Biology 1B—Evolution Lecture 11 (March 19, 2010), Insights from the Fossil Record and Evo-Devo

Extinction

Important points on extinction rates:

- Background rate of extinctions per million species per year:
  About 1 extinction per million species per year, so if there are roughly 10 million species on the planet, that would imply that about 10 species go extinct per year
- Environmental pressures, such as changing temperatures or volcanism, commonly cause extinction of species, but extinction also occurs in a "constant" environment
- Broadly, a typical species lasts 2-10 million years

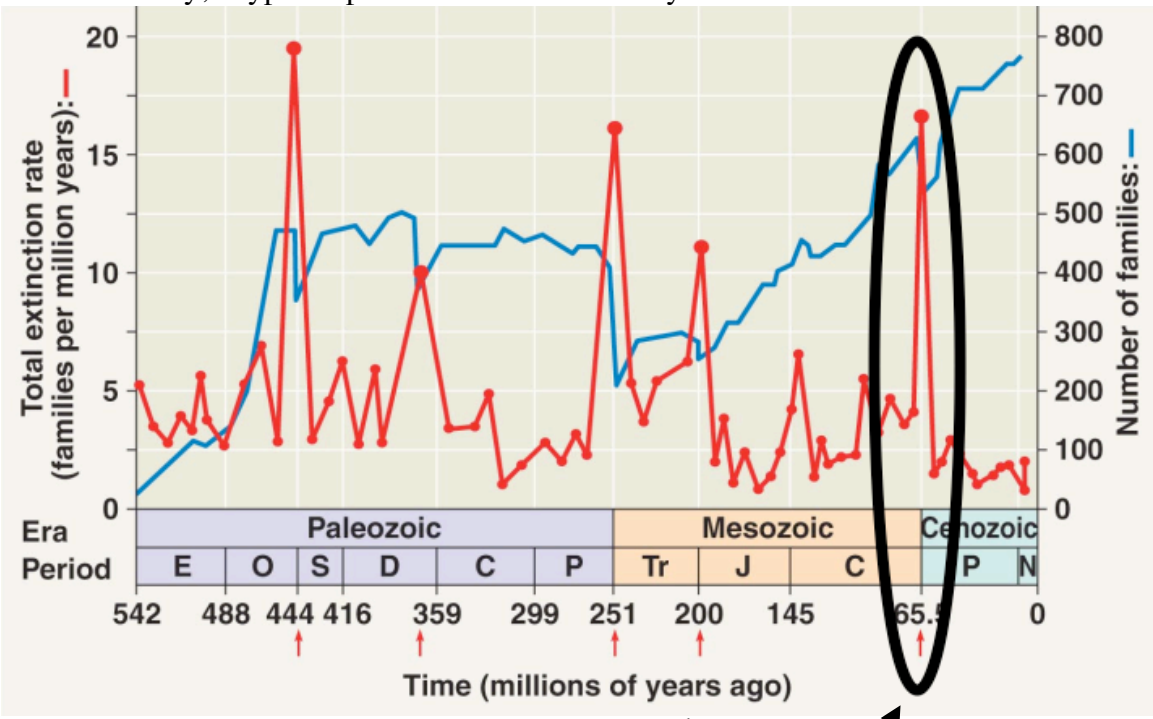


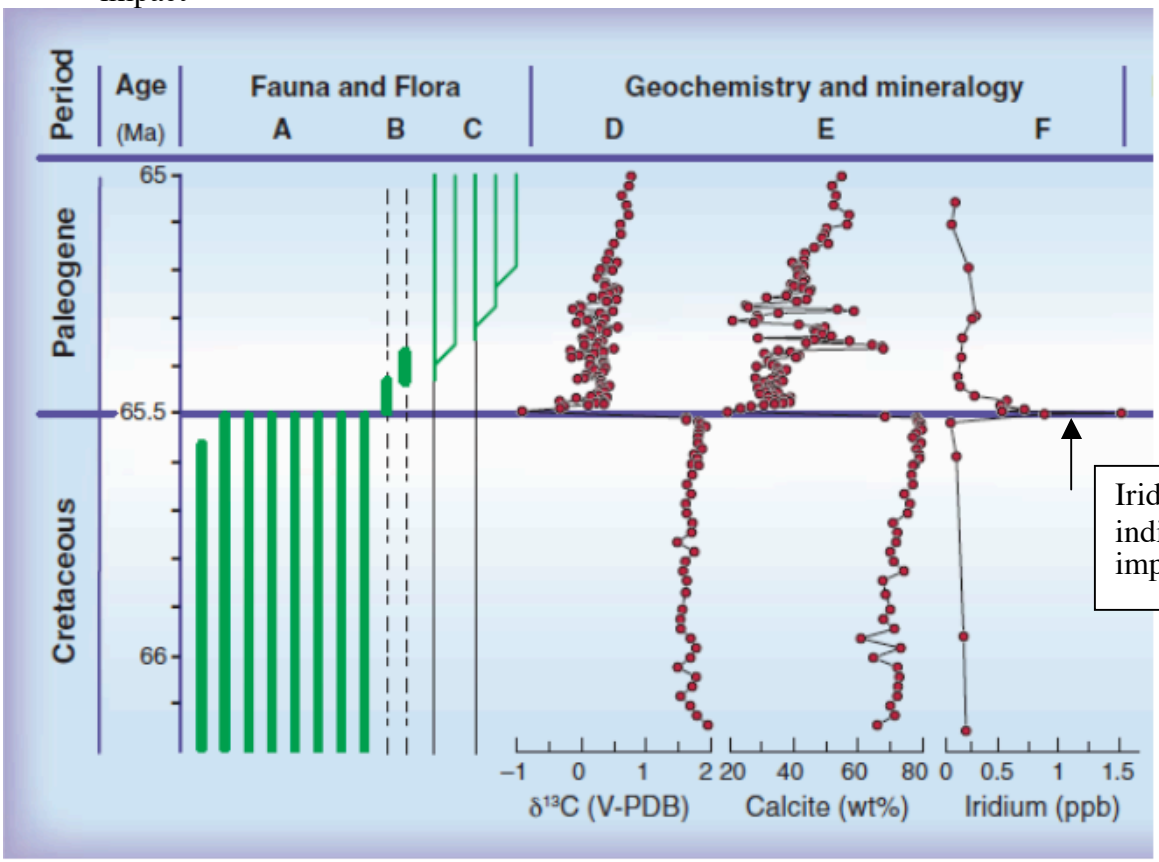
Figure 25.14 (page 521, 8th edition)

Huge extinction the result of a comet impact (more below)

Cretaceous-Paleogene (Tertiary) Extinction—K/T Boundary

- Most importantly, this marked the demise of the dinosaurs (save for modern dinosaurs, which are birds)
