Skeletal System-Appendicular Skeleton

Appendicular Skeleton, basic components:

Paired fins or limbs

Fins: membranous or webbed processes internally strengthened by radiating and thin fin rays

Formed initially at the interface between dermis and epidermis, but then sink into the dermis

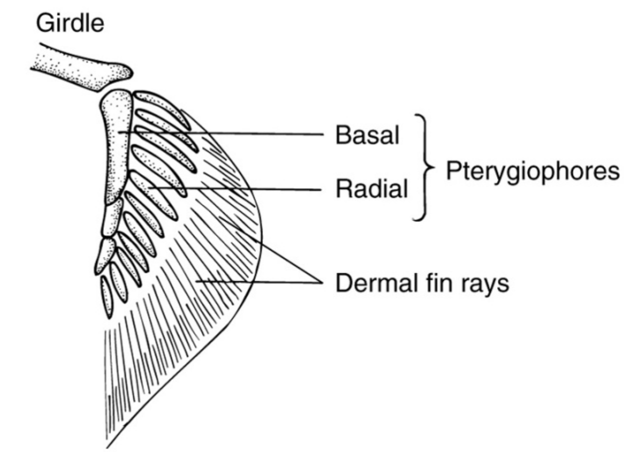
The proximal part of the fin is supported by pterygiophores (basal and radial).

Limbs: composed of three regions

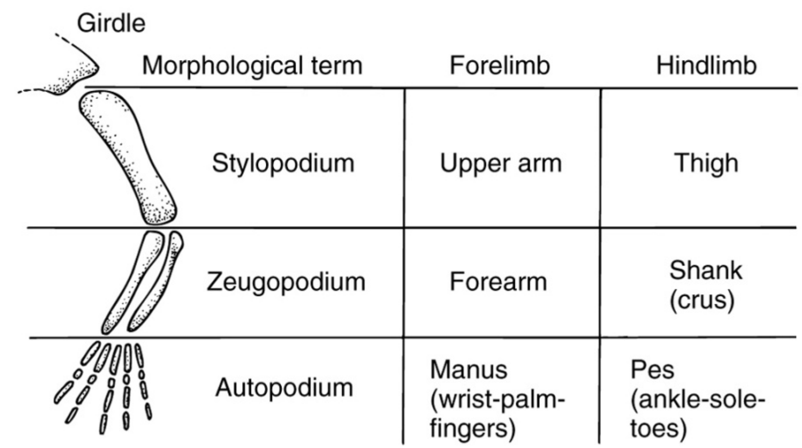
Autopodium (wrist/ankle + digits)

Zeugopodium (ulna-radius, tibia-fibula)

Stylopodium (humerus, femur)



(a) Fin



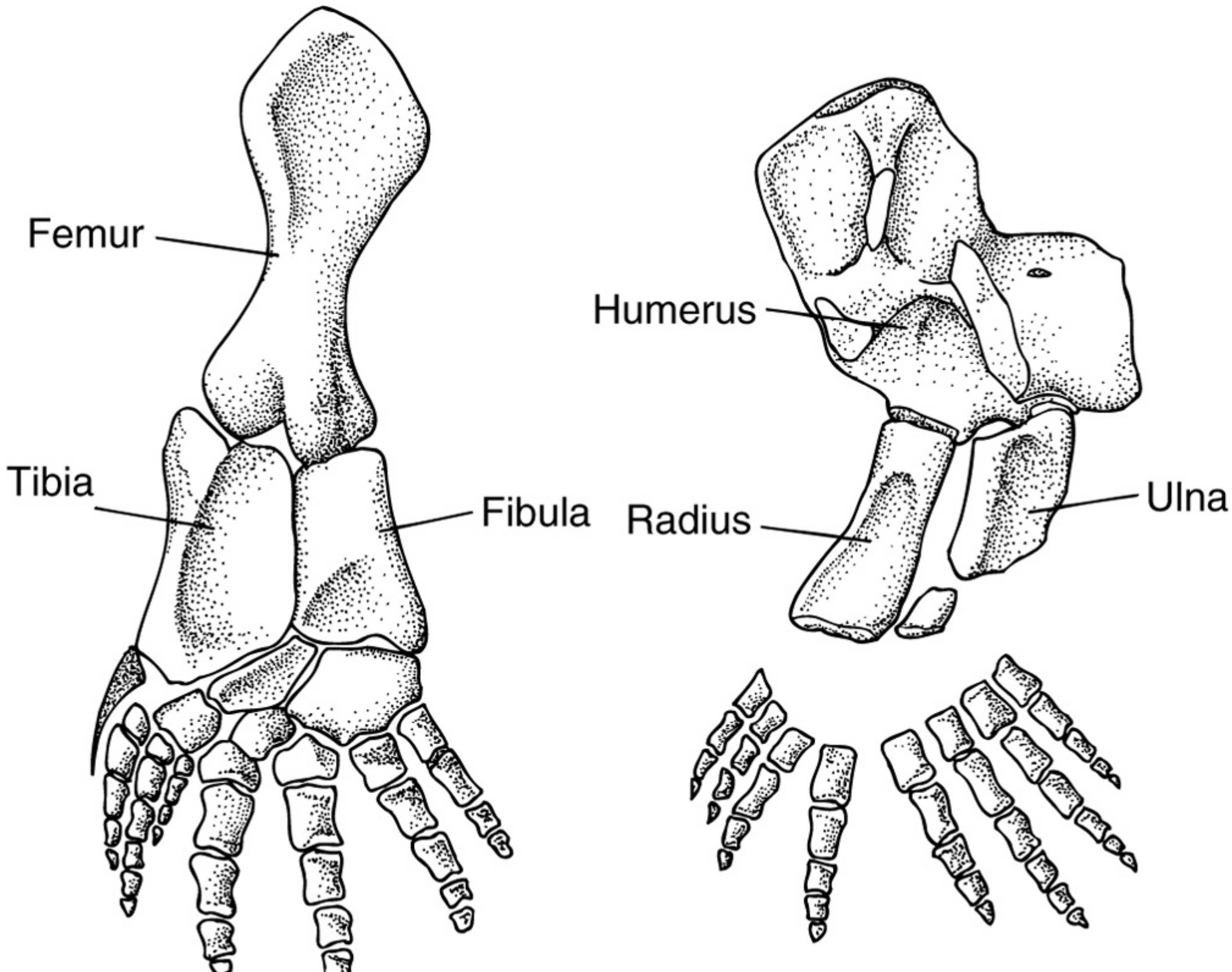
(b) Limb

Overview of the appendicular skeleton:
It includes any projection from the body that plays a role in locomotion or steering. Limbs consist of three major divisions: the proximal, medial, and distal divisions.

1- **Proximal division**: the bone that articulates with the girdle and projects laterally from the body:
Humerus (anterior limb)/ Femur (posterior limb).

