**Overview of Changes in Skull Morphology**

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<tr>
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<th>Ear Bones</th>
<th>Hinge</th>
<th>Jaw Bone</th>
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<tr>
<td>Mammals</td>
<td>3</td>
<td>Sq/D</td>
<td>Dentary</td>
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<tr>
<td>Early Mammals*</td>
<td>3</td>
<td>Sq/D</td>
<td>Dentary</td>
</tr>
<tr>
<td>Therapsida**</td>
<td>1</td>
<td>2 hinges</td>
<td>several bones</td>
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<tr>
<td>Pelycosaurs**</td>
<td>1</td>
<td>2 hinges</td>
<td>several bones</td>
</tr>
<tr>
<td>Reptiles</td>
<td>1</td>
<td>Q/Art.</td>
<td>several bones</td>
</tr>
</tbody>
</table>

*Note: Early mammals include: Morganucodonts, Triconodonts, Multituberculates, and Pantotheres

**Note: Therapsida are advanced & Pelycosaurs are primitive mammal-like reptiles. Together they are called Synapsida or synapsid reptiles.
Mammalian Evolution

- Mammal-like Reptile: Order Therapsida (therapsids)
  - 1 ear bone = hyomandibular (or stapes)
  - double jaw hinge on each side

Mammalian Evolution

- Mammal
  - 3 ear bones = stapes, malleus, incus
  - dentary-squamosal jaw hinge
  - malleus originates from reptilian articular; incus originates from reptilian quadrate; stapes from reptilian stapes

Mammalian Evolution

- Mammal
  - 3 ear bones = stapes, malleus, incus
  - ectotympanic = tympanic bullae
Mammalian Evolution

Changes in The Skull

• **Anapsid** skull - no temporal openings or windows
  – primitive reptile design

• **Parapsid** skull - window up high for muscles to pass through
  – marine reptile pattern

Evolution of the middle ear
Changes in The Skull

- **Diapsid** skull - 2 temporal openings for muscle play
  - most reptiles & dinosaurs

- **Synapsid** skull - window down low
  - mammal-like reptiles (synapsids) & mammals

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Changes in The Skull

![Pelycosaur vs Mammal]

Why did temporal openings originate?

- Some possibilities:
  1) new attachment points for adductor muscles (e.g., masseter muscles)
  2) skull weight reduction

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Mammalian Evolution

- **Generalized Trend in Evolution of Therapsids:**
  1) enlargement of temporal openings
  2) adductor muscles attach to outer surface & zygomatic arch region
  3) secondary palate formation, like mammals (significance?)

![Figure 7. Probabilization in palatal area. Modified from Carroll (1988)]
Mammalian Evolution

- Generalized Trend in Evolution of Therapsids:
  4) heterodont dentition
  5) dentary bone expands...precursor to dentary-squamosal hinge
  6) simplification/fusion of skeletal structure

Mammalian Evolution

- Generalized Trend in Evolution of Therapsids:
  7) elongation of limbs; more slender limbs shifted ventrally
  8) beginnings of endothermy
  9) diaphragm developing (lumbar ribs reduced)

Cynodonts

A Special Group of therapsids...the Cynodonts

- Group of mammal-like reptiles from which mammals evolved
- Retain characteristics of other therapsids:
  1) 1 ear bone
  2) 2 jaw hinges
  3) several jaw bones

- Most mammal-like in anatomical/structural features
Cynodonts

• **Jaw Articulation of Cynodonts**
  - transitional stages of development approaching the classic mammal jaw hinge
  - quadrate-articular & new, second jaw joint (prevention of jaw unhinging/displacement; acts as a bracing point)
  - formation of glenoid fossa (depression in squamosal for articulation) - fits with a lower jaw bone

• **Jaw Articulation of Cynodonts**
  - Enlargement of dentary bone & beginning to form squamosal-dentary articulation; brace point
  - Reduction of postdentaly bones (e.g., articular, quadrate, angular); hearing
**Cynodonts**

