

I. Macroevolution refers to large phenotypic changes in lineages, involving many changes in physiology, morphology and ecology. Examples are the development of amphibians from fish, mammals from reptiles.

The best fossil record is that of the development of mammals from reptiles through a series of so-called mammal-like reptiles. First came the pelycosaurs (mid-Carboniferous, some 320 million years ago), then the therapsids (early Permian), and finally the cynodonts in the late Permian (still Paleozoic, remember). Finally, fossils classified as true mammals appear at the earliest Jurassic, some 213 million years ago. Some of the changes that can be followed in the fossil record of these groups are the development of a mammal-like jaw from a reptile-like jaw, with certain reptile jaw bones moving to become the ear bones in the mammal; the development of legs under the body, rather than out to the side. A major change in the jaw is that of the closing muscles moving from the back of the jaw to the sides of the jaw to be able to exert more closing force. In reptiles, the jaw closing muscles run from the top of the head around the back of the head and anchor on the lower jaw. In mammals, the muscles run from the top of the head to the **sides** of the lower jaw. The evolution of this change can be traced in small steps for 100 million years of fossils. Basically, a hole opened up in the skull to allow the lower jaw and muscles to attach farther forward. Other skull changes involved the development of differentiated teeth and multicusped teeth.

This series of fossils clearly show that macroevolutionary change may be accomplished by a long series of small changes, most of which were probably adaptive, and hence due to natural selection. This is the **extrapolative** model of macroevolution — an extrapolation of the small changes we see in the lab with fruit flies over long periods of time produces new kinds of organisms. The extrapolative model does NOT imply simply the addition of new steps at the end of the line — each stage in the evolution of mammals from reptiles radiated into many forms, some of which were more reptile-like, and some more mammal-like. Whatever else was going on, mammalian adaptations evolved in stages, not all at once.

II. How do such evolutionary changes occur? What factors are responsible for the changes in the bones, for instance?

Morphological changes are generally accomplished by developmental changes.

Such changes may be:

- A. Terminal addition, which leads to "ontogeny recapitulates phylogeny"
- B. Non-terminal addition, which does not lead to recapitulation (**see Fig 21.4 in Ridley**)
- C. Heterochrony (**see Fig 21.1 in Ridley**)
 1. Paedomorphosis (juvenile becoming reproductive)
 - a. padeomorphosis by progenesis -- truncation of later life stages, and hence reproduction moves earlier in time
 - b. neotony - prolongation of juvenile stages -- reproduction occurs at ancestral age, but organism is still juvenile morphology - the axolotl salamander is a classic example -- thyroid hormone will produce a morphological adult

2. Recapitulation -

- a. acceleration - somatic speed up, reproductive age unchanged
- b. Hypermorphosis - unchanged somatically, retarded reproduction --
recapitulation by prolongation of reproductive age

SEE Figures 21.3 and 21.5 in Ridley

III. Von Baer's Law: the general features of an organism appear earlier in development than the more specialized features

Why:?

- A. development is continuous & cumulative, hence early changes will have more drastic effect -- tinker with more or less well-built machine -- early tinkering much more likely to produce damage
- B. early developmental stages more shielded from selection -- selection unlikely to demand changes in protected embryo, more likely to demand changes in adults fending for themselves
- C. **see Figure 21.8 in Ridley**
- D. Neotony is common; thus paedomorphosis is common (humans are just one example)

IV. Developmental transformation: axes and planes. By changing the speed of development along a developmental axis or plane, various morphological transformations can be made.

D'Arcy Thompson diagrams (rubber sheets) show this developmental plane change by control of cell growth gradients. **See Figure 21.10 in Ridley.**

V. Is there any other explanation for macroevolutionary change? Macromutation; also called saltation: entirely new forms arise instantly. This is a "hopeful monster" theory, which is unlikely theoretically, and has almost no supporting evidence. It is due to Goldschmidt.

VI. Higher taxa rise, fall and replace one another: WHY? Is there competition or extinction followed by replacement? Competitive replacement or independent replacement? What patterns would one expect?

Figure 21.12 in Ridley shows the different patterns one would expect under the "gradual extinction, then new group arises", "mass extinction followed by new group arising", and "competitive replacement" theories of group replacement in the fossil record. This test is not foolproof, due to the incompleteness of the fossil record, and the fact that major environmental changes could lead to patterns that look like competitive replacement.

- VII. What do the data show? Is one mode of replacement more common than the others?
- A. at the K-T boundary, the dinosaurs die out. A while later, the mammals radiate. This appears to be a case of mass extinction, followed by the best survivors taking over.
 - B. in plants, angiosperms gradually take over from gymnosperms in the latter Mesozoic and the Cenozoic. This follows the pattern we would expect from competition?
see Figure 21.15 in Ridley
- VIII. Are there any general trends in macroevolution? (a trend is a directional evolutionary change persisting for long enough to be recognizable in fossil record)
- A. Cope's rule (Edward Drinker Cope) — animals (not plants — he could care less) tend to evolve larger size over time. This is not infallible, but does seem to be a trend. Why? For any group of animals, there seems to be a lower size limit, but not an upper size limit. In addition, and especially in macro-animals, the larger a prey is, the more predators it can escape, while the predators must keep getting larger to catch the prey.
 - B. Questions to ask about possible trends: (which of the following is meant by "trend"?)
 - 1. Is there a consistent change in one lineage?
 - 2. Is there average change over several lineages?
3. see Figures 21.3 and 22.14 in Ridley
 - C. Look at Horses: not all lineages followed Cope's Rule, but many did, such as horses
 - D. What explanations are there for macroevolutionary trends?
 - 1. Natural selection explanations:
 - a. driven by directional change in the physical environment -- changes in sea temperature forcing morphological change (heat balance, etc.)
 - b. if change limited by availability of mutations, change will be spread out over long periods of time and thus show trends
 - c. if each stage in evolution forces the next stage — direct competition, predator-prey relations. Coevolution - when two or more species directly influence each other's adaptations - host parasite may be most common. **See Figure 22.7 in Ridley.**
 - 2. Species selection explanations -- must **not** include natural selection which is more powerful. Species selection involves trends made by differential extinction rates or speciation rates, which are correlated with some character, without natural selection playing a role within the species.
 - 3. Chance: a perceived trend may just be due to chance: random variation will, over short periods of time, sometimes look like a trend.