- With the end of the dinosaurs came the adaptive radiation of the mammals
- Luis and Walter Alvarez (of UC Berkeley!) worked to find what caused the K/T boundary/extinction of the dinosaurs
  --Walter, a paleonotologist, noticed a layer of dark silt between fossils of organisms between the Cretaceous (large-bodied animals) and Paleogene (smaller-bodied animals)
  --He asked his father, a physicist, what might be studied in the isotopes in the dark silt layer

--They found a huge spike in the amount of iridium, which suggested a comet impact



--Despite the scrutiny and disbelief of the scientific community, the crater the comet would have left in the Yucatan was eventually found

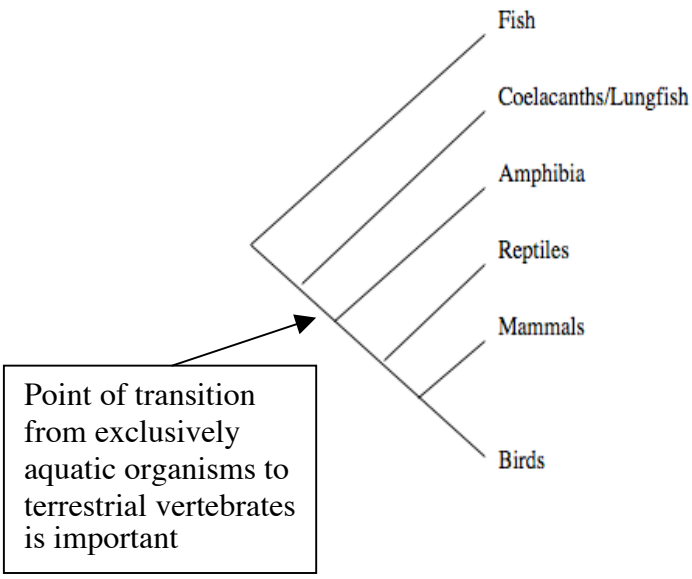
- The massive impact of the comet ejected sediments into the air, halting photosynthesis and changing the raw material of the planet
- It took about 10, 000 years to restore the Earth's normal ecological processes

