Chapter 17: Locomotion and Movement

Exercises — Exercises

Q1 Draw the diagram of a sarcomere of skeletal muscle showing different regions.

SOLUTION

A sarcomere is the functional unit of contraction in a myofibril, bounded by two successive Z lines.

Structure of a Sarcomere (key regions):
- Z line: elastic fibres that bisect each I band; thin (actin) filaments are firmly attached here
- I band (Isotropic band): light band containing only thin actin filaments; located on either side of the A band
- A band (Anisotropic band): dark band containing thick myosin filaments; extends the full length of the myosin filament
- H zone: central pale region within the A band where thick filaments are NOT overlapped by thin filaments (visible in relaxed state)
- M line: thin fibrous membrane in the middle of the A band that holds thick filaments together

Labelled diagram description (left to right along one sarcomere):
Z line | I band | A band (with H zone at centre, M line at midpoint) | I band | Z line

Thin filaments (actin) extend from Z lines inward into the A band, partially overlapping the thick filaments.
Thick filaments (myosin) span the full A band with cross-bridge heads projecting outward.
During contraction, I bands shorten and H zone narrows; A band length remains unchanged.

Answer: A sarcomere (Z line to Z line) contains: I bands (thin actin filaments, light), A band (thick myosin filaments, dark), H zone (centre of A band, no actin overlap), and M line (mid-A band, holds myosin). Thin filaments anchor at Z lines and partially overlap thick filaments.

Q2 Define sliding filament theory of muscle contraction.

SOLUTION

The sliding filament theory states that muscle contraction occurs by the sliding of thin filaments (actin) over thick filaments (myosin), without any change in the length of either filament.

Key points of the theory:
- During contraction, actin thin filaments slide towards the centre of the A band (towards the M line)
- The Z lines, to which thin filaments are attached, are pulled inward, shortening the sarcomere
- The I bands get reduced (shorten) as actin slides in
- The H zone narrows as thin filaments cover more of the thick filaments
- The A band length remains constant throughout contraction
- Energy from ATP hydrolysis powers the cyclic formation and breaking of cross bridges between myosin heads and actin

Answer: The sliding filament theory states that muscle contraction occurs by the sliding of thin (actin) filaments over thick (myosin) filaments. During contraction, actin slides toward the M line, the I bands shorten, the H zone narrows, but the A band length remains unchanged.

Q3 Describe the important steps in muscle contraction.

SOLUTION

Muscle contraction involves the following steps:

1. Neural signal: The central nervous system (CNS) sends a signal via a motor neuron to the muscle fibre.

2. Neuromuscular junction: At the motor-end plate (neuromuscular junction), the neural signal triggers release of the neurotransmitter acetylcholine (ACh).

3. Action potential: ACh generates an action potential in the sarcolemma (plasma membrane of muscle fibre), which spreads throughout the muscle fibre.

4. Calcium release: The action potential causes the release of Ca++ ions from the sarcoplasmic reticulum into the sarcoplasm.

5. Unmasking of active sites: Increased Ca++ binds to a subunit of troponin on the actin filaments. This removes the masking of active (myosin-binding) sites on

actin by tropomyosin.

6. Cross-bridge formation: Using energy from ATP hydrolysis (ATP -> ADP + Pi), the myosin head binds to the exposed active sites on actin, forming cross bridges.

7. Power stroke: The myosin head pulls the actin filaments toward the centre of the A band (M line). The Z lines are pulled inward, shortening the sarcomere — this is contraction.

8. Cross-bridge breaking: Myosin releases ADP and Pi and returns to its relaxed state. A new ATP binds to the myosin head, causing the cross bridge to break.

9. Cycle repeats: The new ATP is hydrolysed and the myosin head re-attaches to the next actin site. This cycle repeats, causing further sliding and contraction.

10. Relaxation: When the neural signal stops, Ca++ is actively pumped back into the sarcoplasmic reticulum. Troponin re-masks the active sites on actin, cross bridges cannot reform, and the muscle relaxes (Z lines return to original position).

Answer: Steps: (1) CNS signal via motor neuron to neuromuscular junction. (2) ACh released, generates action potential in sarcolemma. (3) Ca++ released from sarcoplasmic reticulum. (4) Ca++ binds troponin, unmasking active sites on actin. (5) Myosin head binds actin (cross bridge) using ATP energy. (6) Power stroke slides actin toward M line, shortening sarcomere. (7) New ATP breaks cross bridge; cycle repeats. (8) On signal cessation, Ca++ pumped back, actin masked, muscle relaxes.

Q4 Write true or false. If false change the statement so that it is true.
(a) Actin is present in thin filament
(b) H-zone of striated muscle fibre represents both thick and thin filaments.
(c) Human skeleton has 206 bones.
(d) There are 11 pairs of ribs in man.
(e) Sternum is present on the ventral side of the body.

SOLUTION

(a) Actin is present in thin filament.
TRUE. Actin filaments are the thin filaments of the myofibril.