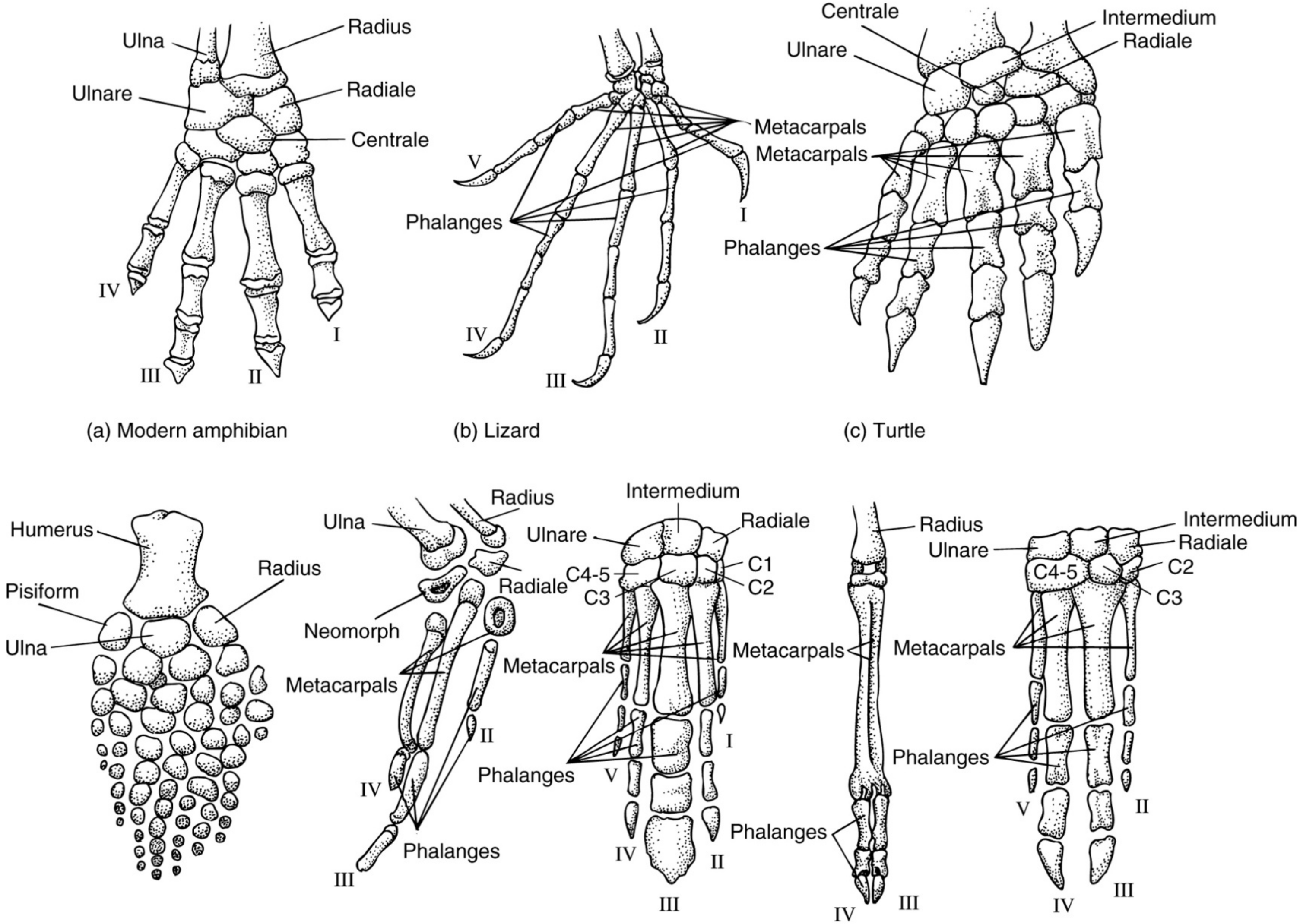
2- **Medial division**: the two bones that articulate with the proximal bone at the knee or elbow. Distally, they articulate with the bones of the hand or foot.
a- Radius and ulna (anterior limb)
b- Tibia and fibula (posterior limb)

3-**Distal division** is made by three subdivisions:
a- Carpus or wrist (anterior limb)/ tarsus or ankle (posterior limb)
b-Palm and sole bones: metacarpal (anterior limb) /metatarsals (posterior limb)
c-the free portion of each digit: phalanges



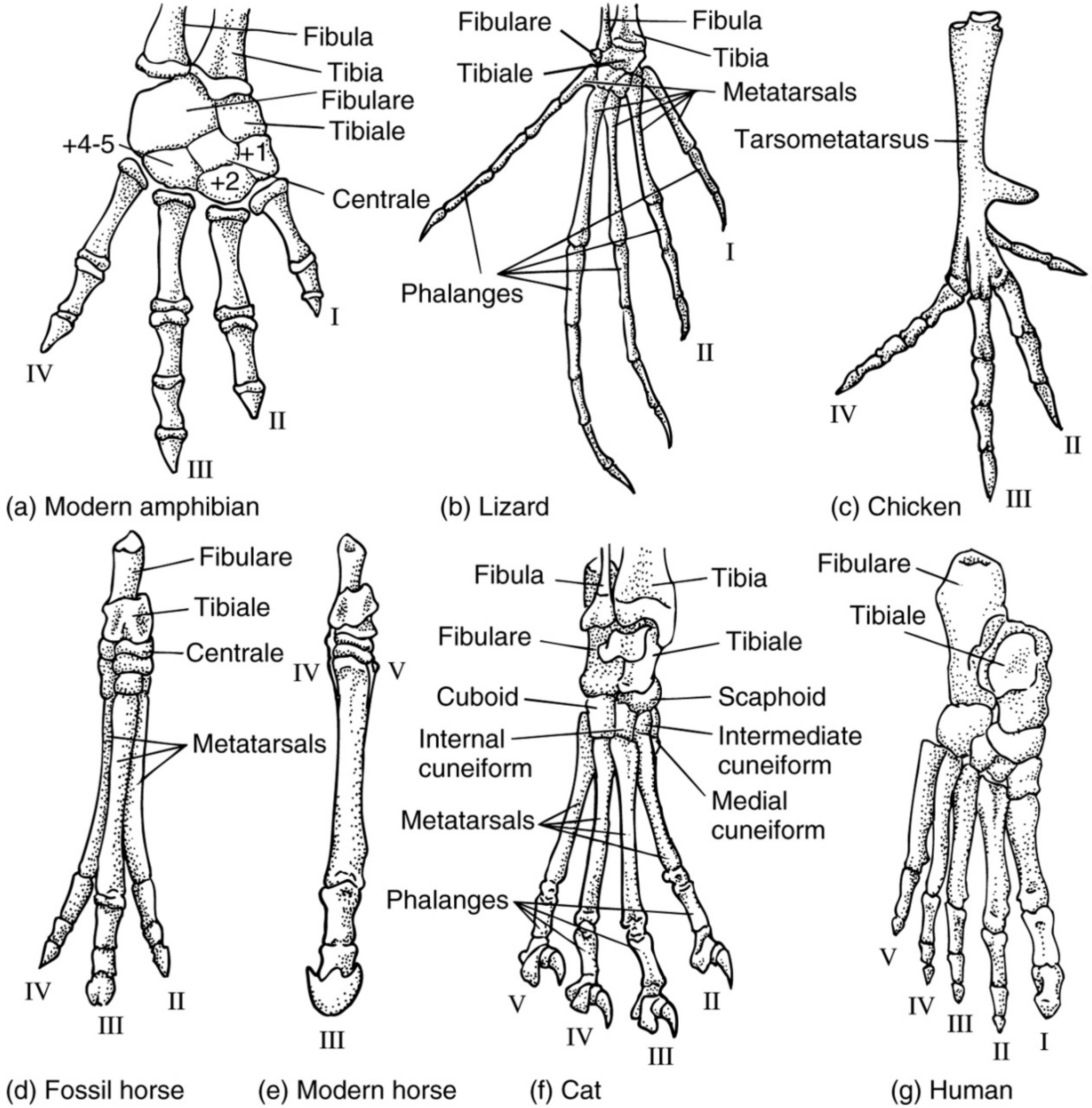
(a) *Ichthyostega* (b) *Acanthostega*

Basic organization of the hind and forelimbs in earliest tetrapods



(a) Modern amphibian (b) Lizard (c) Turtle

(d) Icthyosaur (e) Bird (f) Perissodactyl (g) Artiodactyl (h) Generalized artiodactyl



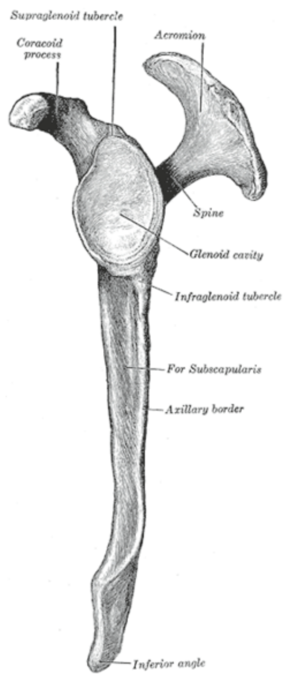
(a) Modern amphibian (b) Lizard (c) Chicken (d) Fossil horse (e) Modern horse (f) Cat (g) Human

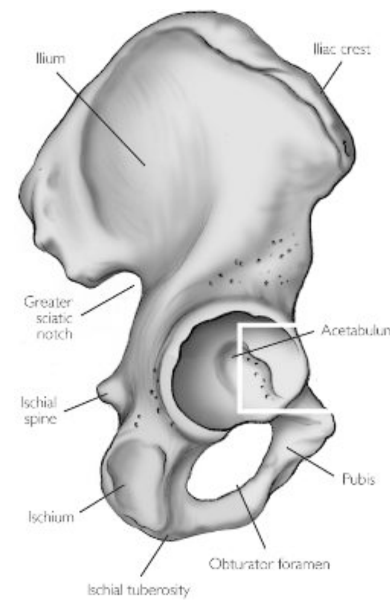
Variation of the tetrapod pes

Girdles

-shoulder or pectoral girdle,
the **glenoid fossa**, a depression within the pectoral girdle, articulates with the humerus

