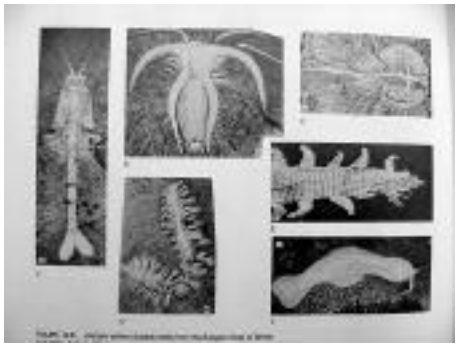
Eukaryotic Organisms

- evolved **~1.7 bya**
- have nucleus and internal chambers called organelles w/ specific functions
- unicellular, colonial or multicellular
  - Introduction of Sexual Reproduction !
  - Multicellular "animal" life evolved ~670 Mya

Burgess Shale ~530 Ma



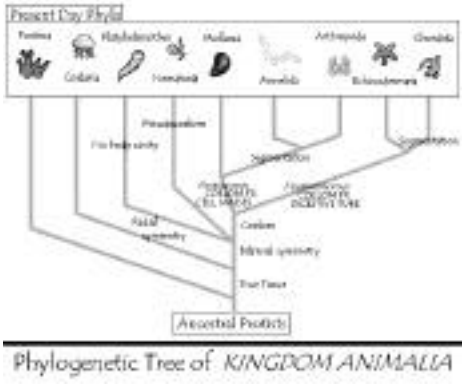
Pikaia gracilens

first chordate ?

Chordates

- Notochord - a stiff rod or chord
- Dorsal hollow nerve cord

- bilateral symmetry
- encephalization - complex central nervous and neural material structure = brain



Phylogenetic Tree of *KINGDOM ANIMALIA*

Vertebrates

- characterized chiefly by a vertebral column

- Earliest known was the conodont
- Fish also evolved during the Cambrian

Conodonts

Conodonts

Gnathostomata

- true jaws
- Arose in the Early - Middle Ordovician (~500 million years ago)

Fish

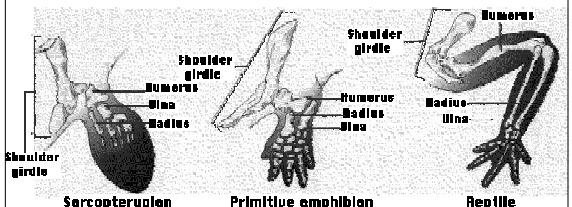
- Chondrichthyes - cartilage fish (sharks)
- Osteichthyes - bone fish
  - Actinopterygii - ray finned fish (look in a fish tank)
  - **Sarcopterygii** - lobe-finned fish (lungfish, coelocanths and eventually tetrapods !
  - Split occurred in Devonian

- The oldest known skeletal remains of terrestrial vertebrates were found in the Upper/Late Devonian ~380 Ma

Amphibians

Some of the problems with living on land:
- Breathing
- Desiccation
- Gravity
- Reproduction

Vertebrate solutions to some problems:
- Lungs
- Various forms of skin protection (scales …)
- Strong limbs, strong limb girdles, complex digits, claws
- Amniotic eggs



- **Tetrapods** originated no later than the Mississippian (about 350 million years ago), the period from which the oldest known relatives of living amphibians are known.
- The oldest **Amniotes** currently known date from the Middle Pennsylvanian (about 330 million years ago)

Mississippian + Pennsylvanian = Carboniferous

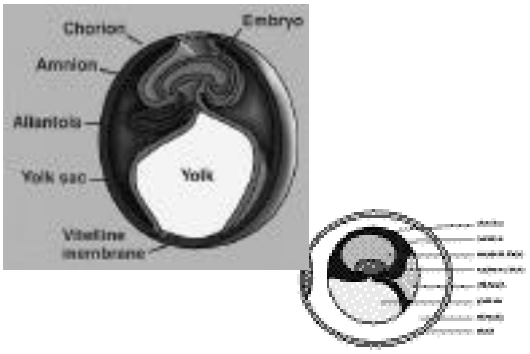
Tetrapods

- four feet
- modified vertebrae (processes etc)
- limbs all have single upper bone and lower paired bones
- the general body plan that we discussed

