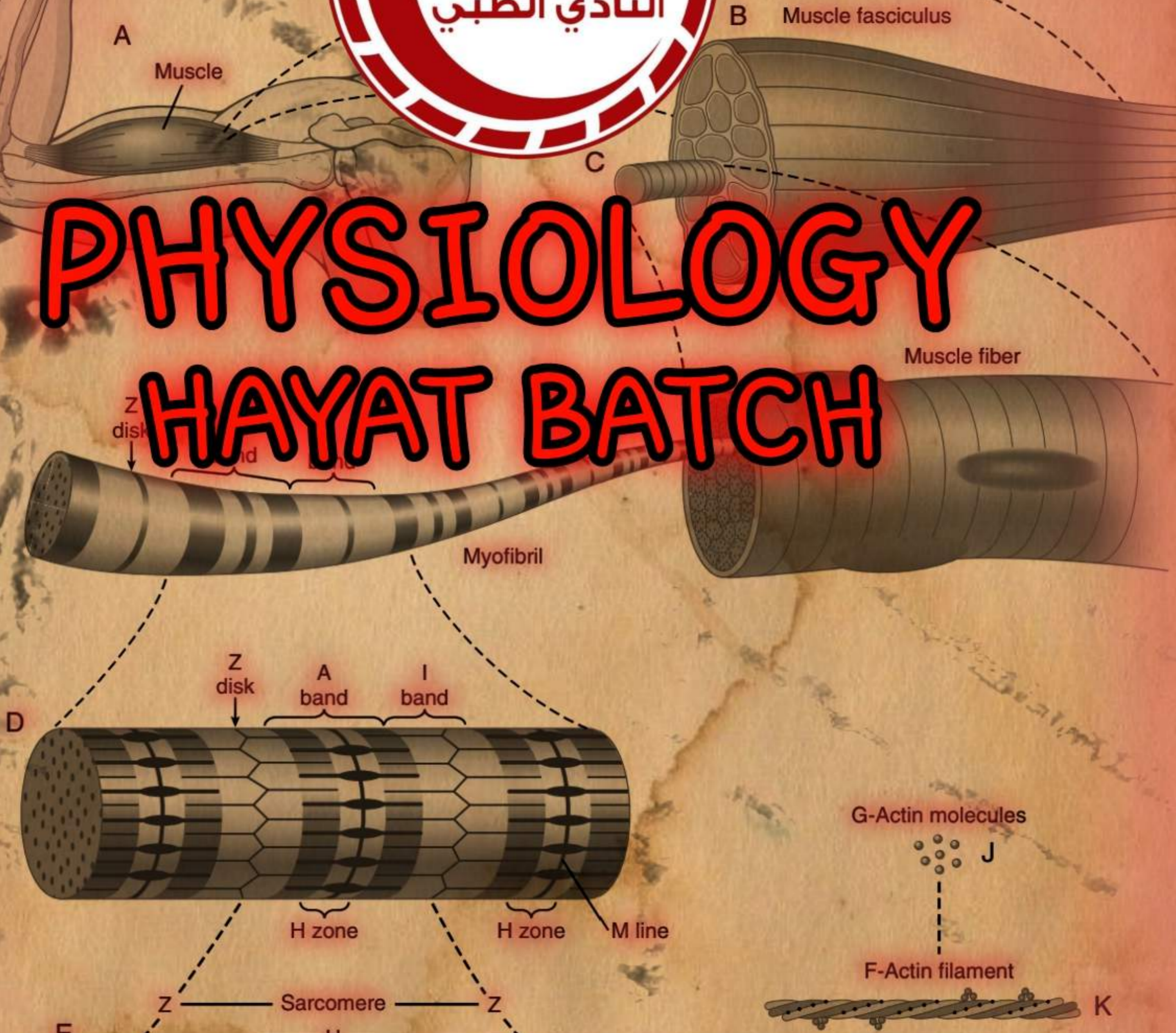




PHYSIOLOGY

HAYAT BATCH



done by: **عبد الودود الخفش** + **Maria Hood**

lecture no: **26**



Figure 6-1. Organization of skeletal muscle, from the gross to the molecular level. F, G, H, and I are cross sections at the levels indicated.

General physiology
Second Semester 2022-2023
Lecture 26
Skeletal Muscle Contraction I