-hip or pelvic girdle
the **acetabulum**, a deep socket in the pelvis, articulates with the femur



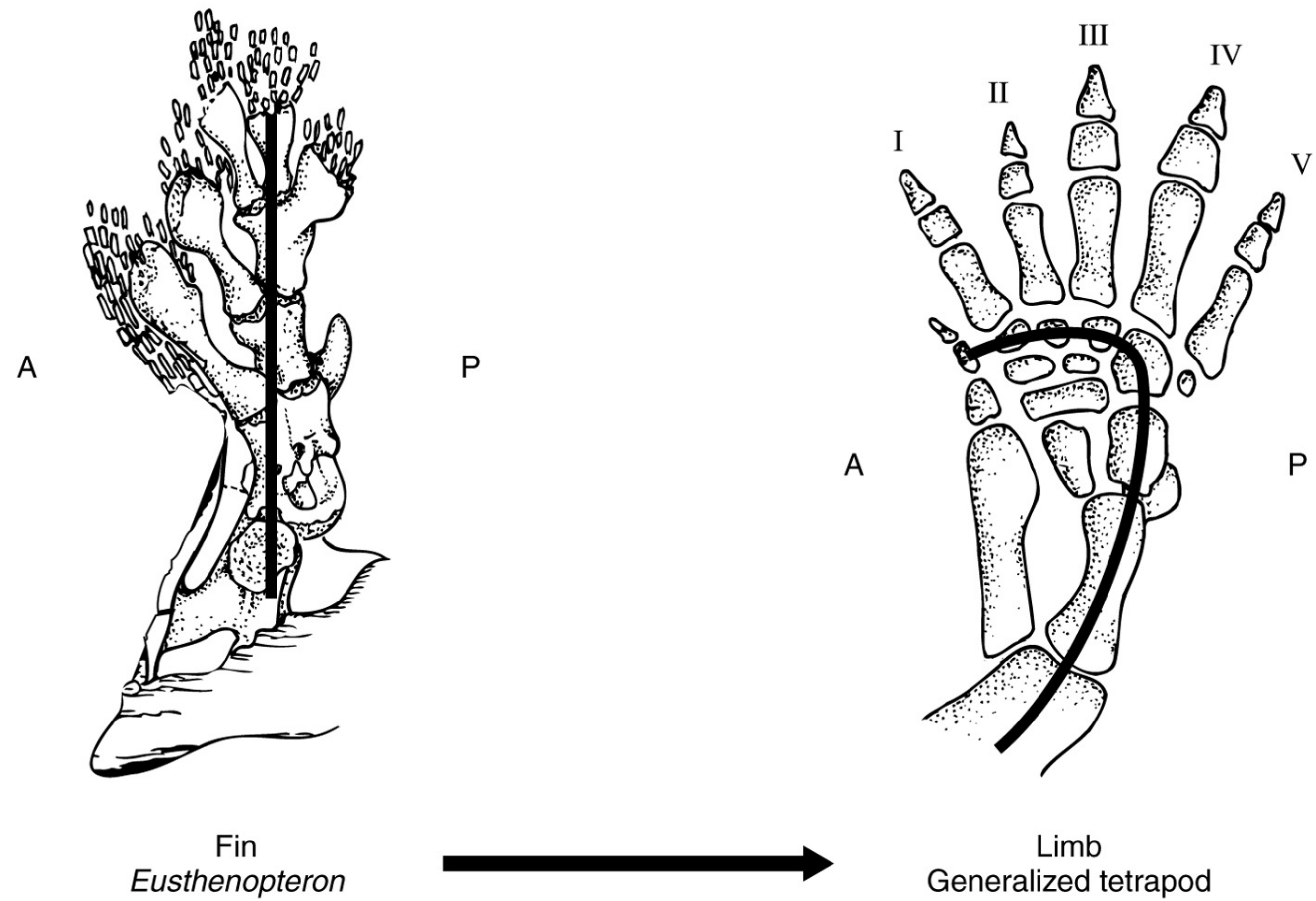


Evolution of the Limbs in Tetrapods

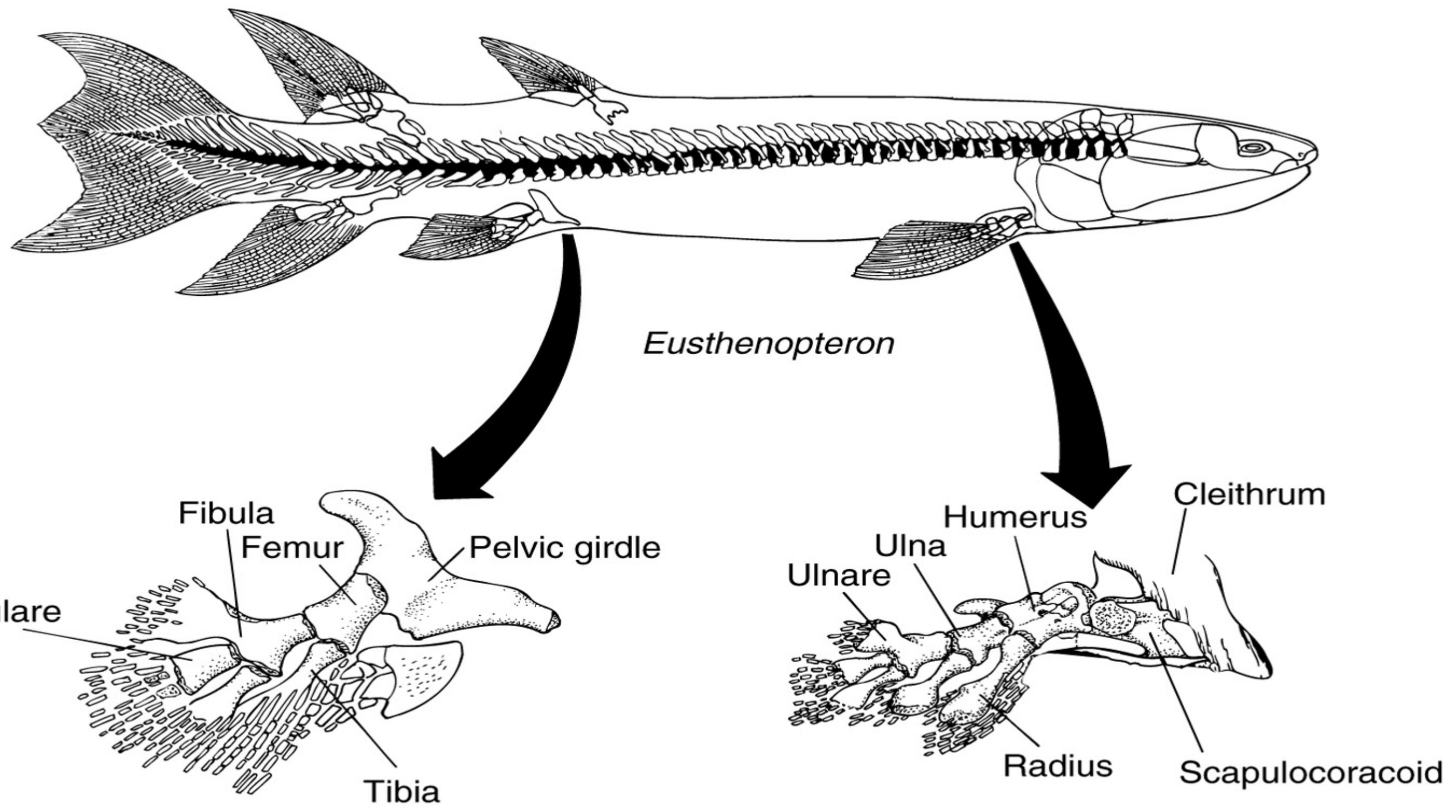
Fossil evidence suggests that the tetrapod limb evolved from the fin of crossopterygian fish.

Idea based on a number of homologies of the fossil fins with the tetrapod limb.

Each fin of a crossopterygian fish consisted of a series of bones emerging from the dorsomedial side of the body.



The proximal bone is considered the equivalent of the humerus/femur. The second element in comparable to the ulna/fibula. The first radial is believed to correspond to the radius/ tibia. The remaining radials are believed to be homologs of the carpal/tarsal bones. **Note the absence of metatarsals and phalanges in the fin. These bones are believed to have evolved a new ossified outgrowths from the margin of the fin. However, transitionals have not been found in the fossil record**



(a) Pelvic girdle and fin

(b) Pectoral girdle and fin

Rhipidistian/Sarcopterygian fish that led to tetrapods had lobe fins.
Lobe fins have muscles and supportive elements that project from the body to the fin and have bones that are homologous to the bones found in early amphibian limbs
There are four types of surviving Sarcopterygians: three lungfish and latimeria. They all have reduced fins
The lungfish Neoceratochus (Australia) has the strongest fins of the group but they are not good for terrestrial ventures.
Used for maneuvers shallow water or crawl around vegetation
Used to borrow into mud during times of draught, estivation.

