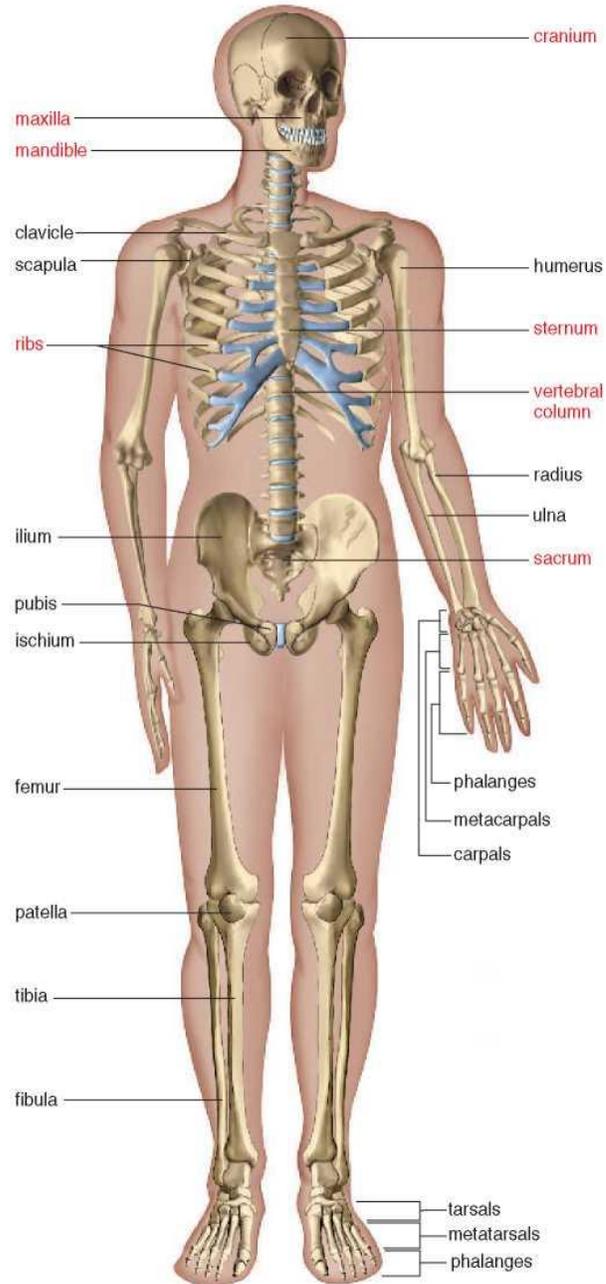


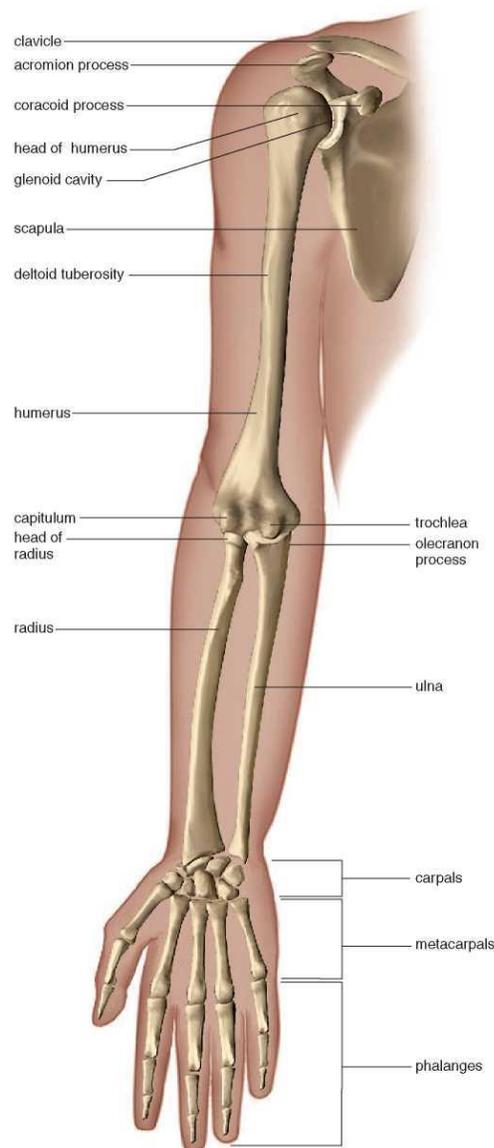
SKELETAL SYSTEM

SKELETAL SYSTEM



- **The skeleton supports the body.** The bones of the legs support the entire body when we are standing, and the coxal bones of the pelvic girdle support the abdominal cavity.
- **The skeleton protects soft body parts.** The bones of the skull protect the brain; the rib cage, composed of the ribs, thoracic vertebrae, and sternum, protects the heart and lungs.
- **The skeleton produces blood cells.** All bones in the fetus have spongy bone with red bone marrow that produces blood cells. Fat is stored in yellow bone marrow.
- **The skeleton stores minerals and fat.** All bones have a matrix that contains calcium phosphate. When bones are remodeled, osteoclasts break down bone and return calcium ions and phosphorus ions to the bloodstream.
- **The skeleton, along with the muscles, permits flexible body movement.** While articulations (joints) occur between all the bones, we associate body movement in particular with the bones of the legs and the feet because we use them when walking.
