While we go through the history of life, remember that all this evolution was occurring concurrently in different lineages. Plants, animals, fungi, and other dominant groups have all been around for over 540 million years

Multicellular organisms have been around for over 650 million years, and basic eukaryotes, about 1 billion years

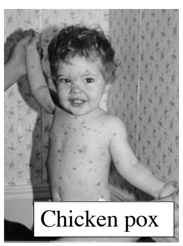
Bacteria and Archaea:
Much longer

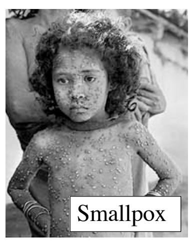
GEOLOGIC TIME SCALE

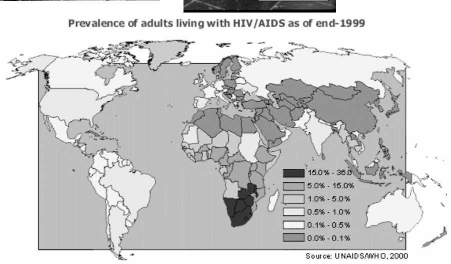
Time Units of the Geologic Time Scale					Development of Plants and Animals
Eon	Era	Period	Epoch	(Ma)	
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	Earliest *Homo sapiens*
			Pleistocene	1.6	
		Tertiary	Pliocene	5.3	Earliest hominids
			Miocene	23.8	
			Oligocene	33.7	"Age of Mammals"
			Eocene	55	
			Palaeocene	65	Extinction of dinosaurs and many other species
	Mesozoic	Cretaceous	"Age of Reptiles"	145	First flowering plants
		Jurassic		208	First birds
		Triassic		248	Dinosaurs dominant First mammals
	Palaeozoic	Permian	"Age of Amphibians"	286	Extinction of trilobites and many other marine animals
		Carboniferous – Pennsylvanian		320	First reptiles Large coal swamps
		Carboniferous – Mississippian		360	Amphibians abundant
		Devonian	"Age of Fishes"	410	First amphibians First insect fossils
		Silurian		438	Fishes dominant
		Ordovician	"Age of Invertebrates"	505	First land plants First fishes
		Cambrian		545	Trilobites dominant First organisms with shells
		Vendian	"Soft-bodied faunas"	650	Abundant Ediacaran faunas
Proterozoic		Collectively called Precambrian comprises about 87% of the geological time scale		2500	First multicelled organisms
Archean				3800	First one-celled organisms Age of oldest rocks
Hadean				4600 Ma	Origin of the earth

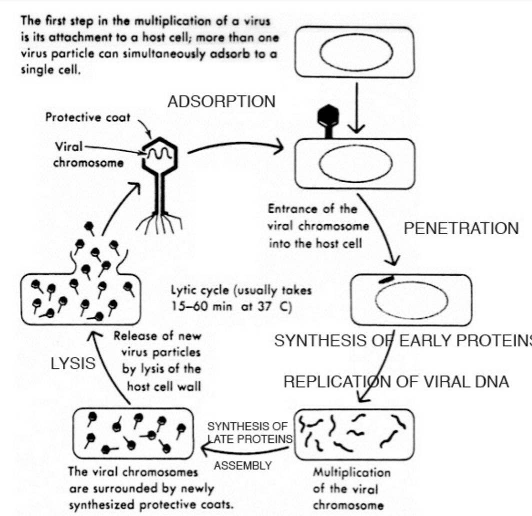
Viruses

- Completely dependent on host cells for reproduction
- Viruses have DNA and a protein coat, but they **are not cells**
- Viruses lack many of the essential qualities of organisms:
  no metabolism, no ability to reproduce themselves,
  no shared ancestry from a common viral ancestor
- Many biologists do not consider viruses to be a form of life
- Viruses are probably evolved from fragments of DNA from cellular hosts similar to the virus's ancestral host
- Viruses cause diseases such as: chicken pox, smallpox, measles, mumps, rabies, flu, the common cold, polio, Ebola, AIDS
- **Lytic** viruses (e.g. bacteriophages) cause host cells to burst (lyse)
- **Retroviruses** (e.g. HIV) contain RNA and reverse transcriptase

