Skeletal System

bones, **cartilage** and **ligaments** are tightly joined to form a strong, flexible framework

bone is active tissue:
→5-7% bone mass/week

Functions of Skeletal System:

1. **Support**
   strong and relatively light; 20% body weight
2. **Movement**
   framework on which muscles act
   act as levers and pivots
3. **Protection**
   brain, lungs, heart, reproductive system
4. **Mineral storage (electrolyte balance**
   99% of body's calcium is in bone tissue
   (1200-1400g vs <1.5g in blood, rest in cells)
   also stores phosphate
5. **Hemopoiesis**
   blood cell formation
6. **Detoxification**
   bone tissue removes heavy metals and other foreign materials from blood
   can later release these materials more slowly for excretion
   but this can also have bad consequences

Skeletal Anatomy

each individual bone is a separate **organ** of the skeletal system

~270 bones (organs) of the Skeletal System

with age the number decreases as bones fuse

by adulthood the number is 206 (typical)

even this number varies due to varying numbers of minor bones:

sesamoid bones – small rounded bones that form within tendons in response to stress

eg. kneecap (patella), in knuckles

wormian bones –bones that form within the sutures of skull

each skeletal organ is composed of many kinds of tissues:

bone (=osseous tissue)
cartilage
fibrous connective tissues
blood (in blood vessels)
nervous tissue

General Shapes of Bones

bones can be categorized according to their general shape:

1. **long:** cylindrical, longer than wide

   rigid levers for muscle actions eg crowbars

   eg. arms, legs, fingers, toes

2. **short:** length nearly equal width

   limited motion, gliding if any

   eg. carpals, tarsals, patella

3. **flat:** thin sheets of bone tissue

   enclose and protect organs

   broad surfaces for muscle attachments

   eg. sternum, ribs, most skull bones, scapula, os coxa

4. **irregular:** elaborate shapes different from above

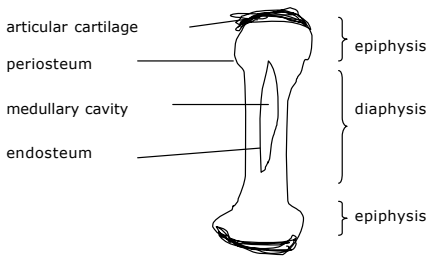
   eg. vertebrae, sphenoid, ethmoid

Bone Structure

bones have outer shell of **compact bone**

usually encloses more loosely organized bone tissue = **spongy (=cancellous) bone**

the general structure of a typical longbone:



epiphyses

large surface area for muscle attachment and pivot

spongy bone with **trabeculae**;

contains **red marrow** (=hemopoietic tissues)

→ produces blood cells in delicate mesh of reticular tissues

in adults red marrow is limited to vertebrae, sternum, ribs, pectoral and pelvic girdles, proximal heads of humerus and femur

with age, red marrow is replaced by yellow marrow

articular cartilage

on surface of epiphyses

resilient cushion of hyaline cartilage

diaphysis

thick **compact bone** but light; hollow → medullary cavity

medullary cavity

yellow marrow – fat (adipose) storage

"fat at the center of a ham bone"

in event of severe anemia, yellow marrow can transform back into red marrow to make blood cells

periosteum

white fibrous connective tissue continuous with tendons
penetrates bone – welds blood vessels to bone

endosteum
fibrous CT that lines medullary cavity

Microscopic Structure (Histology)

A. bone:

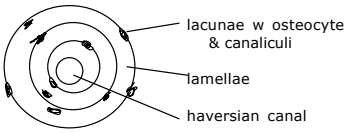
connective tissue; contains **cells** and **matrix**

bone cells = **osteocytes**

matrix predominates; ~ 1/3rd organic and 2/3rd's inorganic

matrix contains lots of collagen fibers

highly organized arrangement of matrix and cells



perforating canals (Volkmann canals) interconnect the haversian canals

periosteum provides life support system for bone cells

blood vessels penetrate bone and connect with those in haversian canals

B. cartilage

resembles bone:
large amount of matrix
lots of collagen fibers

differs:
firm flexible gel is not calcified (hardened)
no haversian canal system
no direct blood supply
→ nutrients and O_2 by diffusion

all bone starts out as cartilage

in bone the matrix is hardened (= **ossified**) by **calcification** (or mineralization)

microscopic structure of cartilage:

chondrocytes in lacunae

kinds of cartilage:
(all similar matrix with lots of collagen fibers; differ in other fibers)