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Lecture objectives

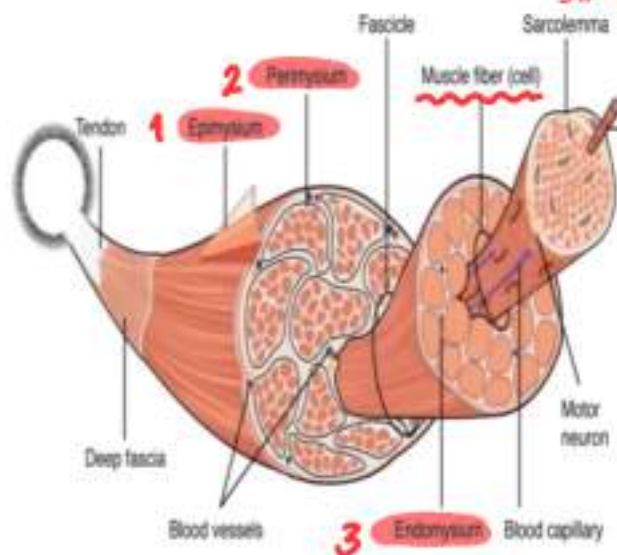
- List the three types of muscles and their primary function
- Review the gross anatomy of the muscle skeletal muscles and microscopic of the muscle fibers
- Identify the structural features of muscle fibers and the components of myofibril
- Define the sarcomere and identify the arrangements of contractile and structural proteins within the sarcomere
- Describe the contractile proteins in the myofibril and their molecular arrangement of Actin and Myosin
- List the cytoskeleton proteins within the sarcomere and their function
- Describe the events in a muscle contraction cycle and the myosin ATPase cycle
- Define the role of ATP in muscle contraction
- **Describe the sliding-filament model of sarcomere contraction**
- Describe the role of calcium ions in muscle contraction and excitation contraction coupling
- Define Rigor Mortis Phenomenon

Types of Muscle

- **Skeletal**
 - Attached to bones
 - Makes up 40% of body weight
 - Responsible for locomotion, facial expressions, posture, respiratory movements, vocalization
 - Joints stabilization etc.
 - Voluntary in action; controlled by somatic motor neurons
 - Striated
 - Heat production
- **Smooth**
 - In the walls of hollow organs, blood vessels, eye, uterus, skin
 - Some functions: propel urine, mix food in digestive tract, dilating/constricting pupils, regulating blood flow, regulate airways resistance etc
 - In some locations, autorhythmic
 - Controlled involuntarily by endocrine and autonomic nervous systems
 - Some have spontaneous activity
 - Non striated
- **Cardiac**
 - Striated
 - Heart: major source of pumping blood and movement of blood in circulatory system
 - Autorhythmic
 - Controlled involuntarily by endocrine and autonomic nervous systems

Functional Anatomy of skeletal muscles .

- Epimysium – loose connective tissue sheath surrounding each skeletal muscle
- Muscle Fasciculi – visible bundles that compose the muscle – these bundles are composed of multiple muscle fibers (cells)
- Perimysium – loose connective tissue surrounding the muscle fasciculi
- Endomysium – loose connective tissue surrounding each muscle fiber – functions to separate and electrically isolate each cell



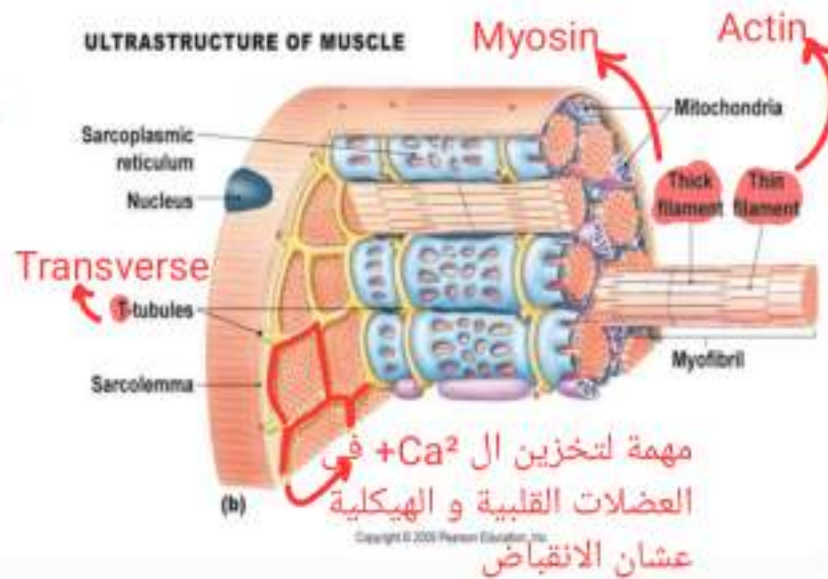
اهم اشياء ،
مهمات لل
muscle
، contraction
باقي التراكيب
تركز عليها كثير

Ultrastructure of muscle fiber

Muscle Fiber – a single **أسطواني** cylindrical cell that contains several nuclei located at the periphery (edge) of the cell – largest are up to **30cm long, 15mm in diameter**, and containing several thousand nuclei

Myofibril – **خيوط** thread like structure extending through the muscle fiber from one end to the other **in the sarcoplasm** – composed of two myofilaments (protein fibers)-actin and myosin

Sarcolemma – cell membrane of a muscle fiber



T tubules, Sarcoplasmic reticulum and Terminal cisterna

T tubules (transverse tubules) – tube like **انغماد** invaginations of the sarcolemma located at regular **intervals** and connecting the sarcolemma with the sarcoplasmic reticulum (ER)

فترة / فترات / مواقع Sarcoplasmic reticulum – endoplasmic reticulum (ER) of the muscle cell – stores calcium ions used in contraction of the muscle

Terminal cisterna – an enlarged end part of the sarcoplasmic reticulum
Triad – 2 terminal cisterna and a T tubule

