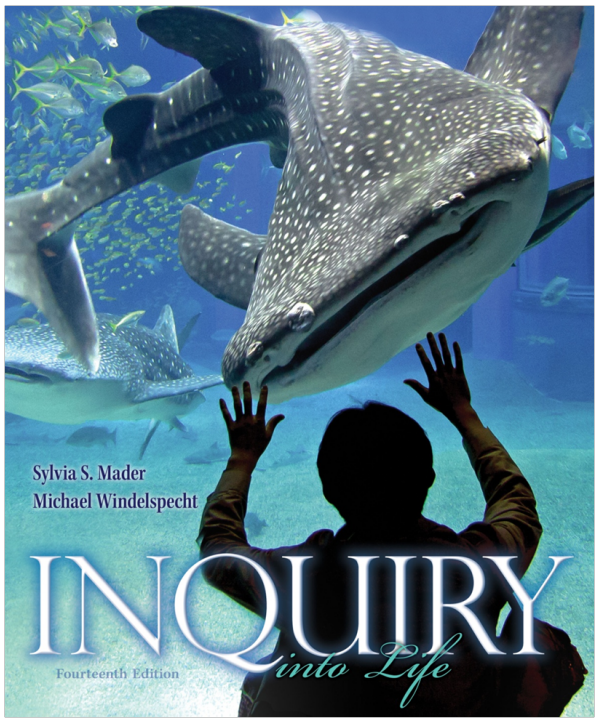


Chapter 14

Musculoskeletal system

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Learning outcomes

- Explain the tissues that involved in musculoskeletal system
- Explain types of bones and function of skeleton
- Describe the main bones in axial and appendicular skeletons
- Explain the difference between slow- and fast- twich muscle fibers

Overview musculoskeletal system

- The **skeleton** provides attachment sites for the muscles.
  - Muscle contraction makes bones move
  - Allows walking, playing sports, holding a book
- The **musculoskeletal system** includes the bones and muscles.
  - Bone and connective tissue make up the skeleton
  - Muscular tissue makes up the muscles

Organization of Bone and Associated Tissues

- Bones classified by their shape
  - Long, short, flat
- Long bones (ex: arm or leg)
  - Enclosed by periosteum
    - Made of tough, fibrous connective tissue
    - Continuous with ligaments
    - Contains blood vessels that service bone
  - Epiphyses – expanded end of a long bone
  - Diaphysis – shaft between the epiphyses
    - **Joint** forms between the diaphysis of two long bones

Bone

- **Compact bone** is highly organized
  - Composed of **osteons** – tubular units
  - **Osteocytes** (bone cells) lie in lacunae
    - Lacunae are arranged in concentric circles around a central canal.
    - *Central canals* contain blood vessels, lymphatic vessels, and nerves.
    - *Canaliculi* connect lacunae with each other and the central canal.

Bone

- **Spongy bone** has an unorganized appearance.
  - Osteocytes are found in trabeculae.
    - Numerous thin plates surrounded by unequal spaces
    - Plates follow lines of stress so spongy bone is strong
- Spaces filled with **red bone marrow**
  - Red bone marrow produces blood cells.
  - In infants, red marrow is present in cavities of all bones.
  - Mit is found in a more limited number of bones in adults.

Anatomy of Bone

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

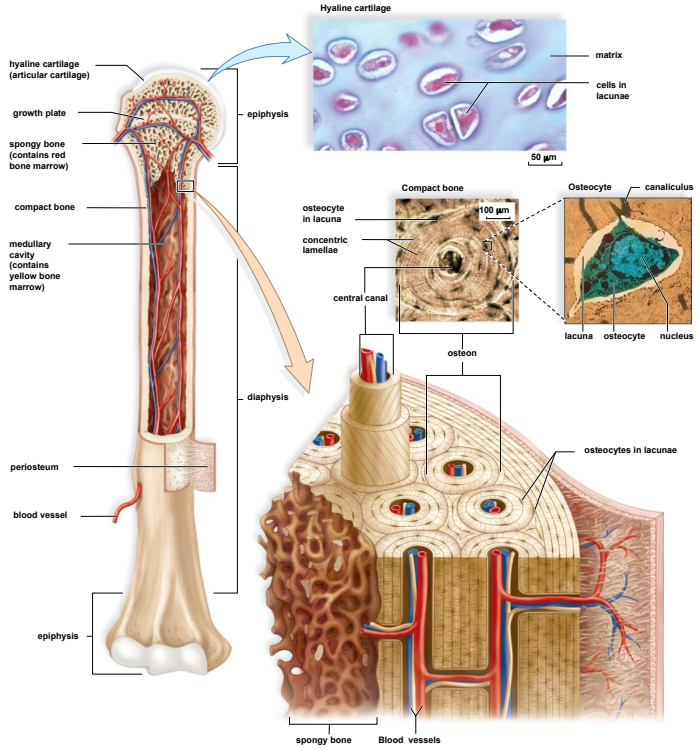


Figure 19.1

(hyaline, bone): © Ed Reschke; (osteocyte): © Biophoto Associates/Photo Researchers, Inc.

Cartilage

- **Cartilage**
  - Not as strong as bone but more flexible
  - Gel-like matrix with many collagen and elastic fibers
  - Cells lie within lacunae which are irregularly grouped
  - No blood vessels

Cartilage

- Three types of cartilage
  - **Hyaline** – firm and somewhat flexible
    - Ends of long bones, nose, ends of ribs, larynx, trachea
  - **Fibrocartilage** - stronger, thick collagen fibers, can withstand both pressure and tension
    - Intervertebral disks, knees
  - **Elastic** - most flexible, elastin fibers
    - Ear flaps and epiglottis

Dense Fibrous Connective Tissue

- Dense fibrous connective tissue
  - Rows of fibroblasts separated by bundles of collagen fibers
  - Forms flared sides of the nose
  - **Ligaments** - connect bone to bone
  - **Tendons** - connect muscle to bone

Bone Development and Growth

- Endochondral Ossification
  - The ends of developing bones continue to grow.
  - Secondary ossification centers appear.
    - Spongy bone forms and does not break down.
  - **Growth plates** remains between primary ossification center and each secondary center.
  - Limbs keep increasing in length as long as the growth plates are present.
  - Eventually, growth plates ossify and the bone stops growing.

