Human Physiology Topic 11

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11.2 Movement

Essential idea: The roles of the musculoskeletal system are movement, support and protection.

Understandings:

- 11.2.U1 Bones and exoskeletons provide anchorage for muscles and act as levers.
- 11.2.U2 Synovial joints allow certain movements but not others.
- 11.2.U3 Movement of the body requires muscles to work in antagonistic pairs.
- 11.2.U4 Skeletal muscle fibers are multinucleate and contain specialized endoplasmic reticulum.
- 11.2.U5 Muscle fibers contain many myofibrils.
- 11.2.U6 Each myofibril is made up of contractile sarcomeres.
- 11.2.U7 The contraction of the skeletal muscle is achieved by the sliding of actin and myosin filaments.

Understandings:

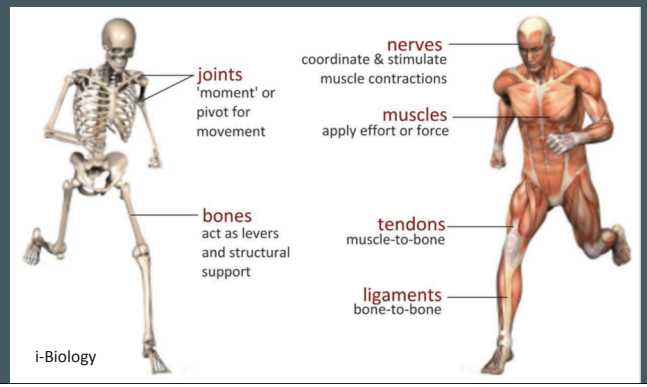
- 11.2.U8 ATP hydrolysis and cross bridge formation are necessary for the filaments to slide.
- 11.2.U9 Calcium ions and the proteins tropomyosin and troponin control muscle contractions.

Applications and Skills:

- 11.2.A1 Antagonistic pairs of muscles in an insect leg.
- 11.2.S1 Annotation of a diagram of the human elbow. Diagram should include cartilage, synovial fluid, joint capsule, named bones and named antagonistic muscles.
- 11.2.S2 Drawing labeled diagrams of the structure of a sarcomere. Drawing should include Z lines, actin filaments, myosin filaments with heads, and the light and dark bands.
- 11.2.S3 Analysis of electron micrographs to find the state of contraction of muscle fibers.

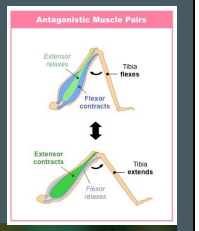
I. Banes and Exoskeletons Anchor Mucles

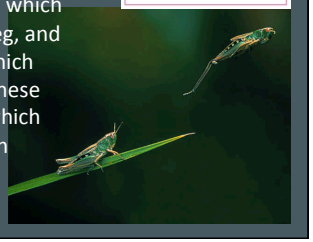
A. Bones and exoskeletons provide anchorage for muscles and act as levers-



II. An Insect Leg has Antagonistic Muscles

A. Antagonistic pairs of muscles in an insect leg-
   1. Grasshoppers (*Acrididae*) are insects that have an exoskeleton on the outside of the body. The muscles are inside the hard shell.
      a. The two main muscles inside are the extensor tibiae muscle which contracts to extends the leg, and the flexor tibiae muscle which contracts to flex the leg. These muscles pull on tendons which are attached to the tibia on either side of the joint.





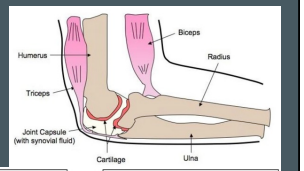
Stephen Dalton; BioNinja

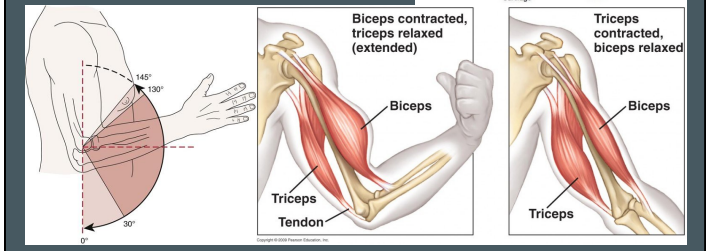
III. Skeletal Muscles are Antagonistic

A. Movement of the body requires muscles to work in antagonistic pairs-
   1. Skeletal muscles, such as the extensor and flexor that occur in pairs are often antagonistic: when one contracts the other relaxes to produce controlled movement in opposite directions.

