Chapter 6: Bone and Bone Tissue

Skeletal system
=_____,_____, _____

Bones are main organs:
- osseous tissue
- dense regular and irregular CT, plus bone marrow

Module 6.1: Introduction to Bones as Organs

FUNCTIONS OF THE SKELETAL SYSTEM

• Functions:
1. Protection

2. Mineral storage and _____

3. Blood cell formation:_____involved in formation of blood cells

(hematopoiesis or hemopoiesis)

4. Fat storage: in yellow bone marrow of _____

5. Movement: bones are sites for skeletal muscle attachment

6. Support: supports weight and provides _____

BONE STRUCTURE CLASSIFICATION

(based on shape)

1. Long bones
- longer than they are wide;
- include most bones in arms and legs

2. Short bones
– roughly cube-shaped
- include carpals and _____

3. Flat bones
– thin and broad bones
- ribs, pelvis, sternum and _____

4. Irregular bones
– include_____and certain skull bones

5. Sesamoid bones
– located within _____

BONE STRUCTURE

Structure of long bone:

- Periosteum
  – membrane surrounds outer surface
- Perforating fibers (Sharpey's fibers)
  - anchors periosteum firmly to bone surface
- Diaphysis – _____
- Epiphysis -_____of long bone (proximal & distal)
- Articular cartilage – hyaline cartilage
- Marrow cavity – contains bone marrow (red or yellow)
- Endosteum – thin membrane lining marrow cavity

Compact bone
- hard, dense outer region
- allows bone to resist stresses (compression & twisting)

• **Spongy bone** (_____bone)
- found inside cortical bone
- *honeycomb-like framework* of bony struts;
- resist forces from many directions

• **Epiphyseal lines**
– *separates* epiphyses from diaphysis
- remnants of epiphyseal plates

• **Epiphyseal plates** (_____**plates**)
- hyaline cartilage found in developing bones of children

Structure of short, flat, irregular, and sesamoid bones
- covered by periosteum
- diploë = two outer layers of thin compact bone with middle layer of spongy bone
- sinuses = air-filled spaces _____

Bone Marrow Transplantation
• Diseases of blood
• Needle is inserted into pelvic bone
• Recipient's marrow is destroyed
• Complications –
• Many recipients can return to a healthy life if transplant "takes"

Module 6.2: Microscopic Structure

MICROSCOPIC STRUCTURE

Extracellular matrix of bone:
• **Inorganic matrix** (65%)
– consisting of_____(hydroxyapatite salts of Ca & P)
• **Organic matrix** (35%)
–osteoid
–consists of collagen fibers and *usual ECM*

Bone cells:
• **Osteogenic –** differentiate into osteoblasts
• **Osteoblasts** – _____
• **Osteocytes –** mature bone cells in lacunae
• **Osteoclasts**
- bone _____
- secrete acid and enzymes

HISTOLOGY OF BONE

Structure of compact bone:

Osteon (Haversian system)
– Lamellae = concentric rings of *thin layers of bone*
– Central canal = contains blood vessels & nerves
– Lacunae =_____for osteocyte
– Canaliculi = _____
– Perforating canals (Volkmann's canals) *perpendicular to central canals*

Structure of spongy bone
- usually not wt. bearing
- not organized into osteons

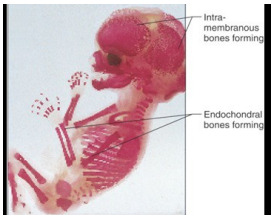
_____ = bony struts

Module 6.3: Bone Formation and Ossification

OSSIFICATION

• **Ossification** (**osteogenesis**)
- Process of bone formation
- Begins in embryonic period and continues throughout adulthood

[fetal "skeleton"]



[14 weeks]

cartilage template fibrous CT
endochondral

fibrous CT
intramembranous

BONE

INTRAMEMBRANOUS

- **Intramembranous ossification**
  - – forms many_____(bones of skull and clavicles)
  - – formed within a *mesenchymal* _____
  - – spongy bone ossifies before outer compact bone layers
  - – forms **primary ossification center**
  - – _____ = areas of incomplete intramembranous ossification

ENDOCHONDRAL OSSIFICATION

- **Endochondral ossification** (**Figure 6.12**):
  - – Bone development for all bones below head except _____
  - – Many bones *complete ossification* by age 7
- Endochondral ossification
  - - bones begin within *hyaline* _____
  - – Hyaline cartilage model made of *chondrocytes*, *collagen*, *and ECM* surrounded by CT **perichondrium**
  - – Cartilage breaks down
  - – Collar formation (periosteum)
  - – _____ ***ossification center*** mid-diaphysis
  - - ***secondary ossification centers*** at _____

  Most bones of skeleton formed this way.

Osteoporosis and Healthy Bones

- Most common bone disease in U.S
- Diagnosed by *bone density measurement*
- **Causes** – *dietary* (calcium and/or vitamin D deficiency)
- **Prevention**
- **Treatment**

Module 6.4: Bone Growth in Length

GROWTH IN LENGTH

Growth in Length

• Long bones lengthen via **longitudinal growth**; involves division of

_____ (not osteocytes or osteoblasts) in epiphyseal plate

• Bone growth takes place at epiphysis on side *closest to diaphysis*

• **Epiphyseal plate**

1. **Zone of reserve cartilage** – (found closest to epiphysis) contains cells that are not directly involved in bone growth but *can be recruited* for cell division if need arises
2. **Zone of proliferation** - consists of *actively dividing chondrocytes* by endochondral ossification
3. **Zone of hypertrophy and maturation** (next region closer to diaphysis) contains *mature chondrocytes*
4. **Zone of calcification** (second to last region) contains dead chondrocytes, some of which have been calcified

