INVERTEBRATE PALEONTOLOGY

SHAAS N HAMDAN

evolution, is the Greatest theory <3

INDEX

CHAPTER ONE : INTRODUCTION

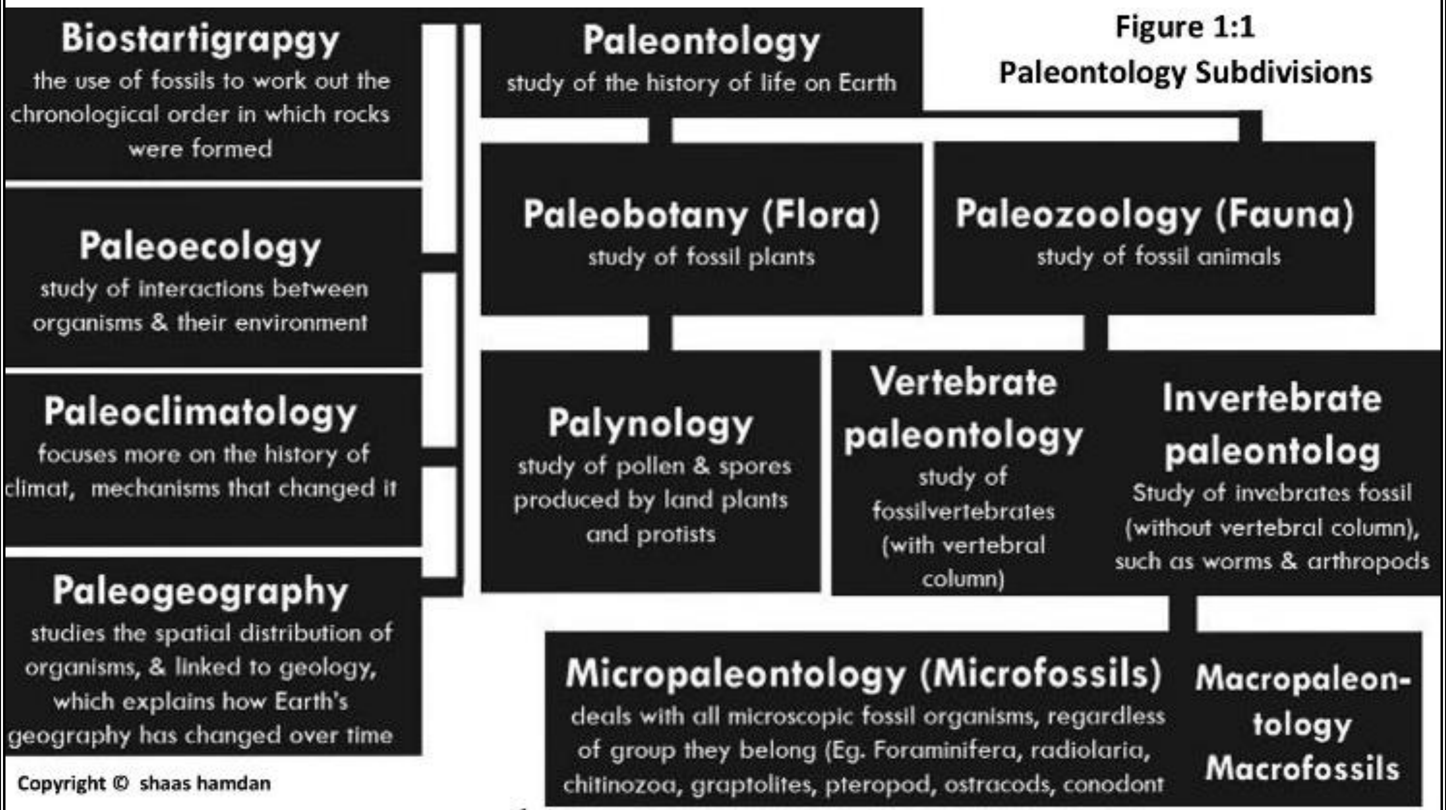


Figure 1:1
Paleontology Subdivisions

1.1 Paleontology & Fossils

- **Paleontology:** study of the history of life on Earth as based on fossils (age, formation, & evolution)
- **A Fossils**: is any preserved remains, impression, or trace of any living thing from a past age
  - ➢ Fossils are the key to understanding of past life (give clues about organisms lived ago)
  - ➢ **provide evidence:** evolution, & Change of earth surface over time
  - ➢ Age of Earth is 4.6Ga, & the oldest fossils 3.5Ga (cyanobacteria that forms Stromatolite structure)
  - ➢ **Fossils age:** youngest from Holocene to the oldest from the Archaean, > 3.48Ga
  - ➢ Most fossil are found in sed. rocks
- Ancient atmosphere had CO_2, H_2O, CO, H_2, N_2, NH_3, H_2S, CH_4, little free O_2

- **There are 2 types of true fossil**

Body Fossils	Actual body or body parts of an organism, whether altered or no
Trace Fossils	indirect signs of past life (Tracks, trails, burrows, borings, impressions, molds, casts)

Table 1:1 types of true fossil

Calcium carbonate $CaCO_3$ (calcareous)	• **Principal mineral of most seashells** • **Aragonite** unstable, may be dissolved (preserved as moulds) or transform to calcite (poor preservation of primary textures) • **Calcite** stable over time, calcitic (brachiopod) shells tends to be well-preserved
Silica SiO_2 amorphous hydrated silica (Opal)	• transforms into quartz & other silicate minerals • Tend to be well preserved in pelagic sediments • Found in skeletons of sponges, & microorganisms • Skeletons may be lost or degraded through opal dissolution & obliteration of original structure through quartz crystallization
Calcium - phosphate	• stable over time (well-preserved) • Principal mineral of bones, teeth, & some shells • **Apatite : $Ca_3(PO_4)_3(F, Cl, OH)$**
Chitin	• insoluble organic substance • long molecule, made of C, N, H, O joined in chains • Insect exoskeleton are made of chitin

Table 1:2 Hard Parts of fossils: Common mineral components

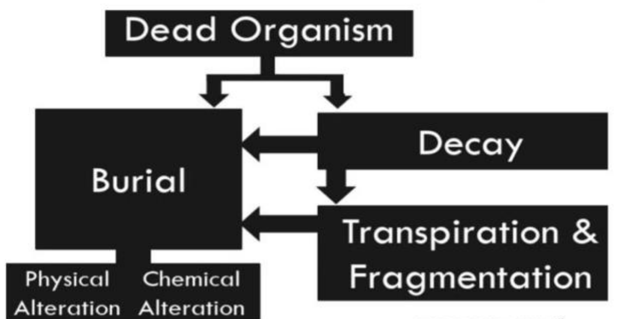


Figure 1:2 The process of fossilization (TAPHONOMY)

Decay	• An organism decays until the process is halted by mineralization, The quicker the organism is mineralized the more complete the preservation • Decay limited in Oxygen-poor emvironment • Decay rates are slower at lower T & acidic env.
Transpiration, & fragmentation	• Remain transported by currents, waves, or animals, During transpiration broken & abraded • The extent of fragmentation & disarticulation is linked to the amount of decay: less decayed before transport, more likely to remain intact
Burial	Control preservation, fossils buried rapidly are more well-preserved than buried gradually after transported
Chemical alteration	• Postburial chemical alteration is common • Calcareous shells recrystallize or dissolve leaving a cavity in rock that is later infilled with sediments • Skeletal material may be replaced: Pyrite replaces hard-soft tissues buried in O-poor marine sediment
Physical alteration	compaction of sediment causes flattening of remain, Rigid tissues whilst flexible components are distorted

- **Conditions favorable for preservation**
  1. Rapid & permanent burial
  2. Continued sediment accumulation
  3. Lack of oxygen (O limits decay & scavenging)
  4. Lack of heat or compression (destroy fossils)
  5. Hard body parts (skeletal, bones, exoskeleton)

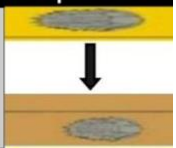
Step	Notes	Shape
Sediment	animal is buried by sediment (volcanic ash, silt) after die, bones are protected from rotting by layer of sediment	
Layers	More sediment layers accumulate above the remains, & minerals (silica) replace Ca-phosphate in the bones	
Movement	Tectonic plates, or giant rock slabs, pushes the fossil closer to the surface	
Erosion	From rain, rivers, & wind wears away the remaining rock layers. Erosion or people digging for fossil will expose preserved remains	

Table 1:4 formation of fossils

1.2 Body Fossils

- actual body or body part of an organism that preserved, & may be altered (chemical or physical change) or not

Unaltered Remains	• Mean little or no chemical or physical change • Skeletal remains (composed of stable calcite or silica) preserved without significant chemical or structural change • Hardparts (mineralized skeletal: shells, teeth, bone) more likely to be preserved close to their original state (they less prone to breakdown) • soft tissues may be preserved without alteration (rare) • skeletal material hard part preserved as original material (Tar impregnation, Amber Entombment, Refrigeration)
Altered Remains	• Chemical or physical change • must be at least ten thousand years old • types of altered remains: Recrystallization, Replacement, Per-mineralization (petrification) & Carbonization

Table 1:5 types of body fossils: unaltered & altered remains

Tar impregnation	• tar pits are excellent areas to preserve fossil • La Brea tar pits in California is one of the most famous areas because of the large number of preserved life forms found in it
Refrigeration Soft Tissue Preservation	During Pleistocene glaciations, ice cover much of NH, some animals (mammoths) fell into crevasses in frozen terrain or trapped in permanently frozen soil
Amber Entombment	• Amber-preserved fossils become trapped in tree resin that hardens after the tree is buried • Small insects & other minute organism become trapped in resin, after burial harden into amber • parts of the Baltic Sea coast & some of the islands in the W-Indies are well known for occurrences of insects preserved in amber

Table 1:6 types of unaltered remains

Figure 1:3 Ice age wooly mammoths from Pleistocene have been found frozen in Siberia & Alaska. Skin, hair, & soft tissue have been preserved in frozen soil

- **Mammoths** Pliocene (5Ma) - Holocene 4,500yr ago

Figure 1:4 Amber

- alteration destroyed DNA & protein structure

Phenomenon	Notes
Recrystalization (narrow type of preservation, important to so many marine invertebrate fossils)	• The mineral shells of most invertebrates are aragonite, increase P transfer aragonite into the calcite, & Further P transfer calcite into larger ones, & replacement Ca by Mg (into dolomite) • Recrystalization cannot be observed except by microscopic organisms
Dissolution (Replacement) complete removal of hard part by solution & deposition of a new mineral in its place **Great detail is preserved**	• A number of minerals can replace the original material depend on the chemistry of pore waters within sediment • These transformations occur at earlier (before or during lithification), or later (after) stages of fossilization • Calcareous (calcitic, aragonitic) shells replaced by silica, pyrite (Fe-sulfide), or fossilization
Permineralization (petrifaction) Useful in studies of the internal structures of organisms (of plants)	• takes place in porous materials (bone, plant, shell) • supersaturated groundwater (rich in $CaCO_3$ or SiO_2) percolates via pore spaces, & precipitates mineral in space • Original wood or shell like material preserved
Silicification (replacement by silica)	• Reveals information about type of organism environment • bacteria, algae, & plant life • The most common type of permineralization
Pyritization (replacement by pyrite, S&Fe)	Organisms are pyritized when they are in marine sediments saturated with iron sulfides
Carbonization Fish, leaves, & woody tissues of plants	• Water transforms organic material of organisms to a thin film of carbon • N, H, & O leaving an outline of the organism

Figure 1:6 Fossil calcareous sponge (originally calcitic, now

Figure 1:5

1.3 Molds & Casts

- **Mold & cast:** 3D preservation where the original is not present
- As remains buried, they surrounded with sediment
- **Mold:** impression of skeletal (or skin) remains in an adjoining rock

External mold	**impression of outer side (Impression of the buried object made in surrounding sediment)**
Internal (steinkern)	Impression shows form or markings of inner surface (of the interior of the buried object)

Table 1:7 The mold types

  - ➢ If buried object hollow, it infilled with sediment, the actual buried object decays or dissolved, leaving internal & external mould
- **Casts:** are formed when an external mould is infilled by sediment or precipitated minerals
  - ➢ It appears as a replica of original buried object
  - ➢ Cast original skeletal material dissolves cavity (mold) fills with materials

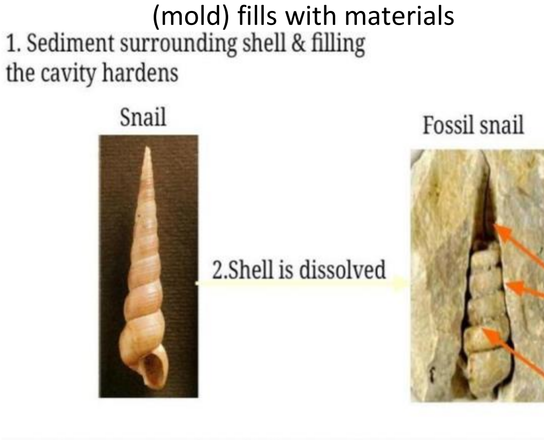


Figure 1:6

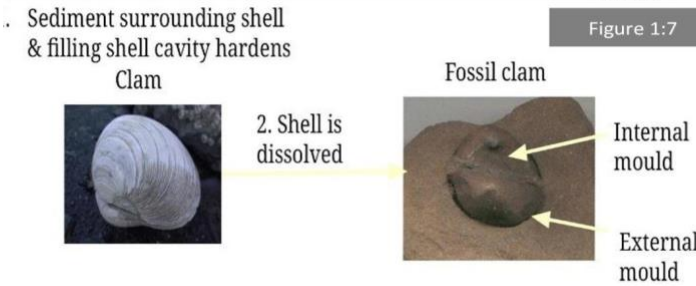


Figure 1:7

CHAPTER TWO: TRACE & PSEUDO-FOSSILS

2.1Trace Fossils

- **Trace fossils:** is the sign of past life, & are the geological records of biological activity
- **Importance of a trace fossils:**
  1. vital part of history & evolution
  2. more important than actual body fossils as they remain present even when the body is decayed & eroded
  3. aided in finding & dating the first organisms to live on land
  4. ichnofossils provide information about the animal that created it & its everyday activity
  5. Detailed study of the anatomy of trace fossils can provide animal's size & morphology, as well as what they were doing while the fossil was ccreate
  6. The same species can produce different structures corresponding to different behaviour patterns
- **The same burrow differently preserved in different substrate according to:** grain size, stability, water contents, & chemical conditions

2.2 Ichnofossils

- **Ichnology:** is the study of trace fossils
- **Ichnofossils:** tracks, trails, & burrows of organisms
- **Burrows:** trace fossils show how an animal such as a worm moved through the soft sediment
  - ➢ The shape & distribution of these fossils can tell us the exact animal that made it
  - ➢ great difficulty in differentiating between certain trace fossils as many look very similar, so it not safe to make assumptions of producer
  - ➢ This results only in educated guesses & debates, as it's the viable option to find organism responsible

This worm tube trace fossil is hollow (the hole goes all the way through it).

