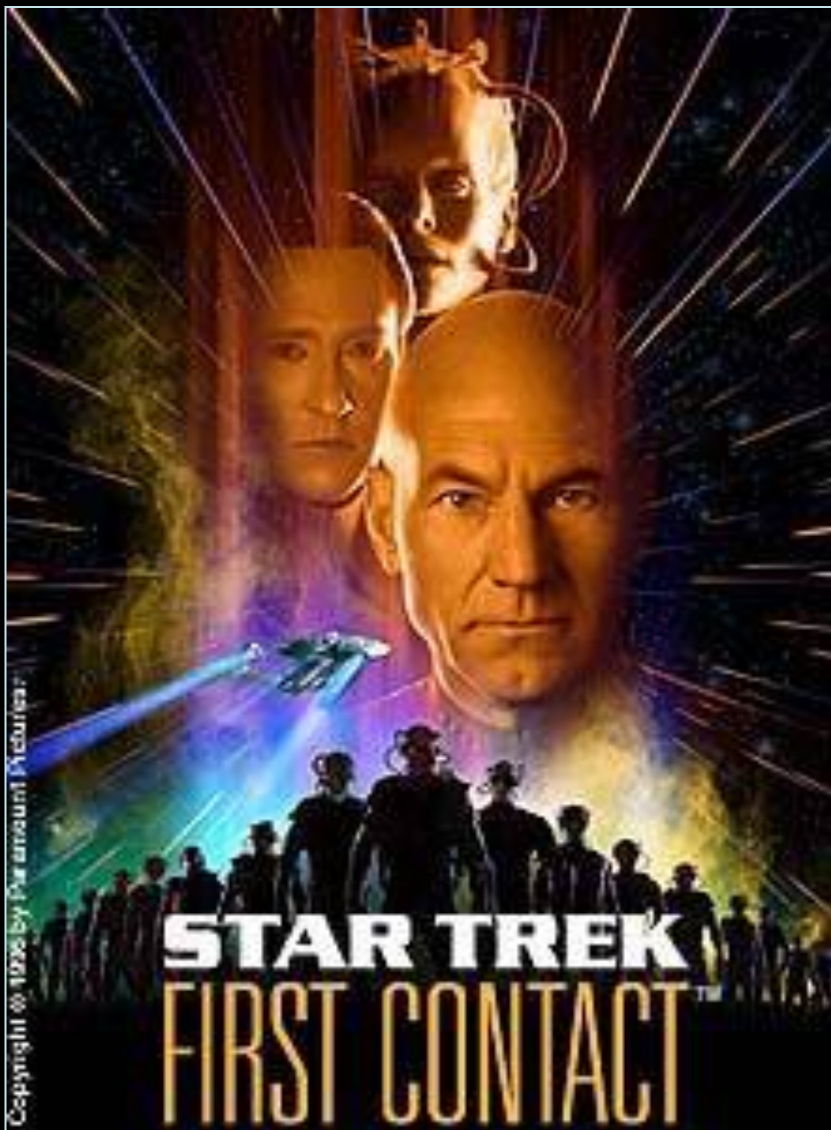
Life: Diversity and Fossils

Diversity of Life on Earth

- Definition of life
- Six Kingdoms
- Three Domains

Taphonomy

- Refractory versus volatile remains
- Destruction
- Modes of preservation



Universal Definition of Life?

Joseph Morales

Living things are systems that tend to respond to changes in their environment, and inside themselves, in such a way as to promote their own continuation.

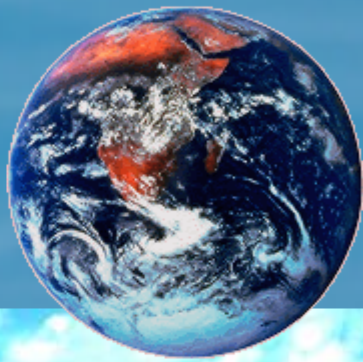
http://baharna.com/philos/life.htm

Universal Definition of Life?

Delenn – Babylon 5

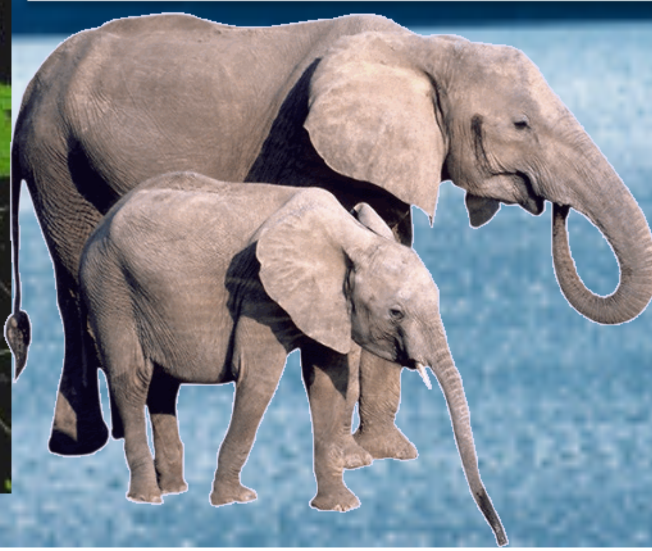
Life does.

Functional Definition of Life on Earth



Self-contained, carbon-based biochemical systems with the following emergent properties:

1. **Metabolism** – can actively convert energy into usable form
2. **Reproduction** – can make genetically similar copies
3. **Behavior** – can interact with both the surrounding environment and other living things



Terminology

Evolution - change in genetic structure of populations of organisms over time. Can result in the development of new species (speciation).

Species - all members of a natural group of interbreeding populations.

Taxa/Taxon - a group of evolutionarily related organisms, e.g., species, genera, families, phyla, etc.

Phylogeny - sequence of events involved in the evolutionary development of taxonomic groups (e.g., species) of organisms.