   Calcified cartilage is replaced with bone.
5. **Zone of ossification** (last region) consists of *calcified chondrocytes and osteoblasts*

• Longitudinal growth continues at epiphyseal plate as long as *mitosis continues* in zone of proliferation:

– Mitotic rate slows around ages of 12-15 years old

Between ages of 18-21 epiphyseal plate is **closed**

– _____ is a *calcified remnant* of epiphyseal plate

GROWTH IN WIDTH

Appositional growth = _____

• Osteoblasts, *lay down new bone*

– Appositional growth does not result in immediate formation of osteons; instead, *new circumferential lamellae* are formed

– Bones may *continue to increase in width* even after epiphyseal plates have *closed* and bone is no longer *lengthening*

Achondroplasia

• Most common cause of **dwarfism**; gene defect

• Defective gene produces an *abnormal growth factor receptor*

• Bones form and grow abnormally

• Long-term problems

ROLE OF HORMONES IN BONE GROWTH

• _____ (GH) – secreted by *anterior pituitary gland*;
enhances protein synthesis and cell division in most all tissues, including bone

• _____ - pronounced effect on bone growth:
– Increases appositional growth in males
– Increases *rate of mitosis in epiphyseal plate*; leads to "growth spurts" in teenage years

• **Estrogen** also plays a role in bone growth:
– Increases *rate of longitudinal growth* and inhibits *osteoclasts*
– Accelerates closure of epiphyseal plate at much *faster rate than testosterone*
→ *average height differences* between genders

Gigantism and Acromegaly

• *Excess GH* can produce two conditions, depending on when in life it develops; both generally caused by a_____that secretes hormone

• **Childhood** – condition is _____

• **Adulthood** – condition is _____

Module 6.5: Bone Remodeling and Repair

BONE REMODELING

• **Bone remodeling** = new bone is formed by **bone**_____and old bone is removed by **bone** _____

– Maintenance of *calcium ion homeostasis*
– *Replacement* of old brittle bone with newer bone
– *Adaptation* to tension and stress

• **PTH** (parathyroid hormone from parathyroid gland) stimulates effects that _____ *blood Ca+2 levels*
o Increases osteoclast activity
o Increases *absorption* of calcium from gut
o Inhibits calcium *loss* in urine

• **Calcitonin** (from thyroid gland)
causes _____ blood Ca+2 levels
o Inhibits osteoclasts
o Increases calcium loss in urine

Thyroid Gland Secretes _____

Parathyroid Glands Secretes _____

• Factors influencing bone remodeling are summarized:

BONE REPAIR

Fractures:

– **Simple fractures** vs_____**fractures**

– *Spiral*

– *Compression*

– *Comminuted*

– *Avulsion*

– *Greenstick*

– *Epiphyseal plate*

Chapter 7: The Skeletal System

Skeletal System =_____bones plus cartilages
- Axial (80 bones)

- Appendicular (126 bones)

Module 7.1: Overview of the Skeletal System

STRUCTURE OF THE SKELETAL SYSTEM & SKELETAL CARTILAGES

Axial skeleton

– **Skull, vertebral column, thoracic cage (ribs, sternum), _____**

• **Appendicular skeleton**

– **Bones of pectoral girdle, upper limb, pelvic girdle, and lower limb**

Pectoral girdle –_____; *anchors* upper limb to trunk

Pelvic girdle –_____bones; *anchors* lower limb to trunk

BONE MARKINGS

Fossa –

Canal (meatus)-

Condyle -

Head -

Foramen –

Module 7.2: The Skull

OVERVIEW OF SKULL STRUCTURE

• Skull = 22 bones organized in *two groups*:

– **Cranial bones** – collectively known as **cranium**, composed of_____bones (STEP OFf my skull)

• Frontal -1

• Occipital -1

• Ethmoid -1

• Sphenoid – 1

• Parietal – 2

• Temporal – 2

– **Facial bones** =_____bones
- Maxillary – 2
- Zygomatic -2
- Nasal -2
- Lacrimal -2
- Palatine -2
- Inferior nasal concha -2
- Mandible -1
- Vomer -1

• Sinuses =_____, membrane-lined *spaces*
paranasal sinuses = frontal, ethmoid, sphenoid, maxillary

CAVITIES OF THE SKULL

• **Orbit** – FLEZMS *7 fused bones*; form walls that encase eyeball, lacrimal gland, and their associated blood vessels, muscles, and nerves
– **Frontal bone**
– **Lacrimal**
– **Ethmoid**
– **Zygomatic**
– **Maxilla**
– **Sphenoid bone**
- and_____**bones**

THE FETAL SKULL

Fontanel (soft spot) = area of incomplete _____
Anterior
Posterior
Sphenoid
Mastoid

HYOID

• **Hyoid**
– doesn't *articulate* with any other bones
– C-shaped bone
– Provides numerous muscle attachment points involved in _____

Forensic Skull Anatomy

- Forensic investigators often must identify human remains with little to go on except bones; can provide many clues (particularly skull); one of most basic traits that can be identified from a skull is *gender*
- Four obvious differences:

Module 7.3: Vertebral Column & Thoracic Cage

OVERVIEW OF THE VERTEBRAL COLUMN

Vertebral column (**spine**) – composed of *about*_____bones (**vertebrae)**

- 7 **cervical** – located in _____
- 12 **thoracic** – articulate with _____
- 5 **lumbar** – in _____

- 5 fused **sacral** (collectively called **sacrum**)
- 3-5 fused **coccygeal** (collectively called **coccyx**)