- **Tracks:** impression of passage of living things,show how animal moved & what its foot-print looked like
  - ➢ tell us a lot about the animal that made them

- **Burrows or borings:** Spaces dug out by living things & preserved as is or filled in

2.3 Taphonomy of Trace Fossils

- **Taphonomy:** study of fossilization
- **Importance of taphonomy:**
  1. provides fossilised evidence
  2. Provide information about past environmental
- **most important goals of taphonomy**: learn about the conditions that formed fossils
- Even via the process of fossilisation is time-dependant & involves periods measured in a geological timescale, many factor determining the conditions under which the traces arose can be traced back to present times
- **Gastroliths:** are rocks which were once within an animal`s stomach, used to grind food in animals lacking suitable grinding teeth
  - ➢ Gastroliths are rounded & polished due to being subjected to the digestive juices within a dinosaur's stomach
  - ➢ They are different to the surrounding geology & found with the fossils of dinosaurs

- **Excrement (coprolites):** are fossilized faeces, considered trace fossils as they provide evidence for an animal`s diet
  - ➢ can range in size from a few mm to over 60 cm
  - ➢ Coprolite may contain undigested remains of food. Usually preserved by replacement

- **Root traces**: are the most common trace fossils in the fossil record left by plant activity
  - ➢ They show the branching & irregular morphology similar to living plant roots

- **Bioturbation:** is the reworking of the morphology of soils & sediments by pants & animals
  - ➢ Burrows & borings are forms of bioturbatio, & formed in soft sediment by locomotive organi-sms which displaced sediment grains aside

Crab burrows on the lower side of a bank of cambrian Formation

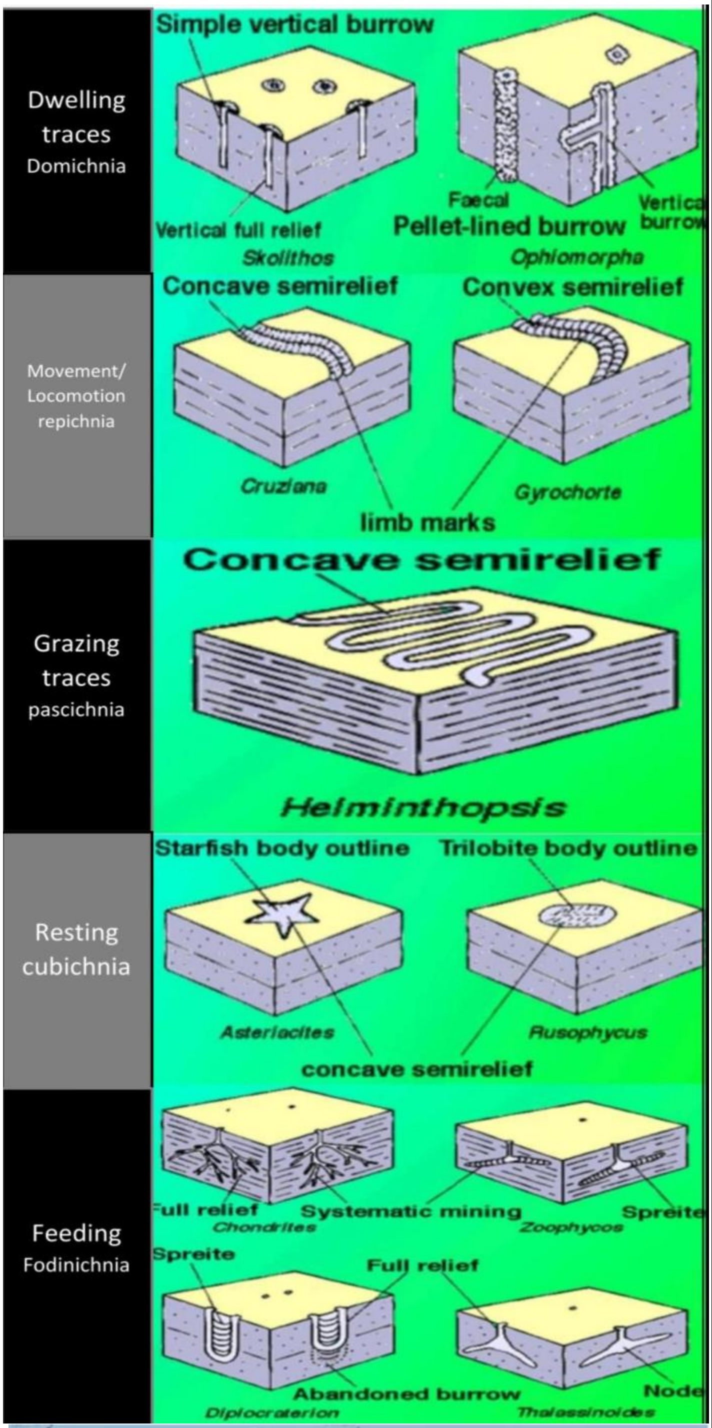
Part of carbonate section of Burj Formation with nodular limestone formed by strong bioturbation

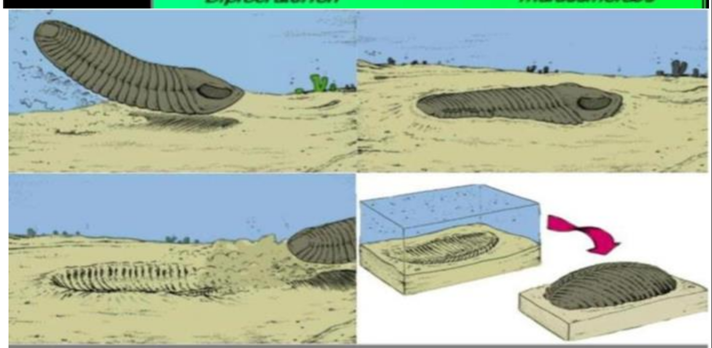
- **Bite marks**: found on some fossils & indicate in the fossil record what animals were hunted & what organisms were hunted
  - ➢ indicate ancient organism's diets

- **Rusophycus:** is resting trace produced by trilobites

2.4 Trace Fossils Classifications

- Faecal pellets determine nodular outer surface to the burrow, & associated with crustaceans
- The cause of trace fossils can be classified into:





The Formation Of Resting

Group	Produced by Notes	Include
Dwelling trace (Domichnia)	• Left by creature making it's home • Include burrows or borings • Horizontal or vertical, preserved in full-relief they are frequently cylindrical & scratches seen along the tube	1. **Skolithos or Pipe Rock** (simple, unpaired pipe) associated with high-energy env. close to shoreline, are known worldwide from sands & sandstones deposited in shallow water, from the Cambrian Period 2. **Ophiomorpha** lined with faecal pellets, Branching is irregular but Y-shaped where present interpreted as a burrow of organism living in near-shore environment
Movement/ Locomotion (repichnia)	• As organism simply moving via sediment, it leaves behind marks that preserved • They are straight or slightly curved, & terrestrial locomotion traces **footprints** • structure is produced by sediments (pass over upper surface of anima)	include tracks & trails 1. **Cruziana** marine ichnogenus, simple burrow having a linear path & paired plough marks left by limbs & appendage, preserved as +ve relief on the base of a sedimentary Layer (convex hyporelief) 2. **Gyrochorte** produced at a shallow depth, preserved in +ve relief on upper surface of a sed. (convex epirelief)
Feeding (Fodinichnia)	• Left by an organism that was feeding • Can be broken down to 3 subcategories depending on how the organism fed: penetrative type preserved in full relief, & another type formed as sediment undergone systematic mining & lastly there are spreites that are most complex feeding traces, that identified by evidence of back-filling	1. **Chondrites**: downward branching burrow 2. **Zoophycos**: complex downward spiralling burrow 3. **Diplocraterion**: feeding/dwelling, vertical, U-shaped burrow with weblike construction 4. **Rhizocorallium**: feeding/dwelling, vertical then horizontal, U-shaped burrow 5. **Thalassinoides**: feeding/dwelling, a network of triple junction interconnected vertical & horizontal tubes, associated with shrimps
Grazing (pascichnia)	Formed by an organism as it was meandering via the sediment in search for food, the loops are regularly spaced & systematic	1. **Nereites & Spiroraphe:** regular, spirally induced grazing patterns on surface 2. **Helminthopsis** complex series of switchbacks
Resting (cubichnia)	• Formed when an organism that at rest left imprint in sediment, imprints mimic morphology of organism • these fossil follow bedding planes & are preserved in semirelief • Resting traces are belong to genera **Rusophycus with trilobites, & Asteriacites with starfish**	

2.5 Pseudofossils

- **Pseudofossils (fake fossils)**: rocks or rock structure look like fossils
- sedimentary features that may confused for fossils:
  1. **Differential Weathering:** Weathering of rock & mineral surfaces yield fossil-looking features
  2. **Nodules:** Formed by filling voids in sediment & incorporation of materials within the body
  3. **Rosettes (desert rose)**: occur when the crystals form In arid sandy condition
  4. **Clusters of gypsum or barite:** sand grains
  5. **Concretions:** mineral growth within sediment forms structures that resemble organisms
  6. **Dendrites:** Precipitation of Mn-Oxide along bedding planes creates fern-like patterns
- Nodules:
  - Chert Nodules: Microcrystalline quartz
  - Septaria: angular cavities or cracks

2.6 Fossils: Biological Classifications

- As fossils clearly represent the remains of ancient organisms, it only makes sense that they should be classified in the same manner as living organisms
- Fundamental unit of bio-classification is species
- Members of a species are able to interbreed & give rise to fertile offspring
- Palaeontologists lacking evidence of reproductive isolation of ancient species, focus on species morphological definitions
- Above the species level increasingly more inclusive groups which are defined by certain characteristics possessed by all their members, These various groupings are as in Table
- This classification heirarchy applies mainly to body fossils

Groupings	Examples
Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	Homo
Species	Homo Sapiens

CHAPTER THREE: TAXONOMY & FOSSILS INDICATORS

3.1 Taxonomy & Fossil identification

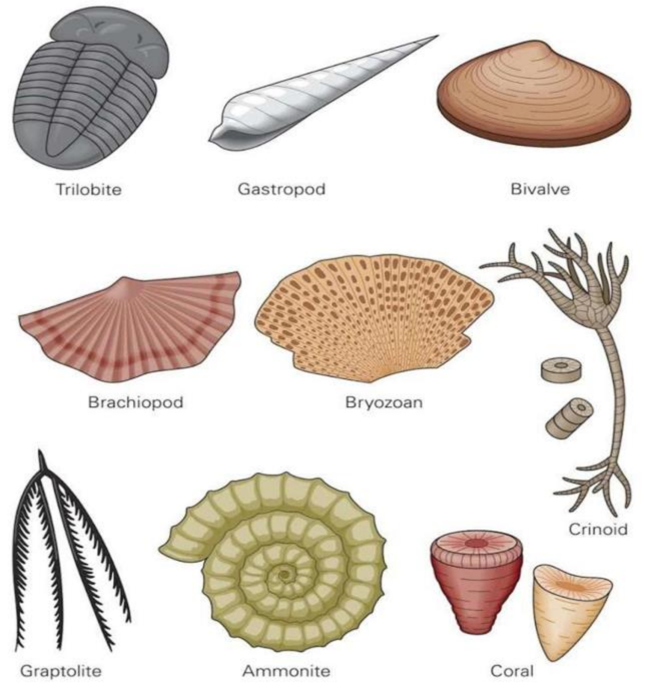
- **Taxonomy:** the science of organisms classification
- Taxonomic classification follows the same principle used for bioclassification, 3 principles (by Carolus)**:** life divided to 3domain (Archaea,Bacteria,Eukarya)

Domain	Occurrence
Archaea (Vast array of single-celled microorganism)	Ocean, soil, wetland, deep water, hot spring, salt lake, black smoker, acidic env.
Bacteria (Tiny single-celled organisms)	All livable environments on Earth
Eukarya	eukaryotic cells (nuclei & organelles)

- Taxonomists divide Eukarya into kingdoms
  - kingdom → phyla → class → order → family → genera (genus) → species
  - Kingdoms are the broadest category of Eukarya & species are the narrowest

Kingdoms of Eukarya & Examples	
Protista	various unicellular, simple multicellular (Eg. diatoms & forams, two of the major plankton types in the oceans)
Fungi	Mushrooms & yeast
Plantae	Trees, grasses, mosses, & ferns
Animalia	Sponges, corals, snails, dinosaurs, ants, lizards, birds, tigers, fish, & people

Examples of macro-invertebrate fossils	
Trilobites	have segmented shell that is divided into 3 parts (type of arthropods)
Gastropods	have a shell that doesn't contain internal chambers (snails)
Bivalves	have a shell divided into 2 similar halves (clams, oysters)
Brachiopods	The top & bottom part of shells have different shapes, symmetry is per-pendicular to plane of shell (lamp)
Bryozoans	colonialinvertebrate, fossil resemble a screen-like grid, Each opening is the shell of a single animal
Crinoids	Animals look like-flower, shells have stalk of numerous circular plates stacked on top of other (sea lilies)
Graptolites	look like tiny carbon-saw blades in a rock, remnants of colonial animals that floated in the sea
Cephalopods	Include ammonites (spiral shell), & nautiloids (straight shell) Shells contain internal chambers & have ridged surfaces squid-like head
Corals	Include colonial organisms that form distinctive mounds or columns & solitary, cone-shaped species



3.2 Fossils as Indicators

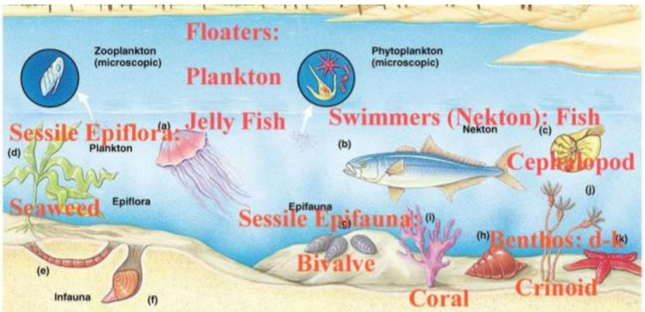
- Environmental limitations that control the distribution of modern plants & animals include:
  1. Marine Ecosystem Realm
  2. Chemistry of the Water (& temperature)
  3. Movement of Ocean Water
  4. Depth, Light, & Latitude
  5. Carbonate Compensation Depth (CCD)
  6. Land Bridges & Barriers (Mountains & Oceans)

Environmental components	
Autotrophs (Producers) **plants**	Manufacture their food **Trophic level:** Lowest & constitute the base of biomass **Energy:**from light (photosynthesis) or inorganic (chemosynthesis)
Heterotrophs (Consumers) Animals	Feed on other organisms **Trophic level:** Higher **Energy:** from other organisms
Herbivores	Feed on producers
Predation	Effect of a predator on prey species
Carnivores	Feed on consumers by predation
Scavengers	Feed on dead organisms
Parasites	Derive nutrition from other organism without killing them

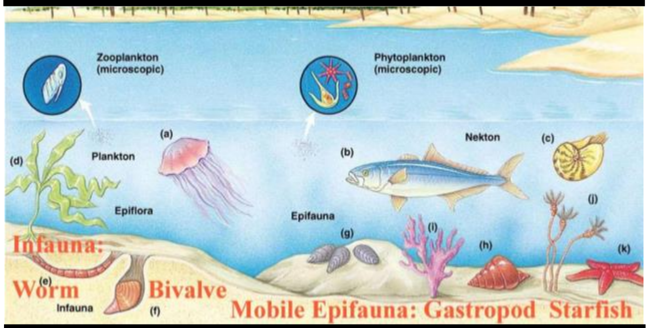
Ecological relationship	
Competition	2 species vie for limited environmental resources
Symbiosis	Is the ecological relationship between organisms living closely together with some form of feeding relationship involved, & there are 3 main symbiotic relationships

Symbiosis types	
Mutualism	both organisms benefit Eg. Bee & pollinating flower
Commensa-lism	One organism benefits, & the other isn't harmed
Parasitism (endopara-site)	Completely dependent on a host for survival, beneficial to one, & harmful to the other, Eg. tapeworms

- **Planktonic:** drift almost passivel, cannot counter actacurrent, <u>phyto- (plant), & zoo- (animal)</u>
- **Nektonic:** active swimmers (fish)
- **Benthic:** Live on the bottom**,** Epifaunal, & Infaunal
- **An organism can change modes during its life**



Marine Ecosystem-Planktonic/Nektonic



Marine Ecosystem–Benthos

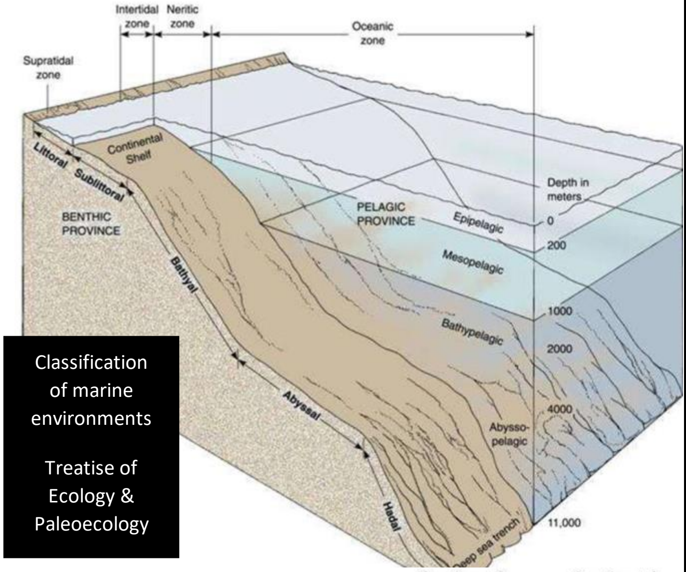
3.3 Limiting Factors

- **Limiting factors (LF)**: Some environment that limits an organism's distribution
  - ➢ **Physical LF:** T, salinity, nutrients, light
  - ➢ **Biological LF:**competition, predation,herbivory
- **Marine Ecosystem**: The ocean divided into 2 realm

