# Chapter 26

## The Tree of Life
## An Introduction to
## Biological Diversity

PowerPoint Lectures for
***Biology*, Seventh Edition**
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## Outline

- Biodiversity - what is it?
- Biodiversity – why is it important?
- Phylogeny (making the tree of life - to be cont'd chapter 25)
- The origins of today's diversity
- Macroevolution – from protobiont to multicellular eukaryotes

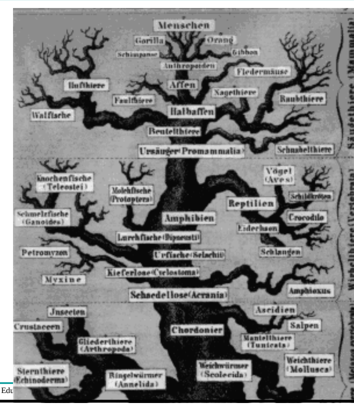


## Changing Life on a Changing Earth

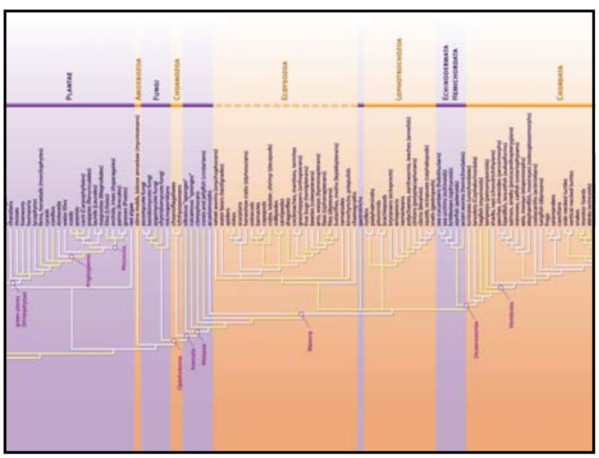
•Life is a continuum
  – Extending from the earliest organisms to the great variety of species that exist today



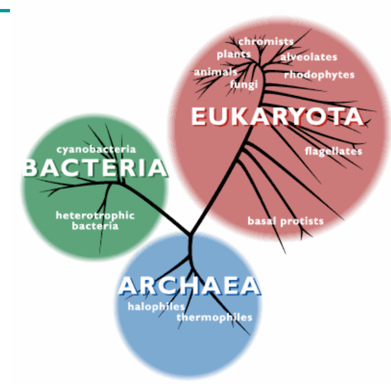
## Early phylogenetic tree (tree of life)





## Finding Nemo?






## Carolus Linnaeus (**Karl von Linné)**


Names are handles that convey information

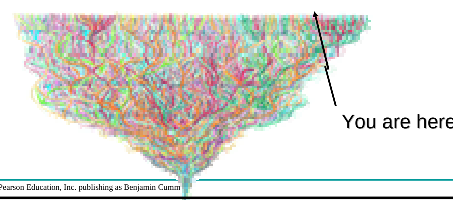


## **What is biodiversity?** It is the whole tree of life!

A single, magnificent genealogy connecting all organisms alive today. Two main lessons for students:

1. **We are *all* related** -- not just in the John Muir sense of all being part of the same worldwide ecosystem, but literally genealogically related !
   ** This should inform our moral treatment of other living things.

2. **We are not all that special** -- just one tiny twig on a strange, gigantic tree that took root on one little planet in an infinite universe.



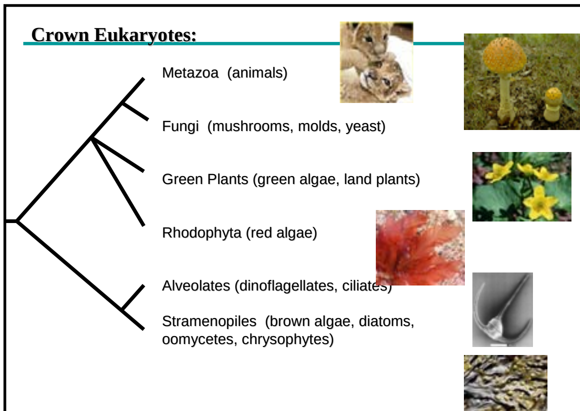



## What is the value of biodiversity?

- ethical: each lineage is a thread in an heirloom fabric that we have the responsibility to pass on to future generations.
- intellectual: we have a basic need to understand the world, how it came to be, and where we fit in it.
- ecological: biodiversity is needed for proper function of ecosystems, and as the raw material for natural selection (future evolutionary potential).
- economic: natural lineages are a potential source for a myriad of products of direct economic benefit (medicines, food, esthetics, shelter, etc.).