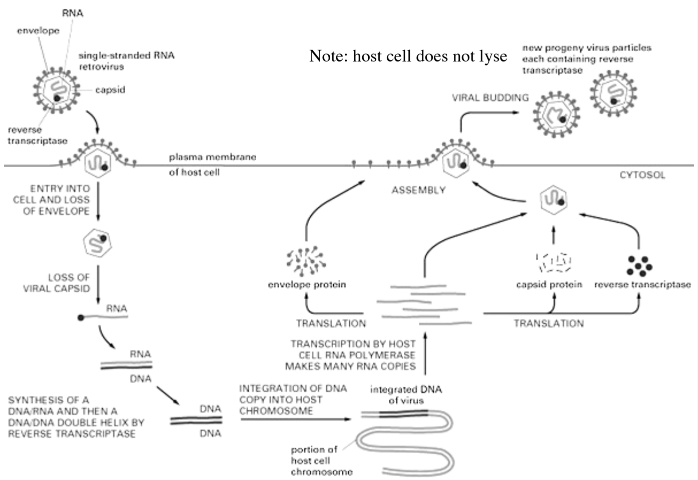




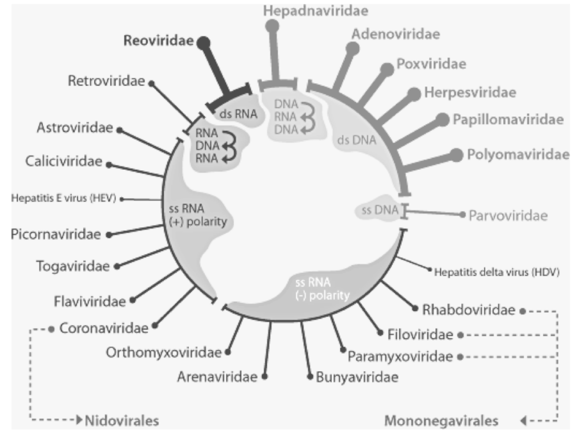




The Life Cycle of a Retrovirus



- Large-scale virus taxonomy does not assume a common ancestor
- Classification considers type of nucleic acid used



Bacteria and Archaea

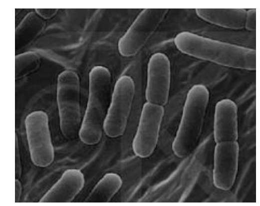
- It is likely that bacteria and archaea make up more than half of the biomass on Earth -- most of which is underground.
- Both are prokaryotic cells that lack many of the structures that eukaryotic cells have -- nuclear membrane, mitochondria, endoplasmic reticulum, Golgi apparatus, lysosomes…
- Double-stranded circular genome (chromosome)
- Some are producers of organic compounds; others are consumers
- Ancient bacteria became the mitochondria and chloroplasts of eukaryotic cells through endosymbiosis
- Many human diseases are caused by bacteria
- Bacteria are essential to global ecology and human health

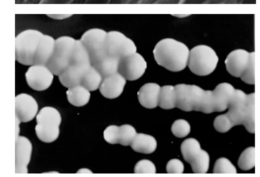
The 3 primary shapes of bacteria do not correspond to clades!

