Essentials of Zoology

(Cytology and Histology)

1st year General Biology/Ecology students

2019-2020

Lec. 8

Intended learning outcomes (ILO's):

By the end of this lecture, students should be able to:

1- List the different types of muscles.

2- Describe the structure and function of each type of muscles.

3- Define the neuromuscular junction and how it works.

4- State the mechanism of contraction for every muscle type.

Excitable tissues

- Muscles & Nerves: Together, the excitable tissues, are characterised by response to external excitation; part of response is electrical.

Muscular tissues

1- Skeletal muscles.

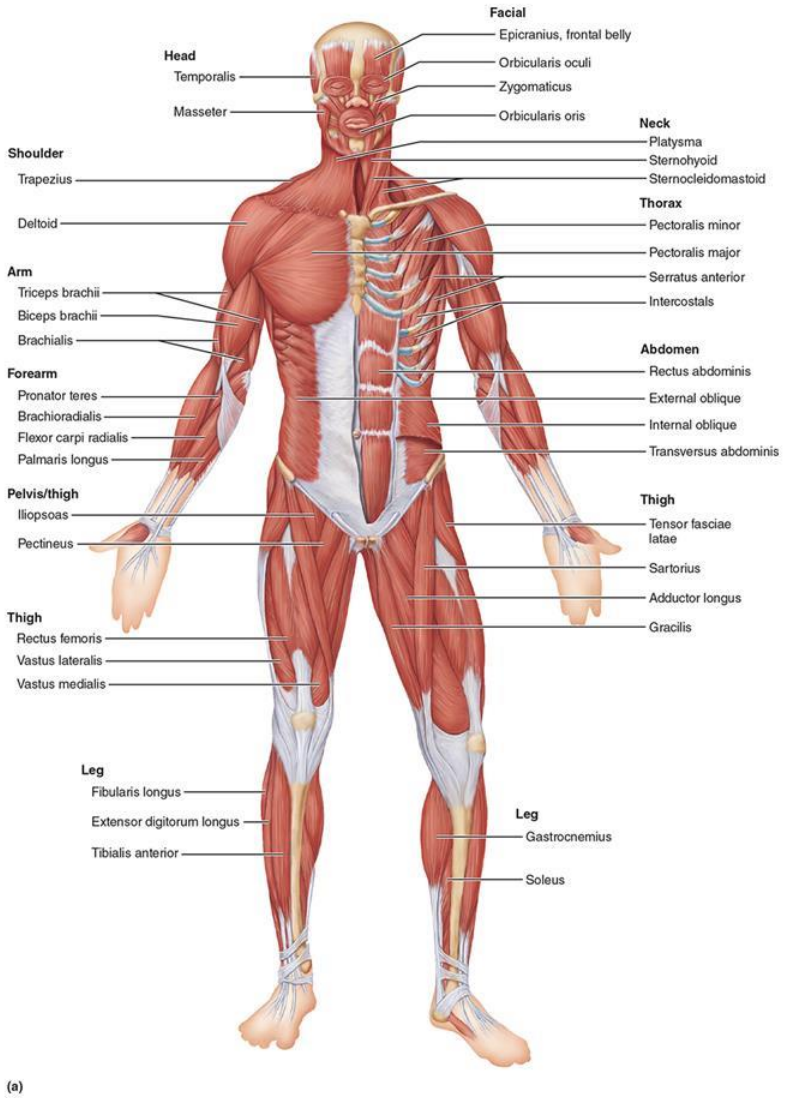
2- Cardiac muscles.

3- Smooth muscles.

1-Skeletal muscles

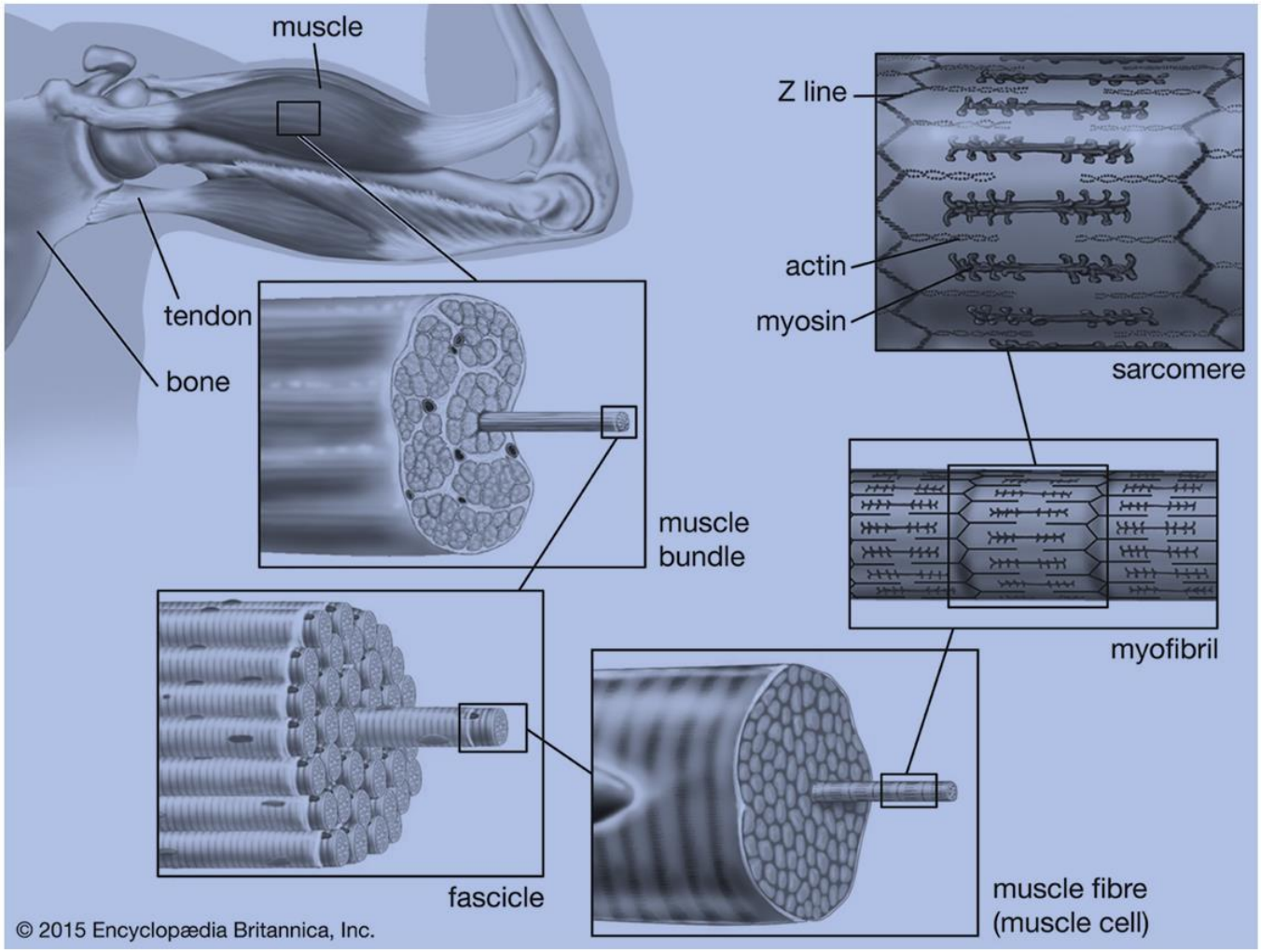
- Striated, voluntary muscles.
- Attached to the skeleton, so, their contraction moves the skeleton.

