

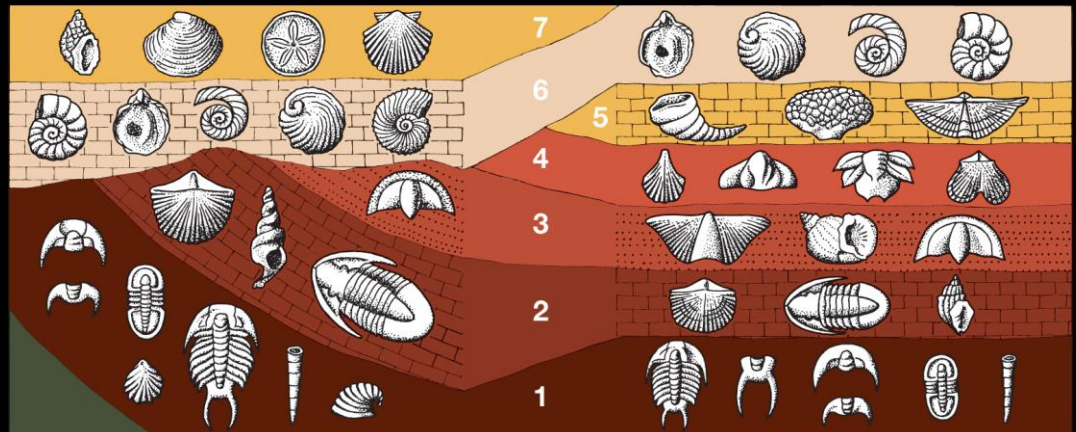
Fossils and Geologic Dating

Principles and Applications



A

B



© Encyclopædia Britannica, Inc.










Earth Science Laboratory – EOSC 110

Ray Rector - Instructor

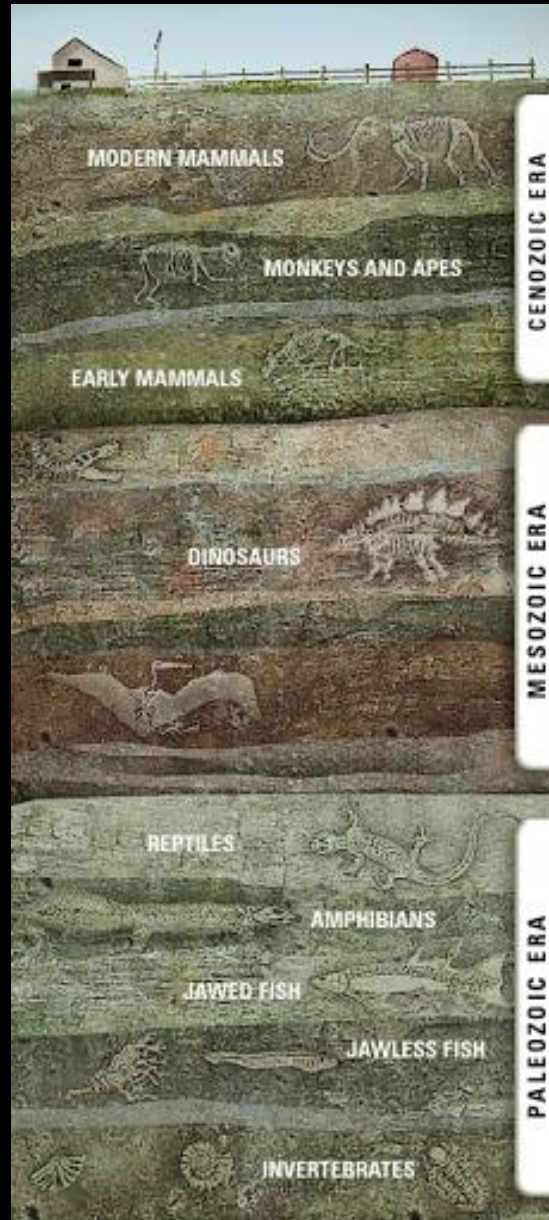
Fossil Laboratory

Today's Topics of Inquiry

- 1) Origin of Fossils
- 2) Types of Fossils
- 3) Preservation of Fossils
- 4) Fossil Succession and the Geologic Time Scale
- 5) Using Fossils to Date Rocks
- 6) Index Fossils of Each Era

GEOLOGIC TIME SCALE			
ERA	PERIOD	EPOCH	SUCCESION OF LIFE
CENOZOIC recent life	QUATERNARY 0-1 Million Years Rise of Man	Recent Pleistocene	
	TERTIARY 62 Million Years Rise of Mammals	Pliocene Miocene Oligocene Eocene	
MESOZOIC middle life	CRETACEOUS 72 Million Years Modern seed bearing plants, Dinosaurs		
	JURASSIC 46 Million Years First birds		
	TRIASSIC 49 Million Years Cycads, first dinosaurs		
PALEOZOIC ancient life	PERMIAN 50 Million Years First reptiles		
	PENNSYLVANIAN 30 Million Years First insects		
	MISSISSIPPIAN 35 Million Years Many crinoids		
	DEVONIAN 60 Million Years First seed plants, cartilage fish		
	SILURIAN 20 Million Years Earliest land animals		
	ORDOVICIAN 75 Million Years Early bony fish		
	CAMBRIAN 100 Million Years Invertebrate animals, Brachiopods, Trilobites		
	PRECAMBRIAN Very few fossils present (bacteria-algae-pollen?)		

EARTH'S HISTORY IS RECORDED IN ITS ROCKS



Scientific Means of Dating Rocks

Two Primary Means of Dating Rocks:

1) Relative Dating

- ✓ Determines the temporal order of rock forming events
- ✓ Does not give numeric ages
- ✓ Use of stratigraphic principles and index fossils

2) Absolute Dating

- ✓ Determines the numeric age of rock forming events
- ✓ Only appropriate for ages of igneous rocks and minerals
- ✓ Primary method is the ***radiometric technique***
- ✓ Used in conjunction with stratigraphic principles and fossils

