the muscle fiber.**

The striated appearance of skeletal muscle fibers is **due to the arrangement of the myofilaments of actin and myosin in sequential order from one end of the muscle fiber to the other**.

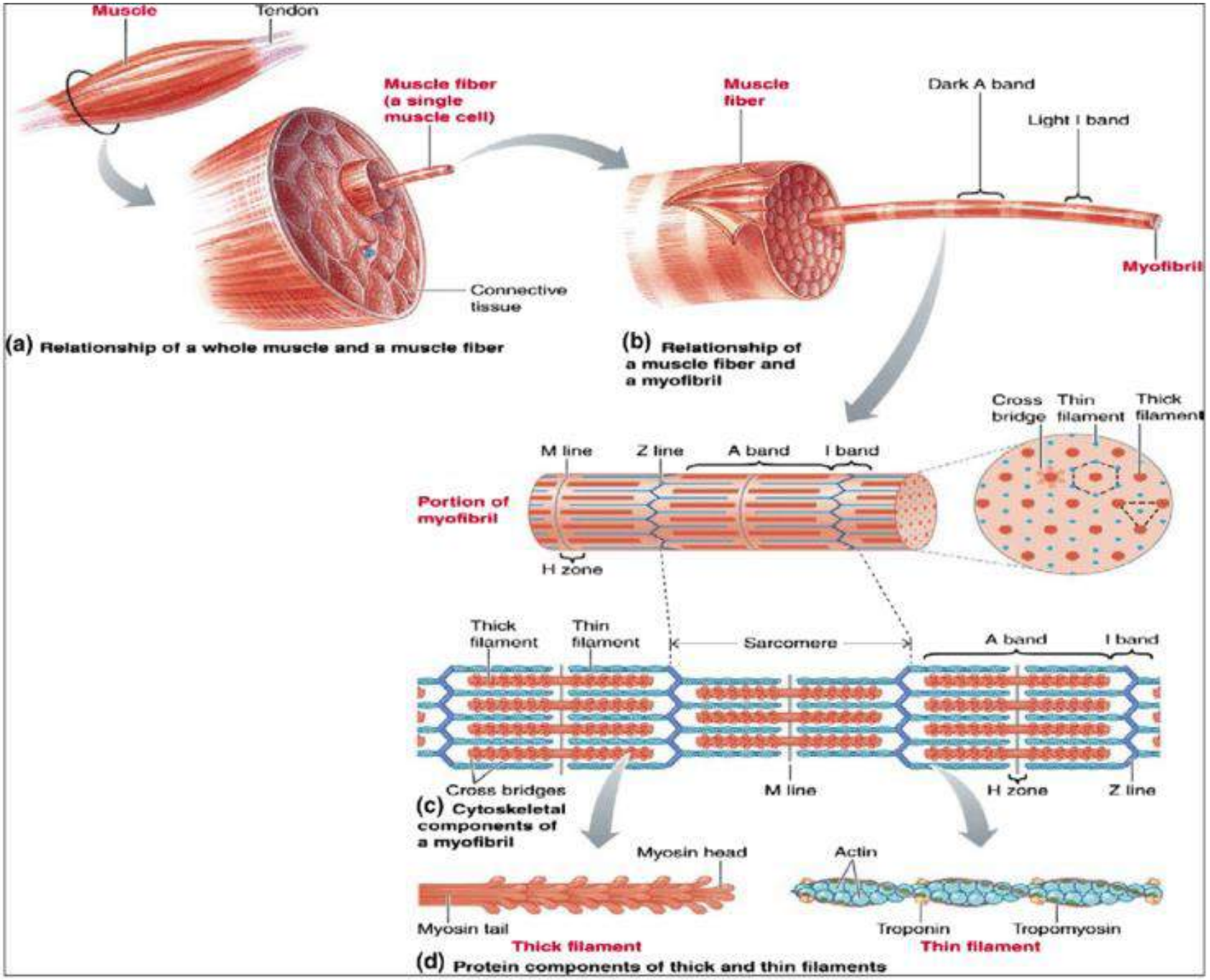
Each **packet of these microfilaments and their regulatory proteins, troponin and tropomyosin (along with other proteins) is called a sarcomere.**

The sarcomere itself is **bundled within the myofibril** that runs the entire length of the muscle fiber and attaches to the sarcolemma at its end.

As **myofibrils contract, the entire muscle cell contracts**.

Each **sarcomere** is approximately 2 μm in length with a three-dimensional cylinder-like arrangement and is **bordered by structures called Z-discs** (also called Z-lines, because pictures are two-dimensional), to which the actin myofilaments are anchored (Figure 3).