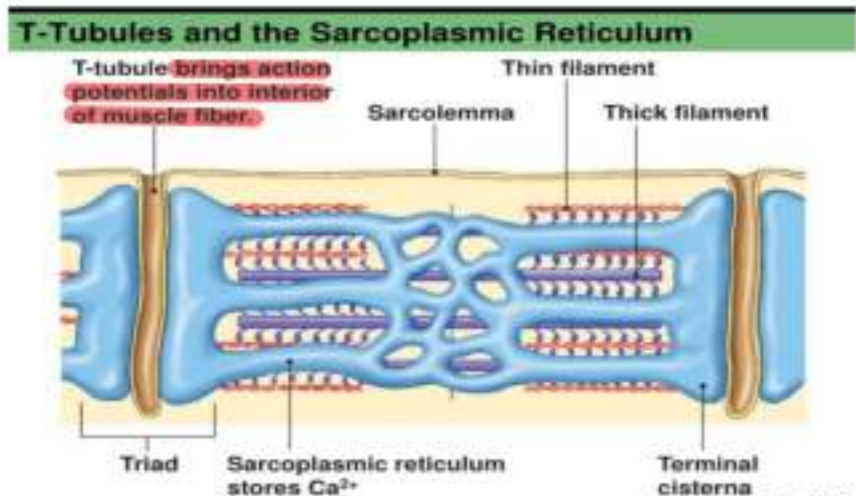
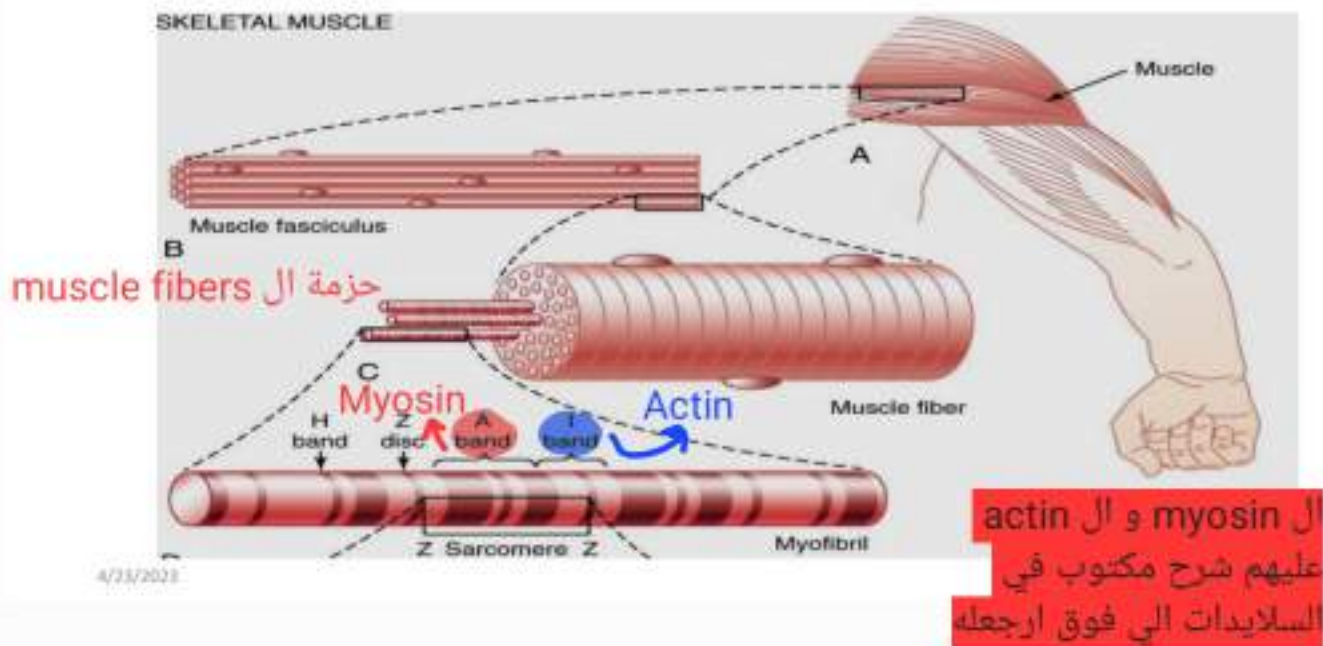