1. **hyaline**
   most common
   eg. covers articular surfaces of joints, costal cartilage of ribs, rings of tracheae, nose
2. **fibrous**
   mostly collagen fibers
   eg. discs between vertebrae, pubic symphysis
3. **elastic**
   also has elastic fibers
   eg. external ear, eustacean tube

Anatomy of Skeletal System

Bone Markings: any bump, hole, ridge, etc on each bone; eg.:

Foramen: opening in bone – passageway for nerves and blood vessels

Fossa: shallow depression – eg a socket into which another bone articulates

Sinus: internal cavity in a bone

Condyle: rounded bump that articulates with another bone

Tuberosity: large rough bump – point of attachment for muscle

Spine: sharp slender process

two main subdivisions of skeletal system:

axial : skull, vertebral column, rib cage

appendicular: arms and legs and girdles

The Axial Skeleton

A. Skull

most complex part of the skeleton

consists of **facial** and **cranial** bones

most bones are paired, not all

bones joined at **sutures**

1. Fontanels

ossification of skull begins in about 3rd month of fetal development

not completed at birth→bones have not yet fused

gaps = **fontanels**
- frontal (anterior)
- occipital (posterior)
- 2 sphenoid
- 2 mastoid

at this stage skull is covered by tough membrane for protection

normally, bones grow together and fuse to form solid case around brain

3. Skull Cavities

inside of skull contains several significant **cavities**:

cranial cavity – largest (adult – 1,300 ml); part of dorsal body cavity
orbits – eye sockets

nasal cavity

buccal cavity

middle and **inner ear cavities**

4. Paranasal Sinuses

in 4 of the bones making up the face

in life lined with mucous membrane to form sinuses

lighten bone, warm and moisten air

6 sinuses:
- **frontal** -2
- **maxillary** -2
- **ethmoid** -1
- **sphenoid** -1

Examples of Paired Skull Bones:

5. Maxilla

cheek bones, upper teeth cemented to these bones

hard palate: palatine process and palatine bones

cleft palate → when bones of **palatine process** of **maxilla bones** do not fuse properly

not only cosmetic effect
can lead to serious respiratory and feeding problems in babies and small children
today, fairly easily corrected

6. Temporal Bone

external auditory meatus - opening to ear canal leads to middle ear chamber

ear ossicles:

malleus = hammer
incus = anvil
stapes = stirrup

7. Mandible = lower jaw

largest, strongest bone of face
articulates at temporal bone

Examples of Unpaired Skull Bones:

8. occipital bone

foramen magnum - large opening in base through which spinal cord passes

occipital condyles - articulation of vertebral column

9. sphenoid bone – irregular, unpaired bone

resembles bat or butterfly;

"keystone" in floor of cranium

→ anchors many of the bones of cranium

contains **sinuses**

sella turcica – depression for the pituitary gland

10. ethmoid – irregular, unpaired bone

honeycomed with **sinuses**

cribiform plate – perforated with openings which allow olfactory nerves to pass

nasal conchae – passageways for air; filtering, warming, moistening

crista galli – attachment of meninges

very delicate and easily damaged by sharp upward blow to the nose

can drive bone fragments through the cribriform plate into the meninges or brain itself

can also shear off olfactory nerves→ loses of smell

11. hyoid bone – single "U" shaped bone in neck just below mandible

suspended from **styloid process** of temporal bone

only major bone in body that doesn't directly articulate with other bones

serves as point of attachment for tongue and several other muscles

B. Vertebral Column

main axis of body

flexible rather than rigid

permits foreward, backward, and some sideways movement

divided into 5 regions:
- **cervical**
- **thoracic**
- **lumbar**
- **sacral**
- **coccygeal**

all but last two are similar in structure:

body
spinous process
vertebral foramen
transverse process
superior and inferior articular process
intervertebral foramen between each pair
separated by **intervertebral discs**