Relative Versus Absolute Dating

Relative Dating

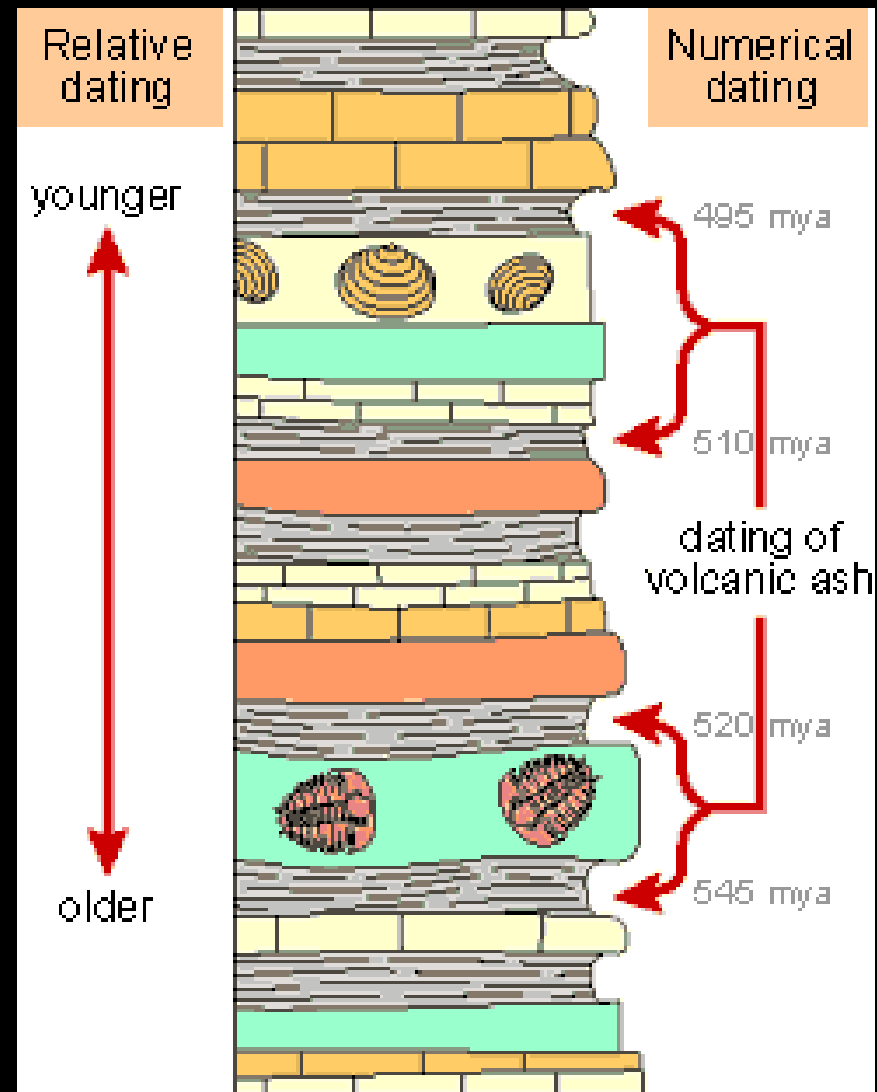
Stratigraphic principles

Fossil Succession

Absolute Dating

Radiometric techniques

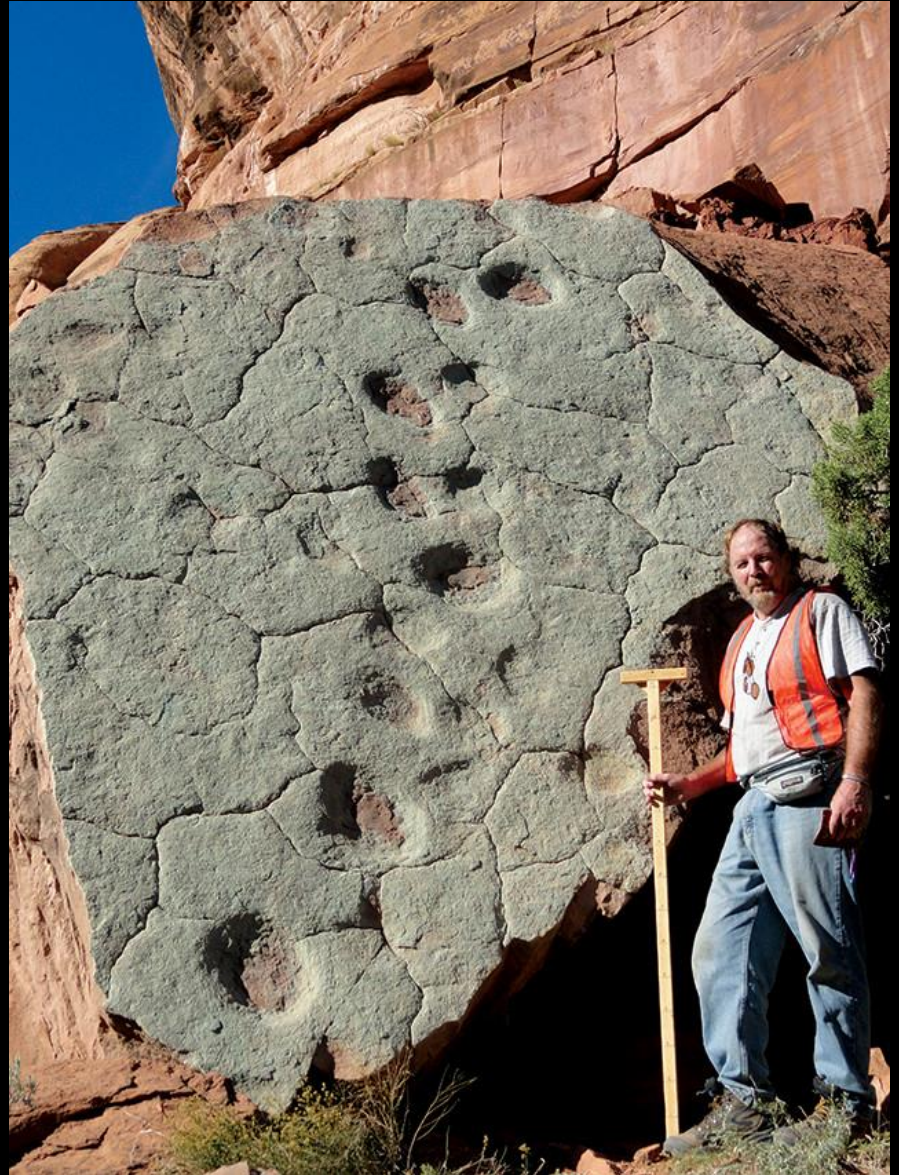
Igneous layers



The Geologic Timescale is Organized by the Fossil Record

Eon	Era	Period		Epoch	
Phanerozoic (<i>Phaneros</i> = “evident”; <i>zoic</i> = “life”)	Cenozoic	Quaternary		Recent, or Holocene	Age of Mammals
				— 10,000 —	
		Tertiary	Neogene	Pleistocene 1.6	
				Pliocene 5	
				Miocene 24	
			Paleogene	Oligocene 38	
				Eocene 58	
				Paleocene 66	
	Mesozoic	Cretaceous		140	Age of Reptiles
		Jurassic		205	
		Triassic		248	
	Paleozoic	Permian		286	Age of Amphibians
		Carboniferous	Pennsylvanian	320	
			Mississippian	360	
		Devonian		408	Age of Fishes
		Silurian		438	
		Ordovician		505	Age of Marine Invertebrates
		Cambrian		544	
Proterozoic (“Early Life”)		Precambrian	2500	Age of Unicellular Life	
Archean (“Ancient”)			~3800		
Hadean (“Beneath the Earth”)			~4600		

What are Fossils?



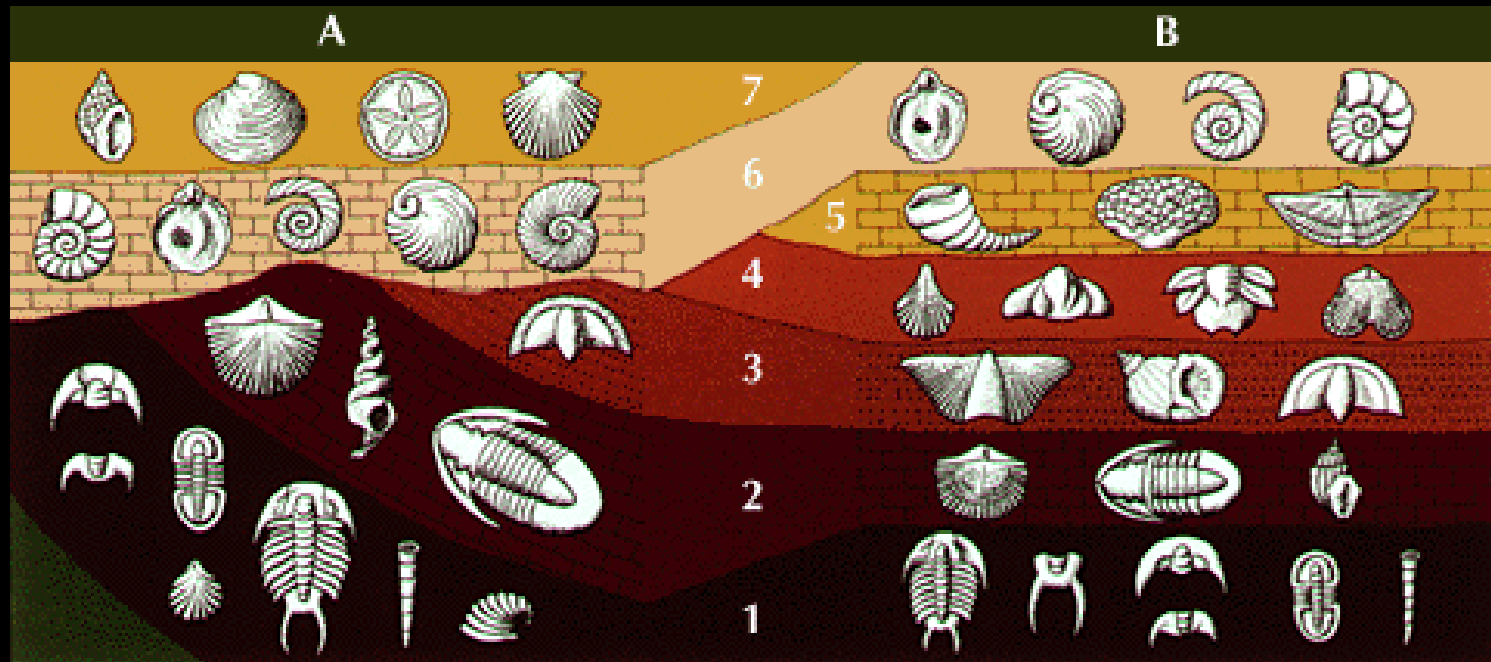
Fossils

- Fossils are the preserved remains or evidence of living things



Question:

- Fossils are usually formed when the organism dies and gets buried in mud or sand. As a result, the hard parts are preserved. What type of rock are fossils usually found in?



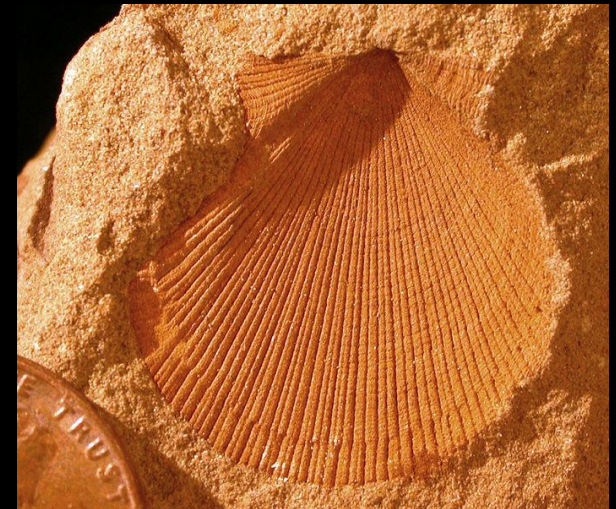
Questions:

- Why are fossils NOT usually found in igneous rock?



Questions:

- What are the 5 types of fossils?



Types of Fossils

1. Body (hard parts) Fossils

2. Trace Fossils - the remains of an organism's activities

- trackways,
- burrows,
- footprints,
- borings,
- nests,
- eggs,
- coprolites (fossil feces),



3. Chemical Fossils

- biomolecules such as proteins, amino acids, lipids, and nucleic acids (RNA, DNA).

Types of Fossils

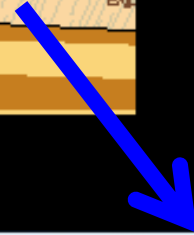
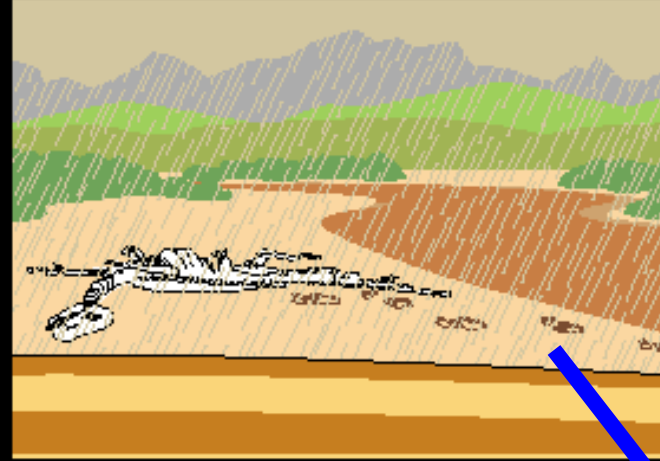
1) Original Remains: The unchanged remains of plants and animals

– Examples

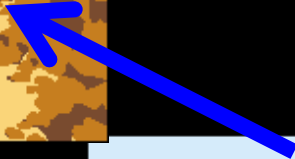
- Hard parts: Bones, Shells
- Animals trapped in ice: Woolly Mammoth
- Animals trapped in tar or in amber
- Shell trapped in sediment



Fossil defined: The natural remains or traces (preservation) of past life.