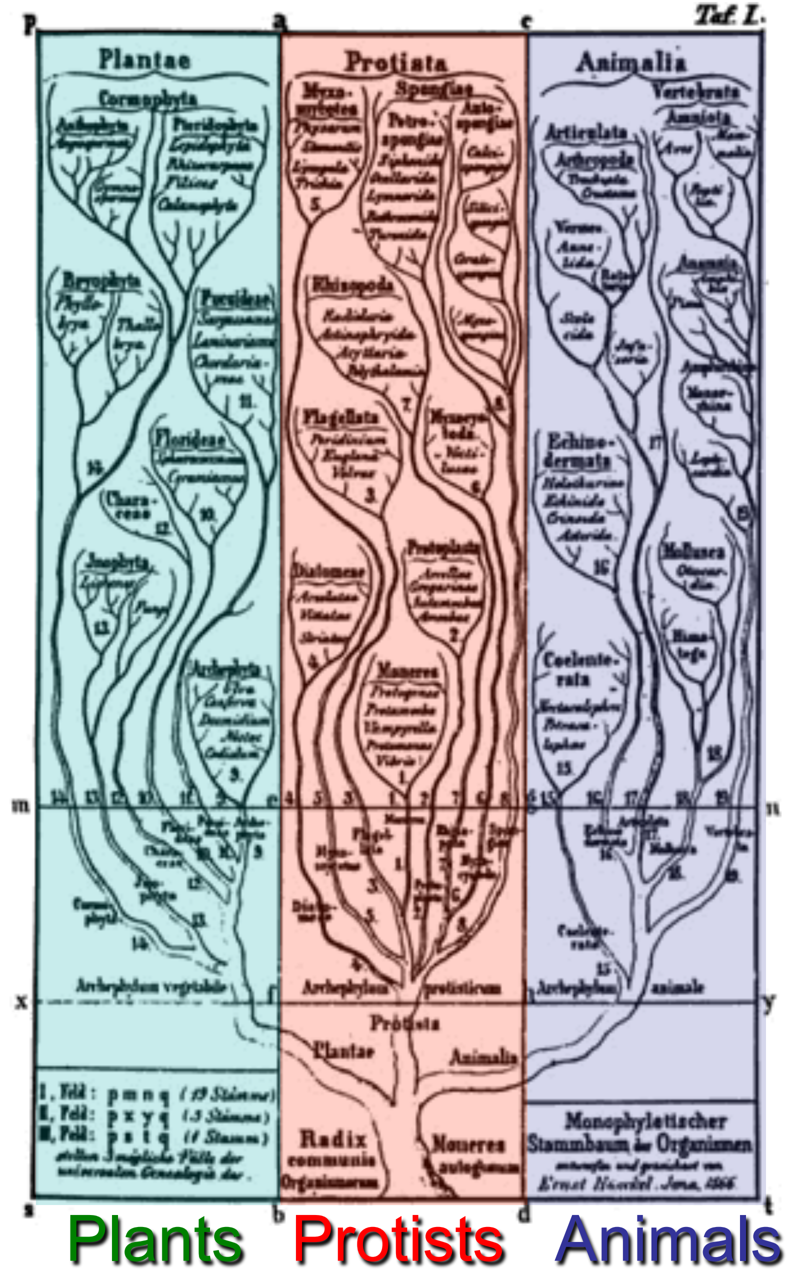
The First Published Phylogeny of Life

Ernst Haekel, Mid-1800's

Our observations of life on Earth lead us to conclude that all living things are related.

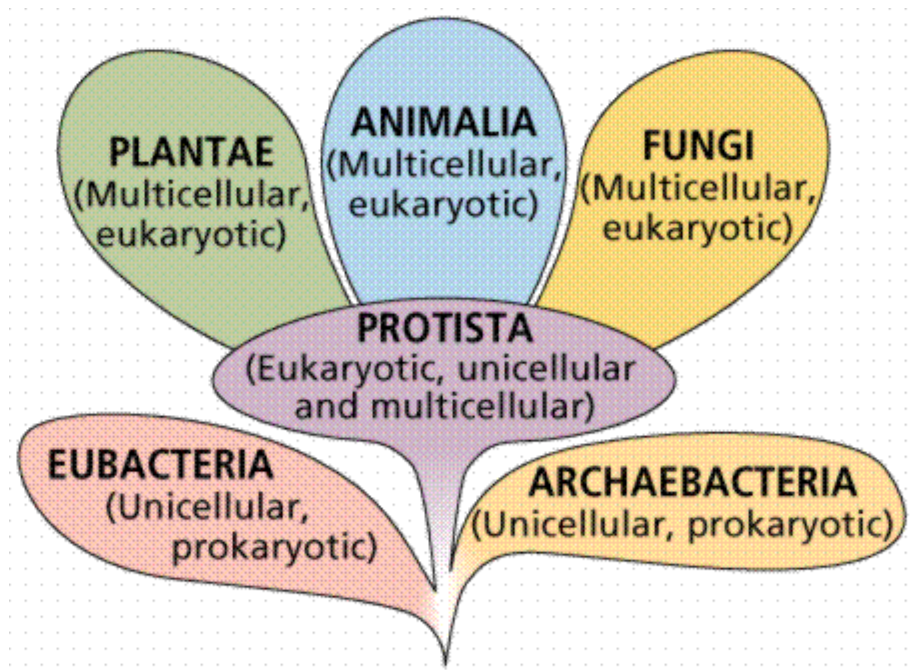
The evolutionary and historical relationship of ancestral and descendant species is called a phylogeny.

Time is the key to understanding phylogenies!



http://www.ucmp.berkeley.edu/education/events/eukevol1.html

Six Kingdoms



http://teachernotes.paramus.k12.nj.us/Nolan/CP%20Bio.htm

Systematics

The science of describing organisms and their evolutionary relationships to each other. It includes (but is not limited to) the studies of:

- Diversity - the total number of taxa in any area
- Disparity - the range of morphological variation in a group
- Taxonomy - formal scientific naming and classification of organisms

Systematics

The standard biological system for formally designating the “address” of a species is a nested hierarchy:

Kingdom Animalia (animals)

Most inclusive

Phylum Chordata (chordates – animals with dorsal notochord)

Class Mammalia (mammals)

Order Carnivora (carnivores: felines, canines, bears, mustellids, etc.)

Family Felidae (felines)

Genus *Felis* (cats)

Species *Felis domesticus* (the house cat)

Least inclusive

The species name is always a binomial (two names) with the genus name and trivial name.