Pelagic	The water mass lying above the ocean floor
Benthic	The bottom of the sea

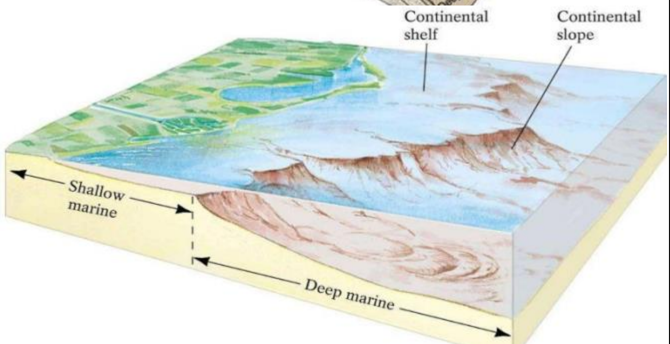
3.4 Organism Distribution

- Marine Organism Distribution Depends on:
  1. Seawater Properties: Density & Viscosity
  2. Light & the Limiting factor of water
- **Density:** $\rho_{\text{aquatic organisms}} = \rho_{\text{water}}$
- **Viscosity**: influences shape & feeding (there are many "filter feeders" in aquatic environment, due to the viscosity of water allowing food to be held in suspension)

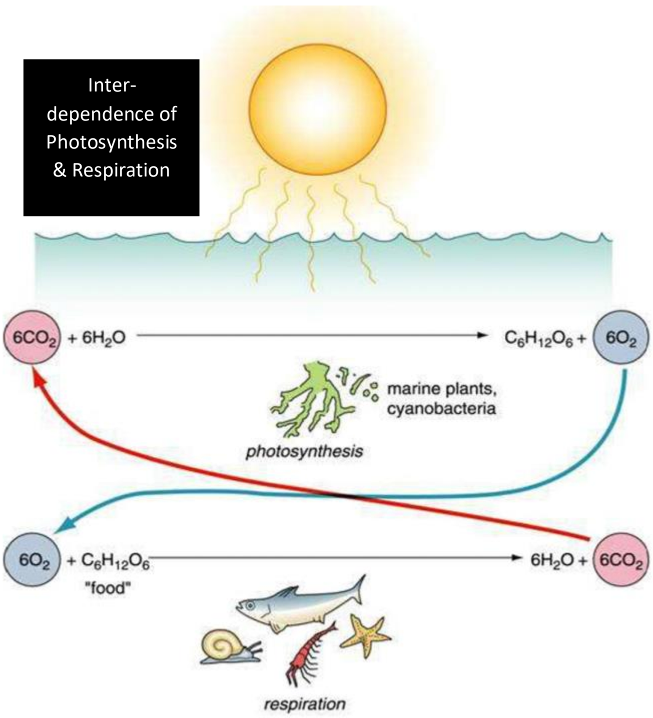


Classification of marine environments

Treatise of Ecology & Paleoecology

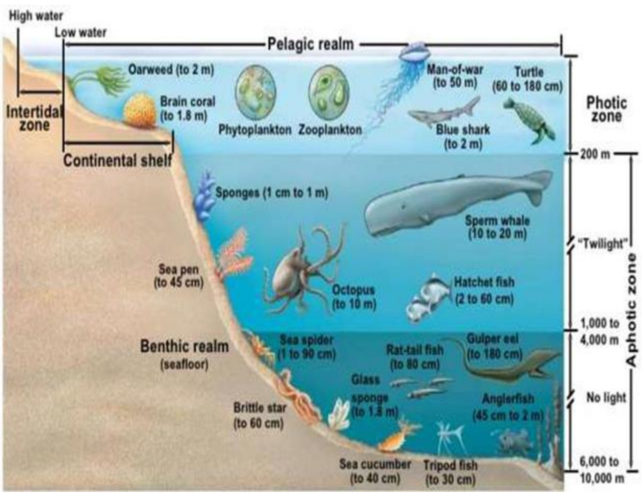


- Light: used by organism for photosynthesis, so this organisms are restricted near surface waters
  - ➢ Clarity of the Water (or the amount of suspended sediment in the water)
  - ➢ **Photic zone**: zone of light penetration
  - ➢ **Euphotic zone**: upper illuminated layers of water in a photic zone; receive sufficient light to support photosynthesis (10-60m) but clear tropical waters > 100m



Inter-dependence of Photosynthesis & Respiration

- **Aphotic zone**: in which light doesn't penetrate



- **Dissolved Gases**: concentrations depend on atm concentration, solubility of gas, water T, & salinity

Nitrogen N	most abundant, & required by plant
Oxygen (O) **6-10ppm**	Enter sea by photosynthesis, river, atm, all organism use it in respiration Max concretion found near surface & Min. At 700-1,000m, warmer, saltier
Carbon Dioxide (CO_2) Increases to 1,000m	Enter sea from respiration, rivee, atm Removed by plant by photosynthesis & used by organisms to make shells increased CO_2 leads to Greenhouse Effect (increase T)
Di-Hsulfide	Produced by anaerobic bacteria

- **P:** increase 1atm/10m, affect vertical migration, bacterial decomposition, & shell production
- **Water energy, turbidity, & sedimentation rates**
  1. Affect distribution of food
  2. Affect nutrient, type, morphology of organism
  3. amount of suspended sediment (filter-feeder)
  4. Affect nature of substrate
  5. Type of infauna (live in substrate) or epifauna (live on substrate; sessile or vagile benthonic)

3.4 The nature of Sea Water

- **Salinity**: measure of the total dissolved solids
  - measured in part/thousand by Wt (ppth,$_o/_{oo}$)
  - terms for various types of water

Normal water	35 ppth, 3.5%Wt (35 pounds of salt/1000 pounds of sea water)
Freshwater	5ppth - < 1ppth
Brackish	< 30ppth
Hypersaline	> 250ppth, found in lakes in arid areas, enclosed areas, isolated seas

- **water temperature** varies with latitude & depth

Near the poles	**Water at or near freezing**
At the equator	**Water as much as 28ºC**
Surface waters	**Warmest (warmed by the Sun)**
Deper water	**T decreases with depth**
At great depth	**Just above freezing**

- **water moderates T**

Cold-blooded organisms	**an increase in T of 10°C causes metabolic activity to double**
Warm-blooded	**little metabolic change with ΔT**

  - T influences reproductive cycles
  - in Geochemical Studies of Paleotemperature use 180/160 (less with greater T)
    - boron & bromine greater if greater T
    - Ca/Mg & Ca/St ratio: less if T increased
  - in Biological studies of paleotemperature use:
    - stenothermal (T-intolerant) versus
    - eurythermal (T-tolerant) organisms
- **Depth**: deep water stores C, N, P
  - **Paleobathymetry**: the ancient water depth determined by type of body & trace fossils
- **Carbonate Compensation Depth (CCD)**: is a particular depth, which $CaCO_3$ from microorganism dissolved as fast as they descent via water column
  - 4-5km, & varying from place to place
  - affects where calcareous sediment accumulate

Above the CCD Warmer Precipitation > dissolution	Calcarous plankton found in the water column, & on the bottom **the bottom of sediment consist of** calcareous (chalk or limestone)
Below the CCD Colder Precipitation of $CaCO_3$ < distribution	Tiny shells of $CaCO_3$ dissolve, & don't accumulate on the bottom **the bottom of sediment consist of** Clay, Silica (shells of plankton include diatoms, or radiolarians)

- **Fossils can be used to interpret paleoclimates:**

1. Fossil spore & pollen grains: types of plants that lived, which is an indication of the paleoclimate
2. Plant fossils: aerial roots, lack of yearly rings, & large wood cell structure indicate tropical climates
3. Presence of corals: tropical climates
4. Marine molluscs (clams, snails, etc.) with spines & thick shells inhabit warm seas
5. Planktonic organisms vary in size & coiling direction with T (Eg. foraminifer Globorotalia)
6. Compositions of the skeletons (Eg. Shells, have higher Mg contents in warmer waters)
7. **O isotope ratios in shells**: O^{16} evaporates easier than O^{18} because it is lighter
   - O^{16} fall by precipitation & locked up in glaciers, leaving sea enriched in O^{18} during glaciation
   - Shells that enriched in O^{18} indicate glaciation

3.5 Fossils & Stratigraphy

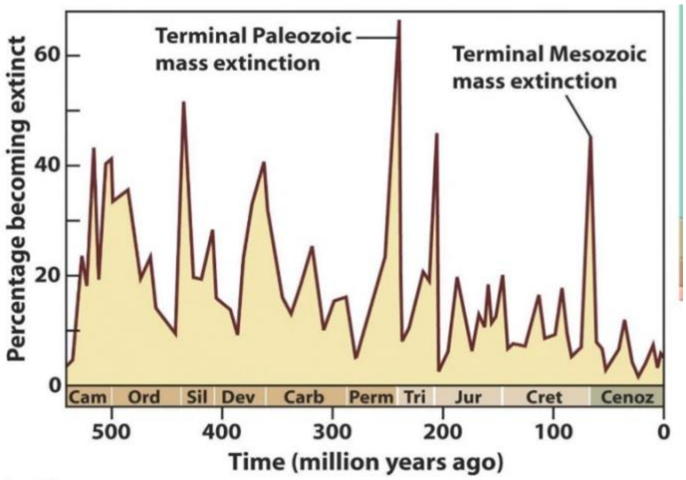
- **Index Fossils (guide):** useful in identifying time-rock units & in correlation
- Characteristics of an Index Fossil:
  1. Abundant, & Easily Identified
  2. Widely Distributed (cosmopolitan)

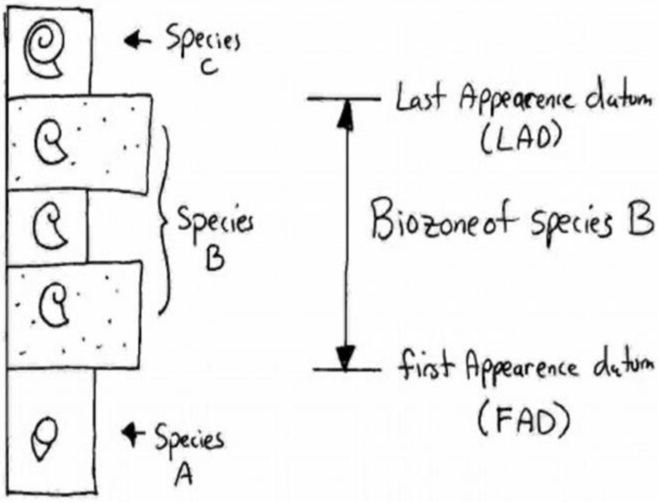
3. Short Geologic Range (rapid rates of evolution)

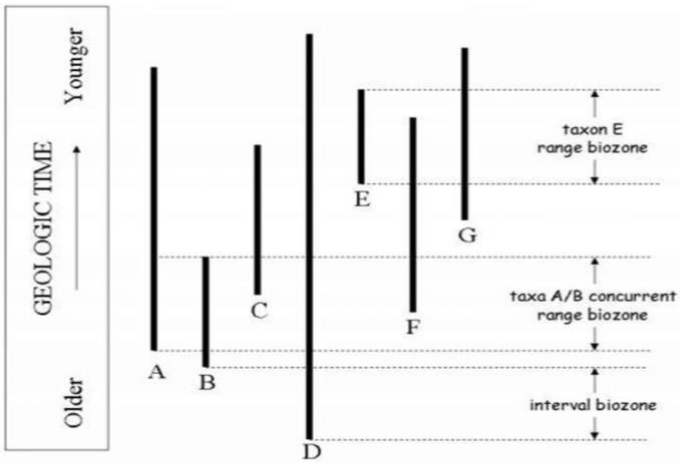
- **Biostratigraphy**: Stratigraphic Paleontology, is the subdiscipline of geology that is concerned with determining the relative ages of sedimentary rocks on the basis of their contained fossils
  - body of rocks delimited from adjacent rocks by their fossil content, & fossil used in Correlation
  - The practical application of biostratigraphy is biostratigraphic correlation
  - Symbols used: **FAD** (1st appearance datum), **FOD** (1st occurrence), **LAD** (Last appearance D)
- **Correlation**: matching sections of the same age
- **Biofacies**: facies distinguished by their fossils
  - Fossil used in relative dating (due to evolution)
  - Every species of fossil plant, animal, & protist has a definite stratigraphic range
- **Range**: time from evolution to extinction
  - every interval of geologic time has been characterized by distinctive faunas & floras
- Biostratigraphic correlation is accomplished by **biozones** (bodies of strata that characterized by distinctive association of fossils species)
  - The assumption: biozone in one region is the same age as the same biozone in a other region (Regardless of distance)

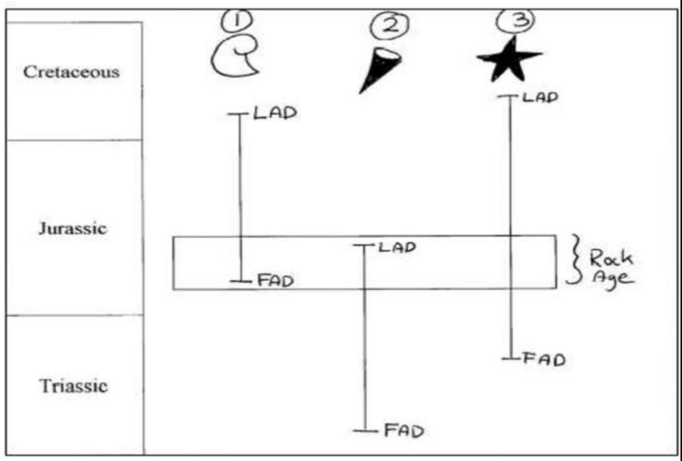
common biozone type used	
Taxon range biozone	Body of strata corresponding to the total range of a specified fossil taxon (Eg. species or genus)
Concurrent range biozone	Body of strata corresponding to the overlapping stratigraphic ranges of specified fossil taxa
Interval biozone	body of strata corresponding to the interval between 2 specified evolutionary events (Eg. interval between 2 extinction or origination events, Or opposite)

- **Principle of Fossil Succession:**
  - Periods & rocks recognized by its fossil content
  - Fossil species appear or disappear via record
  - Geologic Time Scale is based on appearances & disappearance (each Era ends with extinction)
  - Period boundaries coincide with smaller extinction events, followed by appearances of new species
- **Limiting Factors on Correlating with Fossils** (Appearance & disappearance of fossil indicate)
  1. Evolution, & Extinction
  2. Changing environmental conditions: cause organisms to migrate into or out of an area
  3. Reworked Fossils: weathering, erosion, transport, relithification

