Inquiry into Life

Eleventh Edition

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Chapter 19
Lecture Outline

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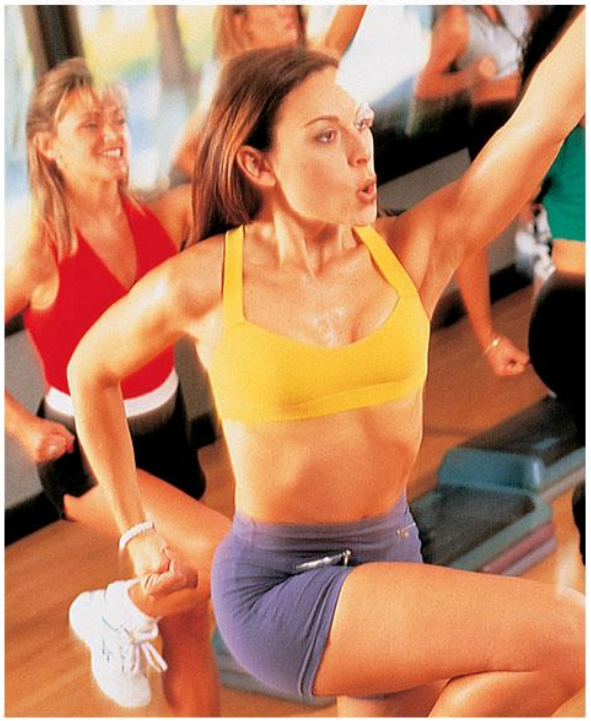


19.1 Anatomy and physiology of bone

- Structure of bone and associated tissues
  - Bone
    - Compact bone-highly organized
      - Composed of osteons- functional unit of bone
      - Osteocytes lie in lacunae
        - » Arranged in concentric circles around central canal
        - » Central canal contains blood vessels, lymphatic vessels, and nerves
      - Lacunae are interconnected by canaliculi
      - Cytoplasmic extensions of osteocytes extend through canaliculi
        - » Allows nutrients to flow from central canal to the cells

Anatomy and physiology of bone cont'd.

- Bone cont'd.
  - Spongy bone-unorganized appearance
    - Osteocytes found in trabeculae
      - Numerous bony plates surrounded by unequal spaces
      - Plates follow lines of stress so spongy bone is light but strong
    - Spaces filled with red bone marrow-produces blood cells
      - Infants-red marrow is present in cavities of all bones
      - Adults-in spongy bone of skull, sternum, ribs, vertebrae, and ends of long bones

Anatomy and physiology of bone cont'd.

- Cartilage
  - Not as strong as bone but more flexible
  - Matrix is gel-like with lacunae for chondrocytes
  - 3 types
    - Hyaline- firm, white, contains collagen fibers
      - Ends of long bones, nose, ends of ribs
    - Fibrocartilage-stronger, thick collagen bands, can withstand both pressure and tension
      - Intervertebral disks
    - Elastic- most flexible, elastin fibers
      - External ears and epiglottis

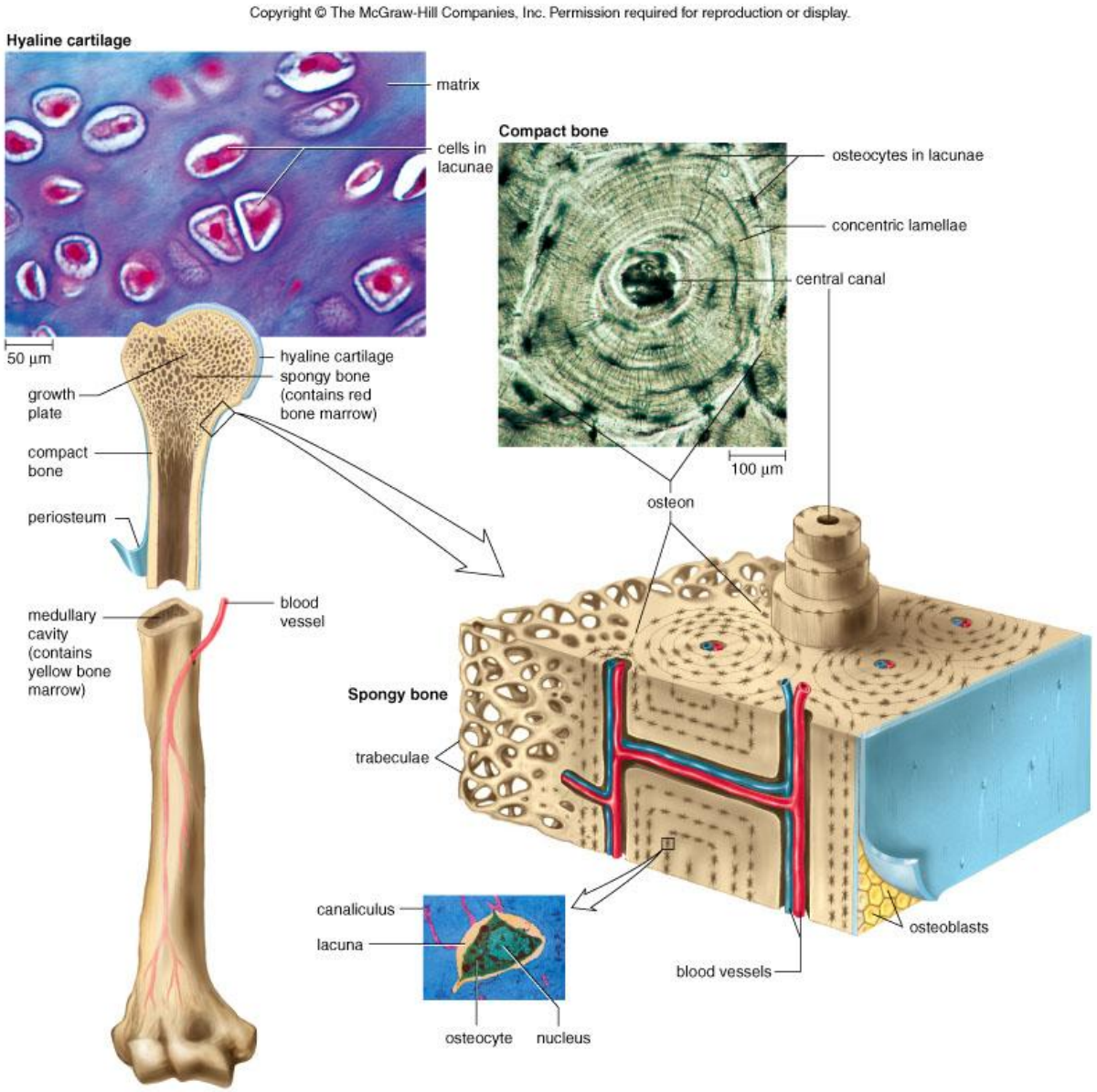
Anatomy and physiology of bone cont'd.

- Dense fibrous connective tissue
  - Rows of fibroblasts separated by collagen fibers
  - Compose structures that connect bone to bone and muscle to bone
  - Very strong
    - Ligaments and tendons

Anatomy and physiology of bone cont'd.

- Organization of tissues in the skeleton
  - Bones are classified by shape
    - Long bones- longer than they are wide
    - A long bone can be used to illustrate organization of tissues
      - Covered by periosteum-fibrous connective tissue
      - Epiphysis- widened end of a long bone
      - composed of spongy bone
      - contains red marrow
      - Diaphysis-shaft of a long bone
      - composed of compact bone
        - » Encloses the medullary cavity filled with yellow marrow