IV. Different Joints allow Different Ranges of Movement

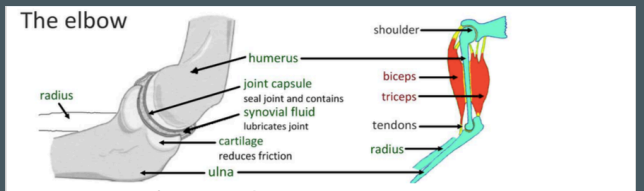
A. Synovial joints allow certain movements but not others-
   1. The elbow is a hinge joint that has limited range of movement.





Pearson Education; Musculoskeletal Key; Anatomy Diagram Pic

Annotation of a diagram of the human elbow



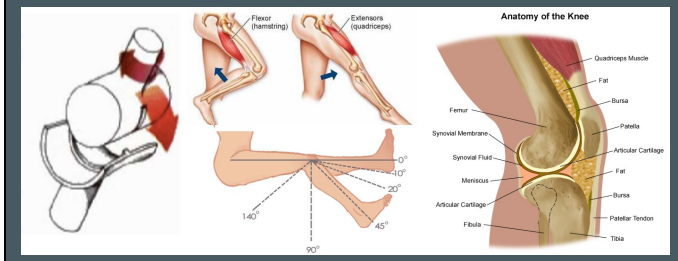
Can you annotate the structures? *Remember structure dictates function*

Structure	Function
Biceps	Bends the arm (flexor)
Triceps	Straightens the arm (extensor)
Humerus	Anchors the muscle (muscle origin)
Radius / Ulna	Acts as forearm levers (muscle insertion) – radius for the biceps, ulna for the triceps
Cartilage	Smooth surface to allow easy movement, absorbs shock and distributes load
Synovial fluid	Provides lubrication, reduces friction in the joint.
Joint capsule	Seals the joint, contains the synovial fluid.
Tendons	non-elastic tissue connecting muscle to bone
Ligaments	non-elastic tissue connecting bone to bone

Bioknowledgy

IV. Different Joints allow Different Ranges of Movement

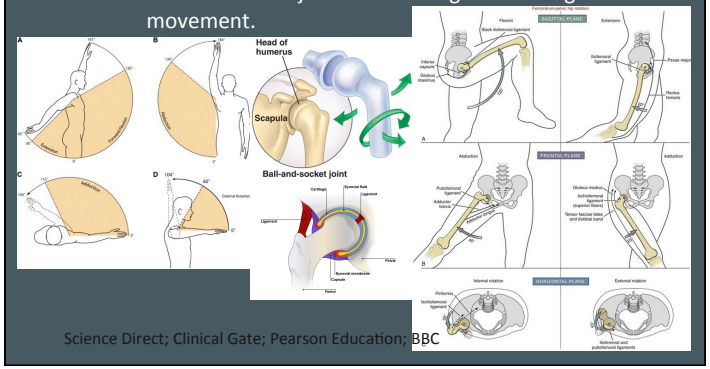
2. The knee is a pivotal hinge joint that is like a hinge joint yet allows some pivotal movement (rotation) as well.
   a. Cartilage and synovial fluid protect and lubricate the knee joint, reducing harm from impact
   b. Strong ligaments hold the knee in place



Stanford Healthcare; Musculoskeletal Key; School Bag Info

IV. Different Joints allow Different Ranges of Movement

3. The hip and shoulder are examples of a ball-and-socket joint that allows movement on all axes and planes.
   a. Ball-and-socket joints allow the greatest range of movement.