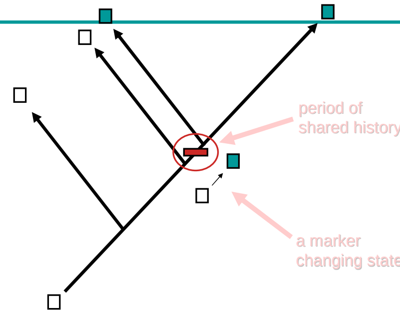
**Crown Eukaryotes:**



### How can we discover phylogenetic history?

- You can't actually see phylogeny, so how do you make inferences about it?
- Think of a huge oak tree buried in a sand dune, with only the tips of the twigs showing -- what would you do?
- The concept of historical markers -- *characters*
- Need to find something that changed its condition along a lineage, and survived in recognizable form to the present.

http://ib.berkeley.edu/courses/bio1b/evolutionfall06/evolutionf06.html




**Phylogenetic Reconstruction:**

**Need to find markers that can be hypothesized to have changed their state on some shared branch in the past, and to have retained a recognizable record of the derived state to the present.**



### Phylogenetics explained:

*homology* -- a feature shared by two lineages because of descent from an ancestor that had the feature.

*transformation* - a heritable change in a homology along a lineage from a prior state to a posterior state

*divergence* -- the splitting of one lineage into two lineages

*reticulation* - the blending of two lineages into one lineage

*monophyly* -- all and only descendants of a common ancestor



### Origins of life

- Geology change life, life changes the planet
- Earth formed ~4.6 billion years ago
- Earth's early atmosphere
  - water vapor & chemicals released by volcanic eruptions
- Some organic compounds may have come from space
- Carbon compounds have been found in some of the meteorites that have landed on Earth



- Laboratory experiments simulating an early Earth atmosphere
  - Have produced organic molecules from inorganic precursors, but the existence of such an atmosphere on early Earth is unlikely

**EXPERIMENT** Miller and Urey set up a closed system in their laboratory to simulate conditions thought to have existed on early Earth. A warmed flask of water simulated the primeval sea. The strongly reducing "atmosphere" in the system consisted of $H_2$, methane ($CH_4$), ammonia ($NH_3$), and water vapor. Sparks were discharged in the synthetic atmosphere to mimic lightning. A condenser cooled the atmosphere, raining water and any dissolved compounds into the miniature sea.

**RESULTS** As material circulated through the apparatus, Miller and Urey periodically collected samples for analysis. They identified a variety of organic molecules, including amino acids such as alanine and glutamic acid that are common in the proteins of organisms. They also found many other amino acids and complex, oily hydrocarbons.

**CONCLUSION** Organic molecules, a first step in the origin of life, can form in a strongly reducing atmosphere.

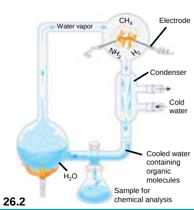



Figure 26.2



- Instead of forming in the atmosphere
  - The first organic compounds on Earth may have been synthesized near submerged volcanoes and deep-sea vents

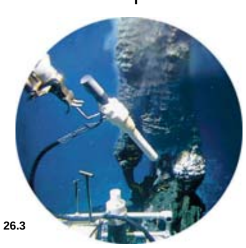


Figure 26.3

## Abiotic Synthesis of Polymers

- Small organic molecules
  - Polymerize when they are concentrated on hot sand, clay, or rock
- Protobionts
  - Are aggregates of abiotically produced molecules surrounded by a membrane or membrane-like structure



- Laboratory experiments demonstrate that protobionts
  - Could have formed spontaneously from abiotically produced organic compounds
- For example, small membrane-bounded droplets called liposomes
  - Can form when lipids or other organic molecules are added to water



## Protobionts

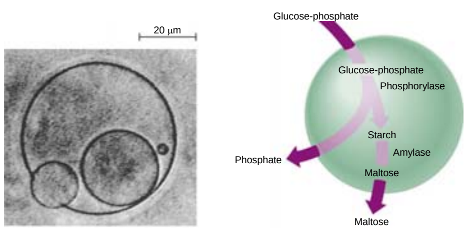



Figure 26.4a, b

**(a) Simple reproduction.** This liposome is "giving birth" to smaller liposomes (LM).

**(b) Simple metabolism.** If enzymes—in this case, phosphorylase and amylase—are included in the solution from which the droplets self-assemble, some liposomes can carry out simple metabolic reactions and export the products.



