**Phylogenies and the History of Life (Ch. 27)**

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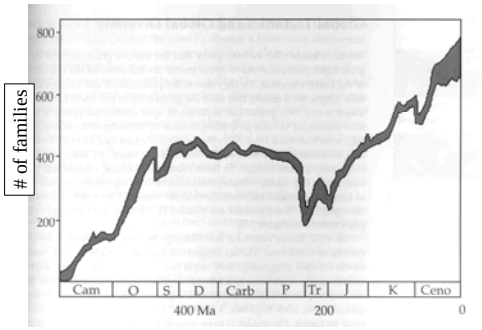
# Phylogenies and the History of Life

## I. Introduction

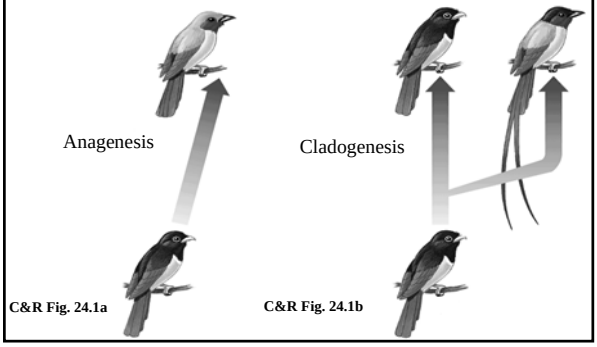
- Life has existed on Earth for some 3.8 billion years:
  - What patterns can be discerned in the tree of life as species appeared and disappeared over the course of history?
  - Why do those patterns exist?

## Global diversity over time




Cowen, "History of Life", 1990

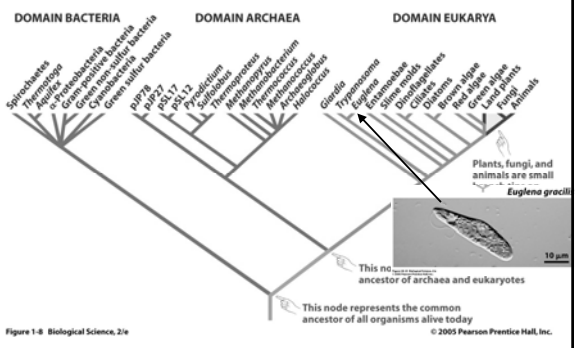
## A. Getting from speciation to the tree of life