- **Classification of the Bones.** The bones are classified according to their shape. Long bones, exemplified by the humerus and femur, are longer than they are wide. Short bones, such as the carpals and tarsals, are cube shaped—that is, their lengths and widths are about equal. Flat bones, like those of the skull, are plate-like with broad surfaces. Round bones, exemplified by the patella, are circular in shape. The 206 bones of the skeleton are also classified according to whether they occur in the **axial skeleton** or the **appendicular skeleton**. The axial skeleton is in the midline of the body, and the appendicular skeleton consists of the limbs along with their girdles.

THE APPENDICULAR SKELETON

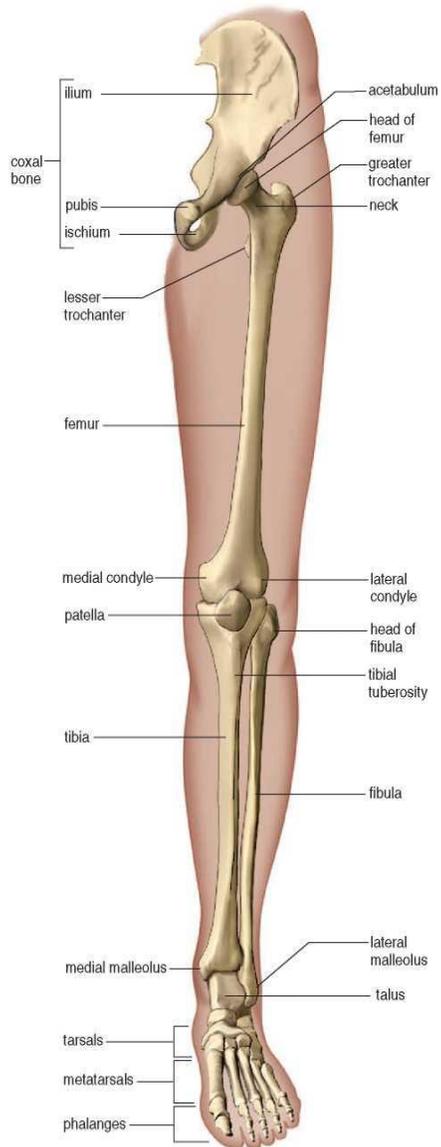


The **appendicular skeleton** consists of the bones within the pectoral and pelvic girdles and their attached limbs. A pectoral (shoulder) girdle and arm are specialized for flexibility.