Paleontology: The study of life in the past.



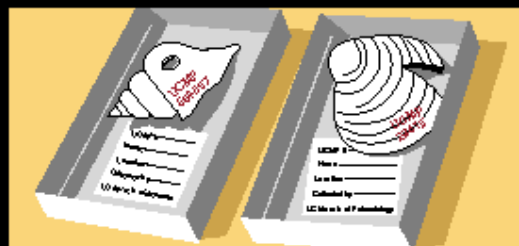
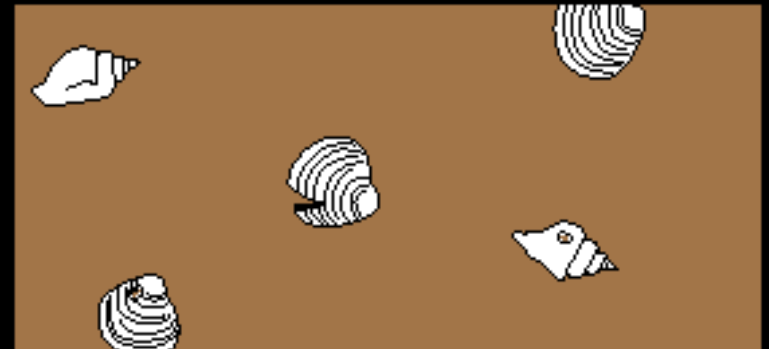
Trace fossils: include any impression or other preserved sign of activity (for example, feeding, scratching, burrowing, walking, or resting).



**Crocodile Coprolite
Green River Formation
Eocene**



Bias in the Fossil Record



Modes of Fossilization

1) Unaltered remains-

- Bone or plant material is still porous, shells may still possess mother of pearl inner linings



2) Soft part preservation

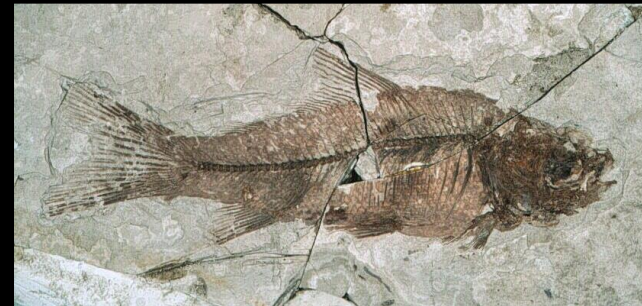
- freezing in permafrost
- dessication,
- lithified tree sap (amber)
- tar



3) Carbonization

Organic-laden hard parts and soft parts preserved as a thin film of organic carbon.

volatile materials (N, O, H, and S) are driven off leaving a thin film of black carbon behind.

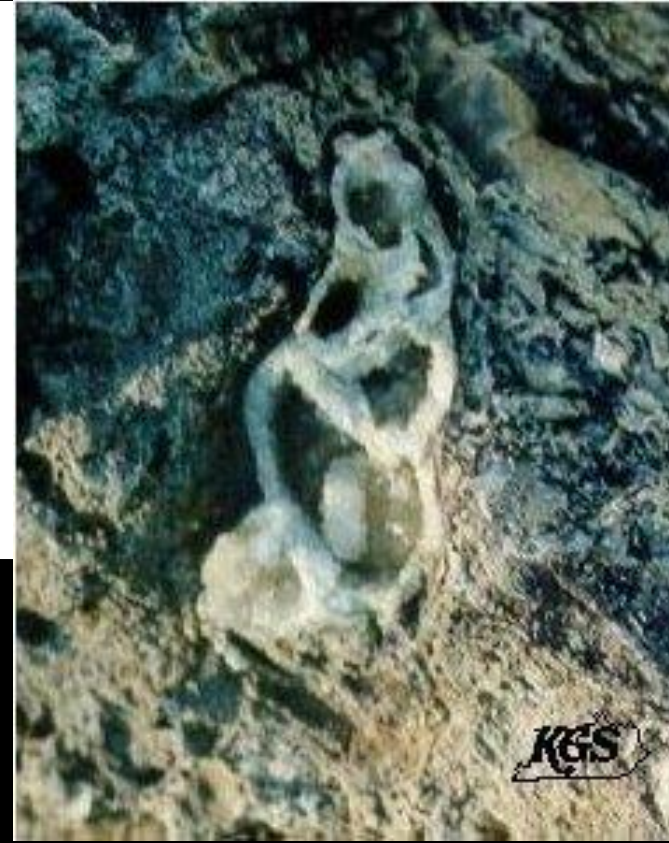


4. Recrystallization of hard parts

- Unstable to stable mineral:
 - Aragonite to calcite
- Recrystallization of same mineral
 - Usually to larger crystals

Replacement: is an atom for atom substitution of a mineral's components with the elements composing the replacing mineral

pyritization



5. Permineralization/ Petrification

porous materials such as bones & trees

- a) Burial
- b) groundwater percolates through its pore spaces.
- c) A solution supersaturated in a mineral (usually silica) precipitates minerals in the microscopic pore spaces.
- d) Structure of the original wood or bone is preserved

5) Permineralization / Petrification



Modes of Fossilization: Molds and Casts

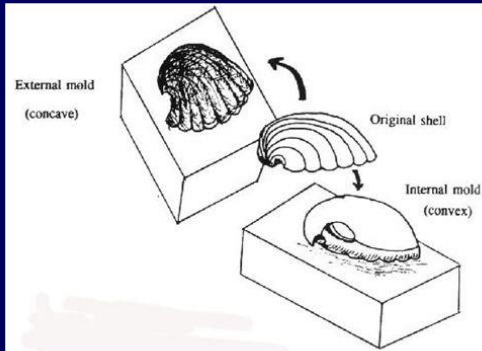


Two types of molds



External mold- imprints of the outside of a fossil. For example, if the original fossil shell was convex, the external mold will be concave.

Internal mold- imprints of the inside of a fossil. They are produced when an organism such as a shell, is filled with sediment that becomes cemented and then the shell dissolves away.



Molds

CAST FOSSIL

- Forms when a mold is filled with sand or mud that hardens into the shape of the organism.

Casts



Molds and Casts

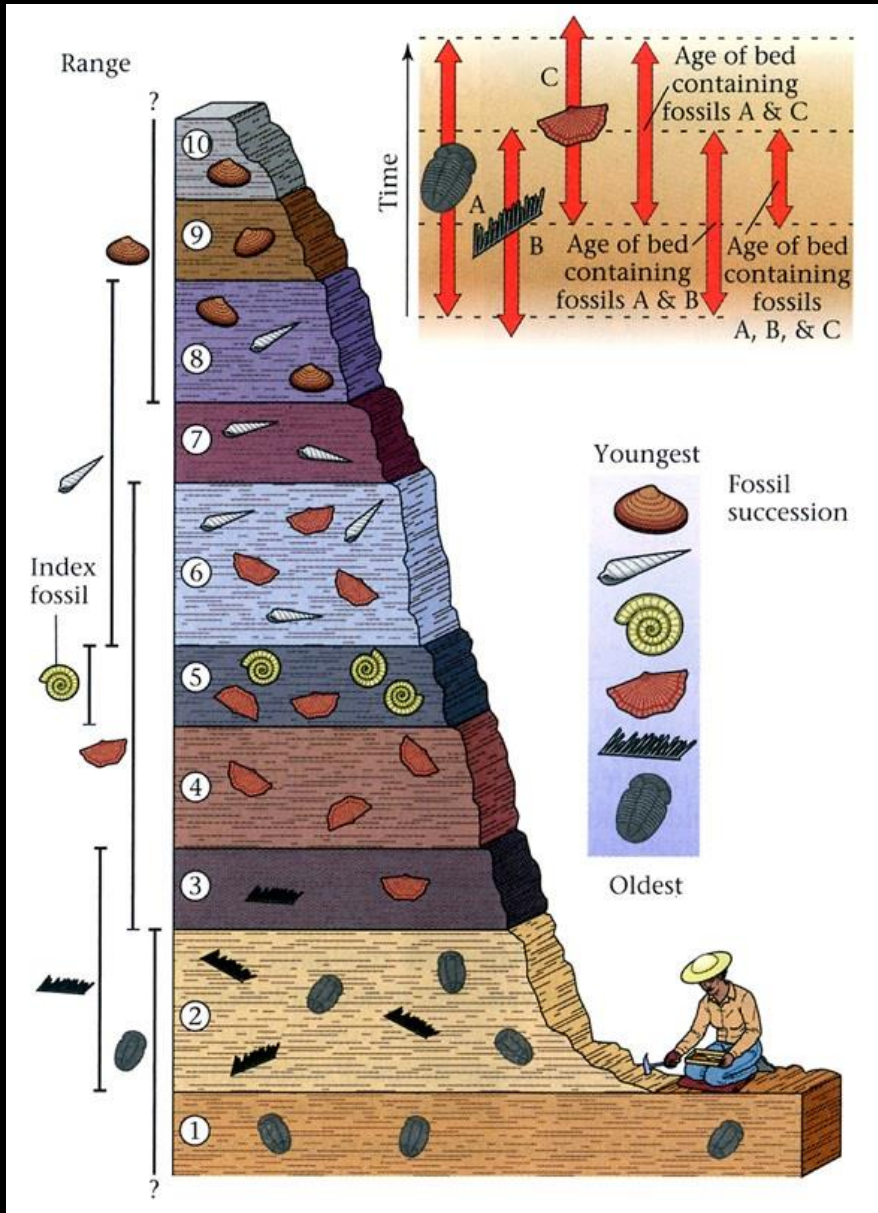




Pamela Gore, 1998



Principle of Fossil Succession



Key Ideas:

Life Evolution: Life on Earth changes over time – marked by extinction and speciation

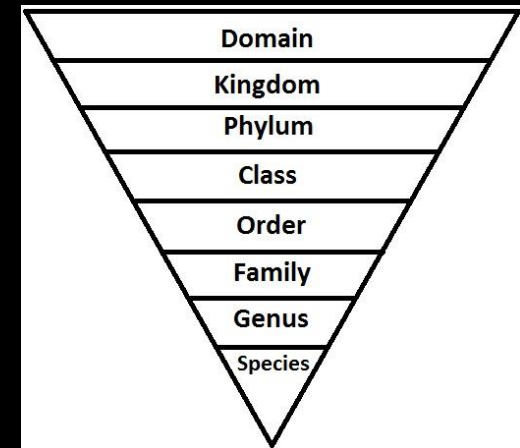
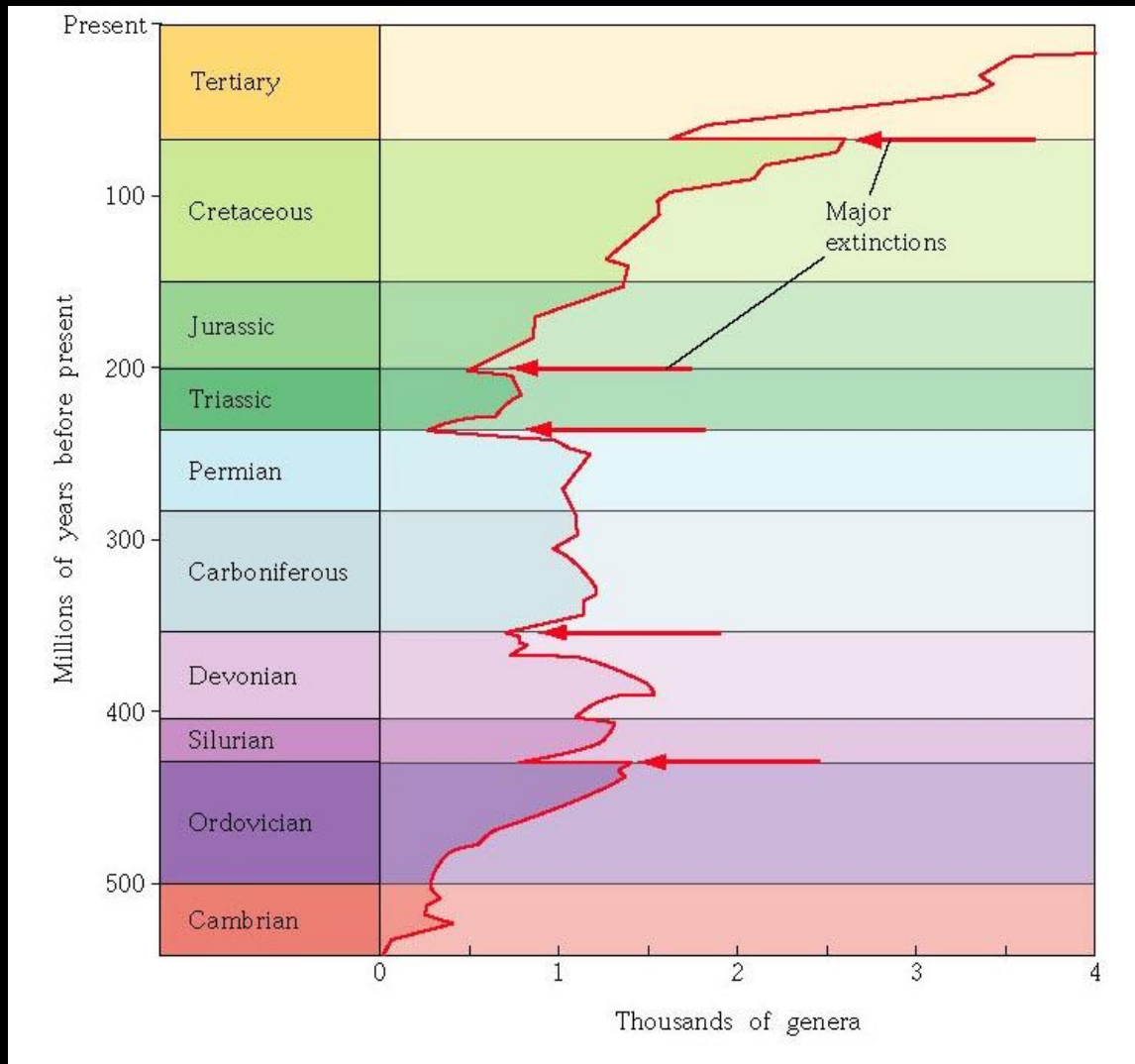
Major life-changing mass-extinction events punctuate Earth history - vast numbers of old species vanish while new species take their place

Every period of geologic time had a unique assemblage of life

A fossil-containing rock has an age equal to that of the fossil

The principle of superposition applies to fossil succession

Changes in the abundance and diversity of life
























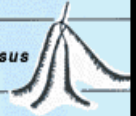


99 % of all of the species that ever existed on Earth are now extinct

Index Fossils

Criteria to be a Useful Index Fossil:

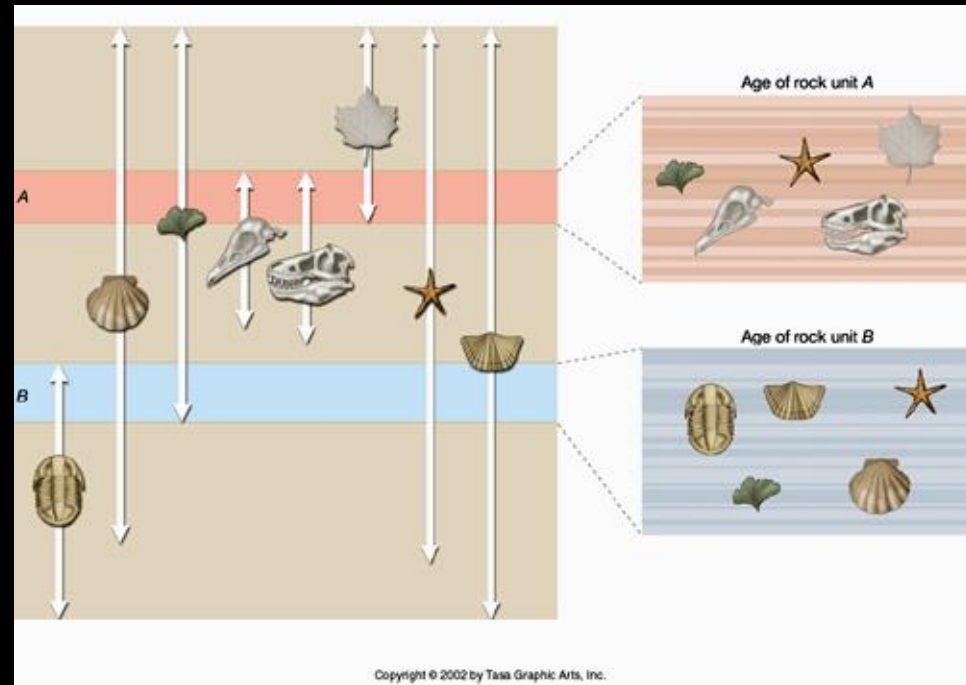
Must have:

- 1) Narrow time range age
- 2) Worldwide distribution
- 3) Preserve in a wide range of depositional settings

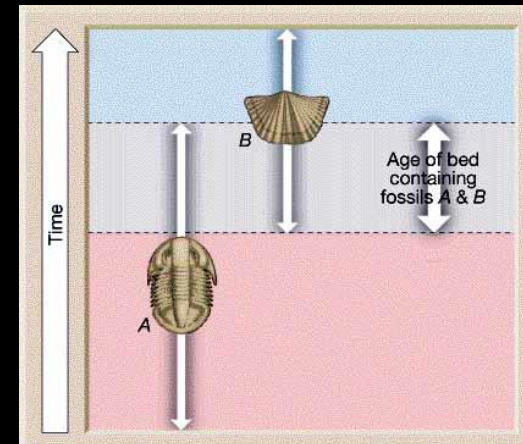
CENOZOIC ERA (Age of Recent Life)	Quaternary Period	<i>Pecten gibbus</i>		<i>Neptunea tabulata</i>	
	Tertiary Period	<i>Calyptrophorus velatus</i>		<i>Venericardia planicosta</i>	
MESOZOIC ERA (Age of Medieval Life)	Cretaceous Period	<i>Scaphites hippocrepis</i>		<i>Inoceramus labiatus</i>	
	Jurassic Period	<i>Perisphinctes tiziani</i>		<i>Nerinea trinodosa</i>	
	Triassic Period	<i>Trochites subbullatus</i>		<i>Monotis subcircularis</i>	
	Permian Period	<i>Leptodus americanus</i>		<i>Parafusulina bosei</i>	
PALEOZOIC ERA (Age of Ancient Life)	Pennsylvanian Period	<i>Dictyoclostus americanus</i>		<i>Lophophyllidium proliferum</i>	
	Mississippian Period	<i>Cactocrinus multibrachiatus</i>		<i>Prolecanites gurleyi</i>	
	Devonian Period	<i>Mucrospirifer mucronatus</i>		<i>Palmatolepus unicornis</i>	
	Silurian Period	<i>Cystiphyllum niagarensis</i>		<i>Hexamoceras hertzeri</i>	
	Ordovician Period	<i>Bathyrus extans</i>		<i>Tetraraptus fruticosus</i>	
	Cambrian Period	<i>Paradoxides pinus</i>		<i>Billingella corrugata</i>	
	PRECAMBRIAN				