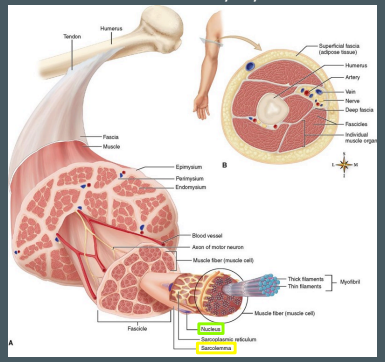


Science Direct; Clinical Gate; Pearson Education; BBC

IV. Different Joints allow Different Ranges of Movement

V. Structure of Muscle Fibers and Myofibrils

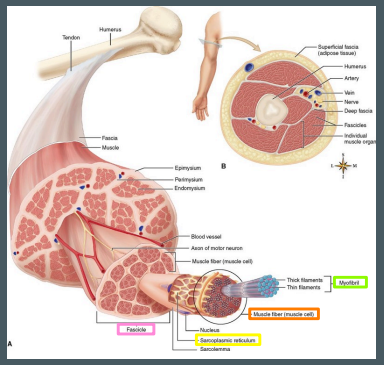
A. Skeletal muscle fibers are multinucleate and contain specialized endoplasmic reticulum AND Muscle fibers contain many myofibrils.
   1. Skeletal muscle is striated – has dark and light bands- and contracts longitudinally.
   2. Muscle fiber cells are held together by the plasma membrane called sarcolemma.
   3. A single muscle cell is multinucleated, with nuclei positioned along the edges.
   4. Many mitochondria are present due to the high demand for ATP.



Basic Medical Key

V. Structure of Muscle Fibers and Myofibrils

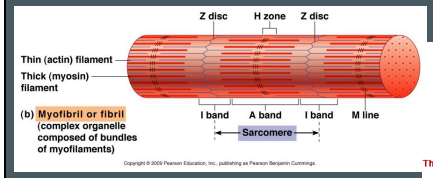
5. Sarcoplasmic reticulum is a specialized type of ER that stores calcium ions and pumps them out into the sarcoplasm when the muscle fiber is stimulated.
6. Myofibrils are the basic rod-like contractile units within a muscle cell. Myofibrils are grouped together inside muscle cells, which are known as muscle fibers.
7. Muscle cells are bundled together in fasciculi, held in place by the sarcolemma.

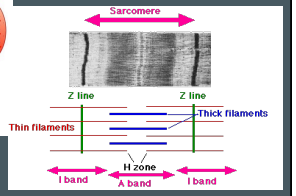


Basic Medical Key

VI. Structure of Myofibrils

A. Each myofibril is made up of contractile sarcomeres-
   1. A sarcomere is a repeating unit of a striated muscle cells
      a. It is the unit found between two z-lines
      b. In between overlapping actin and myosin fibers create dark bands
      c. No overlap between actin and myosin result in light bands

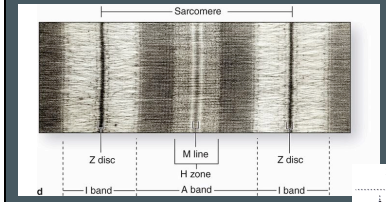


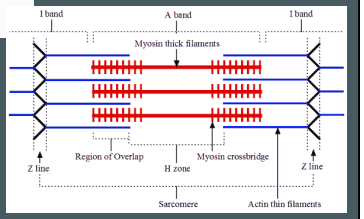


Pearson Education; Sameerb

VII. The Sarcomere

A. Drawing labeled diagrams of the structure of a sarcomere





Basic Medical Key

VII. The Sarcomere

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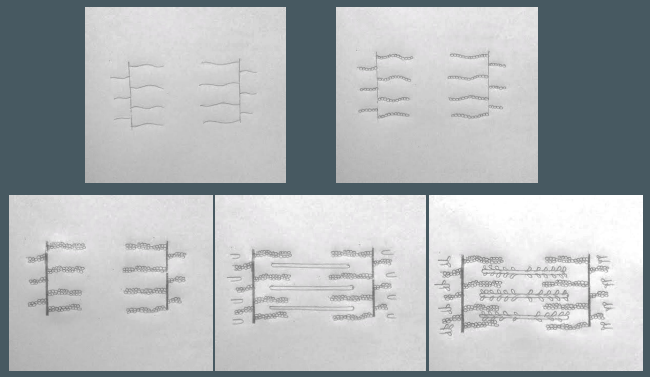
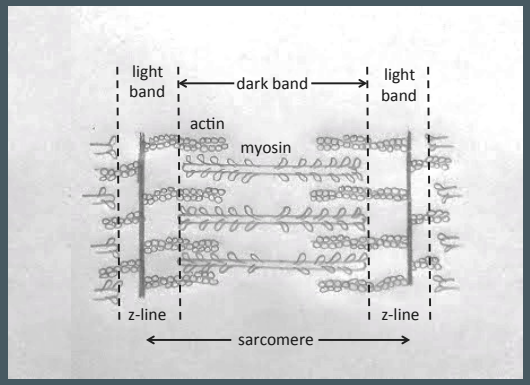