THE PECTORAL GIRDLE AND ARM

A **pectoral girdle** consists of a scapula (shoulder blade) and a clavicle (collarbone). The **clavicle** extends across the top of the thorax; it articulates with (joins with) the sternum and the acromion process of the **scapula**, a visible bone in the back. The muscles of the arm and chest attach to the coracoid process of the scapula. The **glenoid cavity** of the scapula articulates with and is much smaller than the head of the humerus. This allows the arm to move in almost any direction, but reduces stability. Tendons that encircle and help form a socket for the humerus are collectively called the **rotator cuff**. The components of a pectoral girdle follow freely the movements of the arm, which consists of the humerus of the upper arm and the radius and ulna of the lower arm. The **humerus**, the single long bone in the upper arm, has a smoothly rounded head that fits into the glenoid cavity of the scapula. The far end of the humerus has two protuberances, called the capitulum and the trochlea, which articulate respectively with the **radius** and the **ulna** at the elbow.

THE PELVIC GIRDLE AND LEGS



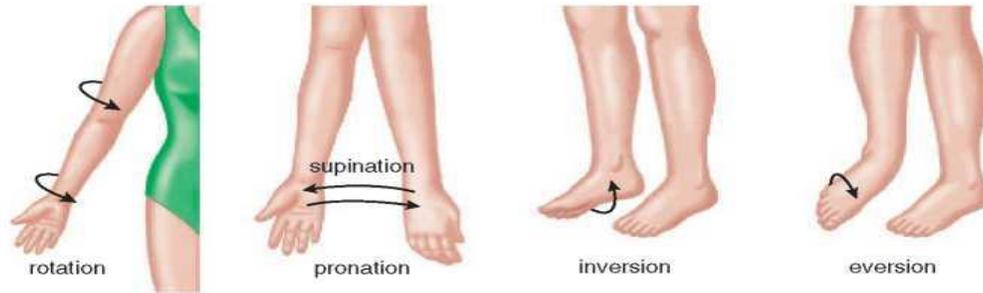
THE PELVIC GIRDLE (hip girdle) consists of two heavy, large coxal bones (hipbones). The **pelvis** is a basin composed of the pelvic girdle, sacrum, and coccyx. The pelvis bears the weight of the body, protects the organs within the pelvic cavity, and serves as the place of attachment for the legs.

- Each **coxal bone** has three parts: the ilium, the ischium, and the pubis, which are fused in the adult. The hip socket, called the acetabulum, occurs where these three bones meet. The ilium is the largest part of the coxal bones, and our hips occur where it flares out. We sit on the ischium, which has a posterior spine called the ischial spine. The pubis, from which the term pubic hair is derived, is the anterior part of a coxal bone. The two pubic bones are joined together by a fibrocartilage disk at the pubic symphysis.
- The **femur** is the longest and strongest bone in the body. The head of the femur articulates with the coxal bones at the acetabulum, and the short neck better positions the legs for walking. The femur has two large processes, the greater and lesser trochanters, which are places of attachment for the muscles of the legs and buttocks. At its distal end, the femur has medial and lateral condyles that articulate with the **tibia** of the lower leg. This is the region of the knee and the **patella**, or kneecap. The patella is held in place by the quadriceps tendon that continues as a ligament which attaches to the tibial tuberosity. At the distal end, the medial malleolus of the tibia causes the inner bulge of the ankle. The **fibula** is the more slender bone in the lower leg. The fibula has a head that articulates with the tibia and a distal lateral malleolus that forms the outer bulge of the ankle.