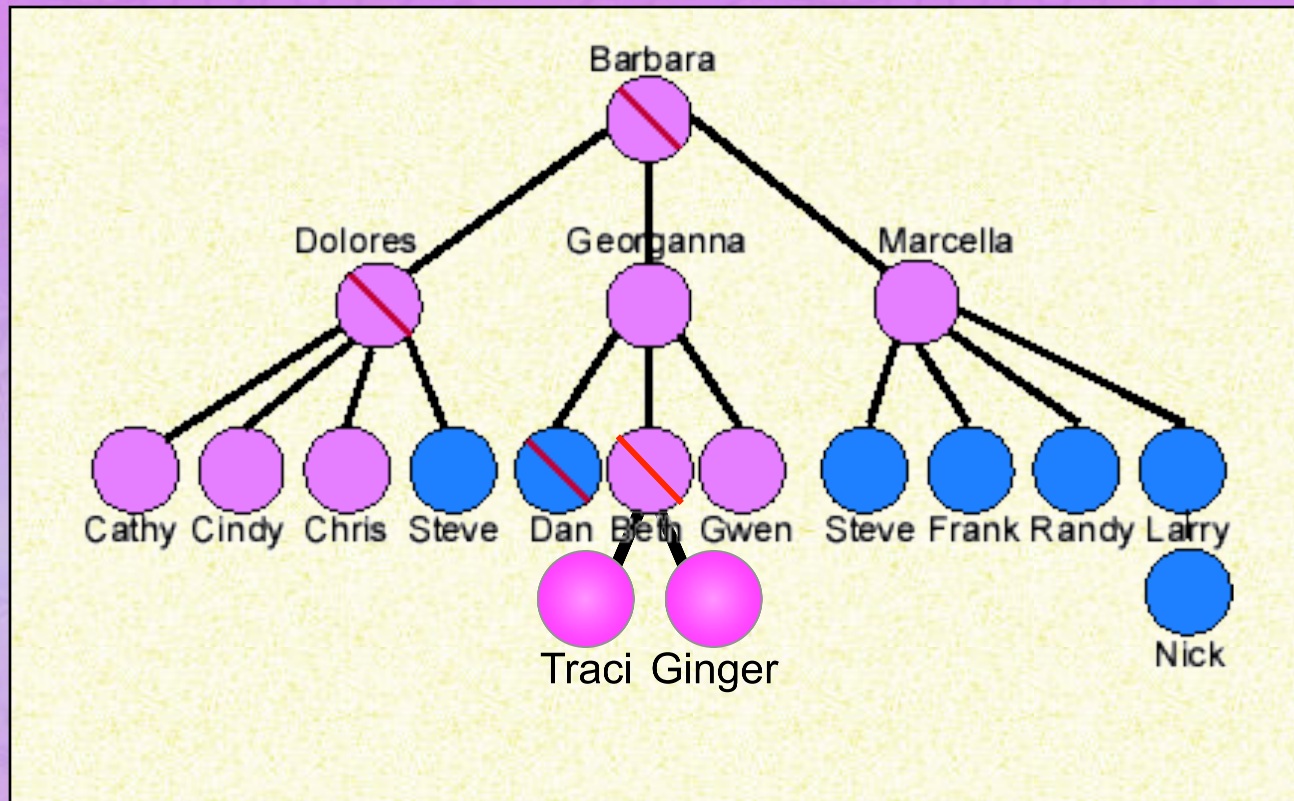
Upper levels based on similarity in body plan and development

Lower levels more subject to lumping and splitting

Systematics

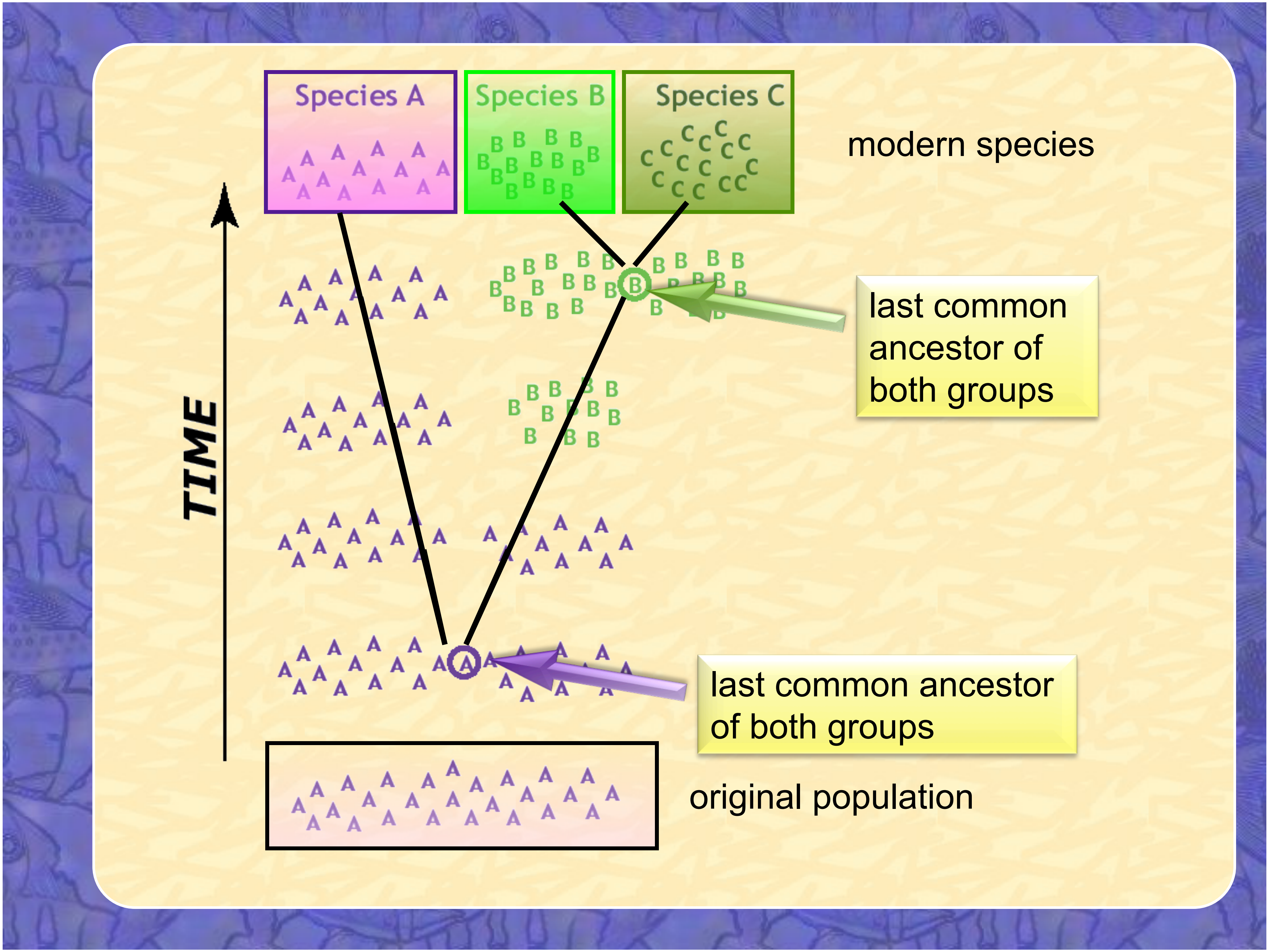
Systemacists also study evolutionary relationships between taxa - or phylogenetics. The most widely used type of phylogenetic analysis is called cladistics, which uses homologous characters to determine evolutionary lineagues.