Index Fossil Age Ranges

- 1) Each index fossil species has a specific determined age range.
- 2) A rock that has an index fossil will be assigned an age range to that of the fossil's age range.
- 3) Finding two or more index fossils in the same rock narrows the age range due to overlap of fossil age ranges



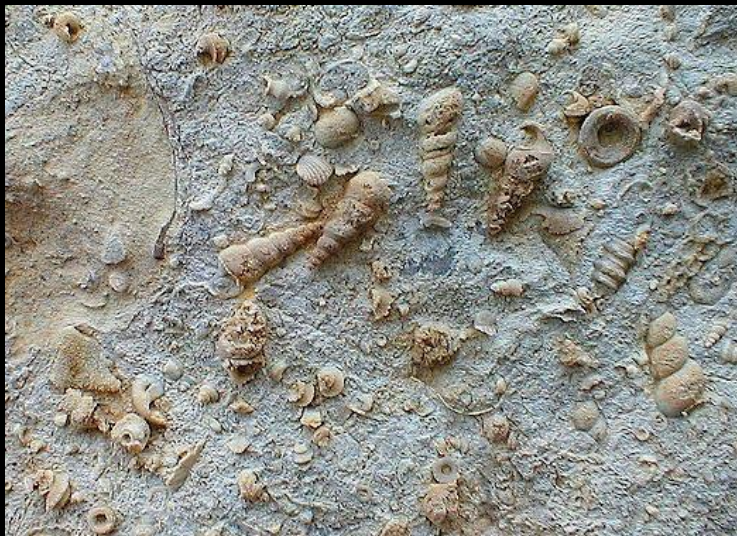
Constraining the age (range) of an index fossil assemblage



Introduction to Marine Invertebrate Fossils

- “stromatolites”
- P. Porifera
- P. Cnideria
- P. Bryozoa
- P. Brachiopoda

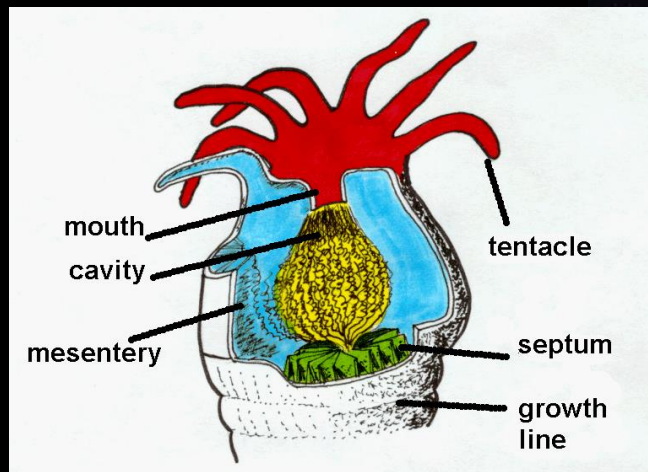
- P. Mollusca
- P. Arthropoda
- P. Echinodermata



Phylum Cnidaria (corals, anemones, jelly fish)



Only the corals
precipitate a
hard carbonate
skeleton



Class Anthozoa (corals)

Three Orders:

- **Or. Scleractinia**
 - Modern corals
 - Cenozoic
- **Or. Rugosa**
 - Horn corals
 - Paleozoic
- **Or. Tabulata**
 - Tabulate corals
 - Paleozoic



Univ. of Michigan Exhibit Museum of Natural History -- Life Through the Ages Diorama

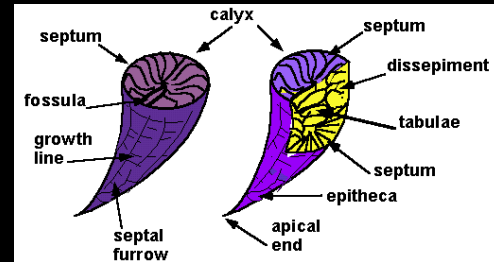
Rugose Corals

In rugosan colonies, each corallite skeleton had its own chamber wall while horizontal partitions (tabulae) were absent and septae longer and generally more complex than those in tabulate corals. Although most rugose corals were solitary animals shaped like a horn (horn corals), some grew in groups such that their skeletons were touching and formed mound-shaped colonies.

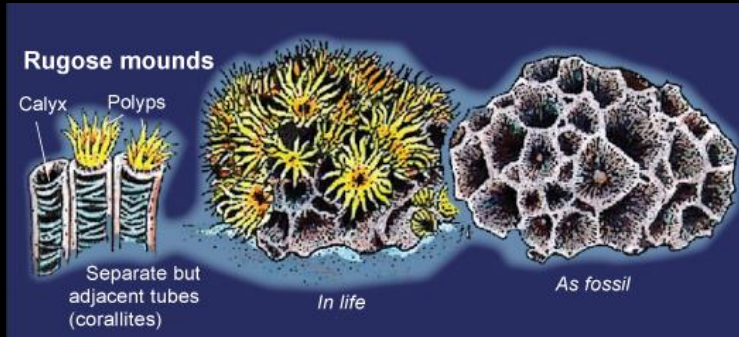
Tabulate Corals

The Tabulata are an extinct form of coral. Their distinguishing feature is their well-developed horizontal internal partitions (tabulae) within each cell, but they have reduced or absent vertical internal partitions (septae). They share the cell walls. The entire tabulate coral is called the corallum, while the individual tubular chambers within the corallum, in which the coral animal (polyp) lived, are called corallites. Most tabulates were colonial and they were the principal Silurian reef former.

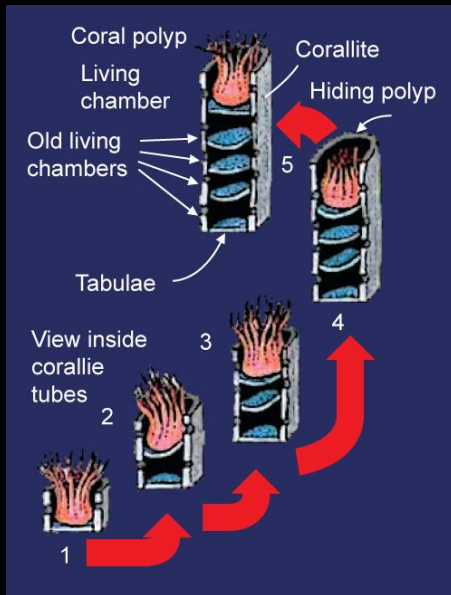
Or. Rugosa (Horn corals)



Ordovician
through
Permian



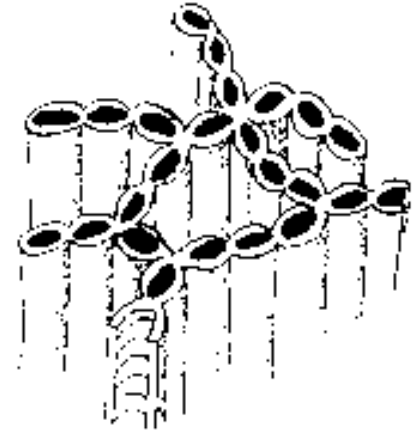
Or. Tabulata (Tabulate corals)



Ordovician
through
Jurassic



Favosites
(Honeycomb Coral)



Halysites
(Chain Coral)



(c) ummp invertebrate paleontology



Phylum Brachiopoda



Platystrophia, an Ordovician brachiopod from Will County, Illinois.



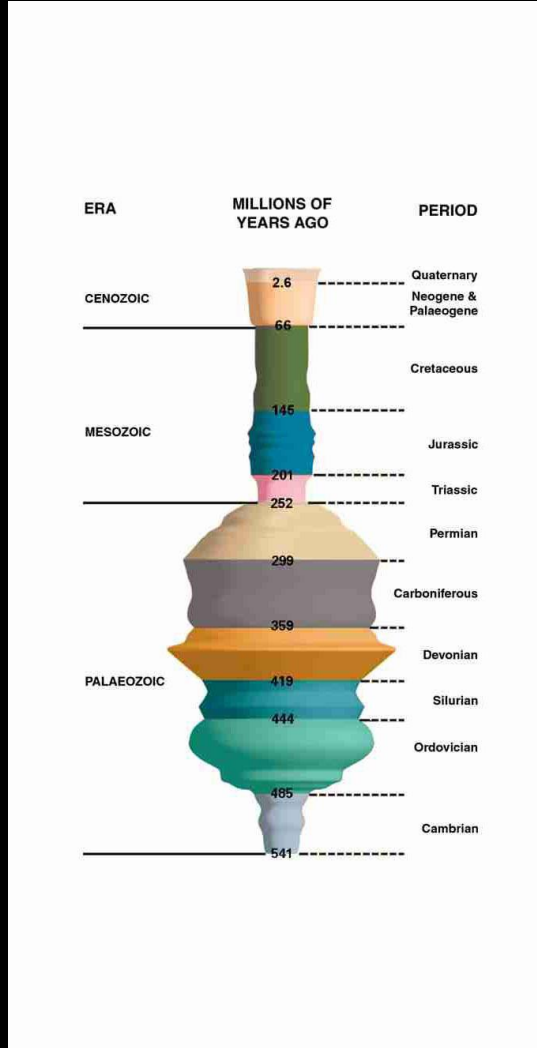
Neospirifer, a Pennsylvanian brachiopod from Peoria County, Illinois.