Remodeling of Bones

- Adult bone is continually broken down and built up.
- **Osteoclasts** break down bone matrix and release calcium to blood.
- **Osteoblasts** pick up calcium from blood and deposit it in new bone matrix.
  - Get trapped in matrix and become **osteocytes** within lacunae
- Remodeling can change bone thickness.
  - Affected by hormones and physical use

Endochondral Ossification of a Long Bone

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

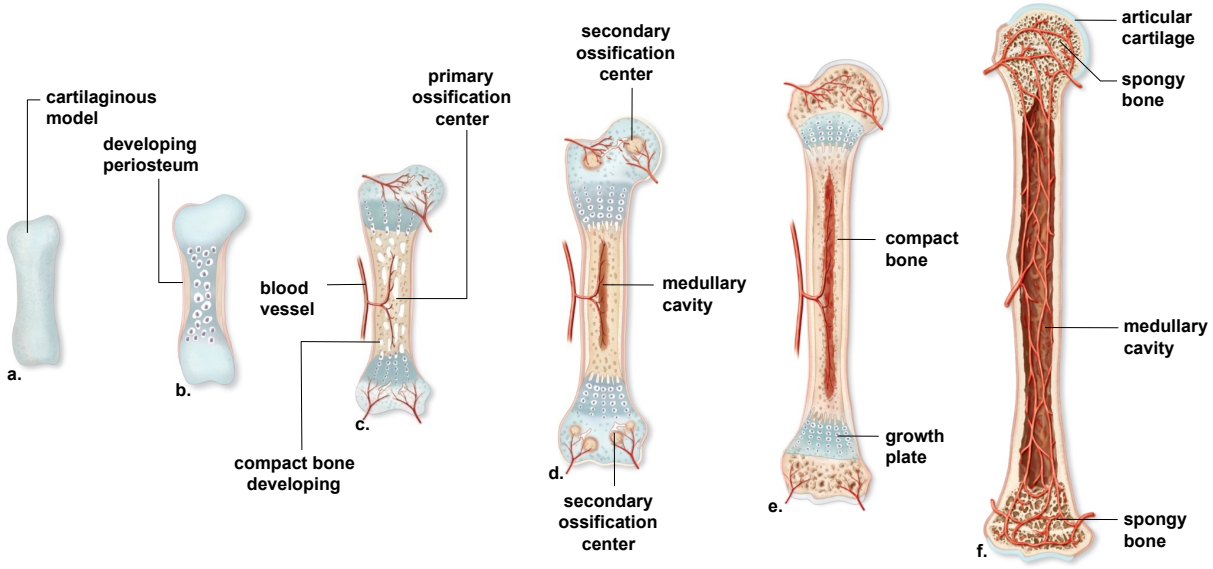


Figure 19.2

Bones of the Skeleton

- Functions of the skeleton pertain to particular bones
  - Supports body
  - Protects soft body parts
  - Produces blood cells
  - Stores mineral and fat
  - With muscles, permits flexible body movement

Classification of the Bones

- There approximately 206 bones classified based on two divisions of the skeleton.
  - **Axial skeleton**
    - Midline of body
  - **Appendicular skeleton**
    - Bones of limbs and the limb girdles

The Skeleton

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

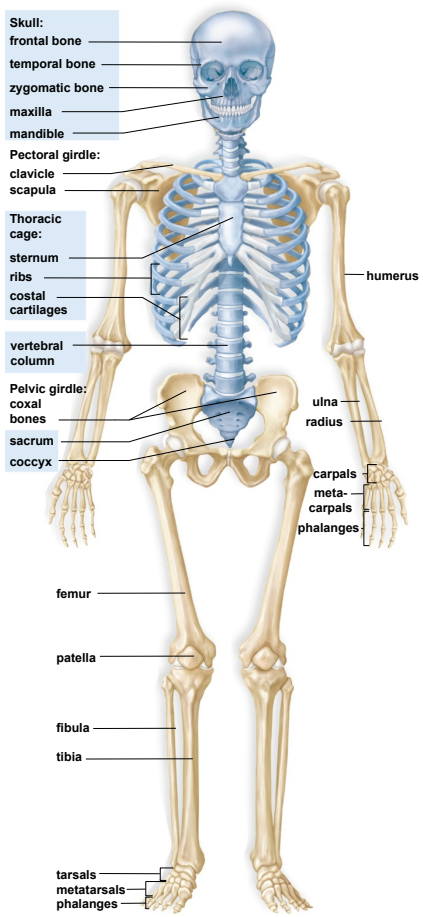


Figure 19.3

The Axial Skeleton
The Skull

- The **skull**
  - Formed by cranium (braincase) and facial bones
- The **cranium**
  - Protects the brain
  - Not completely ossified in infants
    - Fontanels usually close by the age of 24 months by the process of intramembranous ossification
  - The **sinuses**
    - Air spaces lined by mucous membranes
    - Reduce weight of skull
    - Give resonant sound to voice

The Axial Skeleton
The Skull

- **The Cranium**
  - Bones named for the lobes of the brain
    - **Frontal** - forms forehead
    - **Parietal** - sides of braincase
    - **Temporal** - below parietals, has external auditory canal
    - **Occipital** - base of the skull; foramen magnum for passage of spinal cord
  - **Foramen magnum** – spinal cord connects to brain stem
  - **Sphenoid bone** - floor of cranium, part of orbits
  - **Ethmoid bone** - forms part of orbits and nasal septum