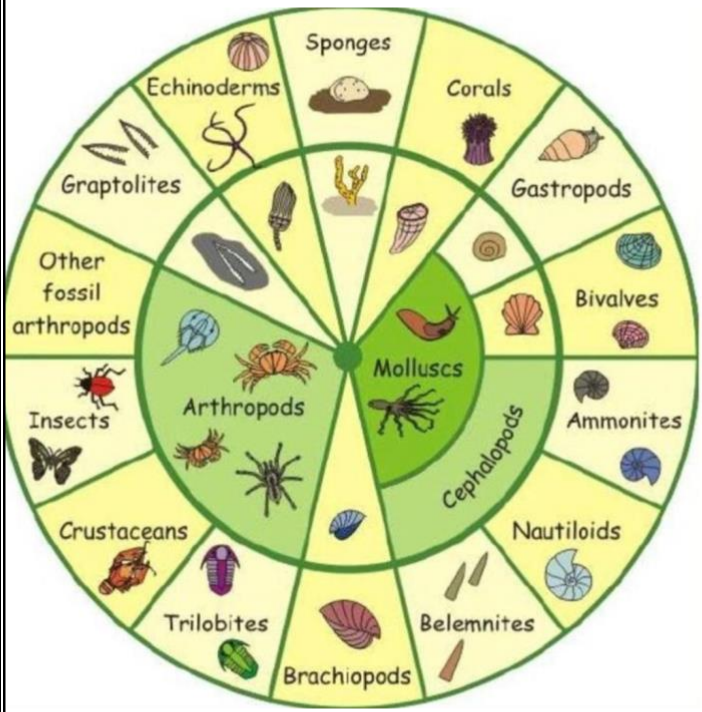




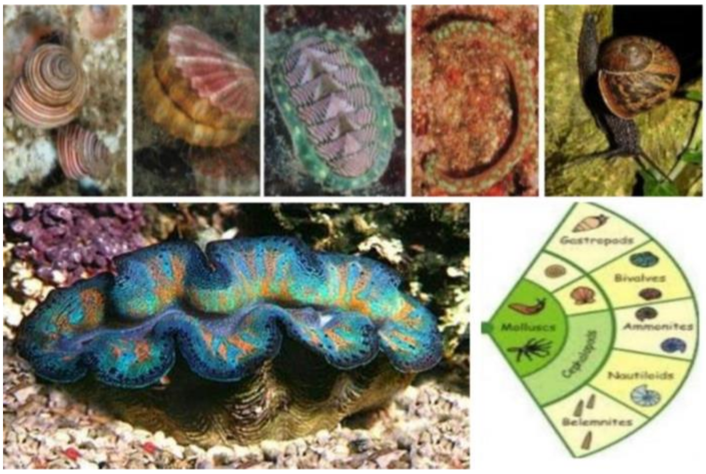




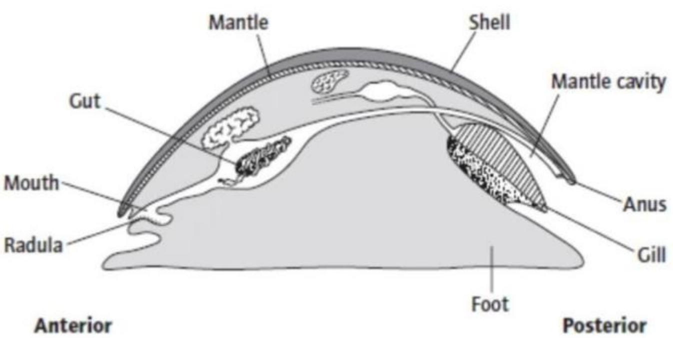
CHAPTER FOUR: PHYLUM MOLLUSCA



4.1 Molluscs



- **Molluscs:** are the fundamental organization (hypothetical archimollusc)



The body of mollusca are divided into: Head, Hard Body : Shell, Mantel, Foot

- Mantle layer of tissue, secreted shell
- mouth & anus at opposite end (but in gastropods both anterior)
- mantle cavity bears gills (gastropods have no gils), & above it's the visceral mass with gut, nervous, circulatory, & muscular system
- shell is of $CaCO_3$ (but may be secondary lost)
- shell external (but internal in some groups)

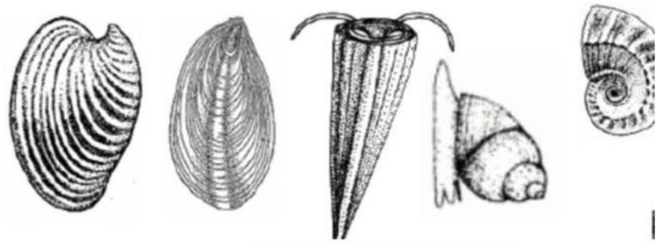
- **Importance of Molluscs to paleontologists:**
  1. Have tremendou morphological diversity (only Phylum Arthropoda has more describe species)
  2. Possess well-calcified skeletons that have easily recognized features
  3. Have an excellent fossil record
  4. The phylum has exploited a wide variety of env.From terrestrial forests to freshwater lakes
- all molluscs share certain characters:
  1. bodies are elongate & bilaterally symmetrical
  2. Most of the organs are contained by a body wall divided into a muscular lower part (foot) used for locomotion or feeding, & upper part (mantle) which covers most of the body along with a free space (the mantle cavity)
  3. Except for the bivalves, sensory structures are concentrated in a head (cephalization)
  4. Have characteristic type of larval development
  5. Most secrete some type of $CaCO_3$ shell from the mantle, they utilize aragonite & calcite

4.2 Phylum Molluscs

- Mollusca is one of the most diverse groups of animals on planet, with $(50 – 20)*10^3$ living species
- A part of almost every ecosystem in the world, molluscs are extremely important members of many ecological communities
- Creatures important to humans as a source of food, jewelry, tools, & pets
- The molluscs include:
  1. **Gastropods**: snails
  2. **Bivalves**: pelecypods, Lamellibranchia
  3. **Cephalopods**: ammonoids, belemnoids, squids
- Molluscs diversified following Permian extinctions, became more diverse than in the Paleozoic
- During the Mesozoic, the molluscs surpassed the brachiopods (dominated the Paleozoic seafloor)

4.2 Cephalopod

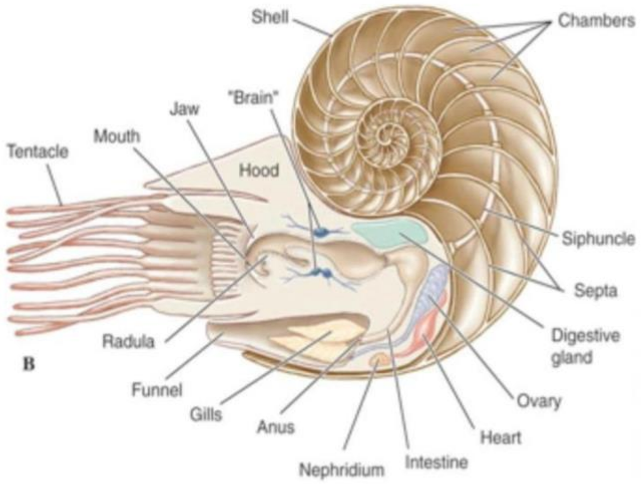
- Predatory animals, group of molluscs quite different from the rest of the phylum



CEPHALOPODA

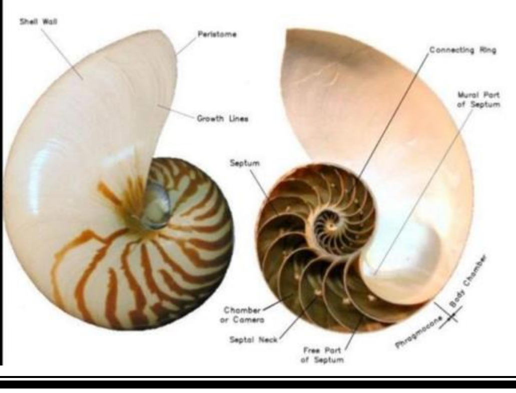
Kingdom	Age	Animalia
Phylum	Cam – Rec	Molluscs
Class	Cam – Rec	Cephalopods
Order	Dev – Cre	Ammonoids (extinct)
	Cam – Rec	Nautiloids
	Cam – Cre	Belemnoids
		Squids

- **Environment**: nektonic (swimmers), or Marine
- Along with the standard molluscan body plan, they have a large well developed head, with large well developed eyes, & a set of prehensile arms that bear rows of suction cups
- **Shell-building cephalopod**: known from Cambrian, They are very important to biostratigraphers (especially for Mesozoic rocks)

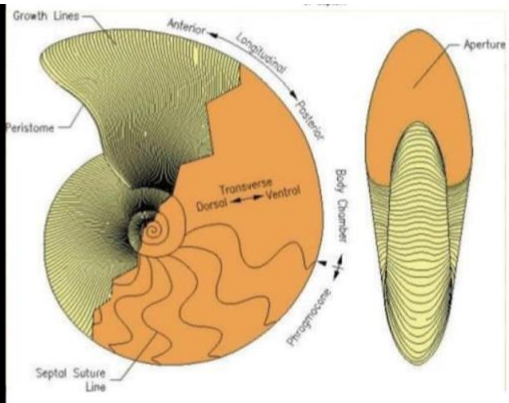


- ➢ **Shell or Conch** (except octopus) structure secreted by the mantle of cephalopods for protection or neutral buoyancy
- ➢ The complete shell is a hollow cone with 2 parts: **Body (Living) Chamber, Phragmocone**
- ➢ **Aperture:** opening on the large end
- ➢ **Apex**: is at the tip of the small end
- ➢ **Shell Wall:** shell or test that forms the cone
- ➢ **Body Chamber, Chambers, Septa, Funnel**
- ➢ **Siphuncle:** in shelled cephalopods (Eg. Nautiloids & ammonoids) a calcareous tube containing living tissue running via all the shell chambers, serving to pump fluid out of vacant chambers in order to adjust buoyancy (About 8-10 tentacles)
- ➢ **Peristome:** The edge of the aperture

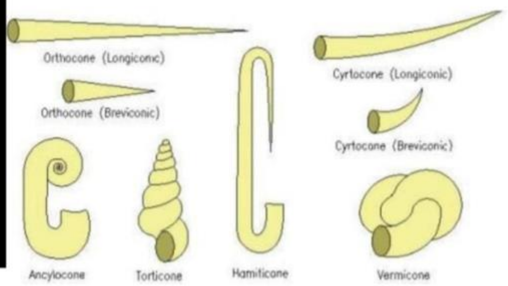
2 lateral views of shell of Nautilus, external on the left & internal on the right



Drawings of an imaginary coiled cephalopod shell



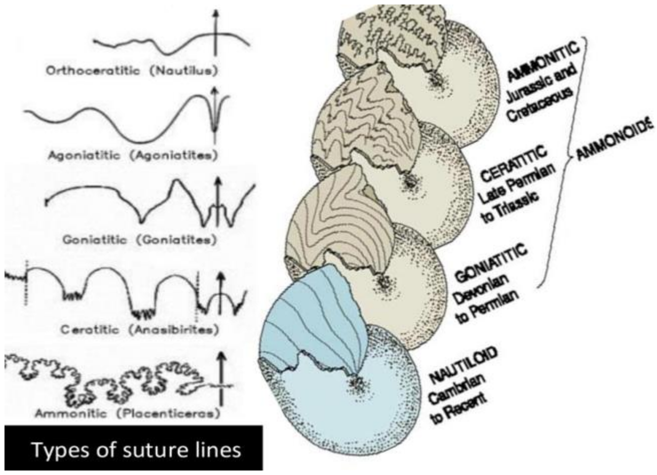
IRREGULAR OR HETEROMORPHIC SHELL SHAPES



4.3 Ammonoids

Kingdom	Age	Animalia
Phylum	Cam – Rec	Molluscs
Class	Cam – Rec	Cephalopods
Order	Dev – Cre	Ammonoids

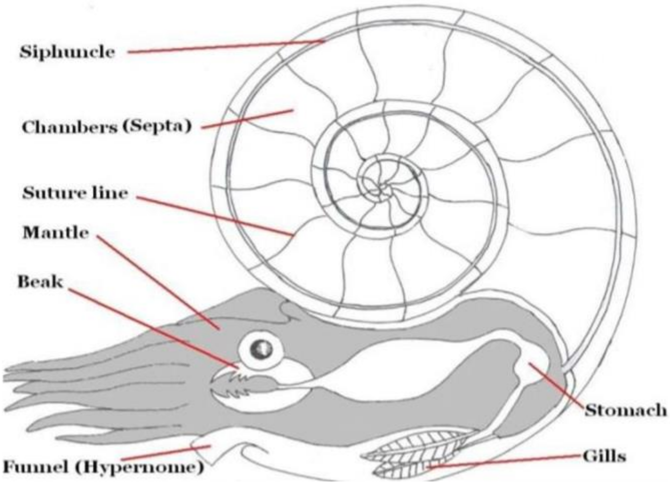
- the dominant swimming invertebrates in Mesozoic
- Mesozoic called the Age of Ammonoids
- useful in correlation of Mesozoic rocks due to morphologically variable, widely distributed, & had short geologic ranges (evolved rapidly)
- One of the most distinctive features is character of the sutures seen outside of the fossils
- **Sutures** are the seam where internal partitions called **septa** intersect the outside wall of the shell
- septae convoluted or wrinkled, & sutures make complex patterns 3 suture patterns of ammonoids are goniatite, ceratite, & ammononite



Types of suture lines

- **Shell Structures**:
  - ➢ **Orthoceratitic Agoniatitic Suture**: simple shallow lobe & saddle broad lobes & saddles with a narrow mid ventral lobe

- **Goniatitic Suture**: strong, angular lobes & angular to rounded saddles
- **Ceratitic Suture** rounded saddle,serrated lobes
- **Ammonitic Suture** complex lobes & saddles
- Septum attached to shell wall along a suture, seen as a series of lines on internal molds
- **Saddles:** parts of the suture line directed adorally (away from mouth)
- The Lobes are parts of the suture line adapically (towards mouth)
- The complexity of the sutures increased via time & used in taxonomy for the identification



4.4 Nautiloids

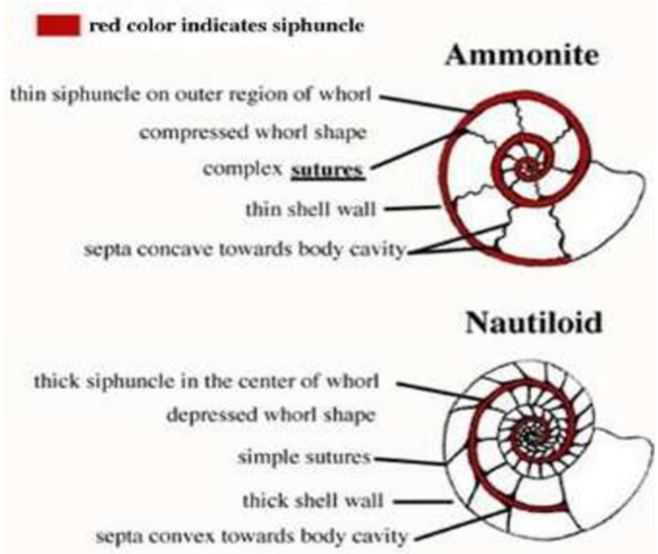
Kingdom	Age	Animalia
Phylum	Cam – Rec	Molluscs
Class	Cam – Rec	Cephalopods
Order	Cam – Rec	Nautiloids

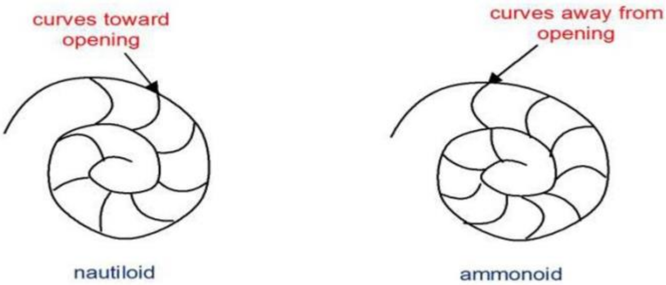
- some are still a live today (with external shell)
- have smoothly curved septa
- housed in a coiled shell, exposing only its head & tentacles to the outside
- Much of the shell is divided into chambers that are filled with gas
- By adjusting the levels of gas the animal may live in the depths of the ocean & move to shallow water at night time to feed



4.5 Ammonoids Vs Nautiloids

- Shells of ammonites & nautiluses are divided into various chambers that can fill with gas or water depend on the animal needs to sink or float
- The differences between Ammonoids & Nautiloids:
  1. Ammonites had 26 chamber, nautiluses has 30
  2. Sutures is curved in the nautilus, & (walls) undulate in the ammonites
  3. The undulation of the sutures creates a “ribbed” look to the ammonite’s shell that is absent in nautiluses, which have smooth shells