- Each muscle is composed of multiple bundles, each bundle is composed of many fascicles حزم of muscle fibers.



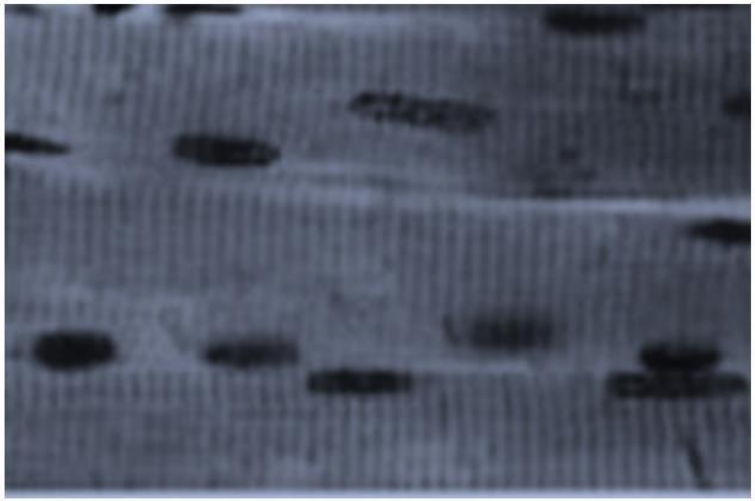
- Each fascicle contains many muscle fibers (elongated muscle cells).
- Fibers and muscles are surrounded by CT layers called fasciae لفافات .
- CT carries blood vessels, lymphatics, and nerve fibers to the muscle.

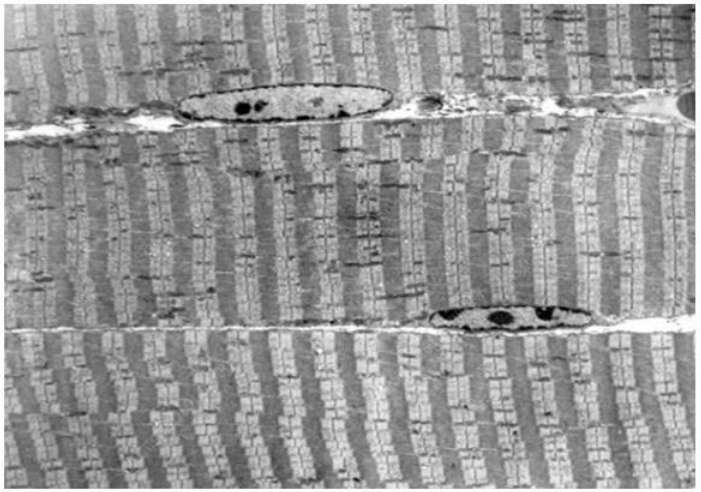
- Muscle fibers are cylindrical, have more than one nucleus (nuclei are multiple, long and peripheral) and they have multiple mitochondria to meet energy needs.



- Muscle fibers are the individual contractile units within a muscle.

- Under the microscope, skeletal muscle appears striated due to the arrangement of cytoskeletal elements in the cytoplasm of the muscle fibers.





- Muscle fibers are, in turn, composed of myofibrils.