"Personal" Lineage

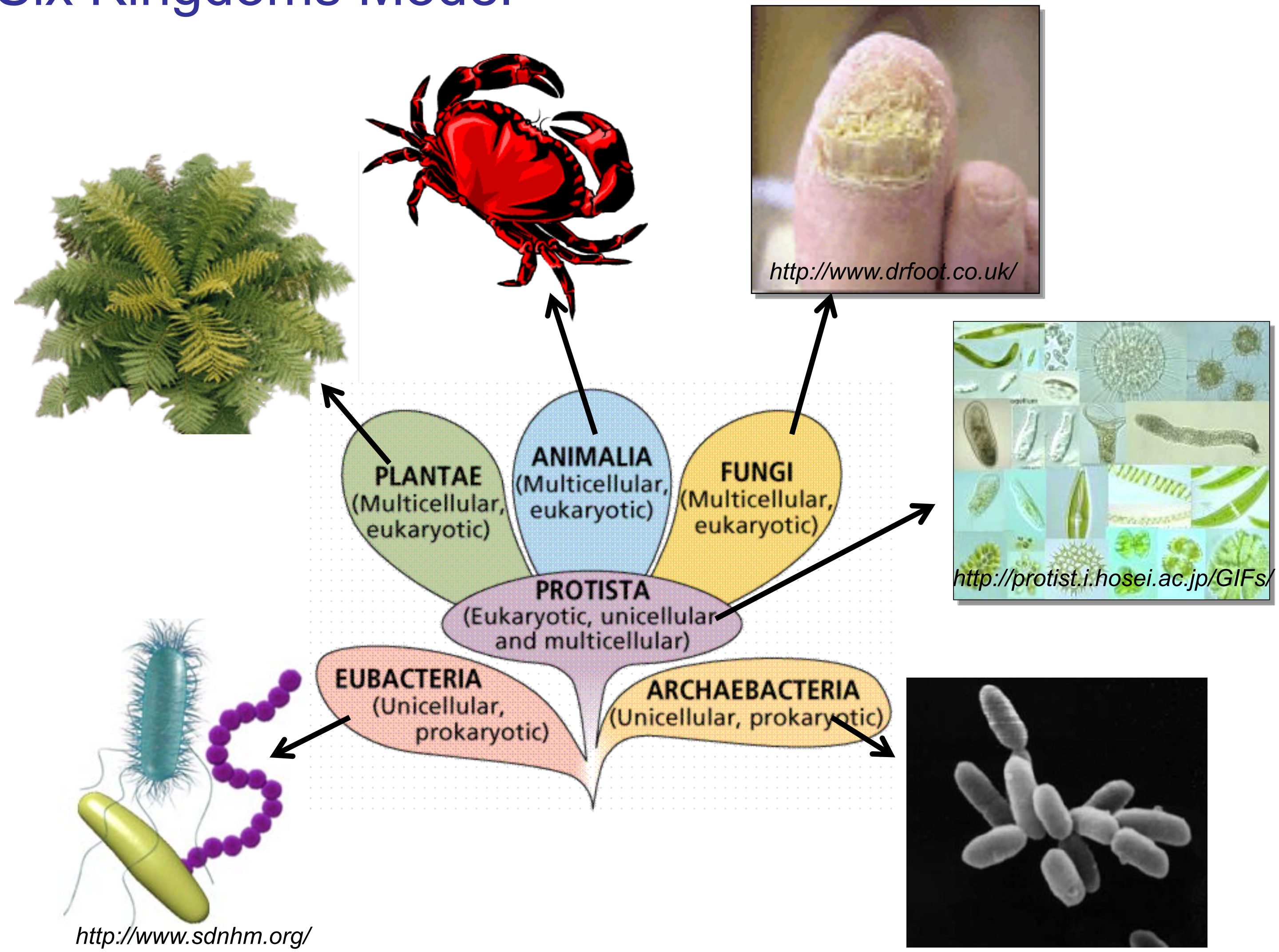


Lineage - group of individuals tracing descent to a common ancestor

An evolutionary lineage traces descent from a common *ancestral species*.


Species A
Species B
Species C
modern species
TIME
last common ancestor of both groups
last common ancestor of both groups
original population

Six Kingdoms Model



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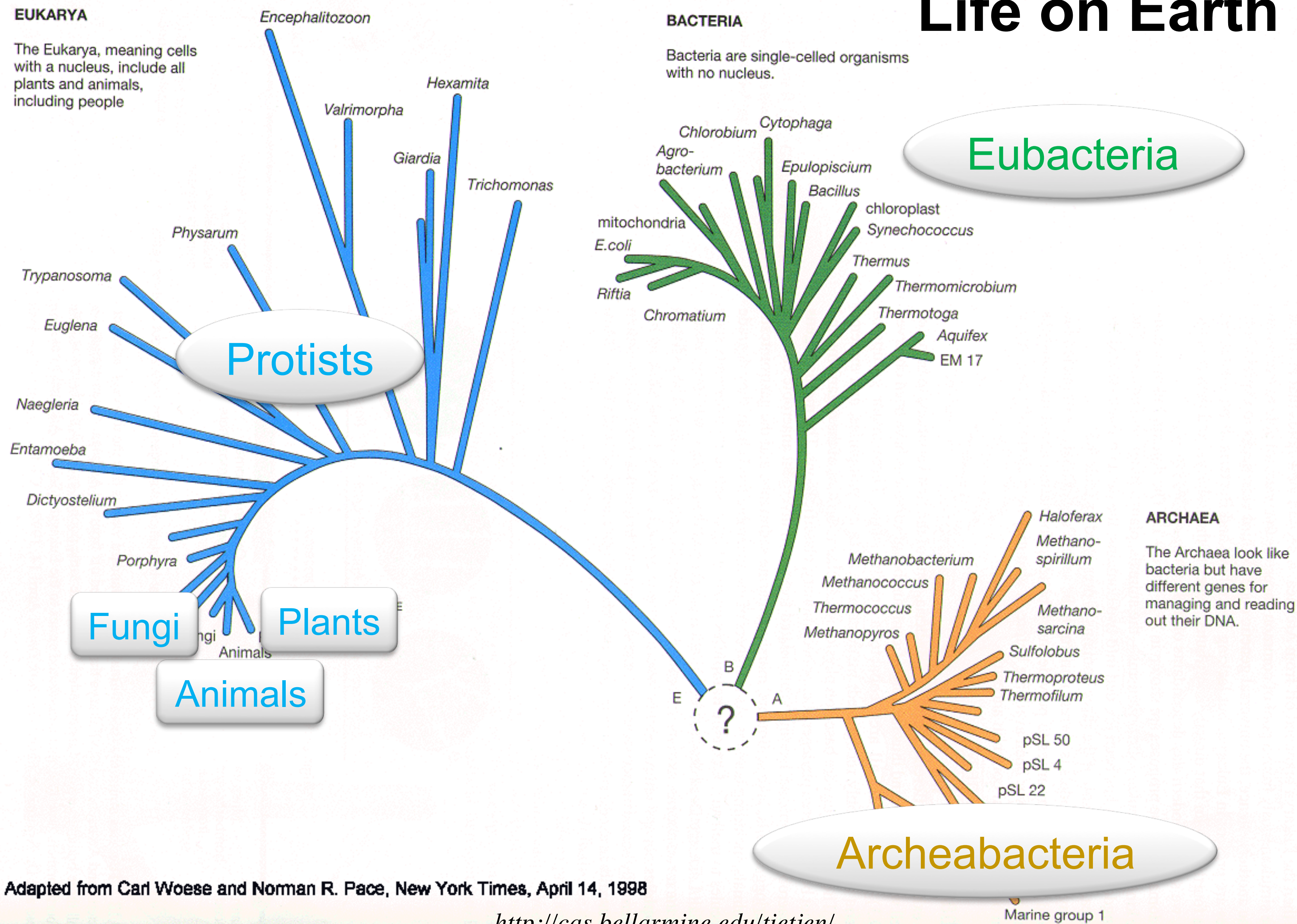
Life on Earth