Cervical (7):

have **transverse foramena**

1st and 2nd are highly modified for movement:

atlas – holds head up
no body or spinous process
"yes" movement of head

axis -- **dens** (odontoid process) – forms pivot
"no" movement

Thoracic (12):

distinguished by **facets** smooth areas for articulation of ribs

each rib articulates at two places
one on body of vertebrae
one on transverse process

Lumbar (5):

short and thick spinous processes

modified for attachment of powerful back muscles

Sacrum (5 fused):

triangular bone formed from fused vertebrae

sacroiliac joint – lots of stress

Coccyx (4-5, some fused):

tailbone

painful if broken

sometimes blocks birth canal, must be broken

C. Ribcage

sternum { **manubrium**, **body** (=gladiolus), **xiphoid process**

ribs: most joined to sternum by **costal cartilages**

true ribs (7prs)

false ribs (5 prs)
include floating ribs (2prs)

Appendicular Skeleton

A. Upper Extremeties

shoulder (=pectoral girdle)
upper and lower arm
wrist and hand

1. Pectoral Girdle:

scapula & **clavicle**

only attached to trunk by 1 joint (between sternum and clavicle)

scapula is very moveable – acts as almost a 4th segment of limb

scapula rides freely and is attached by muscles and tendons to ribs but not by bone to bone joint

extensive flat areas of scapula are used as origins for arm muscles and trunk muscles

clavicle is the most frequently broken bone in the body, sometimes even during birth

2. Upper Arm:

Humerus: longest and largest bone of arm

loosely articulates with scapula by **head** – **glenoid cavity**

large processes of scapula, **acromium** and **coracoid**

→have muscles which help to hold in place

3. Forearm:

very mobile; adds to flexibility of hand

consists of two bones: radius & ulna

they are attached along their length by **interosseous membrane**

ulna:

main forearm bone
firmly joined to humerous at elbow
large process = **olecranon process**, extends behind elbow joint

acts as lever for muscles that extends forearm

radius:

more moveable of two
can revolve around ulna to twist lower arm and hand

4. Hand:

attached by muscles mainly to radius provides great flexibility

large # of rounded bones (**carpals**) provide flexibility

carpals allow movement in all directions

metacarpals also rounded for flexibility

phalanges, not rounded, simple hinges for grasping

B. Lower Extremeties

number and arrangement of bones in the lower limb are similar to those of the upper limb

in the lower limb they are adapted for weight bearing and locomotion, not dexterity

pelvic girdle (pelvis, 2 coxal bones, sacrum, coccyx)
thigh
lower leg
feet

1. Pelvic Girdle

forms large basin of bone
→receptacle for many internal organs

origin of thigh muscles and trunk muscles

rigid connection to axial skeleton; strength, not flexibility

large flaring portion = **false pelvis**

smaller actual opening = **true pelvis**

→actual space child must fit through in women

pelvis consists of a pair of **innominate bones** (= os coxae) that articulate with sacrum

each innominate is produced by fusion of three bones:

ilium – upper, fan shaped
ischium – bottom
pubis – front

pubic symphysis: anterior joint of fibrous cartilage

in women before birth it softens to allow expansion of birth canal

as bipedal animals the pelvis must support most of the body weight

→viscera bear down on pelvic floor

→ pelvis is funnel shaped; yet must remain large enough for the birth canal

pelvis is easiest part of skeleton to distinguish between sexes

2. Upper Leg = Thigh

made up of single bone = **femur**; largest bone in body

head fits in large deep socket = **acetabulum** of pelvis

great strength, less flexibility than humerous

kneecap = patella;

a **sesamoid** bone = bones found where tension or pressure exists; eg thumb and large toe

in tendons at knee joint; does not articulate directly with any other bone

acts as kind of a bearing
→allows tendon to slide smoothly across knee joint

if patella is lost through accident or injury get ~30% loss of mobility and strength due to > friction