(b) H-zone of striated muscle fibre represents both thick and thin filaments.
FALSE. The H zone is the central region of the A band where only thick (myosin) filaments are present and thin (actin) filaments do NOT overlap. Corrected: H

zone represents only thick filaments.

(c) Human skeleton has 206 bones.
TRUE. An adult human skeleton consists of 206 bones.

(d) There are 11 pairs of ribs in man.
FALSE. There are 12 pairs of ribs in human beings. Corrected: There are 12 pairs of ribs in man.

(e) Sternum is present on the ventral side of the body.
TRUE. The sternum is a flat bone on the ventral midline of the thorax.

Answer: (a) True. (b) False — H zone has only thick filaments, not both. (c) True. (d) False — there are 12 pairs of ribs. (e) True.

Q5 Write the difference between:
(a) Actin and Myosin
(b) Red and White muscles
(c) Pectoral and Pelvic girdle

SOLUTION

(a) Actin vs Myosin:
- Actin: thin filament; polymer of monomeric G (globular) actins forming F (filamentous) actin; two F actin strands wound helically; located in the I band; also carries associated proteins tropomyosin and troponin; active binding sites for myosin are present on it (masked at rest by troponin)
- Myosin: thick filament; polymer of meromyosin monomers; each meromyosin has a globular head (HMM) and a tail (LMM); located in the A band; globular head is an ATPase enzyme with binding sites for ATP and active sites for actin; forms cross bridges during contraction

(b) Red muscles vs White muscles:
- Red muscles: contain high amounts of the red pigment myoglobin; rich in mitochondria; depend on aerobic respiration for energy (ATP); fatigue slowly; also called slow fibres or aerobic muscles
- White muscles: contain little myoglobin; appear pale/whitish; fewer mitochondria but high sarcoplasmic reticulum; depend on anaerobic respiration for energy; fatigue quickly; also called fast fibres or anaerobic muscles

(c) Pectoral girdle vs Pelvic girdle:
- Pectoral girdle: connects upper limbs (fore limbs) to the axial skeleton; each half

consists of a clavicle (collar bone) and a scapula; scapula has a glenoid cavity that articulates with the head of humerus (shoulder joint); bones are not fused, allowing greater mobility

- Pelvic girdle: connects lower limbs (hind limbs) to the axial skeleton; each half (coxal bone) is formed by fusion of three bones — ilium, ischium and pubis; the two halves meet ventrally at the pubic symphysis; has the acetabulum which articulates with the femur (hip joint); is more robust and weight-bearing

Answer: (a) Actin = thin filament in I band, polymer of G-actin, carries troponin/tropomyosin; Myosin = thick filament in A band, has ATPase globular head, forms cross bridges. (b) Red = myoglobin-rich, many mitochondria, aerobic; White = myoglobin-poor, fewer mitochondria, anaerobic. (c) Pectoral = clavicle + scapula, connects fore limbs, shoulder joint; Pelvic = ilium/ischium/pubis fused, connects hind limbs, hip joint.

Q6 Match Column I with Column II:

Column I: (a) Smooth muscle (b) Tropomyosin (c) Red muscle (d) Skull

Column II: (i) Myoglobin (ii) Thin filament (iii) Sutures (iv) Involuntary

SOLUTION

(a) Smooth muscle -> (iv) Involuntary

Smooth (visceral) muscles are involuntary muscles not under voluntary control of the nervous system.

(b) Tropomyosin -> (ii) Thin filament

Tropomyosin is a protein associated with the actin (thin) filament; it masks the active binding sites for myosin in the resting state.

(c) Red muscle -> (i) Myoglobin

Red muscles are rich in myoglobin, the red-coloured oxygen-storing pigment, which gives them their reddish colour.

(d) Skull -> (iii) Sutures

The flat bones of the skull fuse end-to-end via dense fibrous connective tissue called sutures, forming immovable fibrous joints.

Answer: (a) Smooth muscle - (iv) Involuntary; (b) Tropomyosin - (ii) Thin filament; (c) Red muscle - (i) Myoglobin; (d) Skull - (iii) Sutures.

Q7 What are the different types of movements exhibited by the cells of human body?

SOLUTION

Cells of the human body exhibit three main types of movements:

1. Amoeboid movement:
- Exhibited by specialised cells such as macrophages and leucocytes (white blood cells) in blood
- Effected by pseudopodia formed by streaming of protoplasm (similar to Amoeba)
- Cytoskeletal elements like microfilaments are involved

2. Ciliary movement:
- Occurs in internal tubular organs lined by ciliated epithelium
- Coordinated beating of cilia in the trachea helps remove dust particles and foreign substances
- Ciliary movement also facilitates passage of ova through the female reproductive tract

3. Muscular movement:
- Required for movement of limbs, jaws, tongue, eyelids, etc.
- Made possible by the contractile property of muscle cells
- Used for locomotion and other body movements

Answer: Three types: (1) Amoeboid movement — by macrophages/leucocytes via pseudopodia and microfilaments; (2) Ciliary movement — by ciliated epithelium in trachea and female reproductive tract; (3) Muscular movement — by contractile muscle cells for locomotion and body movements.