## The "RNA World" and the Dawn of Natural Selection

- The first genetic material
  - Was probably RNA, not DNA



- RNA molecules called ribozymes have been found to catalyze many different reactions, including
  - Self-splicing
  - Making complementary copies of short stretches of their own sequence or other short pieces of RNA

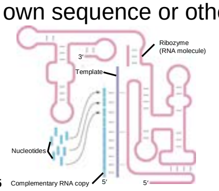



Figure 26.5



- Early protobionts with self-replicating, catalytic RNA would have been more effective at using resources and would have increased in number through natural selection

## Fossils

- Index fossils
  - Are similar fossils found in the same strata in different locations
  - Allow strata at one location to be correlated with strata at another location

Figure 26.6



- The absolute ages of fossils
  - Can be determined by radiometric dating

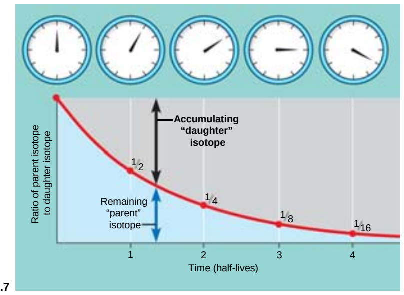



Figure 26.7



- The magnetism of rocks
  - Can also provide dating information
- Magnetic reversals of the north and south magnetic poles
  - Have occurred repeatedly in the past
  - Leave their record on rocks throughout the world



## The Geologic Record

- By studying rocks and fossils at many different sites
  - Geologists have established a geologic record of Earth's history



- The geologic record is divided into
  - Three eons: the Archaean, the Proterozoic, and the Phanerozoic
  - Many eras and periods
- Many of these time periods
  - Mark major changes in the composition of fossil species



- The geologic record

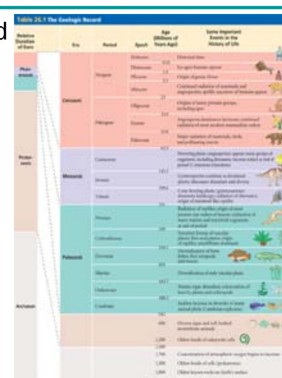


Table 26.1

## Mass Extinctions

- The fossil record chronicles a number of occasions
  – When global environmental changes were so rapid and disruptive that a majority of species were swept away

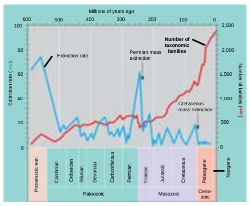



Figure 26.8



- Two major mass extinctions, the Permian and the Cretaceous
  – Have received the most attention
- The Permian extinction
  – Claimed about 96% of marine animal species and 8 out of 27 orders of insects
  – Is thought to have been caused by enormous volcanic eruptions



- The Cretaceous extinction
  – Doomed many marine and terrestrial organisms, most notably the dinosaurs
  – Is thought to have been caused by the impact of a large meteor


Figure 26.9



- Much remains to be learned about the causes of mass extinctions
  – But it is clear that they provided life with unparalleled opportunities for adaptive radiations into newly vacated ecological niches



- The analogy of a clock
  – Can be used to place major events in the Earth's history in the context of the geological record

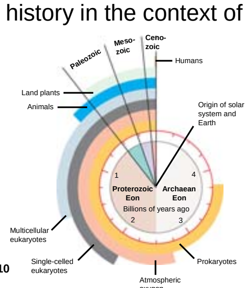



Figure 26.10



- Concept 26.3: As prokaryotes evolved, they exploited and changed young Earth
- The oldest known fossils are stromatolites
  – Rocklike structures composed of many layers of bacteria and sediment
  – Which date back 3.5 billion years ago

**(a)** Lynn Margulis (top right), of the University of Massachussetts, and Kenneth Nealson, of the University of Southern California, are shown collecting bacterial mats in a Baja California lagoon. The mats are produced by colonies of bacteria that live in environments inhospitable to most other life. A section through a mat (inset) shows layers of sediment that adhere to the sticky bacteria as the bacteria migrate upward.

