Answers to Questions for Comprehension

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Q1.

- Smooth muscle cells are non-striated, have a single nucleus, and are usually arranged in parallel lines, forming sheets. They are under involuntary control and found in the walls of many internal organs.
- Cardiac muscle is only found in the heart and forms the wall of this organ. Its cells are striated, and each has a single nucleus. Cardiac muscle cells are tubular and branched, forming a tough, net-like structure. Cardiac muscle contraction is involuntary.
- Skeletal muscles are tubular and striated. Skeletal muscle contraction is voluntary. These muscle cells are long, and each has a number of nuclei (multinucleated). They are usually referred to as fibres, rather than cells.

Q2. To lengthen, a muscle must relax so that an opposing force can pull the muscle back to its full length. The arrangement of opposing pairs of muscles around a joint (in effect, a fulcrum) allows them to act together to stretch each other out and provides the force to move a bone (in effect, a lever) in opposite directions.

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Q3. Skeletal muscle fibre consists of hundreds of thousands of cylindrical sub-units called **myofibrils**. Each of these is made of even finer **myofilaments**, which contain protein structures responsible for muscle contraction.

Q4. An **actin** (thin) **myofilament** consists of two strands of protein molecules that are wrapped around each other, somewhat like two strands of beads loosely wound together. A **myosin** (thick) **myofilament** is also composed of two strands of protein wound around each other; however, a myosin myofilament is about 10 times longer than an actin myofilament, and the myosin strands have a different shape. One end of a myosin myofilament consists of a long rod, while the other end consists of a double-headed globular region, often called the "head."

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Q5. When a muscle fibre contracts, the heads of thousands of myosin myofilaments move first. This moves them closer to their rod-like "backbone" and a few nanometers in the direction of the flex. Because the heads are attached (chemically bound) at this time to actin myofilaments, the actin myofilaments are pulled along with the myosin heads as they flex. As a result, the actin myofilaments slide past the myosin myofilaments in the direction of the flex. As one myosin head after another flexes, the myosin, in effect, "walks" in place, step by step, along the actin. Each step requires a molecule of ATP to provide the energy that repositions the myosin head before each flex.

Q6. The **sliding filament model** of muscle contraction can be described as follows:

- Within each myofilament, the actin is anchored at one end, at a position in striated muscle tissue called the Z line. Because it is tethered like this, the movement of actin pulls its "anchor" (the Z line) along with it.
- As actin moves past myosin, it drags the Z line toward the myosin.
- The mechanism of muscle contraction depends on the structural arrangement of thousands of myosin myofilaments in relation to thousands of pairs actin myofilaments. With one actin molecule being pulled inward in one direction, and the other actin molecule being pulled inward in the opposite direction, the two pairs of actin drag the Z lines towards each other as they slide past the myosin. As the Z lines are pulled closer together, the plasma membranes to which they are attached move towards one another, and the entire muscle fibre contracts.

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Q7. No, the muscle cannot contract without calcium ions. When the calcium ion concentration in the sarcoplasm is low, tropomyosin inhibits myosin binding, and the muscle is relaxed. When the calcium ion concentration is raised, Ca^{++} binds to troponin. This causes the troponin-tropomyosin complex to be shifted away from the attachment sites for the myosin heads on the actin. When this repositioning has occurred, the myosin heads attach to actin and, using ATP energy, move the actin myofilament to shorten the myofibril.

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Q8. Creatine phosphate is a high-energy compound that builds up when a muscle is resting. This compound cannot participate directly in muscle contraction; instead, it can regenerate ATP. The chemical reaction occurs in the midst of sliding filaments. Therefore, it is the speediest way to make ATP available to muscles. Creatine phosphate provides enough energy for only about eight seconds of intense activity, and then it is spent.

Q9. Fermentation, such as creatine phosphate breakdown, supplies ATP without consuming oxygen. This allows the muscle to continue activity in anaerobic conditions.

Q10. Aerobic cellular respiration, completed in mitochondria, usually provides most of a muscle's ATP. Glycogen and fat are stored in muscle cells. Therefore, a muscle fibre can use glucose from glycogen and fatty acids from fats as fuel to produce ATP when oxygen is available.

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Q11. When a muscle uses fermentation to supply its energy needs, it incurs an oxygen deficit. Oxygen deficit is obvious when a person continues to breathe heavily after exercising. Replenishing an oxygen deficit requires replenishing creatine phosphate supplies and disposes of lactate. Lactate can be changed back to pyruvate and metabolized completely in mitochondria; it can also be sent to the liver to synthesize glycogen.

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Q12. Muscle atrophy can occur through lack of or the reduction of use of skeletal muscle.

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Q13. Hypertrophy is an increase in the size of individual muscle fibres, whereas atrophy is a reduction in the size of individual muscle fibres.

Q14. A muscle fatigues due to the depletion of energy reserves. Fatigue is apparent when a muscle relaxes, even though stimulation continues.

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Q15. Eye muscle is composed of fast-twitch fibres, and soleus muscle is composed of slow-twitch fibres. Hint: Have students examine the graph in Figure 10.12.

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Q16. Aerobic capacity of endurance athletes is greater due to factors such as hypertrophy, more active enzyme activity in the muscle fibres, more numerous mitochondria in the muscle fibres, and a greater density of blood vessels surrounding muscle fibres.

Q17. Muscle enlargement is produced only by frequent periods of high-intensity exercise in which muscles work against a high resistance, as in weight lifting. As a result of resistance training, fast-twitch muscle fibres become thicker, so the muscle grows by hypertrophy—an increase in the size of the muscle fibre.