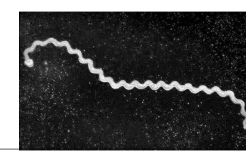
Bacillus (bacilli): rod-shaped cells

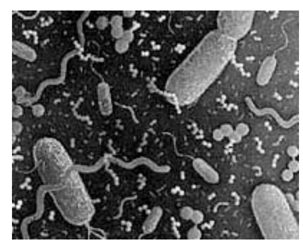
Coccus (cocci): sphere-shaped cells

Spirillum (spirilla): spiral-shaped cells







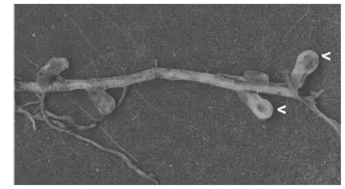


Bacterial chemistry and metabolism

- Autotrophic bacteria include photosynthesizers and chemoautotrophs
- Most bacteria are heterotrophs and aerobic (require oxygen)
- Many bacteria can carry out fermentation: a metabolic pathway
  glucose -> (glycolysis) -> pyruvic acid -> ethanol or lactic acid
  (although other products of fermentation are possible)
- Fermentation can occur in the absence of oxygen; thus, many bacteria are anaerobic, either obligately or facultatively
- An extremely important anaerobic process is nitrogen fixation:
  the conversion of elemental nitrogen (N_2) to ammonia (NH_3), and the conversion of ammonia to nitrate (NO_3)
- Bacteria are the only organisms that can convert elemental nitrogen into these compounds that are needed by other living things
- Nitrogen fixation can only occur in low-oxygen environments

Nitrogen fixing bacteria grow symbiotically with the roots of plants

Bacterial nodules on soybean roots



Bacterial nodules on clover roots

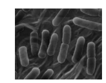
Once fixed, nitrogen can enter the flow of nutrients within an ecosystem, and can be transferred via the food chain -- for example when a plant gets eaten, or when a plant-eating animal gets eaten itself.
In addition, bacteria (and some fungi) can release fixed nitrogen from dead organisms through **decomposition,** thus returning it to the environment and making it available to organisms again.

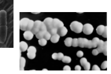
Diseases caused by bacteria

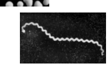
Bubonic plague, cholera, diphtheria, syphilis, gonorrhea, leprosy, scarlet fever, tetanus, tuberculosis, typhoid, whooping cough, bacterial pneumonia, meningitis, ulcers, etc.

Bacteria cause diseases by their tremendous numbers (biological overload), by the destruction of body tissues, and/or by the production of toxins.

A few bacterial toxins are among the most poisonous substances known to science. (For example, tetrodotoxin)





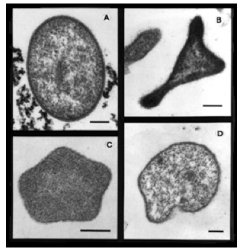


Bacteria are essential to Eukaryotes

- Most eukaryotes could not survive if it weren’t for the existence of nitrogen-fixing bacteria
- Animals depend on bacterial symbionts in the intestines or gut to aid in digestion or to synthesize essential vitamins
- Bacteria rid the world of dead eukaryotes and metabolic wastes

Archaea and Eukaryotes form the clade Neomura

- Different cell wall composition than Bacteria
- Use histone proteins
- Several types of RNA polymerase
- Similar transcription and translation factors



Archaea are prokaryotic cells (no nuclei), but are not bacteria

Many live in extreme environments:
Thermophiles, Halophiles, and Acidophiles…
but these are ecological classifications, not clades

"PROTISTS"

- represent the first eukaryotes
- are ancient lineages very distantly related to multicellular eukaryotes
- are not monophyletic (not all descended from a shared ancestor)
- may have plantlike qualities (chloroplasts) or animal-like qualities (motility, heterotrophy) or a combination of both
- include (but are not limited to):

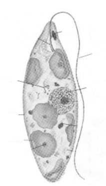
  Kinetoplastids (euglenozoa, amoeboids, radiolaria)

  Alveolates (ciliates, paramecium, dinoflagellates, plasmodium)

  Slime molds (true slime molds, cellular slime molds)

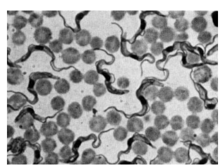
  Some red and brown algaes (which are not true plants)