Bones of the Skull

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

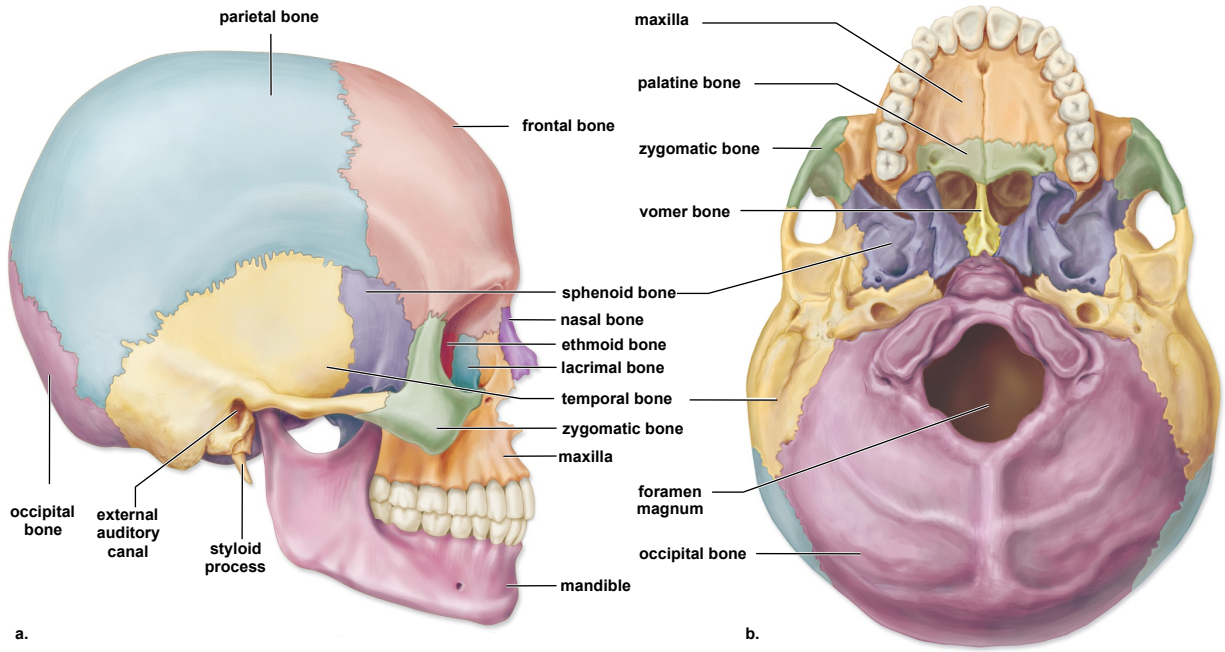


Figure 19.4

The Axial Skeleton
The Skull

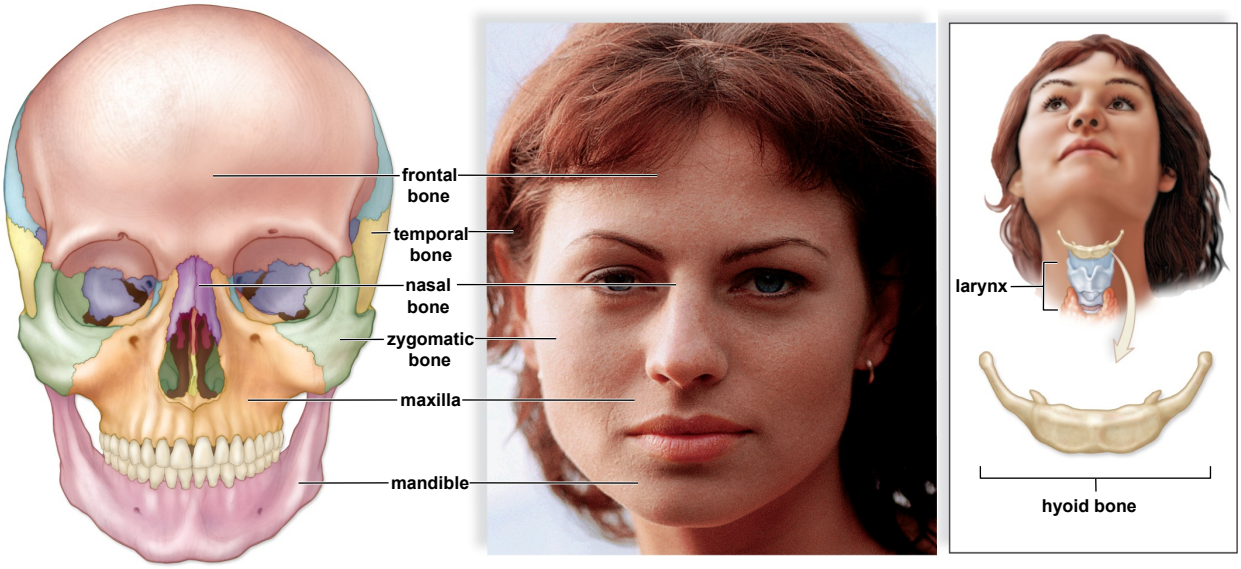
- **Facial Bones**
  - **Mandible** - lower jaw; only movable bone of the skull
  - **Maxillae** - upper jaw; also forms anterior hard palate
  - **Zygomatic bones** - cheekbones
  - **Nasal bones** - bridge of nose
  - **Lacrimal bones** - contain the nasolacrimal canals
  - Temporal and facial bones - also bones of the cranium which contribute to the face

The Axial Skeleton
Hyoid bone

- Hyoid bone
  - Only bone in the body which does not articulate with another bone
  - Attached to the larynx via membrane, and to the temporals by muscles and ligaments
  - Anchors the tongue and attaches muscles associated with swallowing

Bones of the Face and the Hyoid

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



b: © Corbis RF

Figure 19.5

The Axial Skeleton
Vertebral Column

- **Vertebral column**
  - 33 vertebrae
  - Four normal curvatures
    - Abnormal curvatures
      - *Scoliosis* - abnormal lateral (sideways) curvature
      - *Kyphosis* – hunchback
      - *Lordosis* – swayback
  - Spinal cord passes through the vertebral canal
  - Spinal nerves exit through intervertebral foramina
  - Spinous processes serve as attachment sites for muscles