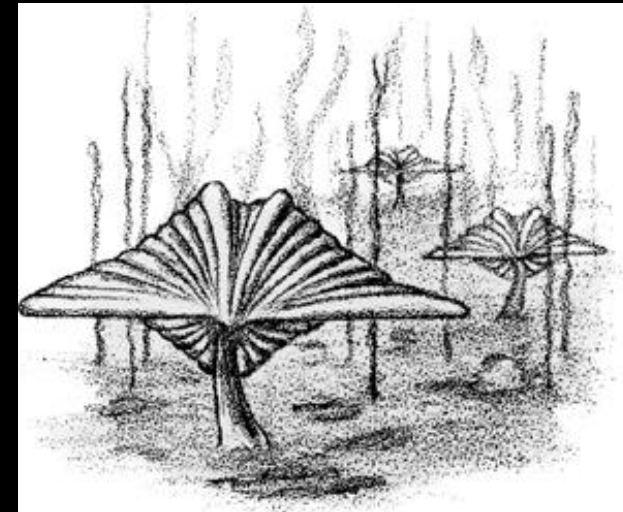
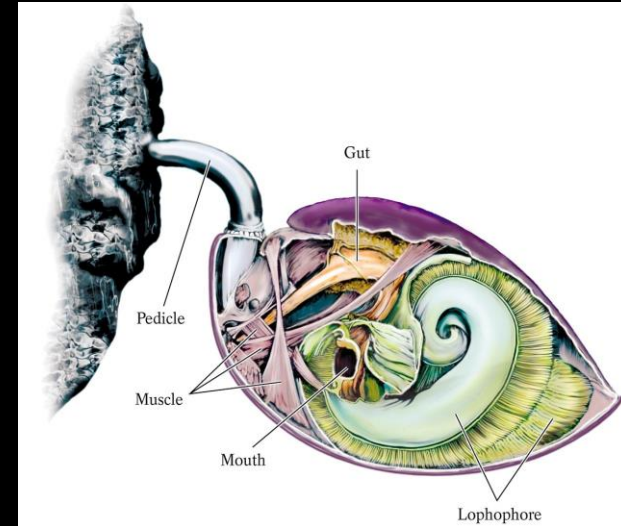
Pennsylvanian brachiopods and bryozoa from Will County, Illinois.



Composita, a Pennsylvanian brachiopod from Edgar County, Illinois.

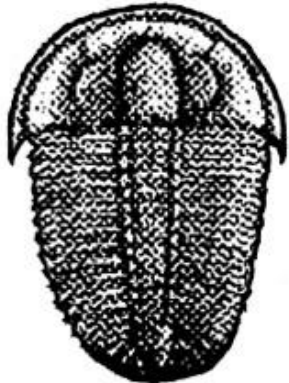
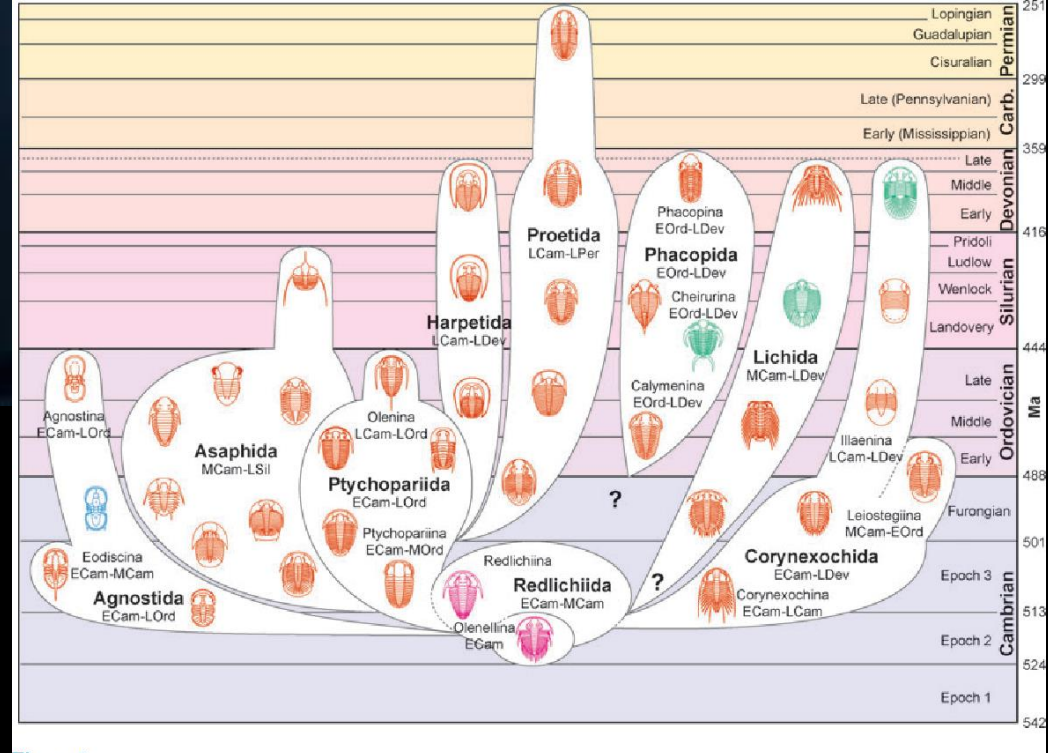
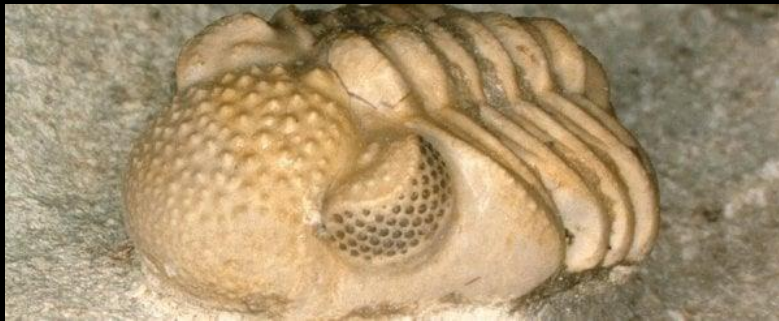


Most diverse during the Paleozoic

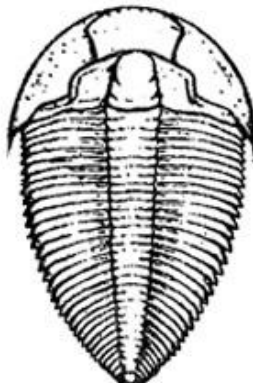


Phylum Arthropoda - Class Trilobita

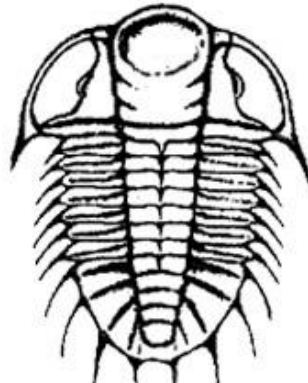
Cambrian to Permian



**Elrathia
Kingi**



**Alokistocare
Harrisi**



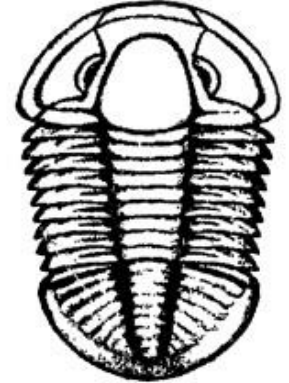
**Olenoides
Nevadensis**



**Bolaspidella
Housensis**



**Peronopsis
Interstricta**

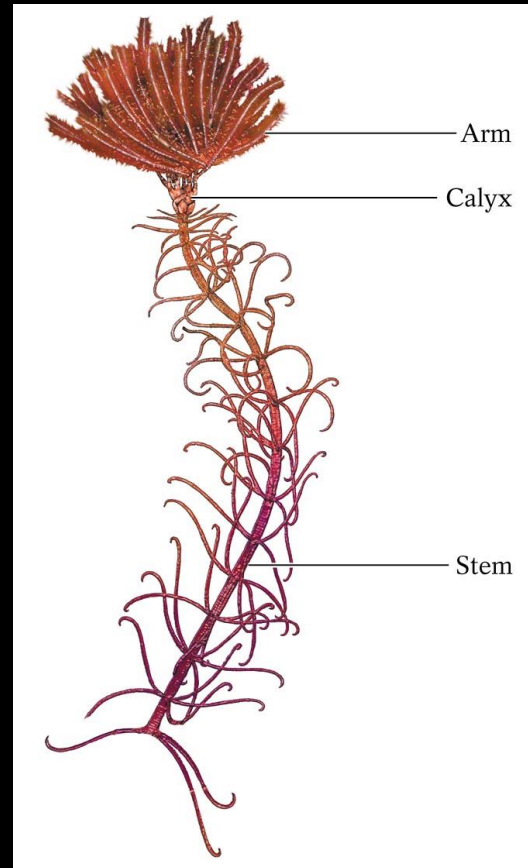


**Asaphiscus
Wheeleri**

P. Echinodermata – Class Crinoid

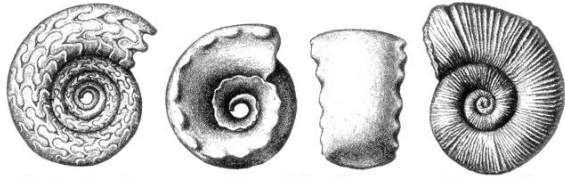


- Greatest diversity in the Paleozoic
- Most groups went extinct at the P/T boundary (225 Ma)
- ***Good indicator of a Paleozoic fossil assemblage***