Kinetoplastids



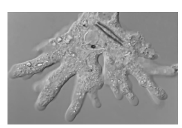
Euglenozoa, such as *Euglena*, often have chloroplasts and move around using a tail-like flagellum

Trypanosomes, such as *Trypanosoma*, include blood parasites that cause diseases in mammals



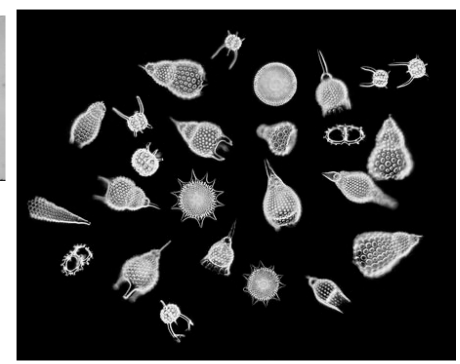
Trypanosoma, African sleeping sickness, is transmitted through the saliva of biting tsetse flies

Sarcodines, such as *Amoeba*, are amorphous cells with pseudopods used in locomotion and in feeding

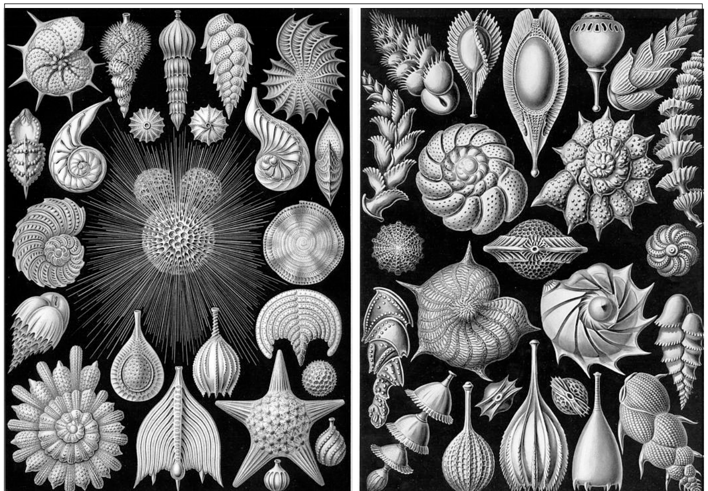


Two kinds of kinetoplastids, **Foraminifera** and **Radiolaria**, form amazing microscopic shells made of calcium carbonate or silica.

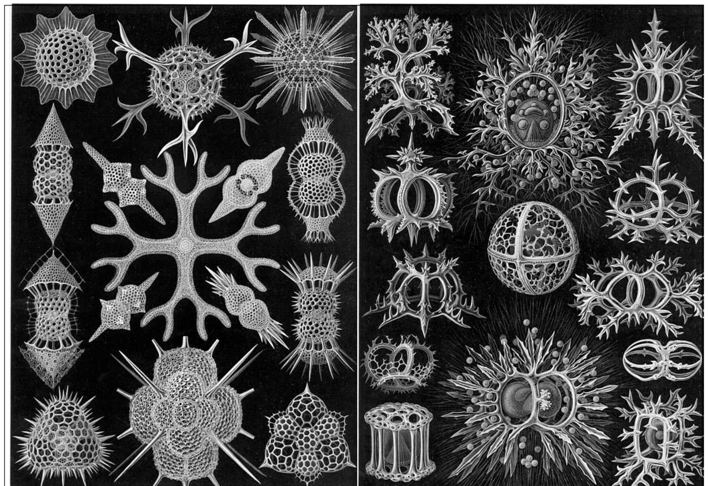
Foraminifera: Calcium carbonate shells, form limestone



