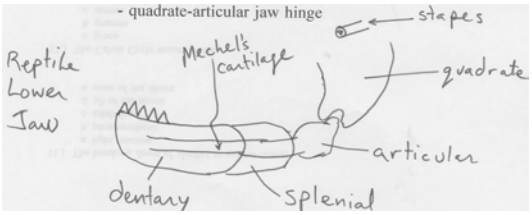
Overview of Changes in Skull Morphology

	Ear Bones	Hinge	Jaw Bone
Mammals	3	Sq/D	Dentary
Early Mammals*	3	Sq/D	Dentary
Therapsida**	1	2 hinges	several bones
Pelycosauria**	1	2 hinges	several bones
Reptiles	1	Q/Art.	several bones

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

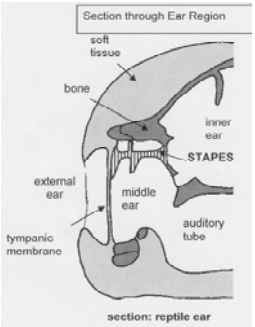
**Note: Therapsida are advanced & Pelycosaurs are primitive mammal-like reptiles. Together they are called Synapsida or synapsid reptiles.

Mammalian Evolution



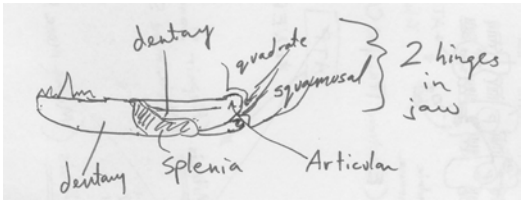
- Reptile
  - 1 ear bone = hyomandibular (or stapes)
  - quadrate-articular jaw hinge

Mammalian Evolution



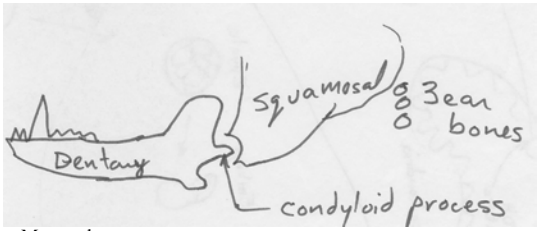
- Reptile
  - 1 ear bone = stapes

Mammalian Evolution



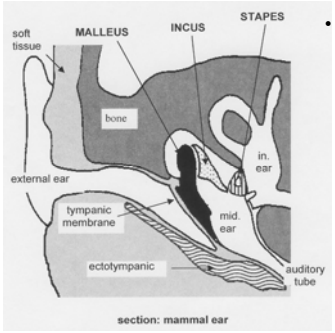
- Mammal-like Reptile : Order Therapsida (therapsids)
  - 1 ear bone = hyomandibular (or stapes)
  - double jaw hinge on each side

Mammalian Evolution



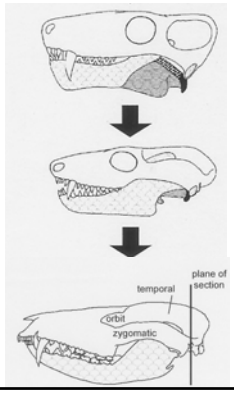
- Mammal
  - 3 ear bones = stapes, malleus, incus
  - dentary-squamosal jaw hinge
  - **malleus** originates from reptilian articular; **incus** originates from reptilian quadrate; **stapes** from reptilian stapes

Mammalian Evolution

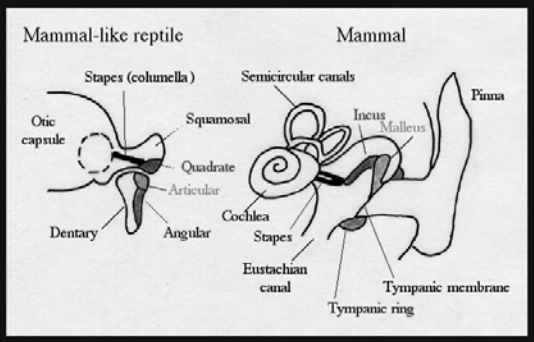


- Mammal
  - 3 ear bones = stapes, malleus, incus
  - ectotympanic = tympanic bullae

