The Cambrian Explosion and Beyond
Chapter 15

Singe-celled organisms dominate much of the history of the living earth. Multi-cellular organisms first appear in the fossil record !565 million years ago. In about 40 million years, the basic body plan for every major phylum of animals appears (both extant and extinct). This brief period of massive diversification is called the Cambrian Explosion.

I) The Fossil Record – nearly all of the information that we have concerning the evolution of life comes from the fossil record.

A) Fossil Formation

1) Compression and Impression – material is buried and covered before decomposition. Two-dimension imprint is left in hardened rock

2) Mineralization – organism are buried in sediment and dissolved minerals precipitate in the cells. Three-dimensional fossil is recovered with minerals replacing organic matter.

3) Casts or molds – material is buried and covered. After decomposition, the unfilled space is a mold or when filled with mineral is a cast.

4) Unaltered remains – the organic material is found, in tact and essentially unaltered (pollen grains in mud cores, animals in amber, etc.)

B) Dating Fossils
(www.enchantedlearning.com/subjects/dinosaurs/dinofossils/Fossildating.html)

1) Stratigraphy – Sedimentary rock layers (strata) are formed episodically and horizontally over time. Newer layers are formed on top of older layers, pressurizing them into rocks. Paleontologists can estimate the amount of time that has passed since the stratum containing the fossil was formed. Generally, deeper rocks and fossils are older than those found above them.

2) Magnetic Field – the Earth's magnetic field has switched poles (i.e., N ⇔ S) periodically over time and can help date fossils

3) Radioisotope dating - Unstable radioactive isotopes of elements, such as Uranium-235, decay at known rates over time (its half-life, which is over 700 million years). An accurate estimate of the rock's age can be determined by examining the ratios of the remaining radioactive element and its decay product(s). Over time, the unstable radioactive Uranium decays into Lead-207. By comparing the relative proportion of Uranium-235 and Lead-207, the age of the igneous rock can be determined. Potassium-40 decaying to argon-40 is also used to date fossils. Various elements decay at different rates and therefore some are good for short time spans and others are good for longer (e.g., The half-life of carbon-14 is 5,568 years).

4) Index fossils – common fossils found through the globe and serve to "index" the stratigraphic record (e.g., Ammonites were common during the Mesozoic Era. 245 to 65 mya)

C) Strengths and Weaknesses – there are some biases in the fossil record.

1) Geographic – fossilization is a specialized process and require a specific set of conditions. Most fossils are found are found in lowland and marine environments.

2) Taxonomic – most fossils are marine animals, but only ~10% of extant species are marine. Many, many organisms do not have bodies or body parts that are appropriate for fossilization.

3) Temporal – the earth's crust is constantly recycled (erosion and subduction). Newer fossils are therefore old rocks are more rare than new ones as are the fossils they contain.

4) Distributional – Generally, very few individuals of a species are fossilized and finding them is very difficult. A species limited to a small geographic area, existing as a small population, or arising and going extinct very quickly is not likely to be captured (or found) in the fossil record.

II) The Geological Timeline – The history of the earth is divided into Eons, Eras, Periods, Epochs and Stages originally defined by the types of fossils they contained.

A) The Phanerozoic Eon

Era	Period	Epoch	mybp	Major Events
Cenozoic	Quanternary	Recent (Holocene)	0.01	Several episodes of glaciations, extinctions of large mammals.
		Pleistocene	1.8	
	Tertiary	Pliocene	5.2	Earliest hominids
		Miocene	23.8	Opening of the Red Sea. Radiation of grazing animals
		Oligocene	33.5	Very dry climate, Alps and Himalayas form. First primates
		Eocene	55.6	Ice at poles. Radiation of angiosperms and insects.
		Paleocene	65.0	India meets Eurasia. First horse
Mesozoic	Cretaceous		144	Cool climate. Rocky Mountains form. First flowering plants and placental mammals
	Jurassic		206	Warm climate with little seasonal variation. First bird
	Triassic		251	Warm climate, Atlantic ocean begins to form. First dinosaurs and mammals
Paleozoic	Permian		290	Glaciation on southern continents. First plant vessels
	Carboniferous		353.7	Warm climate little seasonal variation. First reptiles
	Devonian		408.5	Climate cools. First insects, ferns, vascular plants, winged insects, tetrapods (amphibians), seed plants
	Silurian		439	First land plants, jawed fish
	Ordovician		495	First bryozoans, jawless fish
	Cambrian		543	Warm climate. First Shelled organisms, Arthropods diversify, first cordates
Pre-Cambrian	Vendian		670	
	Sturtian		800	Origin of life in past

B) The Cambrian Explosion – most of the known animal body plans were formed during the Cambrian (543 mybp).