JOINT MOVEMENTS



a. Angular movements



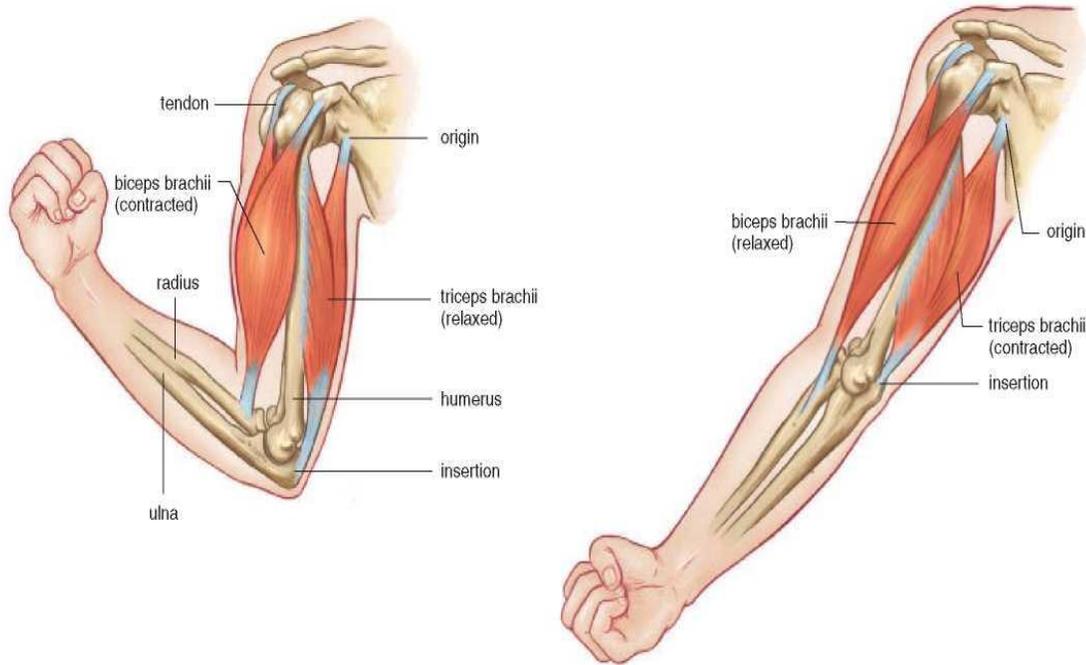
b. Circular movements

c. Special movements

- **Flexion** decreases the joint angle. Flexion of the elbow moves the forearm toward the upper arm; flexion of the knee moves the lower leg toward the upper leg. *Dorsiflexion* is flexion of the foot upward, as when you stand on your heels; *plantar flexion* is flexion of the foot downward, as when you stand on your toes.
- **Extension** increases the joint angle. Extension of the flexed elbow straightens the arm so that there is a 180° angle at the elbow. Hyperextension occurs when a portion of the body part is extended beyond 180°. It is possible to hyperextend the head and the trunk of the body.

- **Adduction** is the movement of a body part toward the midline. For example, adduction of the arms or legs moves them back to the sides, toward the body.
- **Abduction** is the movement of a body part laterally, away from the midline. Abduction of the arms or legs moves them laterally, away from the body.
- **Rotation** is the movement of a body part around its own axis.
- **Supination** is the rotation of the lower arm so that the palm is upward; **pronation** is the opposite—the movement of the lower arm so that the palm is downward.
- **Circumduction** is the movement of a body part in a wide circle, as when a person makes arm circles. If the motion is observed carefully, one can see that, because the proximal end of the arm is stationary, the shape outlined by the arm is actually a cone.

MUSCULAR SYSTEM (SKELETAL MUSCLES)