Amniota

- The amniotic egg possesses a unique set of membranes: amnion, chorion, and allantois. The amnion surrounds the embryo and creates a fluid-filled cavity in which the embryo develops.
- Allows eggs to be laid outside of water or very moist environments - frees the terrestrial vertebrates from having to live next to bodies of water
- **the Amniotes**

Amniotic egg

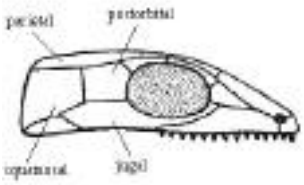


Great Split

- Between 310 and 320 million years ago the Amniotes split into two groups characterized by skull morphology
  - Synapsida
  - Reptillia

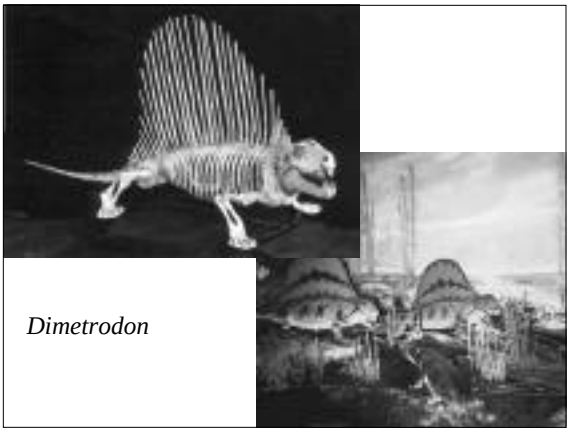
Anapsida

primitive condition - solid cheek bones



Synapsida

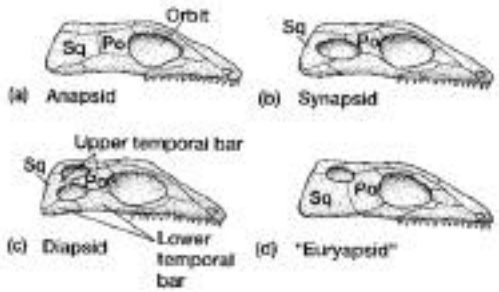
- skull roof has developed a low opening (fenestra) behind the eye - the lower temporal fenestra



Dimetrodon

The other branch of the Amniotes is Reptilia composed of the

- Anapsids
  - Primitive condition (turtles)
- Diapsids
  - Two temporal fenestrae
  - All living reptiles (except turtles)
  - Dinosaurs



Next Big Divergence

- During the Permian - about 250Ma the Diapsid Amniotes diverged into two groups
  - Lepidosauromorpha (lizards and snakes)
  - Archosauromorpha (crocodiles, dinosaurs, pterosaurs, birds)

Archosaurs

- Dinosaurs
- Crocodilians
- Pterosaurs
  - Your textbook mentions Thecodonts - this is actually an outdated term that is not in common use anymore. It was in common use when it was thought that Dinosauria was not monophyletic (pg 48).

Archosaurs

- Fenestrae in front of orbit (Antorbital)
- Fenestrea in mandible (Mandibular)
- Laterally compressed, serrated teeth
- No teeth in palate
- Semi-erect or upright posture

Dinosauriformes

- Among the new forms of the Middle Triassic: earliest remains of Dinosauriformes:
- Dinosauriforms comprise dinosaurs, and their primitive relatives

Characterized by:

- Simple hinge-joint ankle without heel
- Fully upright stance of hindlimbs: inturned head of femur
- Tibia, fibula, and metatarsals all long and slender
- Very long hindlimbs
- Longer, S-shaped neck (cervicals very distinct shape from dorsals)