Transition from Fin to Limb
Examples of hypothesis to explain limb development include:

Hypothesis 1 Draught
Devonian period was characterized by draught.
Reinforced lobe fins allowed to move from a drying pond to a larger one.
Limbs have been proposed as an evolutionary development that allowed fish to move from one pond to another during time of drought.
Extant species burrow and estivate.

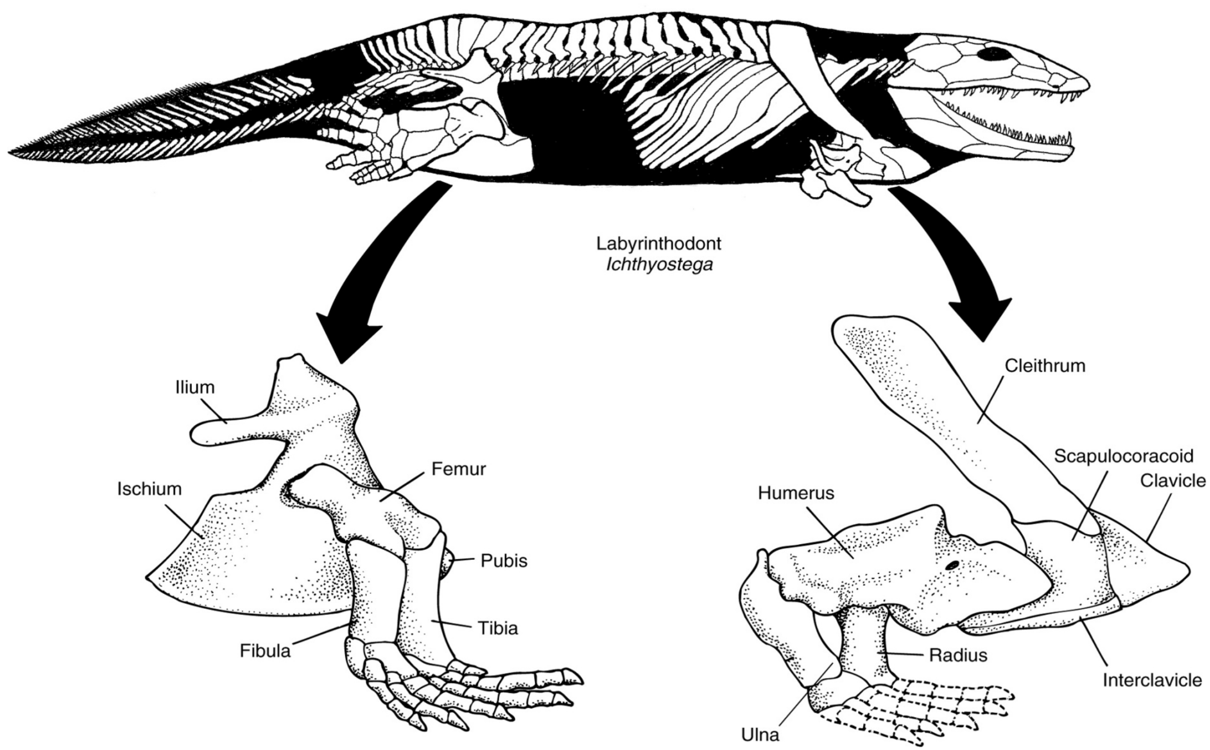
Hypothesis 2-Predatory Stress
Some species hung out in shallow water with think vegetation to escape predators.
Lobe fins used to in maneuvering evolved into better support allowing for brief ventures onto land.
Limbs evolved from modified fins that enabled organisms to crawl up moist shore areas to escape predators

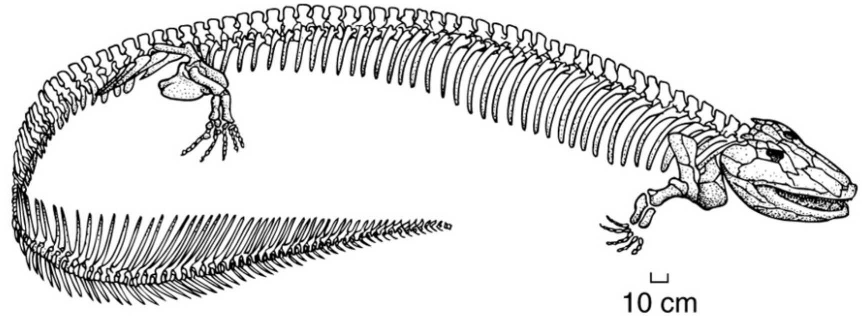
Hypothesis 3- Breathing
Development of limbs occurred to allow to get out of the water to breathe using lungs.
Generally discounted as they only need to lift their head out of the water

Early tetrapods had limbs which projected at right angles from the bodies

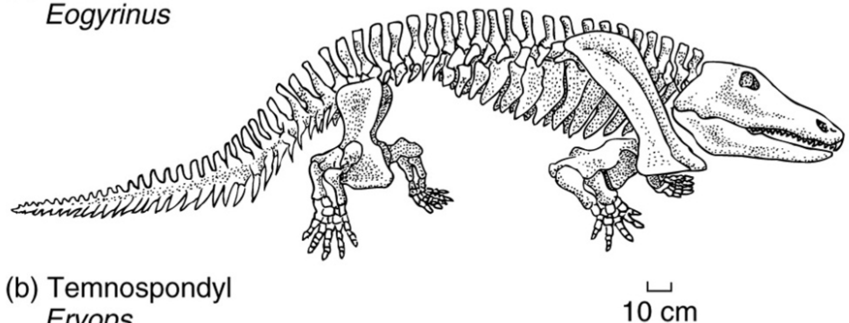
-In early labyrinthodons the typical pendactyl arrangement of the digits is found

- The humerus and femur were short and thick
- The radius/tibia and ulna/fibula combinations were relatively equal in thickness since they received equal distributions of weight.
- Joints evolved in the limbs where bending was required for more flexible locomotion

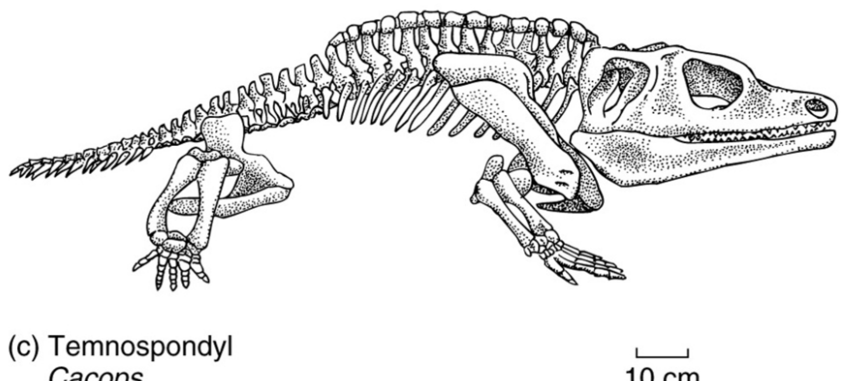




(a) Anthracosaur
Eogyrinus



(b) Temnospondyl
Eryops



(c) Temnospondyl
Cacops

Amphibians

Modern amphibians generally have short limbs projecting from the side of the body

Podial elements (carpals/tarsals) are often cartilaginous

Hands usually only have four digits.