- **Spinal curvatures** – C-shaped vertebral column of newborn → S-shaped secondary curvatures as infant grows
  - **Primary curvatures** (_____and *sacral*) present during fetal dev.
  - **Secondary curvatures** (_____and *lumbar*) dev. after fetal period

- **Abnormal spinal curvatures**:
  - **Scoliosis** – abnormal_____*curvatures*
  - **Lordosis** (**swayback**) – exaggerated *cervical* and_____curvatures
  - **Kyphosis (hunchback)**
    - exaggeration of_____*curvature*

STRUCTURE OF THE VERTEBRAE

- **Cervical** (**7**) – smallest vertebrae
  - _____ **foramina** allows passage of vertebral arteries and veins
  - **C1** (_____)
    - Lacks **vertebral body**
    - Articulates with *occipital condyles* and *C2*
  - **C2** (_____)
    - **Dens** (**odontoid process**) protrudes from body
  - Allows for *rotational movement* of head at neck; (shaking your head "no")

• **Thoracic vertebrae** (**12**)
- long spinous processes
- **Superior** and **inferior costal facets** (articulate with **head of rib**)
- **Transverse costal facets** on transverse processes (articulate with _____ **on rib**)

Posterior view: Shaped like _____

• **Lumbar vertebrae** (**5**)
– *largest* and *heaviest* of all vertebrae (_____)

Posterior view- shaped like _____

• **Sacrum** – 5 *fused* sacral vertebrae
– **Sacral promontory** – bony *projection* at anterior margin of base (superior aspect)
- **Sacral foramina** – *4 pairs of holes* allows for _____ _____

• **Coccyx** = 4 fused (3-5) vertebrae

STUDY BOOST: REMEMBERING SKULL BONES AND

• **PEST OF** 6 (*six cranial bones*): Parietal, Ethmoid, Sphenoid, Temporal, Occipital, Frontal
• **Virgil Is Now Making My Pet Zebra Laugh** (*facial bones*): Vomer, Inferior nasal conchae, Nasal, Mandible, Maxillae, Palatine, Zygomatic, Lacrimal
• **For Easier Sinus Memorization** (*paranasal sinuses*): Frontal, Ethmoidal, Sphenoidal, Maxillary
• **Breakfast at 7**, **lunch at 12**, **dinner at 5** (*number of vertebrae*): 7 cervical, 12 thoracic, and 5 lumbar

Sphenoid = Bat bone **Ethmoid = iceberg in skull**


Thoracic giraffe


Lumbering moose

INTERVERTEBRAL DISC

• **Intervertebral disc**
= *fibrocartilage pad* found between bodies vertebrae
• **Nucleus pulposus** – *jelly-like* substance; shock absorber
• **Anulus fibrosus** – outer ring of _____
Herniated disc or "slipped disc"

Herniated Disc
• A tear in anulus fibrosus can allow nucleus pulposus to *protrude*, a condition known as a **herniated disc** (commonly called a **slipped disc**)
• Bulging nucleus pulposus *compresses* nerve
• Treatments

THE THORACIC CAGE

• **Thoracic cage**
=
– **sternum**
• **Manubrium** – *superiormost*
• **Body** - middle
• **Xiphoid process** – inferior

Rib cage= 12 pairs of ribs and their costal cartilages
• Ribs 1–7 (_____**ribs** or **vertebrosternal** ribs) attach to sternum via their *costal cartilages*
• Ribs 8–12 (_____**ribs**) not directly attached to sternum
– **Vertebrochondral** ribs 8–10 – attached to *cartilage of 7th rib*
– _____ or **vertebral** ribs 11 & 12
- are not attached to sternum

Structure of a typical rib.

The Sternum and CPR

• **Cardiopulmonary resuscitation** (**CPR**)

• *Correct placement of hands on sternum is critical*

Module 7.4: Bones of the Pectoral Girdle and Upper Limb

PECTORAL GIRDLE

• **Pectoral girdle** – **clavicle** and **scapula**

- **Clavicle**
  - – Sternal end
  - – Acromial end
- **Scapula**
  - **- Acromion**
  - – **Coracoid process**
  - – **Subscapular fossa** (anterior aspect)
  - – **Glenoid cavity** (articulates with head of humerus)
  - – **Spine** (_____*ridge)*
  - – **Supraspinous fossa**
  - – **Infraspinous fossa**

THE HUMERUS

• **Humerus**

- **head** articulates with *glenoid cavity* at shoulder joint
- _____ **neck** is a groove surrounding head
- _____ **neck** proximal diaphysis
- **greater & lesser tubercle** lateral and anterior to head
- olecranon fossa
- coronoid fossa
- capitulum
- trochlea

BONES OF THE FOREARM

Bones of forearm (**antebrachium**)

• **Radius** (_____bone)

- head, neck, radial tuberosity, styloid process

• **Ulna** (_____)

- trochlear notch, olecranon, coronoid process, radial notch, styloid process

BONES OF THE WRIST: CARPALS

Wrist (**carpus**) –_____(**carpals**)
(lateral to medial)
– **Scaphoid** *,* **Lunate** *,* **Triquetrum**, **Pisiform** (proximal)
– **Trapezium**, **Trapezoid**, **Capitate***,* **Hamate** (distal)

BONES OF THE HAND AND FINGERS: METACARPALS AND PHALANGES

Metacarpals – 5 each hand
Phalanges – 14 each hand
- **proximal**, **middle**, and **distal** _____
- **Thumb** proximal & distal phalanx

Wrist Fractures

• Wrist is the most *frequently injured* region of upper limb;