Dinosauria

- First appeared ~228 Ma and went extinct ~65 Ma
- Dinosauria defined as most recent common ancestor of Iguanodon and Megalosaurus and all of its descendants
- Diagnosis includes:
  - Semiopposable manual digit I (“thumb”)
  - Manual digits IV and V reduced in size
  - MAYBE three or more sacrals (but some primitive forms lack this)
  - Semiperforate acetabulum

Dinosauria

- First appeared ~228 Ma and went extinct ~65 Ma
- Dinosauria is divided into two clades, **Ornithischia** and **Saurischia** based on the structure of the pelvis

Saurischia

("lizard-hipped" or "reptile-hipped")

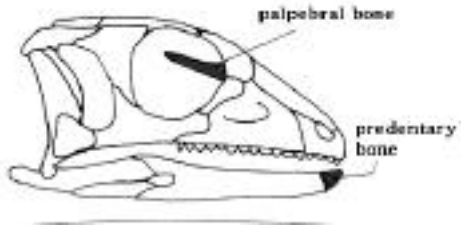
Ornithischia

("bird-hipped")

Ornithischia

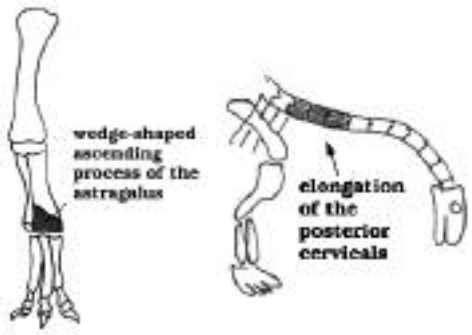
Ornithischia (“bird hips”):

- Defined as Iguanodon and all taxa cıoser to Iguanodon than to Megalosaurus
- Also diagnosed by presence of the predentary bone (an extra bone joining the two anterior ends of the dentary, forming a beak) and five or more sacrals
- All known ornithischians were most likely herbivores, with leaf-shaped teeth
- have a pubis that points backwards.

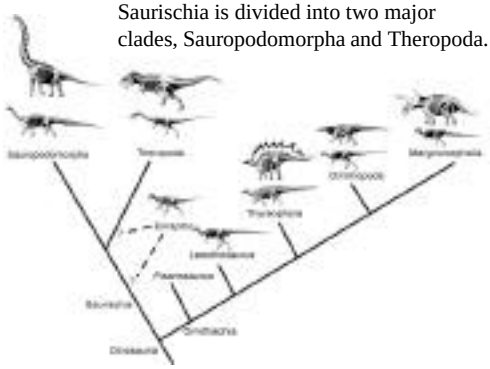


Saurischia

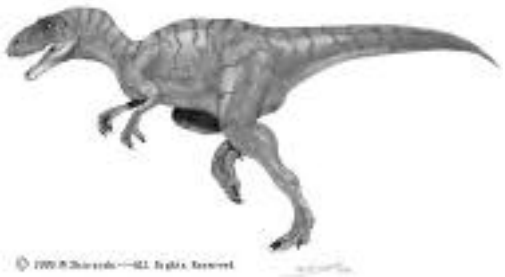
- Saurischia ("lizard hips"):
- Defined as Megalosaurus and all taxa closer to Megalosaurus than to Iguanodon
- Diagnosed by:
- Long necks where posterior cervicals are longer than anterior cervicals
- Manus with an enlarged digit I ungual (thumb claw)
- Manual digit II is the longest in the hand
- Some saurischians retain the primitive carnivorous condition; others have leaf-shaped teeth and were probably herbivores.



Saurischia is divided into two major clades, Sauropodomorpha and Theropoda.



Theropoda



Theropoda

- Theropoda is an incredibly diverse group of dinosaurs. Most of the Mesozoic theropods were sharp-toothed predators, although there have been a few toothless, possibly herbivorous groups. During the Jurassic (or possibly Triassic), some theropods evolved into feathered, flying forms. Their descendants are today's birds.