Anatomy of a long bone



- Fig 19.1

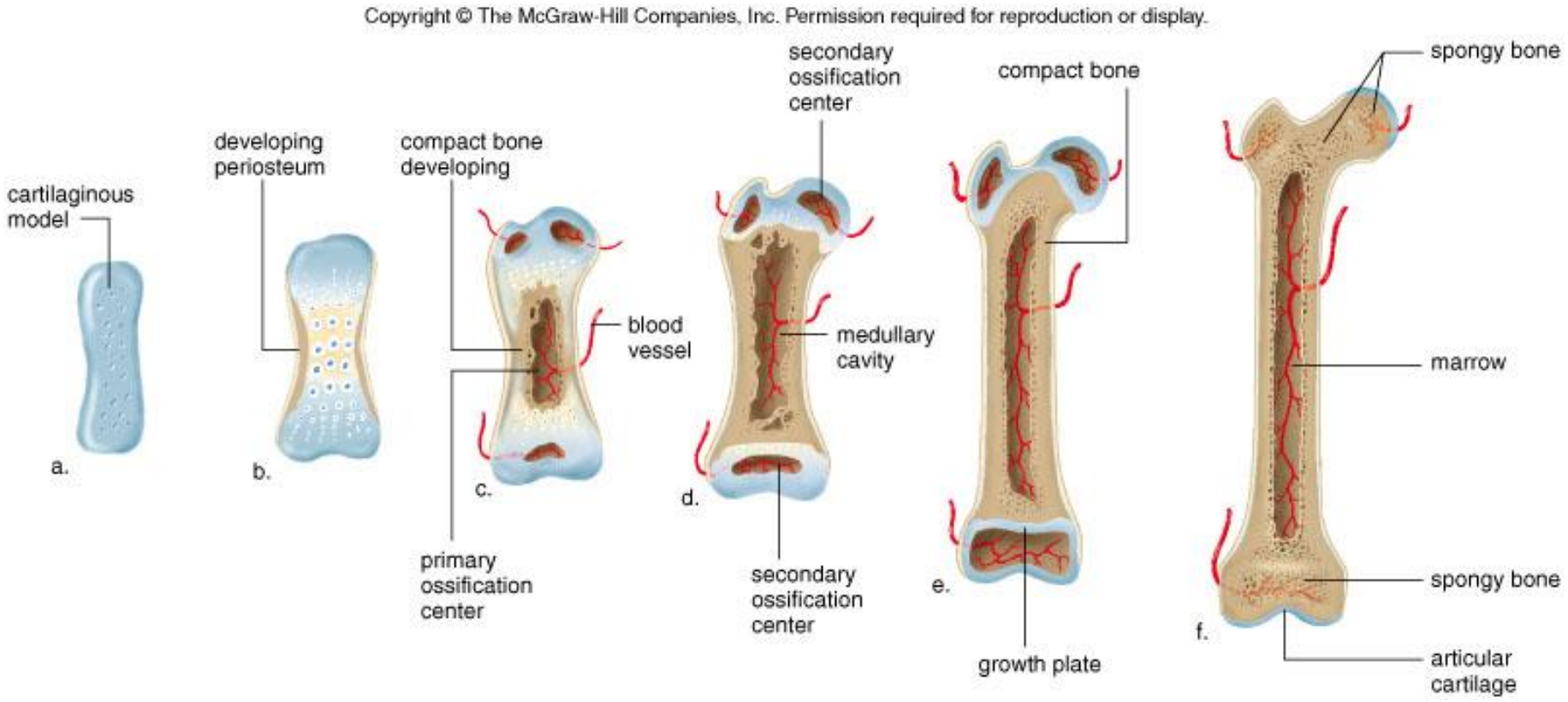
Anatomy and physiology of bone cont'd.

- Bone growth and repair
  - Remodeling of bones
    - Bone is continuously broken down and built up
    - Osteoclasts-break down bone matrix and release calcium to blood
      - Process takes about 3 weeks
    - 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
      - Adults require higher calcium intake per day than children
        - » Osteoporosis-weak, thin bones which fracture easily

Anatomy and physiology of bone cont'd.

- Bone development and growth
  - Endochondral ossification
    - Hyaline cartilage "template" forms first
    - Cartilage breaks down in center, and periosteum develops
      - Osteoblasts migrate in and produce spongy bone-primary ossification center
      - Other osteoblasts then produce compact bone beneath the periosteum and spongy bone is broken down
    - Secondary ossification centers form in ends of the bone
      - Spongy bone forms and is not broken down
      - Growth plate-band of cartilage between primary and secondary growth centers
        - » Allows growth in length to continue

Endochondral ossification of a long bone



- Fig 19.2

Anatomy and physiology of bone cont'd.

- Overall summary of bone growth and repair
  - All bones except bones of skull develop from endochondral ossification
  - Long bones have growth plates that allow growth in length
    - Regulated by growth hormones and sex hormones
  - Bone remodeling is constantly occurring
    - Bone matrix serves as a reservoir for minerals

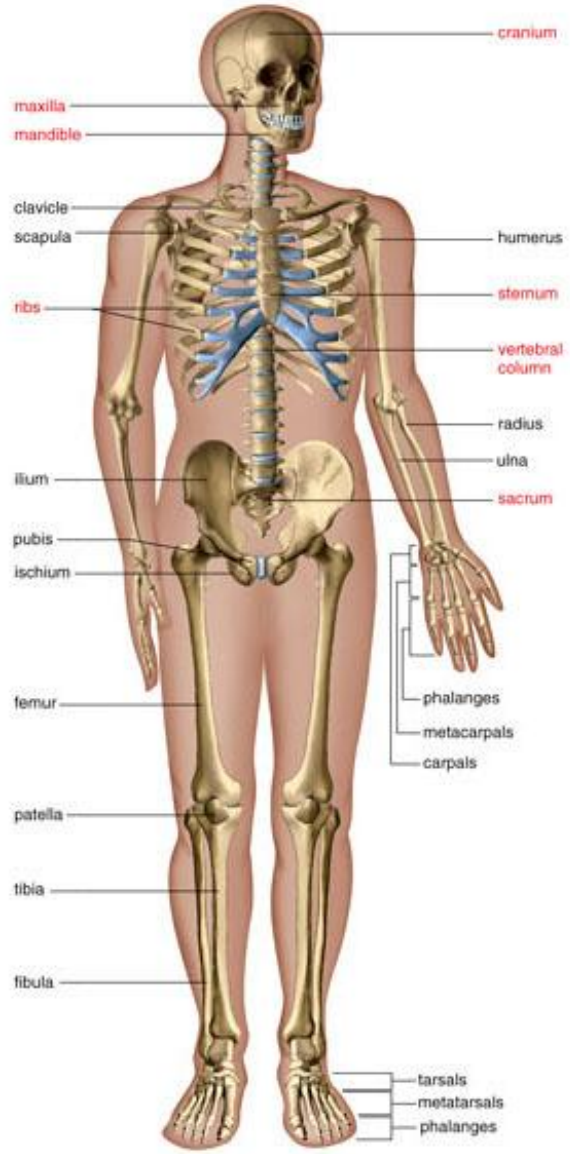
19.2 Bones of the skeleton

- Functions pertain to particular bones
  - Structural support
    - Bones of lower limbs, esp. femur
  - Protection of soft body parts
    - Skull, rib cage
  - Production of blood cells
    - Red marrow in ends of long bones, sternum, pelvis
  - Storage of minerals and fat
    - Calcium phosphate in bone matrix
    - Fat in yellow marrow
  - Locomotion
    - Along with muscles

Bones of the skeleton cont'd.

- Classification of bones
  - Axial skeleton
    - Skull, vertebral column, rib cage, hyoid bone
  - Appendicular skeleton
    - Bones of limbs and the limb girdles
  - further classified by shape
    - Long- bones of limbs
    - Short- cube shaped bones of digits
    - Round- like the patella
    - Irregular- like vertebrae
    - All bones have depressions and protruberances (processes) for attachment of muscles

The skeleton

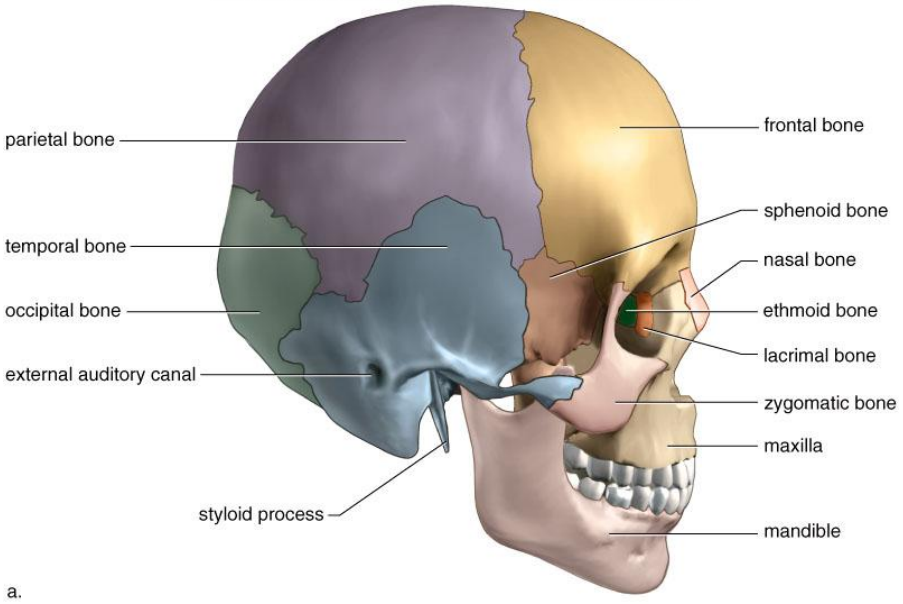


- Fig 19.3

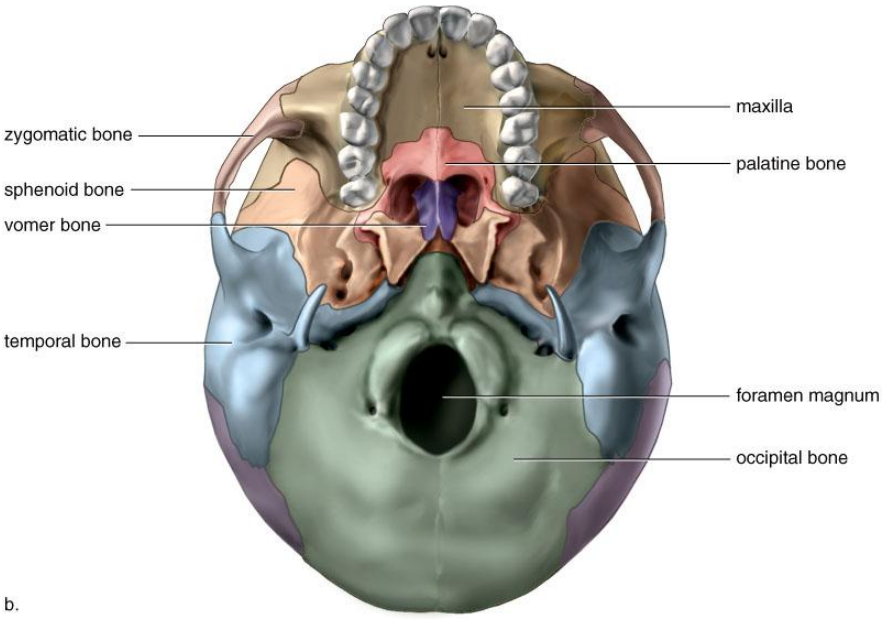
Bones of the skeleton cont'd.