Mammalian Evolution



Evolution of the middle ear



Changes in The Skull

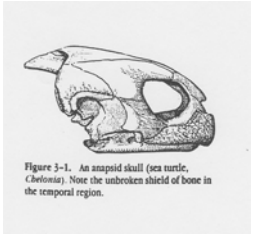
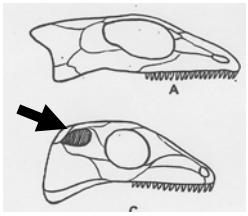
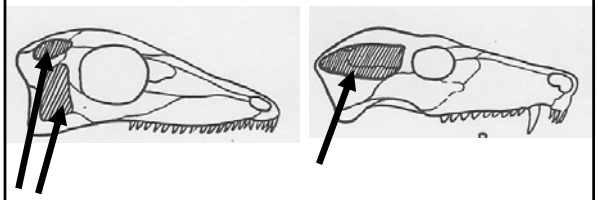


Figure 3–1. An anapsid skull (sea turtle, *Chelonia*). Note the unbroken shield of bone in the temporal region.



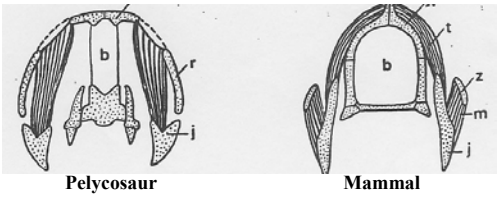
- **Anapsid** skull - no temporal openings or windows
  - primitive reptile design
- **Parapsid** skull - window up high for muscles to pass through
  - marine reptile pattern

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

Changes in The Skull



Pelycosaur **Mammal**

Why did temporal openings originate?

- Some possibilities:

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

Mammalian Evolution

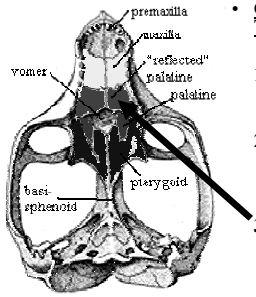


Figure 7. Probainognathus in palatal view. Modified from Carroll (1988)

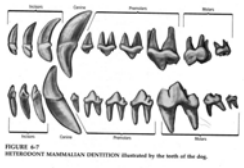
- **<u>Generalized Trend in Evolution of Therapsids</u>:**

1) enlargement of temporal openings

2) adductor muscles attach to outer surface & zygomatic arch region

3) secondary palate formation, like mammals (significance?)

Mammalian Evolution



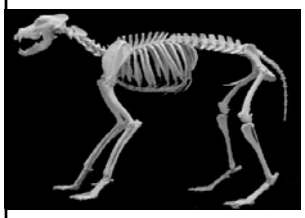
- **<u>Generalized Trend in Evolution of Therapsids</u>:**

4) heterodont dentition

5) dentary bone expands...precursor to dentary-squamosal hinge

6) simplification/fusion of skeletal structure

Mammalian Evolution



- **<u>Generalized Trend in Evolution of Therapsids</u>:**

7) elongation of limbs; more slender limbs shifted ventrally

8) beginnings of endothermy

9) diaphragm developing (lumbar ribs reduced)

Cynodonts

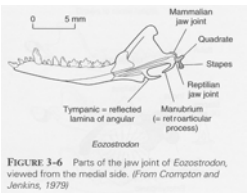


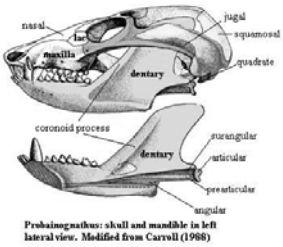
FIGURE 3–6 Parts of the jaw joint of *Eozostrodon*, viewed from the medial side. *(From Crompton and Jenkins, 1979)*