1) Major Body Plans:

Diploblasts – ectoderm and endoderm, asymmetrical or radially symmetrical

Triploblasts – Ectoderm, endoderm and mesoderm. Tripolblasts are bilaterally symmetrical.

Acoelomate – body cavity is a solid mass of mesoderm (no body cavity).

Pseudocoelomate – have body cavities but are not derived from mesoderm.

Coelomate – true fluid filled body cavity derived from mesoderm (tube in tube). Requires a hydrostatic skeleton resulting in improvements in movement.

Protostomes – gastrulation forms the mouth first.

Deuterostomes – gastrulation forms the anus first then the mouth.

Other – many other body plans were formed but have subsequently gone extinct (e.g., Burgess Shale)

III) Macroevolutionary Patterns

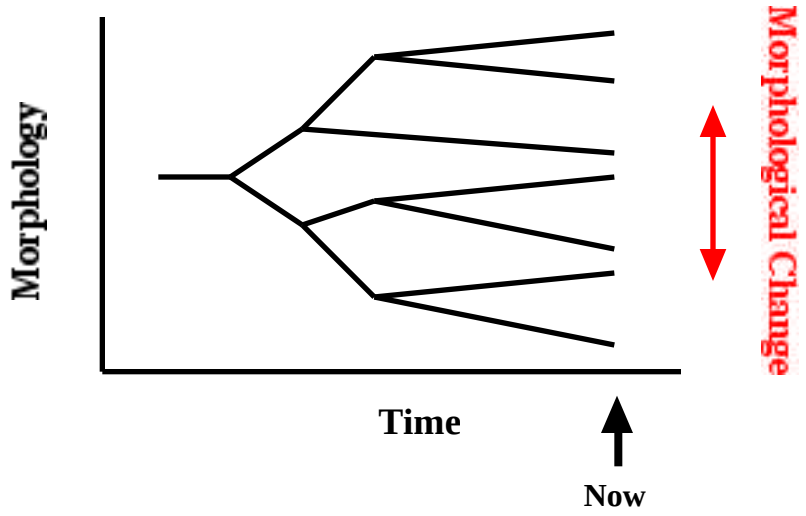
A) Adaptive Radiations – single ancestral species diversifies into a large number of species occupying a wide variety of niches.

1) Ecological opportunity – open niches with few competitors.

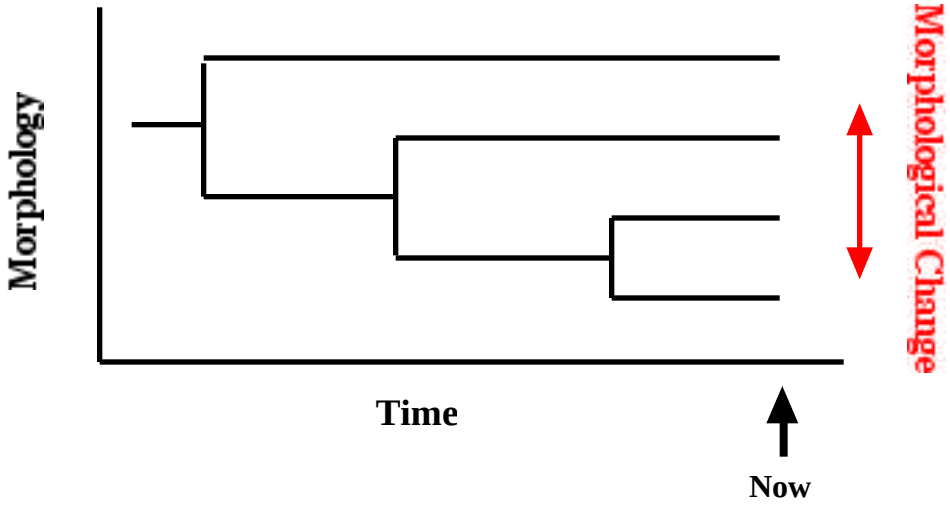
2) Key innovations – morphological changes that allow diversification (pharyngeal jaw in fish, arthropod joints)

B) Rates of Morphological Change – the fossil record seems to indicate an alteration between long periods lack of change with short bursts of morphological change.