- The axial skeleton
  - Cranial bones of the skull- protect the brain
    - Incomplete ossification in infants- *fontanels*
    - 8 bones named for lobes of brain
      - Frontal- forms forehead
      - Parietal-sides of braincase
      - Temporal-below parietals, has external auditory canal
      - Occipital-base of the skull; foreman magnum for passage of spinal cord
      - Sphenoid bone-floor of cranium; articulates with most of the other bones and forms part of the orbits
      - Ethmoid bone-forms orbits and the nasal septum
    - Locate these bones on the following diagram

Bones of the skull



a.



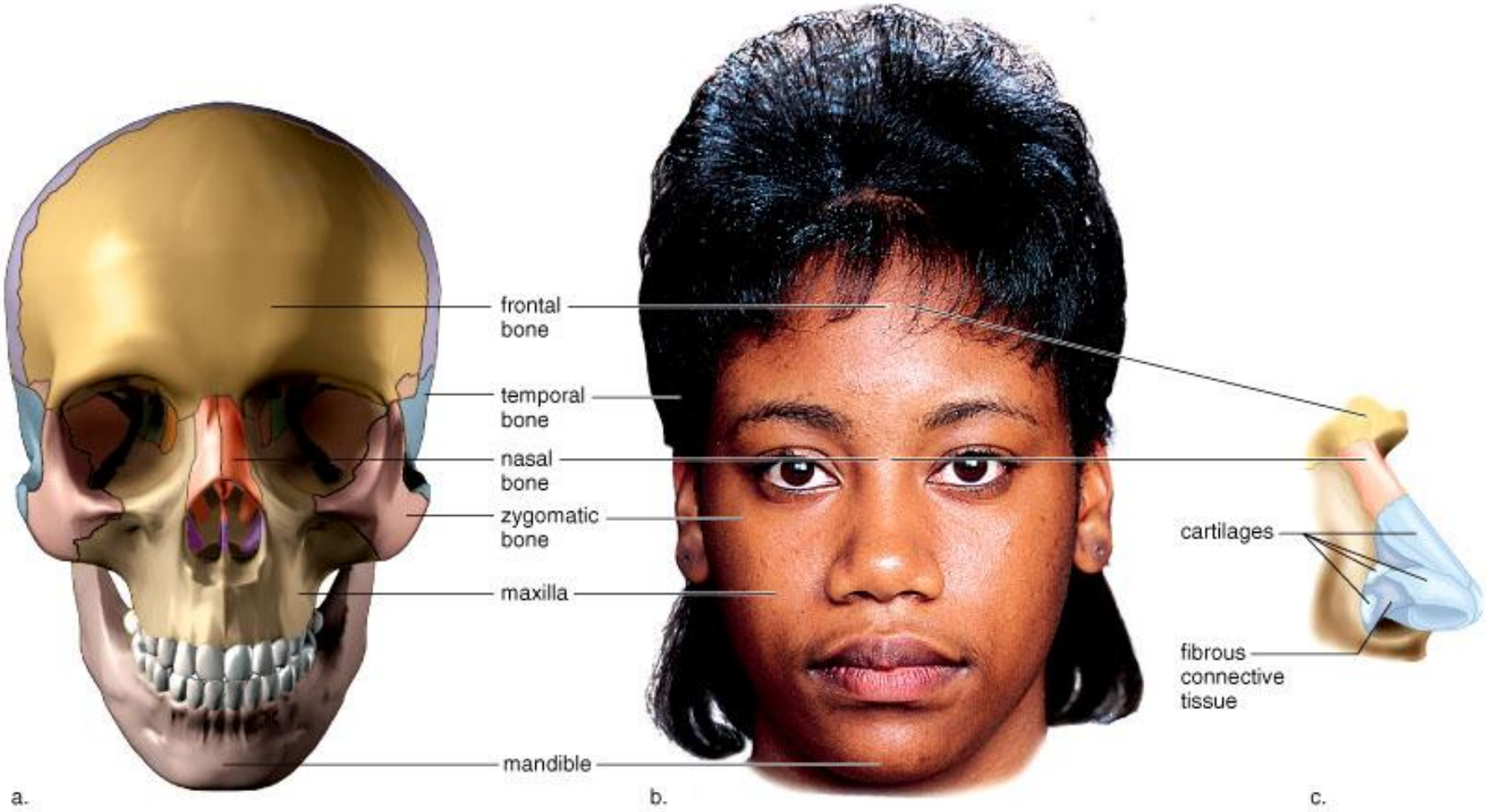
b.

- Fig. 19.4

Bones of the skeleton cont'd.

- 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 are also bones of the cranium which contribute to the face
  - Locate these bones on the following diagram

Bones of the face



- Fig. 19.5

Bones of the skeleton cont'd.

- Hyoid bone
  - The hyoid is the only bone in the body which does not articulate with another bone
  - Has a membranous attachment to the larynx, and to the temporals by muscles and ligaments
  - Anchors the tongues and attaches muscles associated with swallowing

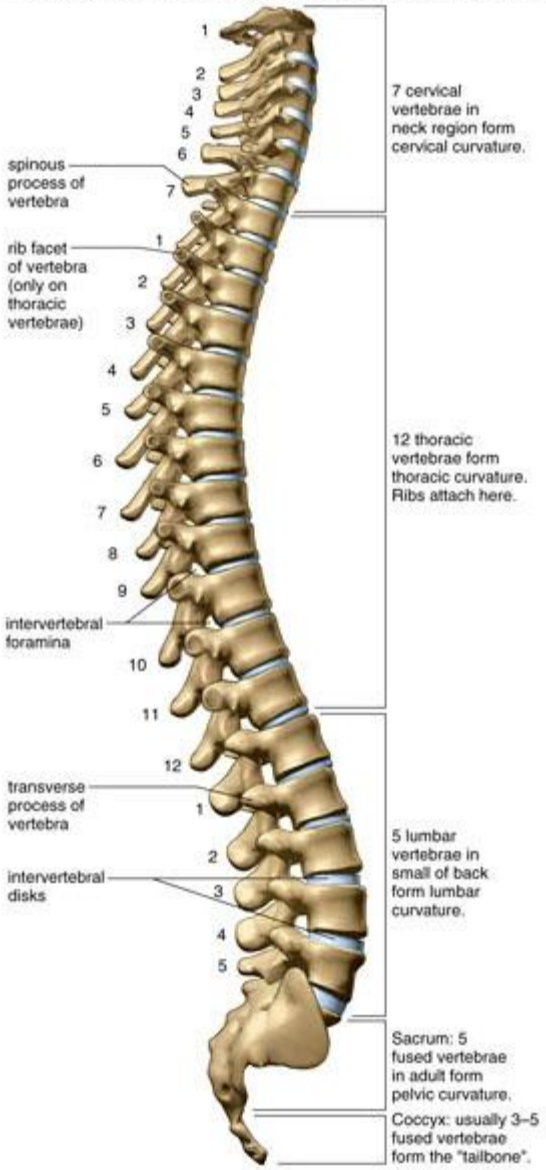
Bones of the skeleton cont'd.

- Vertebral column
  - 33 vertebrae with 4 curvatures
  - Spinal cord passes through the vertebral canal and spinal nerves exit through intervertebral foramina
  - Types of vertebrae
    - 7 Cervical vertebrae-first 2 are specialized
      - Atlas- articulates with the skull
      - Axis- allows rotation of the skull
    - 12 Thoracic vertebrae- have 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- coccygeal vertebrae form "tailbone"

Bones of the skeleton cont'd.