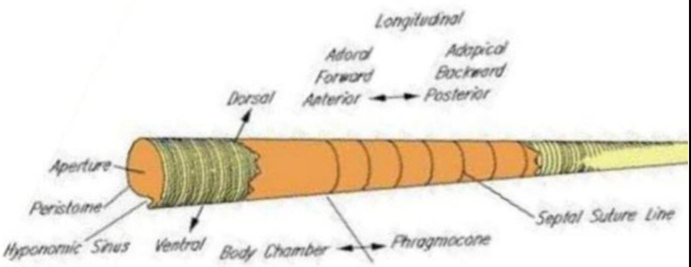


- Chambers are separated by sutures

4.6 BELEMNITES

- died with ammonites & dinosaurs
- looked like a squid
- have internal soild calcareous shell made of fiber-calcite, arranged in concentric layer (resembles cigar in size, shape, & color) called rostrum
- had large eyes, & swam quickly
- Many people will be familiar with belemnite rostra, they are straight, & look rather like bullets

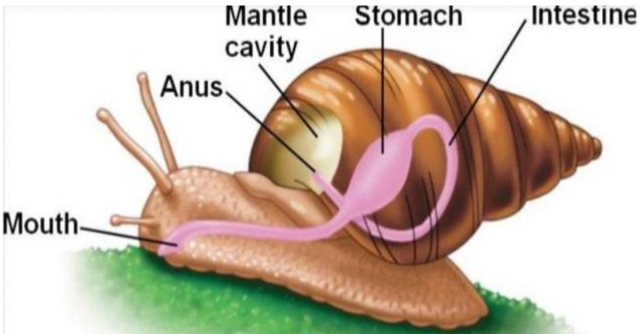

- The front part of this shell is chambered
- highly successful during the Jurassic & Cretaceous

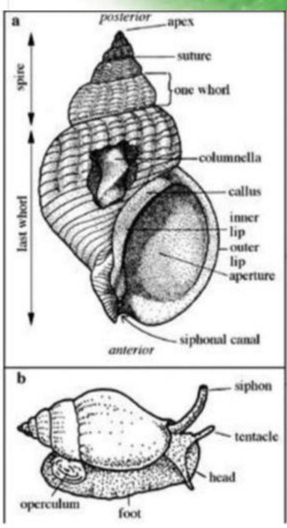


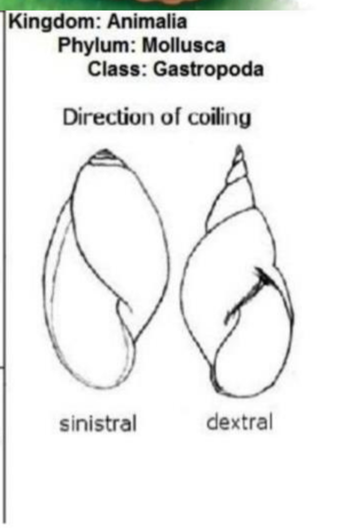
4.7 PHYLUM MOLLUCSA: Class

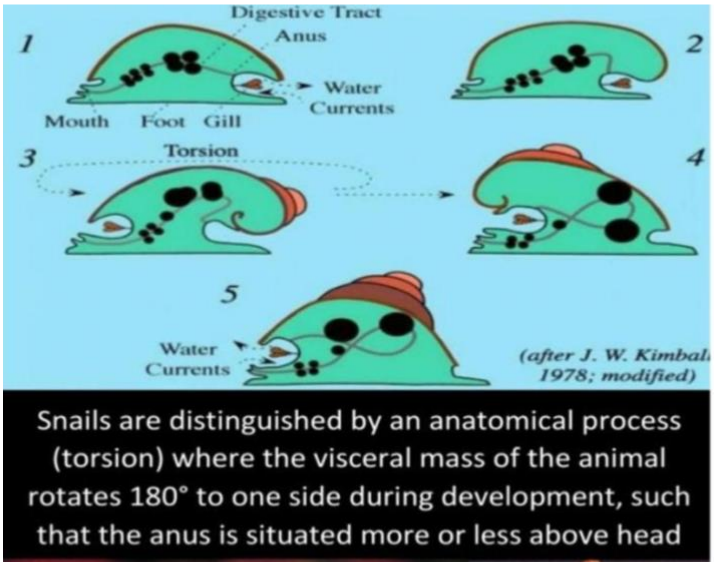
Kingdom	Age	Animalia
Phylum	Cam – Rec	Molluscs
Class	Cam – Rec	Gastropoda

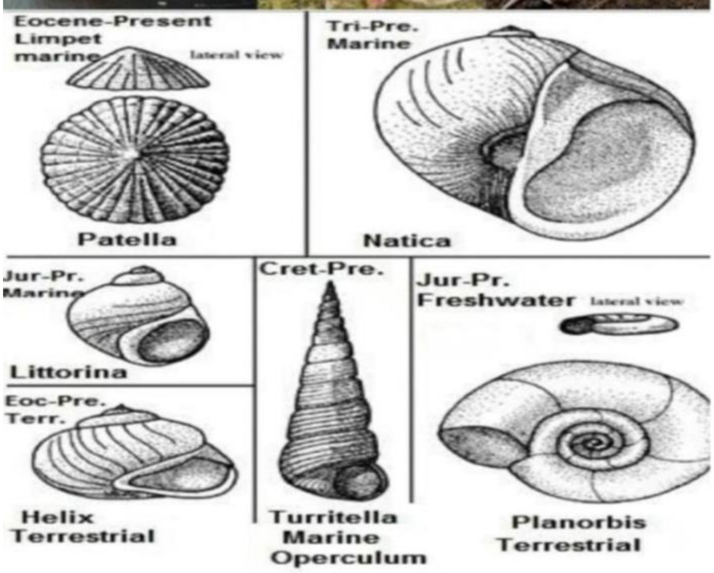
- **ggastro** : stomach, **poda** : foot
- **largest & most diverse class in Phylum Mollusca**
- **gastropods occupy habitats including** terrestrial, marine, & freshwater environments
- have a large single foot for locomotion, a mantle that produces the single shell, A single siphon
- They have a well-developed head bearing a pair of cephalic tentacles & eyes that are situated near the outer bases of the tentacles
- Numerous species have operculum, which in many species acts as a trapdoor to close the shell, This is made of a horn-like material, & may be calcareous
- The uppermost part of the shell is formed from the larval shell (the protoconch)
- snails as well feed using their rasp tongue (radula)
- **different snail groups may be distinguished by** composition of their radula & shape of their teeth
- Some gastropods are scavengers, feeding on dead plant or animal matter, others are predator
- Some are herbivores, feeding on algae or plant material, & a few species are external or internal parasites of other invertebrates
- shells are made of $CaCO_3$ (aragonite, calcite)
- Mainly are dextral (right handed spiral, right aperture) but a few rare cases are sinistral









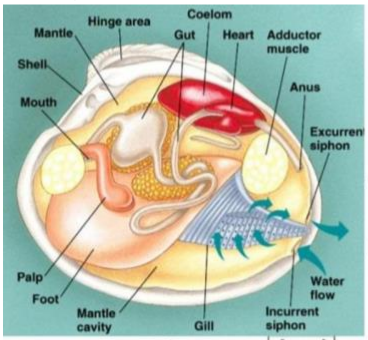


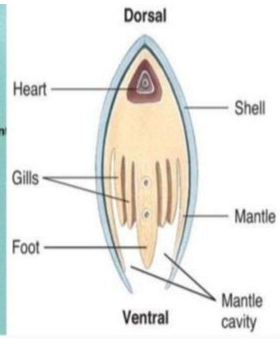
Gastropoda	Notes
Marine Gastropoda	Patella, Littorina, Buccinum, & Turritella
Patella **Eocene-present**	Is a genus of sea snails with gills, true limpets, marine gastropod mollusks in the family Patellidae, the true limpets, or cap like, cone like shell, oval aperture attached beach rocks
Buccinum Pliocene-Rec	oval shell shaped with large last whorl
Littorina **Jurassic-present**	Is a genus of small sea snails, marine gastropod in the family Littorinidae, the winkles or periwinkles Snails live in tidal zone of rocky shores circular shell, rounded aperture
Turritella **Cretaceous-present**	Is a genus of medium-sized sea snails with an operculum, marine gastropod in the family turritellidae have tightly coiled shells, whose overall shape is basically that of an elongated cone **Env.** multi whorls shell, shallow water
Natica **Eocene-Recent**	Genus of small-medium predatory sea snail marine gastropods in family Naticidae, moon snails
Planorbis	Genus of air-breathing freshwater snails, aquatic pulmonate gastropod (Planorbidae family) The ram's horn snails, or planorbids have sinistral or left-coiling shells

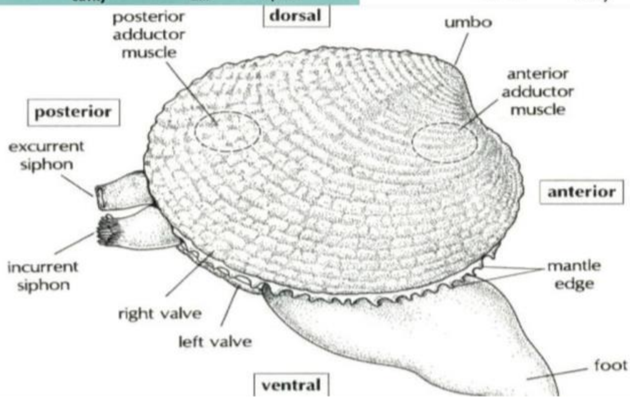
4.8 bivalvia

Kingdom	Age	Animalia
Phylum	Cam – Rec	Molluscs
Class	Cam – Rec	Bivalvia
		Clams, oysters, mussels, scallops

- Defining characteristics: 2-valved shell, Body flattened laterally, Little cephalization (no head)
- Foot hatchet, modified for burrowing in sand/mud
- In bivalves the soft parts are partially or completely enclosed between 2 hinged valves
- Most of the soft parts are to be found close to the back of the enclosed space, adjacent to the hinge
- A mantle lines both valves almost as far as their outermost edges, is responsible for secreting shell
- The body doesn't occupy all the space inside the valves even when closed
- Residual space is taken up by mantle cavity, into which hang respiratory gills & the muscular foot
- The gill create currents using the cilia with which they are covered
- Strong muscles, the adductor muscles, are used to close the valves
- 2 siphons (incurrent & excurrent) draw water into & out of the mantle cavity, respectively
- Cilia on gills pull water into & out of shell through siphons, brings oxygen, food particles
- Since many clams burrow into sediment, these siphons allow the clam to feed & breathe

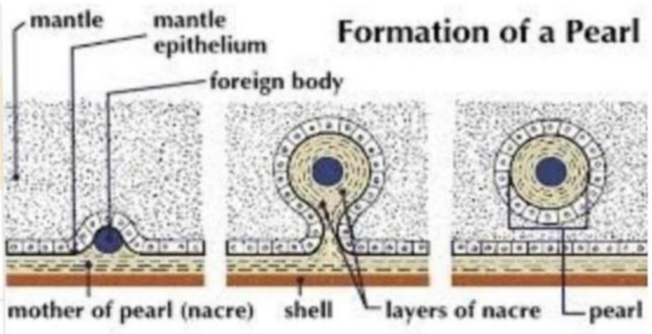




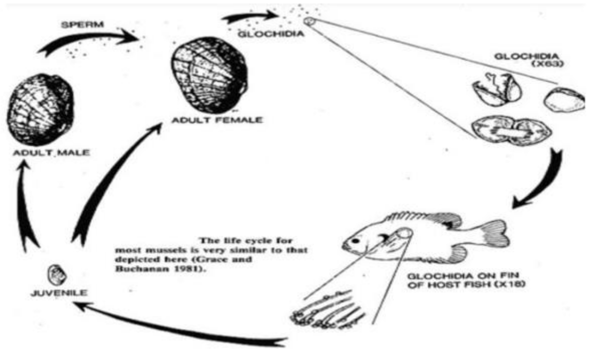


- **SHELL**
  - ➢ mollusk shell functions: acts as a skeleton for the attachment of muscles, protects against predators, & in burrowing species it helps to keep mud & sand out of the mantle cavity
  - ➢ Its main component is $CaCO_3$
  - ➢ formed by deposition of crystals of this salt in an organic matrix of the protein, conchiolin
  - ➢ Not all bivalves are burrowers, mussels secrete strong byssal threads to attach to rocks
- **Oysters** cement themselves to hard substances include other oysters
- **Scallops** are unattached & swim for short distances by rapidly ejecting water from mantle cavity & flapping their valves
  - ➢ Three layers make up the shell:
  1. Thin outer periostracum of horny conchiolin, often much reduced due to mechanical abrasion, fouling organisms, parasites disease
  2. Middle prismatic layer of $CaCO_3$
  3. Inner calcareous (nacreous) is dull texture or iridescent mother-of-pearl, depend on species
  - ➢ Calcium for shell growth is obtained from the diet, or taken up from seawater

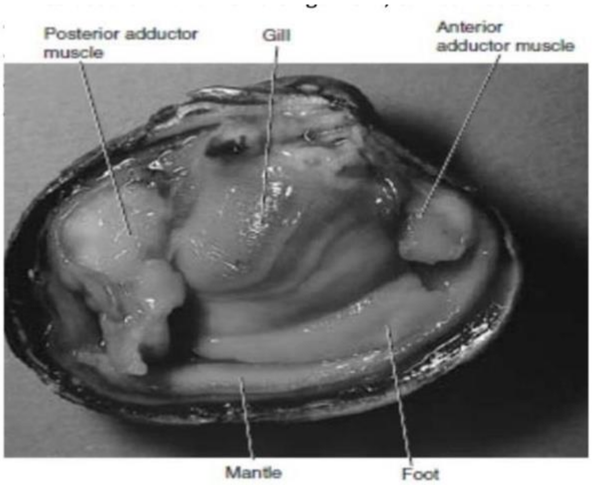
- **PEARL FORMATION** a foreign object (sand grain, parasitic larva) lodges between mantle & shell
    - ➢ The bivalve encapsulates the object with layers of nacreous shell & so a pearl is formed
    - ➢ all bivalves are capable of forming pearls it is only those with an inner mother-of-pearl layer that produce pearls of commercial importance
    - ➢ The best quality natural pearls are produced by pearl oysters, Pinctada spp



- BIVALVES: Larvae parasitic on host fish gills or fins as glochidia
- **Importance**: Biodiversity, Human food, Pollution monitors, & Jewelry (pearls)



- **CLAMS**
    - ➢ Eg. Mya: infunal, deep borrowers
    - ➢ Clams are It is a common name, used to refer to any molluscans within Class Bivalvia



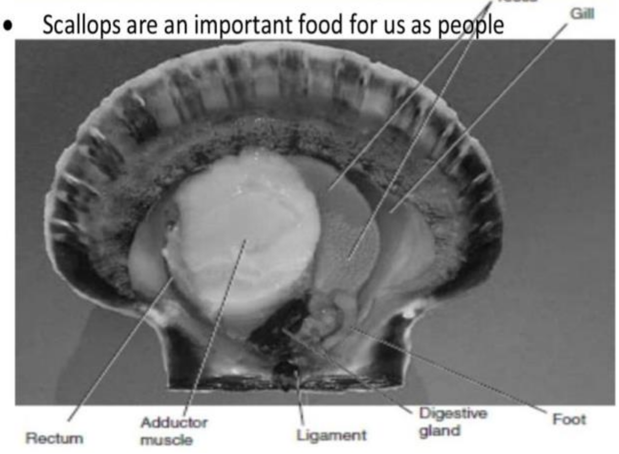
- ➢ very diverse group of bivalves in there is notable variation in shape, size, thickness, color & degree of sculpturing of shell
- ➢ The one feature that all clams have in common is that they burrow into the sea-bed
- ➢ shell & body display modifications necessary for this type of existence
- ➢ They live in freshwater & marine habitats, & range in adult size from microscopic to the giant clam, which can weigh 200kg (440lb).
- ➢ have 2 calcareous shells (valves) joined near hinge structure with a flexible ligament, & filter feeders