Figure 12-4

Skeletal muscle organization and Ultrastructure of muscle fiber

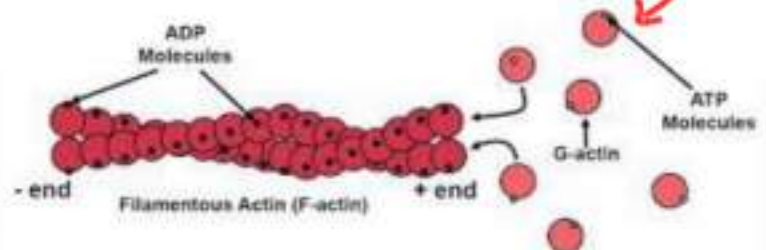


Ultrastructure of muscle fiber

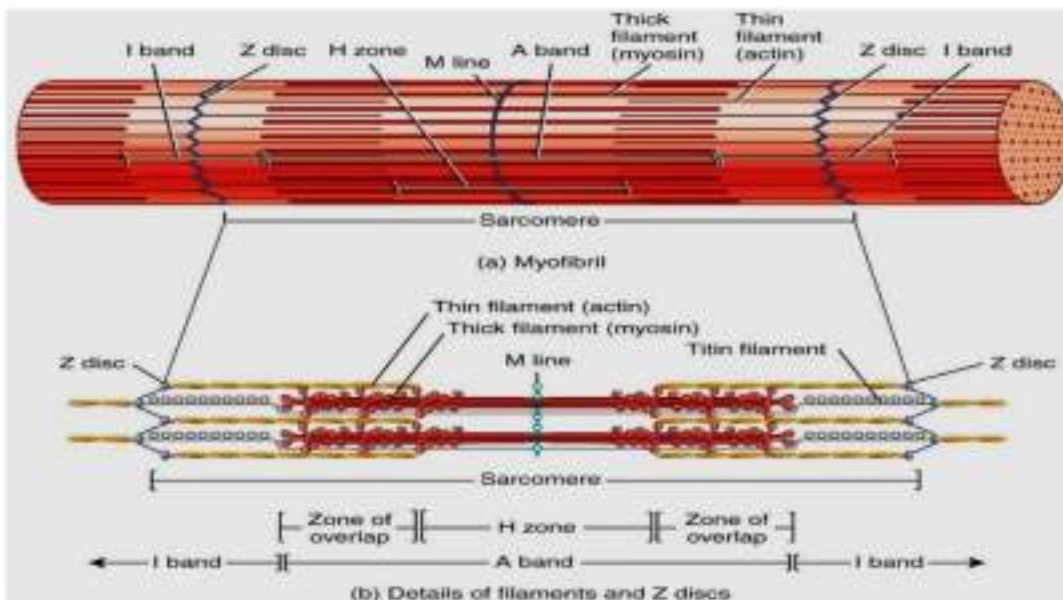
- Sarcomere – the basic structural and functional unit of skeletal muscle – the smallest portion of skeletal muscle capable of contraction
- Z disk – a network of protein fibers (titin – a protein responsible for elastic recoil) forming attachment sites for actin myofilaments
- Actin myofilaments – thin filaments resembling two strands of pearls twisted together
- Myosin myofilaments – thick filaments resembling bundles of miniature golf clubs

شوفه بسلايد ١٣ زي عصي القولف

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The Arrangement of a Sarcomere

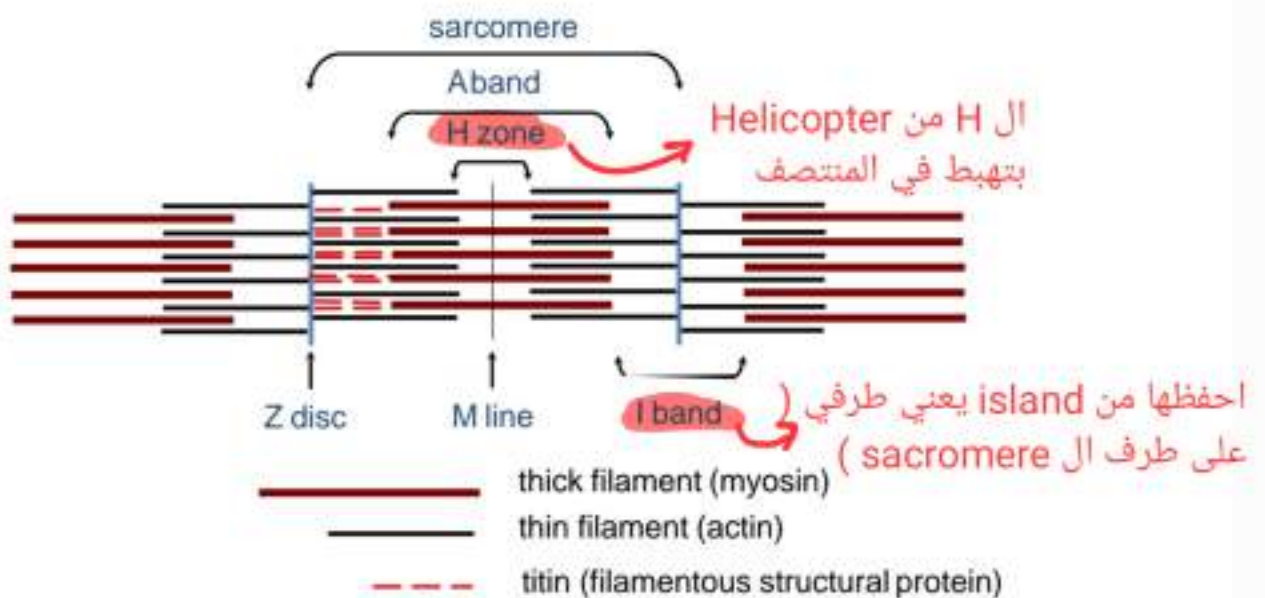


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The Sarcomere



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Ultrastructure of sarcomeres