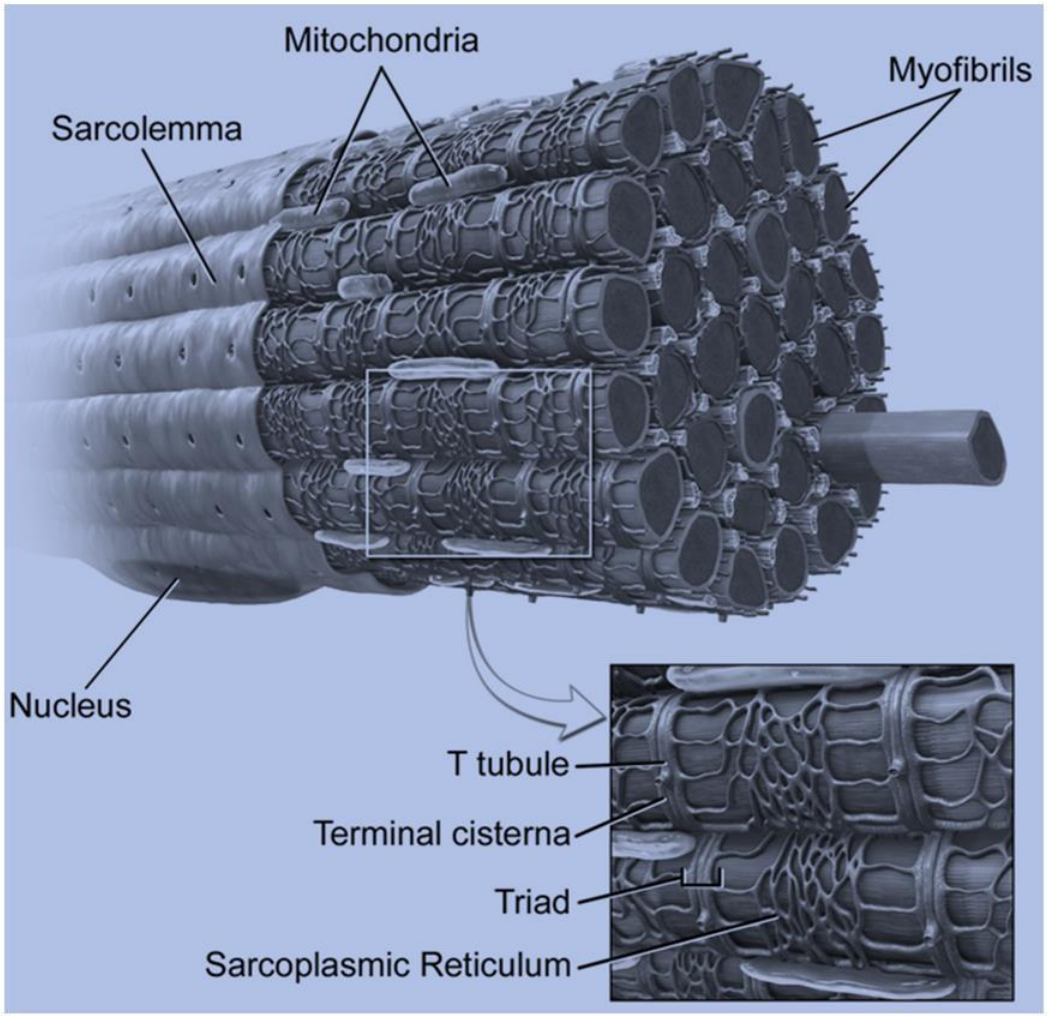
- Myofibrils are composed of actin and myosin filaments (Thin and thik filaments), repeated in units called sarcomeres, which are the basic functional units of the muscle fiber.

- The sarcomere is responsible for the striated appearance of skeletal muscle and forms the basic machinery necessary for muscle contraction.

- Every single organelle/structure of a muscle fiber is arranged to ensure "form meets function".

- The cell membrane is called the sarcolemma with the cytoplasm known as the sarcoplasm.

- The myofibrils lie in the sarcoplasm. (Myofibrils are long protein bundles about 1 μm in diameter each containing myofilaments (Act.+Myo.)).

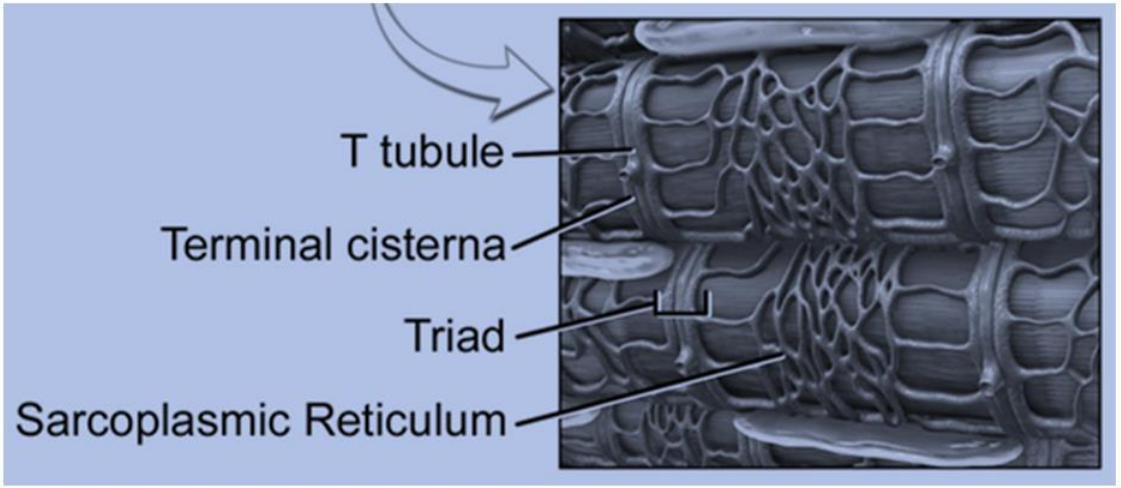


- Unusual flattened myonuclei are pressed against the inside of the sarcolemma.