Are we in a sixth mass extinction?

- Very difficult to know for sure, as we don't even know how many species there are on the planet (we've only described 1.6 million of perhaps 10-15 million total species)
- Amphibians are closely tied to environmental conditions, and 30% of known species are now endangered
- Better evidence of a mass extinction might come from the loss of megafauna (smilodons, mastodons) that might be the result of humans hunting, climate change, or both
  --North American and Australian megafauna went extinct roughly after humans arrived in North America
  --Africa still has many megafauna, suggesting that they evolved with the humans and human ancestors there
- We also see extinctions of large birds, such as rails and moas soon after the recent colonization of Pacific Islands by humans

Major Transitions in Phenotypes

Vertebrate Fish ⟶ Amphibian Tetrapods



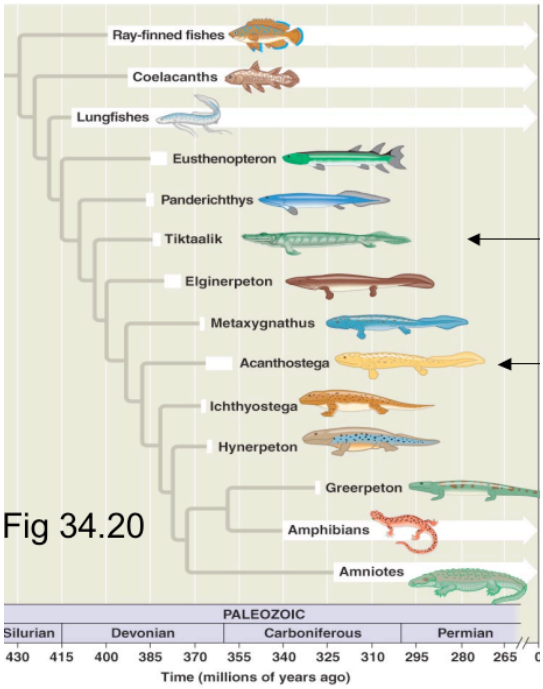


Figure 34.20 (page 711, 8th edition)

- There is a huge jump between these groups (particularly in phenotypes), which cannot be constructed from modern fauna—this is where the fossil record comes into play
- The transition from ancestors of lungfish to ancestors of tetrapods, and key insights are coming from fossils
  --Acanthostega has a moving neck, lungs, limbs, but no wrists and a weak rib cage that would have made breathing on land very difficult, so it probably lived in a swamp
  --Tiktaalik, however, has the evolved traits of Acanthostega plus wrists and a stronger rib cage (see image below)
- The extinct forms are not necessarily direct ancestors, but they do allow us to see how and when certain traits/adaptations evolved

Evolution of Novel Structures and Exaptation

- The hammer and anvil bones of the middle ear of mammals that act as transmitters from the outer ear into the inner ear
- There is a complete set of fossil transitions that takes us from the original function of the bones (articulation points of the jaw) in cynodonts and synapsids