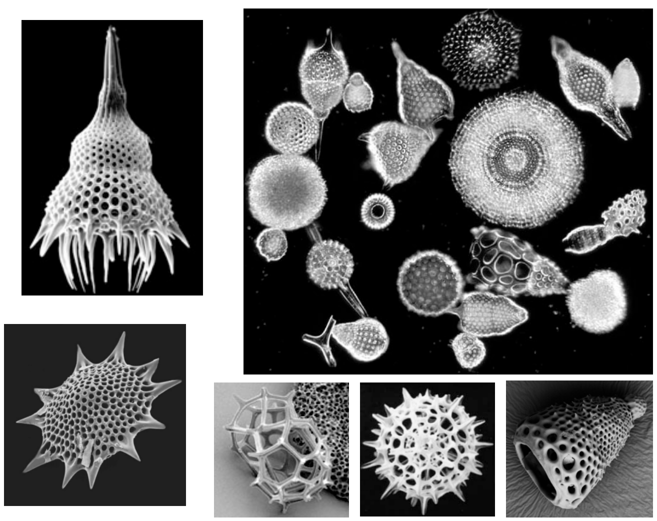
Radiolaria: Silica shells, form seafloor ooze



FORAMINIFERA

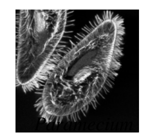


RADIOLARIA



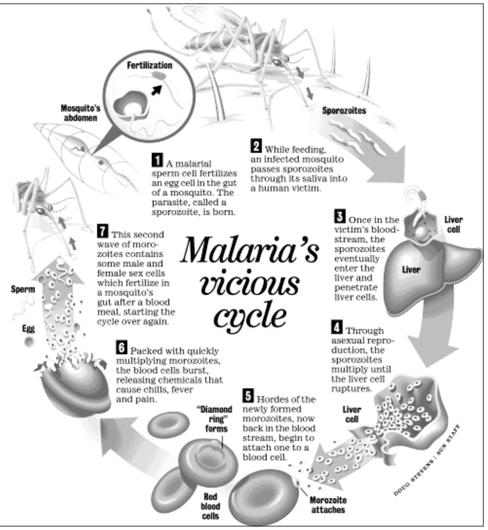
<u>Alveolates I: Ciliates and Dinoflagellates</u>

- Ciliates have small hairs, known as cilia, used for locomotion
- Some have tentacles for capturing prey, or use <u>extrusomes</u>: poisonous "darts" used for defense or capture of prey



- Many ciliates perform a sex-like process known as conjugation, where two individuals fuse, and join haploid nuclei that have undergone meiosis to form a new recombinant diploid "gamete" nucleus in each
- Alveolates known as <u>dinoflagellates</u> are important in marine food chains, and as endosymbionts for marine animals. Some contain <u>saxitoxin</u> and are responsible for red tides.

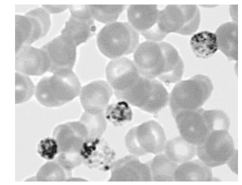
The alveolate *Plasmodium* is the blood parasite that causes Malaria, one of the top health problems in tropical areas around the world. This protist, transmitted by *Anopheles* mosquitoes, has a complex life cycle requiring both an insect host and a human host.



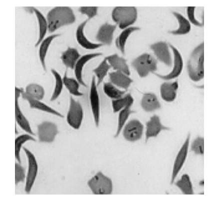
In the human host, malaria merozoites are made in the liver, and enter the blood stream to infect red blood cells. Malaria symptoms (fever, chills) occur when many infected red blood cells lyse all at once

Individuals with sickle-cell anemia (individuals who are double-recessive homozygotes for a particular gene) have abnormal red blood cells that form clumps, clog blood vessels and inhibit circulation.

Although selection has acted against the sickle cell allele in much of the world, it is still fairly common in human populations (especially in Africa) where malaria is present. Sickle cells resist infection by malaria; in some parts of Africa, natural selection actually favors individuals who are heterozygous for sickle cells.



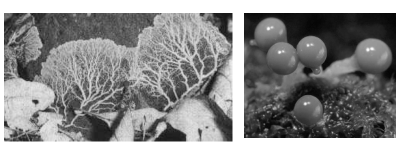
Red blood cells and *Plasmodium* Merozoites



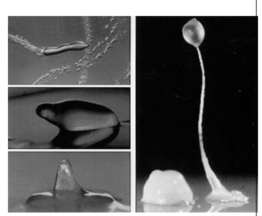
Sickle cells
(red blood cells)

Slime molds: pretty weird.