- Intervertebral disks
  - Composed of fibrocartilage
  - Absorb shock and allow flexibility
  - Can herniate and rupture
    - Puts pressure on the spinal cord

The vertebral column

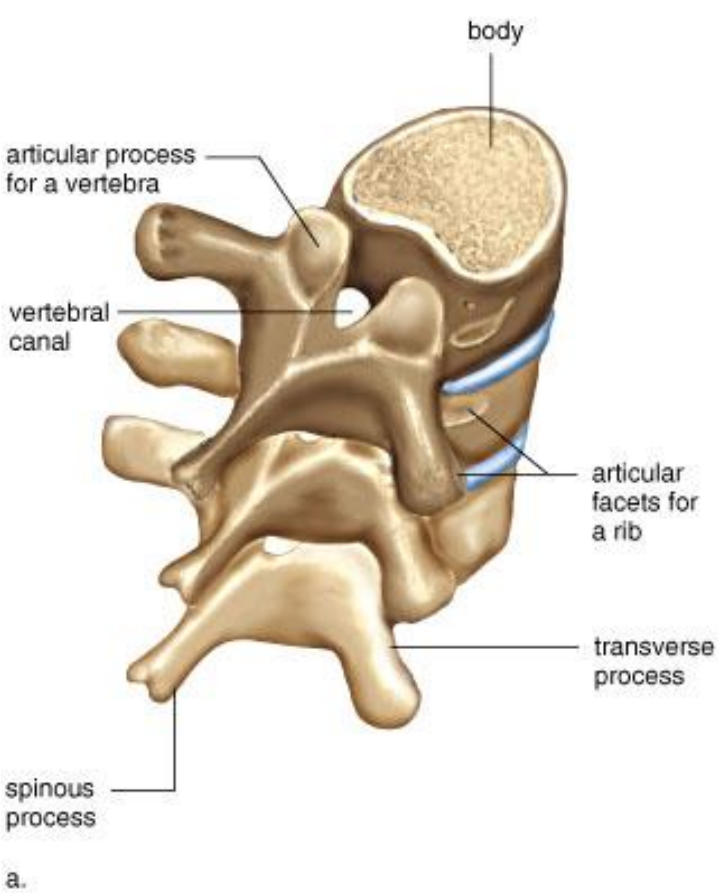


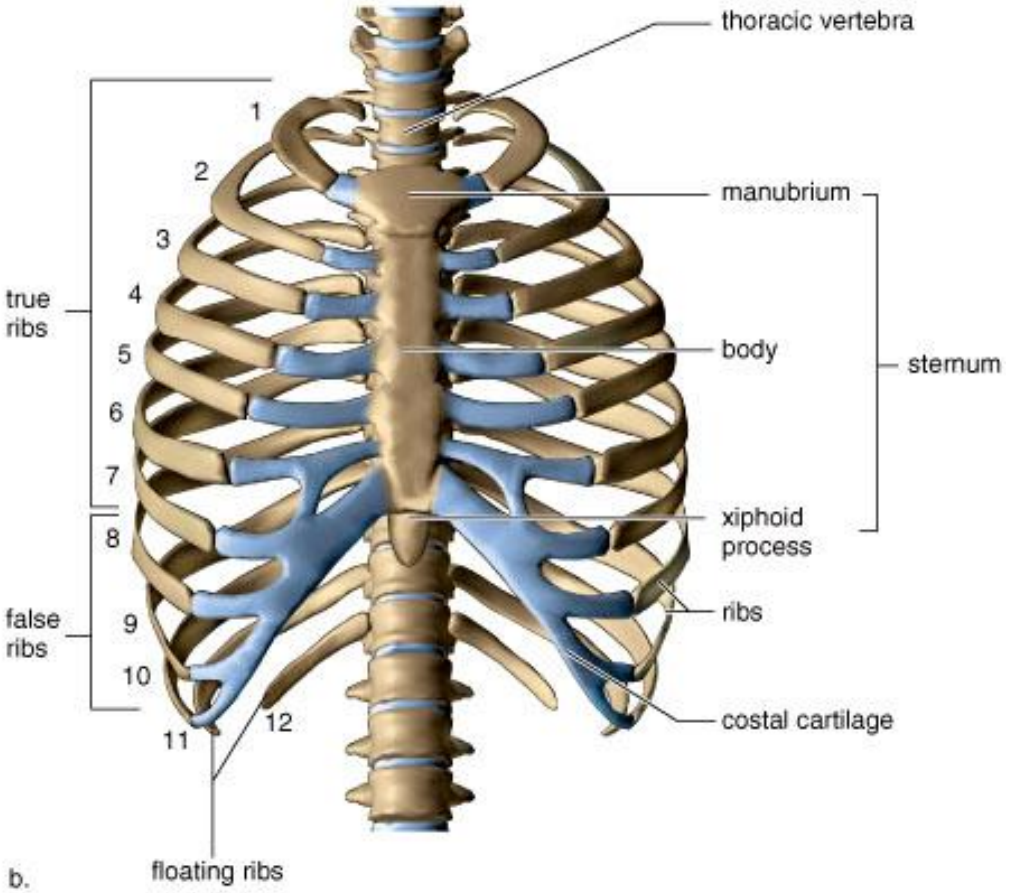
- Fig 19.6

Bones of the skeleton cont'd.

- The rib cage
  - Ribs- each originates at a thoracic vertebra and proceeds to anterior thoracic wall
    - True ribs-7 upper pair which articulate directly with sternum by means of a costal cartilage
    - False ribs- next 3 pair which first join in a common cartilage and then to the sternum
    - Floating ribs- last 2 pair do not articulate with the sternum at all
  - Sternum- lies in midline
    - Manubrium- articulates with clavicle and first pair of ribs
    - Body or blade- point of junction between manubrium and body is an important landmark-identifies second pair of ribs
      - Allows counting of ribs to determine apex of heart
    - Xiphoid- has a process for muscle attachment

Thoracic vertebrae and rib cage





- Fig 19.7

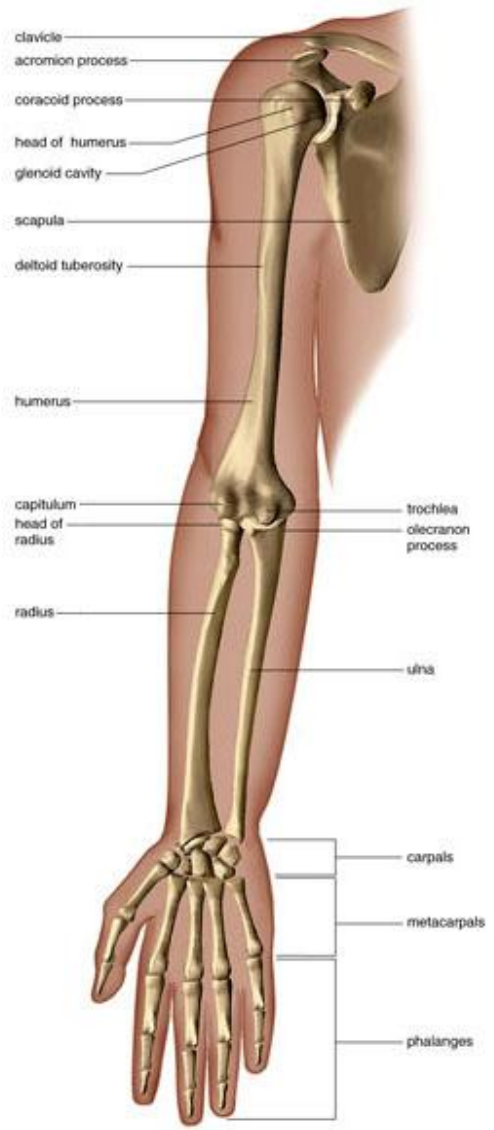
Bones of the skeleton cont'd.

- Appendicular skeleton
  - Pectoral girdle
    - Pectoral girdle
      - Clavicle- collar bone: articulates with sternum and acromion process of scapula
      - Scapula- glenoid fossa articulates with humerus
        - » Coracoid process- point of muscle attachment
        - » Spine- muscle attachment

Bones of the skeleton cont'd.

- Upper limb
  - Humerus- head articulates with the glenoid fossa of the scapula
    - Deltoid tuberosity- point of attachment of the deltoid muscle
    - Capitulum and trochlea-at distal end for articulation with the radius and ulna
  - Radius- bone of forearm; "radiates" across the ulna when hand is turned palm downward
  - Ulna- bone of forearm; olecranon process forms the elbow
  - Carpal bones- bones of the wrist
  - Metacarpals- 5 bones that form the palm
  - Phalanges- bones of the digits: thumb has 2, the other fingers have 3 each
- Locate the bones of the pectoral girdle and upper limb on the following diagram

Bones of the pectoral girdle and upper limb



- Fig. 19.8

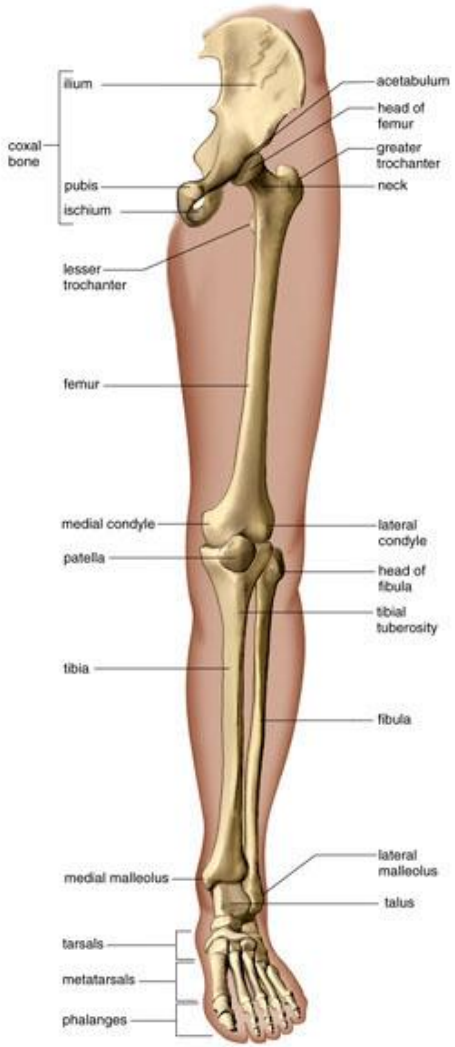
Bones of the skeleton cont'd.