Phylum Mollusca - Class Cephalopoda

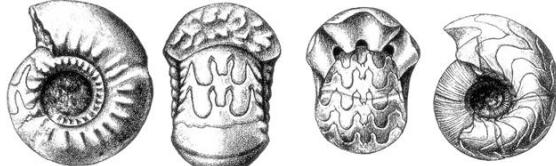
CEPHALOPODS



Protoceras 1x

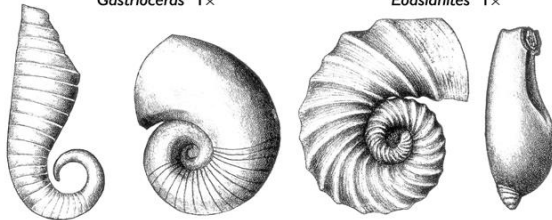
Temnocheilus 1/3x

Lytoceras 1/3x



Gastrioceras 1x

Eoasianites 1x

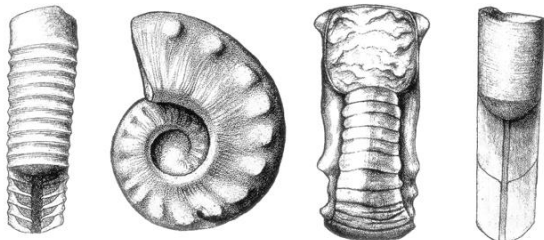


Jolietoceras 1/3x

Charactoceras 1/4x

Lechritrochoceras 2/3x

Ascoceras 2x



Dawsonoceras 1/3x

Metaceras 1/3x

Michelinoceras 1/3x



Tracking Cephalopods Through Time

Era	Period
Paleozoic	Cambrian ← 541 million to 485 million years ago → First cephalopods emerge
	Ordovician ← 485 million to 444 million years ago → Cephalopod shell shapes diversify
	Silurian ← 444 million to 419 million years ago →
	Devonian ← 419 million to 359 million years ago → The first coiled ammonoids emerge
	Carboniferous ← 359 million to 299 million years ago →
	Permian ← 299 million to 252 million years ago → The Great Permian Extinction occurs
Mesozoic	Triassic ← 252 million to 201 million years ago → Cephalopods diversify in wake of Permian Extinction
	Jurassic ← 201 million to 145 million years ago → Ammonoids and belemnites become prominent Some soft-bodied squids develop
	Cretaceous ← 145 million to 66 million years ago → Ammonoids and belemnites become extinct with dinosaurs Some soft-bodied octopods develop
Cenozoic	Paleogene ← 66 million to 23 million years ago → Mammals and fishes become dominant ocean predators Nautilus are the only remaining shelled cephalopod
	Neogene ← 23 million to 2.6 million years ago →
	Quaternary ← 2.6 million years ago to present → Only eight species of cephalopods with coiled shells remain

Ammonites and Belemnites

Paleozoic and Mesozoic



Geologic range for some of the Cephalopods

Ammonites, belemnites, othoconic nautiloids:

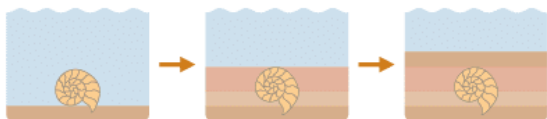
- **Greatest abundance in the Mesozoic**
- Many groups went extinct at the K/T boundary (66 Ma)
- **Good indicator of a Mesozoic fossil assemblage**



HOW DID AMMONITE FOSSILS FORM?

HOW AMMONITE FOSSILS FORM

Dead ammonites were buried by sediment millions of years ago. Chemical processes then eventually produced a fossil.



AMMONITE SHELLS

Ammonite shells are made of the calcium carbonate mineral aragonite. Over long time periods the aragonite can change into a more stable mineral form of calcium carbonate, called calcite.



Calcium carbonate



Aragonite

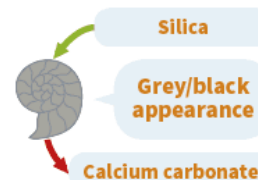
Calcite



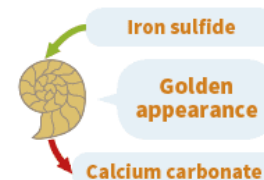
FOSSILISATION AND MINERALS

Over time the chambers of the buried ammonite shell can fill with mineral deposits. This produces detailed fossils and some shell can remain intact. In other cases the shell dissolves and mineral deposits fill the cavity to produce a cast.

SILICIFICATION



PYRITIZATION

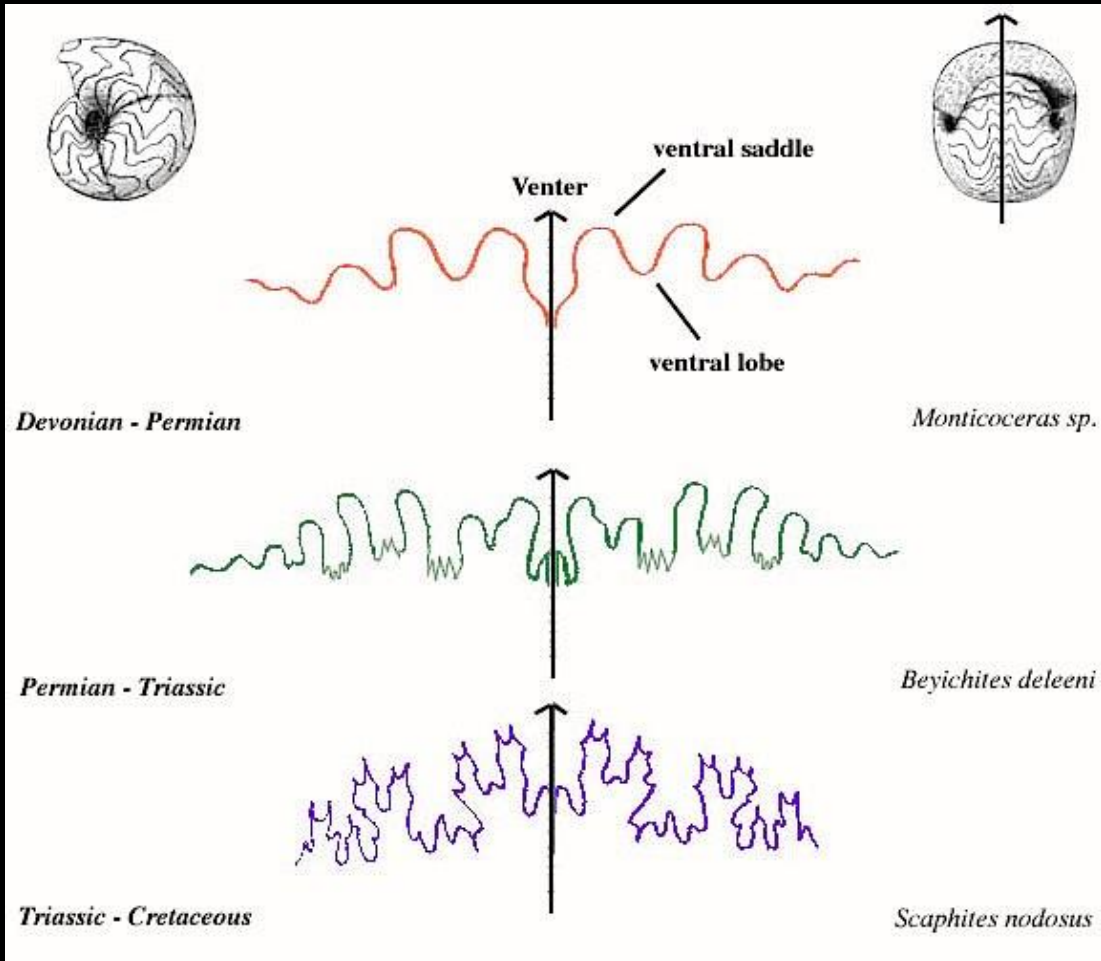


In silicification, silica-rich solutions replace calcium carbonate with silica. Pyritisation occurs in sediment saturated with iron sulfides. Pyritised fossils can oxidise and slowly disintegrate in humid conditions.