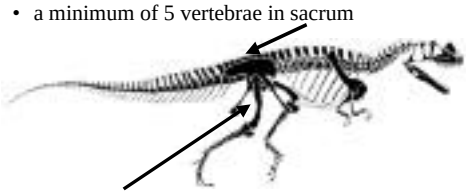
Theropoda ("beast foot"):

- Characterized by extremely hollow limb bones
- Most retain the primitive condition of bladelike, serrated teeth, indicating they were carnivores
- All, from smallest to largest, were obligate bipeds
- Only dinosaurs with feathers or feather-like structures

Theropoda ("beast foot"):

This group is characterized by 20 or more evolutionary novelties, including

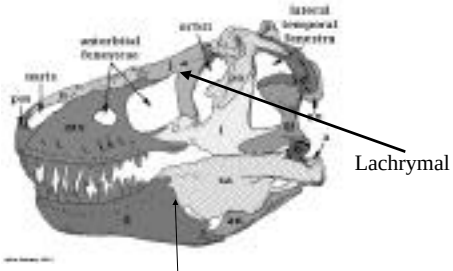
- a minimum of 5 vertebrae in sacrum



- slightly curved femur which is over twice as long as the humerus

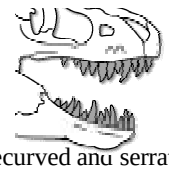
Theropoda ("beast foot"):

- Pes with digits II - IV, digit I separated from pes
- Pes length greater than width - bilateral symmetry from digit III



Lachrymal

- Lachrymal bone (in front of eye) extents to dorsal surface of skull
- an extra joint in the lower jaw



- large, recurved and serrated teeth designed for cutting through and consuming flesh

probably the ancestral condition,

not all Theropods have teeth (not all were meat eaters, but all meat-eaters were Theropods)

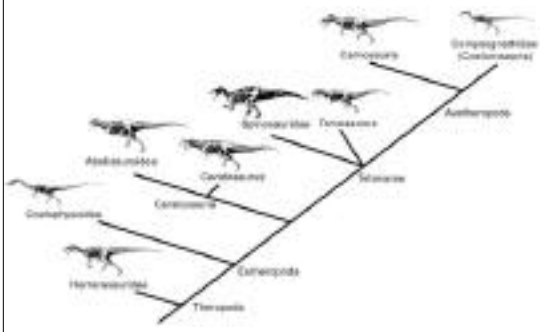
• manus with claws and reduction or loss of digits IV and V

• hands able to grab with digits I - III (though some “advanced” theropods have only digits I-II)

• well defined processes on cervical and caudal vertebrae called zygopophyses

Theropoda

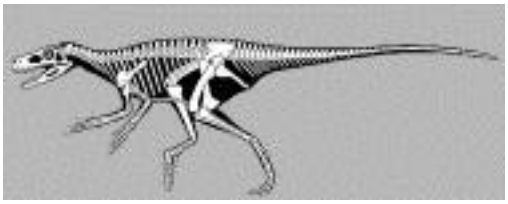
- Three Major Clades
  - HERRERASAURIDAE
  - CERATOSAURIDAE
  - TETANURAE



HERRERASAURIDAE

- Late Triassic
- Either a basal clade for Theropoda or a basal clade for Saurichia (will treat as prior)
- Shares 12 evolutionary novelties with Theropoda

- long pubis w/ relation to femur associated with 3 sacral vertebrae
- semiperforate to open acetabulum with well developed medial wall
- femur nearly twice as long as humerus
- elongate skull nearly equal in length to femur
- serrated and recurved conical teeth
- long and equally sized metatarsals I and V on pes
- manus with 5 digits but IV and V reduced without claws



Eoraptor

- possible very primitive theropod Eoraptor (may be a non-theropod saurischian, or a non-dinosaurian dinosauriform). Sometimes classified as a Herrerasauridae