- Pelvic girdle
  - Pelvis is composed of pelvic girdle, sacrum, and coccyx
  - Protects internal organs, bears weight of body, serves as point of attachment for lower limbs
  - 2 coxal bones each composed of 3 fused bones
    - Ilium- largest of the three
    - Ischium-has a posterior spine called the ischial spine
    - Pubis-fused with opposite side at pubic symphysis
  - Acetabulum- for articulation with the femur

Bones of the skeleton cont'd.

- Lower limb
  - Femur- largest bone; greater and lesser trochanters attach muscles of thigh, medial and lateral condyles articulate with tibia
  - Tibia-weight bearing bone of lower leg; medial malleolus forms "bulge" on medial side of ankle
  - Patella- kneecap; held in place by quadriceps tendon which attaches to tibial tuberosity
  - Fibula- smaller bone on lateral side of tibia; lateral malleolus forms "bulge" on lateral side of ankle
  - Tarsals- ankle bones
    - Calcaneus- heel bone
  - Metatarsals- instep of foot
  - Phalanges- digits

Bones of the pelvic girdle and lower limb

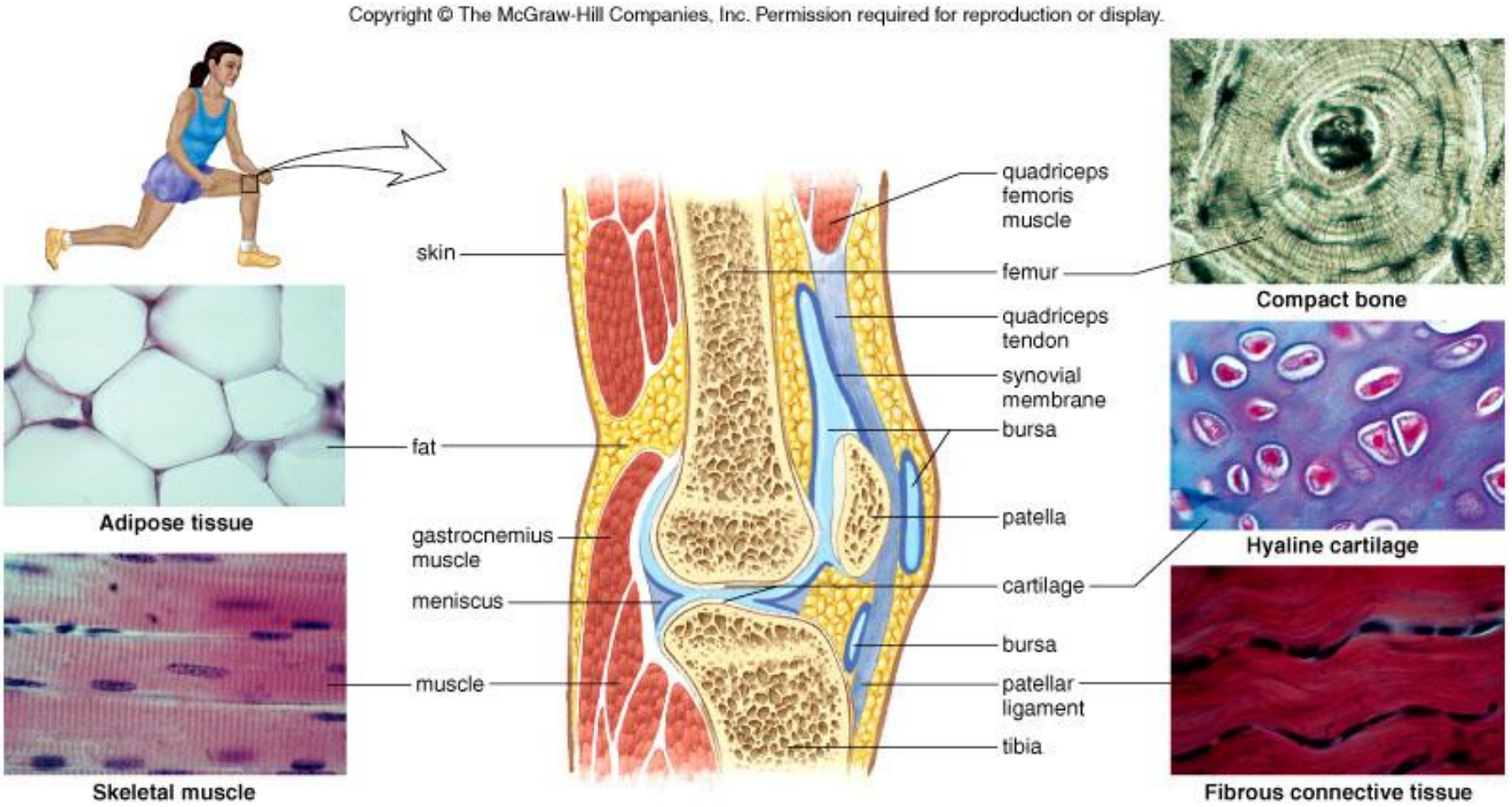


- Fig. 19.9

Bones of the skeleton cont'd.

- Articulations
  - Fibrous- immovable
    - Sutures between bones of skull
  - Cartilaginous- connected by hyaline cartilage
    - Costochondral junctions
  - Synovial- freely movable
    - Stabilized by tendons
    - Synovial membrane- lines joint capsule
    - Menisci-cartilage between bones within the joint; shock absorbers
    - Bursa- fluid filled sacs; decrease friction between tendons and ligaments

Knee joint



- Fig. 19.10

Bones of the skeleton cont'd.

- Types of synovial joints
  - Hinge joints- permit movement in one direction only
    - Ex: knee
  - Ball and socket joints- permit movement in all planes
    - Ex: hip joint
  - Pivot joint- permit only rotational movement
    - Ex: joint between radius and ulna
- Osteoarthritis
  - Deterioration of an over-worked joint
  - Wearing away of articular cartilage
  - Joint replacement
  - Glucosamine and chondroitin sulfate

Examples of movements at synovial joints

TABLE 19.1 EXAMPLES OF MOVEMENTS AT SYNOVIAL JOINTS

Type	Movement
Flexion	Forearm toward the arm
Extension	Forearm away from the arm
Abduction	Arms sideways, away from body
Adduction	Arms back to the body
Rotation	Head to answer "no"