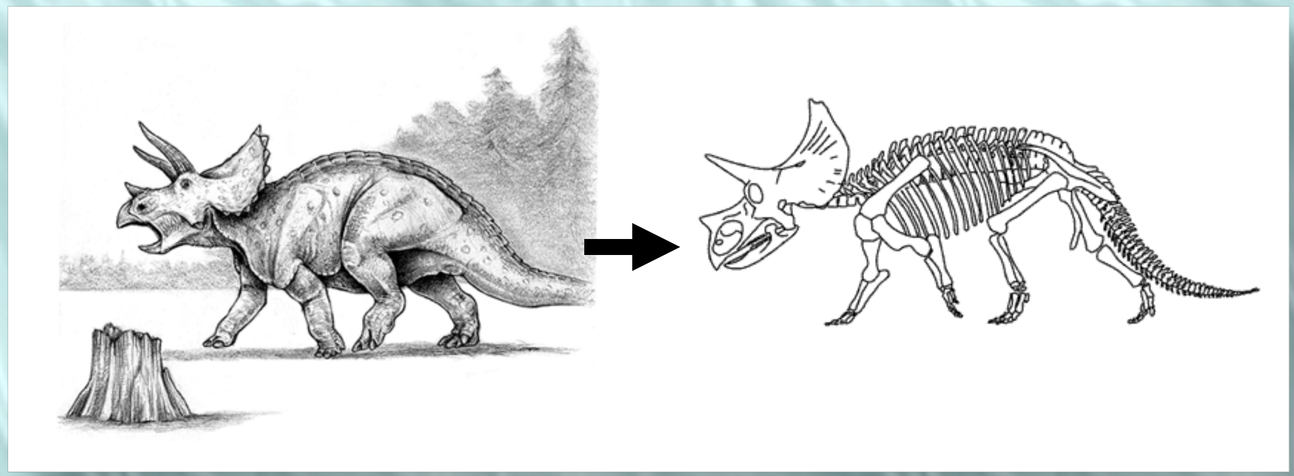


Adapted from Carl Woese and Norman R. Pace, New York Times, April 14, 1998

http://cas.bellarmine.edu/tietjen/

Taphonomy - the study of the post-mortem history of organic matter.

- Building blocks of organic remains
- Post-mortem history
- Modes of preservation



Chemical Composition of the Human Body

PRIMARY ELEMENTS

H	63.0%
O	25.5%
C	9.5%

SECONDARY ELEMENTS

Ca	0.31%
P	0.22%
K	0.06%
S	0.05%
Na	0.03%
Cl	0.03%
Mg	0.01%

TRACE ELEMENTS (<0.01%)

Cr	Mn
Co	Mo
Cu	Se
F	Si
I	Sn
Fe	Zn

(Frieden 1972)

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(Frieden 1972)

carbohydrates

$C_nH_{2n}O_n$

amino acids

$C_6H_{14}N_2O_2$ **(lysine)**

Heme a

$C_{49}H_{56}O_6N_4Fe$

Soft Parts and Hard Parts

Volatile ("soft")- easily and quickly digested

e.g, sugars, starches, fats, simple proteins

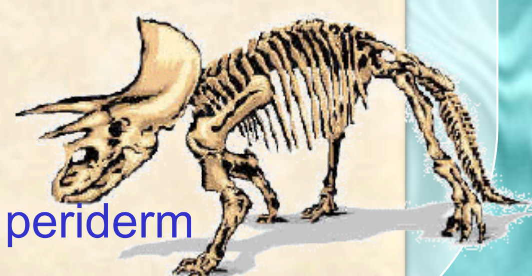


Refractory ("hard")- tough to break down

e.g., biominerals, wood


Common Refractory Biomolecules

Sporopollenin	*oxidative polymer* of *carotenoid* or *carotenoid esters* dinoflagellates, acritarchs, plant spores and pollen
Cellulose	*polysaccharide carbohydrate* plant cell walls
Lignin	*polyaromatic* woody plants
Melanin	*polyaromatic* cephalopod ink, fungi pigment
Chitin	*polysaccharide carbohydrate* arthropod cuticle, fungi hyphae
Collagen	*protein polymer* chordate bone and skin, graptolite periderm



(Allison and Briggs 1991)

Common Biominerals

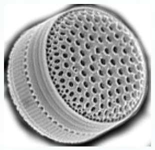
Aragonite $CaCO_3$

scleractinian corals, some mollusks, some algae

Calcite $CaCO_3$

rugose and tabulate corals, some brachiopods, bryozoans, some mollusks, echinoderms, calcareous nannofossils

Carbonates



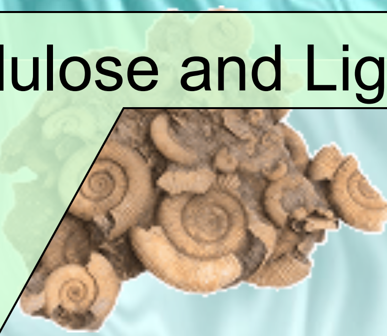
Opalline Silica $SiO_2*(H_2O)$

silicoflagellates, diatoms, radiolarians, some sponges

Apatite $Ca_5(PO_4)_3(OH, F)$

Chordates, conodonts, some brachiopods

(Allison and Briggs 1991)



Cellulose and Lignin

Apatite and Collagen

Organisms with readily identifiable hard parts have good fossil records, e.g.