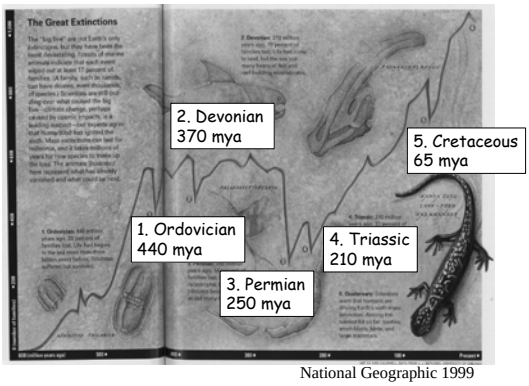

C&R Fig. 24.1a

C&R Fig. 24.1b

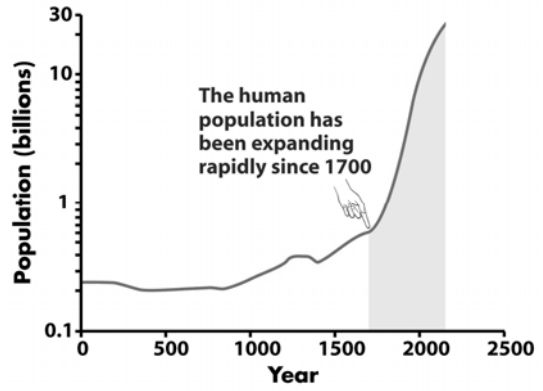
## 3 Domain Scheme



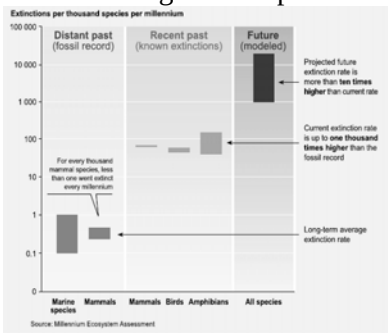

## B. The "Sixth Extinction"?

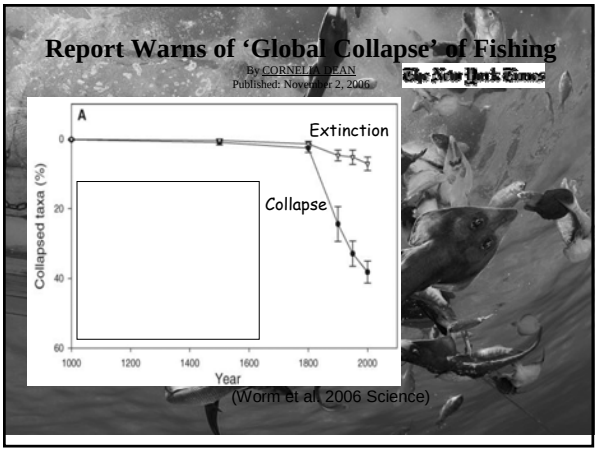



National Geographic 1999




Current extinction rates are 10-100 fold higher than past

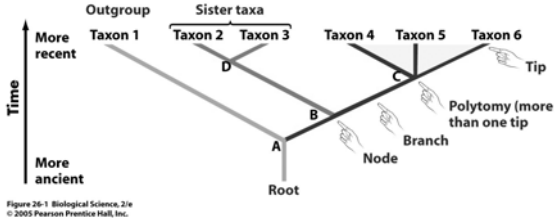



## II. Background
## A. Phylogenies 101

- The evolutionary history of a group of organisms is called a **phylogeny**.
- A **phylogenetic tree** shows ancestor-descendant relationships among evolutionary groups (usually species or populations).

1. Basic structure of a phylogeny



26.2 Phylogenetic tree of some of the great apes

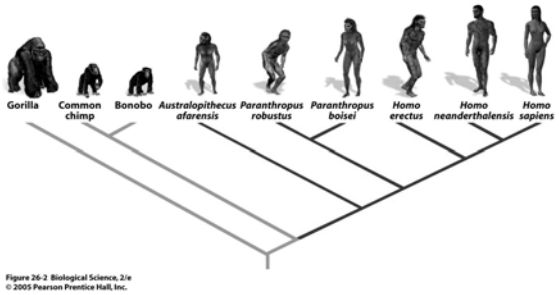



Figure 26-2 Biological Science, 2/e
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Fig. 26-3. Which phylogeny is not like the others?

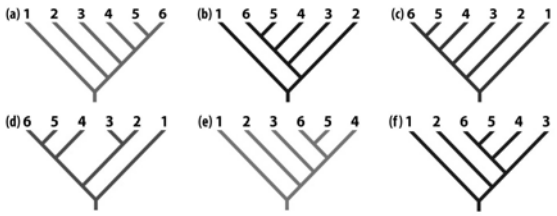


Figure 26-3 Biological Science, 2/e
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## 2. How Do Researchers Estimate Phylogenies?

• Morphological and genetic characteristics are used to estimate phylogenetic relationships among species.

•**Phenetic approach:** similarity indices, clustering

•**cladistic approach:** focus on **synapomorphies** (shared derived characters of the species under study)

26.4

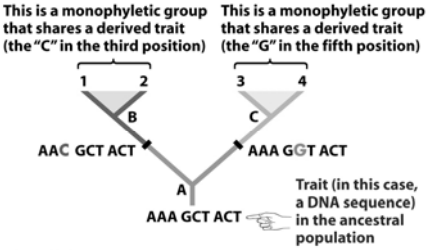


Figure 26-4 Biological Science, 2/e
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## Problem with cladistic approach?

• Convergent evolution: homoplasy (= analogous traits) vs. homologous traits.

• How to avoid this problem?

• **Parsimony**: identify the phylogenetic tree that minimizes the overall number of convergent evolution events.

• **Parsimony**: the most likely explanation or pattern is the one that implies the least amount of change or the least complexity.

• **Assumption**: convergent evolution is less likely than similarity due to shared descent.