• Fractures

Colles fracture

Module 7.5: Bones of the Pelvic Girdle and Lower Limb

BONES OF THE PELVIC GIRDLE AND LOWER LIMB

Pelvic girdle =

• **coxal bones** (also known as **os coxae**)

• Articulates with **sacrum** (axial skeleton)

Pelvis – bowl-shaped sacrum and two coxal bones; creates *boundary* for pelvic cavity
Pelvic inlet – oval *opening* formed by sacrum and pelvic girdle
Pelvic brim – bony *ridge* surrounding inlet that defines boundaries between **greater** and **lesser pelvis**

• Each_____is composed of 3 *fused bones*:
ilium, **ischium**, and **pubis**

Female and male pelvis differ between genders:
female pelvis (adapted for *childbirth*) is *wider* and *shallower* than male

- **Shape of greater pelvis**:
  - pelvis is *wider* in females with *flared* iliac crests
  - increases distance between ASIS
- **Coccyx and sacrum**:
  - female sacrum is *wider* and *shorter* than male sacrum
  - while female coccyx is more *moveable* and more *posterior* than male

- **Pelvic inlet and outlet**: female inlet is usually *wider* and *oval-shaped* whereas male inlet is *narrow* and *heart shaped*; female outlet is generally *wider* than male
- **Acetabula**: generally *farther apart* in females and pointed more *anteriorly* than in males
- **Pubic arch**:
  – angle measured in females = _____
  – male arch measures between _____

FEMUR AND PATELLA

- **Femur** – *largest* and *strongest* bone
  – **head** articulates with_____at hip joint
  – **Neck**
  – **Greater and Lesser trochanter**
  – **Linea aspera**
  – **Medial** and a **lateral condyles**
  – **Patellar surface**

- **Patella**

BONES OF THE LEG: TIBIA AND FIBULA

- **Tibia** (_____bone) larger bone, wt. bearing
  – Tibial tuberosity
  – Medial malleolus

- **Fibula** (_____bone)
  – Lateral malleolus

BONES OF THE ANKLE AND FOOT: TARSALS, METATARSALS, AND PHALANGES

- **Tarsals** – *7 short bones*
  - – *Proximal* tarsals: _____, **calcaneus**, and **navicular**
  - – *Distal* tarsals medial to lateral: 3 **cuneiforms (medial**, **intermediate**, **lateral**) and **cuboid**
- **Metatarsals –** 5 in each foot
- **Phalanges –** 14 in each foot

STUDY BOOST: REMEMBERING BONES OF THE ARM AND LEG

Carpals: Stop Letting The People Touch The Cadaver's Hand

= Scaphoid, Lunate, Triquetrum, Pisiform, Trapezium, Trapezoid, Capitate, Hamate (Mentions "hand", so remember that it describes carpals, not tarsals; trapeziUM is by thUMb)

Tarsals: College Needs Me In Lab Classes

= Talus, Calcaneus, Navicular; Medial, Intermediate, & Lateral cuneiform, Cuboid

Chapter 8: Articulations

Articulations (joints) = where bones meet
- allow _____
- provide _____
- allow long bones to_____(epiphyseal plate)

Module 8.1: Classification of Joints

FUNCTIONAL CLASSIFICATION

Based on_____:
- **Synarthrosis** – no *movement* between articulating bones
- **Amphiarthrosis** – small amount of *movement* between articulating bones
- **Diarthrosis** – freely *moveable*, allowing a wide variety of specific movements

STRUCTURAL CLASSIFICATION

Based on their_____*features*:

- **Fibrous joints** – *dense regular collagenous CT;* (synarthroses or amphiarthroses)
- **Cartilaginous joints** – *cartilage*; (synarthroses or amphiarthroses)
- **Synovial joints** – fluid-filled joint capsule with hyaline cartilage at articular ends; (diarthrosis)

Module 8.2: Structural Classification: Fibrous Joints

FIBROUS JOINTS

3 types:
- **Suture**
- **Gomphosis**
- **Syndesmosis**

- **Suture** - fibrous CT _____ of cranium; *immoveable* joint

- **Gomphosis** – tooth in bony socket (**periodontal ligament**); _____ joint

- **Syndesmosis** – joint between tibia & fibula, ulna & radius (interosseous membrane);
  _____

Module 8.3: Structural Classification: Cartilaginous Joints

CARTILAGINOUS JOINTS

2 types:
- **Synchondrosis**
- **Symphysis**

Synchondrosis - *hyaline cartilage*;
Synarthroses (epiphyseal plate, 1st sternocostal and costochondral joints);

_____

Epiphyseal Plate Fractures
- **Epiphyseal plate** in a child's long bone is one of the *weakest parts* of a developing skeleton

- **Treatment**

FIBROUS JOINTS

- **Symphysis** – *fibrocartilaginous pad*; *amphiarthrosis*
  – _____
  – **Pubic symphysis**

Module 8.4: Structural Classification: Synovial Joints

SYNOVIAL JOINTS

Synovial Joints:
– **Joint cavity** (**synovial cavity**) – space found between articulating bones

– **Articular capsule** – double-layered structure
  • Outer fibrous layer
  • Inner synovial membrane → synovial fluid (lubricates, metabolic fcn., shock absorber)

-_____**cartilage** – hyaline cartilage; *covers* all exposed articulating bones within a joint

– **Diarthrosis**

STABILIZING AND SUPPORTING FACTORS

• Synovial joints allow more *mobility*
– less *stable* than other joint types
- structures that provide additional stabilization:
Ligament – dense regular CT connects _____