1) Gradual Evolution – change within a lineage (anagenesis) occurs continually over time along with speciation (cladogenesis).



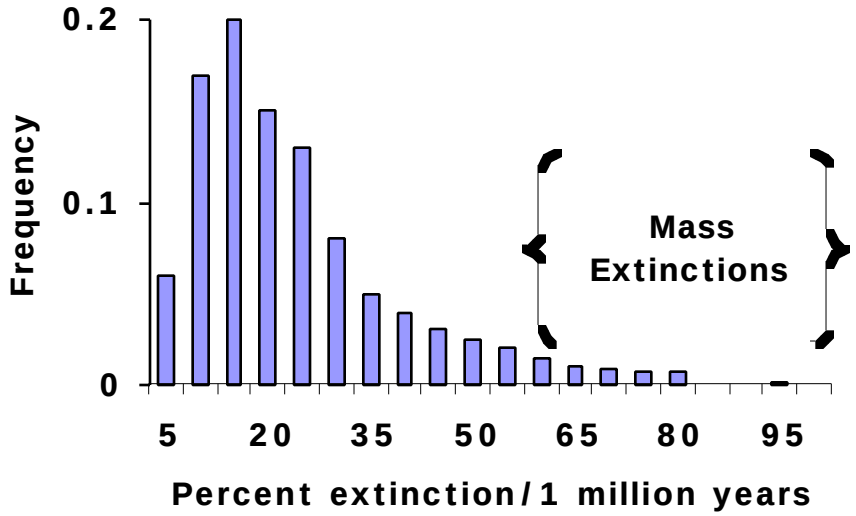
2) Punctuated equilibrium – all morphological change occurs at the time of speciation that is very rapid



IV) Extinctions – is the ultimate fate of all species.

A) Background extinctions – "normal" rate at which species have gone extinct. Can vary significantly from taxa to taxa, but is generally constant probability of extinction.

B) Mass extinctions – notable time in the fossil record where a large percentage, globally, (i.e., greater than 60%) of species living at that time have gone extinct.