The Axial Skeleton
Vertebral Column

- **Types of vertebrae**
  - **7 cervical vertebrae** – first 2 are specialized
    - Atlas – "yes" motion
    - Axis – "no" motion
  - **12 thoracic vertebrae** – articular facets to articulate with the ribs; prominent spinous processes
  - **5 lumbar vertebrae** – large bodies and thick processes
  - **5 sacral vertebrae** – fused to form the sacrum
  - **3-5 coccyx** – fused to form "tailbone"

The Vertebral Column

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

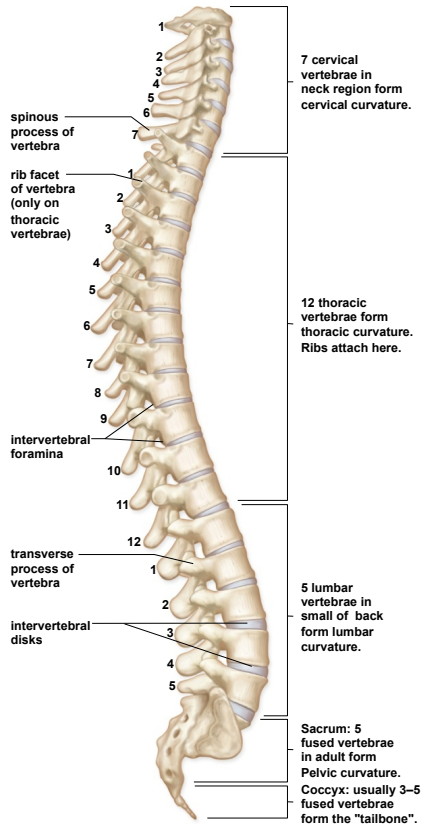


Figure 19.6

Rib Cage

- **Rib cage** (thoracic cage)
  - Part of axial skeleton
  - Composed of thoracic vertebrae, ribs and associated cartilages, and sternum
  - Both protective and flexible
    - Protects the heart and lungs
    - Flexible during inspiration and expiration

The Axial Skeleton
The Ribs

- Ribs – 12 pairs
  - Each originates at a thoracic vertebra and proceeds to anterior thoracic wall
  - "True ribs" - 7 upper pairs which articulate directly with sternum by means of a costal cartilage
  - "False ribs" - next 3 pairs which first join in a common cartilage and then to the sternum
  - "Floating ribs" - last 2 pairs which do not articulate with the sternum at all

The Axial Skeleton
The Sternum

- **Sternum** or breastbone
  - Along with the ribs, helps protect heart and lungs
  - Formed when three bones fuse during fetal development
    - **Manubrium** - articulates with clavicle and first rib pair
    - **Body** - point of junction between manubrium and body an important landmark - identifies second pair of ribs
      - Allows counting of ribs to determine apex of heart
    - **Xiphoid** – serves as attachment site for diaphragm

Thoracic Vertebrae and the Rib Cage

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

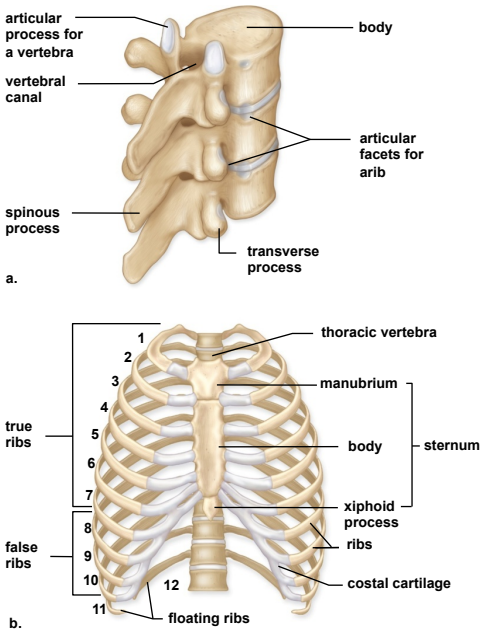


Figure 19.7

The Appendicular Skeleton

- Consists of bones within the pectoral and pelvic girdles and their attached limbs
  - The **pectoral girdles** and upper limbs are specialized for flexibility
  - The **pelvic girdle** and lower limbs are specialized for strength

Appendicular Skeleton
The Pectoral Girdles and Upper Limbs

- Upper limb
  - **Humerus** - Upper arm bone
  - **Radius** - bone of forearm
  - **Ulna** - bone of forearm
- Hand
  - **Carpal bones** – eight bones of the wrist
  - **Metacarpals** - five bones that form the palm
  - **Phalanges** - bones of the digits

Bones of the Pectoral Girdle and Upper Limb

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

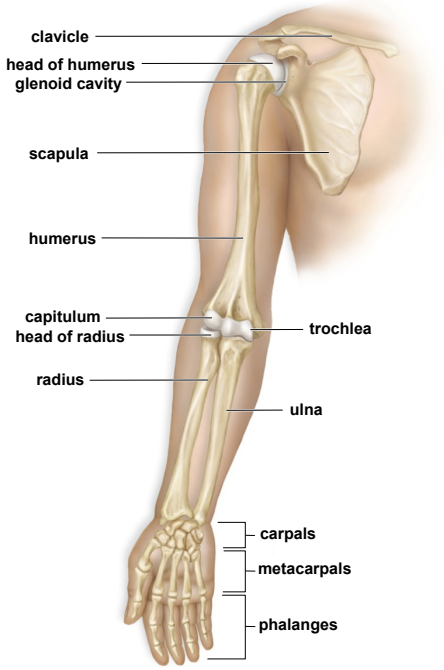


Figure 19.8

Appendicular Skeleton
The Pelvic Girdle and Lower Limb

- **Pelvic Girdle**
  - Composed of two coxal bones (hipbones) each composed of three fused bones
    - **Ilium** - largest of the three
    - **Ischium** - has posterior spine called ischial spine
    - **Pubis** - fused with opposite side at pubic symphysis
  - Pelvis includes pelvic girdle, sacrum, and coccyx
    - Protects internal organs, bears weight of body, serves as point of attachment for lower limbs