The **thin filament** of the sarcomere are strands that are **thinner than myosin** Likewise, because the myosin strands and their multiple heads have **more mass and are thicker, they are called the thick filament of the sarcomere.**


Muscle
Tendon
Muscle fiber (a single muscle cell)
Connective tissue
(a) Relationship of a whole muscle and a muscle fiber
Muscle fiber
Dark A band
Light I band
Myofibril
(b) Relationship of a muscle fiber and a myofibril
Cross bridge
Thin filament
Thick filament
M line
Z line
A band
I band
Portion of myofibril
H zone
Thick filament
Thin filament
Sarcomere
A band
I band
Cross bridges
M line
H zone
Z line
(c) Cytoskeletal components of a myofibril
Myosin head
Actin
Myosin tail
Troponin
Tropomyosin
Thick filament
Thin filament
(d) Protein components of thick and thin filaments

TYPES OF SKELETAL MUSCLE

- SKM ***are not all alike – in composition and function.***
- E.g : Difference in the myoglobin content.
- RED muscle fibers – rich in myoglobin, appears darker, more mitochondria and blood vessels
- White muscle fibers – low content of myoglobin.
- Differ in the speed with which they contract and relax and fatigued.

1. SLOW OXIDATIVE FIBERS

1. Smallest in DIA and are LEAST powerful among them.
2. Rich in Myoglobin [reddish] and highly vascularized.
3. Large amount of Mitochondria – generates ATP by aerobic cellular respiration [oxidation – hence the name].
4. Slow rate of contraction.
5. Very Resistant to fatigue. >>> Prolonged contraction
6. Adapted for endurance and maintenance of posture.
7. **Twitch contractions lasting 100-200 msecs.**

2. FAST OXIDATIVE GLYCOLYTIC FIBERS

1. Intermediate in Diamter b/w these types.
2. Rich in myoglobin.
3. Richly vascularized.
4. Generates considerable amount of energy,
5. Moderately resistant to fatigue.
6. Generates ATP by anaerobic glycolysis.
7. FASTER RATE OF CONTRACTION.
8. **Twitch contractions lasting less than 100 msecs.**

FAST GLYCOLYTIC FIBERS

1. Largest in diameter
2. Contain most myofibrils.
3. Capable of generating most powerful contraction.
4. Low myoglobin content, fewer blood capillaries
5. Large amount of GLYCOGEN
6. Generates ATP by glycolysis.
7. ***Faster fatigue.***

SKELETAL MUSCLE PHYSIOLOGY

5. PROPERTIES OF SKELETAL MUSCLE

1. IRRITABILTY / EXCITABILITY AND CONTRACTALITY

- With an [application of] adequate stimulus, SKM are excited.
- In other words, when mechanical / electrical/ thermal / chemical stimulus of adequate strength is applied, SKM gets excited, shows irritability.
- When Excited, they **CONTRACT >>> Immediately RELAX.**
- Extent of irritability is influenced by *strength* and *duration* of stimulation.
- When *repeatedly* stimulated, SKM looses irritability, gradually becomes *lesser and lesser excitable* and ultimately seizes to respond to stimulus of any strength – referred to as **FATIGUE** - due to accumulation of bi products of metabolism.
- Can be demonstrated by applying electrical current of sufficient strength to an isolated piece of skeletal muscle >>> results in ***contraction followed by relaxation.***
- The duartion of such an event is **0.1 SECONDS** and consists of various phases : *Latent Phase* [0.01 seconds], *Period of contraction* [0.04 seconds] and *Period of relaxation* [0.05 seconds]

2. REFRACTORINESS [*Refractory Period*]

- *After* stimulation, there is *brief* period, during which the muscle is ***not*** *excitable to a second stimulus.* – it means, *muscle fails to contract* [and relax] to a second stimulus [fails to respond]
- Duration : 0.002 [mammalian] 0.005 Second [frog SKM]

Heat shortens the refractory period, **cold prolongs** the refractory period

- ***Absolute Refractory Period***: *is the first part of RP, during when muscle remains unexcitable to stimulus of any strength.*
- ***Relative Refractory Period***: *The latter half of RP, when the muscle is excitable to relatively stronger stimulus.*

3. **TONICITY**

   In the body SKM ***always remain in a state of light tension*** – referred to as tone of the muscle. Tone is defined as reflex sustained and partial contraction.

4. **CONDUCTIVITY**

   After stimulation, the wave of contraction, starts at the point of stimulus and propagated both the ways along the muscle.

5. **EXTENSIBILITY AND ELASTICITY:** Muscles extends when stretched , without being damaged and goes back to it's original length [slowly] – called ***extension remainder.***

SKELETAL MUSCLE in HOMEOSTASIS

- Skeletal muscles contribute to the maintenance of homeostasis in the body by generating heat.
- Muscle contraction requires energy, and when ATP is broken down, heat is produced.
- This heat is very noticeable during exercise, when sustained muscle movement causes body temperature to rise, and in cases of extreme cold, when shivering produces random skeletal muscle contractions to generate heat.