Feet have four-five digits

Long bones are more slender than those observed in ancient amphibians

Reptiles

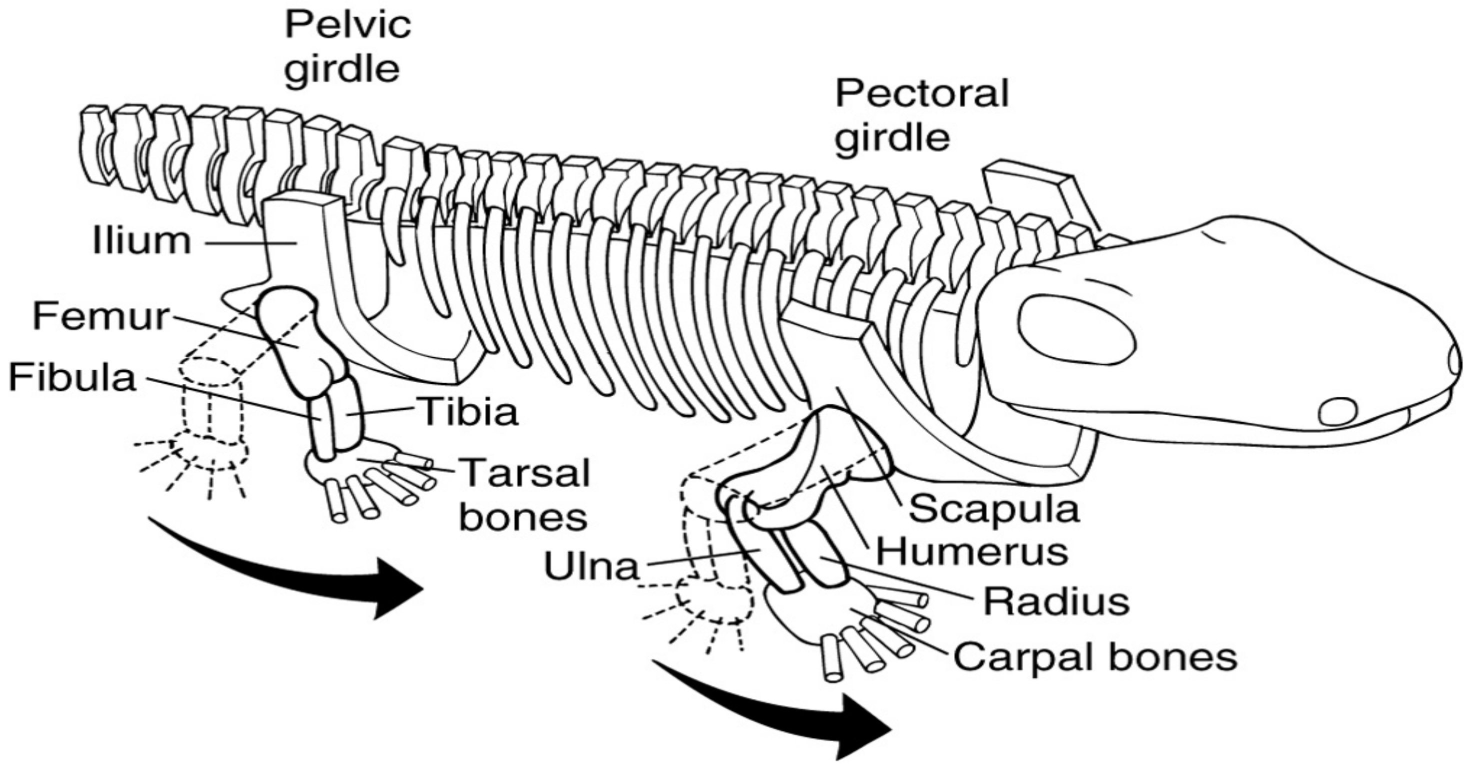
- Most modern reptiles have limbs positioned at the sides of the body although
Some dinosaurs and therapsids had limbs placed under the body as seen in mammals
- Reptilian limbs have the pentadactyl arrangement of digits

- Stronger limbs than amphibian limbs

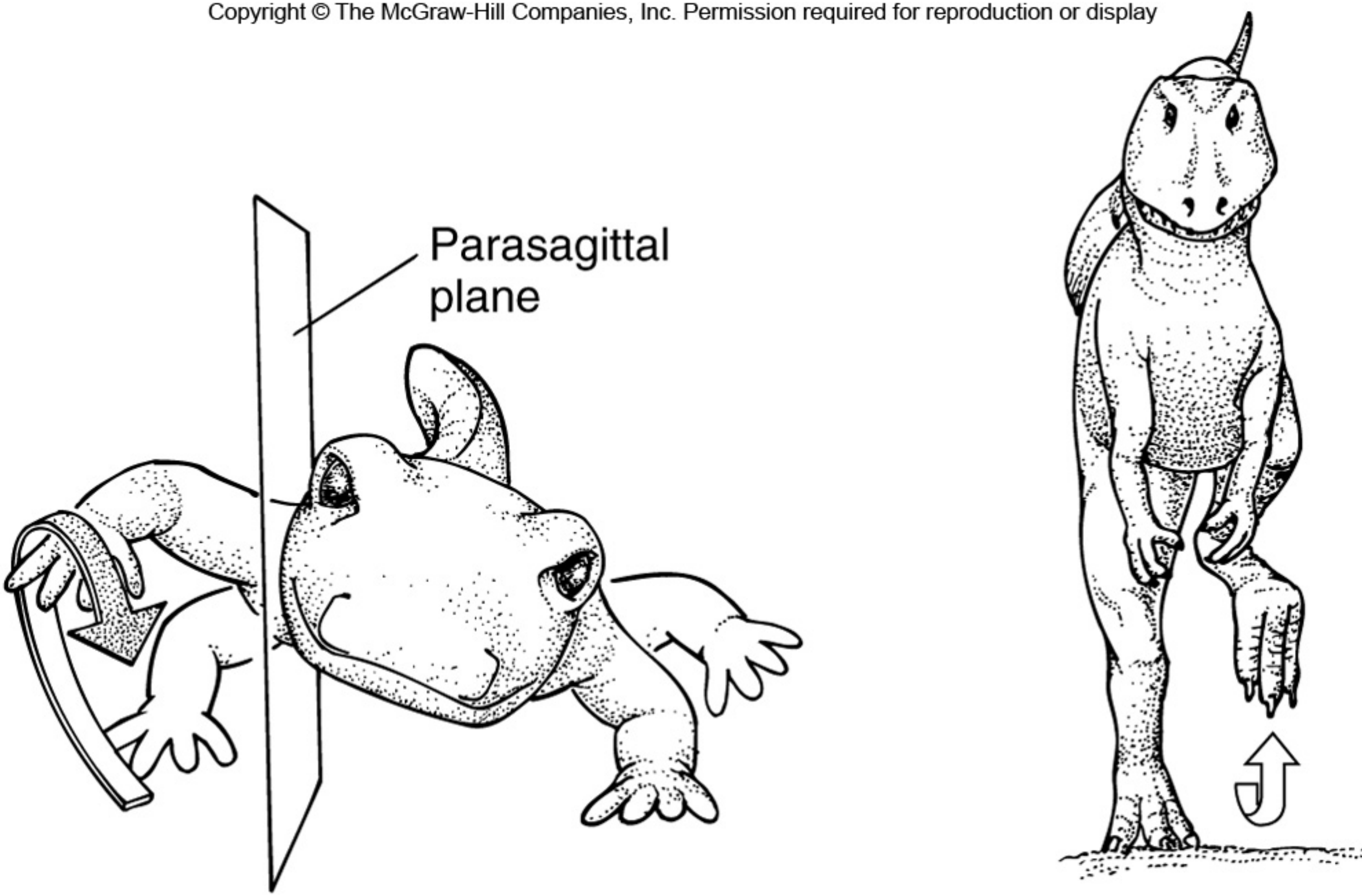
-In general, the number of podial bones is reduced due to fusion when compared to amphibians. These bones are ossified in reptiles.