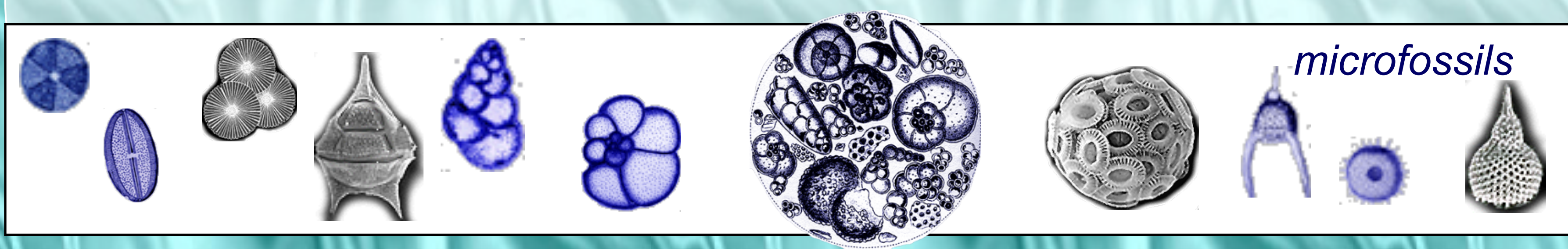
Calcite and Aragonite

Calcite and Aragonite

Sporopollenin

- Clams, snails, and other creatures with **shells**
- Corals and other organisms that make **rocky skeletons**
- Animals with **bones**
- Plants with **wood**
- Plant **spores** and **pollen**
- Many microscopic organisms with **hard parts**

Calcite, Aragonite, Silica, Sporopollenin, and others



Post-Mortem Destruction

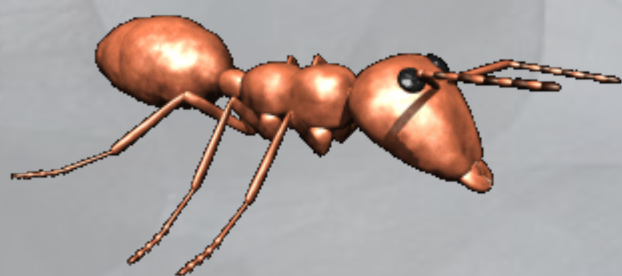
The fossil record is biased specifically against organisms without hard parts. Preservation of these animals requires some kind of special conditions. The more robust remains are also more likely to be preserved than delicate bits.

In a typical shallow water marine environment, approximately 40% of bottom-dwelling species have hard parts. Almost all of those species have fossil records.

Of the remaining 60% of species, almost none are found as fossils.

Post-Mortem Destruction

Remains left on the surface tend to degrade much more quickly than interred remains due to ***physical***, ***chemical***, and ***biological*** processes



scavenging, decay, recycling, accidental destruction

Preservation of fossil remains depends on relatively rapid and permanent burial.

Post-mortem Decay

http://lauri.vox.com/library/posts/tags/dog/

A lot of energy goes into building and maintaining a living organism.

http://saltlakecity.about.com/

Post-mortem Decay

As long as an organism is alive, it expends energy and resources to maintain its body. While disease can cause some deterioration, most carcasses are relatively whole before death.

How an organism dies is important in determining whether or not it will be fossilized.

http://www.wildlifemanagementpro.com/2007/12/05/wyoming-offers-great-pronghorn-hunting-on-public-land/

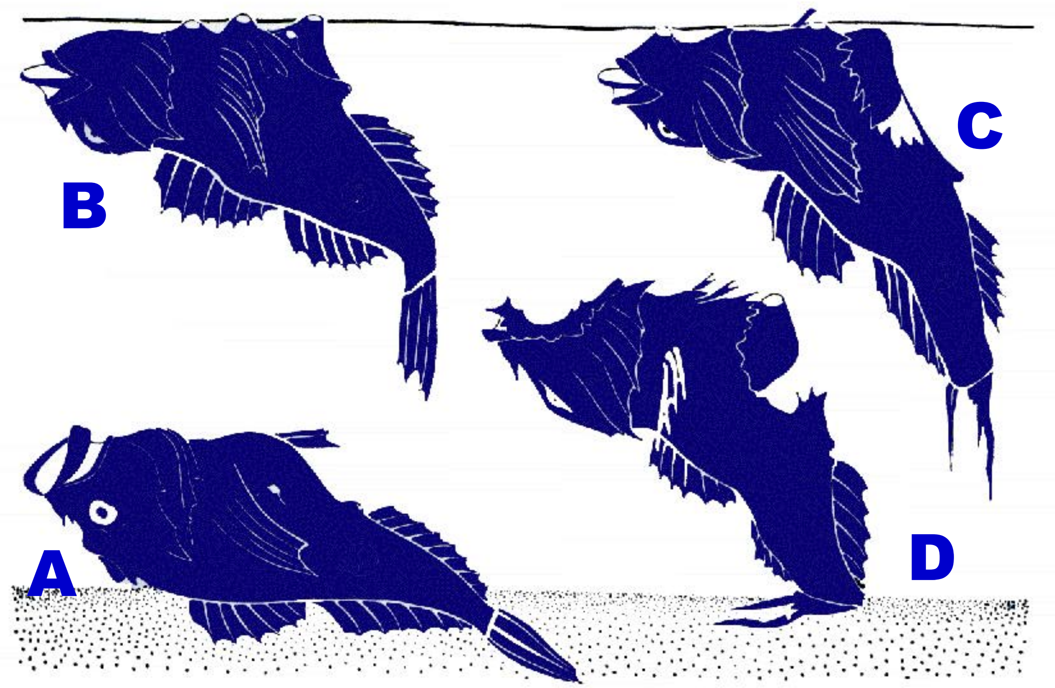
http://www.outdoorsunlimited.net/

Post-mortem Decay

Predators and scavengers will strip even the hardiest carcasses, removing some parts and scattering others.

http://www.kaibab.org/

Post-Mortem Decay

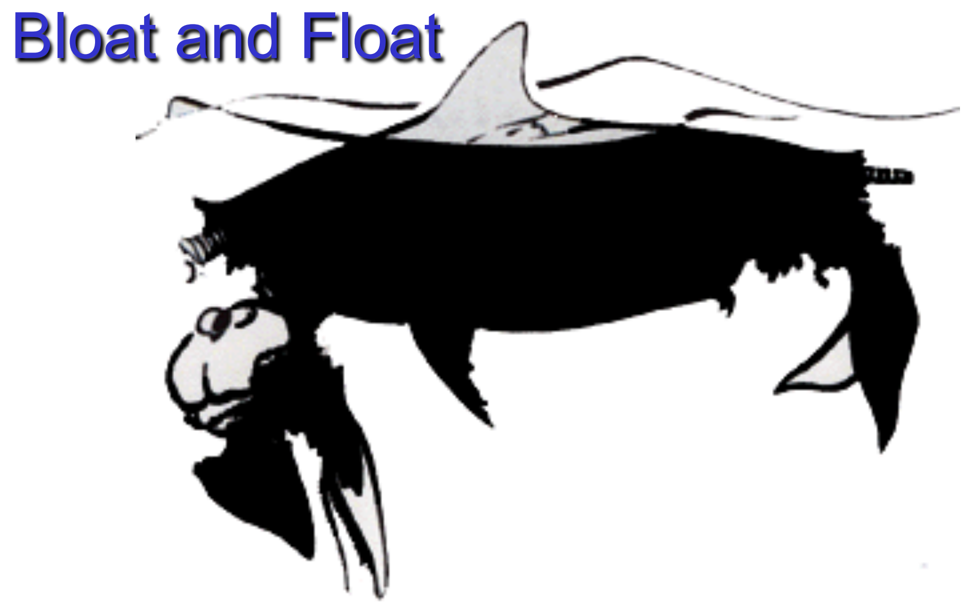


Schaefer, W. 1972. Ecology and palaeoecology of marine environments. University of Chicago Press.