- Table 19.1

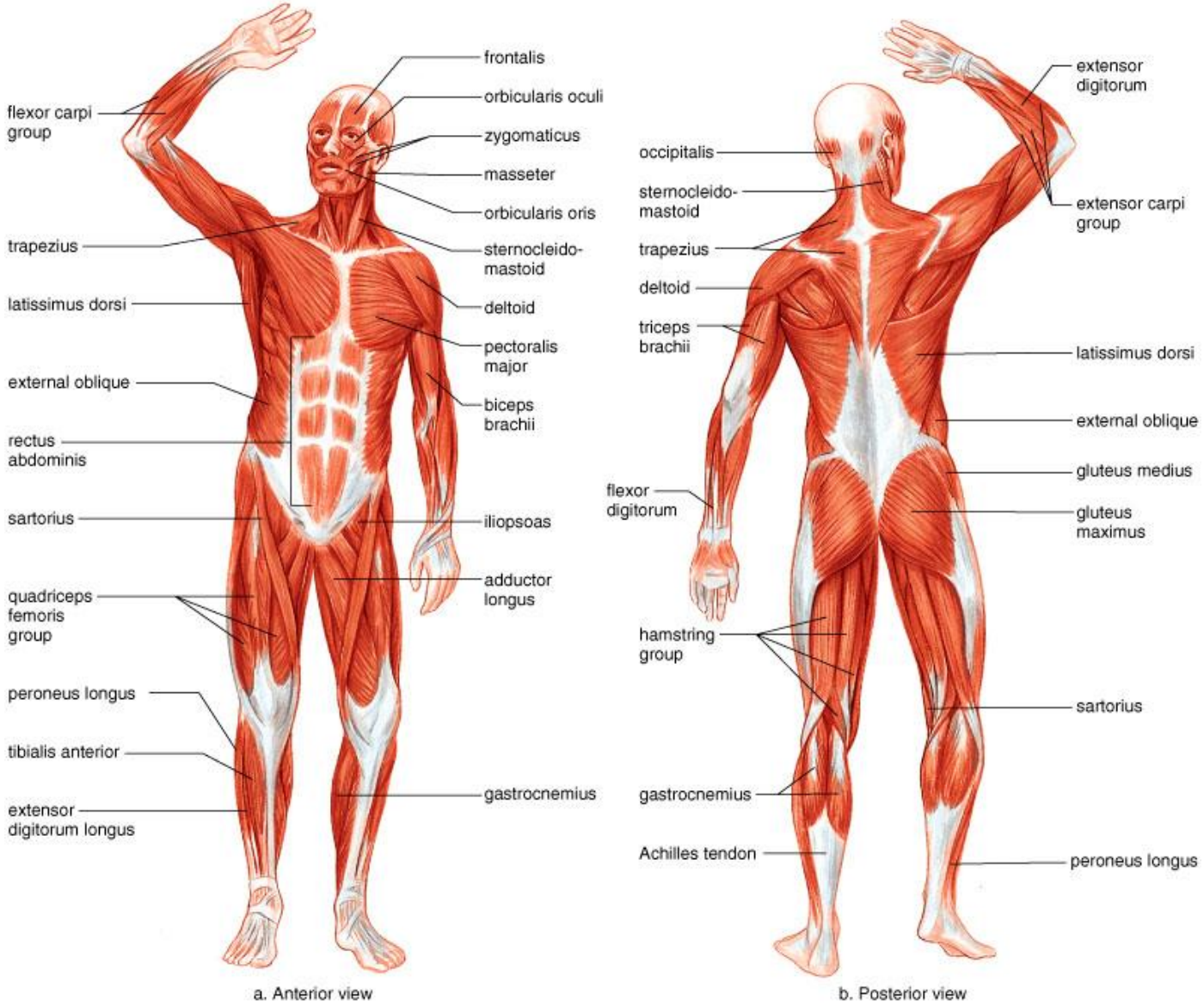
19.3 Skeletal muscles

- skeletal muscles
  - Striated and voluntary
  - Covered by connective tissue fascia
  - Attached to bone by tendons
    - Origin- less movable end of a muscle
    - Insertion-more movable end
    - Action- the movement contraction produces
  - Muscles are arranged in functional groupings
    - Prime mover-muscle doing most of the work
    - Synergists- assist the prime mover
    - Most muscles have an antagonist- moves in opposite direction
      - Ex: biceps brachii and triceps brachii

Skeletal muscles cont'd.

- Major skeletal muscles
  - Nomenclature
    - Size- "maximus"- largest ex: gluteus maximus
    - Shape- ex: deltoid has shape of Greek letter
    - Location- ex: frontalis overlies the frontal bone
    - Direction of muscle fibers- "rectus" means straight
      - Ex: rectus abdominis
    - Number of attachments- "biceps" means two ex: biceps brachii
    - Action- ex: extensor digitorum extends the digits
  - Identify the major muscles on the following diagram

Human musculature



- Fig. 19.12

Skeletal muscles cont'd.

- Actions of muscles
  - Action is the movement the muscle produces
  - Principal actions of the major human muscles are listed in the following 2 slides

Muscles (anterior view)

TABLE 19.2 MUSCLES (ANTERIOR VIEW)

Name	Action
Head and neck	
Frontalis	Wrinkles forehead and lifts eyebrows
Orbicularis oculi	Closes eye (winking)
Zygomaticus	Raises corner of mouth (smiling)
Masseter	Closes jaw
Orbicularis oris	Closes and protrudes lips (kissing)
Upper limb and trunk	
External oblique	Compresses abdomen; rotates trunk
Rectus abdominis	Flexes spine
Pectoralis major	Flexes and adducts shoulder and arm ventrally (pulls arm across chest)
Deltoid	Abducts and raises arm at shoulder joint
Biceps brachii	Flexes forearm and supinates hand
Lower limb	
Adductor longus	Adducts thigh
Iliopsoas	Flexes thigh at hip joint
Sartorius	Rotates thigh (sitting cross-legged)
Quadriceps femoris group	Extends leg
Peroneus longus	Everts foot
Tibialis anterior	Dorsiflexes and inverts foot
Flexor digitorum longus	Flexes toes
Extensor digitorum longus	Extends toes

- Table 19.2

Muscles (posterior view)

TABLE 19.3 MUSCLES (POSTERIOR VIEW)

Name	Action
Head and neck	
Occipitalis	Moves scalp backward
Sternocleidomastoid	Turns head to side; flexes neck and head
Trapezius	Extends head; raises and adducts shoulders dorsally (shrugging shoulders)
Upper limb and trunk	
Latissimus dorsi	Extends and adducts shoulder and arm dorsally (pulls arm across back)
Deltoid	Abducts and raises arm at shoulder joint
External oblique	Rotates trunk
Triceps brachii	Extends forearm
Flexor carpi group	Flexes hand
Extensor carpi group	Extends hand
Flexor digitorum	Flexes fingers
Extensor digitorum	Extends fingers
Buttocks and lower limb	
Gluteus medius	Abducts thigh
Gluteus maximus	Extends thigh (forms buttocks)
Hamstring group	Flexes leg and extends thigh at hip joint
Gastrocnemius	Plantar flexes foot (tiptoeing)

- Table 19.3

19.4 Mechanism of muscle fiber contraction

- Muscle fiber
  - Each muscle cell is called a muscle fiber
  - Cell membrane is called the sarcolemma
  - Sarcoplasmic reticulum- endoplasmic reticulum running throughout muscle fiber
    - Has expanded portions which store calcium ions
  - T tubules- extend into cell from the sarcolemma
  - Myofibrils- composed of contractile filaments, arranged in bundles surrounded by the sarcoplasmic reticulum

Microscopic anatomy of a muscle

TABLE 19.4 MICROSCOPIC ANATOMY OF A MUSCLE

Name	Function
Sarcolemma	Plasma membrane of a muscle fiber that forms T tubules
Sarcoplasm	Cytoplasm of a muscle fiber that contains the organelles, including myofibrils
Glycogen	A polysaccharide that stores energy for muscle contraction
Myoglobin	A red pigment that stores oxygen for muscle contraction
T tubule	Extension of the sarcolemma that extends into the muscle fiber and conveys impulses that cause Ca^{2+} to be released from the sarcoplasmic reticulum
Sarcoplasmic reticulum	The smooth ER of a muscle fiber that stores Ca^{2+}
Myofibril	A bundle of myofilaments that contracts
Myofilament	Actin filaments and myosin filaments whose structure and functions account for muscle striations and contractions

- Table 19.4

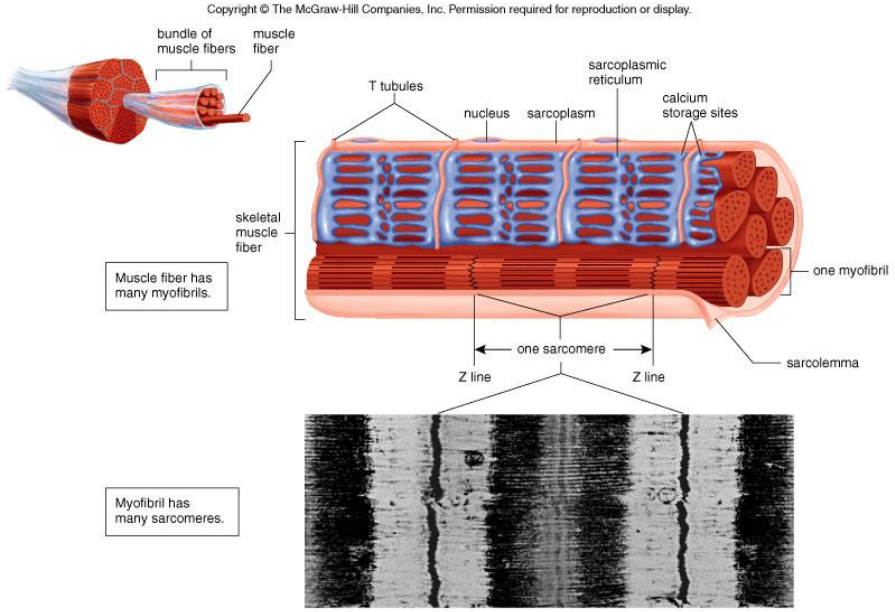
Mechanism of muscle fiber contraction cont'd.

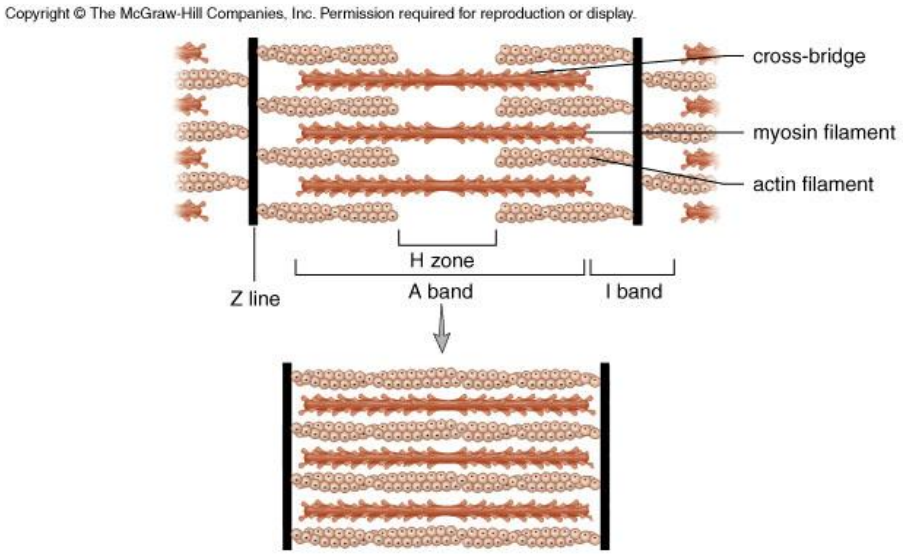
- Myofibrils and sarcomeres
  - Myofibrils are cylindrical and run the length of the muscle fiber
  - Striated appearance due to arrangement of contractile filaments
- Contractile myofilaments
  - Myosin
    - Each myosin molecule is shaped like a golf club
      - Straight portion ending in a double globular head or crossbridge
      - Cross bridges occur on each side of a sarcomere but not in the middle
  - Actin
    - Consists of 2 intertwining actin filaments
    - Tropomyosin and troponin are associated proteins

Mechanism of muscle fiber contraction cont'd.