- A patella and a calcaneum are present in some lizards

- Most reptiles have an epiphysis which is cartilaginous



Digit orientation. Toes tended to point laterally in early tetrapods (dashed lines). However, accompanying more efficient terrestrial, the direction of digits changed along with limb position. Torsion of the humerus and femur brought the toes forward and more in line with the direction of travel. Note in particular how opposite ends of the humerus are rotated to bring the toes forward



(a) Salamander

(b) Dinosaur

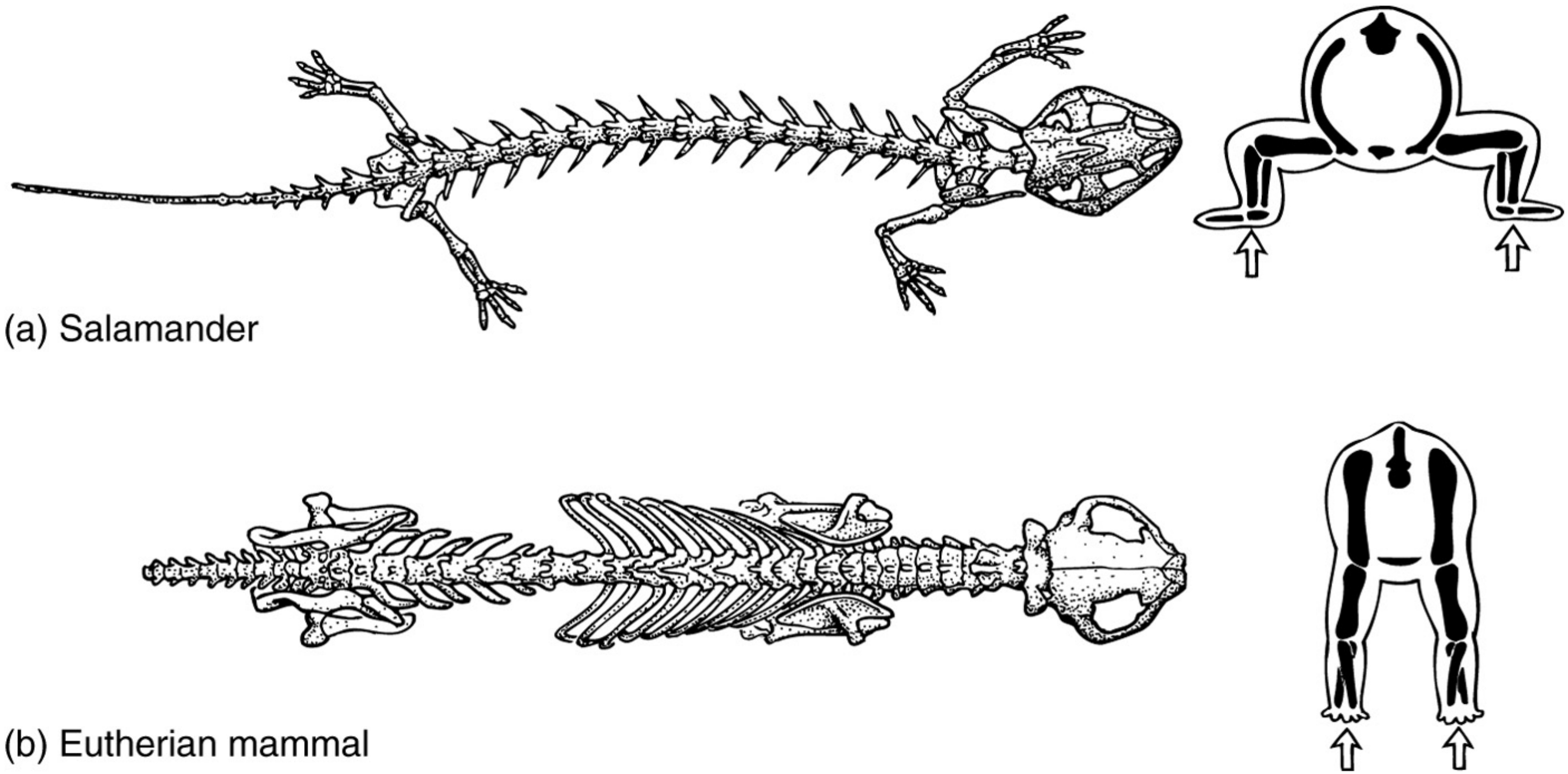
Mammals

The humerus and femur and the podial bones become longer as a means of increasing step length

The position of the limbs shifts from the sides of the body to under the body. With this change, the bones of the forearm and leg no longer share equally in weight transfer

The epiphysis is ossified in mammals

Mammalian arrangement of podial is variable due to deletion of fusion



Change in limb posture. A) the sprawled posture exhibited by the salamander was typical of fossil amphibians as well as of most reptiles. B) Eutherian mammal. This posture began to change in synapsids so that in late therapsids, the limbs were thought to be carried more under the body, a reflection of increased efficiency in locomotion

The Pectoral Girdle:

1-**Endoskeleton component**: cartilage and bone.

In fish, the endoskeletal component serves to support the fins and limb articulation.

In higher vertebrates, the endoskeleton serves as a base for muscle attachment and limb articulation.

The endoskeleton components are maintained in a similar manner seen in fish.

The primary changes that occur include expansion of the shoulder girdle and ossification of the structure.

The expansion is related to the increased limb size and musculature required to control the limb.

2- **The dermal component** ties the the endoskeletal girdle to the body and provides added strength.

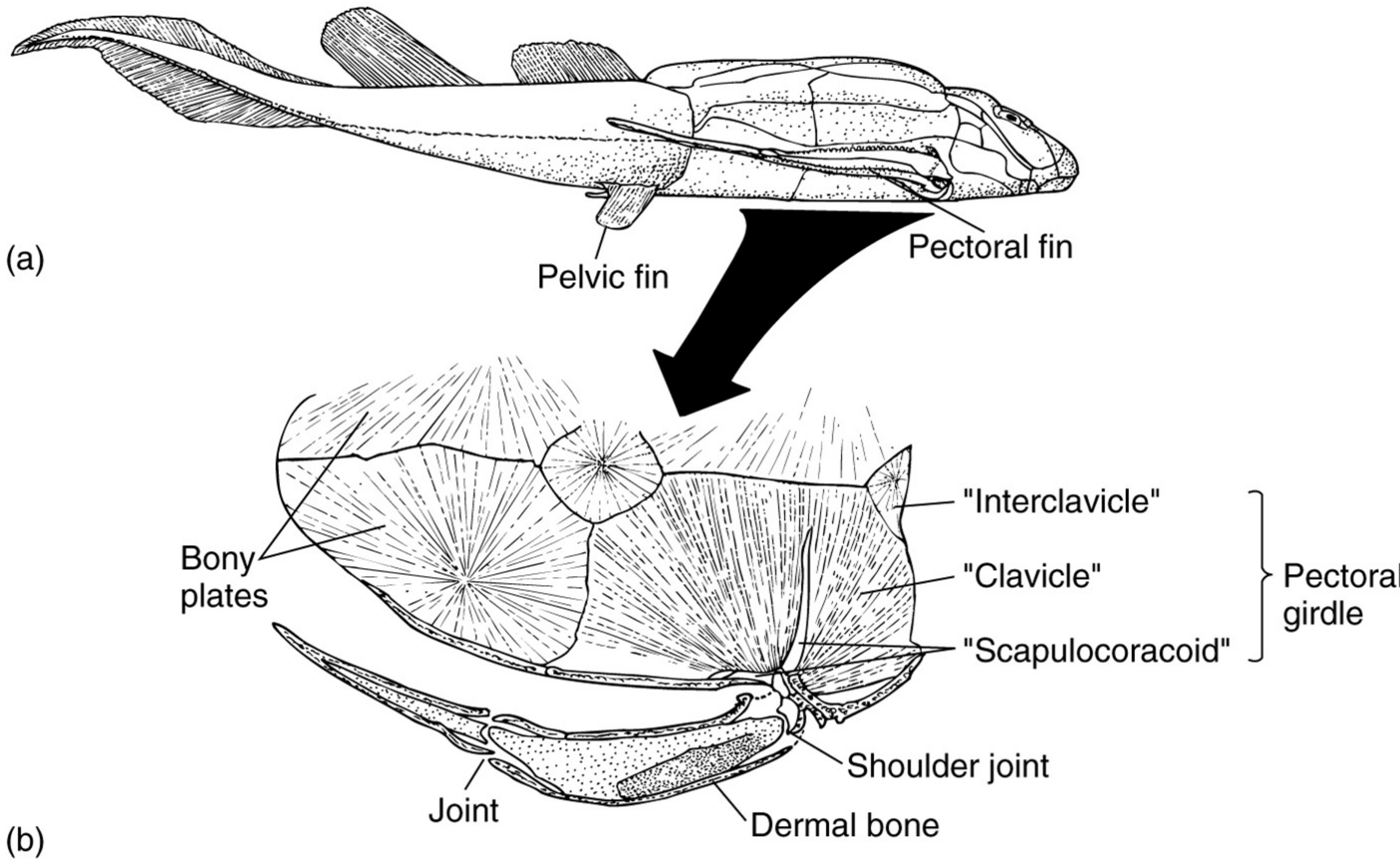
-**Fish** have a pectoral girdle that is tied to the posterior of the skull dermal elements.

The fin is articulated to a cavity in the endoskeleton division called the **glenoid fossa**.

The **scapula**, which may be cartilaginous or ossified, is superior to the glenoid fossa.

A **coracoid** plate lies below the fossa.

The dermal bones include a ventrally located **clavicle** and a long dorsally located bone called the **cleithrum**. In teleost fish, the clavicle is absent.