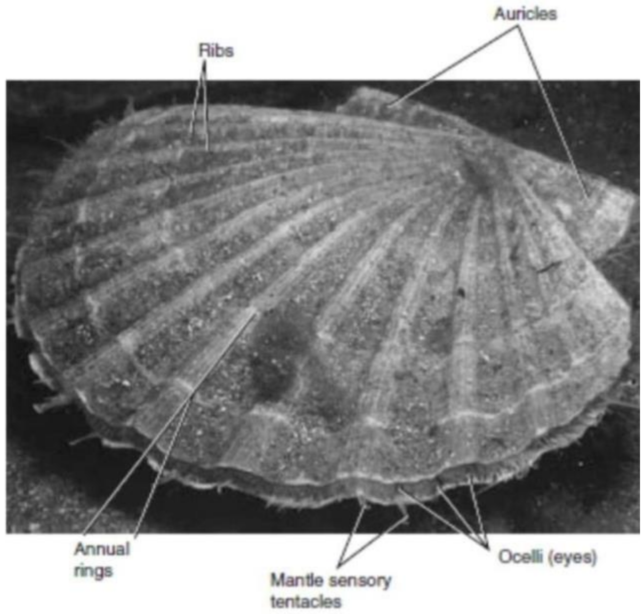
- **MUSSELS**
    - ➢ Common name Mussels (Eg. Mytilus: epifunal)
    - ➢ In mussels the 2 shell valves are similar in size, & triangular, live in saltwater & freshwater
    - ➢ Most of which live on exposed shores in the intertidal zone, attached by means of their strong byssal threads (beard) to firm substrate
    - ➢ Both marine & freshwater mussels filter feeders, they feed on plankton & other microscopic sea creatures which are free-floating in seawater

- **SCALLOPS** (Eg. Pecten : swimmer)
    - ➢ primarily applied to any one of numerous species of saltwater clams or marine bivalve mollusks in a family Pectinidae, & scallops
    - ➢ model scallop shell consists of 2 similarly shaped valves with a straight hinge line along top devoid of teeth & which produces pair of flat wings or "ears" (called "auricles", via this is also the term for 2 chamber in its heart) on either side of its midpoint
    - ➢ Most species of the scallop family are free-living active swimmers, mostly slow-moving
    - ➢ Scallops are an important food for us
-

active swimmers, which are mostly slow-moving

- Scallops are an important food for us as people



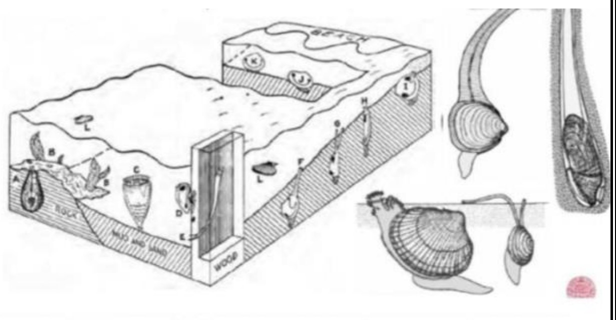


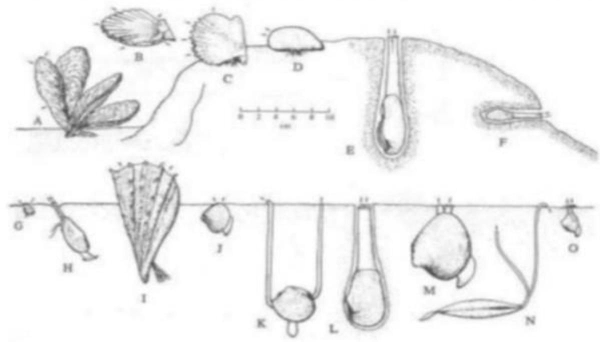
- **OYSTERS** (Eg. Ostrea: epifunal)
  - ➢ saltwater bivalve molluscs that live in marine or brackish habitats
  - ➢ In some species the valves are highly calcified, & many are irregular in shape
  - ➢ shell valves are circular & hinged together on the dorsal side by a horny ligament
  - ➢ The right valve is flat while the left is cupped
  - ➢ At rest on the sea-bed the flat valve is uppermost, & cupped is cemented to substrate
  - ➢ The shell is thick & solid & both valves have distinct concentric sculpturing
  - ➢ The oyster is sessile (immobile) mollusc

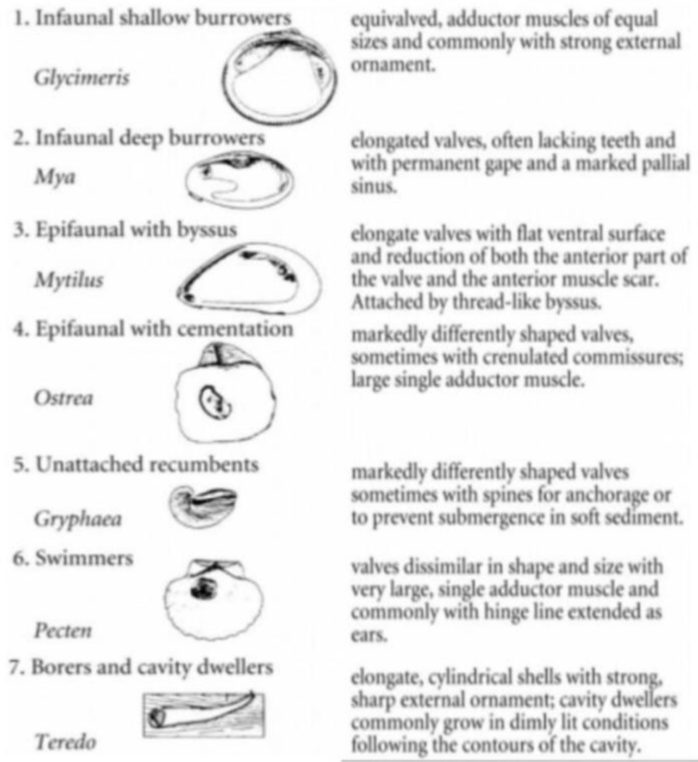
4.9 ecology of bivalves

- **Ecology**: is the study of interactions between organisms & their environment
- **Ecology of marine & fresh water**: benthic, infaunal or epifaunal
- include burrowing, browsing, cemented, free lying, swimming, boring forms
- filter feeders, deposit feeders

- **Reef-forming bivalves:** Rudists (Jurassic-Cretaceous) reef builders, Differential valves, Cone-shaped right valve, Left valve acts as a lid, Probably had symbiotic algae like modern Tridacna





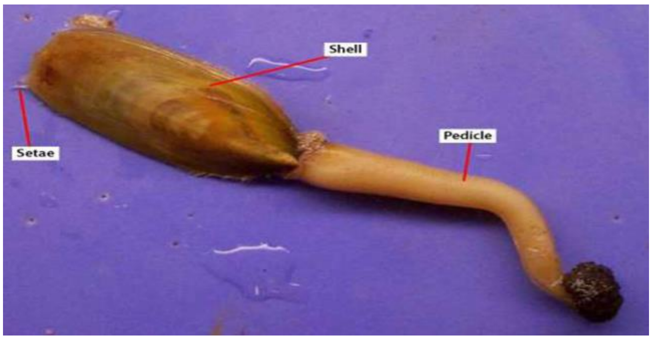


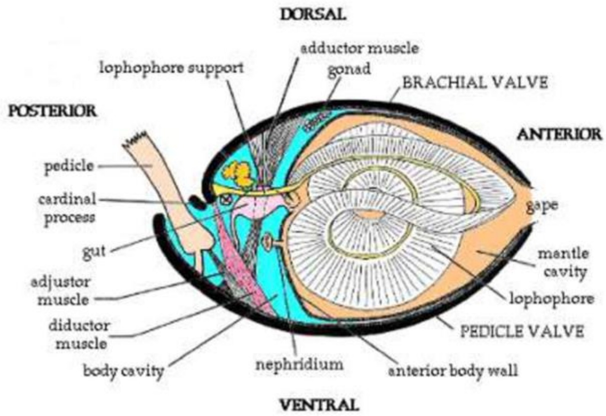
1. Infaunal shallow burrowers *Glycimeris*	equivalved, adductor muscles of equal sizes and commonly with strong external ornament.
2. Infaunal deep burrowers *Mya*	elongated valves, often lacking teeth and with permanent gape and a marked pallial sinus.
3. Epifaunal with byssus *Mytilus*	elongate valves with flat ventral surface and reduction of both the anterior part of the valve and the anterior muscle scar. Attached by thread-like byssus.
4. Epifaunal with cementation *Ostrea*	markedly differently shaped valves, sometimes with crenulated commissures; large single adductor muscle.
5. Unattached recumbents *Gryphaea*	markedly differently shaped valves sometimes with spines for anchorage or to prevent submergence in soft sediment.
6. Swimmers *Pecten*	valves dissimilar in shape and size with very large, single adductor muscle and commonly with hinge line extended as ears.
7. Borers and cavity dwellers *Teredo*	elongate, cylindrical shells with strong, sharp external ornament; cavity dwellers commonly grow in dimly lit conditions following the contours of the cavity.

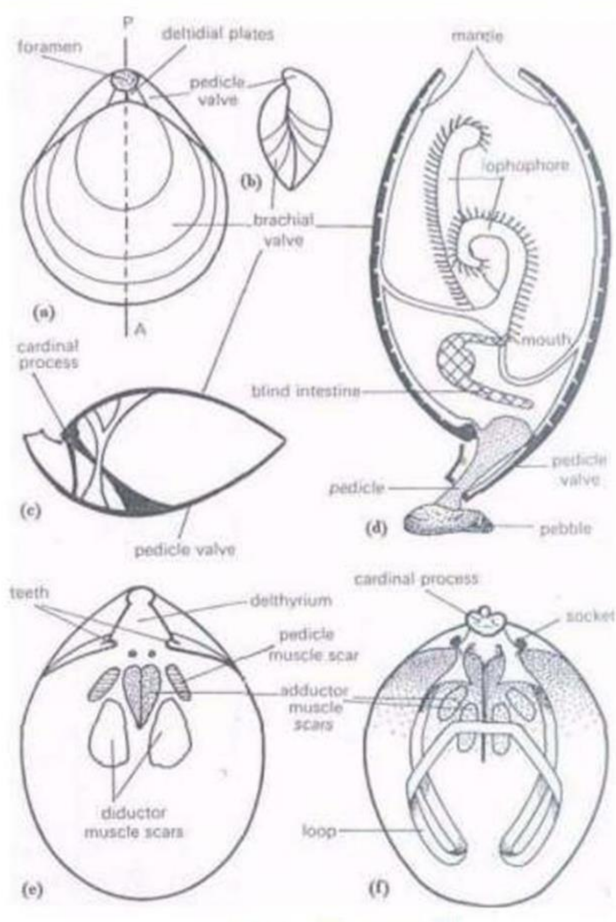
CHAPTER FIVE: PHYLUM BRACHIOPODS

Phylum	Cam – Rec	Brachiopoda (lamp)
Class		articulata
		interticulata
Shells	The top & bottom part have different shapes, symmetry is perpendicular to plane of shell (lamp)	
Chief Characteristics	Bivalved (2 shells), with Bilateral symmetry (symmetry plane passes via the center of each shell)	
Valves	The 2 valves differ in size & shap	
Mode of life	Inhabitants of shallow marine	
Environments	Live in a fixed position on sea floor	

- The larger valve will have an opening near the hinge line via which the pedicle extended in life
- there are enough similarities in Brachiopods Class general morphology to consider them together
- The brachiopod shell encloses the body except for the pedicle
- **Pedicle Valve**: valve on the ventral side of the body
  - The pedicle commonly emerges through it
  - The pedicle emerges from the shell at its Posterior margin & opposite margin is Anterior
  - The valves open slightly along the anterior during feeding, but remain in contact along the posterior by means of a Hinge in the Articulata & by a muscles in Inarticulata (Soft Body)
- **Brachial Valve**: the valve on the Dorsal side
  - Takes its name from the brachia, arm-like projections, which make up the lophophore
- The pedicle valve is the larger, projecting at its posterior end beyond the brachial valve
- The body & mantle line the shell & in some cases soft tissue extend by minute tubules into shell wall
- The main part of the body is small, & much of the mantle cavity is taken up by the lophophore
- This may be a lobed disc or 2 coiled or folded arms called Brachial each of which has a groove leading back to the mouth & fringed with ciliated tentacles
- Maintain water currents along 3 paths, a median outgoing flow, & incurrent flow on either side
- Minute organism, frequently diatom, filtered from the incurrent water & passed along the lophophore grooves to mouth & thence to the digestive tract
- The intestine ends blindly in living articulate brachiopods, but opens in anus in inarticulates
- Most brachiopods are attached by a pedicle
- Pedicle typically stout fleshy stalk attached to the pedicle valve by muscles
- Its distal end is fixed to a rock or shell





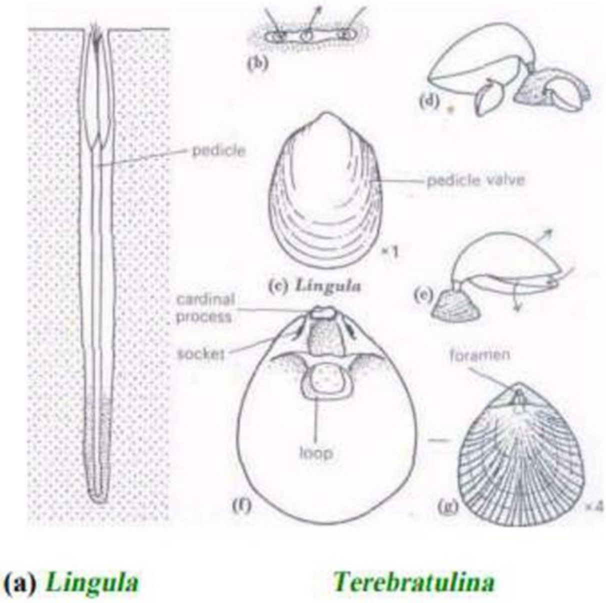


pedicle (ventral) valve

89 Morphology of an articulate brachiopod.

Internal Morphology of Brachiopods

Jurassic brachiopod with lophophore supports



Morphology & mode of life of brachiopods
A-C: inarticulate brachiopod, Lingula
D-G: an articulate brachiopod, Terebratulina

A. in feeding position at the mouth of burrow
B. slit-like opening of burrow (arrows indicate incurrent & excurrent flow of water)
D. attached to a stone & to other shells
E. in feeding position with open shell (as for b)
F. interior of the brachial valve
G. brachial valve exterior

5.2 Brachiopoda Classifications

Phylum	Brachiopoda (lamp)
Class	articulata
	interticulata
Order	Orthida, Strophomenida, Pentamerida, Rhynchonellida Spiriferida, Terebratulida

- **Articulate** have a hinge-like articulation between the shells utilising teeth & sockets
- **Inarticulate** held together entirely by musculature
- Articulate are most useful to Geologists

5.3 Class Inarticulata

- Primitive brachiopods with phosphatic orchitinous valves, & no hinge
- Valves held together with muscles & soft parts

Phylum	Range	Brachiopoda (lamp)
Class	Cam - Rec	interticulata
Order	Cam - Rec	Lingula: 51 genera
	Cam-Holo	Acrotretida: 62 genera

- **Lingula:** well known interticulata
  - ➢ Shells composed of chitino-phosphatic material (contain phosphate & rarely calcareous)
  - ➢ Shell muscles is complex
  - ➢ pedicle (stalk) develops from ventral mantle, soft extension of the body wall, intestine with anal opening
  - ➢ biconvex (both valves convex) beak for attachment to surface apical, or located at the tip, in both valves, fleshy pedicle emerging between valves at the tapered end

- **Order Acrotretida**
  - ➢ circular in outline
  - ➢ shell contains phosphate or punctate calcareous
  - ➢ pedicle opening confined to the ventral valve

5.4 Class Articulata

- **Articulata**: Brachiopods with calcareous valves attached together with a hinge

Phylum	Range	Brachiopoda (lamp)
Class	Cam -Rec	Articulata
Order	Ord -Holo	Rhynchonellida:300genera
	Ord - Jur	Spiriferida: > 300genera
	Dev -Holo	Terebratulida: >300genera
	Ord - Jur	Strophomenida:400genera
		Pentamerus
		Rafinesquina
		Atrypa
		Leptaena
		Spirifer

- Shells by means of teeth & sockets, calcareous
- musculature less complicated than Inarticulata
- larval pedicle develops from rear region, no outside opening from intestine
- **Rhynchonellida:**
  - ➢ Narrow-hinged with functional pedicle
  - ➢ dorsal valve with or without median septum
  - ➢ lophophore (of Holocene genera) dorsally spiral & attached to crura (supporting structures), spondylia rare