- Sliding filaments
  - Upon stimulation, sarcoplasma depolarizes and an action potential spreads along the membrane
  - Sarcomeres within the myofibrils shorten- causes contraction of the muscle fiber
    - Actin filaments slide past the myosin filaments and approach one another
  - SLIDING FILAMENT THEORY
    - Concept that thick and thin filaments slide past each other and cause the muscle to contract.
- Skeletal muscle contraction
  - Neuromuscular junction
    - One motor neuron can synapse with few or many muscle fibers in a muscle

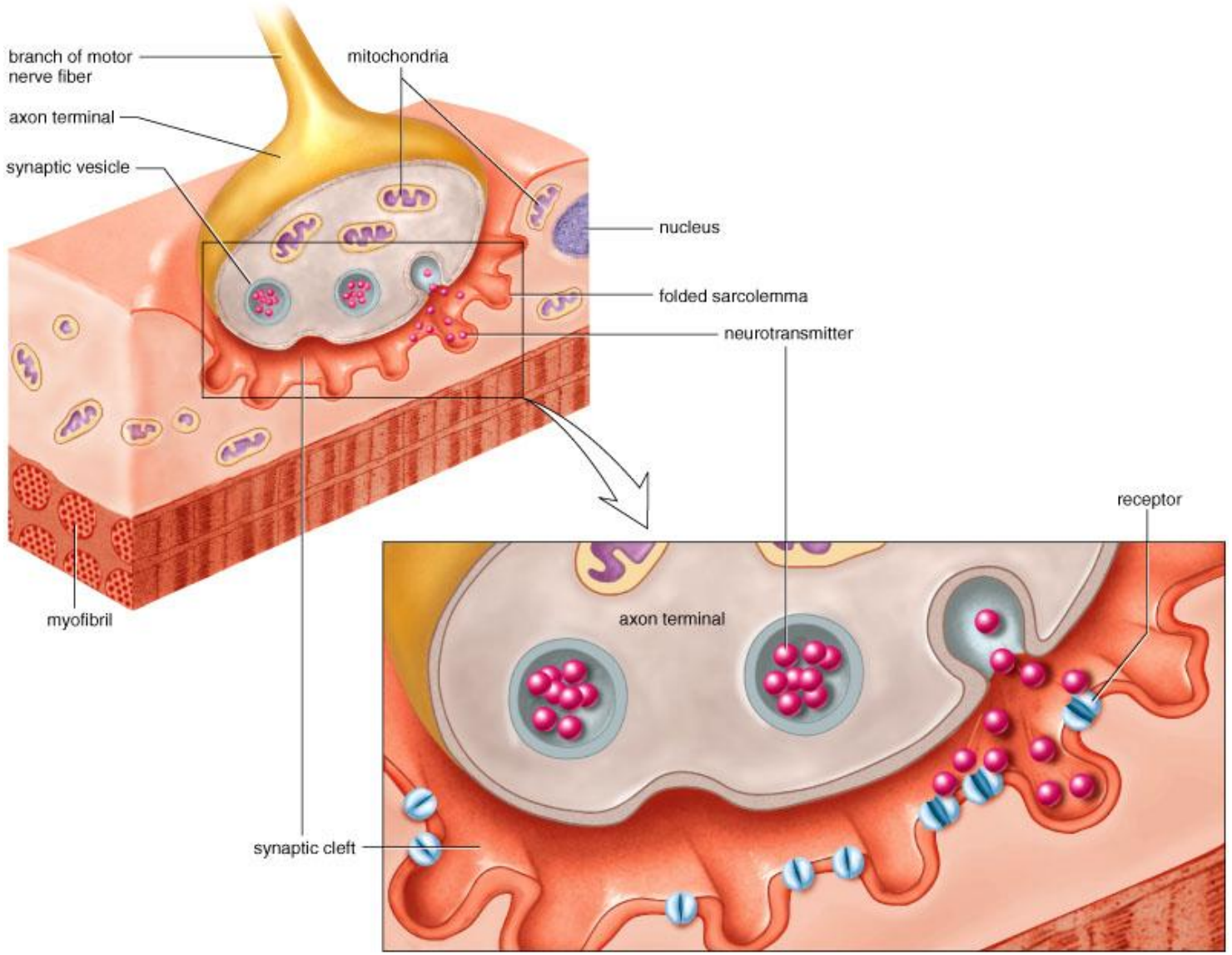
Anatomy of a muscle fiber





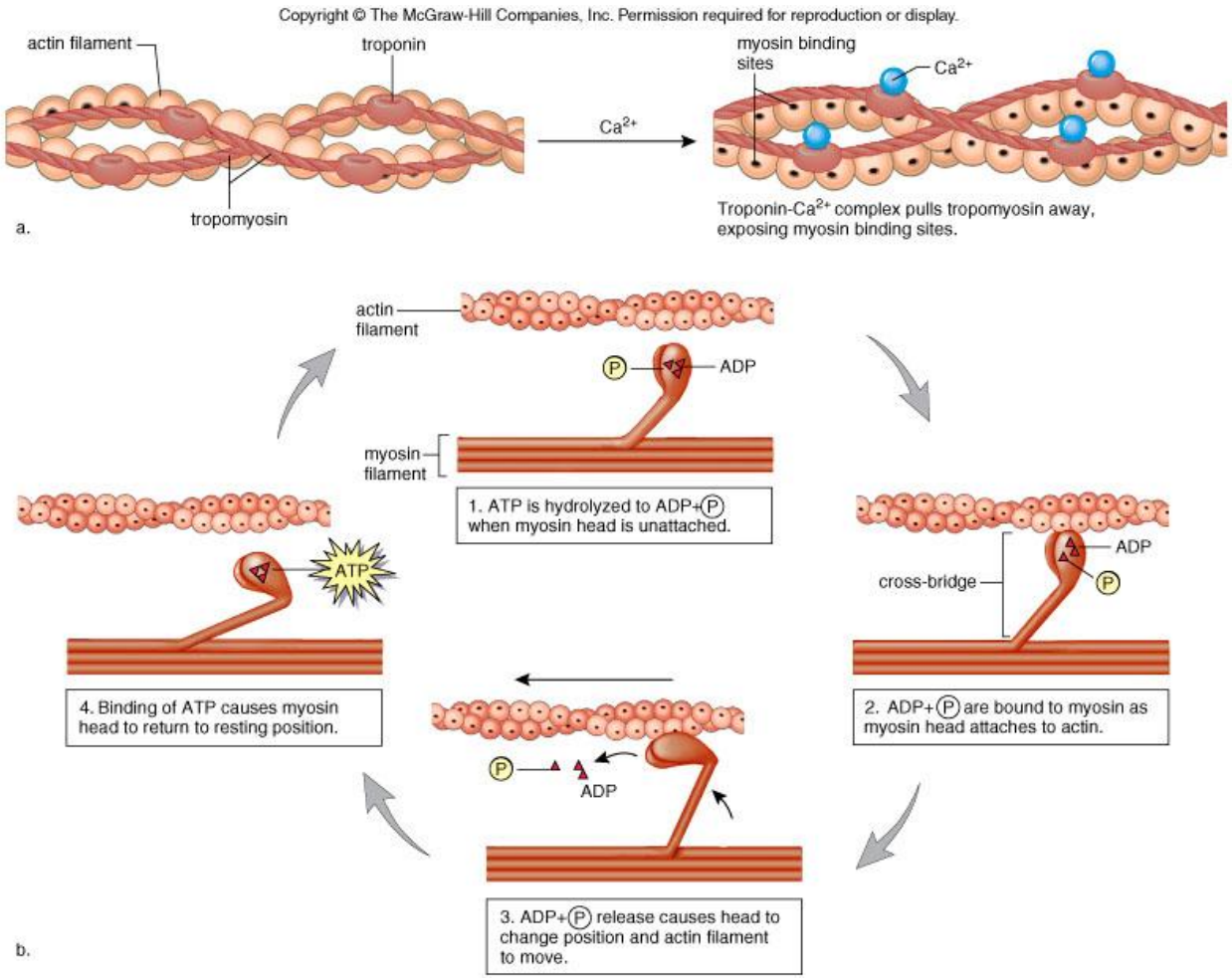
- Fig 19.13

Neuromuscular junction



- Fig 19.14

The role of calcium and myosin in muscle contraction



- Fig 19.15

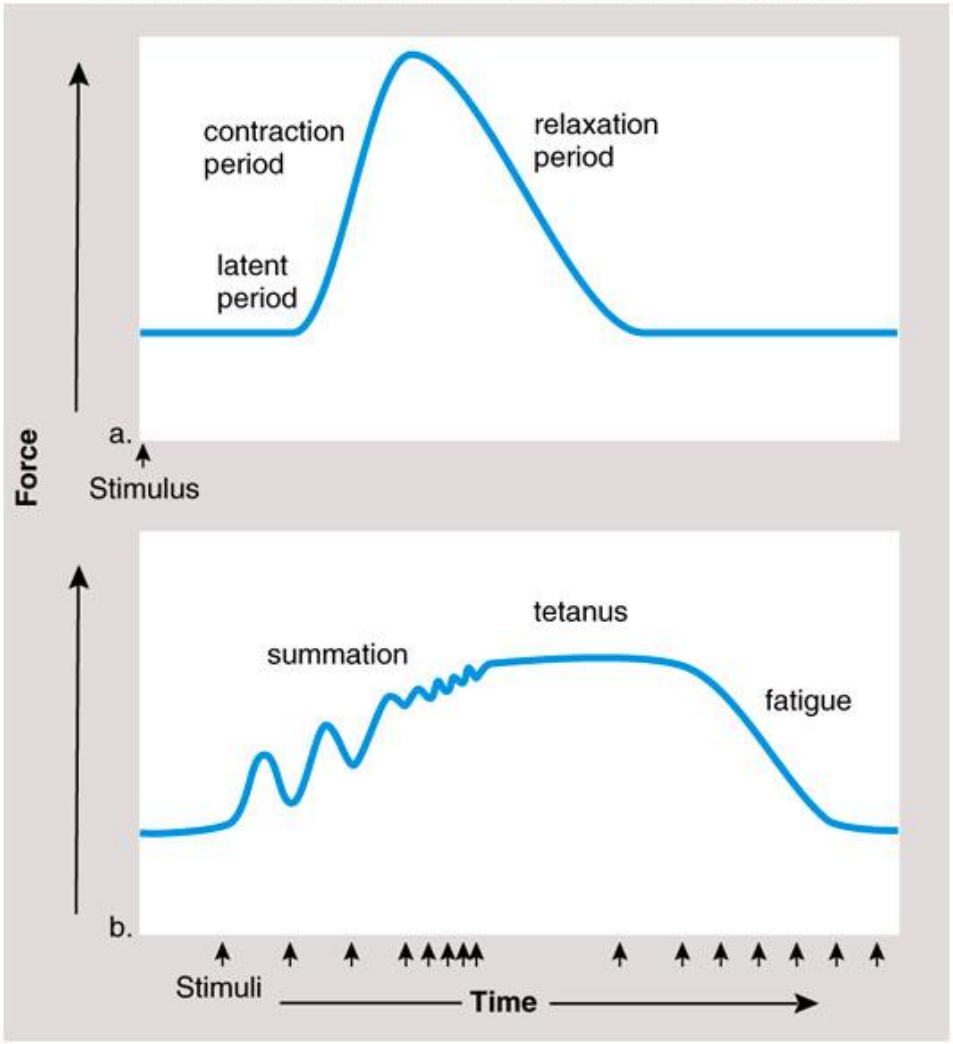
19.5 Whole muscle contraction

- In the laboratory
  - Single muscle fiber contracts completely along its length in response to a stimulus- *all or none law*
  - whole muscle can contract to various degrees
  - Myogram-visible pattern of contraction recorded in the laboratory
  - Muscle twitch-response of a muscle to a single threshold stimulus
    - 3 phases
      - Latent period-from stimulus to onset of contraction
      - Contraction period-while muscle is contracting
      - Relaxation period-muscle returns to resting length

Whole muscle contraction cont'd.

- In the laboratory cont'd.
  - Whole muscle contraction
    - Unlike a single fiber, whole muscle exhibits degrees of contraction
      - Stronger stimulation causes more fibers to contract
    - Tetany- response to a rapid series of stimuli
      - Muscle can respond to the next stimulus without relaxing completely
      - Summation- increased muscle contraction until a maximum sustained contraction (tetany) is reached
- Athletics and muscle contraction
  - Exercise and size of muscle
    - Disuse causes atrophy- decrease in size
      - Muscle fibers are replaced by fat and fibrous tissue