Appendicular Skeleton
The Pelvic Girdle and Lower Limb

- Lower limb
  - *Femur* - largest bone
  - *Tibia* - weight bearing bone of lower leg
  - *Patella* - kneecap
  - *Fibula* - smaller bone on lateral side of tibia
  - *Tarsals* - ankle bones
    - Calcaneus - heel bone
  - *Metatarsals* - instep of foot
  - *Phalanges* - digits

Bones of the Pelvic Girdle and Lower Limb

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

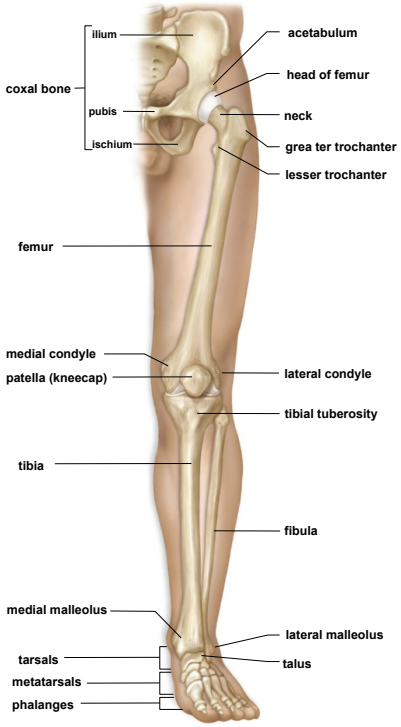


Figure 19.9

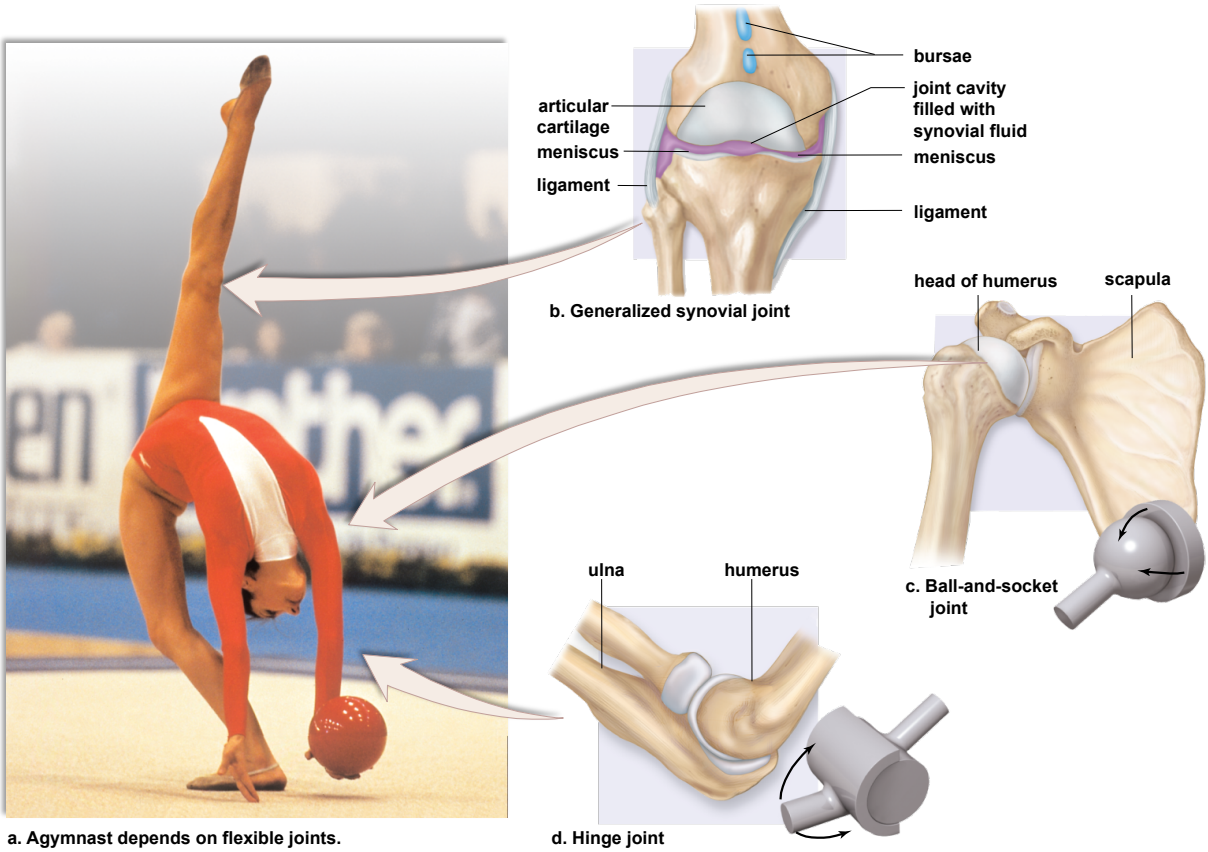
Appendicular Skeleton
Joints

- Bones are joined at joints, classified as
  - **Fibrous** – immovable
    - **Sutures** between cranial bones
  - **Cartilaginous** – slightly movable
    - Connected by hyaline cartilage
      - Ribs / sternum
    - Connected by fibrocartilage
      - Intervertebral discs
  - **Synovial** – freely movable
    - Produce **synovial fluid**

Appendicular Skeleton
Joints

- Types of Synovial Joints
  - **Hinge joint** – permits movement in one direction only
    - Ex: knee
  - **Pivot joint** – permits only rotational movement
    - Ex: joint between radius and ulna
  - **Ball and socket joint** – permits movement in all planes
    - Ex: hip joint

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



a. Agymnast depends on flexible joints.

a: © Gerard Vandystadt/Photo Researchers, Inc.