Tendon - dense regular CT connects _____

Bursae and tendon sheaths provide stabilization forces

Bursitis

• Most *common sites* of bursitis

• Clinical features

ARTHRITIS

• **Arthritis** – defined as *inflammation* of one or more joints which results in pain and limitations of joint movement:
– **Osteoarthritis (OA)** – most common; associated with _____, *injuries*, and advanced *age*; characterized by pain, joint stiffness, and lost mobility
– **Rheumatoid arthritis (RA)** – associated with joint destruction; _____
– **Gouty arthritis** – joint damage due to inflammatory reaction to _____ deposits

Module 8.5: Functions of Synovial Joints

MOVEMENTS AT SYNOVIAL JOINTS

• **Gliding movements** – *sliding motion* between articulating surfaces
• **Flexion**, **Extension**, **Hyperextension**
• **Abduction, Adduction**
• **Circumduction, Rotation**
• **Inversion, Eversion**
• **Supination, Pronation**
• **Dorsiflexion, Plantar flexion**

Module 8.6: Types of Synovial Joints

TYPES OF SYNOVIAL JOINTS

- **Plane joint** (gliding joint) – most simple and least mobile articulation between *flat surfaces* of two bones

- **Hinge joint** – *convex* articular surface of one bone interacts with *concave* depression of second bone

- **Pivot joint** – one bone pivots or rotates around other

- **Condylar** (**ellipsoid) joint** – *convex* surface of one bone fits into concave articular surface of a second bone

- **Saddle joint** – each bone's articulating surface has both a *concave* and *convex* region

- **Ball-and-socket joint** – spherical surface of one bone fits into *cup-shaped depression* in second bone

SPECIFIC HINGE JOINTS

Elbow – very stable hinge joint:

- **Humeroulnar joint** – articulation between *trochlea* of humerus and *trochlear notch* of ulna
- **Humeroradial joint** – articulation between *capitulum* of humerus and *head* of radius

A & P FLIX: MOVEMENT AT THE ELBOW

- **Knee**:
  - _____ **joint** – articulation between *femoral and tibial condyles*
  - **Patellofemoral joint** – articulation between posterior surface of *patella* and anterior patellar surface of *femur*
  - **Medial** and **lateral meniscus** – fibrocartilage *pads* between femoral and tibial condyles
  - **Tibial collateral ligament** (medial collateral) – connects femur, medial meniscus, and tibia to one another to provide *medial joint stabilization*

Knee Injuries and the Unhappy Triad

- **Shoulder** (_____) – ball-shaped head of *humerus* and *glenoid cavity:*
  - – **Glenoid labrum** – *fibrocartilaginous ring*; increases depth of glenoid cavity to provide more *stability*
  - – **Biceps brachii tendon** - helps keep head of humerus within glenoid cavity
  - – **Rotator cuff**, providing most of joint's structural stabilization:_____, **infraspinatus**, **subscapularis**, and _____

- **Hip** (_____) – *acetabulum* and ball-shaped *head of femur*:
  - – **Acetabular labrum** – *fibrocartilaginous ring* that helps to stabilize head of femur within acetabulum

Hip Joint Replacement Surgery

- **Hip replacement** – surgical procedure that replaces a painful damaged joint with an *artificial prosthetic device*

- Severe *arthritis*, *trauma*, *fractures*, and *bone tumors* can all progress to point where hip joint replacement is an option

- **Total replacement**

- **Partial replacement**

Chapter 9 & 10: The Muscular System

Module 9.1: Overview of Skeletal Muscles

Structure of a Skeletal Muscle

Skeletal muscles are not made of muscle cells alone

- Skeletal muscle contains blood vessels that supply muscle cells with oxygen and glucose, and remove wastes, and nerves that coordinate muscle contraction
- Skeletal muscle also contains connective tissue
- Each individual muscle cell (fiber) is surrounded by the _____
- Several muscle cells are bundled together into a_____by the _____
- All fascicles that make up a muscle are, in turn, enclosed by the _____
- Interconnected connective tissues taper down and connect to tendons or other connective tissues; attach muscle to bone or other structure to be moved

Functions of Skeletal Muscles

- Muscle contractions are involved in more than just movement of bones at a joint:
  -
  - Contraction of **diaphragm** muscle is a vital function associated with respiratory system
  - _____ – sitting, standing, holding head upright
  - Skeletal muscles attached to facial skin allow for facial expression; muscles in throat assist with swallowing
  - Sphincters composed of skeletal muscle allow conscious control over opening and closing of body openings
  - _____of soft tissue – abdominal walls, pelvic floor

- **Functional groups of muscles**: generally takes cooperation of several individual muscles working as a group to perform a movement or action
    - _____ (**prime movers**) provide most force for a given muscle action
    - _____have opposite action of agonist; allows for modulation and control of agonist movement
    - _____aid agonists by supplying supplemental force, minimizing unwanted movement, and by helping to stabilize joints
    - _____also provide stabilizing force that anchors a bone; protection from injury due to unnecessary movements
- **Muscle origin and insertion** – skeletal muscles begin and end at distinct anatomical locations
    - _____– anchoring point on a bone, where skeletal muscle "originates from"; typically not involved directly with movement of joint
    - _____– moving end of muscle whose tendon attaches to a bone or other structures

Chapter 10: Muscle Tissue and Physiology

Module 10.1: Overview of Muscle Tissue

Types of Muscle Tissue

- The three types of cells in muscle tissue are
    -
    -
    -
- Generating a force called **muscle tension** is a basic function common to each muscle tissue type
- **Skeletal Muscle**
    - Shape –
    - Striations –
    - # of Nuclei –

