EVOLUTION OF APPENDAGES

- 3 theories of appendage evolution:
  - Gill Arch Theory
  - Fin Fold Theory
  - Fin Spine Theory
- None are entirely supported!!
- Paired appendages likely evolved more than once

EVOLUTION OF APPENDAGES

- Paired Fins - 3 types
  - Lobe Fin: Sarcopterygian fish
    - **Axis** = central skeletal base
    - **Preaxials** = extend from the anterior portion of the axis
    - **Postaxials** = extend from the posterior portion of the axis
  - Finfold Fin: Chondrichthyian fish
    - Base composed of **Pro- Meso-** and **Metapterygium**
    - **Radials** extend outward from the base
  - Ray Fin: Actinopterygian fish
    - **Basalia**: series of bones forming the base on primitive bony fish
    - **Radialia**: secondary series of support bones
    - **Lepidotrichia**: parallel fin rays supporting main body of fin

- Pectoral fins generally more important
- Pelvic fins less important and may be:
  - lost or greatly reduced
  - positioned in a variety of different places
  - adapted as accessory reproductive organs

Pectoral Girdle

- Provides support for the anterior appendages
- Duplex structure including both dermal and endochondral elements
  - Dermal elements for strength
  - Endochondral elements for articulation of the limb (glenoid fossa)

Pectoral Girdle

- Dermal Elements
  - Cleithrum
    - Primitively the main structural element
  - Clavicle
    - Joins two sides together
  - Supracleithrum
    - Connects girdle to back of skull

Pectoral Girdle

- Endochrondral Elements
  - Scapula
    - Main bone for articulation of the limb
  - Coracoid
    - Like the clavicle connects two sides together
  - Suprascapula
    - Additional point for muscle attachment
- Major trend is for the reduction of dermal elements and attachment to the sternum (axial skeleton)

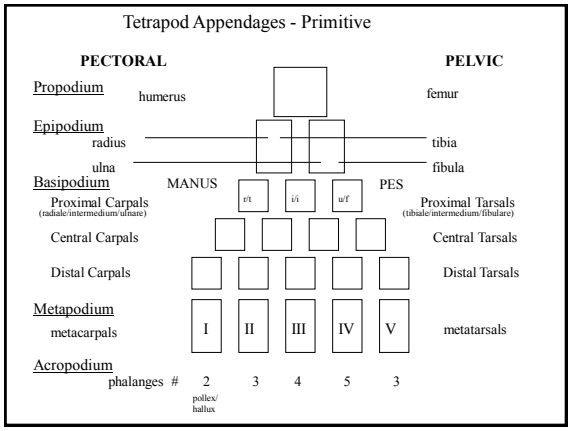
Pelvic Girdle

- Entirely endochrondral
- Initially just a means of joining two posterior fins together
  - **Ischiopubic bar** -> **basipterygium**
- Tetrapods - adapted to support the weight of posterior portion of the body
  - Attachment of limb to sacrum (axial skeleton)
- Ventral cartilage plate develops in all tetrapods
  - Two points of ossification = **ischium** & **pubis**
- Dorsal plate develops independently
  - Single point of ossification = **ilium**
- All three bones fuse together to form the acetabulum for articulation of the femur

- Tetrapod limbs - derived directly from a lobe fin
  - Both sets of limbs are composed of 5 sets of elements:

	Pectoral	**Pelvic**
Propodium	Humerus	Femur
Epipodium	Radius	Tibia
	Ulna	Fibula
Basipodium	Carpals	Tarsals
Metapodium	Metacarpals	Metatarsals
Acropodium	Phalanges	Phalanges

- Autopodium in book = basi-, meta-, and acropodium
  - Forefoot autopodium = manus
  - Hindfoot autopodium = pes



Locomotor Patterns

- Fish:
  - swim via undulations of the trunk from side to side
- Most amphibians:
  - locomotion similar to fish
    - splayed limb posture
      - limbs maintain body off the ground and translate undulations to the substrate
- Anuran amphibians
  - utilize **saltatory** locomotion
    - all aspects of the skeleton adapted for this locomotion

- Primitive reptiles:
  - similar to amphibians, but limbs take on more of the primary locomotor function
- Archosaurs:
  - either primative reptilian or bipedal locomotion
    - Pterosaurs - adapted for flight
- Birds:
  - independently adapted for flight
- Mammals:
  - perpendicular limb posture
    - elbows rotated posteriorly
    - knees rotated anteriorly

Most mammals are modified for specific modes of locomotion:

- **volant locomotion**
- **fossorial locomotion**
- **bipedal locomotion**
- **brachiation**
- **aquatic locomotion**
- **saltatorial locomotion**
- **cursorial locomotion**
- **glissant locomotion**

The Pectoral Appendage (Forelimb)