Skeletal Muscles

- Three types of muscle tissue
  - Smooth
  - Cardiac
  - Skeletal
- Skeletal muscle makes up greatest percentage of muscle tissue in the body
  - Voluntary because its contraction is controlled consciously to stimulate by the nervous system

Skeletal Muscles Work in Pairs

- Skeletal muscles are voluntary
- They are covered by layers of connective tissue called fascia.
  - Extend beyond muscle to form tendon
- Tendons attach skeletal muscles to bones.
- When a muscle contracts, one bone remains stationary, the other moves
  - **Origin** of a muscle is on the stationary bone
  - **Insertion** of a muscle is on the bone that moves

Skeletal Muscles

- Antagonistic pairs of muscles bring about movement in opposite directions.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

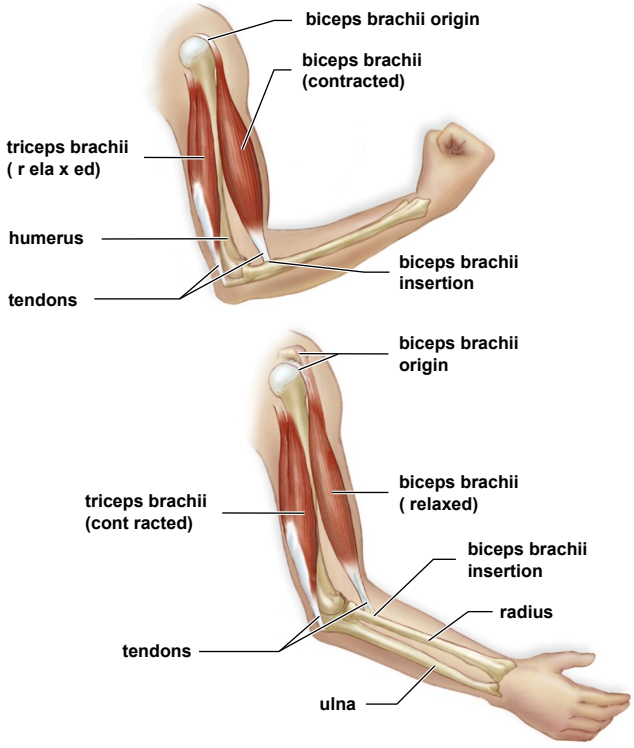


Figure 19.11

Major Skeletal Muscles

- 650 human skeletal muscles
- Named based on the following characteristics:
  - Size - “maximus” - largest
    - ex: Gluteus maximus
  - Shape – include trapazoid (trapezius),
    - ex: latissimus (wide)
    - ex: Deltoid has shape (triangle) of the Greek letter
  - Location –
    - ex: frontalis overlies the frontal bone
    - ex: pectoralis (chest)

Major Skeletal Muscles

– Direction of muscle fibers - “rectus” means straight
  • ex: rectus abdominis
– Number of attachments - “biceps” means two
  • ex: biceps brachii
– Action – movement caused by muscle
  • ex: extensor digitorum extends the digits

Skeletal Muscles

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

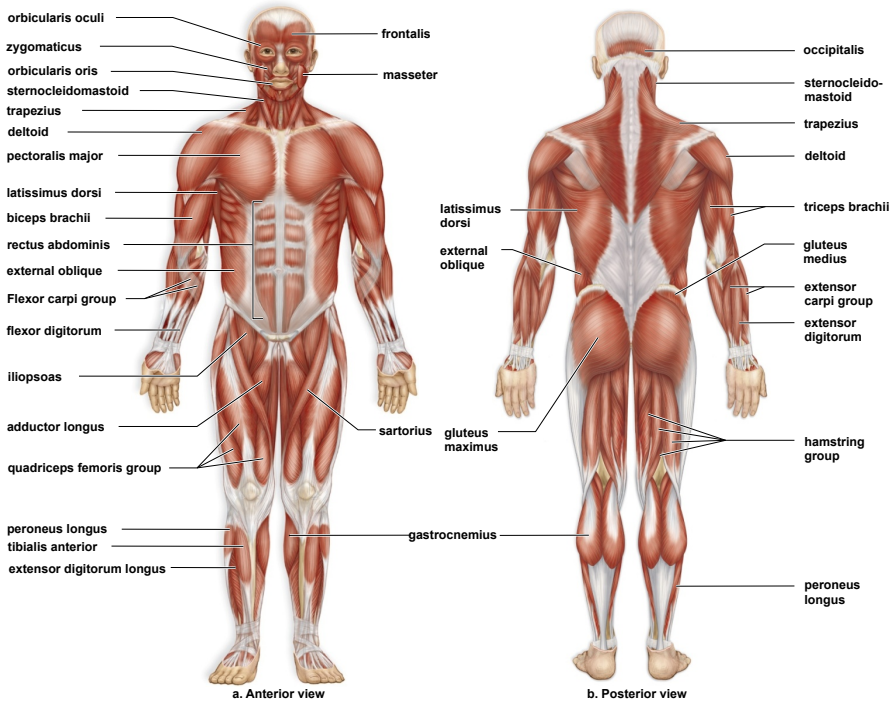


Figure 19.12

Mechanism of Muscle Fiber Contraction

- Muscle Fiber
  - A cell containing typical cellular components which have been given special names
    - **Sarcolemma** – plasma membrane
    - **Sarcoplasmic reticulum** – endoplasmic reticulum
    - **Sarcoplasm** – cytoplasm
  - Unique structures
    - **T (Transverse) tubules** – penetrate into the cell so that they come in contact with expanded portions of the sarcoplasmic reticulum

Mechanism of Muscle Fiber Contraction

- Muscle Fiber
  - Sarcoplasmic reticulum
    - Expanded portion stores Ca^{+2}, essential for contraction
    - Encases hundreds or thousands of **myofibrils**, the contractile portion of muscle cells (fibers)
    - Other organelles such as mitochondria are located in the sarcoplasm between myofibrils
      - Sarcoplasm also contains glycogen, to provide energy for muscle contraction