Bloat and Float

- **A** carcass sinks
- **B** carcass fills with decay gas, and floats
- **C** decay continues, with pieces detaching
- **D** gas escapes, allowing carcass to sink

Post-Mortem Decay



Schaefer, W. 1972. Ecology and palaeoecology of marine environments. University of Chicago Press..

Large carcasses (especially of well-constructed animals like dolphins) can float for weeks or months before sinking

Different parts fall off at different times, spreading the remains over a wide area.

Post-Mortem Destruction

Organisms that lived (and died) in environments in which they were not likely to be buried before complete disintegration don't have good fossil records.

Burial requires relatively high sedimentation rates (at least periodically), and so fossils are most likely found in environments in which sediment is being accumulated.

Since marine environments are more likely to accumulate sediment than terrestrial environments, the fossil record of ocean life is much better than that of land organisms.

Modes of Preservation

Organism remains are frequently altered in one way or another before, during, and after burial.

Both chemical and physical alterations are common, and the resulting fossil is frequently not composed of the same material as the original remain.

Unaltered Remain

Some fossils are essentially unaltered organic material. Such preservation is exceedingly rare for soft parts, but more common for hard parts.

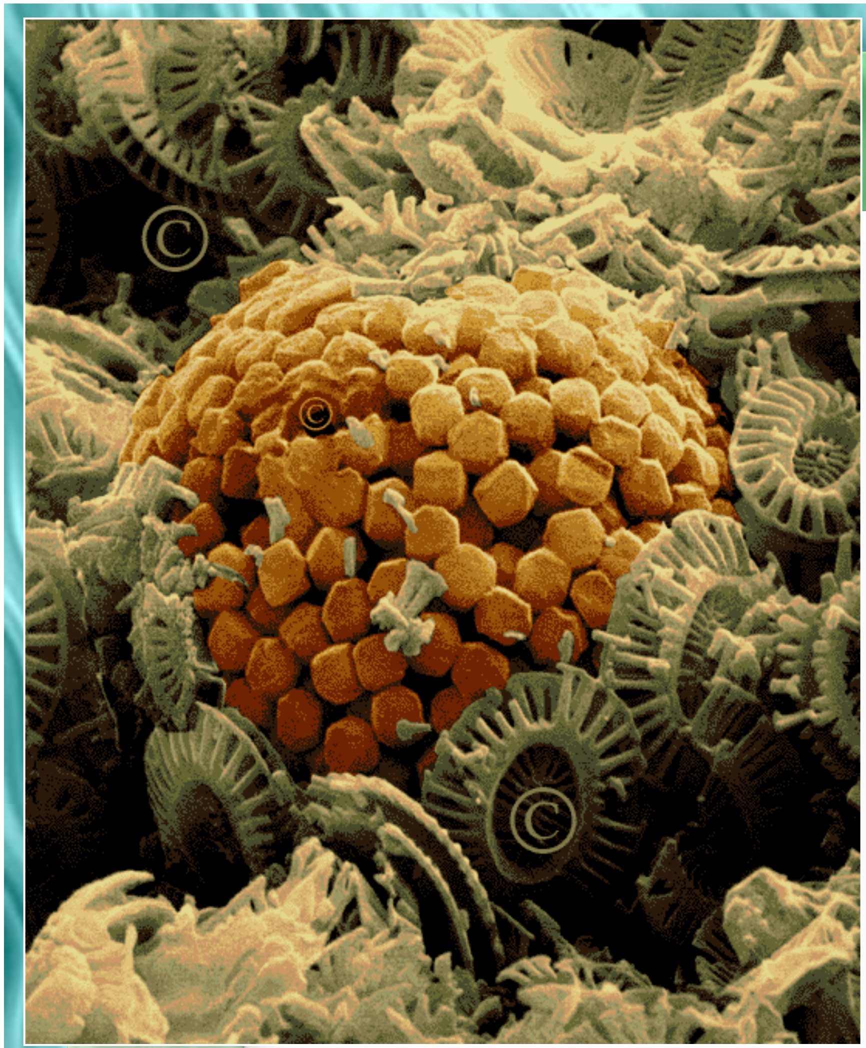
http://www.calacademy.org/

Distillation

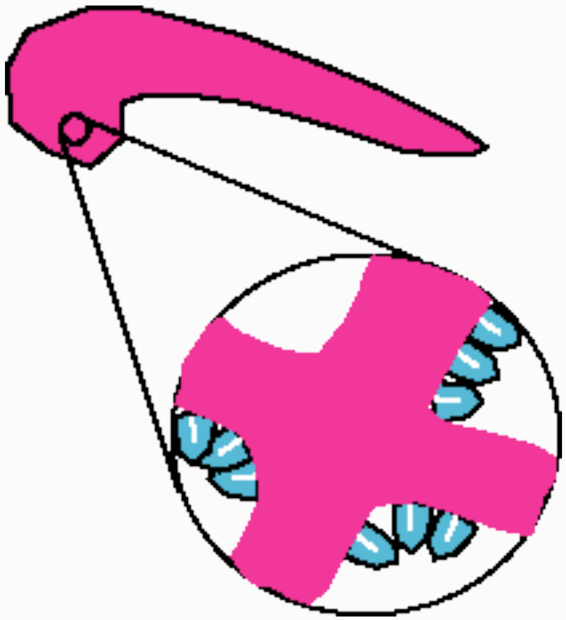
Alteration of organic molecules leaving behind a carbon film. Can result in very fine scale preservation of soft parts.

300-million-year-old arachnid with what look like silk-spinning structures

http://researchnews.osu.edu/archive/silkspin.htm



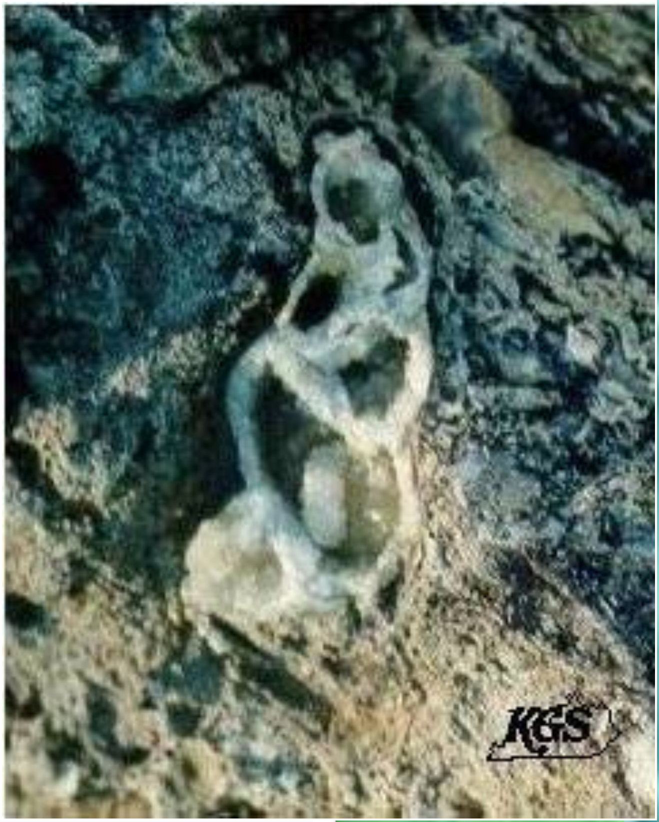
Permineralization



Void spaces in remain fill with mineral crystals. The mineralogy of infill may or may not be the same as that of the remain.