- Control –
- Location –

- **Cardiac Muscle**
  - Shape –
  - Striations –
  - # of Nuclei –
  - Control –
  - Location –
  - Intercalated discs

- **Smooth Muscle Tissue**
  - Shape –
  - Striations –
  - # of Nuclei –
  - Control –
  - Location –

Properties of Muscle Cells

1. **Contractility** – ability to contract where proteins in the cell draw closer together
2. _____ – ability of a cell to respond to a stimulus
3. **Conductivity** – ability of a cell to conduct electrical changes across the plasma membrane

4. _____– ability of a cell that allows it to be stretched without being ruptured

5. _____– ability of a cell that allows it to return to its original length

Structure of Muscle Cells

- **Myocytes** (muscle cells)
  -
  - Sarcolemma
  - Sarcoplasmic reticulum (SR)
  -

Module 10.2: Structure and Function of Skeletal Muscle Fibers

Structure of the Skeletal Muscle Fiber

- Skeletal muscle tissue consists of many_____and their surrounding _____ (extracellular matrix)
- _____ **tubules** (**T-tubules**) - inward extensions of sarcolemma that surround each myofibril

Structure of the Myofibril

Myofilaments - hundreds to thousands make up myofibrils (3 types):

- **Thick filaments** –
- **Thin filaments** –
- **Elastic filaments** –

Duchenne Muscular Dystrophy (DMD)

- **DMD** is a degenerative muscular disease occurring almost exclusively in boys
- Caused by a defective gene for the protein_____, coded on **X chromosome**

Dystrophin is a structural protein found in **striated muscle fibers** that anchors the sarcolemma to the surrounding connective tissue and to the myofibrils

In the absence of normal **dystrophin**, the sarcolemma breaks down and the muscle fiber is destroyed and replaced with **fatty** and **fibrous connective tissue**

Symptoms (arising between 2 and 12 years of age) include weakness of the proximal limb muscles and a waddling gait; generally wheelchair-bound by age 12 and dead from **respiratory** or **cardiac failure** by age 20

Putting It All Together: The Big Picture of Skeletal Muscle Structure

- Multiple muscle fibers (surrounded by extracellular matrix called the **endomysium**) form a **fascicle**
- Each_____is surrounded by a layer of connective tissue called the **perimysium**
- **Bundles** of **fascicles** make up a skeletal **muscle**, which is surrounded by the _____, a connective tissue layer
- The **perimysium** and **epimysium** come together at the end of the muscle to form a _____that binds the muscle to its attaching structure (usually bone)
- Skeletal muscles are enclosed by a layer of thick connective tissue called _____, which anchors them to the surrounding tissues and holds groups of muscles together

Sarcomere

- The **sarcomere** –**functional unit** where contraction occurs
- Striations:
  - _____ – only thin filaments

- _____ – both thin and thick filaments

- **I band**
- **Z disc (line)**
-
-
- **M line**
-

The Sliding-Filament Theory

- Sliding filament theory (mechanism) explains how tension is generated during muscle contraction

The **I band** and the **H zone**_____while the

A band remains _____

Z-discs closer together, shortening the sarcomere

_____are arranged end to end within each **myofibril** and when simultaneously contracted, shorten the whole **muscle fiber**

Module 10.4: The Process of Skeletal Muscle Contraction and Relaxation

The Neuromuscular Junction

- M**otor neuron**
- _____**–** junction between neuron and muscle cell
- The **axon terminal** of the neuron contains **synaptic vesicles** filled with the neurotransmitter_____(**ACh**)
- The_____is the **space** between **axon terminal** and muscle fiber
- The **motor end plate** is a specialized region of the muscle plasma membrane

Skeletal Muscle Contraction

Muscle contraction can be broken down into **three phases**:

1.

- An action potential signals the release of acetylcholine from the axon terminal into the synaptic cleft
- Acetylcholine diffuses across the synaptic cleft where it can bind to receptors on the motor end plate
- Channels open allowing Na^+ ions to enter the muscle fiber generating a muscle potential

Review

1. The end plate potential is generated by the influx of_____into the motor end plate.

    a. calcium
    b. sodium
    c. potassium
    d. chloride

2. Acetylcholine is released from the synaptic terminus in response to

    a. A ligand binding to a receptor on the synaptic terminus
    b. Sodium flowing into the synaptic terminus
    c. Potassium entering the synaptic terminus
    d. An action potential arriving at the synaptic terminus

3. The term “synaptic cleft” refers to

    a. A fold on the motor end plate
    b. A vesicle in the synaptic terminus
    c. The gap between the neuron and the muscle fiber
    d. The space between adjacent muscle fibers

2.

- The muscle potential signals the SR to release Ca^{++} into the cytosol
- Calcium ions bind to _____
-
- Active sites of actin are exposed

Review

1. _____ is released from the SR in response to arrival of an action potential

    a. Na^+
    b. K^+
    c. P_i
    d. Ca^{++}

2. Tropomyosin

    a. Covers actin active sites
    b. Binds calcium ions
    c. Is a small, globular protein
    d. Has three subunits

3.

