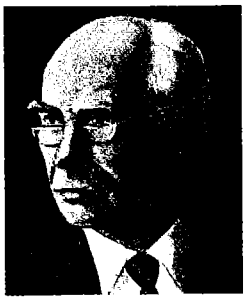
Science Applications



Muscle Function

Andrew F. Huxley (b. 1917)

The British physiologist Andrew F. Huxley is largely responsible for explaining how muscle fibers contract. After making pioneering discoveries in how nerves conduct impulses, a feat for which he shared the 1963 Nobel Prize in Medicine or Physiology, Huxley turned his attention to muscle fibers. It was he who in the 1950s proposed the sliding filament model along with its mechanical explanation of muscle contraction.

Today, research physiologists continue to find out more about how muscle fibers work. These discoveries are being applied in many different professions. For example, nutritionists use this information in advising athletes and others concerning what and when to eat to maximize muscular strength and endurance. Athletes themselves, along with their coaches and trainers, use current concepts of muscle science in helping them improve their performance. Of course, health professionals such as physicians, nurses, and physical therapists use information about muscular problems such as myasthenia gravis and muscular dystrophy to help treat patients. Many other professions, such as massage therapy, occupational therapy, ergonomics, physical education and fitness, dance, art, and biomechanical engineering also rely on up-to-date information on muscle structure and function.

OUTLINE SUMMARY

INTRODUCTION

A. Muscular tissue enables the body and its parts to move
   1. Three types of muscle tissue exist in body (see Chapter 3)
   2. Movement caused by muscle cells (called *fibers*) shortening, or contracting
   3. Muscle movement occurs when chemical energy (obtained from food) is converted into mechanical energy

MUSCLE TISSUE

A. Types of muscle tissue (Figure 7-1)
   1. Skeletal muscle—also called *striated* or *voluntary muscle*
      a. Microscope reveals crosswise stripes or striations
      b. Contractions can be voluntarily controlled
   2. Cardiac muscle—composes bulk of heart
      a. Cardiac muscle fibers are branched
      b. Has dark bands called *intercalated disks*
      c. Cardiac muscle fiber interconnections allow heart to contract efficiently as a unit
   3. Nonstriated muscle, or involuntary muscle—also called *smooth* or *visceral muscle*
      a. Lacks striations when seen under a microscope; appears smooth
      b. Found in walls of hollow structures such as digestive tract, blood vessels, etc.
      c. Contractions not under voluntary control

B. Function—all muscle fibers specialize in contraction (shortening)

STRUCTURE OF SKELETAL MUSCLE

A. Composition—mainly striated muscle fibers and connective tissue
   1. Most skeletal muscles extend from one bone across a joint to another bone

OUTLINE SUMMARY—cont'd

2. Parts of a skeletal muscle
   a. Origin—attachment to the bone that remains relatively stationary or fixed when movement at the joint occurs
   b. Insertion—point of attachment to the bone that moves when a muscle contracts
   c. Body—main part of the muscle
3. Muscles attach to bone by tendons—strong cords of fibrous connective tissue; some tendons enclosed in synovial-lined tubes (tendon sheaths) and are lubricated by synovial fluid
4. Bursae—small synovial-lined sacs containing a small amount of synovial fluid; located between some tendons and underlying bones

B. Microscopic structure (Figure 7-3)
1. Contractile cells called *fibers*—grouped into bundles
2. Fibers contain thick myofilaments (containing myosin) and thin myofilaments (containing actin)
3. Basic functional (contractile) unit called *sarcomere*
   a. Sarcomeres separated from each other by dark bands called *Z lines*
   b. Sliding filament model explains mechanism of contraction
      (1) Thick and thin myofilaments slide past each other to contract
      (2) Contraction requires calcium and energy-rich ATP molecules

FUNCTIONS OF SKELETAL MUSCLE

A. Movement
1. Muscles produce movement; as a muscle contracts, it pulls the insertion bone closer to the origin bone; movement occurs at the joint between the origin and the insertion
   a. Groups of muscles usually contract to produce a single movement
      (1) Prime mover—mainly responsible for producing a given movement
      (2) Synergist—helps the prime mover produce a given movement
      (3) Antagonist—opposes the action of a prime mover in any given movement

B. Posture
1. A continuous, low-strength muscle contraction, called *tonic contraction*, enables us to maintain body position
   a. Only a few of a muscle's fibers shorten at one time
   b. Produce no movement of body parts
   c. Maintain muscle tone called *posture*
      (1) Good posture reduces strain on muscles, tendons, ligaments, and bones
      (2) Poor posture causes fatigue and may lead to deformity

C. Heat production
1. Survival depends on the body's ability to maintain a constant body temperature
   a. Fever—an elevated body temperature—often a sign of illness
   b. Hypothermia—a reduced body temperature
2. Contraction of muscle fibers produces most of the heat required to maintain normal body temperature

FATIGUE

A. Reduced strength of muscle contraction
B. Caused by repeated muscle stimulation without adequate periods of rest
C. Repeated muscular contraction depletes cellular ATP stores and outstrips the ability of the blood supply to replenish oxygen and nutrients
D. Contraction in the absence of adequate oxygen produces lactic acid, which contributes to muscle soreness
E. *Oxygen debt*—term used to describe the metabolic effort required to burn excess lactic acid that may accumulate during prolonged periods of exercise; the body is attempting to return the cells' energy and oxygen reserves to pre-exercise levels