Zones and bands of myofibril

- Zones – areas of measurement that make up the sarcomere to show contraction in the sliding filament model a.
- M line – center line of a sarcomere and attachment site for myosin filaments
- **H zone** – area of the sarcomere extending out from the M line on either side - **composed of myosin only (no actin)**
- **A band** – area of the sarcomere **extending from one end of the myosin to the other end**, includes the M line, the H zone, and the area where actin and myosin overlap
- **Z disk** – the area of the sarcomere indicating the **ends of the sarcomere** and the attachment site for actin filaments.
- **I band** – area that includes the Z disk, made out of 2 ends of adjoining sarcomeres, and composed of actin only (no myosin)
- **Sliding filament model** – used to show/explain muscle contraction with one sarcomere – in this model myosin and actin filaments slide past one another **shortening or narrowing the H zone and I band**, the filaments themselves do not shorten



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Just know the main component of the filament and the main protein

الكالسيوم بييجي بيتحد مع ال troponin بالتالي يتم تغير مواقع البروتينات و من ضمنها بروتين ال tropomyosin بالتالي تتكشف مواقع ال G-actin active site و ترتبط ال myosin في ال actin

The Actin Filament

Form the I band
 - Anchored at one end to Z disc
 Overlap with myosin filament in a portion of the A band
 1 μm long: very uniform, *منظم / متجانس*
nebulin forms guide for synthesis

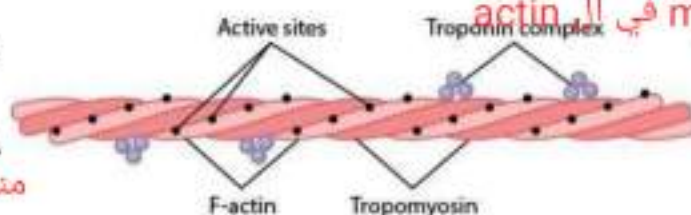


Figure 6-7

- 1 F-actin** **Monomer that made F-actin helix**
- double-stranded helix
 - composed of polymerized **G-actin**
 - ADP bound to each G-actin (active sites)
 - myosin heads bind to active sites
- 2 Tropomyosin** **So its name is relaxing protein**
- covers active sites
 - prevents interaction with myosin
- 3 Troponin** **لانه يعمل relax للعضلة**
- I - binds actin
 - T - binds tropomyosin
 - C - binds Ca²⁺

كل واحد يمسك بشيء حسب اسمه ، يعني كل كرة شابكة بشيء معين و تسمت بإسمه

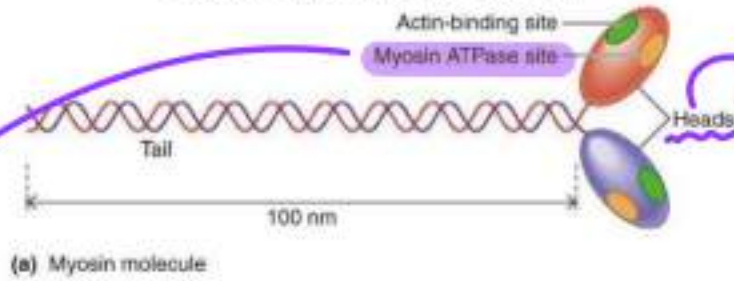


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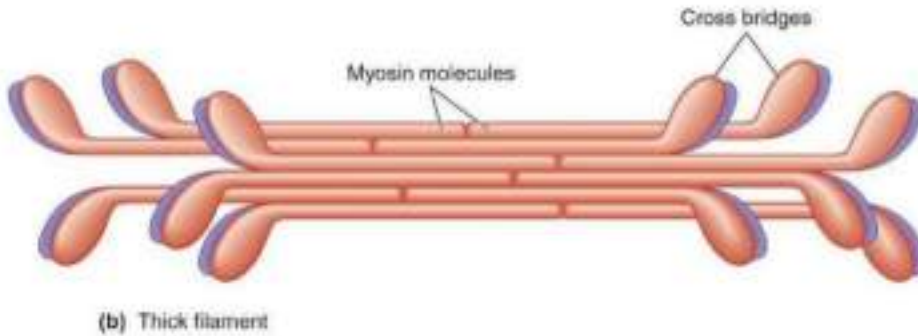
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الشرح الي هون مهم و ركز عليه الدكتور و جاي عليه سؤال خصوصا المظلل

Structure and Arrangement of Myosin Molecules Within Thick Filament



بتحد مع ال actin أثناء
ال contraction
بسوي bridge



This site binding with ATP

و هذا مهم لعملية ال contraction/ relaxation

لما ال ATP يرتبط بهذا ال site و الي هو عبارة عن enzyme ،
رح يتكسر إلى:

ADP + phosphate + energy

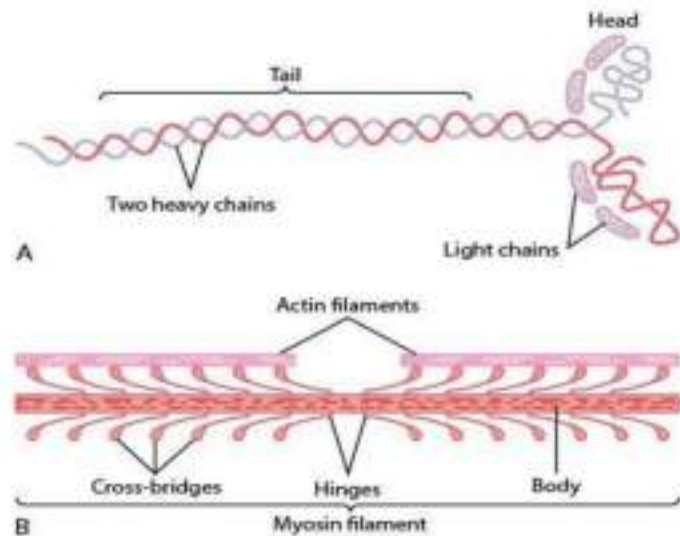
، طبعا بعد ما يصير ال ATP عملية hydrolysis و يصير ADP رح
يبقى متصل في مكانه لحد ما تتم عملية ال contraction ، الآن
عشان يصير relaxation رح تنفك ال ADP و تتكشف المواقع
لاجل قدوم ATP آخر و ترتبط لأداء عملية ال relaxation
انفصال actin عن myosin

هذه الطاقة
تتخزن في ال
myosin head
و هذه الطاقة
تستعمل لعمل ال
cross bridges
and sliding of
actin over
myosin

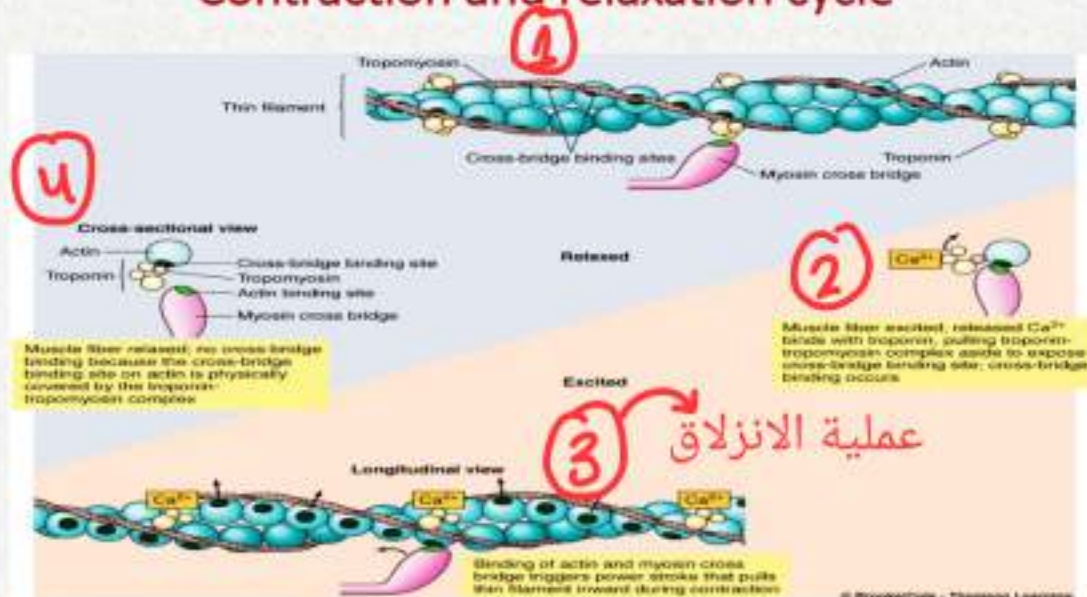
عشان هيك الي بموت
بتشنج لانه فش ATP
تعمل relaxation