<u>A Special Groups of therapsids....the Cynodonts</u>

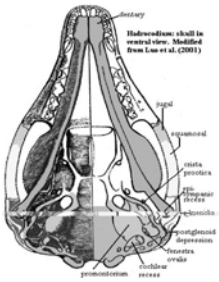
- **Group of mammal-like reptiles from which mammals evolved**
- **Retain characteristics of other therapsids:**

  1) 1 ear bone
  2) 2 jaw hinges
  3) several jaw bones

- **Most mammal-like in anatomical/structural features**

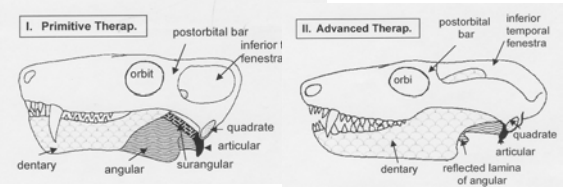


Cynodont jaw articulation



Mammalian squamosal-dentary joint

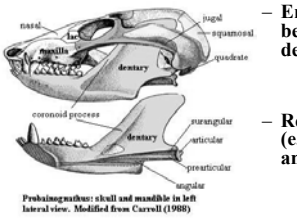
Cynodonts



- **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**

Cynodonts

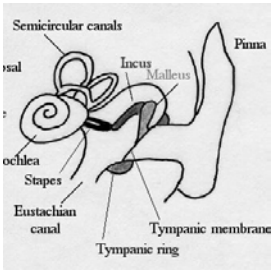
- **Jaw Articulation of Cynodonts**
  - **Enlargement of dentary bone & beginning to form squamosal-dentary articulation; brace point**
  - **Reduction of postdentary bones (e.g., articular, quadrate, angular); hearing**



Cynodont jaw articulation

Cynodonts

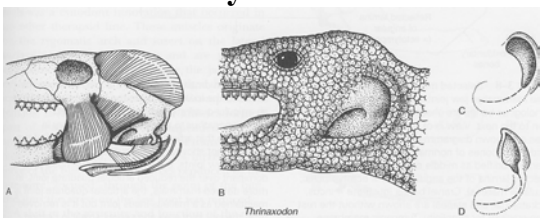
- **Jaw Articulation of Cynodonts**



– **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**

Cynodonts

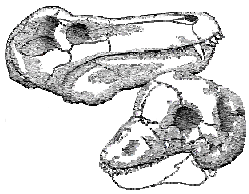


- **Jaw Articulation of Cynodonts**

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

Cynodonts

- **Cynodont Dentition Characteristics:**



– **Beginnings of heterodonty; progresses jaw muscle changes**

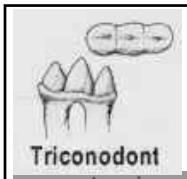
large incisors-canines & small premolars-molars (primitive cynodont)

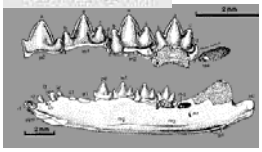
↓

large incisors, canines, premolars, and molars (advanced cynodont & early mammal)

- premolars & molars not differentiated

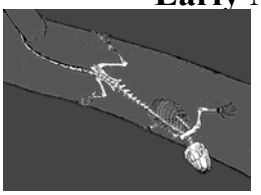
Cynodonts

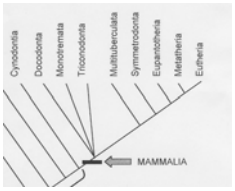




- **Cynodont Dentition Characteristics:**
  - **new teeth erupt between older teeth – continual (~6 generations of replacement)**
  - **stage set for molar evolution = tricodont teeth**
- **Cynodont Skeletal Feature:**
  - **lateral flexure of vertebral column**