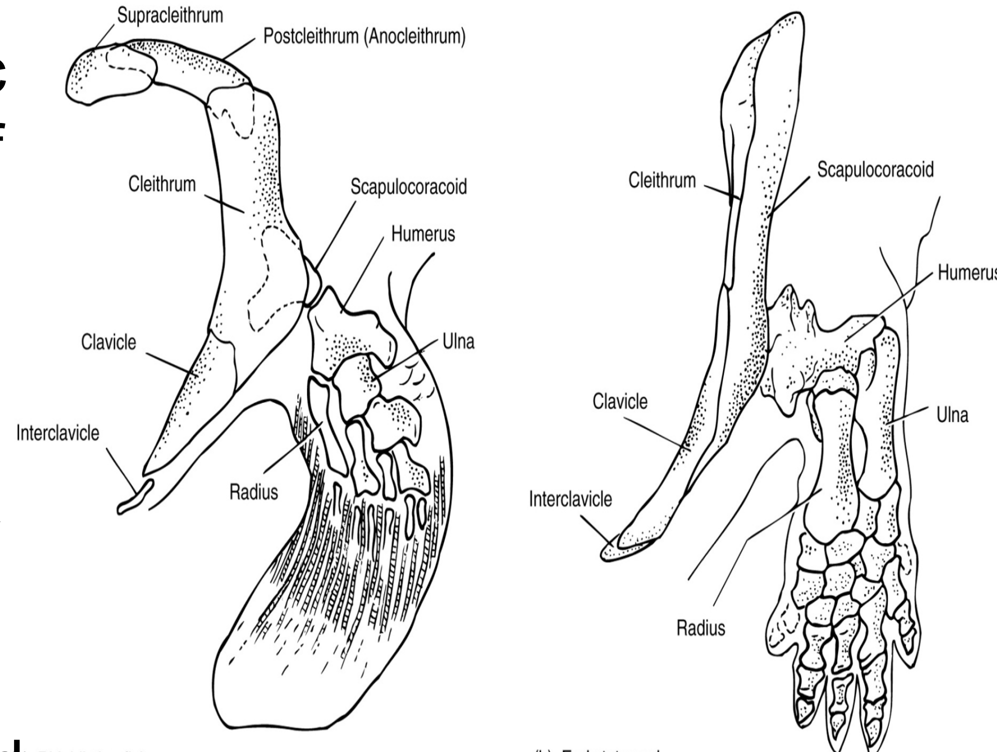

(a)
Pelvic fin
Pectoral fin
(b)
Bony plates
"Interclavicle"
"Clavicle"
"Scapulocoracoid"
Pectoral girdle
Shoulder joint
Joint
Dermal bone

-**Ancestral tetrapods** undergo some fairly dramatic changes including the loss of dermal bones attaching the pectoral girdle to the skull.

The clavicle and cleithrum become narrow bones rather than plates.

The interclavicle is introduced in early tetrapods.

The clavicle attaches to the interclavicle.



(a) Rhipidistian fish *Eusthenopteron*

(b) Early tetrapod *Eryops*

-In **subsequent vertebrates** the general trend is a reduction in bone number either through loss or fusion.

The cleithrum is usually lost.

The interclavicle persists in reptiles and some prototherian mammals.

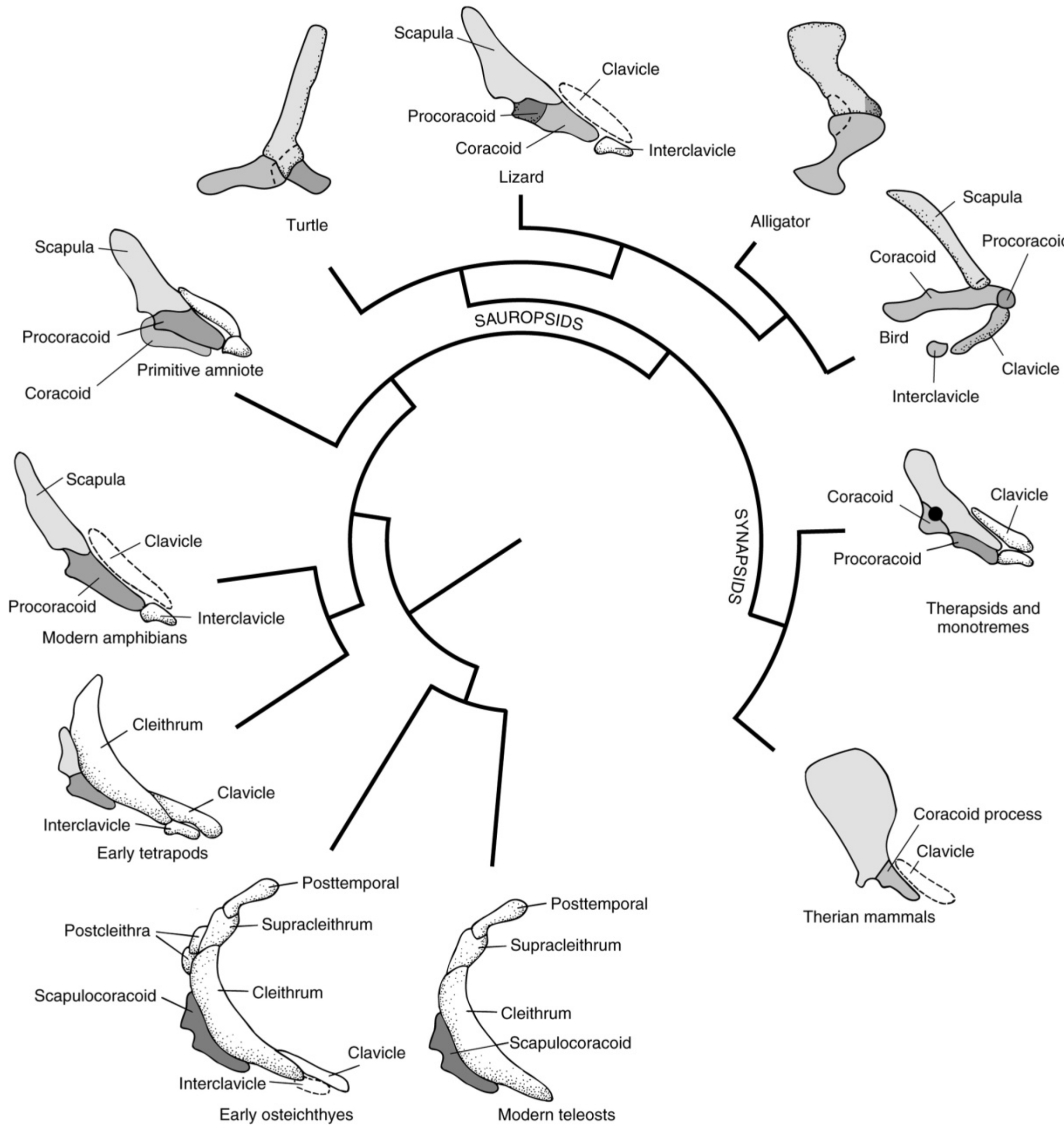
The presence of the clavicle is variable:

In the **cat and humans**, clavicle forms the collar bone.

In **other mammals**, the clavicle is lost or vestigial.

In **birds**, the clavicle and interclavicles fuse to form the furcula or wishbone.

Summary of pectoral girdle evolution



Pelvic Girdle

In contrast to the pectoral girdle, the pelvic girdle only contains endoskeletal elements.

In **fish**, it appears as a simple cartilaginous or bone plate present in the ventral musculature (abdomen).
The girdle in fish has no connection to the vertebral column.

In **terrestrial vertebrates**, the pelvis girdle expands and becomes more closely tied into the body.

Three major transformations in terrestrial vertebrates:

a) The ventral portion expands into a large plate of bone that ossifies anteriorly into the pubis and posteriorly into the ischium. The external portion of this bone serves as a site for limb muscle attachment.