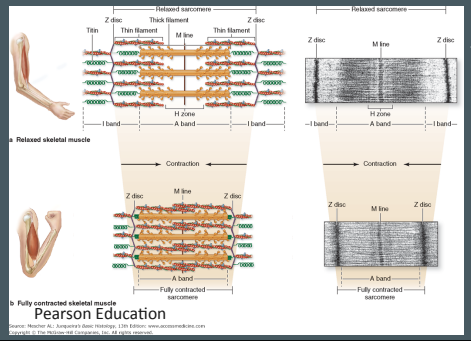
Draw it Neat



Draw it Neat

VIII. Mechanism of Skeletal Muscle Contraction

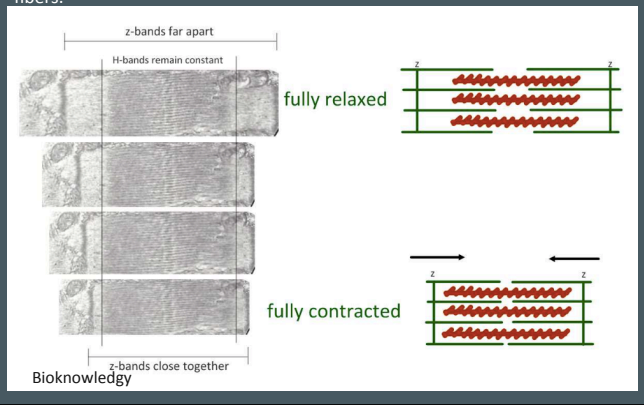
A. The contraction of the skeletal muscle is achieved by the sliding of actin and myosin filaments-
   1. When muscles contract, actin slides over the myosin and causes the sarcomere to shorten



Can you determine the state of muscle contraction based on a micrograph?

- In the relaxed state the z-lines are farther apart and the m-line has more visible light
- In the contracted state less light is visible between both the a-band and m-line.

Analysis of electron micrographs to find the state of contraction of muscle fibers.

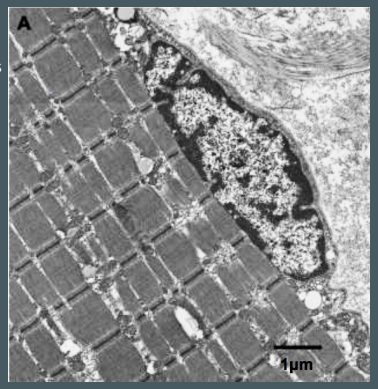


Analyze the micrograph and use it to answer the following:

1. Deduce whether the myofibrils are contracted or relaxed
2. Calculate the magnification of the electron micrograph
3. Measuring an individual sarcomere accurately is difficult due to their small size. Commonly scientists use the formula below:

mean sarcomere length (µm) = total length of n sarcomeres / n

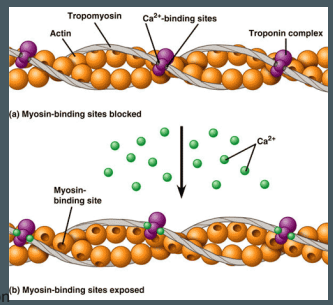
   a. Measure the total length of five sarcomere from z-line to z-line
   b. Calculate the mean length of a sarcomere