- The myosin head becomes cocked once an_____is bound
- The head is able to bind to the active site of actin forming a crossbridge
- A_____occurs when ADP + P_i are released from the myosin head
- Myosin can bind to another ATP which breaks the link with the actin active site

The crossbridge cycle may be repeated as long as the stimulus to contract continues and ATP is available

Review

1. Hydrolysis of ATP is responsible for

    a. Release of the myosin heads from the actin active sites
    b. Recocking of the myosin heads
    c. The power stroke
    d. The movement of tropomyosin, exposing the actin active sites

2. The binding of ATP to myosin is responsible for

    a. Release of the myosin heads from the actin active sites
    b. Recocking of the myosin heads
    c. The power stroke
    d. The movement of tropomyosin, exposing the actin active sites

3. The power stroke

    a. Pulls the thick filaments toward the Z lines
    b. Positions the myosin heads in their high-energy position
    c. Shortens the length of the thin filaments
    d. Pulls the thin filaments toward the M lines

Botulism and Botox

- The bacterium_____produces the most lethal known biological poison—as little as one gram of crystalline toxin is enough to kill about **one million adults**

- Exposure to the **botuminum toxin** through contaminated food causes the disease **botulism**:

The toxin binds to motor neurons of the NMJ and **blocks** the release of acetylcholine from synaptic vesicles

This paralyzes the affected muscle, and without proper treatment, death from **respiratory failure** will follow

- The toxin can be used to treat painful muscle spasm and migraine headaches when injected in minute quantities; also used cosmetically to relax facial muscles (as_____)

Skeletal Muscle Relaxation

1. _____ (AChE) degrades the ACh
2. ATP breaks _____
3. Calcium ions are pumped back into the_____(active transport)
4. Troponin and tropomyosin block the active sites of actin

Review

1. During muscle fiber relaxation

    a. Calcium levels in the sarcoplasm rise
    b. Calcium is pumped back into the SR
    c. Calcium is released from the SR
    d. Calcium is pumped into the extracellular fluid

2. Acetylcholinesterase in the synaptic cleft degrades acetylcholine, allowing

    a. Depolarization of the motor end plate
    b. Calcium levels in the sarcoplasm to rise
    c. Tropomyosin to expose actin active sites
    d. Sodium channels to close

3. Which aspect of muscle relaxation requires ATP?

    a. Motor end plate repolarization
    b. Blockage of actin active sites by tropomyosin
    c. Sarcomeres returning to their original length
    d. Pumping calcium ions back into the SR

Rigor Mortis

- The progressive stiffening (contraction) of skeletal muscles begins about 3–4 hours after death, as the pumps that drive calcium ions back into the SR no longer have ATP to fuel their activity

- As a result, Ca^{++} ions remain in the cytosol, where they bind to troponin and initiate muscular contraction all over the body

- The muscle fibers are unable to relax without_____, so the myosin heads cannot detach from actin

- The muscles remain contracted until the proteins of the myofilaments begin to degenerate, about 48–72 hours after death

Module 10.5: Energy Sources for Skeletal Muscle

Sources of Energy for Muscle Contraction

- The required ATP is generated by:

Immediate cytosolic reactions

_____**catabolism** in the cytosol

_____**catabolism** in the mitochondria

Immediate Sources of Energy

- The main immediate energy is stored as ATP in the muscle fiber and is rapidly consumed during muscle contraction
- _____– it can immediately regenerate enough ATP for about 10 seconds of maximum muscle activity

Creatine Supplementation

- Research has demonstrated that supplementation with_____does mildly improve performance for activities that require short bursts of muscle activity
- The effects on **endurance-type activities** are minimal to nonexistent
- Creatine may actually be detrimental in some cases:
    - Causes **weight gain** from **water retention**
    - **Massive doses** may cause **kidney damage**
- Skeletal muscles have a maximal storage capacity for creatine; therefore, huge doses are a waste of money because the excess is simply excreted in the urine

Glycolytic Energy Sources

-
    - Occurs in cytosol
    - _____catabolism

Break glucose down into pyruvate

Glucose found in the blood and stored in muscle or liver cells as glycogen

It can replenish ATP for 30–40 seconds of sustained contraction

- Glycolysis, or anaerobic catabolism, does not require oxygen directly

If oxygen is abundant, pyruvate formed by glucose catabolism enters the _____for oxidative catabolism

If oxygen is not abundant, the pyruvate is converted into lactic acid

Oxidative Energy Sources

- Oxidative catabolism or aerobic catabolism

Requires_____directly

The amount of ATP produced depends on the type of fuel used by the fiber (glucose can produce 30 – 38 ATP)

Oxidative catabolism is the predominant energy source after one minute of contraction and provides nearly 100% of the necessary ATP after several minutes; it can provide ATP for hours, as long as oxygen and fuels are available

Module 10.6: Muscle Tension at the Fiber Level

Twitch Contraction

- A **muscle twitch** is the smallest muscle contraction
- The three phases of a twitch on a myogram include the following:

Relaxation period

- The_____**period** begins at the onset of the latent period and ends at the beginning of the contraction period
- During this time (about 5 ms) the muscle fiber is unable to respond to further stimuli

- Cardiac muscle and smooth muscle have refractory periods as long as their contractions, so the cells must fully relax before they can contract a second time

Tension Production and the Timing and Frequency of Stimulation

- _____**-** increase in tension caused by repeated stimulation

The pumps in the SR membranes have inadequate time to pump all of the released calcium ions back into the SR before the fiber is restimulated

Therefore, the concentration of calcium ions in the cytosol increases with each stimulation

- _____**(incomplete) tetanus**

Results when fibers are stimulated about 50 times per second

Fiber partially relaxes between stimuli

- _____ (**complete**) **tetanus**

Occurs when the fiber is stimulated at a rate of 80–100 stimuli per second

Fib er does not relax between stimuli

The Length-Tension Relationship

-

Classes of Skeletal Muscle Fibers

•

Small diameter, slow-twitch fibers

Slow fibers rely on oxidative catabolism and have large numbers of mitochondria

Well-developed blood supply and myoglobin molecules

Slow fibers predominate in postural muscles that must sustain contractions for long durations