Ammonite suture patterns



Suture pattern more complex through time



Baculites: Mesozoic



orthoconic nautiloid:
Paleozoic



Belemnite: Mesozoic



In your handout with questions

Ammonoidea

Mesozoic



ammonoids

Nautiloidea

Paleozoic



nautiloids

Belemnitoidea

Belemnite: Mesozoic



belemnoids

Sepioidea



cuttlefish, *Sepia*

Coleoidea

Myopsida



nearshore squid, *Loligo*

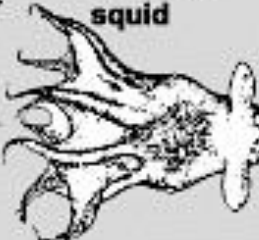
Teuthoidea

Oegopsida



oceanic squid

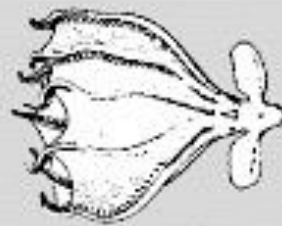
Vampyromorpha



finned octopods

Octopoda

Cirrata



Incirrata



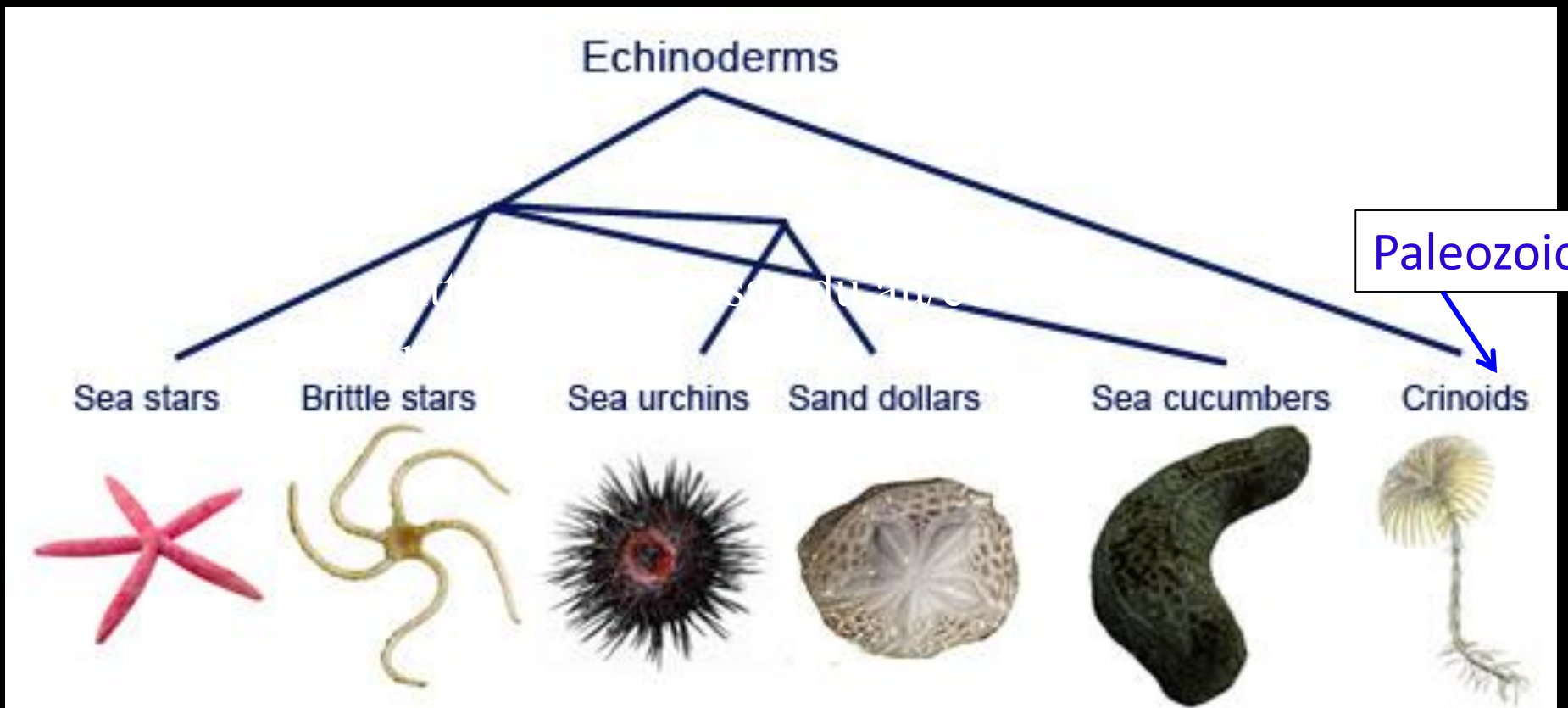
octopods, octopus

SUBCLASS

ORDER

SUBORDER

P. Echinodermata



P. Echinodermata



C. Echininoidea
“Echinoids”

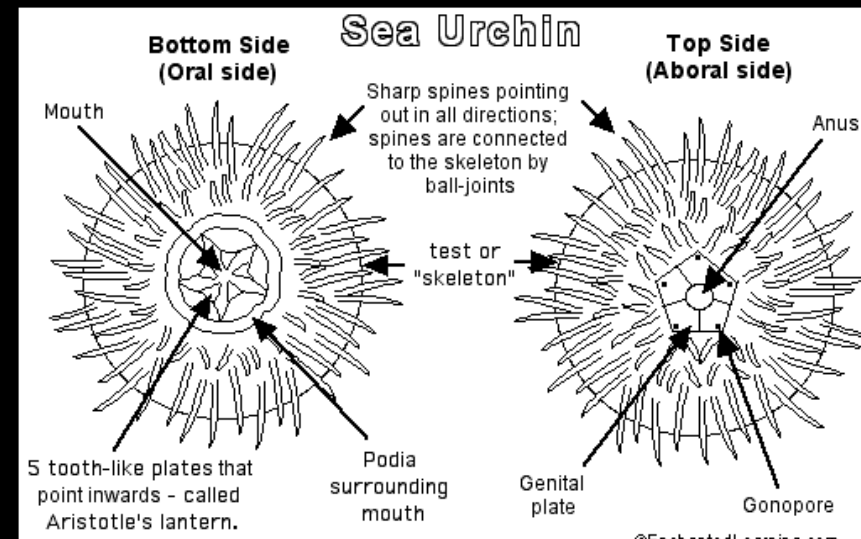
“sea urchins”

“heart urchins”

“sand dollars”



Echinoderms have **radial symmetry**, many having **five or multiples of five arms**. They have a shell, made mainly of calcium carbonate, which is covered by skin.



Phylum Mollusca

(clams, snails, squids etc.)

- Class Gastropoda: Paleozoic
 - Snails
- Class Bivalvia: Paleozoic
 - Bivalves or clams
- Class Cephalopoda: Mesozoic
 - Squid, octopus, nautilus, ammonites

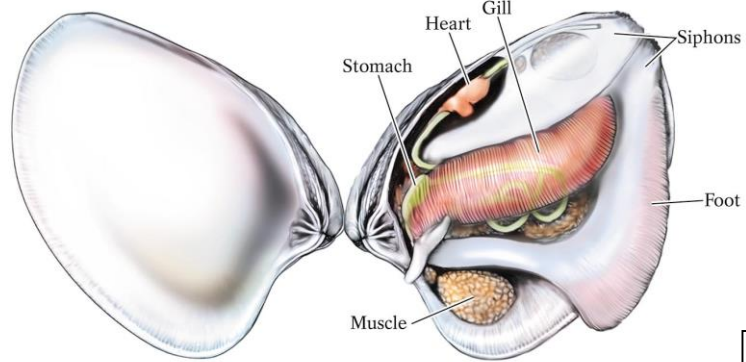
“Archaeogastropods”



Phylum Mollusca C. Gastropods

“neogastropods”

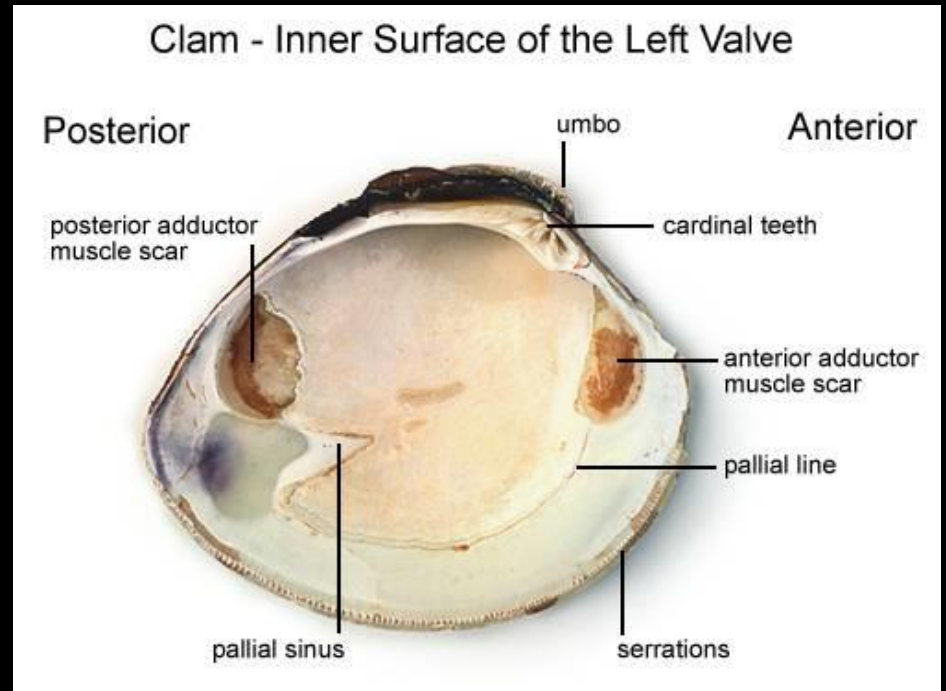
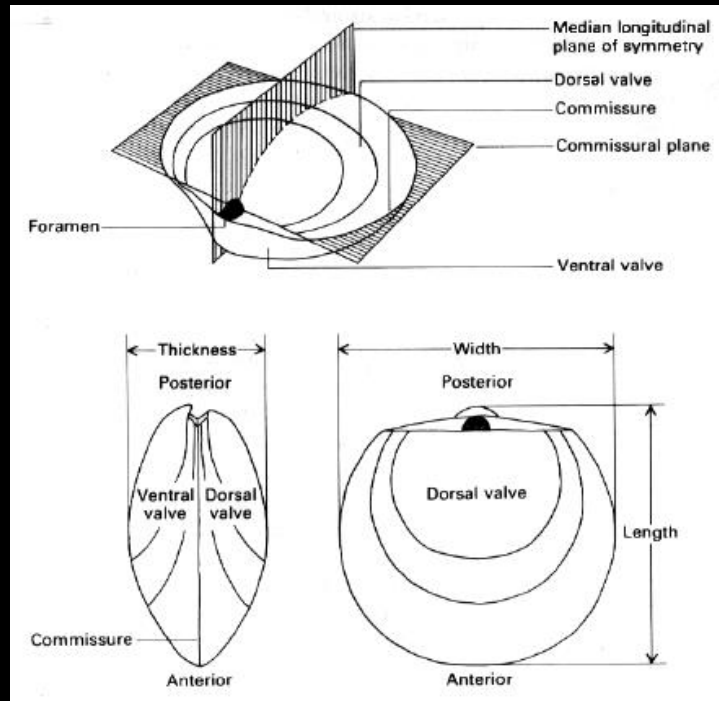




Phylum Mollusca

C. Bivalvia

- Found throughout the Phanerozoic
- Cenozoic:
 - Greatest diversity & range of habitats
 - Adaptions for deep burrowing, etc



Mesozoic assemblages

- Belemnites
- Ammonites (complex sutures)
- Dinosaurs



Cenozoic assemblages

- Gastropods
- Echinoids
- Bivalves
- ~~Scleractinian~~
~~(modern) corals~~

Paleozoic assemblages

- Tabulate corals
- Rugose corals
- Brachiopods
- Crinoids
- Trilobites

Phylum Bryozoa (moss animals)



Branching forms most diverse during the Paleozoic

Phylum Bryozoa (moss animals)