3. Lower Leg

consists of two bones: tibia and fibula

tibia (=shinbone)

main bone, articulates with both femur and foot

→more strength, less mobility

fibula

small, offers extra support for lower leg and foot

4. Foot

like hand, made of many bones

thick angular bones; must support all the weight of the body

arches: strung with ligaments to provide double arches = shock absorbers

arches also furnish more supporting strength than any other type of construction →more stability

if ligaments and muscles weaken, arches are lost = flatfootedness = fallen arches,

→ more difficult walking, foot pain, back pain

high heals redistribute the weight of foot→throw it foreward; ends of metatarsals bear most weight

→sore feet

Articulations

Articulations = joints between bones

hold bones together while usually allowing some movement

can be classified by:

1. **degree of movement**
2. **structure of the joint**

<u>Degree of Movement</u>

Synarthroses (="joined together", joint)

→immoveable

Amphiarthroses (=on both sides, joint)

→slightly moveable

Diarthroses (through a joining)

→freely moveable

<u>Structure of the Joint</u>

Fibrous Joints

articular surface of both bones

joined by fibrous connective tissue

Cartilaginous Joints

articular surface joined by some kind of cartilage (eg. fibrous or hyaline)

Synovial Joints

articulation is surrounded by **joint capsule** and **synovial membrane**

joint capsule
articular cartilage
joint cavity
synovial membrane
synovial fluid
periosteum

In general structure is correlated with function:

therefore, three major kinds of joints:

1. **immoveable ~ fibrous**
2. **slightly moveable ~ cartilaginous**
3. **freely moveable ~ synovial**

Examples of the 3 kinds of articulations

1. Immoveable (Fibrous) Joints

eg. sutures

– only in skull

eg. gomphoses

-teeth in socket

eg. syndesmoses

- fibrous bands between two bones

- distal tibiofibular joint

2. Slightly Moveable (Cartilaginous)

eg. symphyses

-fibrocartilage pad or disc

-midline of body

-symphysis pubis

-intervertebral discs

eg. synchondroses

-hyaline cartilage joins two bones

-epiphyseal discs; temporary

-costal cartilage between ribs and sternum

3. Freely Moveable (Synovial)

most body articulations

provide for many different kinds of motion:

eg. uniaxial

hinge joint (fingers, toes, elbow)

pivot joints (head, radius at hand)

eg. biaxial

condyloid joints (metacarpals-phalanges

saddle joints (metacarpal-thumb)

eg. multiaxial

gliding joint (carpals, tarsals)

ball and socket joints (shoulder, hip)

Includes **tendons** and **ligaments**

both composed mainly of **fibrous connective tissue**

consist of parallel strands of **collagen fibers**

continuous with periosteum and embedded in bone

rarely break but tear away from bone

when mature have few cells

→slow to repair

tendons – specialized structures that attach muscle to bone across joints

often enclosed by tendon sheath

ligaments – bind bones together across joints

more elastic than tendons

hold joints in place

limit their range of motion

Bursa

synovial sacs spaced around joints between tendons or ligaments

cushion → reduce friction

Exercise and Synovial Joints

synovial fluid is warmed by exercise and becomes thinner

→this is more easily absorbed by articular cartilage

→provides more effective cushion against compression

this warmup and compression also helps to distribute nutrients to cartilage cells (nonvascular tissue) and squeeze out metabolic wastes

→ **warm up is good for you**

Skeletal Physiology

Composition of Bone

bone is the densest tissue in the body
→ only 20% water

bone has a grain just like wood:

grain runs longitudinally for greatest strength

bone tissue consists of cells and matrix:

cells: =**osteocytes**

cells that secrete the matrix

matrix:

2/3rd mineral salts (bone only)
calcium & phosphorus

($CaPO_4$, CaOH, $CaCO_3$)
also Mg, Na, K

tends to accumulate metals:lead & radium
→ bone cancer, leukemia

1/3rd collagen and proteins (cartilage and bone)

mixture of organic and inorganic components allow bone to be strong without being brittle

Physiology of Bone

bone is active tissue:

→5-7% bone mass/week

mature haversian canal systems are replaced up to 10x's during a lifetime

→equiv. of skeletal mass is replaced every 7 years

most calcium in body is contained in teeth and skeleton

→ acts as a mineral **reservoir**, esp for calcium, and phosphate

calcium is used in body for:

muscle contractions
nerve impulses
synapses
heart beat
secretions
blood clotting
cofactors for enzymes

a supply of calcium must be constantly available for all these activities

blood calcium homeostasis is maintained by dissolving or depositing bones via osteocytes

cells = osteocytes (in lacunae)

two kinds of bone cells:

osteoblasts bone forming cells

also works alongside osteoclasts to rework bone

osteoclasts bone destroying cells

very large cells produced by cell fusions
contain up to 300 nuclei

amoeboid movement

wraps around small section of bone
secretes enzyme to digest it

Bone Formation

parts of skeleton begin to form in 1st few weeks of development

begins in fetus as cartilage template

Ossification = conversion of cartilage or other connective tissueinto bone

in longbones ossificaton begins 3rd month of development

centers of ossification in longbones:

begins in diaphysis

at birth additional centers in epiphyses

epiphyseal cartilage disappears when bone has completed its growth (in length)

Bone Maintenance and Remodeling

the skeletal system is strongest in early adulthood

bones continue to grow and remodel themselves throughout life

bone growth in diameter occurs by combined action of osteoblasts and osteoclasts

even after bone growth has stopped, osteoblasts and osteoclasts continue working

in adult these opposing processes balance each other out so bone neither grows nor shrinks

bone destruction is not always a pathological process:

a. bones constantly adapting to stresses
reaction to mechanical stresses

tension regions + chg
compresed regions – chg
affects PTH activity

strengthens weak areas

b. old bone removed to reduce bulk

c. minerals are added or removed from reservoir as Calcium is metabolized

99% of body's Ca^{++} is in bone
(1200-1400g vs 1.5g in blood)

two hormones involved - antagonists

PTH

→stimulates bone destruction (osteoclasts)

Calcitonin

→stimulates bone formation (osteoblasts)

Ca^{++} deficiency:

severe neuromuscular problems
hyperexcitability
loss of function

Ca^{++} excess:

Calcium deposits in blood vessels, kidneys and soft organs

Effects of Aging on Skeletal System

Skeletal Changes from Childhood to Adult:

A. infancy & childhood

change size, proportion,

growth in length is cartilage of epiphyseal disc

growing faster than ossification proceeds

growth hormone plays major role

→ stimulates cartilage

thyroid hormone

→ proper proportions

head becomes proportionately smaller
facial bones more prominent
thorax more elliptical
pelvis larger and wide
legs proportionately longer
vertebral column develops two additional curves
(already had thoracic and pelvic curves)
cervical curve ~3mo; lifts head
lumber ~1 yr; standing, walking

B. Puberty

sex hormones (estrogen & testosterone) stimulate

ossification

→ epiphyseal closure

facial features develop rapidly

also produce masculinizing and feminizing features of skeleton

male – deep and funnel shaped; whole skeleton larger and heavier

female – shallow, broader and flaring

C. Adulthood:

Bone maintenance and remodeling

bone destruction is not always a pathological process:

a. bones constantly adapting to stresses

b. old bone removed to reduce bulk

c. minerals are added or removed from reservoir as calcium is metabolized

D. Old Age

reabsorption outweighs growth

→ bone become brittle

shaggy margins, spurs, joint problems

cartilage keeps growing: big ears

Disorders of Skeletal System

1. Fractures

repairs more slowly than skin; up to 6 months

a. clot (hematoma) formation

hours
broken blood vessels, damaged tissues, bone cells die

b. soft callus (fibrocartilage)

days
growth of new capillaries
disposal of dead tissue

c. bony callus

weeks
spongy bone tissue grows around area and replaces fibrocartilage
join two pieces firmly together

d. remodeling

months
dead portions of original area reabsorbed
compact bone replaces spongy bone
ends are remodeled to blend in
usually thickened area remains
misset bones may heal crooked
but weight bearing bones usually reassume proper shape
elec current speeds calcification and repair

new synthetic materials may soon be useful in replacing missing bone
also bone grafts