- **Spiriferida** Lophophore supported by a calcareous spiral structure (brachidium)
  - ➢ Punctate or impunctate
  - ➢ usually biconvex
  - ➢ delthyrium open or closed

- **Terebratulida** Pedicle functional, cyrtomatodont teeth, lophophore supported wholly or in part by a calcareous loop, short or long & free or attached to a median septum

- **Strophomenida** Teeth deltidiodont when present
  - ➢ ventral muscles large
  - ➢ shell substance pseudopunctate (with rods of calcite), rarely impunctate

Shells	Function
Adaptation	Reasons
Large pedicle opening	To support a large pedicle for attachment to the sea bed
Strongly ribbed valves	Th strengthen the shell against wave action
A folded (zigzagged) margin	To reduce the amount & size of sediment moving into the shell when the valves are open
Thick (havy) shell	To provide extra stability on the substrate & prevent it from rolling in the current
extension of the valves to form ' wings '	To provide a large surface area and prevent sinking into soft muddy sediment
Smooth,weakly ribbed valves	No need to be robust in quiet conditions
No pedicle opening	Pedicle not needed for attachment in calm environment

5.5 brachiopods fossils

- are the first animal to appear in Cambrian (542Ma)
- Their evolution & distribution was wide & rapid
- >35,000 species in >2,500 genera are known, & the number of described species increases yearly
- Articulate & inarticulate appeared at the same time in advanced state of development, indicating a long evolution from forms without shells
- evolution lost or unrecorded in Precambrian times
- The Inarticulata, the most abundant brachiopods of the Cambrian, soon gave way to the Articulata & declined greatly in number & variety toward the end of the Cambrian
- They were represented in the Ordovician (488Ma-444Ma) but decreased thereafter
- In the Cretaceous (145.5Ma-65.5Ma) the punctate calcareous
- Inarticulata proliferated,but this trend soon ended
- The Inarticulata dwindled via Cenozoic, from 65.5Ma to Holocene (9 genera known during Holo)
- Inarticulate genera represent 6.5% of all brachiopod genera

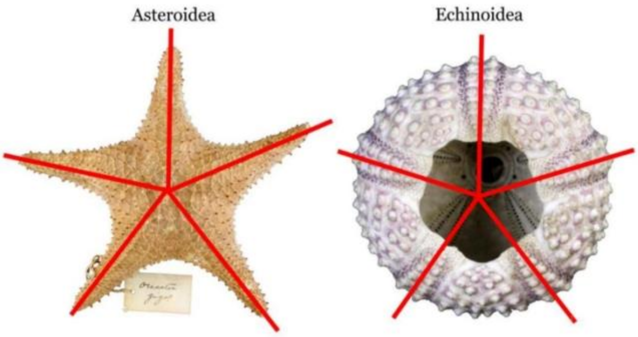
CHAPTER SIX: PHYLUM ECHINODERMATA

6.1 Echinoderms Phylum

Phylum	Echinodermata
Class	**Crinoidea:** Sea lilies
	Echinoidea: Sea urchins & sand dollars
	Asteroidea: Sea Stars, aka, or Starfish
	Ophiuroidea: Brittle stars
	Holothuroidea: Sea cucumbers

- **Echinoderms** is The spiny skinned Marine animals

- Echinodermata = spiny (echinos) + skin (derma)
- All have calcite plates embedded in their skin, which form their skeleton, lack body segmentation
- Have 5 fold symmetry (pentameral), so their bodies organized in patterns of 5 (e.g. 5 arms of starfish)
- Crinoids have as few as 5 Arms, but usually they have arms in multiples of five

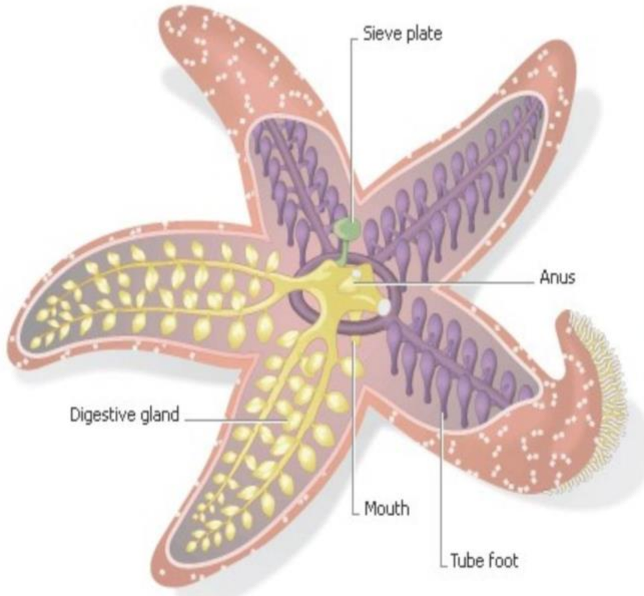


- Some attached to seafloor by stem with **Holdfasts** “roots”, & others are free-moving bottom dwellers
- are filter feeders, substrate eaters or carnivores
- Echinoderm possess unique water vascular system
- Seawater is taken into a system of canals & used to extend many tube feet, which have sucker on their tips & aid animal in attaching itself to solid surfaces
- About 6,000 species, all of them are marine

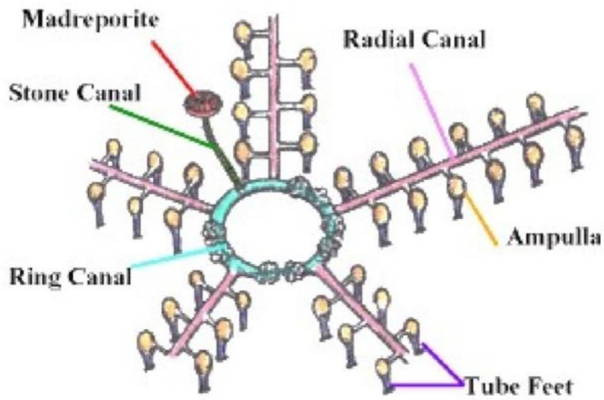
6.2 Echinoderms Phylum

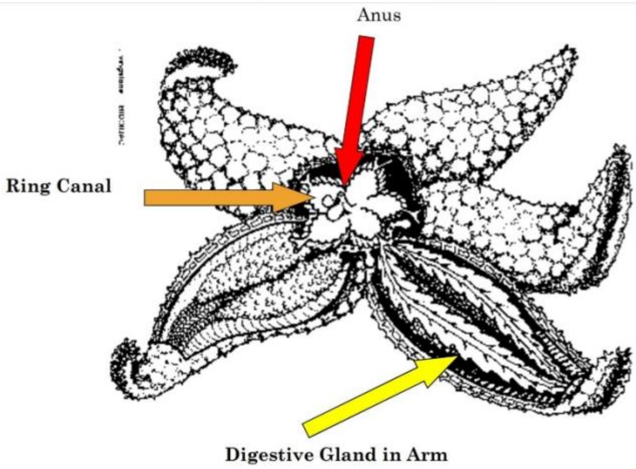
Phylum	Echinodermata
Class	**Asteroidea:** Sea Stars, aka, or Starfish

- **Sea stars** are starshaped echinoderms
- Carnivores-clams, mussels, bivalves
- Motile by way of tube feet
- endoskeleton made of calcareous plates ($CaCO_3$)
- breathes through dermal “skin gills”
- **Starfish arm** contains a digestive gland & gonads
- **Ampulla:** the top of the tube feet (like Medicine dropper that is squeezed to create pressure)
- **eye** is at the end of the arms (red coloured)
- The **anus** of the starfish is on the top (aboral side)



- **Madreporite** water vascular opening, opens into a radial canal which then goes out to the arms in radial canals, & then feed water to the tube feet

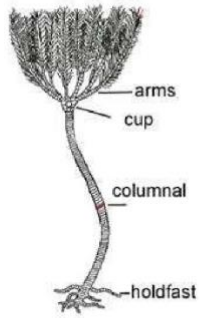




6.3 Crinoidea(sea lilie or crinoid)

Phylum	Echinodermata	Cam - Rec
Class	**Crinoidea:** Sea lilies	Cam - Rec

- looking animal, look-like plants
- characterised by a mouth on the top surface that is surrounded by feeding arms
- Most have more than 5 arms
- Resemble flowers, Consist of a calyx with arms, atop a stem of calcite Disks called columnals
- The crinoid is attached to the seafloor by Holdfasts
- Some are swimmers (Marine, deep water animals)



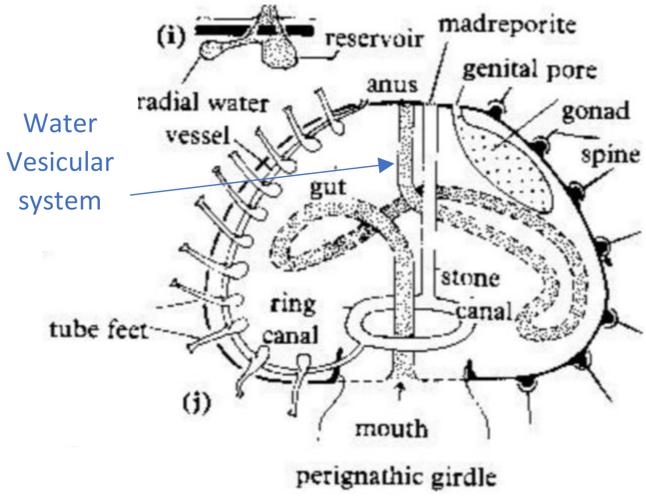
- common fossils from Paleozoic-age marine rocks, although none have been found in Cambrian rocks
- Especially abundant during the Mesozoic

6.4 Echinoidea (sand dollars)

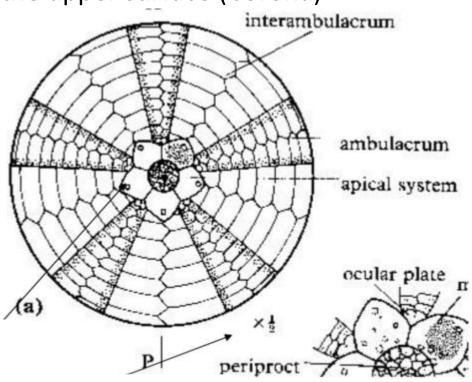
Phylum	Echinodermata	Cam - Rec
Class	**Echinoidea:** sand dollars & sea urchins	Ord - Rec
Order	**Regular** with perfect pentameral 5-symmetry	
	Irregular echinoids with altered symmetry	

- **Lack arms, eat algae or eaters, & have spines**
- **Test shapes (skeleton) range** globular (sea urchins) to highly flattened (in sand dollars or heart urchins)
- Have 5-part symmetry
- **There are 2 types** the regulars & the irregulars
- marine in shallow depths to the abyssal planes

6.5 Echinoidea Morphology



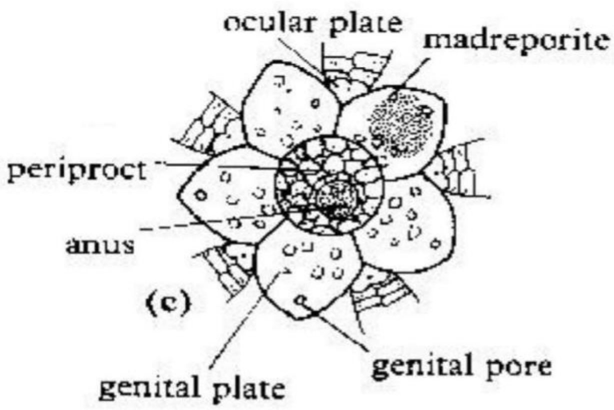
- **Morphology:** have a hard shell which when alive is covered by a very thin skin & have an endoskeleton
- The skeleton (Test) is made of calcite with tiny interlocking plates which protect & enclose most of soft parts inside.
- The test is hemispherical, the interlocking plates arranged in 10 double columns radiating out from the top of the upper surface (Corona)



AMBULACRUM

INTERAMBULACRUM

- **There are 2 types of plate:**
  1. **Ambulacrum**: occur near the <u>Tube Feet</u> are
  2. **Interambulacrum**



- **Tube Feet** connected to the Water Vascular System (system of hydraulic tubes) Through which water is circulated around the body & used to extend the tentacles through the test & can act like feet

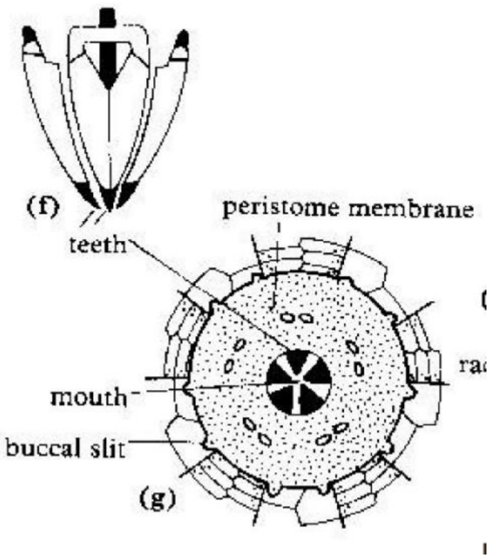
- The water vascular system starts with an opening to the external environment (**Madreporite)** From this a straight canal **stone canal** leads to **ring canal**
- **Apical System** Towards the top (Apex) of the Test, made of 10 small plates that are interconnected
- One plate has a special function (**Madreporite**): It is porous & allows sea water into the body, & water then passes via **Radial Canals** & into the tube feet

6.6 Regular echinoids

Phylum	Echinodermata
Class	**Echinoidea:** sand dollars & sea urchins
Order	**Regular** perfect pentameral 5-symmetry
	Cidaroida : pencil urchins **Echinoida :** long-spined sea urchin **Clypeasteroida:** sand dollars & sea biscuits, above center **Spatangoida :** heart urchins, Micraster **Cassiduloida:** sand-dollar-like group (rare today) make up the irregular echinoids

- usually circular when viewed from above
- show a 5-fold symmetry, a regular pattern
- apical system is situated on the top & contains anus in centre surrounded by periproct (membrane)

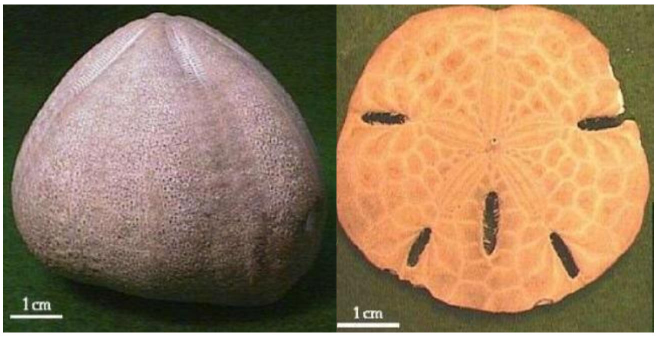
- The mouth is situated on the underside (oral Surface) usually in the centre
- The mouth of most echinoids is provided with five hard teeth arranged in a circlet
- Jaws are present, they are rarely preserved
- **Aporal Surfaces:** the upper surface is called



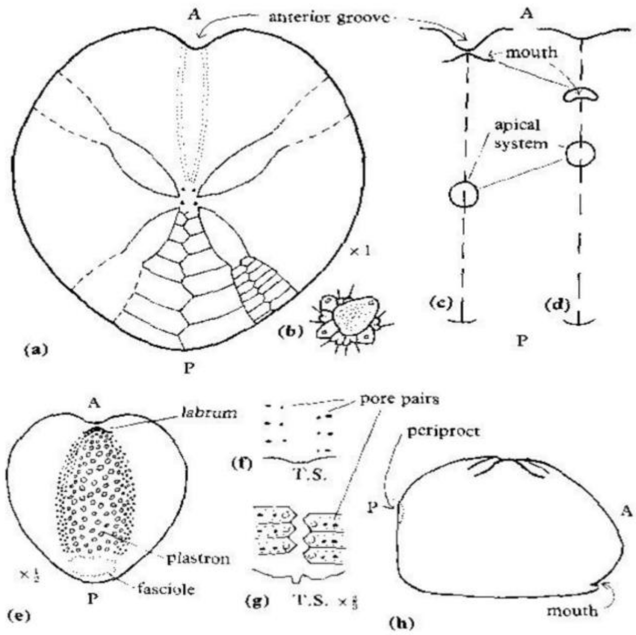
- Regular echinoids have 5-fold radial symmetry
- Mouth & anus (periproct) at opposite poles
- Regular echinoids are mostly epifaunal mobile grazers that sometimes occur in rocky subtidal & intertidal environments