Q8 How do you distinguish between a skeletal muscle and a cardiac muscle?

SOLUTION

Skeletal muscle vs Cardiac muscle:

Location:
- Skeletal muscle: attached to skeletal bones; present in limbs, trunk, face, etc.
- Cardiac muscle: found exclusively in the wall of the heart

Appearance/Striations:
- Skeletal muscle: striated (shows alternating dark A bands and light I bands);

fibres are long, cylindrical and unbranched
- Cardiac muscle: also striated; fibres are short, cylindrical and branched; cells interconnect forming a network

Control (Voluntary vs Involuntary):
- Skeletal muscle: voluntary — under direct control of the nervous system; contracts on command
- Cardiac muscle: involuntary — NOT under direct voluntary control of the nervous system; contracts rhythmically and automatically

Nuclei:
- Skeletal muscle: multinucleate (syncytium); nuclei are peripheral
- Cardiac muscle: typically uninucleate or binucleate; centrally placed nuclei

Fatigue:
- Skeletal muscle: can fatigue with repeated stimulation
- Cardiac muscle: does not fatigue under normal conditions; contracts rhythmically throughout life

Answer: Both are striated. Skeletal muscle is voluntary, unbranched, multinucleate, attached to bones. Cardiac muscle is involuntary, branched, uninucleate/binucleate, found only in the heart, and contracts rhythmically without fatigue.

Q9 Name the type of joint between the following:
(a) atlas/axis
(b) carpal/metacarpal of thumb
(c) between phalanges
(d) femur/acetabulum
(e) between cranial bones
(f) between pubic bones in the pelvic girdle

SOLUTION

(a) Atlas/Axis: Pivot joint
A pivot joint allows rotation. The atlas (first cervical vertebra) rotates around the axis (second cervical vertebra), permitting the head to turn side to side.

(b) Carpal/metacarpal of thumb: Saddle joint
A saddle joint allows movement in two planes (flexion/extension and abduction/adduction). The joint at the base of the thumb is a classic saddle joint.

(c) Between phalanges: Hinge joint

Hinge joints allow movement in only one plane (flexion and extension). The interphalangeal joints between finger and toe bones are hinge joints.

(d) Femur/acetabulum: Ball and socket joint
The rounded head (ball) of the femur fits into the cup-shaped acetabulum (socket) of the pelvic girdle. This joint allows movement in multiple planes (hip joint).

(e) Between cranial bones: Fibrous joint (Sutures)
The flat bones of the skull are fused end-to-end by dense fibrous connective tissue called sutures. These are immovable fibrous joints.

(f) Between pubic bones in the pelvic girdle: Cartilaginous joint (Pubic symphysis)
The two halves of the pelvic girdle meet ventrally and are joined by fibrous cartilage at the pubic symphysis — a cartilaginous joint that permits very limited movement.

Answer: (a) Pivot joint; (b) Saddle joint; (c) Hinge joint; (d) Ball and socket joint; (e) Fibrous joint (sutures); (f) Cartilaginous joint (pubic symphysis).

Q10 Fill in the blank spaces:
(a) All mammals (except a few) have _____ cervical vertebra.
(b) The number of phalanges in each limb of human is _____
(c) Thin filament of myofibril contains 2 'F' actins and two other proteins namely _____ and _____.
(d) In a muscle fibre Ca++ is stored in _____
(e) _____ and _____ pairs of ribs are called floating ribs.
(f) The human cranium is made of _____ bones.

SOLUTION

(a) All mammals (except a few) have 7 cervical vertebrae.
Seven cervical vertebrae are present in almost all mammals including human beings.

(b) The number of phalanges in each limb of human is 14.
Each hand (fore limb) has 14 phalanges (digits). Each foot (hind limb) also has 14 phalanges.

(c) Thin filament of myofibril contains 2 'F' actins and two other proteins namely tropomyosin and troponin.
Tropomyosin runs along the length of F actin. Troponin is distributed at regular intervals on tropomyosin and masks the active sites for myosin in the resting

state.

(d) In a muscle fibre Ca++ is stored in the sarcoplasmic reticulum.
The sarcoplasmic reticulum (SR) acts as a calcium ion reservoir. On receiving a neural signal, Ca++ is released from the SR into the sarcoplasm.

(e) 11th and 12th pairs of ribs are called floating ribs.
The last two pairs of ribs (11th and 12th) are not connected ventrally to the sternum or to other ribs, so they are called floating ribs.

(f) The human cranium is made of 8 bones.
The cranium (hard protective covering for the brain) is formed by 8 cranial bones.

Answer: (a) 7; (b) 14; (c) tropomyosin and troponin; (d) sarcoplasmic reticulum; (e) 11th and 12th; (f) 8 bones.