The Myosin filaments and myosin molecule

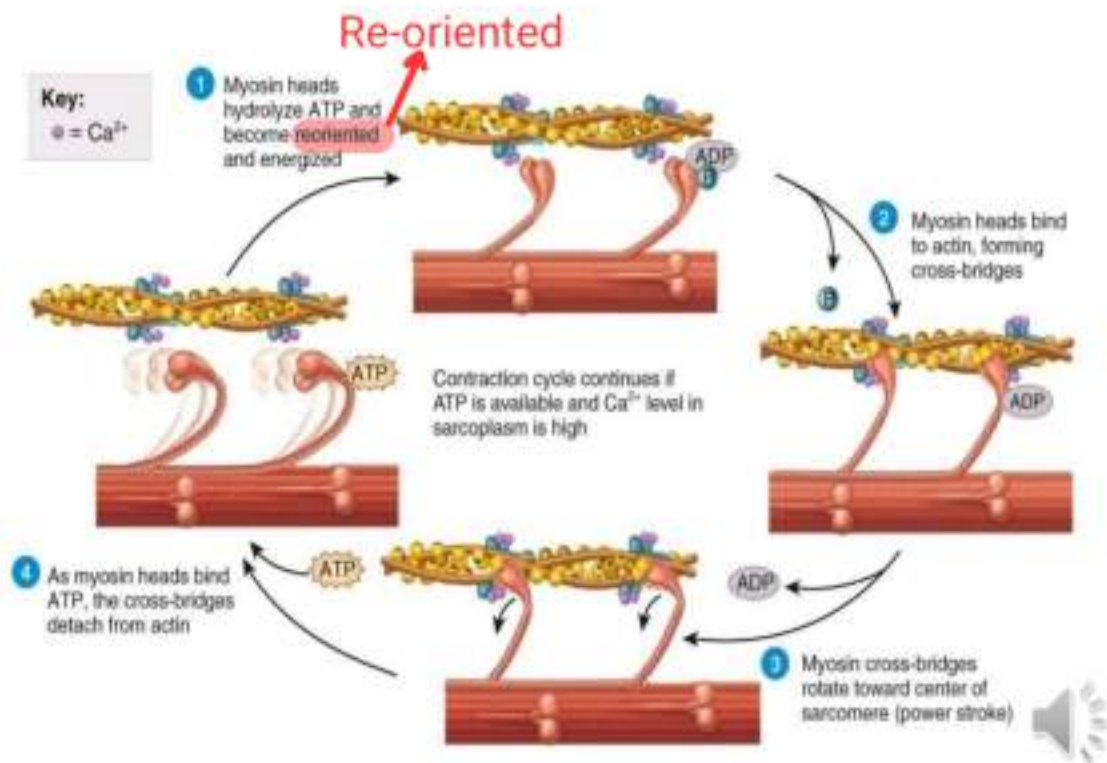
- Present in the A band
- Myosin Filaments are composed of multiple myosin molecules which is six polypeptide chain
- Two heavy chains Spirally around each other to form the tail
- The four light chains are also part of the myosin head, two to each head. .
- Thus each myosin molecule has two "heads" attached to a single "tail"
- "head" region - site of ATPase activity



Contraction and relaxation cycle



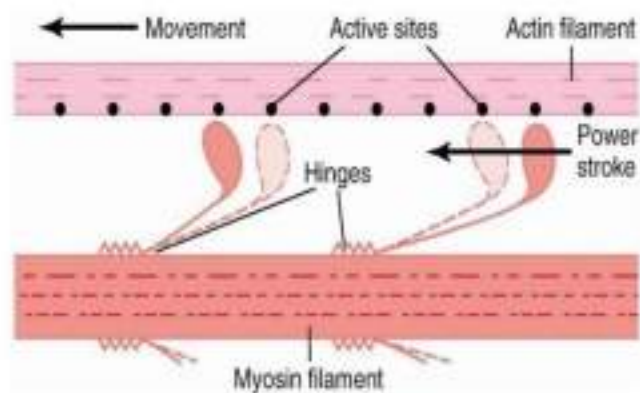
Contraction and relaxation cycle



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“Walk-Along” Theory



The heads of the cross-bridges bend back and forth and step by step walk along the actin filament, pulling the ends of two successive actin filaments toward the center of the myosin filament

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The Sliding Filament Mechanism Relaxed and Contracted States of sarcomeres

طول ال filaments ما بتغير ، فقط
بصير تداخل و تقل المسافة بينهم)

Contraction results from the sliding action
due to engagement and coupling of actin
and myosin filaments

ال functional group الي
هي sacromere رح يقصر
بس البروتين (ال
molecules) ما رح يتغير

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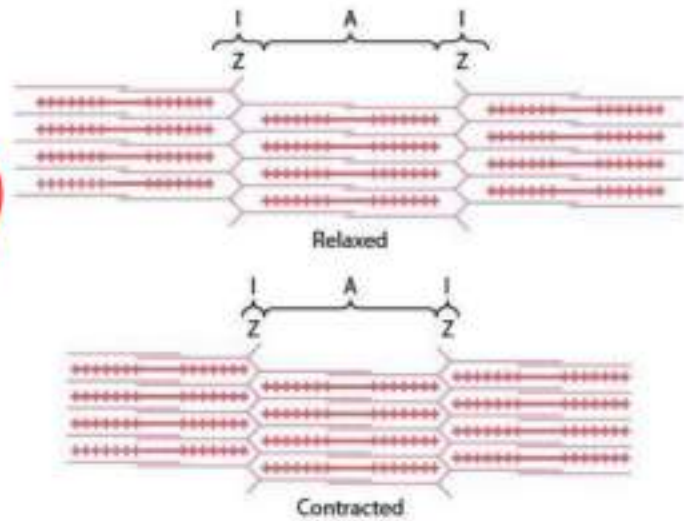
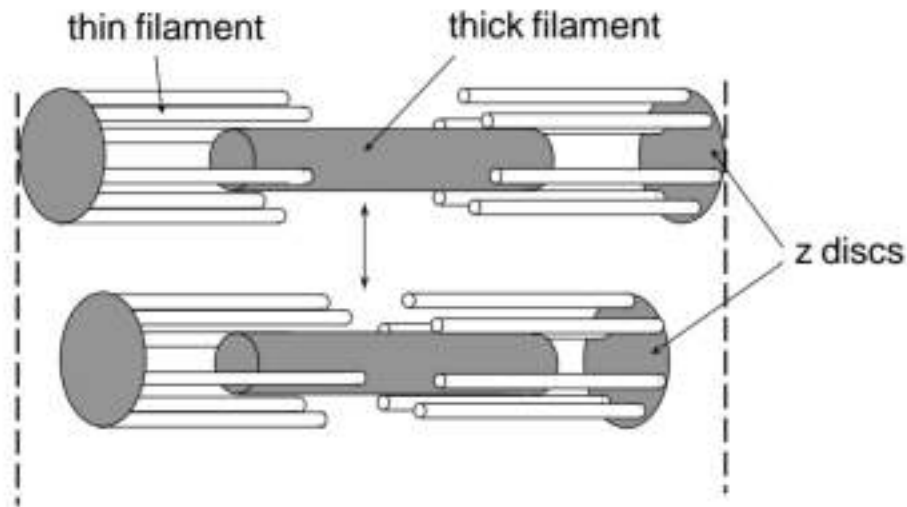