- Mitochondria lie between the myofibrils.

- The muscle fiber does not have smooth endoplasmic cisternae, it contains a sarcoplasmic reticulum.

- The sarcoplasmic reticulum surrounds the myofibrils and holds a reserve of the Ca^{++} needed to cause a muscle contraction.



- Sarcoplasmic reticulum has dilated end sacs known as terminal cisternae.

- In between two terminal cisternae is a tubular infolding called a transverse tubule (T tubule). T tubules are the pathways for action potentials to signal the sarcoplasmic reticulum to release Ca^{++}, causing a muscle contraction.

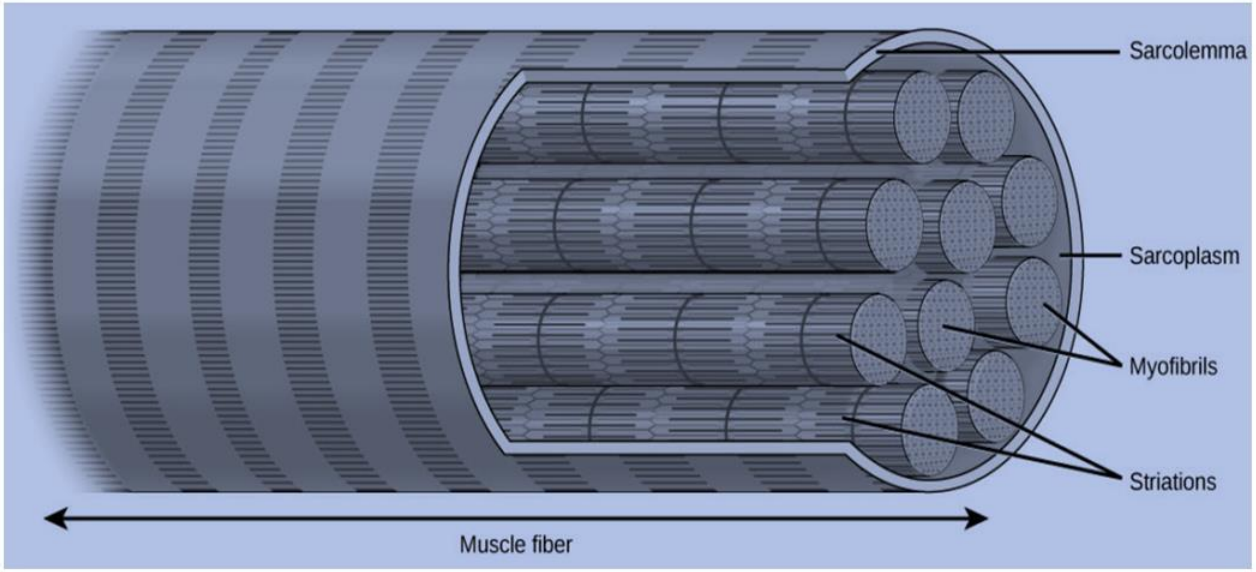
- Together, 2 terminal cisternae and a transverse tubule form a triad.

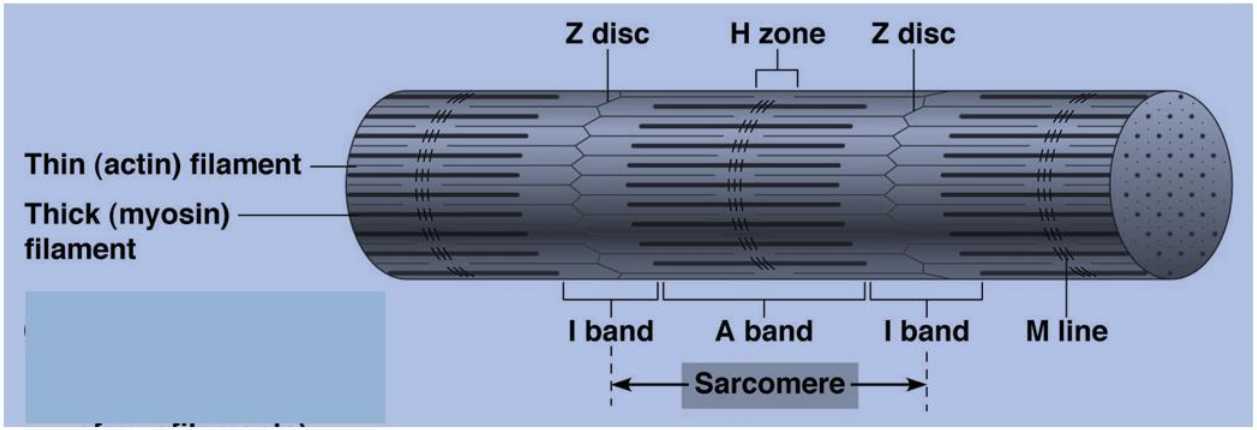
Structure of the sarcomere

- Sarcomere is the distance between two successive Z lines in a myofibril.

- Sarcomere is the functional unit for muscle contraction.

- The dark band is called A-band (made of thick myosin filaments).