Skeletal Muscle Fiber Structure and Function

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

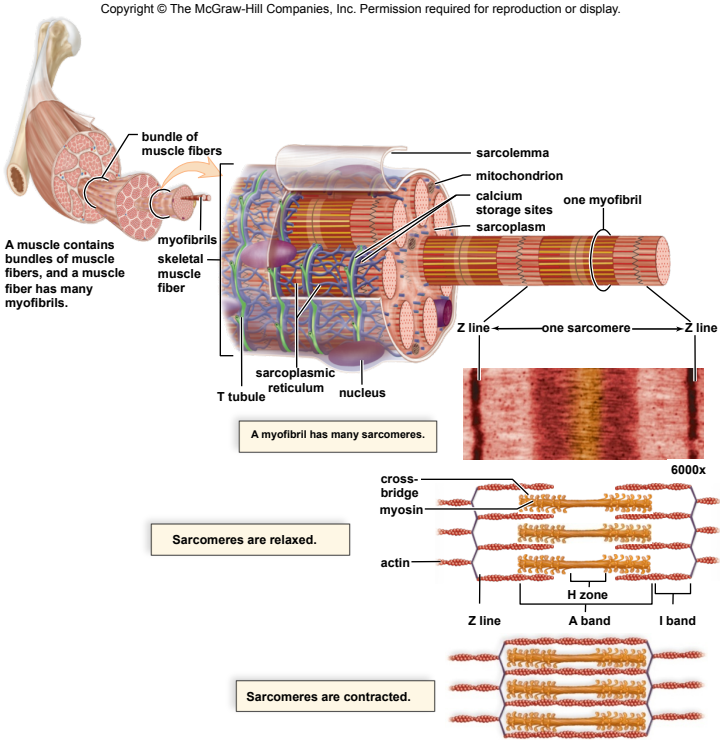


Figure 19.13

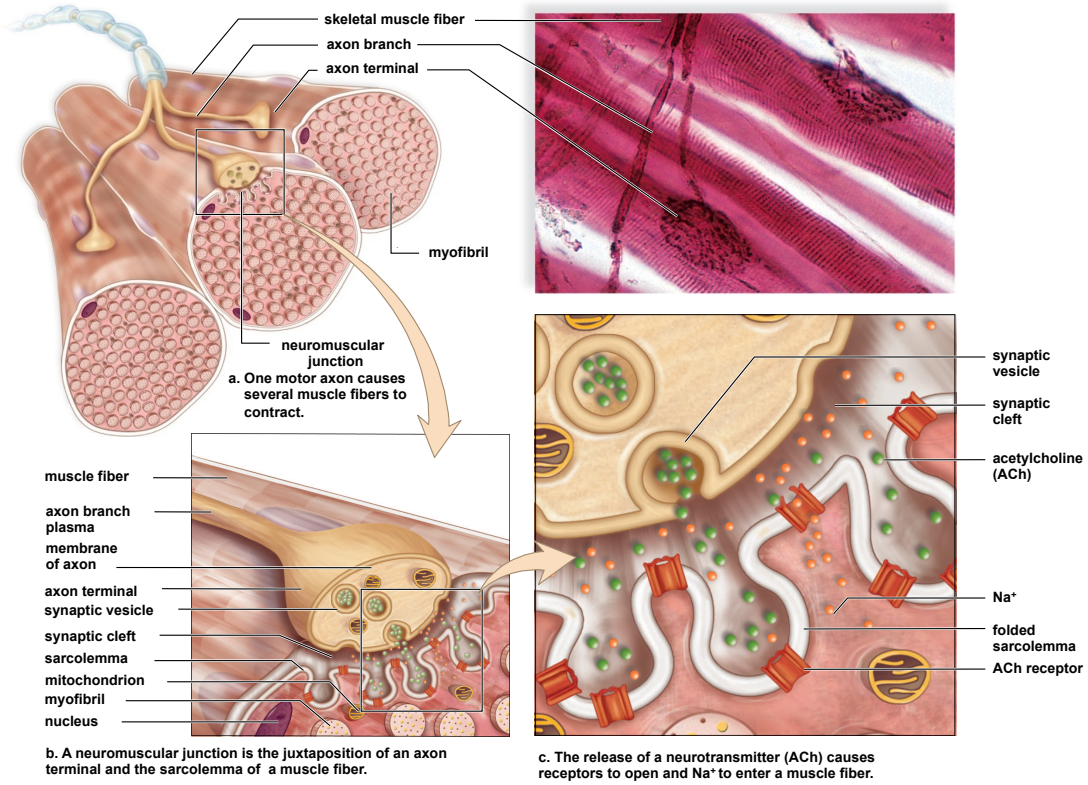
© EM Research Services, Newcastle University

Skeletal Muscle Contraction

Animation

Neuromuscular Junction

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



© Victor B. Eichler, Ph.D.

Energy for Muscle Contraction

- ATP previously produced before strenuous exercise lasts only a few seconds
- Muscles acquire new ATP in three ways
  - **Creatine phosphate (anaerobic) breakdown**
    - Used first before O_2 enters mitochondria
  - **Cell respiration (aerobic)**
    - Occurs only as O_2 is available
  - **Fermentation (anaerobic)**
    - When O_2 is not delivered to meet demands of vigorously contracting muscle

Oxygen Debt

- Debt occurs when a muscle uses creatine phosphate or fermentation to supply its energy needs.
- Ability to use oxygen debt is important because blood glucose can be spared and used by the brain.
- Repaying an oxygen debt requires two actions.
  - Replenish creatine phosphate supplies
  - Dispose of lactate
    - Metabolized in mitochondria or sent to the liver to reconstruct glycogen

Physiology of Skeletal Muscle Contraction

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

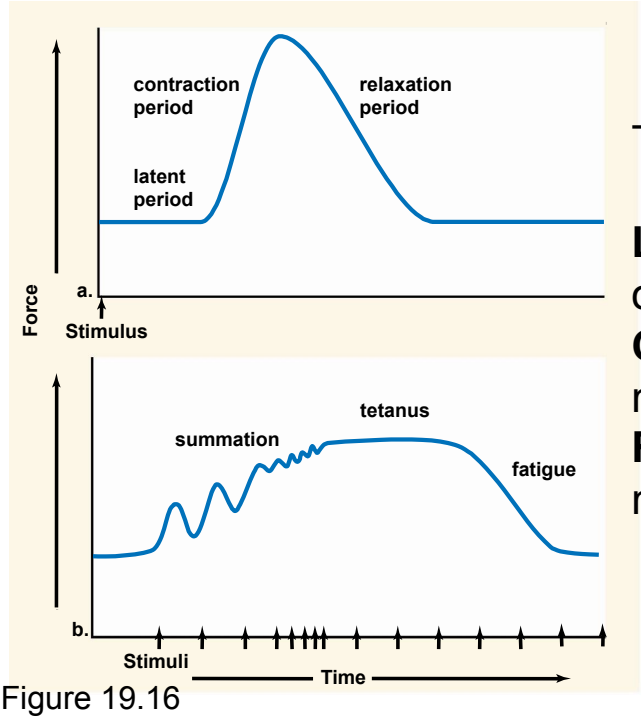


Figure 19.16

The myogram has three stages.