Figure 6-5

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Which band shortens - I or A?

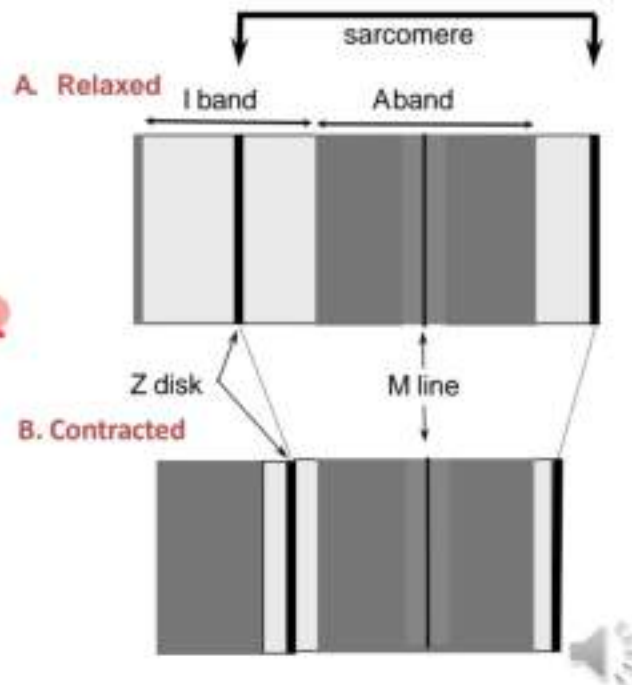


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Which band shortens - I or A?

- The A band appears dark
- The I band appears light
 - So, when the I band filament is pulled into the A band, the I band is obscured!
- **The I band appears to shorten.**



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Role of ATP and Fenn effect

- Large amounts of ATP are cleaved to form ADP during the contraction process, and the greater the amount of work performed by the muscle, the greater the amount of ATP that is cleaved; this phenomenon is called *the Fenn effect*.
- Before contraction begins, the heads of the cross bridges bind with ATP. The ATPase activity of the myosin head immediately cleaves the ATP but leaves the cleavage products, ADP plus phosphate ion, bound to the head. In this state, the conformation of the head is such that it extends perpendicularly toward the actin filament but is not yet attached to the actin.
- When the troponin-tropomyosin complex binds with calcium ions, active sites on the actin filament are uncovered and the myosin heads then bind with these sites.
- When Cross bridges formed the energy previously stored by cleavage of ATP in the relaxed state is used for the power stroke.
- Once the head of the cross-bridge tilts, release of the ADP and phosphate ion that were previously attached to the head is allowed.
- **At the site of release of the ADP, a new molecule of ATP binds. This binding of new ATP causes detachment of the head from the actin.**
- After the head has detached from the actin, the new molecule of ATP is cleaved to begin the next cycle, leading to a new power stroke.
- That is, the energy again "cocks" the head back to its perpendicular position ready to begin the new power stroke cycle.

هاي ركز عليها الدكتور

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تصلب / تخشب الميت Rigor Mortis

1. Myosin head attached to actin



RIGOR

Rigor mortis:

- state of contracture that occurs following death
- due to loss of ATP

حكي شوية حكي هون Cytoskeletal Proteins

- Longitudinal cytoskeletal proteins include two large proteins called titin and nebulin
- Titin
 - elastic anchor protein
 - Helps align the thick filament
 - Adds an elastic element to the sarcomere.
 - Titin is anchored at the M-Line, runs the length of myosin, and extends to the Z disc.
- Nebulin
 - stabilizing protein associated with the thin filament
 - None elastic
 - Spans the length of the thick filament
- Myomesin plays an important in the structure of sarcomeres. They are found in the M-band region of the sarcomere, between the thick filaments (myosin).
- It's main purpose in this setting is to provide structural integrity by linking the antiparallel myosin fibers and titin filaments which are connected to the Z-discs

Cytoskeletal Proteins : Transverse cytoskeletal proteins

- Transverse cytoskeletal proteins link thick and thin filaments, forming a "scaffold" for the myofibrils and linking sarcomeres of adjacent myofibrils
- A system of intermediate filaments holds the myofibrils together, side by side
- **Dystrophin**: An acting binding protein which anchors the entire myofibrillar array to the cell membrane
- In patients with muscular dystrophy, dystrophin is defective or absent

مهم ، اهم
واحد