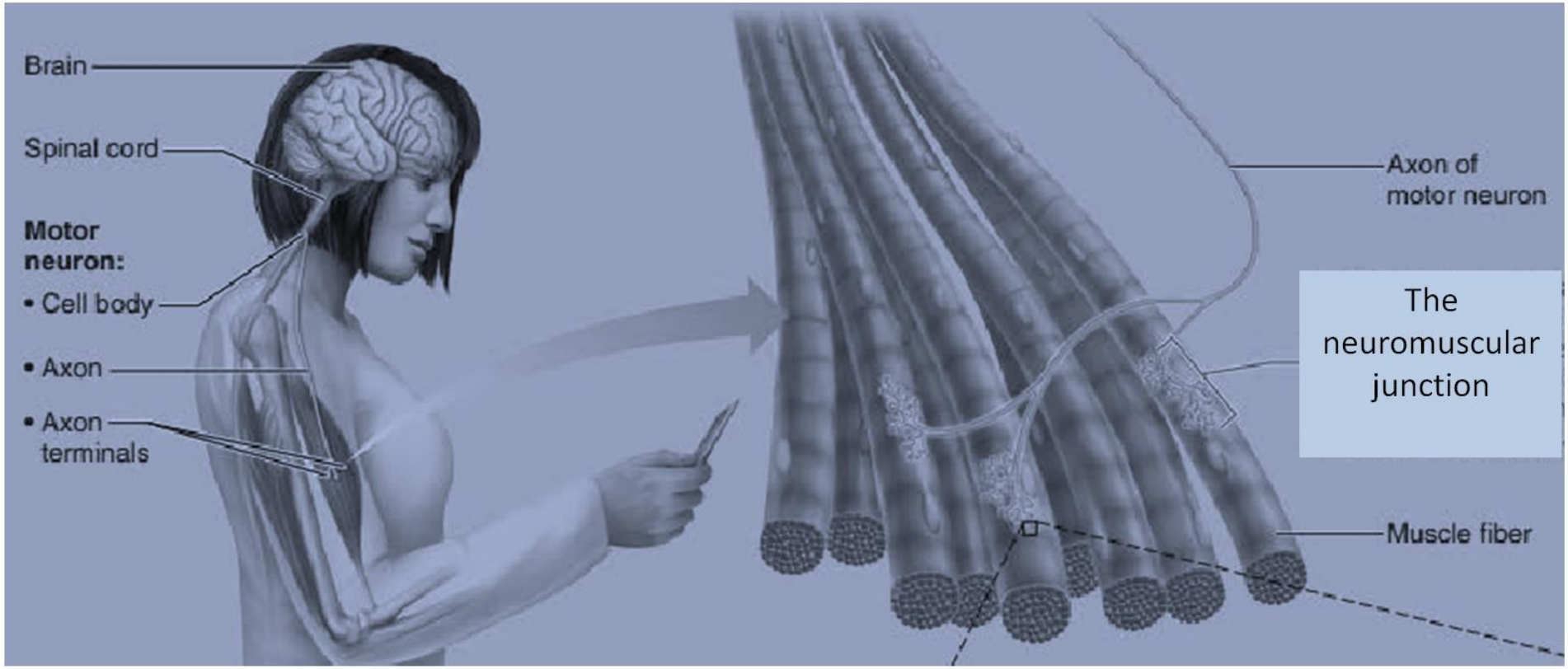


- The light band is called I-band (thin actin filaments).

- In the middle of the dark band there is a pale region called H-zone.

- In the middle of the light band there is a dark line called Z- line.

Neuromuscular junction



- The neuromuscular junction is the region where the motor neuron contacts the skeletal muscle.

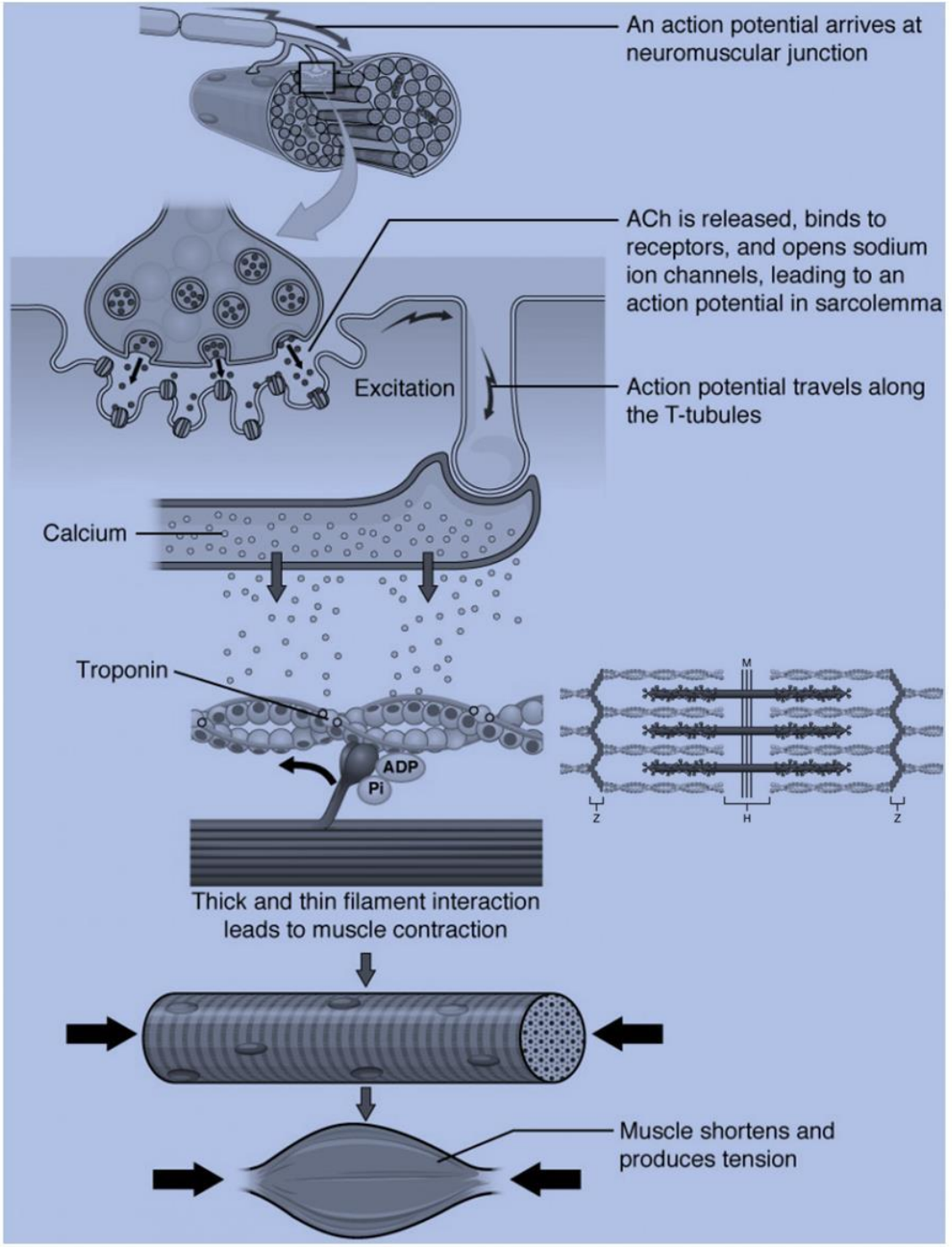
- It consists of multiple axon terminals and the underlying junctional folds of the sarcolemma.