## Whale Evolution: A Case History

Phylogeny based on morphological data

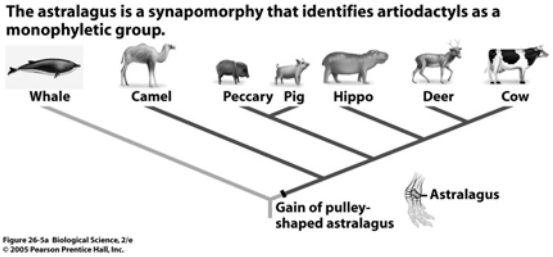


Figure 26-5a Biological Science, 2/e
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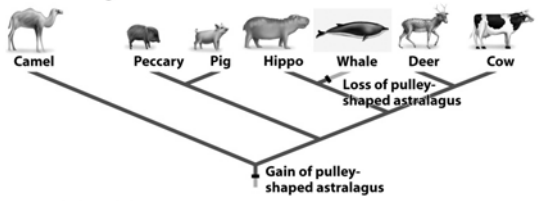
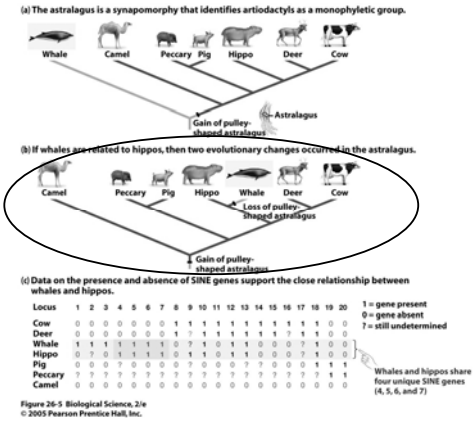
Alternative hypothesis: whales most closely related to hippos

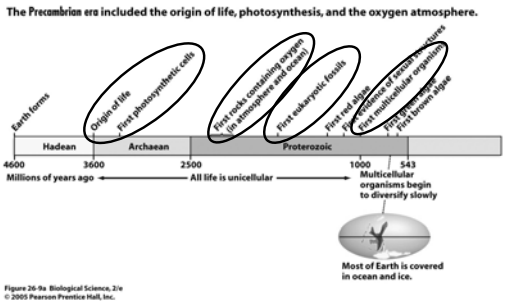


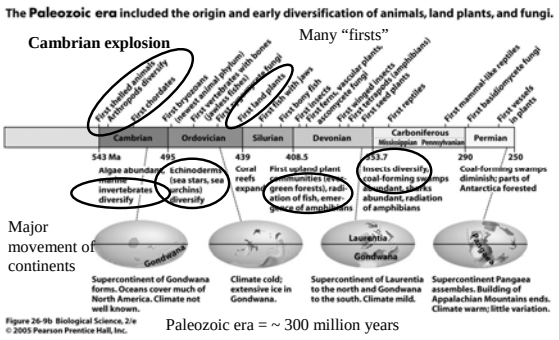

## B. Using the Fossil Record

- The fossil record is the only source of direct evidence about what prehistoric organisms looked like, where they lived, and when they existed.
- Not covered in lecture. See pp. 548-50.
  - How do fossils form?
  - What are the limitations of the fossil record (the 4 biases)?

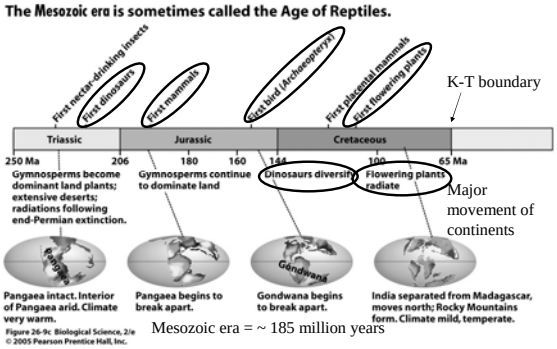
## C. Life's Timeline



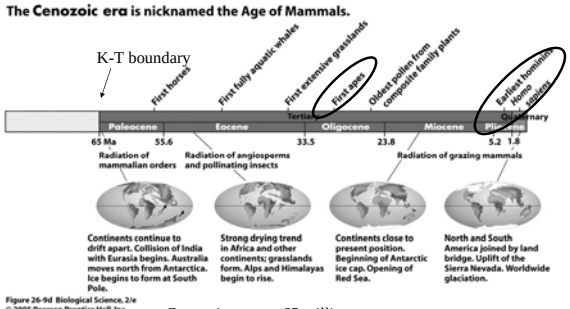

Precambrian = ~ 4 billion years



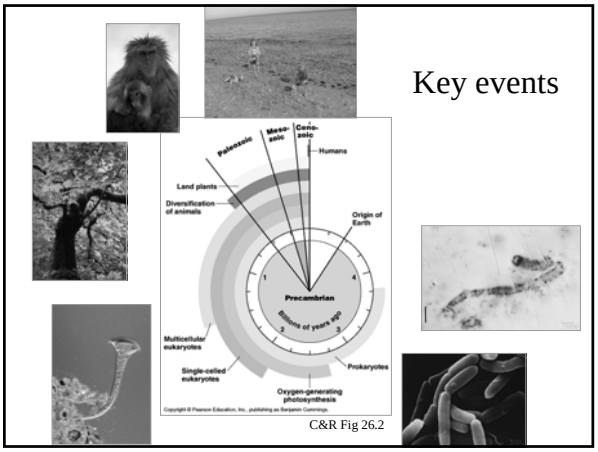

Paleozoic era = ~ 300 million years




Mesozoic era = ~ 185 million years




Cenozoic era = ~ 65 million years




C&R Fig 26.2

## Main points

- Differences in time scales of major eras
- Pattern: “firsts”, radiations, extinctions
- Eras named for various fossil formations – what life forms predominated
- Very recent evolution of humans

## III. Lessons from major branching and pruning of the tree of life

•Is the pace of evolution constant?