Continued

OUTLINE SUMMARY—cont'd

ROLE OF OTHER BODY SYSTEMS IN MOVEMENT

A. Muscle functioning depends on the functioning of many other parts of the body
B. Most muscles cause movements by pulling on bones across movable joints
C. Respiratory, circulatory, nervous, muscular, and skeletal systems play essential roles in producing normal movements
D. Multiple sclerosis, brain hemorrhage, and spinal cord injury are examples of how pathological conditions in other body organ systems can dramatically affect movement

MOTOR UNIT (Figure 7-4)

A. Stimulation of a muscle by a nerve impulse is required before a muscle can shorten and produce movement
B. Motor neuron—nerve cell that transmits an impulse to a muscle, causing contraction
C. Neuromuscular junction—point of contact between a nerve ending and a muscle fiber
D. Motor unit—combination of a motor neuron with the muscle fibers it controls

MUSCLE STIMULUS

A. A muscle will contract only if an applied stimulus reaches a certain level of intensity
   1. Threshold stimulus—minimal level of stimulation required to cause a muscle fiber to contract
B. Once stimulated by a threshold stimulus, a muscle fiber will contract completely, a response called *all or none*
C. Different muscle fibers in a muscle are controlled by different motor units having different threshold-stimulus levels
   1. Although individual muscle fibers always respond all or none to a threshold stimulus, the muscle as a whole does not
   2. Different motor units responding to different threshold stimuli permit a muscle as a whole to execute contractions of graded force

TYPES OF SKELETAL MUSCLE CONTRACTION

A. Twitch and tetanic contractions
   1. Twitch contractions are laboratory phenomena, not normal muscle activity; they are a single contraction of muscle fibers caused by a single threshold stimulus
   2. Tetanic contractions are sustained muscular contractions caused by stimuli hitting a muscle in rapid succession
B. Isotonic contractions
   1. Contractions that produce movement at a joint because the muscle changes length
   2. Concentric contractions—the muscle shortens insertion end of the muscle to move toward to the point of origin
   3. Eccentric contractions—the muscle lengthens under tension, thus moving the insertion away from the origin
   4. Most types of body movements (walking, running, etc.) are produced by isotonic contractions
C. Isometric contractions
   1. Contractions that do not produce movement; the muscle as a whole does not shorten
   2. Although no movement occurs, tension within the muscle increases

EFFECTS OF EXERCISE ON SKELETAL MUSCLES

A. Exercise, if regular and properly practiced, improves muscle tone and posture, results in more efficient heart and lung functioning, and reduces fatigue
B. Muscles change in relation to the amount of work they normally do
   1. Prolonged inactivity causes disuse atrophy
   2. Regular exercise increases muscle size, called *hypertrophy*

OUTLINE SUMMARY—cont'd

C. Strength training is exercise involving contraction of muscles against heavy resistance
   1. Strength training increases the numbers of myofilaments in each muscle fiber, and as a result, the total mass of the muscle increases
   2. Strength training does not increase the number of muscle fibers

D. Endurance training is exercise that increases a muscle's ability to sustain moderate exercise over a long period; it is sometimes called *aerobic training*
   1. Endurance training allows more efficient delivery of oxygen and nutrients to a muscle via increased blood flow
   2. Endurance training does not usually result in muscle hypertrophy

SKELETAL MUSCLE GROUPS (Table 7-1)

A. Muscles of the head and neck (Figure 7-7)
   1. Facial muscles
      a. Orbicularis oculi
      b. Orbicularis oris
      c. Zygomaticus
   2. Muscles of mastication
      a. Masseter
      b. Temporal
   3. Sternocleidomastoid—flexes head
   4. Trapezius—elevates shoulders and extends head

B. Muscles that move the upper extremities
   1. Pectoralis major—flexes upper arm
   2. Latissimus dorsi—extends upper arm
   3. Deltoid—abducts upper arm
   4. Biceps brachii—flexes forearm
   5. Triceps brachii—extends forearm

C. Muscles of the trunk (Figure 7-8)
   1. Abdominal muscles
      a. Rectus abdominis
      b. External oblique
      c. Internal oblique
      d. Transversus abdominis
   2. Respiratory muscles
      a. Intercostal muscles
      b. Diaphragm

D. Muscles that move the lower extremities
   1. Iliopsoas—flexes thigh
   2. Gluteus maximus—extends thigh
   3. Adductor muscles—adduct thighs
   4. Hamstring muscles—flex lower leg
      a. Semimembranosus
      b. Semitendinosus
      c. Biceps femoris
   5. Quadriceps femoris group—extend lower leg
      a. Rectus femoris
      b. Vastus muscles
   6. Tibialis anterior—dorsiflexes foot
   7. Gastrocnemius—plantar flexes foot
   8. Peroneus group—flex foot

MOVEMENTS PRODUCED BY SKELETAL MUSCLE CONTRACTIONS (Figures 7-9 through 7-11)

A. Flexion—decreases an angle
B. Extension—increases an angle
C. Abduction—away from the midline
D. Adduction—toward the midline
E. Rotation—around an axis
F. Supination and pronation—hand positions that result from twisting of the forearm
G. Dorsiflexion and plantar flexion—foot movements (upward and downward ankle movement)
H. Inversion and eversion—foot movements (sideways)