**(b)** Some bacterial mats form rocklike structures called stromatolites, such as these in Shark Bay, Western Australia. The Shark Bay stromatolites began forming about 3,000 years ago. The inset shows a section through a fossilized stromatolite that is about 3.5 billion years old.

**Figure 26.11a, b**



## The First Prokaryotes

- Prokaryotes were Earth's sole inhabitants
  - From 3.5 to about 2 billion years ago
- Electron transport systems of a variety of types
  - Were essential to early life
  - Have: some aspects that possibly precede life itself
- The earliest types of photosynthesis
  - Did not produce oxygen



- Oxygenic photosynthesis
  - Probably evolved about 3.5 billion years ago in cyanobacteria

**Figure 26.12**



## New Ecological Opportunities!!!!

- When oxygen began to accumulate in the atmosphere about 2.7 billion years ago
  - It posed a challenge for life
  - It provided an opportunity to gain abundant energy from light
  - It provided organisms an opportunity to exploit new ecosystems



## Eukaryotes

- Eukaryotic cells arose from symbioses and genetic exchanges between prokaryotes
- Among the most fundamental questions in biology
  - Is how complex eukaryotic cells evolved from much simpler prokaryotic cells
- The oldest fossils of eukaryotic cells
  - Date back 2.1 billion years



## Endosymbiotic Origin of Mitochondria and Plastids

- The theory of endosymbiosis
  - Proposes that mitochondria and plastids were formerly small prokaryotes living within larger host cells

- The prokaryotic ancestors of mitochondria and plastids
  - Probably gained entry to the host cell as undigested prey or internal parasites

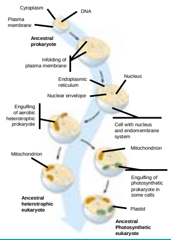



Figure 26.13



- In the process of becoming more interdependent
  - The host and endosymbionts would have become a single organism

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- The evidence supporting an endosymbiotic origin of mitochondria and plastids includes
  - Similarities in inner membrane structures and functions
  - Both have their own circular DNA

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## Eukaryotic Cells as Genetic Chimeras

- Additional endosymbiotic events and horizontal gene transfers
  - May have contributed to the large genomes and complex cellular structures of eukaryotic cells

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- Some investigators have speculated that eukaryotic flagella and cilia
  - Evolved from symbiotic bacteria, based on symbiotic relationships between some bacteria and protozoans


Figure 26.14

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## Multicellularity

- Multicellularity evolved several times in eukaryotes
- After the first eukaryotes evolved
  - A great range of unicellular forms evolved
  - Multicellular forms evolved also

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## The Earliest Multicellular Eukaryotes

- Molecular clocks
  - Date the common ancestor of multicellular eukaryotes to 1.5 billion years
- The oldest known fossils of eukaryotes
  - Are of relatively small algae that lived about 1.2 billion years ago



- Larger organisms do not appear in the fossil record
  - Until several hundred million years later
- Chinese paleontologists recently described 570-million-year-old fossils
  - That are probably animal embryos

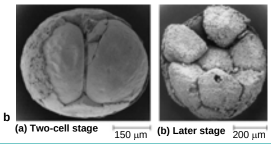



Figure 26.15a, b



## The Colonial Connection

- The first multicellular organisms were colonies
  - Collections of autonomously replicating cells

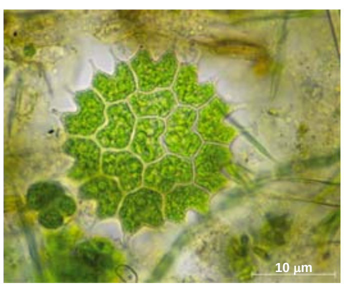



Figure 26.16

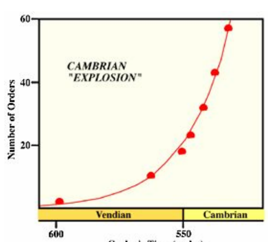


- Some cells in the colonies
  - Became specialized for different functions
- The first cellular specializations
  - Had already appeared in the prokaryotic world