Sequence of contraction

- An individual muscle fiber contraction begins with a signal (the neurotransmitter = Ach) from the motor neuron innervating that fiber.

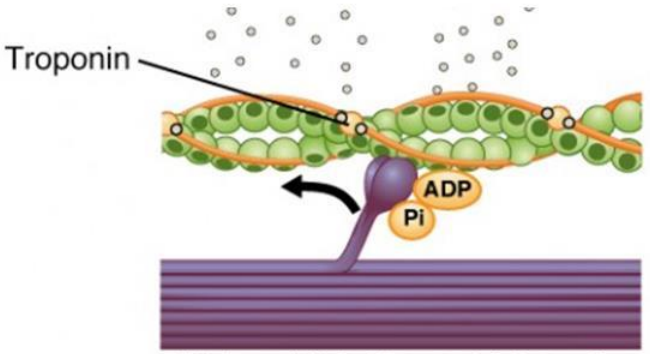
- The local membrane of the fiber depolarizes (Na^+ enter) triggering an action potential that spreads to the rest of the membrane and the T-tubules.

- This triggers the release of Ca^{++} from storage in the sarcoplasmic reticulum. Ca^{++} then initiates contraction (pulling of actin strands by myosin causing shortening of muscle fiber).



- Contraction is sustained by ATP.

- As long as Ca^{++} ions remain in the sarcoplasm to bind to troponin, which keeps the actin-binding sites "unshielded," and as long as ATP is available to drive the cross-bridge cycling and the pulling of actin strands by myosin, the muscle fiber will continue to shorten to an anatomical limit.