- **Jaw Articulation of Cynodonts**
  - Postdentary bones became smaller and detach from the dentary to be enclosed in a tympanic bulla = beginnings of the mammalian ear with 3 ear bones
    - articular bone = malleus ("hammer")
    - quadrate bone = incus ("anvil")
    - angular bone = tympanic bulla

- **Unique advancement among cynodonts** = new attachment for masseter muscles, i.e., attach along zygomatic arch and lateral surface of dentary = advanced function

**Cynodont Dentition Characteristics:**
- Beginnings of heterodonty; progresses jaw muscle changes
  - large incisors-canines & small premolars-molars (primitive cynodont)
  - large incisors, canines, premolars, and molars (advanced cynodont & early mammal)
  - premolars & molars not differentiated
Cynodonts

- Cynodont Dentition Characteristics:
  - New teeth erupt between older teeth – continual (~6 generations of replacement)
  - Stage set for molar evolution = tricodont teeth

- Cynodont Skeletal Feature:
  - Lateral flexure of vertebral column

Early Mammals

- Early Mammals (late Triassic-Jurassic):
  - Monophyletic evolution from cynodonts
    - Morganucodonts
    - Triconodonts (ancestors of monotremes)
    - Multituberculates
    - Symmetrodonts
    - Pantotheres (ancestors of marsupials & eutherians)

- Some Advances over Cynodonts:
  1) Increase in brain size = increased hearing/olfaction
  2) Dentary-squamosal jaw hinge (only 1 jaw hinge)
  3) Differentiated premolars & molars - diphyodont teeth, single replacement - indicative of change in reproduction, namely lactation
Early Mammals

• Some Advances over Cynodonts:
  4) fusion of pelvic girdle
  5) dorsoventral flexure of vertebral column - useful in locomotion*
  6) increased neuromuscular control - allowed greater niche separation, e.g., arboreal mammals
  7) endothermy, hair, mammary glands

Early Mammals

• Mammals in the Mesozoic Era: (late Triassic - Jurassic)
  – 1st significant adaptive radiation in early (archaic) mammals
  – Several early radiations from cynodonts, but most are “dead-ends” in evolution
  – We look briefly at the 2 major lines which lead to modern mammals (simplified vs. complex view)

Early Mammals

• Two groups of early mammals:
  1) Morganucodontidae (origin of monotremes)
     • triconodont molars
  – Morganacodonts - early off-shoot in late Triassic
  – Triconodonts
  – Multituberculates - 1st mammal herbivores, disappear in early Tertiary Period
Early Mammals

- Two groups of early mammals:
  2) Kuehneotheriidae (origin of marsupials & eutherians)
    - tribosphenic molars
      - Symmetrodonts - late Triassic to late Cretaceous
      - Pantotheres - late Jurassic, later split into metatheria & eutheria
• Mammals in the Cretaceous Period:
  1) Extinction of dinosaurs
  2) tremendous drift of land masses = numerous island land masses
     – Basic mammal design refined through natural selection
       (speciation derived from predation, competition, geographic
        isolation, coevolution with angiosperms)
     – leads to increased diversity in foraging, reproductive,
       thermoregulation strategies

• Mammals in the Cretaceous Period:
  – Stage set for huge adaptive radiations in mammals during the
    Cenozoic Era

Cretaceous  Tertiary

Gondwanaland: 200 Ma
Therapsid Reptiles (Cynodonts)

- X-Morganucodontids
- Prototheria
- X-Triconodonts
- X-Multituberculates
- Monotremes
- X-Symmetrodonts
- X-Pantotheres

Phylogeny of “Perfection”?

- Marsupials
- Metatherians
- Eutherians

- Monotremes
- X-Multituberculates
- X-Pantotheres
- X-Morganucodontids
- Therapsid Reptiles (Cynodonts)

Phylogeny of the Middle Ear

- 1 ear bone
- 2 jaw hinges

- 3 ear bones
- D-S art.

- 3 cusps in row

- ind. 3 ear bones; d-s art.