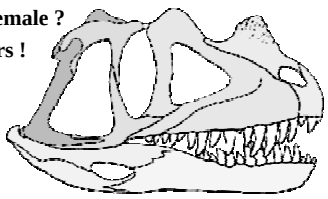
Eoraptor

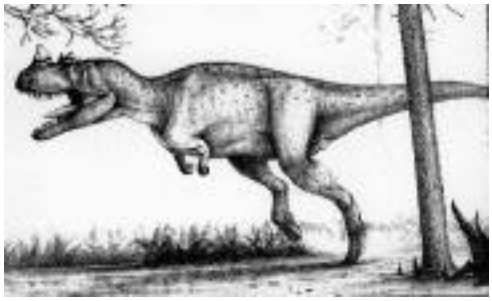
CERATOSAURIDAE

- "horned lizard"
- found on all continents by Antarctica
- contains two clades
  - COELOPHYSOIDEA (end Jurassic)
  - NEOCERATOSAURIA (K-T boundary)

CERATOSAURIDAE

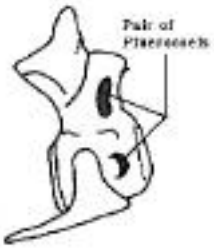
- Some had prominent headgear such as large bony horns or crests on the dorsal surfaces of their skulls
  - **sexual display ?**
  - **male or female ?**
  - **no feathers !**





CERATOSAURIDAE

- fusion of bones in the ankle and feet (astragalus and calcaneum)
- sacrum fused to ilium and ribs
- two fenestra on pubis
- four digits with digit IV reduced
- **most** had a space between the maxilla and premaxilla filled by a tooth from the dentuary



• two pairs of cavities in cervical vertebrae called pluerocoels

•Fusion of ilium, pubis, and ischium in adults

TETANURAE

- "stiff tail"
- best known theropods
- immediate ancestors to birds

- dentition in maxilla only anterior to the orbital
- antorbital and maxillary fenestrae

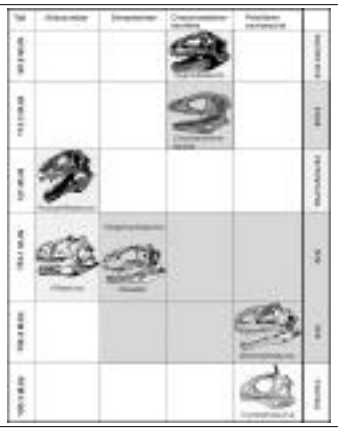
- increased pneumaticity of the skull
- Manus with digits I - III (though III is absent sometimes)
- Development of a large notch on the ischium
- well developed stiffening of the caudal vertebrae

TETANURAE

- includes Avetheropods
  - increased anterior extension of pubis into a pubic foot - muscle attachment
  - asymmetrical premaxillary teeth
- Avetheropods includes the clades
  - CARNOSAURIA
  - COELUROSAURIA

CARNOSAURIA

- includes the Allosaurids and Sinraptors
- The taxon Carnosauria once included all large theropods, from large ceratosaurs to megalosaurs to tyrannosaurs. More recent research shows that most of these are more closely allied to other groups. Today, only the allosaurids and their relatives are considered true carnosaurs (The precise definition: all animals sharing a more recent common ancestor with Allosaurus than with modern birds).



COELUROSAURIA

- includes may subgroups including
  - Maniraptora (which led to birds)
    - Deinonychosauria
    - Aviale
  - Oviraptorosauria
  - Arctometatorsalia
    - includes Troodontids, Ornithomimosaurs, Tyrannosaurids
  - Therizinosaura

Tyrannosaurids

- D-shaped cross sections of the teeth in premaxillary
- opening in the jugal
- very small forelimbs
- Manus with only digits I - II
- Short neck

Ornithomimosaurs

- heading on page 74 is spelled wrong, it should be ORNITHOMIMOSAURIA
- “bird-like” dinosaurs
- lightly build skull and small head
- long neck
- large orbits

others

Oviraptor

- a Coelurosaur
- toothless jaws
- short snout
- unique skull formation