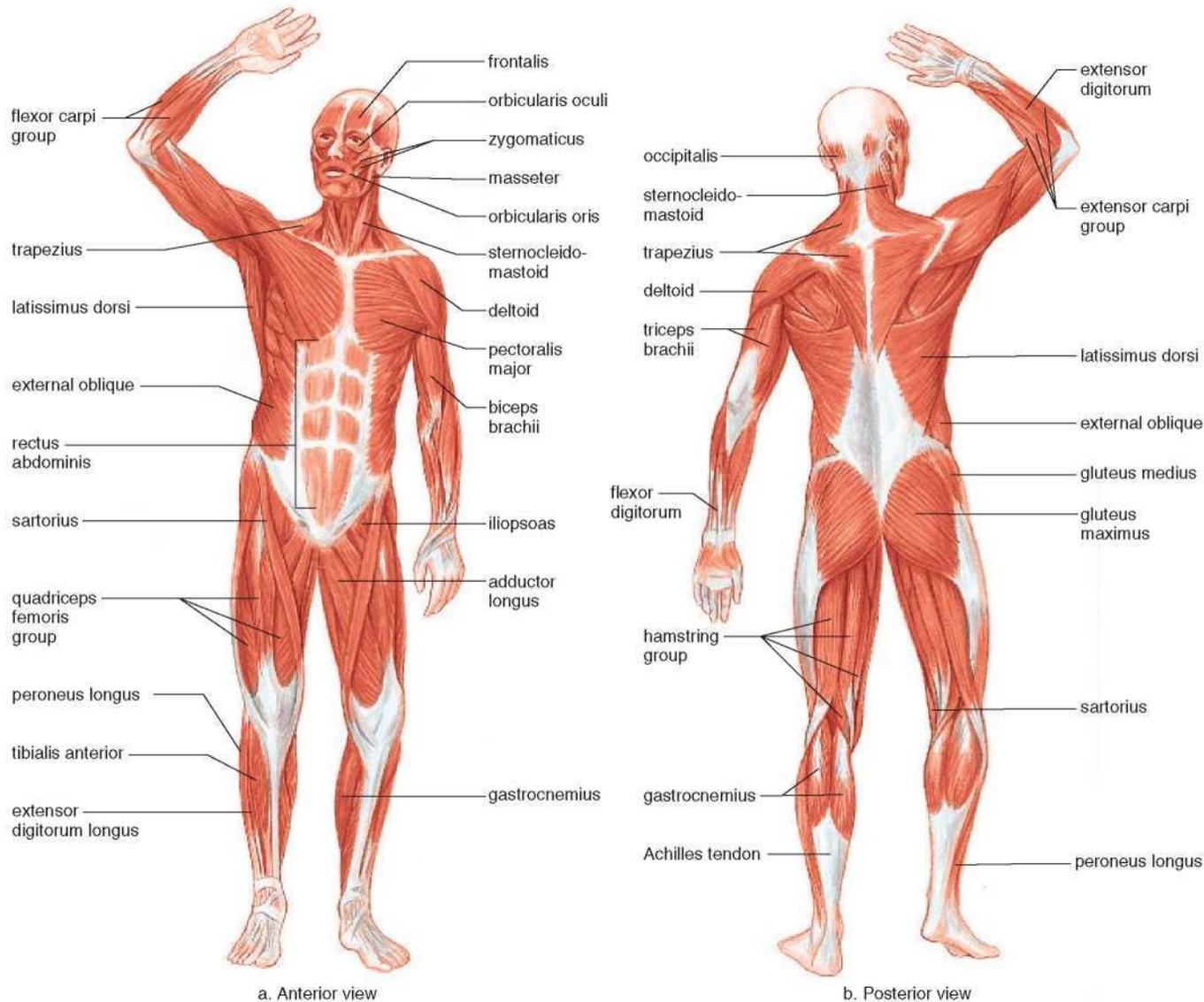
The *origin* of a muscle is on a bone that remains stationary, and the *insertion* of a muscle is on a bone that moves when the muscle contracts.

The muscles in this drawing are *antagonistic*. When the biceps brachii contracts, the lower arm flexes, and when the triceps brachii contracts, the lower arm extends.

Muscles have various functions, which they are more apt to perform well if they are exercised regularly.

- *Skeletal muscles support the body.* Skeletal muscle contraction opposes the force of gravity and allows us to remain upright.
- *Skeletal muscles make bones move.* Muscle contraction accounts not only for the movement of arms and legs but also for movements of the eyes, facial expressions, and breathing.
- *Skeletal muscles help maintain a constant body temperature.* Skeletal muscle contraction causes ATP to break down, releasing heat that is distributed about the body.
- *Skeletal muscle contraction assists movement in cardiovascular and lymphatic vessels.* The pressure of skeletal muscle contraction keeps blood moving in cardiovascular veins and lymph moving in lymphatic vessels.
- *Skeletal muscles help protect internal organs and stabilize joints.* Muscles pad the bones that protect organs, and they have tendons that help hold bones together at joints.