- Propodium - Humerus
  - Not much variation
  - Expanded at both ends for muscle attachment and articulation
- Epipodium - Radius & Ulna
  - Radius = main supporting element of forearm; little variation
  - Ulna = major bone for muscle attachment
    - may be fused to radius or lost in some vertebrates
    - usually provides articulation for elbow joint (trochlear notch)
    - olecranon process for attachment of triceps
    - in birds is the major bone of the forearm

- Basipodium - carpals in 3 series
  - Proximal carpals
    - primitively 3 (radiale, intermedium & ulnare)
  - Central carpals
    - primitively 4; reduced to 2 or less in modern tetrapods
  - Distal carpals
    - primitively 5; may be fused or lost
- Metapodium - metacarpals
  - proximal element of each digit contained within the palm
  - may be greatly elongated or lost as digits are reduced

- Acropodium - phalanges
  - Reptilian formula 2.3.4.5.3
  - Mammalian formula 2.3.3.3.3
  - Lots of modifications in numbers of digits from 5 to 1

The Pelvic Appendage (Hindlimb)

- Propodium - Femur
  - Very stout bone
  - Capitulum provides articulation with acetabulum
  - Modified in mammals to allow perpendicular posture
- Epipodium - Tibia & Fibula
  - Tibia
    - main supporting element of hind leg
    - little variation
  - Fibula
    - mostly for muscle attachment
    - may be fused to tibia or lost in some vertebrates

- Basipodium - tarsals in 3 series
  - proximal tarsals - primitively 3 (tibiale, intermedium & fibulare)
    - fibulare modified into calcaneum
    - tibiale & intermedium fuse to form astragalus
    - calcaneum & astragalus form extra intertarsal joint in foot
  - central tarsals - primitively 4; reduced to 2 or less in modern tetrapods
  - distal tarsals - primitively 5; may be fused or lost
- Metapodium - metatarsals
  - proximal element of each digit
  - may be greatly elongated or lost as digits are reduced

- Acropodium - phalanges
  - Repilian formula 2.3.4.5.3
  - Mammalian formula 2.3.3.3.3
  - Lots of modifications in numbers of digits from 5 to 1

Specializations of Limb Structures

- Amphibians
  - Caecilians - lack limb girdles and limbs
  - Urodels - manus & pes reduced in number of bones and digits
  - Anurans - limbs modified for saltorial locomotion
    - **Radioulna** = fused radius & ulna for increased strength
    - **Tibiofibula** = fused tibia & fibula
    - Astragalus & Calcaneum elongated to increase foot length
    - Metatarsals & phalanges elongated - also increase of foot length

- Reptiles (modern)
  - Snakes, legless lizards & amphisbaenians
    - girdles & limbs lacking in most
  - Other reptiles
    - display primitive limb structures with little variation
- Birds
  - Anterior limbs modified for flight (more later)
  - Hindlimbs modified for bipedal locomotion
    - pelvic girdle fused into synsacrum
    - fibula greatly reduced
    - **Tibiotarsus**
      - fusion of tibia, astragalus & calcaneum
    - **Tarsometatarsus**
      - fused and elongated distal tarsals and metatarsals
      - forms extra leg segment and joint for speed and flexibility

- Mammals
  - Modifications for different locomotor styles seen mainly in manus & pes
    - **Plantigrade** foot
      - primitive foot posture with entire foot on the ground
    - **Digitigrade** foot
      - modification for cursorial locomotion
      - only the acropodium is in contact with the ground.
      - metapodium greatly elongated - increased limb length
      - digits often reduced to 4 or less
    - **Unguligrade** foot
      - also for cursorial locomotion
      - only the unguis in contact with the ground
      - digits reduced to as few as one
      - epipodium elongated
      - basipodium greatly reduced in number of elements
      - metapodium greatly elongated

- 2 types of Unguligrade foot
  - **Paraxonic** foot
    - seen in the order Artiodactyla (cows, deer, etc.)
    - axis of weight evenly distributed between digits 3 & 4
    - digits 2 & 5 greatly reduced; 1 absent
  - **Mesaxonic** foot -
    - seen in the order Perissodactyla (horses, rhinos, etc.)
    - axis of weight is mainly on digit 3
    - other digits lost or reduced

Modifications for Flight

- **Pterosaurs** - flying archosaurs
  - normal humerus, radius & ulna
  - manus modified for support of flight membrane
  - 4 digits; 3 normal with claws
  - digit 4 greatly elongated
  - **pteroid** bone extended from metacarpals towards shoulder
- **Birds**
  - entire forelimb modified as a wing
  - humerus and ulna enlarged
  - **carpometacarpus** = fusion of 3 distal carpals & 3 metacarpals
  - 3 digits remain, phalanges reduced in number

- **Bats**
  - epipodium and manus modified for support of flight membrane
  - humerus normal
  - radius elongated, ulna reduced or absent
  - basipodium normal
  - metapodium & acropodium of digits 2-5 greatly elongated
  - digit 3 longest

Modifications for Swimming

- **hyperphalangy** common
- forelimb usually adapted for control
- tail used for propulsion
- hind limbs lost or reduced in whales and manatees
- fusiform body shape common