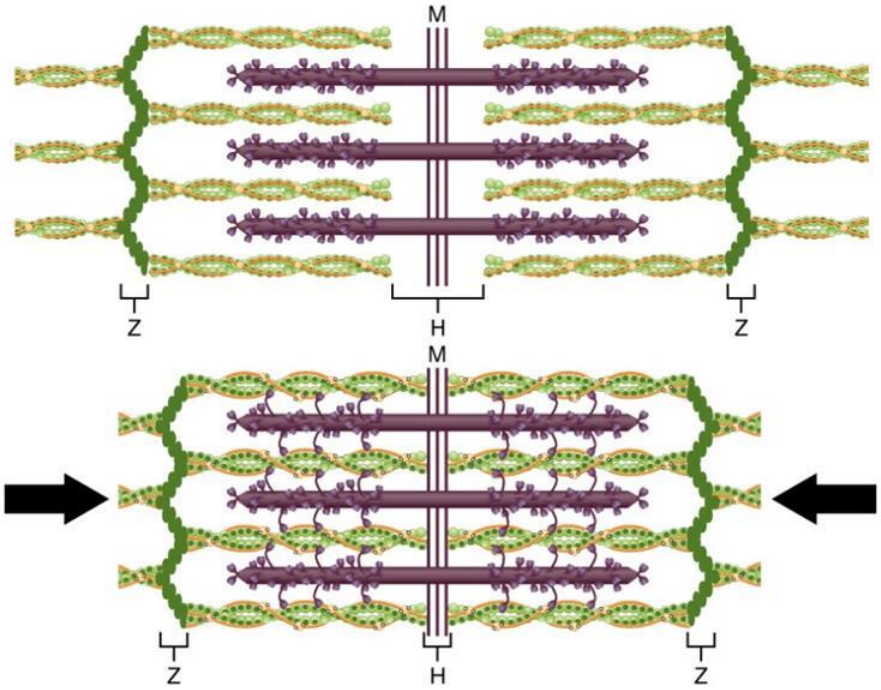


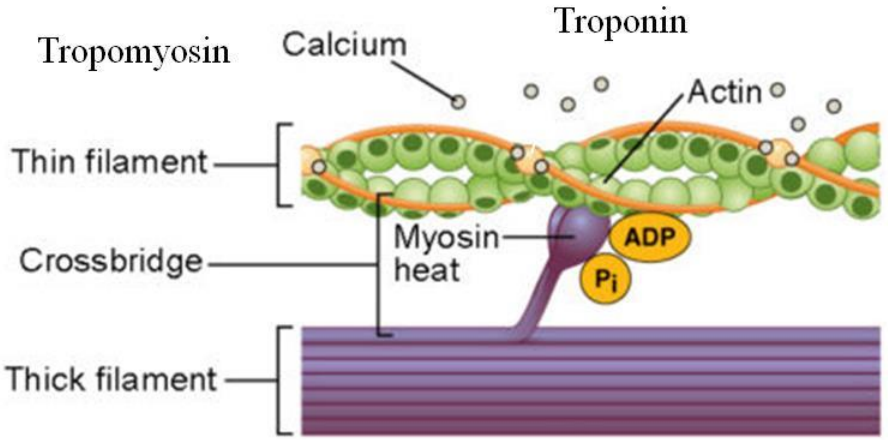
Thick and thin filament interaction leads to muscle contraction

Cross-bridge cycling (Sliding filament model of contraction)

When signaled by a motor neuron, a skeletal muscle fiber contracts as the thin filaments are pulled and then slide past the thick filaments within the fiber's sarcomeres, this process is known as the sliding filament model of muscle contraction.

- The sliding can only occur when myosin-binding sites on the actin filaments are exposed by a series of steps that begins with Ca^{++} entry into the sarcoplasm.



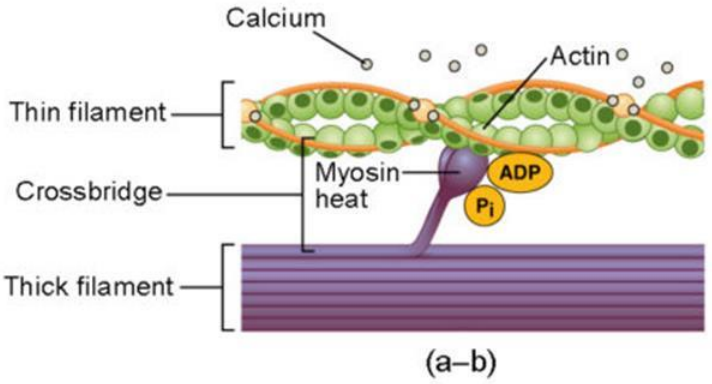


(Tropomyosin is a protein that winds around the chains of the actin filament and covers the myosin-binding sites to prevent actin from binding to myosin.)

Tropomyosin binds to troponin to form a troponin-tropomyosin complex, which prevents the myosin "heads" from binding to the active sites on the actin filaments.

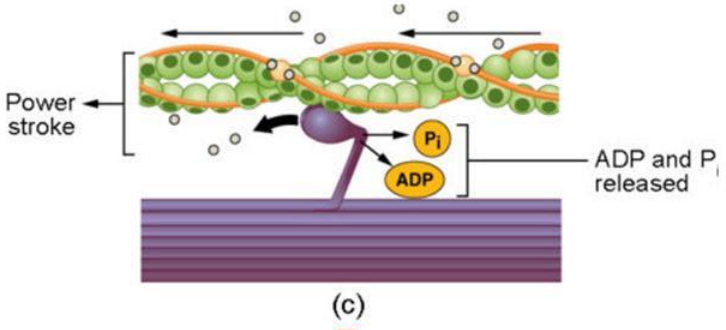
(Troponin also has a binding site for Ca^{++}.)

To initiate muscle contraction, tropomyosin has to expose the myosin-binding site on an actin filament to allow cross-bridge formation between the actin and myosin microfilaments.



- The first step in the process of contraction is binding of Ca^{++} to troponin so that tropomyosin can slide away from the binding sites on the actin strands.

- This allows the myosin heads to bind to these exposed binding sites and form cross-bridges.



- The thin filaments are then pulled by the myosin heads to slide toward the center of the sarcomere.

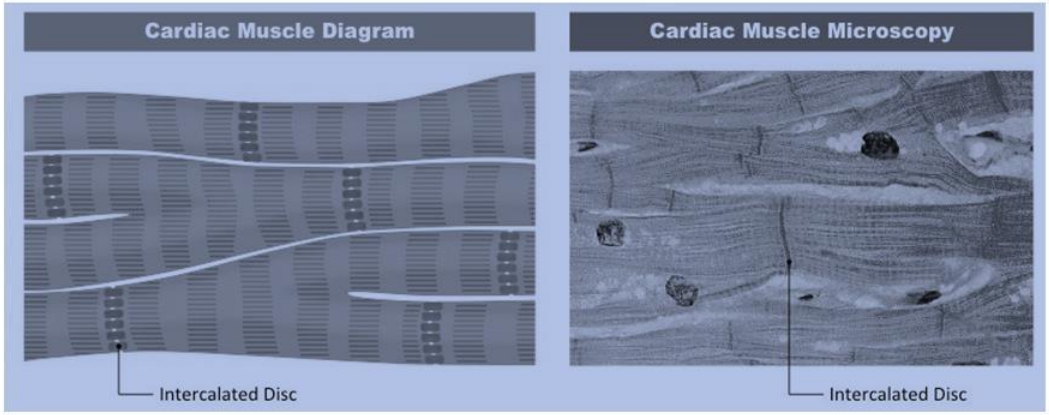
- But each head can only pull a very short distance before it has reached its limit and must be "re-cocked" before it can pull again, a step that requires ATP.

2- Cardiac muscle

- Cardiac muscle is striated, involuntary muscle.

- Similar to skeletal muscle, cardiac muscle is organized into sarcomeres, with the same banding organization as skeletal muscle.

- The sarcoplasm contains a single, oval, prominent and central nucleus.