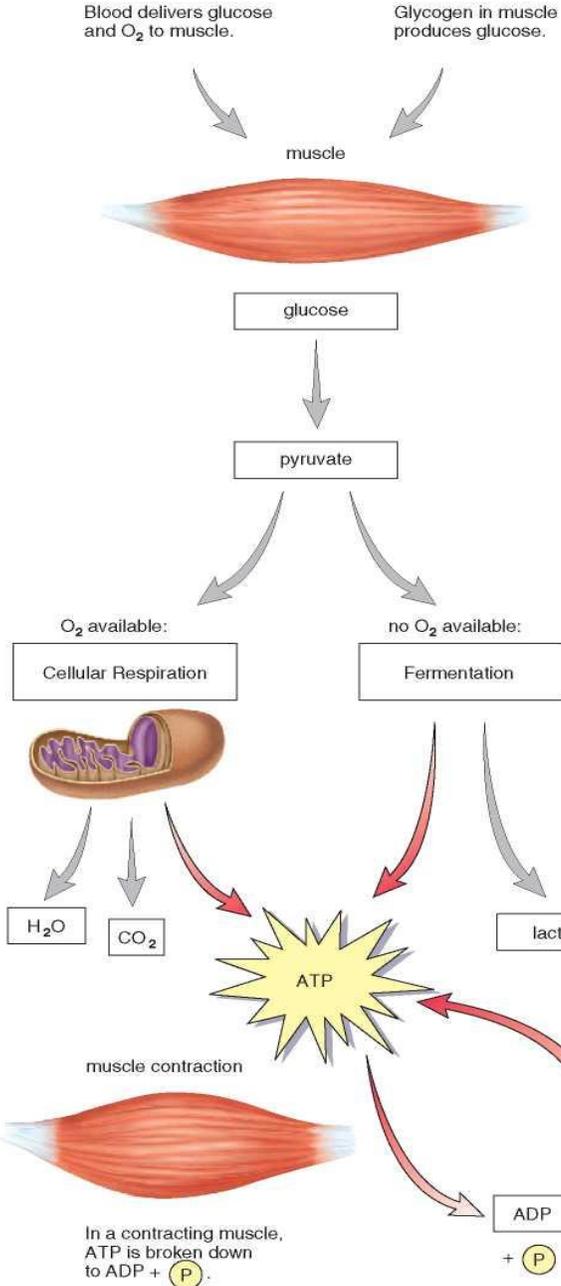
SKELETAL MUSCLES



Skeletal muscles are given names based on the following characteristics and examples:

- **Size.** The gluteus maximus that makes up the buttocks is the largest muscle.
- **Shape.** The deltoid is shaped like a triangle. Location. The frontalis overlies the frontal bone.
- **Direction of muscle fibers.** The rectus abdominis is a longitudinal muscle of the abdomen Number of attachments. The biceps brachii has two attachments, or origins.
- **Action.** The extensor digitorum extends the fingers and digits. Extension increases the joint angle and flexion decreases the joint angle; abduction is the movement of a body part sideways away from the midline and adduction is the movement of a body part toward the midline.

ENERGY SOURCES FOR MUSCLE CONTRACTION



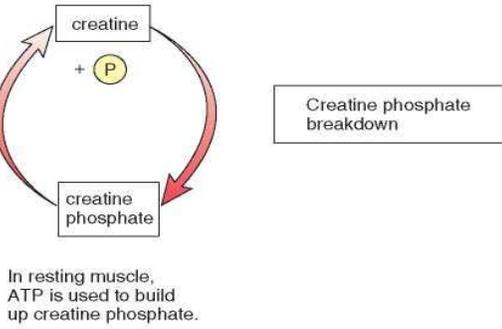
In athletes, there is

- better blood supply to muscles;
- more myoglobin stored in muscles;
- an increase in fatty acid metabolism that spares blood glucose;
- a smaller O_2 debt due to a more rapid increase in O_2 uptake at the onset of work;
- a reduction in lactate and H^+ formation.