http://www.ldeo.columbia.edu/

Recrystalization



The biominerals (plus any permineralized crystals) re-crystallize, maintaining the same bulk chemical composition of the original. This process usually destroys fine scale features.

Replacement

The remain is replaced by a mineral. The process can preserve very fine detail (especially in pyritization and phosphatization), or can obliterate details.

Common Replacement and Permineralization Minerals

Pyrite (FeS)

Common in stinky, reducing environments

Hematite (Fe_2O_3)

With limonite, the main kind of "rust."

http://www.nysm.nysed.gov/

http://www.ndc.edu/

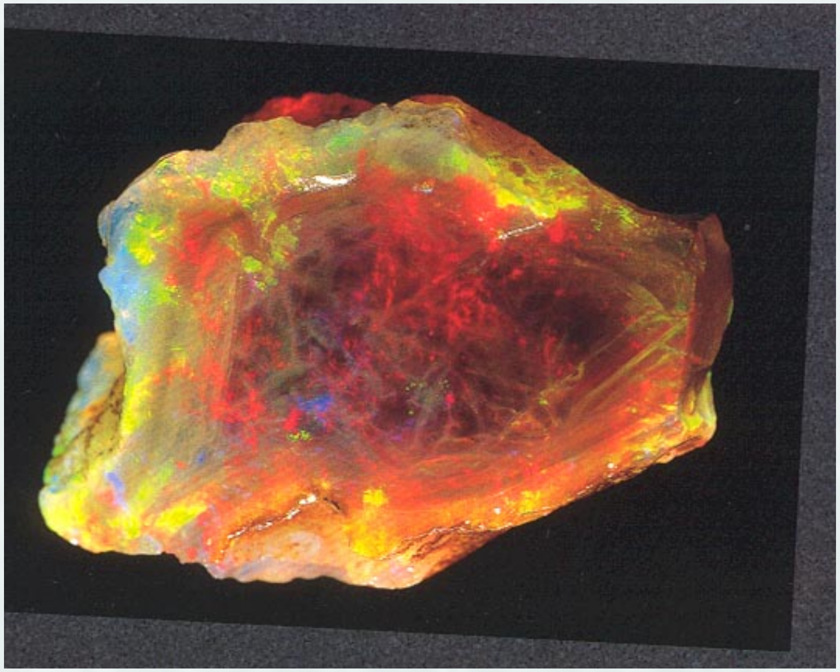
Common Replacement and Permineralization Minerals

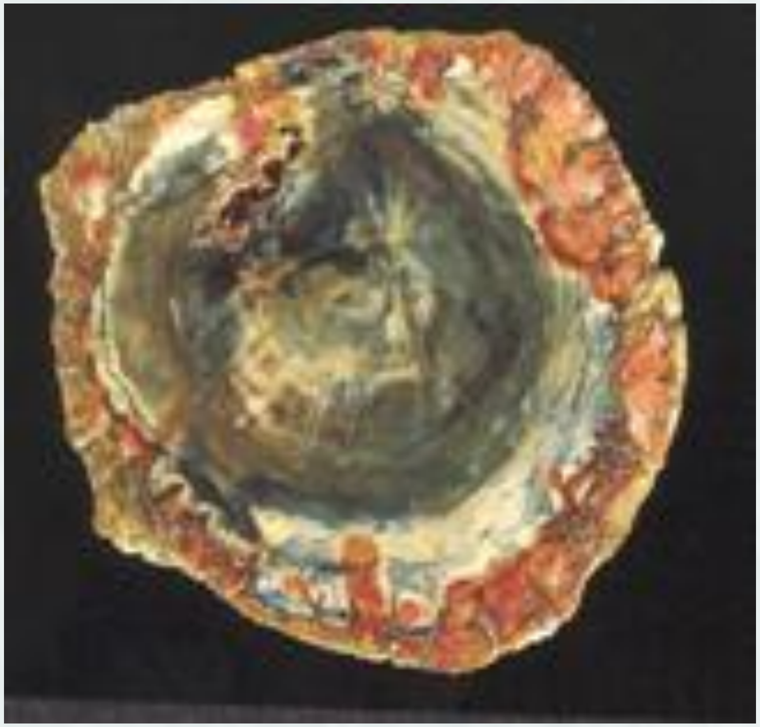
Iron oxide precipitation

Manganese oxide precipitation

http://www.scalefighter.com/

Common Replacement and Permineralization Minerals





Opalline silica ($SiO_2 \cdot H_2O$) and chert (SiO_2)

Commonly precipitated where concentration of silica ions (derived from unstable silicates) is high (e.g., volcanic regions).

http://www.ncsec.org/

Common Replacement and Permineralization Minerals

Lime Scale

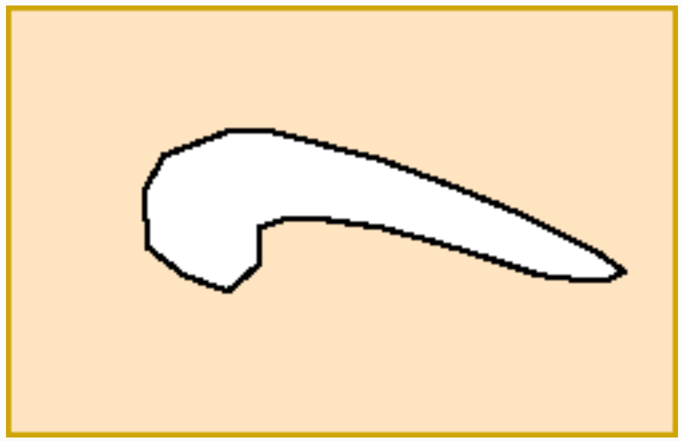
Calcite ($CaCO_3$) precipitation

"scale" build-up in water heaters and pipes

http://www.scalefighter.com/

http://cwx.prenhall.com/

Casts and Molds



Molds form when a buried remain dissolves after (or during) lithification, leaving impressions of the remain and containing a void space. A cast is a secondary infilling of a mold.

http://www.uky.edu/