- Bizarre organisms with a motile, amoeba-like plasmodium stage (not to be confused with the *Plasmodium* blood parasite) and a stationary fruiting stage.
- True slime molds and cellular slime molds have different life cycles, and are probably not related to one another



True slime mold



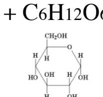
Cellular slime mold

PHOTOSYNTHESIS:

One of the most important chemical reactions for life on Earth.

$$6\ CO_2 + 12\ H_2O + (light) \rightarrow 6\ O_2 + C_6H_{12}O_6 + 6\ H_2O$$

In other words:



In the presence of water, carbon dioxide and light can react to form free oxygen and glucose sugar.

Chloroplasts of *Bryopsis* algae

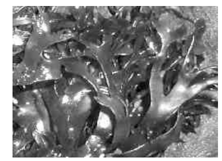
This is made possible by the chemical properties of chlorophyll pigments inside organelles known as chloroplasts. Chlorophyll traps light energy and helps convert it into chemical energy

Important points about Algae:

- Algae have been around longer than green plants, animals, or fungi
- Algae were the first truly multicellular organisms
- Algae are not monophyletic relative to other Eukaryotes
- Like green plants, algae have chloroplasts containing chlorophyll, and use light to produce glucose and oxygen through photosynthesis
- Algae were first classified as “green”, “brown”, or “red”, based on the types of chlorophyll pigments that each contains: chlorophyll *a*, chlorophyll *b*, chlorophyll *c*, and chlorophyll *d*



Brown algaes, such as *Fucus*, *Ascophyllum*, and kelps, contain chlorophyll *a* and chlorophyll *c*.

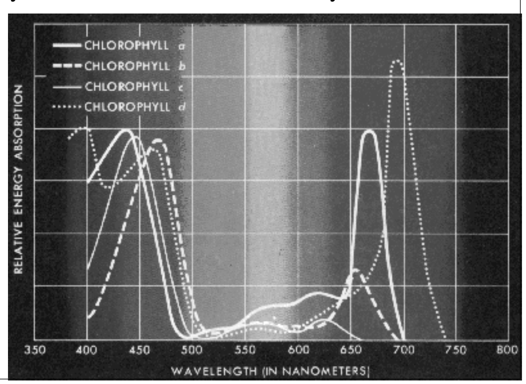
Red algae, such as *Chondrus* (the source of carrageenan) contain chlorophyll *a* and chlorophyll *d*.

Green algae and plants contain chlorophyll *a* and chlorophyll *b*.

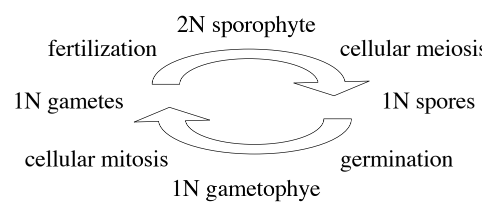
Pigments **absorb** some wavelengths of light, and **reflect** others.

The combination of chlorophylls (and other pigments) in algae and plants determines not only their colors, but also the kind of light they can use for photosynthesis, and thus, the habitats they can live in.

In water, blue light waves penetrate deeper than red light waves; thus, red algae (with chlorophyll *d*) can live in deeper water than brown or green algae, and brown algae (with chlorophyll *c*) can live in deeper water than green algae.



- Algal life cycles are characterized by alternation of generation, which was also the original basis of life cycles in green plants
- In basic alternation of generation, a diploid sporophyte phase produces haploid spores that give rise to a haploid, gametophyte stage. Gametophyes produce diploid gametes that grow into new diploid sporophytes, and the cycle goes on.



ALTERNATION OF GENERATION