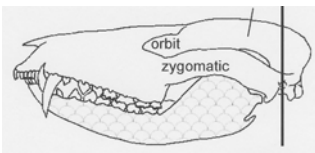
Early Mammals

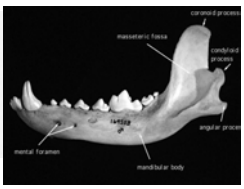




- **Early Mammals(late Triassic-Jurassic)**
  - **monophyletic evolution from cynodonts**
    - **Morganucodonts**
    - **Triconodonts (ancestors of monotremes)**
    - **Multituberculates**
    - **Symmetrodonts**
    - **Pantotheres (ancestors of marsupials & eutherians)**

Early Mammals





- **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

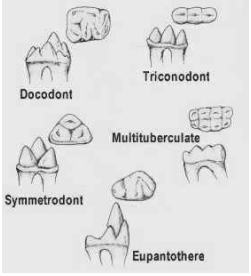
Early Mammals

- **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)**

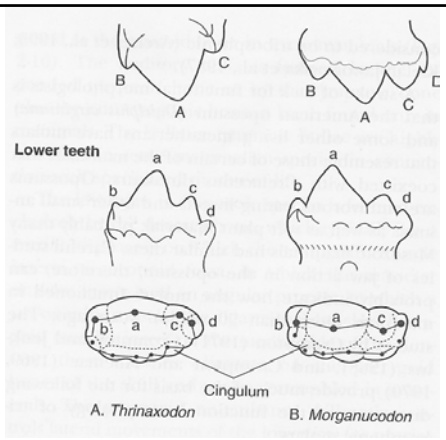
Early Mammals

- **Two groups of early mammals:**



1) Morganucodontidae (origin of monotremes)
- **triconodont molars**

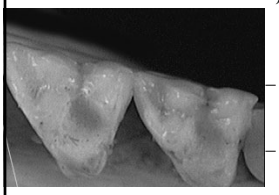
- **Morganucodonts - early off-shoot in late Triassic**
- **Triconodonts**
- **Multituberculates - 1st mammal herbivores, disappear in early Tertiary Period**



Early Mammals

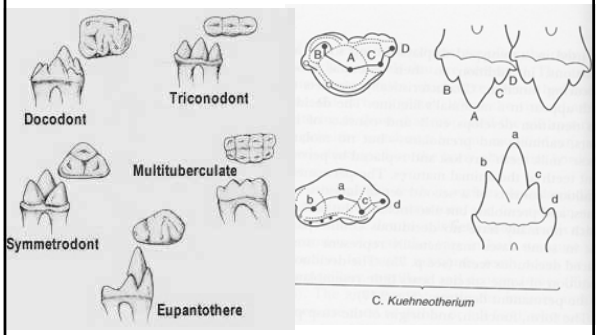
- **Two groups of early mammals:**

2) Kuehneotheriidae (origin of marsupials & eutherians)
- **tribosphenic molars**

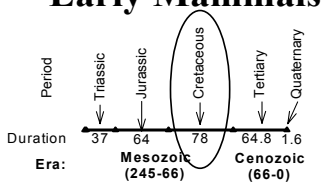


– **Symmetrodonts - late Triassic to late Cretaceous**

– **Pantotheres - late Jurassic, later split into metatheria & eutheria**



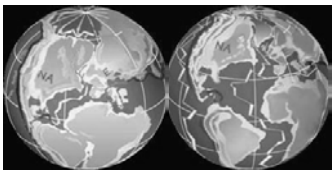
Early Mammals



- **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**

Early Mammals

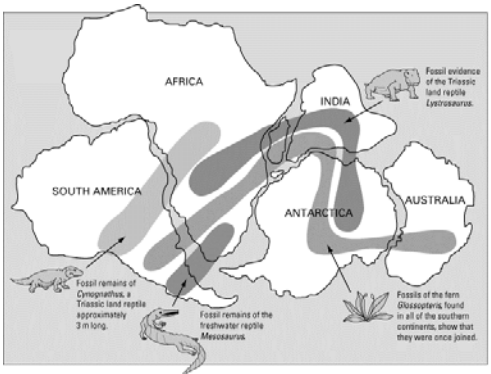
- **Mammals in the Cretaceous Period:**
  - **Stage set for huge adaptive radiations in mammals during the Cenozoic Era**