•What potential mechanisms could lead to rapid evolution?

•What mechanisms lead to adaptive radiations?

•What are the major extinction events in earth’s history and how have they occurred?

•What have been the consequences for those species that survive?

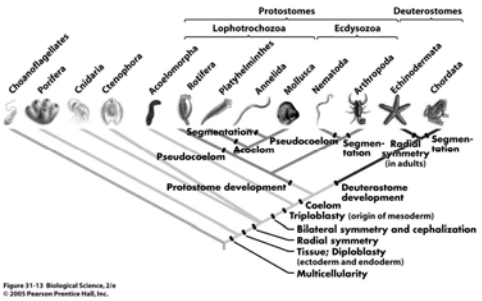
## A. The Cambrian Explosion

• Bottom line: when they finally happened, animals happened fast.

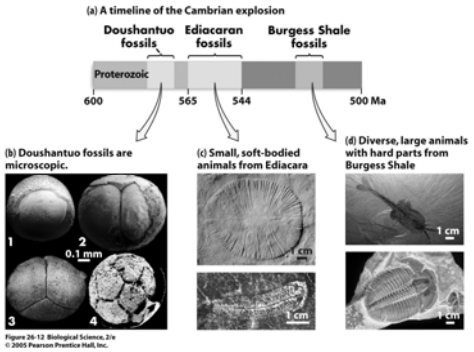
• Animals first originated around 565 million years ago (**Ma**).

•Soon after that, animals diversified into almost all the major groups extant today. This is known as the **Cambrian explosion**.

## Animal phylogeny (Ch. 32)



## 1. Cambrian Fossils: pattern




## 2. The Genetic Mechanisms of Change

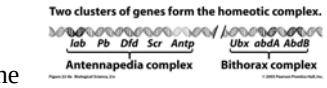
• How did the major changes chronicled in the fossil record occur?

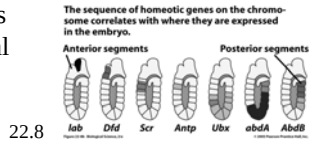
## Evo - devo

- Combination of several fields of study:
  - Paleontology;
  - comparative anatomy;
  - developmental biology;
  - molecular genetics
- Clarify the genetic basis for novel structures such as heads, tails, and limbs
- Called **evo-devo**, because it combines evolutionary and developmental studies.

## Gene Duplications and the Cambrian Explosion

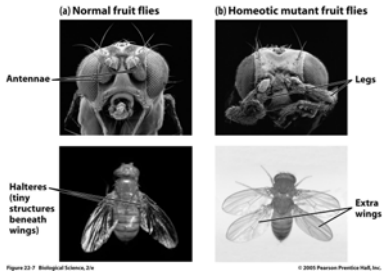
•"New genes, new bodies" hypothesis: should be a strong correlation between the number of homeotic genes (*hox)* present in various animal groups and the morphological complexity of the animals.



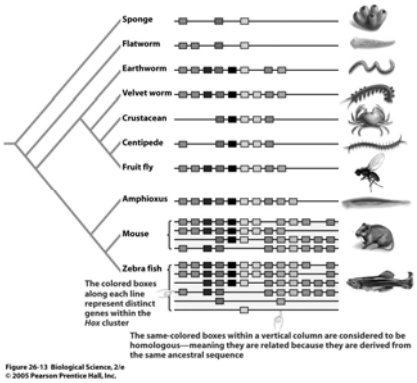



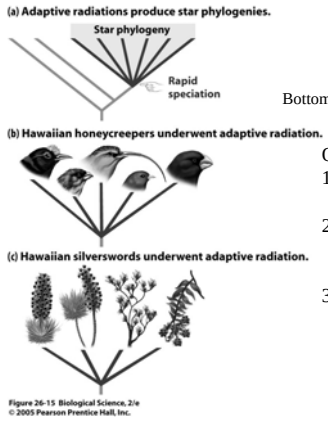

22.8

## Effects of homeotic mutations in fruit flies




Number & type of Hox genes correlates with complexity






## B. Adaptive Radiations

Bottom line: major diversification events.

Questions:

1. What events trigger adaptive radiations?
2. What "signal" do adaptive radiations leave in phylogenies?
3. What role does morphological innovation play in adaptive radiations?