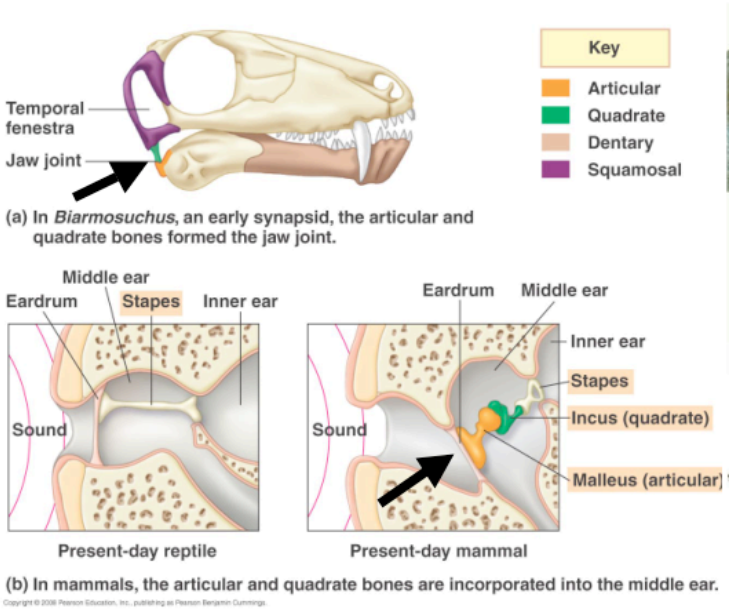


Figure 34.31 (page 721, 8th edition), see also Figure 25.6 (page 513, 8th edition)

- Co-opting structures from one function to another is known as **exaptation** (don't need a new structure to arise, can simply modify an existing one)
- Feathers are another example—their original purpose may not have been for flight, but rather for attracting mates or thermoregulation
  --new studies have found dinosaurs with feathers that were colored, but not for flight, suggesting their use in display

Evolutionary Novelties—Development and "Deep Homology"

- Re-programming of developmental pathways can cause changes in timing/location of expression of key regulatory genes
- Within sets of genes, there are often duplicates, allowing one copy to be kept and others to be used for new functions

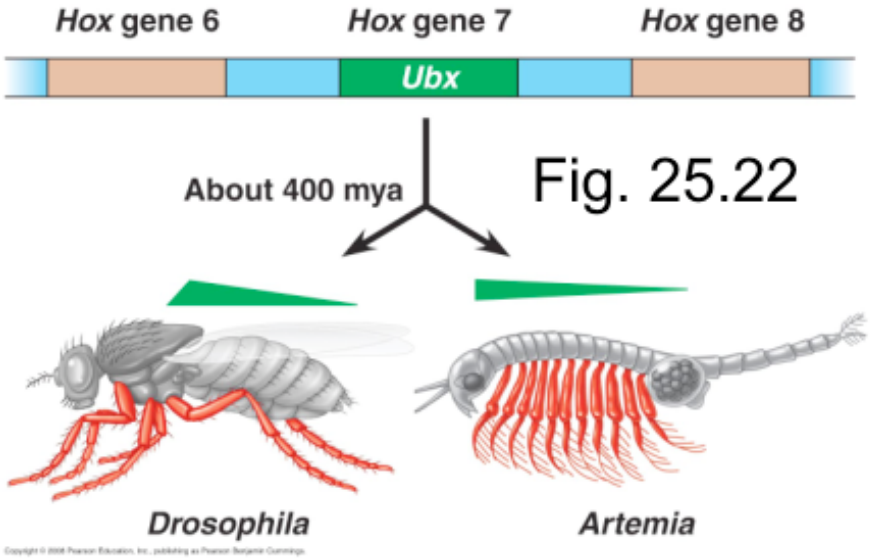
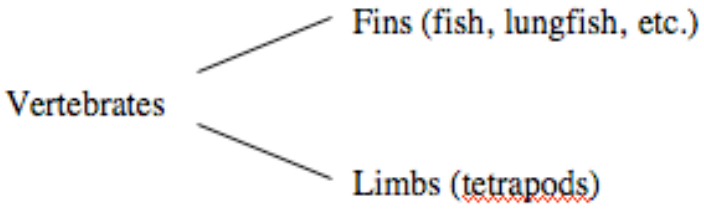


Figure 25.22 (page 527, 8th edition)

- In insects, the Ubx gene suppresses leg development to 6 legs, but it can have a different effect in other species

Deep Homology:

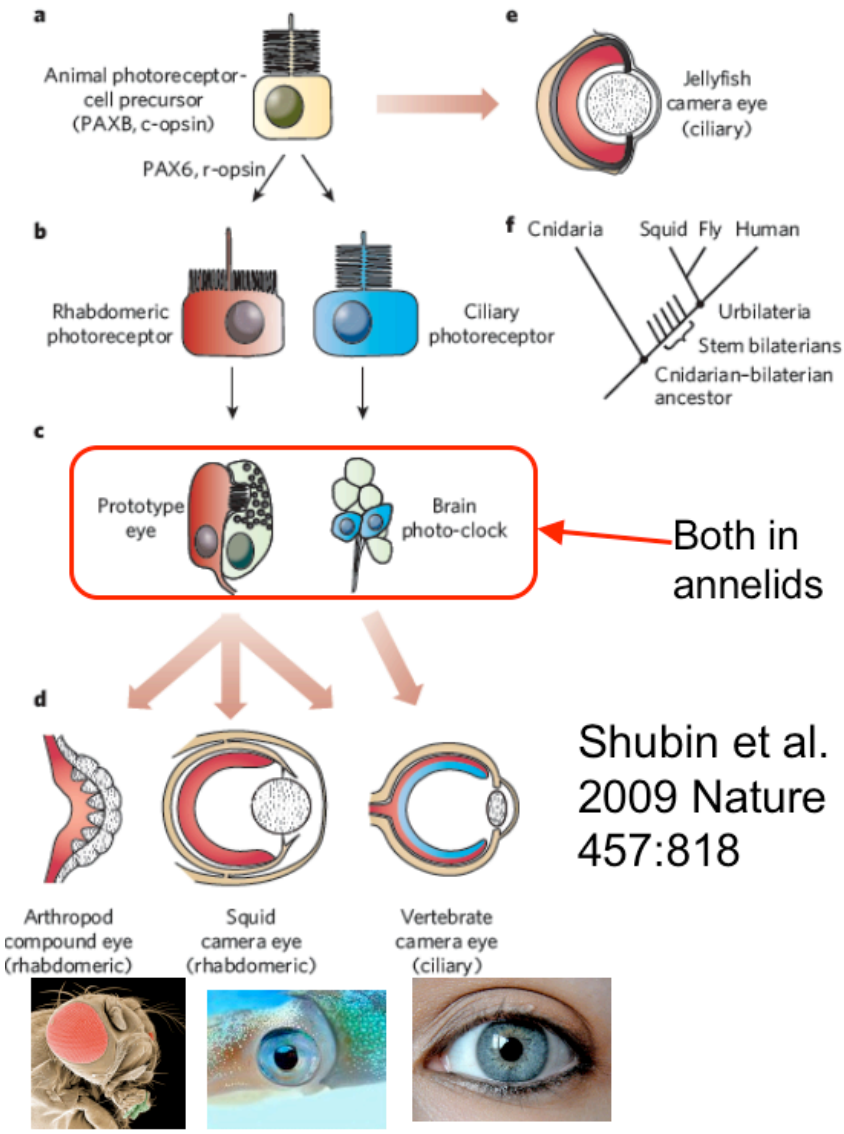
- Very different structures that have a common site of developmental genes



These structures have very different anatomy, yet they have similar patterns of *Hox* gene expression

Origin of Novelty: the Eye

- Eyes of humans and squid are analogous (i.e. independently evolved between vertebrates and mollusks)—the diagram below shows multiple types of eyes
- Homologous genes code for these types of eyes, yet there is a range of structures and consequent sight capability within the two groups


a
Animal photoreceptor-cell precursor (PAXB, c-opsin)
PAX6, r-opsin
e
Jellyfish camera eye (ciliary)
b
Rhabdomeric photoreceptor
Ciliary photoreceptor
f
Cnidaria
Squid
Fly
Human
Urbilateria
Stem bilaterians
Cnidarian–bilaterian ancestor
c
Prototype eye
Brain photo-clock
Both in annelids
d
Shubin et al. 2009 Nature 457:818
Arthropod compound eye (rhabdomeric)
Squid camera eye (rhabdomeric)
Vertebrate camera eye (ciliary)