2. Vertebral curvature

normally spine has two "S" shaped curves

provides flexibility and resilient support

several types including:

scoliosis – abnormal lateral curvature
may appear spontaneously
or be result of polio, rickets or TB

3. Osteoporosis

bones lose mass and become more brittle

group of diseases in which bone reabsorption outpaces bone deposition

affects entire skeleton but esp spongy bone of vertebrae and neck of femur

esp in post menopausal women

sex hormones
stim bone deposition,
decrease osteoclast activity

menopause – sharp reduction in sex hormones

esp post menopausal women (esp caucasian women)

by 70 yrs the average white woman has lost 30% of her bone mass (some up to 50%)

not as drastic in men
bone loss begins ~60 yrs and seldom exceeds 25% loss

smoking also reduces estrogen levels

low body fat reduces estrogen production by ovaries in young female runners and dancers

most serious consequence is pathologic fractures
esp in hip, wrist and vertebral column

also, as bones become less dense they compress like marshmallows

→ results in **kyphosis** → exaggerated thoracic curve
(widow's hump, dowager's hump)

<u>suggestions</u>:
need good bone mass by 35 or 40
plenty of weight bearing exercise, esp before menopause
good calcium uptake (850-1000 mg/d) early in life, esp 25-40
fluoridated water helps harden bones
don't smoke
hormone replacement therapy only slows loss, doesn't replace lost bone
-No longer recommended, too dangerous

4. Rickets

childhood disease: bowed legs, deformed pelvis,
due to Vit D (or Ca^{++}) deficiency during growing years
body unable to absorb calcium from intestine
reduces calcification – bones stay soft

5. Osteoarthritis

most common age change is degeneration of joints
=wear and tear arthritis
rarely occurs before age 40; affects 85% of those over 70
as joints age get gradual softening and loss of articular cartilage
bone formation at margin of articular cartilage
as cartilage becomes roughened by wear, joint movements may be accompanied by crunching or cracking sounds (=**crepitus**)
affects especially fingers, intervertebral joints, hips and knees

bony spurs may form as cartilage wears away →deform joint
interfere with movement, pain

6. Rheumatoid Disease

far more severe than OA
is an autoimmune attack against synovial membrane
inflammation of synovial membranes and degeneration of cartilage
synovial membranes fill with abnormal tissue growth = granulation tissue
may erode articular cartilage, bones and ligaments
mainly small joints of body; wrists, ankles
tends to flare up and subside periodically
affects women far more than men
typically begins between age 30 – 40
no cure, but can be slowed with steroids, cortisone, etc

7. Osteomyelitis

any infection of bone, cartilage or periosteum
localized or general
usually bacterial

8. Ruptured (herneated) disc

intervertebral discs pad vertebrae
with age outer layer thins and cracks; inner layers less firm
extra pressure can cause rupture
= herneated disc: pain, numbness, partial paralysis

9. Gout

group of diseases characterized by elevated **uric acid** in blood
forms sodium urate crystals in synovial fluid causing severe pain
exacerbated by alcoholism

10. Bursitis

inflammation of bursal sacs around joints
fills with fluid
usually caused by blow or friction
="housemaids knee"
="water on the knee"

11. Tendonitis

inflammation, usually due to overuse

12. Achondroplastic Dwarfism

spontaneous mutation of genes, not necessarily from parents
long bones of limbs stop growing in childhood while growth of other bones is not affected
→ results in short stature but normal sized head and trunk
not same as pituitary dwarfism, only certain cartilage cells are affected

13. Polydactyly & Syndactyly

too many or too few fingers and toes