## The "Cambrian Explosion"

•Most of the major phyla of animals
  - Appear suddenly in the fossil record that was laid down during the first 20 million years of the Cambrian period






- Phyla of two animal phyla, Cnidaria and Porifera
  - Are somewhat older, dating from the late Proterozoic

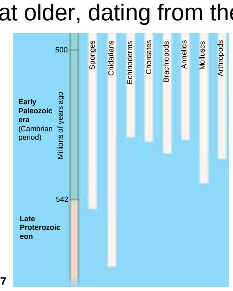



Figure 26.17

- Molecular evidence
  - Suggests that many animal phyla originated and began to diverge much earlier, between 1 billion and 700 million years ago
- Plants, fungi, and animals
  - Colonized land about 500 million years ago
- Symbiotic relationships between plants and fungi
  - Are common today and date from this time



## Continental Drift

- Earth's continents are not fixed
  - They drift across our planet's surface on great plates of crust that float on the hot underlying mantle



- Often, these plates slide along the boundary of other plates
  - Pulling apart or pushing against each other

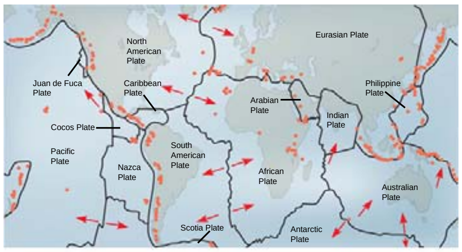



Figure 26.18



- Many important geological processes
  - Occur at plate boundaries or at weak points in the plates themselves

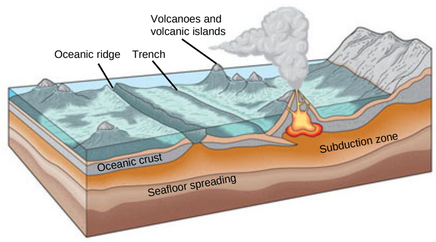



Figure 26.19



- The formation of the supercontinent Pangaea during the late Paleozoic era
  - And its breakup during the Mesozoic era explain many biogeographic puzzles

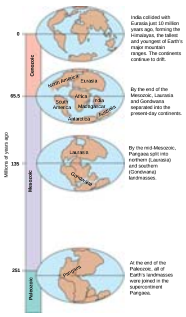



Figure 26.20



- New information has revised our understanding of the tree of life
- Molecular Data
  - Have provided new insights in recent decades regarding the deepest branches of the tree of life

## Previous Taxonomic Systems

- Early classification systems had two kingdoms
  - Plants and animals



- Robert Whittaker proposed a system with five kingdoms
  - Monera, Protista, Plantae, Fungi, and Animalia

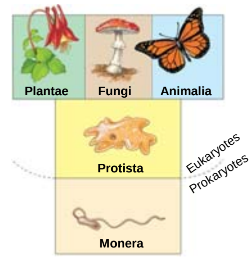



Figure 26.21



## Reconstructing the Tree of Life: A Work in Progress

- A three domain system
  - Has replaced the five kingdom system
  - Includes the domains Archaea, Bacteria, and Eukarya
- Each domain
  - Has been split by taxonomists into many kingdoms



- One current view of biological diversity

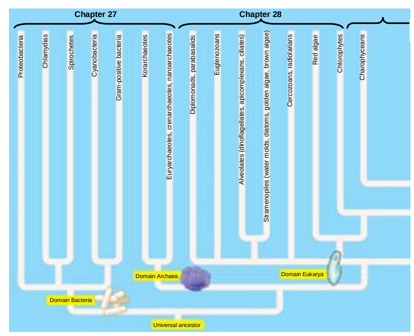



Figure 26.22



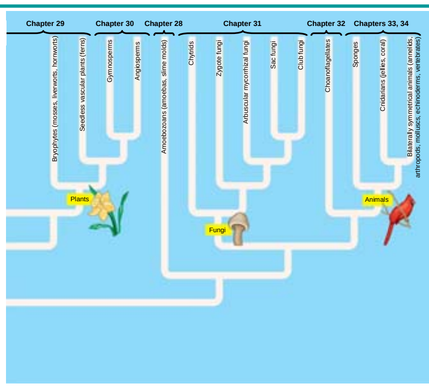



Figure 26.21