Latent Period: from stimulus to onset of contraction
Contraction Period: while muscle is shortening
Relaxation Period: when muscle returns to resting length

Athletics and Muscle Contraction

- **Exercise and Size of Muscles**
  - Muscles not used decrease in size (atrophy).
  - If stimulation is not restored, muscle fibers are gradually replaced by fat and fibrous tissue.
  - Forceful activity over a prolonged period causes muscle to increase in size.
    - Hypertrophy occurs only if muscle contracts to at least 75% of maximum tension.
    - An increase in the number of myofibrils within fibers causes hypertrophy.

Athletics and Muscle Contraction

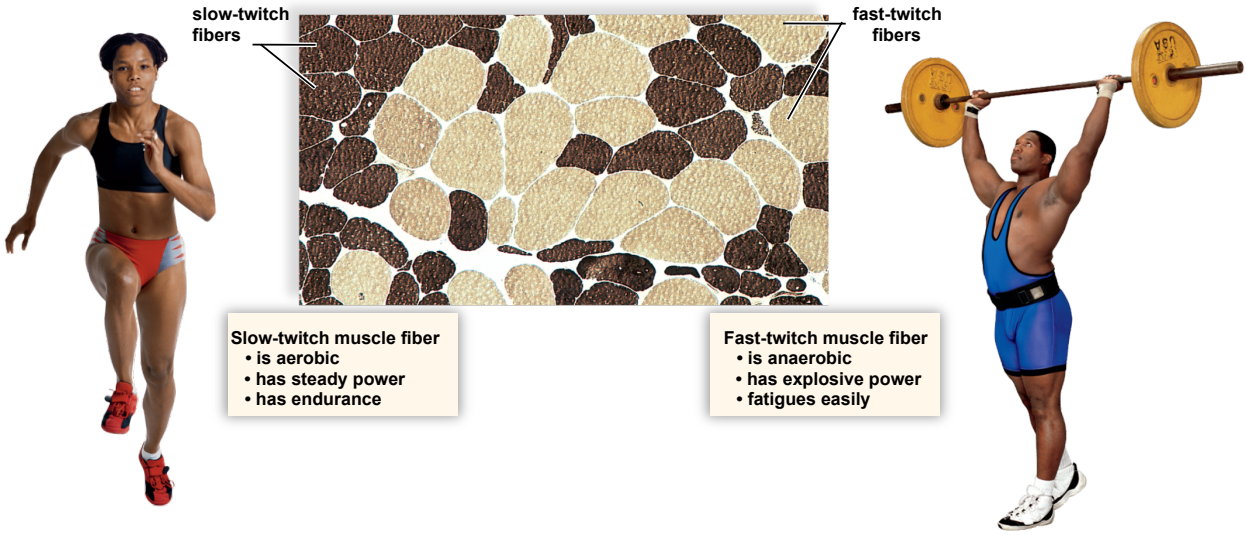
- **Slow-Twitch and Fast-Twitch Muscle Fibers**
  - Different types of metabolism
  - **Slow-twitch fibers** (tend to aerobic)
    - Have steadier "tug" and more endurance
    - Produce most energy aerobically
    - Have many mitochondria and are dark in color from myoglobin
    - Have low maximum tension which develops slowly
    - Have substantial reserves of glycogen and fat
    - Ex: Long-distance running, biking, jogging

Athletics and Muscle Contraction

- **Slow-Twitch and Fast-Twitch Muscle Fibers**
  - **Fast-twitch fibers** (tend to be anaerobic)
    - Develop maximum strength in a burst
    - Motor units contain many fibers
    - Fibers are light in color due to fewer mitochondria and little to no myoglobin
    - Dependence on anaerobic energy leaves them vulnerable to accumulation of lactic acid and fatigue
    - Ex: Sprinting, weight lifting, swing a golf club

Slow-Twitch and Fast-Twitch Muscle Fibers

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



(woman): © Rubberball/Getty RF; (fibers): © G.W.Willis/Visuals Unlimited; (man): © Corbis RF

Disorders of the Skeleton and Joints

- Disorders of the Skeletons and Joints
  - **Osteoporosis**
    - Bones lose mass and mineral content
    - Leads to an increase risk of fractures

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

(left): © Alfred Pasieka/Photo Researchers, Inc.; (right): © Yoav Levy/Phototake USA.com

Bones fractures

Disorders of the Skeleton and Joints

- **Arthritis**
  - **Osteoarthritis**
    - Degenerative joint disease (cartilage)
  - **Rheumatoid arthritis**
    - Autoimmune disease
    - Joints and other tissues are attacked

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

© Dr. P. Marazzi/Photo Researchers, Inc.

Figure 19.20

Disorders of the Muscles

- Disorders of the Muscles
  - **Fibromyalgia**
    - Severe pain in neck, shoulders, back, and hips
    - Chronic fatigue
    - May be due to low levels of serotonin or other neurotransmitters involved with pain perception

Disorders of the Muscles

- **Muscular dystrophies** (MD)
  - Genetic diseases
  - Vary greatly in severity
  - Most common form is Duchenne muscular dystrophy
    - Results from abnormal gene coding for dystrophin
    - Affects mainly boys, because it is an X-linked disorder