- Muscle fibers are shorter than skeletal muscle fibers and branched.

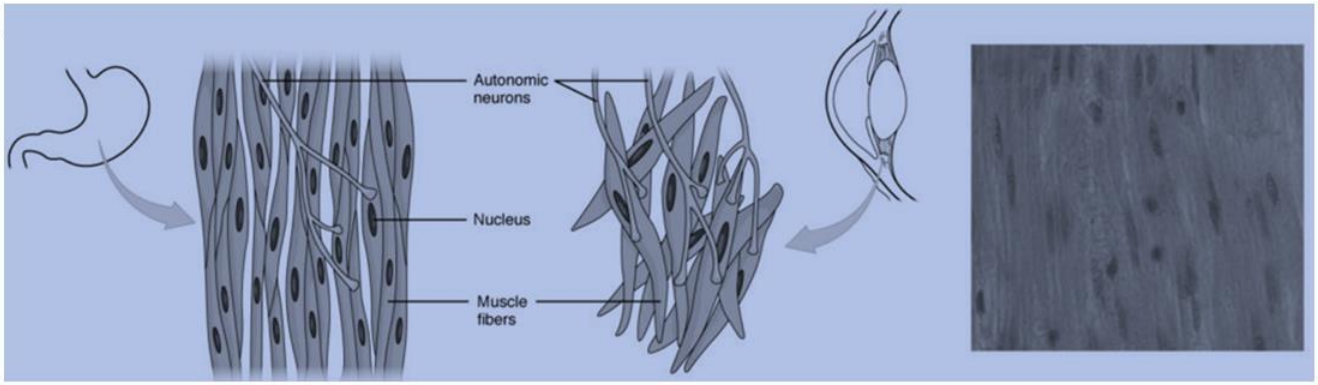
- The short cardiac muscle fibers are joined together by intercalated discs, which appear under microscope as dark lines.

- The intercalated disc allows the cardiac muscle cells to contract in a wave-like pattern so that the heart can work as a pump.

3- Smooth muscles

- Unstriated (smooth), involuntary, muscle.

- Muscle fibers are short and have no sarcomeres and each fiber has a single central nucleus.



- Have actin and myosin contractile proteins (form thin and thick filaments).

- Thin filaments are anchored by dense bodies. A dense body is analogous to the Z-discs of skeletal and cardiac muscle fibers and is fastened to the inner membrane of sarcolemma.

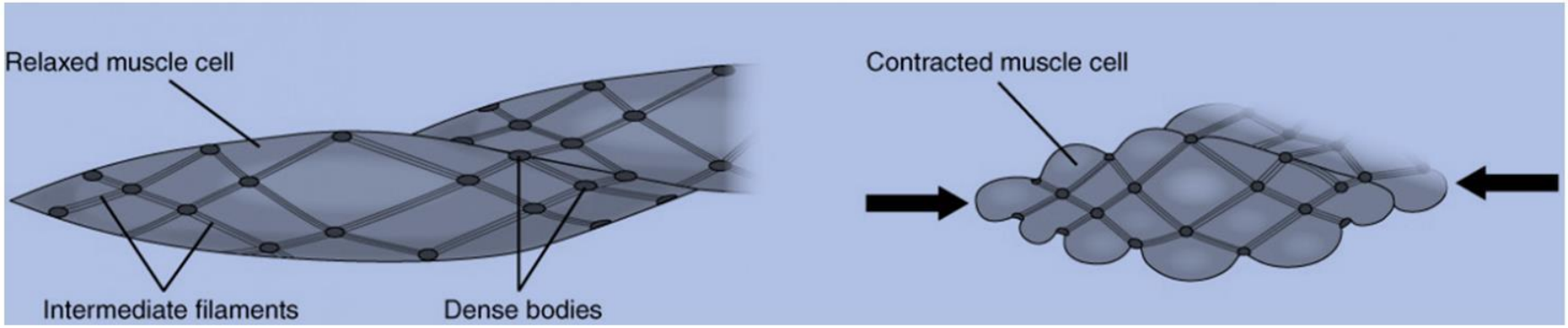
- Because smooth muscle cells do not contain troponin, cross-bridge formation is not regulated by the troponin-tropomyosin complex but instead by the regulatory protein calmodulin.

- In a smooth muscle fiber, external Ca^{++} passing through opened calcium channels in the sarcolemma, and additional Ca^{++} released from sarcoplasmic reticulum, bind to calmodulin.

- Ca^{++}-calmodulin complex then activates the enzyme myosin kinase, which, in turn, activates the myosin heads by phosphorylating them (converting ATP to ADP and P_i, with the P_i attaching to the head).

- Myosin heads can then attach to the binding sites on actin and pull on the thin (actin) filaments. The thin filaments also are anchored to the dense bodies, that also have cord-like intermediate filaments attached to them.

- Sliding of thin filaments slide past the thick filaments will pull on the dense bodies, which then pull on the intermediate filaments networks throughout the sarcoplasm.



- This arrangement causes the entire muscle fiber to contract in a manner whereby the ends are pulled toward the center, causing the midsection to bulge in a corkscrew motion.

علي **جميع الشعب**، عمل الأتي:

١- يقوم احد طلاب الشعبة بتجميع اسماء الطلاب (الإسم كاملا) و البريد الإلكتروني في جدول واحد في ملف وورد و ارساله مرة واحدة الي البريدالإلكتروني

Ghoneim2007@gmail.com

و يكون عنوان الرسالة: طلاب الفرقة الأولي شعبة حيوان وكيمياء (كمثال)

Thank you