Muscles that are not used or that are used for only very weak contractions decrease in size, or atrophy. **Atrophy** can occur when a limb is placed in a cast or when the nerve serving a muscle is damaged. If nerve stimulation is not restored, muscle fibers gradually are replaced by fat and fibrous tissue. Unfortunately, atrophy can cause muscle fibers to shorten progressively, leaving body parts contracted in contorted positions.

Forceful muscular activity over a prolonged period causes muscle to increase in size as the number of myofibrils within the muscle fibers increases. Increase in muscle size, called **hypertrophy**, occurs only if the muscle contracts to at least 75% of its maximum tension.

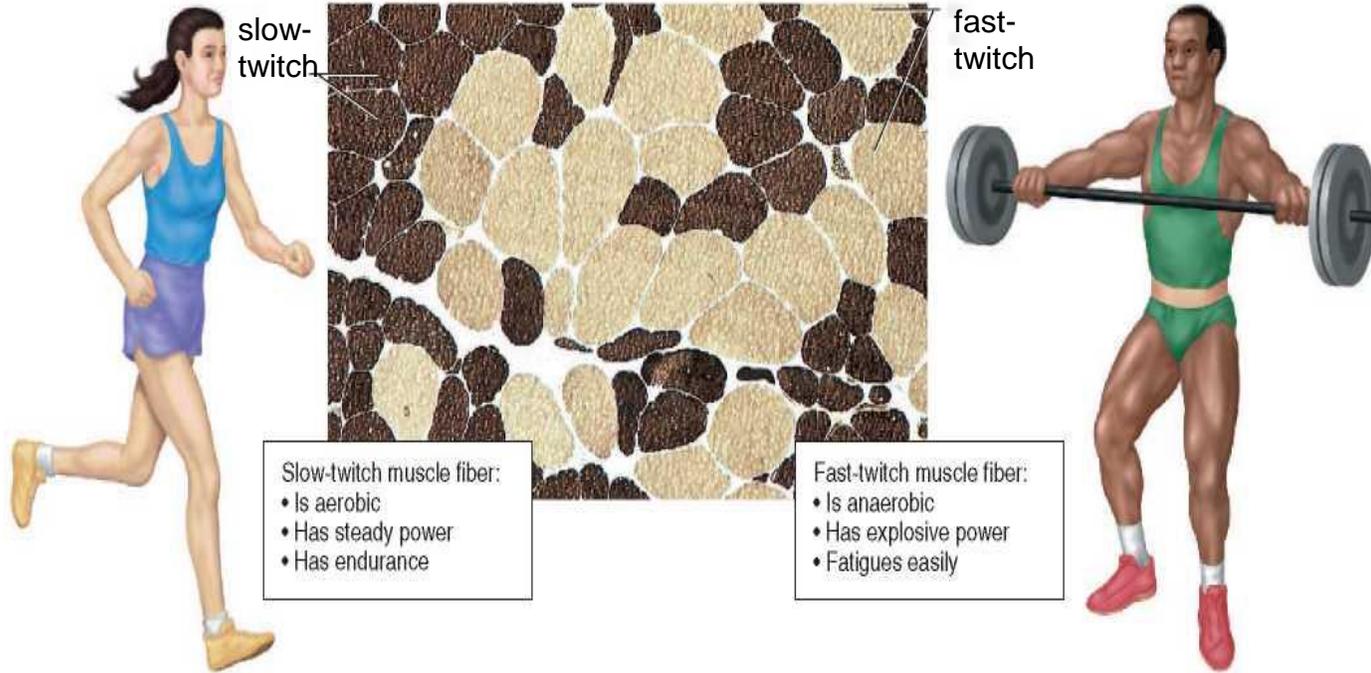
Some athletes take anabolic steroids, either testosterone or related chemicals, to promote muscle growth. This practice has many undesirable side effects, such as cardiovascular disease, liver and kidney dysfunction, impotency and sterility.