Anatomy Box

IX. The Control of Skeletal Muscle Contractions

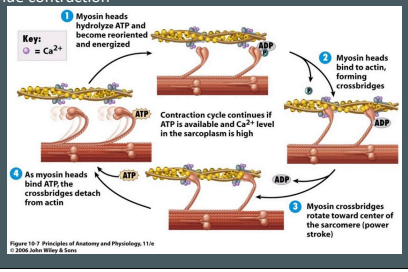
A. Calcium ions and the proteins tropomyosin and troponin control muscle contractions –
   1. Tropomyosin blocks actin binding sites
   2. A nerve signal causes the sarcoplasmic reticulum to release calcium ions
   3. Calcium ions bond to troponin causing tropomyosin to unblock actin's binding sites



Pearson Education

X. The Role of ATP in the Sliding of Filaments

A. ATP hydrolysis and cross bridge formation are necessary for the filaments to slide-
   1. Myosin heads are bound to the actin binding sites creating a cross bridge, and are stimulated to move
   2. This causes the actin to slide over myosin towards the center of the sarcomere
   3. ATP releases the myosin head and resets it
   4. Myosin is now able to form a new cross bridge with a different binding site and continue contraction



Wiley

NOS: Developments in scientific research follow improvements in apparatus - fluorescent calcium ions have been used to study the cyclic interactions in muscle contraction.

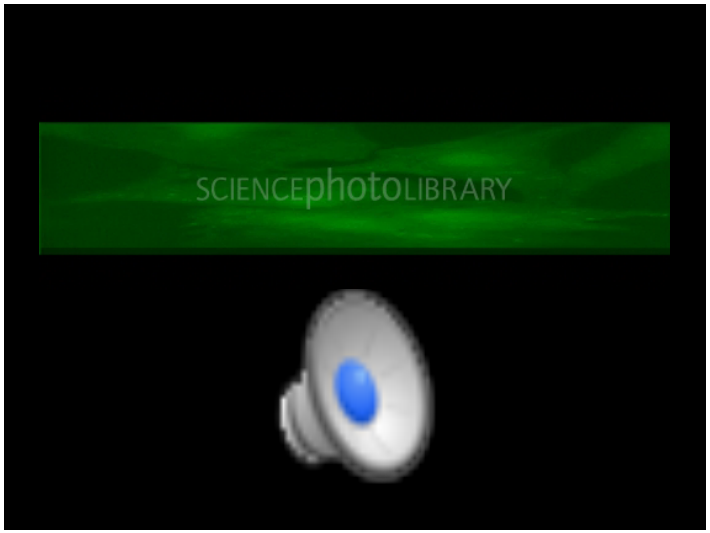
Ashley and Ridgway (1968) were the first to study the role that Calcium ions (Ca^{2+}) plays in the coupling of nerve impulses and muscle contraction. Their work was made possibly by the use of aequorin, a Ca^{2+} binding bioluminescent protein. Upon Ca^{2+}- binding aequorin emits light. The timing of light emission peaks between the arrival of an electrical impulse at the muscle fiber and the contraction of the muscle fiber. This is consistent with theory of release of Ca^{2+} from the sarcoplasmic reticulum

The light emissions are detected and recorded using specially adapted **microscopes** and **cameras**.

A number of researchers have used **fluorescent dyes** to visualise and measure the **movement of myosin** and actin.

Aequorin and the fluorescent dyes used in research only emit for a few short **nano-seconds** making them ideal to measure the rapid movements found in muscle cells.

Royalsocietypublishing.org



Explain how skeletal muscle contracts [8 marks]

- Muscles / fibers / myofibrils contain (repeating0 units called sarcomeres;
- Muscles / sarcomeres contain actin and myosin filaments;
- Actin fibers are thin AND myosin fibers are thick;
- Arriving action potential causes a release of calcium ions from the sarcoplasm / endoplasmic reticulum;
- Calcium ions bind to troponin causing troponin and tropomyosin to move;
- Binding sites on actin are exposed;
- ATP binds to myosin heads releasing them / breaking cross bridges;
- ATP is hydrolyzed / split into ADP + P_i;
- ATP/ energy causes myosin heads to change shape / swivel / become cocked;
- Myosin heads bind / form cross-bridges to (exposed) actin binding sites;
- Myosin heads swivel / move actin (releasing ADP + P_i);
- Myosin filaments move actin filaments towards the center of the sarcomere;
- Sliding of filaments / actin and myosin shortens the sarcomere