•

Large diameter, fast twitch fibers that fatigue quickly

Rely mainly on glycolytic catabolism with fewer mitochondria

Lower levels of myoglobin and less extensive blood

There are three subtypes that are categorized based on their energy production method

- **IIa** (**fast oxidative-glycolytic**)
- **IIx** (**fast oxidative**)
- **IIb** (**fast glycolytic**) – produce extremely fast, powerful twitches

- Most muscles contain all fiber classes, each of which is stimulated under different conditions

A baseball player sitting in the dugout uses primarily type I fibers in the back and abdomen to remain sitting upright

When the player gets up and jogs to the plate to bat, primarily type IIa fibers in the legs are used

When the player hits the ball, the bat is swung using type IIx and IIb fibers in the arms

Module 10.7: Muscle Tension at the Organ Level

Motor Units

- _____ **unit –** A single motor neuron and all the muscle fibers that it innervates
- The number of fibers in a motor unit varies depending on the motor unit's function

Muscles requiring fine motor control have small motor units (as few as 10 muscle fibers per motor unit, as in the larynx and fingers)

Those requiring less control (and generation of more power) have large motor units (as many as 2000–3000 fibers per motor unit, as in the postural muscles of the back, or the large muscles of the legs)

- Initiation of a contraction activates a small number of motor units

- As greater force is required more motor units must be stimulated, a process known as _____

-

Vital for the maintenance of erect posture, stabilization of joints, heat production, and preserving a level of preparedness for movement

The nervous system alternates which motor units it activates, so that some can rest while others contract

Types of Muscle Contractions

- _____**contractions** (tension generated by the muscle is constant, but muscle length changes):

Isotonic_____**contractions** maintain constant **tension** while the muscle shortens

Isotonic_____**contractions** maintain constant tension but the muscle lengthens

- _____**contractions** is where the muscle length remains unchanged because the external force applied equals that generated by the muscle

- A muscle is able to lengthen while it is contracting because the elastic filaments in its myofibrils allow it to stretch considerably

Module 10.8: Skeletal Muscle Performance

Delayed-Onset Muscle Soreness

- The phenomenon of muscle soreness following exercise was thought for many years to be due to the accumulation of lactic acid produced during glycolysis

- Current research suggests instead that it is more likely due to minor structural damage, in particular, that caused by isotonic eccentric muscle contractions

- The most effective treatment for DOMS is more exercise; unfortunately, once the exercise ceases, the pain returns until the muscle is sufficiently conditioned through training

- Other treatment modalities such as massage, topical therapies, acupuncture, and oral medications have shown little benefit

•

Changes Caused by Physical Training

- _____– the changes in muscle structure as a result of changes in function related to physical training

The majority of mature skeletal muscle fiber nuclei are_____(do not undergo mitosis)

_____**cells** (a small population of unspecialized cells) do retain mitotic ability, can help repair injured skeletal muscle

Changes in response to training are within the muscle fibers and do not involve changes in the number of muscle fibers

- **Endurance training** – more repetitions with lighter weight

Increased oxidative enzymes, and mitochondria

More efficient use of fatty acids and non-glucose fuels for ATP production

Increases in the blood vessel network supplying the muscle

- **Resistance** (**strength**) **training** – fewer repetitions with heavier weight

The diameter of the muscle fibers increase

A decreased proportion of mitochondrial proteins and blood supply to the muscle because of fiber enlargement, not because mitochondria or vessels are actually lost

- Disuse leads to:

a decrease in the number of myofibrils

a decrease in the size of the fiber

a decrease in oxidative enzymes, which is termed

a decline in both strength and endurance

Muscular Fatigue

- _____is the inability to maintain a given level of intensity during activity

The depletion of creatine phosphate, glycogen, and glucose involved in ATP production

Decreased availability of_____to muscle fibers

Environmental conditions, particularly extreme heat; sweating in response to heat may also cause electrolyte disturbances

Module 10.9: Smooth and Cardiac Muscle

Smooth Muscle

- _____ has the following functions:

_____ propels materials through hollow organs

Sphincters that control the passage of materials

Changes diameter of tubing to regulate flow rates through hollow organs (blood vessels, the respiratory tract, and the gastrointestinal tract)

- Smooth muscle cells contain myosin and actin filaments arranged differently than in skeletal and cardiac muscle; there are no_____, and therefore no _____

- Both thick and thin filaments are longer and the thin filament lacks _____

Types of Smooth Muscle:

- Single unit smooth muscle is

The predominant type in the body

Impulse spreads rapidly through the cells causing the cells to contract in a coordinated wave as a single unit

Respond to multiple stimuli including mechanical, hormonal, neural

- Multi-unit smooth muscle:

Made up of individual cells that contract independently

Responds primarily to nerve stimulation

Cardiac Muscle

- Cardiac muscle cells are structurally similar to skeletal fibers with some major differences:

Shorter, branched cells with one nucleus and abundant myoglobin

Do not require stimulation from the nervous system

Naming of Muscles

1. Action:
2. Direction:
3. Location:
4. Divisions:
5. Shape:
6. Attachment:
7. Latin names:

Levator scapulae

Gluteus maximus

Transversus abdominis

Internal oblique

Rectus abdominis

Flexor carpi ulnaris

Adductor longus

Brachialis

Sternocleidomastoid

Biceps brachii

Pectoralis major

Sartorius

Triceps brachii

Quadriceps femoris

Deltoid

Trapezius

Rhomboideus

External oblique

Platysma

Buccinator

Serratus ventralis

Masseter

Vastus lateralis