      - Can cause fibers to contract leaving body in contorted positions
    - Forceful activity over prolonged period causes muscle to increase in size

Physiology of skeletal muscle contraction

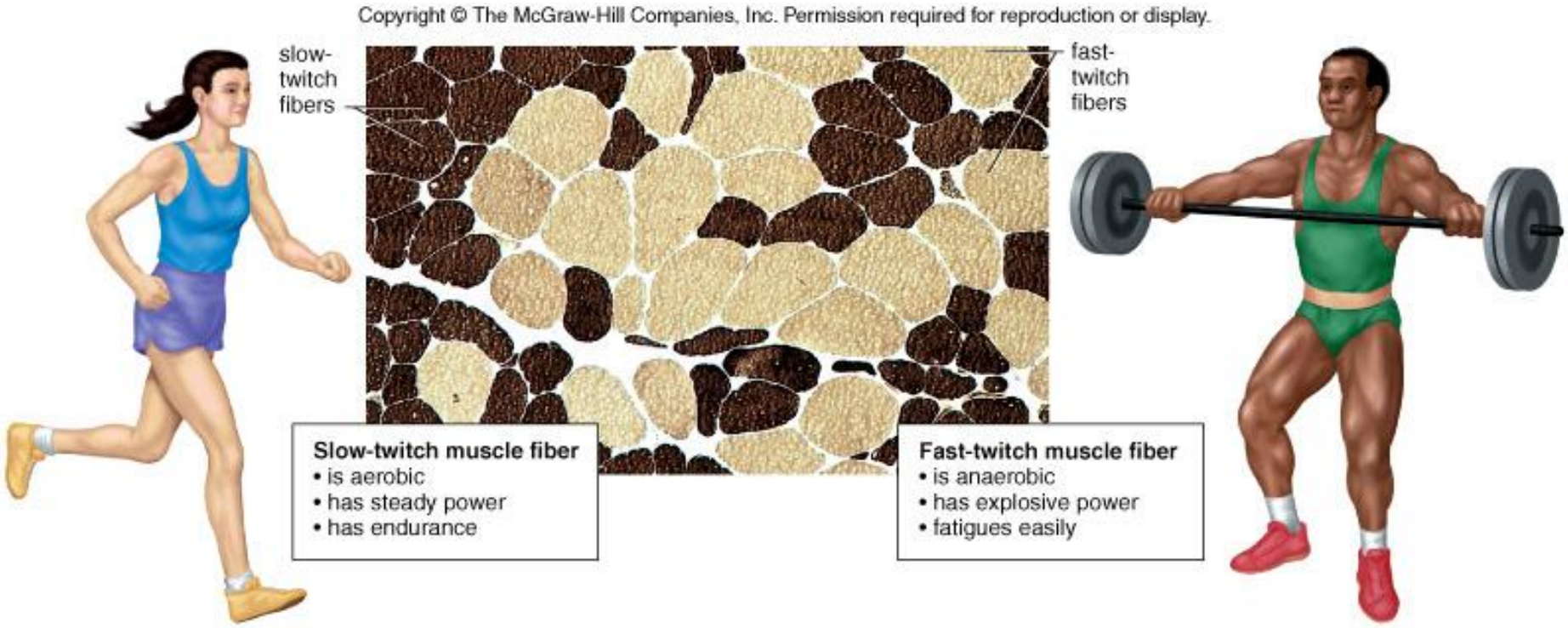


- Fig 19.16

Whole muscle contraction cont'd.

- Athletics and muscle contraction cont'd.
  - Slow-twitch and fast-twitch muscle fibers
    - Slow-twitch fibers
      - 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
      - Substantial reserves of glycogen and fat
    - Fast-twitch fibers
      - Anaerobic
      - Develop maximum tension rapidly
      - Dependence on anaerobic energy leaves them vulnerable to accumulation of lactic acid and fatigue

Slow- and fast-twitch muscle fibers



- Fig. 19.17

A checklist for staying fit

TABLE 19A A CHECKLIST FOR STAYING FIT

Children, 7–12	Teenagers, 13–18	Adults, 19–55	Seniors, 55 and up
Vigorous activity 1–2 hours daily	Vigorous activity 1 hour 3–5 days a week, otherwise 1/2 hour daily moderate activity	Vigorous activity 1 hour 3 days a week, otherwise 1/2 hour daily moderate activity	Moderate exercise 1 hour daily 3 days a week, otherwise 1/2 hour daily moderate activity
Free play	Build muscle with calisthenics	Exercise to prevent lower back pain: aerobics, stretching, yoga	Plan a daily walk
Build motor skills through team sports, dance, swimming	Plan aerobic exercise to control buildup of fat cells	Take active vacations: hike, bicycle, cross-country ski	Daily stretching exercise
Encourage more exercise outside of physical education classes	Pursue tennis, swimming, horseback riding—sports that can be enjoyed for a lifetime	Find exercise partners: join a running club, bicycle club, outing group	Learn a new sport or activity: golf, fishing, ballroom dancing
Initiate family outings: bowling, boating, camping, hiking	Continue team sports, dancing, hiking, swimming		Try low-impact aerobics, boating. Before undertaking new exercises, consult your doctor

- Table 19A