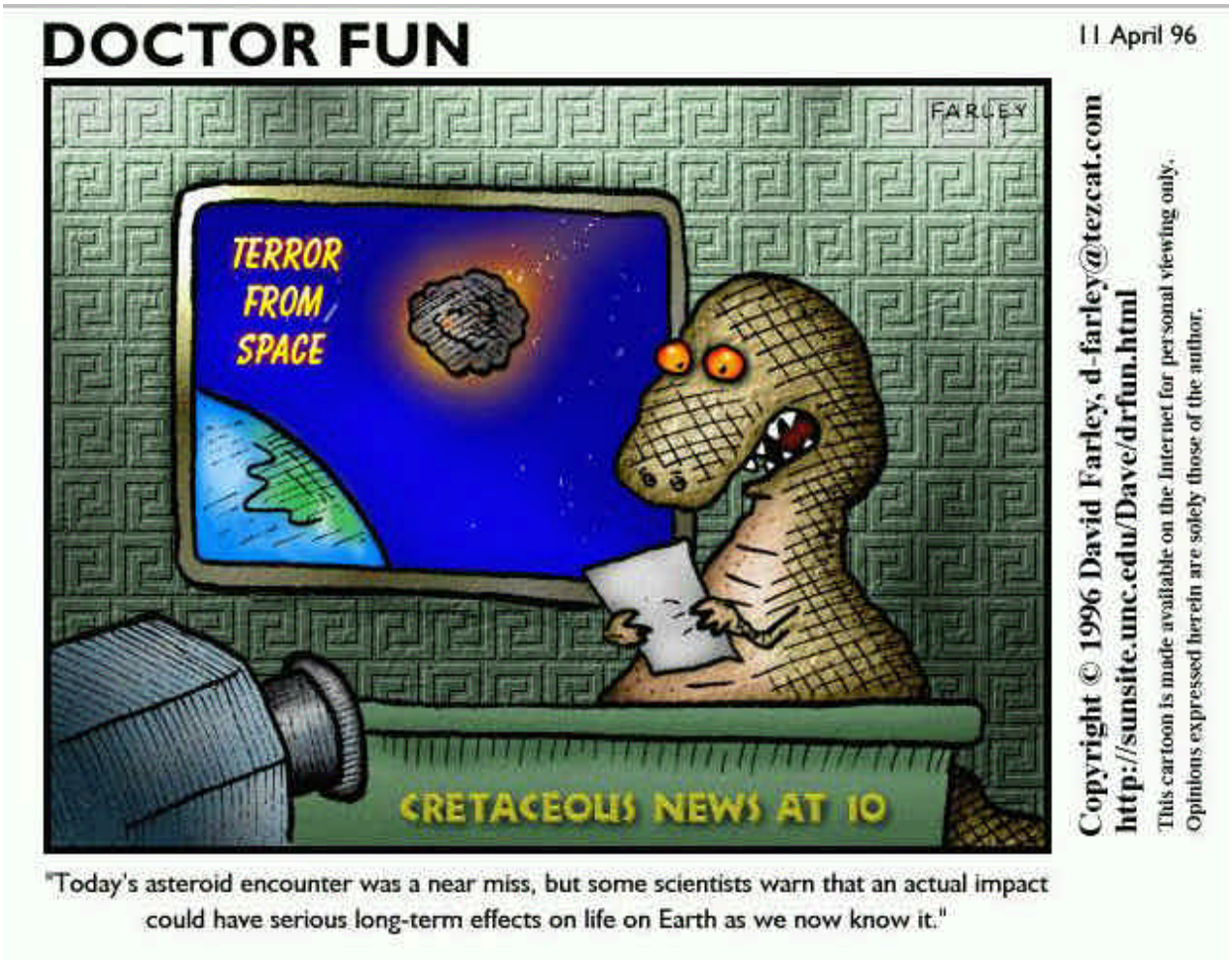
1) Five Major Mass Extinctions
- **a) terminal-Ordovician (440 mybp)**
- **b) late-Devonian (365 mybp)**
- **c) end-Permian (250 mybp)**
- **d) end-Triassic (215 mybp)**
- **e) Cretaceous-Tertiary boundary (K-T, 65 mybp)**

2) Causes of Mass Extinctions – highly variable and may be different for each of the above.

a) K-T extinction is thought to be due to a large (i.e., 10 Km diameter) asteroid striking the Earth near Yucatan, Mexico about 65 mybp.

- **i) Iridium layer coincides with K-T boundary layer globally**
- **ii) Shocked quartz particles previously only found at other asteroid impact sites also found globally**
- **iii) microtektites (glass particles) are formed by the heat of the impact and often teardrop shaped (due to ejection).**
- **iv) 180 Km crater indicated by magnetic and gravitational anomalies, dated to 65.06 ± 0.18 mybp**

b) Result of the K-T impact



i) Global cooling and global winter - vaporization of water and sulfur dioxide as well as dust and soot caused by enormous fires would have caused acid rain and global cooling

ii) Impact would have set off major earthquakes (~13 on Richter scale) resulting in increased volcanic activity.

iii) Impact in the ocean likely caused a tremendous tidal wave. A 300 Km long sand deposit similar to those found associated with tidal waves was found in Texas. In Haiti, there is a mixed sand layer typical of tidal waves that is sandwiched between a tektite layer below and an iridium layer above.

C) Modern Extinctions – species extinctions are without a doubt occurring due to human mediated causes. The rate of extinction appears to be higher than that equated with non-human events, but much less than typically considered a mass extinction. The rate of species extinction is not globally uniform, but affects some species rich areas disproportionately.