In a contracting muscle, ATP is broken down to ADP + P.

In resting muscle, ATP is used to build up creatine phosphate.

SLOW-TWITCH AND FAST-TWITCH MUSCLE FIBERS



All muscle fibers metabolize both aerobically and anaerobically. Some muscle fibers, however, utilize one method more than the other to provide myofibrils with ATP. **Slow-twitch fibers** tend to be aerobic, and fast-twitch fibers tend to be anaerobic. Slow-Twitch Fibers Slow-twitch fibers have more endurance despite motor units with a smaller number of fibers. These muscle fibers are most helpful in sports like long-distance running, biking, jogging, and swimming. Because they produce most of their energy aerobically, they tire only when their fuel supply is gone.

Fast-twitch fibers tend to be anaerobic and seem to be designed for strength because their motor units contain many fibers. They provide explosions of energy and are most helpful in sports activities like sprinting, weight lifting, swinging a golf club, or throwing a shot. Fast-twitch fibers are light in color because they have fewer mitochondria, little or no myoglobin, and fewer blood vessels than slow-twitch fibers do. Fast-twitch fibers can develop maximum tension more rapidly than slow-twitch fibers can, and their maximum tension is greater. However, their dependence on anaerobic energy leaves them vulnerable to an accumulation of lactic acid that causes them to fatigue quickly.

Integumentary System

Muscle contraction provides heat to warm skin.



Skin protects muscles; rids the body of heat produced by muscle contraction.

Skeletal System

Muscle contraction causes bones to move joints; muscles help protect bones.



Bones provide attachment sites for muscles; store Ca^{2+} for muscle function.

Nervous System

Muscle contraction moves eyes, permits speech, creates facial expressions.



Brain controls nerves that innervate muscles; receptors send sensory input from muscles to brain.

Endocrine System

Muscles help protect glands.



Androgens promote growth of skeletal muscle; epinephrine stimulates heart and constricts blood vessels.

Cardiovascular System

Muscle contraction keeps blood moving in heart and blood vessels.



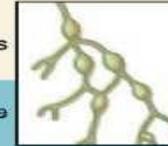
Blood vessels deliver nutrients and oxygen to muscles, carry away wastes.

How the Muscular System works with other body systems



Lymphatic System/Immunity

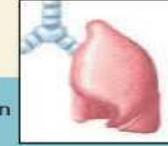
Skeletal muscle contraction moves lymph; physical exercise enhances immunity.



Lymphatic vessels pick up excess tissue fluid; immune system protects against infections.

Respiratory System

Muscle contraction assists breathing; physical exercise increases respiratory capacity.



Lungs provide oxygen for, and rid the body of, carbon dioxide from contracting muscles.

Digestive System

Smooth muscle contraction accounts for peristalsis; skeletal muscles support and help protect abdominal organs.



Digestive tract provides glucose for muscle activity; liver metabolizes lactic acid following anaerobic muscle activity.

Urinary System

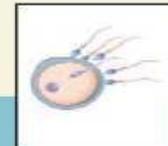
Smooth muscle contraction assists voiding of urine; skeletal muscles support and help protect urinary organs.



Kidneys maintain blood levels of Na^+ , K^+ , and Ca^{2+} , which are needed for muscle innervation, and eliminate creatinine, a muscle waste.

Reproductive System

Muscle contraction occurs during orgasm and moves gametes; abdominal and uterine muscle contraction occurs during childbirth.



Androgens promote growth of skeletal muscle.

REVIEW QUESTIONS

- What is tone, and how is it maintained? By what mechanism does the strength of muscle contraction vary?
- What are differences between origin and insertion parts of the skeletal muscles?
- What are the three ways a muscle fiber can acquire ATP for muscle contraction? How are the three ways interrelated?
- What is atrophy? Hypertrophy?
- Contrast slow-twitch and fast-twitch fibers in as many ways as possible.
- How does the muscular system help maintain homeostasis?