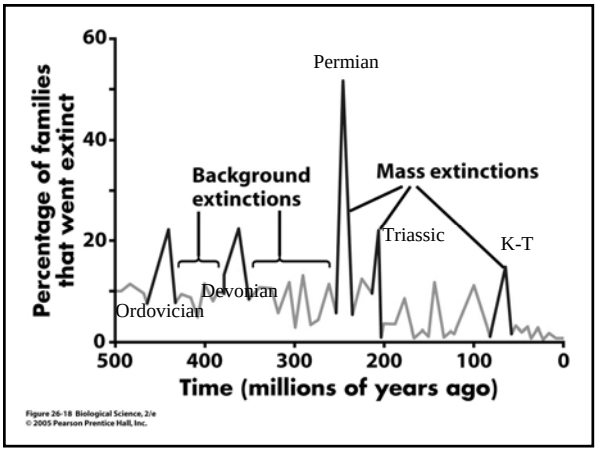
## C. Mass Extinctions

- Bottom line: major losses of diversity

•A **mass extinction** is the rapid extinction of many groups throughout the tree of life (loss of at least 60% of all species within 1 million years). They are caused by catastrophic episodes.

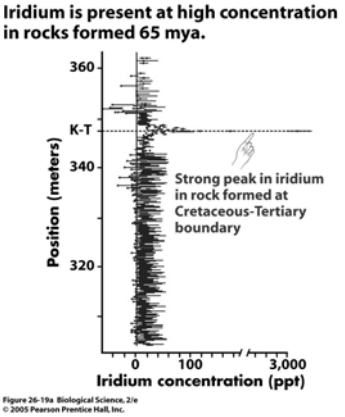
## Questions

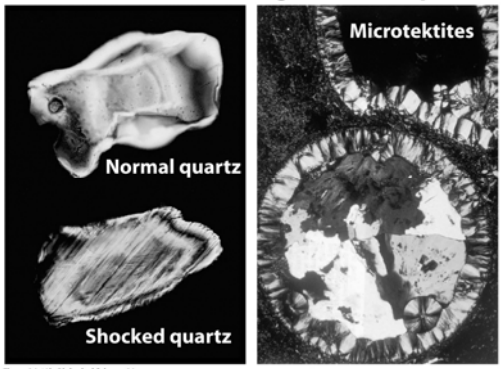
- What event likely wiped out the dinosaurs?
- What three pieces of evidence support this hypothesis?
- What were the consequences for species persisting after this event?

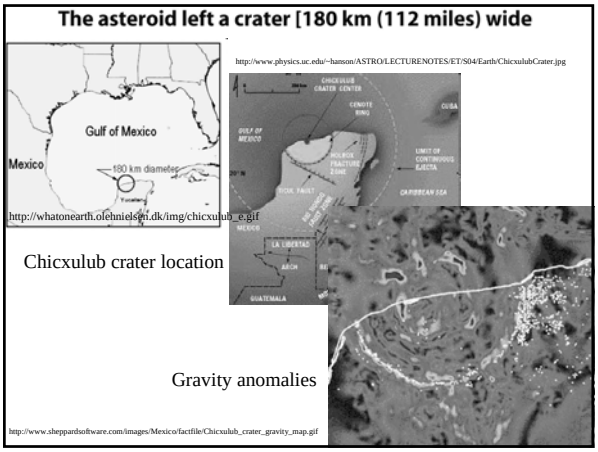



## What Killed the Dinosaurs? (Mass extinction at K-T boundary)

- Early hypothesis: climate change.
- Recent **impact hypothesis:** an asteroid struck Earth and caused widespread destruction and extinction (**Figure 27.16**).






## Recovery

- Ferns appear to have replaced diverse woody and flowering plants in many habitats following the K-T extinction.
- Mammals diversified to fill the niches left empty following the dinosaur extinctions.

## KEY CONCEPTS

- Phylogenies and the fossil record are the major tools that biologists use to study the history of life.

## KEY CONCEPTS

- The Cambrian explosion was the rapid morphological and ecological diversification of animals that occurred during the Cambrian period.

## KEY CONCEPTS

- The new field of “evo-devo” is providing insights into how major events in the history of life occurred, by revealing the genetic mechanisms involved.

## KEY CONCEPTS

- Adaptive radiations are a major pattern in the history of life. They are instances of rapid diversification associated with new ecological opportunities and new morphological innovations.

## KEY CONCEPTS

- Mass extinctions have occurred repeatedly throughout the history of life. They rapidly eliminate most of the species alive in a more or less random manner.