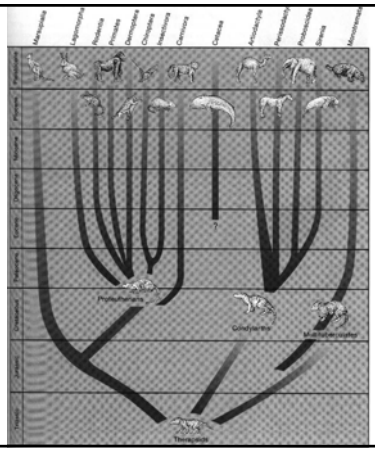
Cretaceous

Tertiary

Gondwanaland: 200 Ma

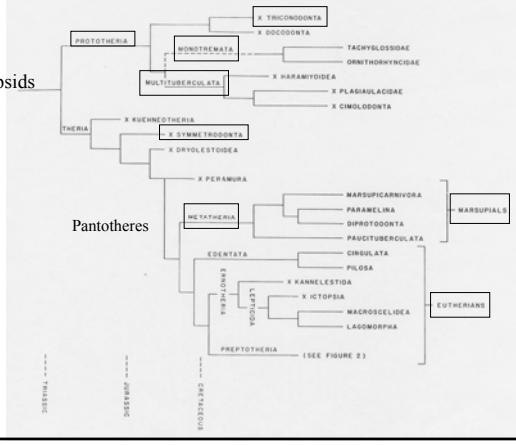


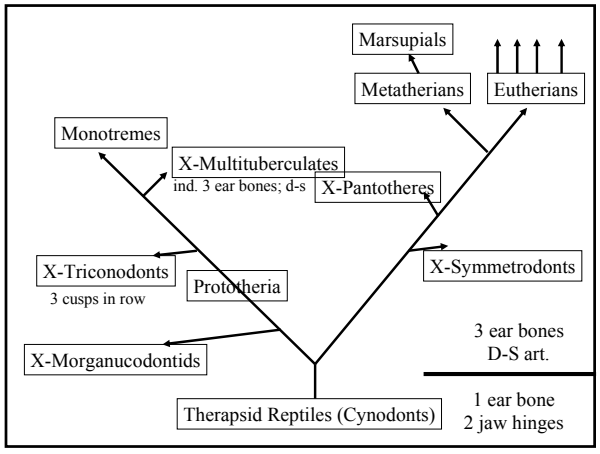
Biogeography

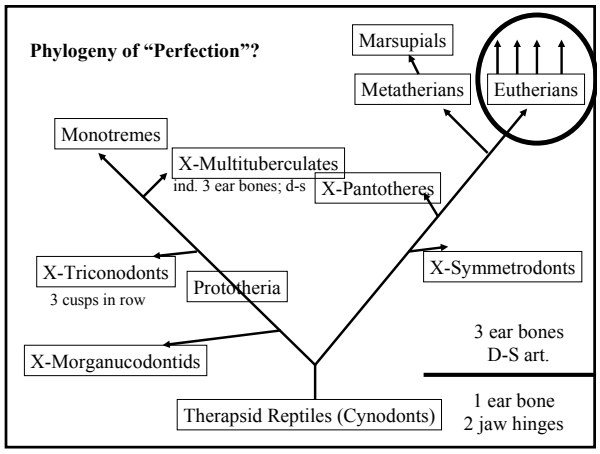


Therapsids

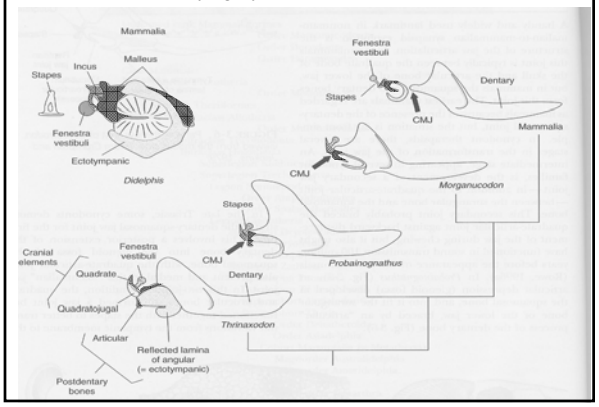
Pantotheres



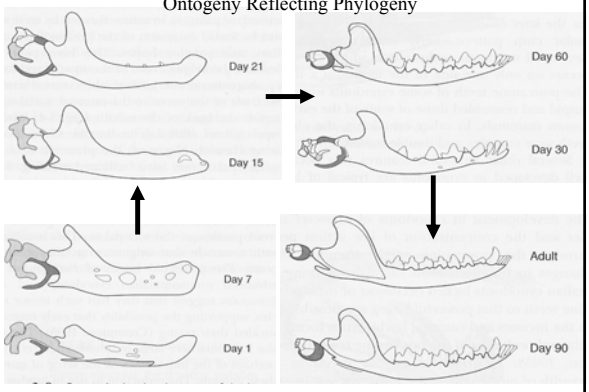


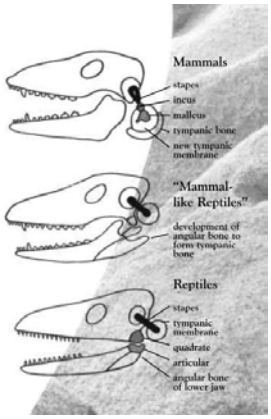


Phylogeny of the Middle Ear

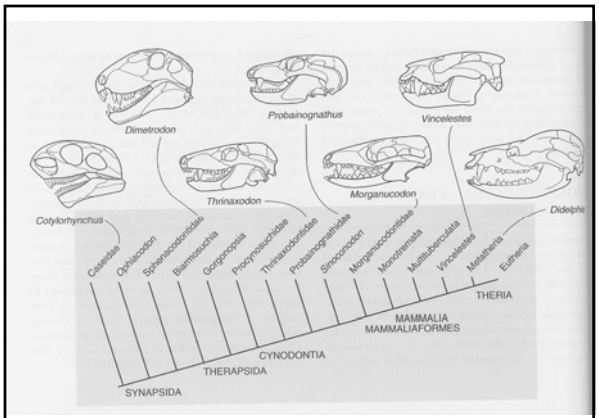


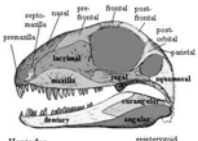
Ontogeny Reflecting Phylogeny



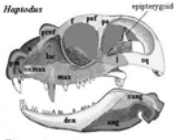


Evolution of Mammalian Middle Ear & Jaw Articulation

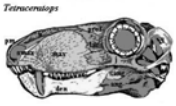




Haptodus

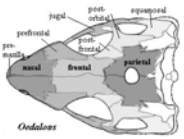


Tetraceratops

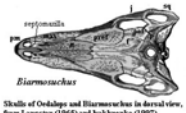


Biarmosuchus

Skulls of Haptodus, Tetraceratops and Biarmosuchus in left lateral view from Carroll (1988), Laurin & Reisz (1996), and Ivakhnenko (1999), respectively.



Oedaleops



Biarmosuchus

Skulls of Oedaleops and Biarmosuchus in dorsal view, from Langston (1965) and Ivakhnenko (1997).

http://www.ucmp.berkeley.edu/geology/anim4.html