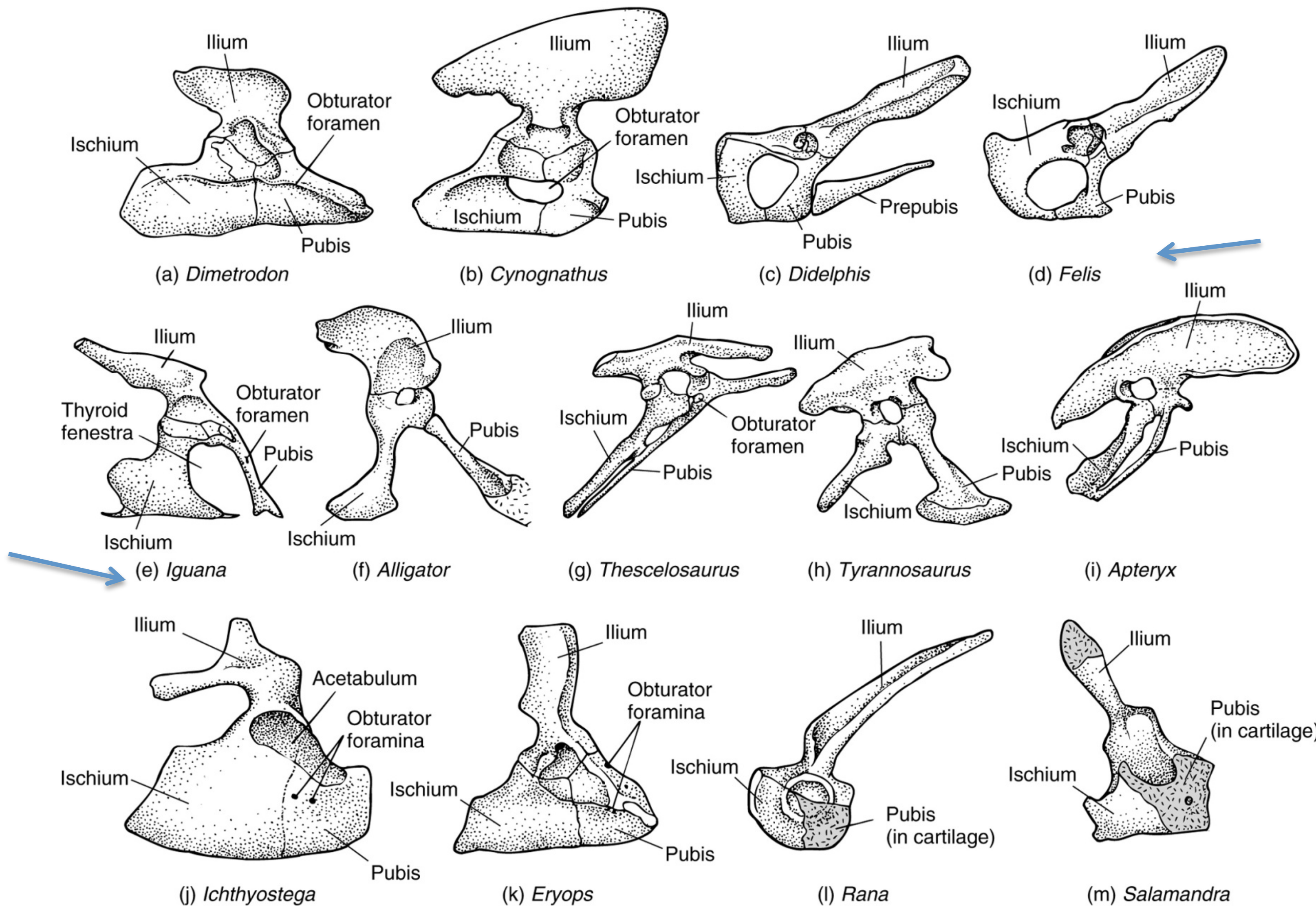
b) A dorsal ossified process the ileum, which serves to an attachment site either to the vertebral column (mammals) or the sacral ribs (reptiles).

c) The presence of the acetabulum at the region that the three bones converge to provide articulation for the proximal portion of the femur.

There are a number of variations in the structure of the pelvic girdle depending on the limb posture and weight distribution of the organism.

For example,
In reptiles, the ileum is attached to two or more sacral ribs and projects dorsally in a backward direction.

In mammals, the ileum extends anteriorly as it extends to the sacrum. The pubis and ischium extend posteriorly. Thus the entire structure has rotated with changes in musculature to accommodate the limb position under the body.

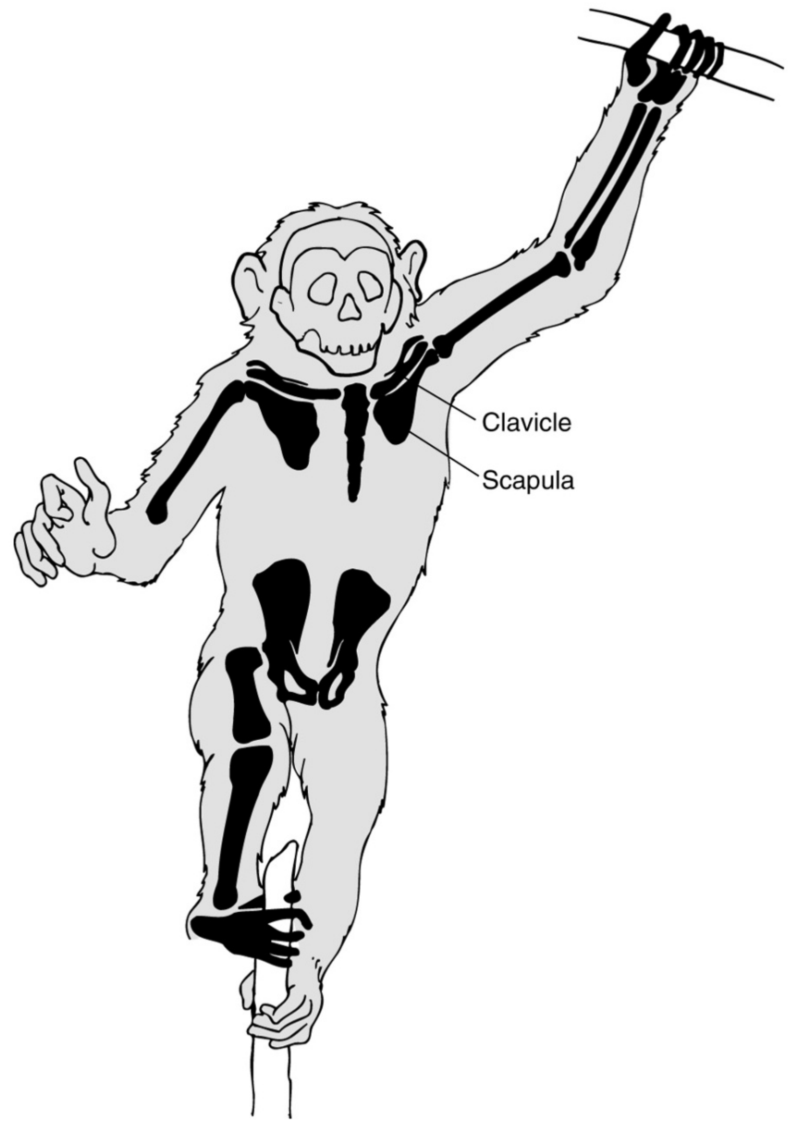

Ilium
Obturator foramen
Ischium
Pubis
(a) *Dimetrodon*
Ilium
Obturator foramen
Ischium
Pubis
(b) *Cynognathus*
Ilium
Ischium
Prepubis
Pubis
(c) *Didelphis*
Ilium
Ischium
Pubis
(d) *Felis*
Ilium
Thyroid fenestra
Obturator foramen
Pubis
Ischium
(e) *Iguana*
Ilium
Pubis
Ischium
(f) *Alligator*
Ilium
Ischium
Obturator foramen
Pubis
(g) *Thescelosaurus*
Ilium
Pubis
Ischium
(h) *Tyrannosaurus*
Ilium
Ischium
Pubis
(i) *Apteryx*
Ilium
Acetabulum
Obturator foramina
Ischium
Pubis
(j) *Ichthyostega*
Ilium
Obturator foramina
Ischium
Pubis
(k) *Eryops*
Ilium
Ischium
Pubis (in cartilage)
(l) *Rana*
Ilium
Pubis (in cartilage)
Ischium
(m) *Salamandra*

Humans retain evidence of the distant human ancestors that swung through trees, brachiating mode of locomotion

Brachiators have long arms with grasping hands. Human arms are still relatively long.

Brachiators have manus, digits II through V form a hook to grasp overhead branches. Humans have a very similar grip.

Cursorial (running) animals like the cat, the clavicle reduced. In brachiators, like monkeys, the clavicle is a prominent shoulder structure to serve transfer the weight of the body to the arm. Humans retain this prominent clavicle



The design of our hindlimbs and pelvic girdle accommodates compromises to our upright bipedal posture.

The birth canal is wide, especially in human females.

But widening for this places the heads of the femur far apart and outside the center line of body weight.

A bend in the femur just above the knee allows the limb to swing directly beneath the body.