6.7 Irregular echinoids

- These aren't circular but flattened or eart shaped

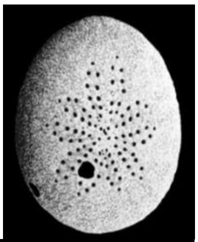


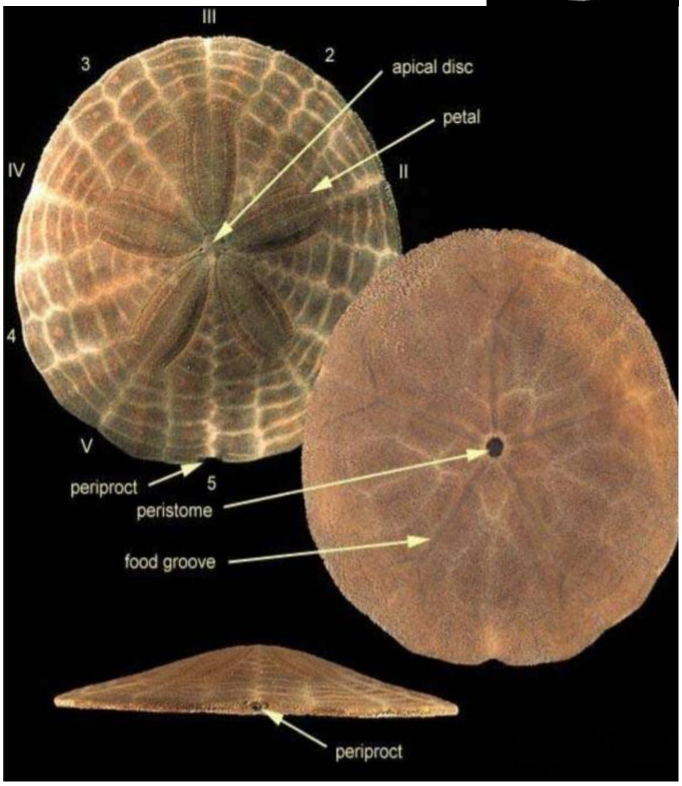
- They have 5 rows of ambulacrum & interambulacrum plates but instead of 5-fold symmetry they show a bilateral symmetry



- bilateral symmetry, occur in infaunal environments
- Mouth toward anterior on ventral side, & periproct in posterior interambulacral area
- The depths at which individuals lived can be deduced by their external morphology
- The Anus isn't enclosed within the apical system, Instead it lies either:
  1. On the aboral side half way up the side (Posterior). Sometimes in a groove
  2. On the oral surface towards the posterior (The mouth is found on the oral Surfaces either:
     - In the centre with jaws
     - Closer to front (anterior) without jaws
     - So easier to define anterior & posterior

- the 2 rows of pores within the double ambulacrum plate can diverge from each other & then converge lower down the test forming a distinctive pattern called **petals or petaloid**
- The posterior interambulacrum area can extend down across the oral surface, this occurs when the mouth is posterior closer to the anterior end
- This forms flatish ridge on the oral surface **plastron**
- This project like a lip across part of mouth: **labrum**



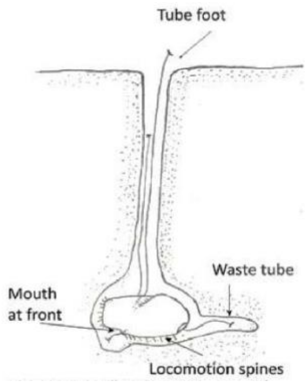


6.8 Echinoids, Mode of Life

- Varies depending on regular or irregular
- Sea urchins feed mainly on algae & can feed on sea cucumbers & invertebrates, such as mussels, polychaetes, sponges, brittle stars, & crinoids
- **Regular Echinoids:** usually mobile, moving about looking for food & protection
  - ➢ Many are capable of living on hard rocks: anchor themselves to the rocks via tube feet even in relatively shallow water
  - ➢ between the sub littoral zone down to 100m
  - ➢ use the tube feet to climb steep rock surfaces
  - ➢ On sand they use their spines to support them & move using the spines on the oral surface & low down on the aboral (move in any direction)
  - ➢ They eat sea weed & partly carnivorous: bryozoa & sponges in particular
  - ➢ Have strong jaws e.g. Echinus lives on rocks
- **Irregular Echinoids**

FLATTENED TEST	• **Clypeaster** (sea biscuits), is a genus of echinoderms belonging to the family Clypeasteridae • Lived in loose sediment (partially or completely buried) & moved forward by moving spines to plough through soft sediment • **Clypesater** typical form of shallow waters of tropical areas • tube feet extract organic sediment & transfer to food tubes • Lives in shallow water 0.5 - 5m • Fossils found between Eoc-Rec
HEART SHAPED	• **Micraster:** an extinct genus (Cre - Paleo) & Echinocardium which completely buried (50m - 200m below sea level) • Lived in burrows of soft sediment (Micraster in fine lime mud) • Sand is pushed aside & backwards • Organic matter is extracted from sediment & waste disposed behind

- Some food is also obtained from the sea water via a Funnel which extends from the burrow
- The tube feet in the upper areas extend out of the burrow
- Water is drawn into the animal & cilia help waft it into the tube feet respiratory system
- All are gregarious



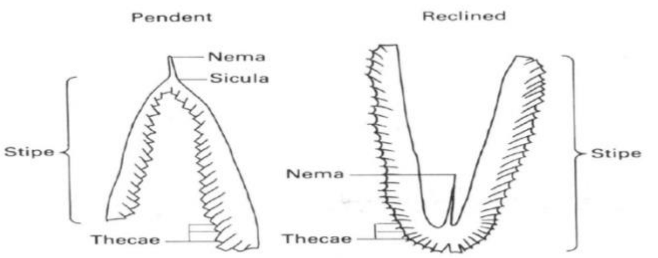
- **Upper Ord to Rec**:
  - ➢ In the Carboniferous the numbers peaked briefly but reduced during the Permian
  - ➢ Most of the fossil from the Pale incomplete, consisting of isolated spines & small clusters of scattered plates from crushed individuals, mostly in Dev & Carboniferous rocks
  - ➢ During the Tri the numbers increased with new species due to a major adaptive radiation after the Permian extinction provided new niches
  - ➢ Irregular appear in the Jur, & increase quickly because they were more efficient food grazers & had improved sanitation with anus removed from the apical system, in limestone & chalk
  - ➢ Micraster very important fossil as it evolved quite quickly & palaeontologists were able to show it changing its mouth & anus positions over time

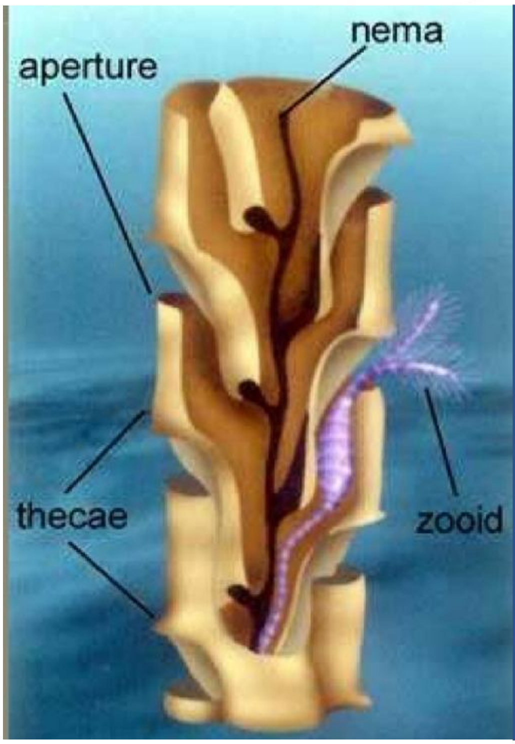
CHAPTER SEVEN: GRAPTOLITES

- **Graptolithina:** class of Michordate animals, & the Members of which are known as *graptolites*
- Graptolites are fossil colonial animals
- extinct marine creatures formed twig-like or net-like colonies composed of one or more branches

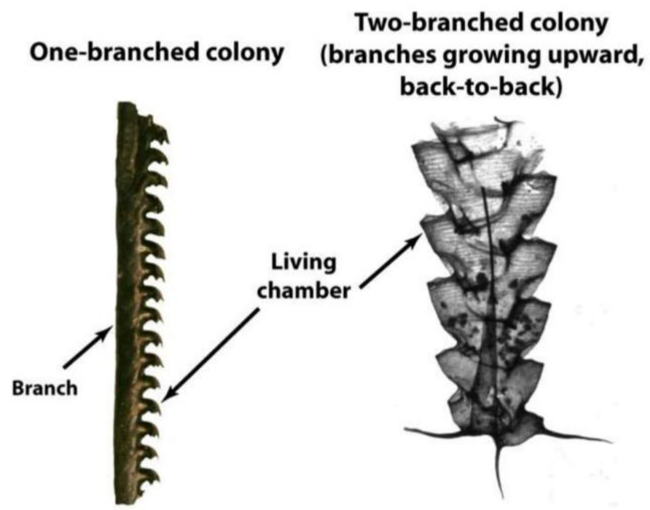
Kingdom	Animalia
Phylum	Hemichordata
Class	Graptolithina (Graptolites) (Cam- Carbo)
Order	Graptoloidea, Dendroidea

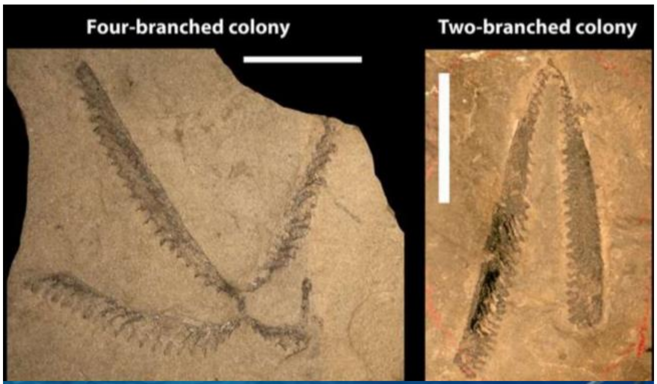
- **Preservation**: Graptolite fossils are often found in shale & mud rocks where sea-bed fossils are rare, this type of rock formed from sediment deposited in relatively deep water that had poor bottom circulation, deficient in Oxygen, & no scavengers
    - The dead planktonic graptolites sunk to sea-floor, become entombed in the sediment & are thus well preserved
- **Morphology**
    - Each graptolite colony is known as a ***rhabdosome*** & has a variable number of branches (***stipes***) originating from an initial individual (***sicula***)
    - Each subsequent individual (***zooid***) is housed within a tubular or cup-like structure (***theca***)

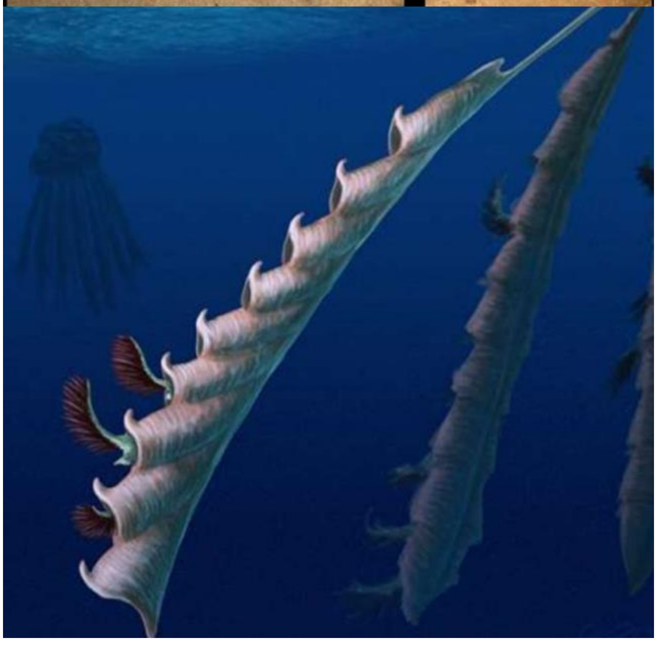




Close up showing how the individual animals (zooids) lived in the graptolite skeleton



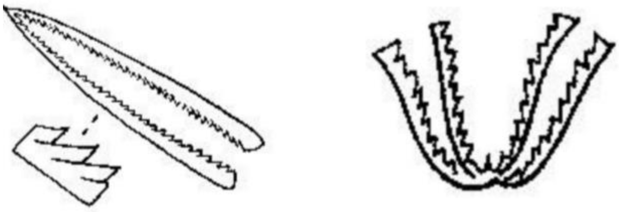




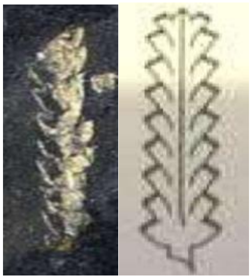
- The number of branches & the arrangement of the thecae are important features in the identification of graptolite fossils, It is uncertain what the individual animals (zooids) looked like but they were probably cup-shaped & had feather-like arms that they used to collect microscopic food particles from the surrounding water
- The skeleton is made out of layers of a protein (***chitin***) which often alters to black carbon when it becomes fossilised

- The individual tubes are usually less than one millimetre in diameter

UNISERIAL on one side & **BISERIAL** on both sides

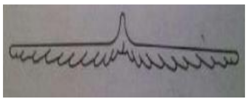


THECAE form as overlapping cups along the length of the skeleton (**STIPE**), The colony can contain a varying number of stipes commonly 1, 2, 4, 8 etc

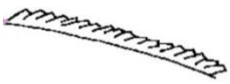


Diplograptus
Silurian
Biserial
Scandent
Simple theca

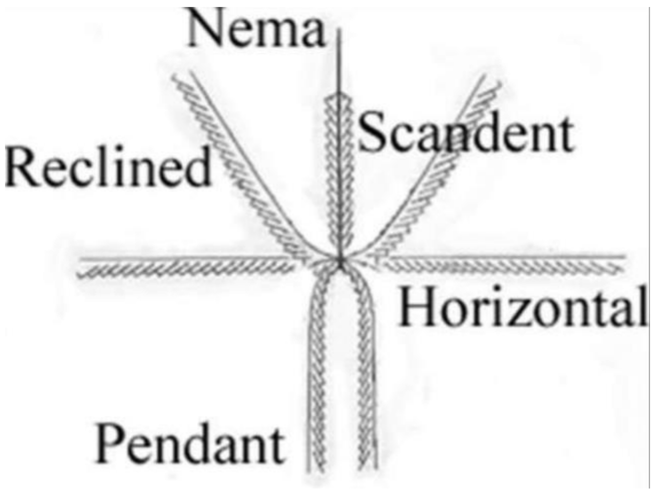
Dicellograptus (Ordovician)
Unuserial, Reclined, Sigmoidal theca



Didymograptus (Ordovician)
unuserial, pendent, simple theca



Monograptus



- **Where did they live?** Some graptolites lived on the bottom of the ocean, where they would stick to the surface with a special structure
  - They grew upwards, just like a plant, adding more living chambers as the colony got older
  - Other floated in the seawater, perhaps drifting with the ocean currents like seaweed

- Different kinds of graptolite colonies had branches with different shapes (straight, curved, or spiral)

7.2 Orders

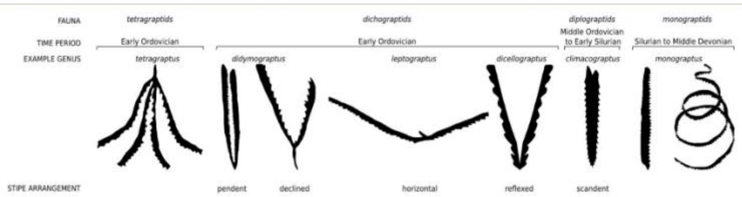
Phylum	Hemichordata
Class	Graptolithina (Graptolites): Cam- Carbon
Order	Graptoloidea: Ord - Dev
Order	Dendroidea (Dendroid): Cam - Carbon

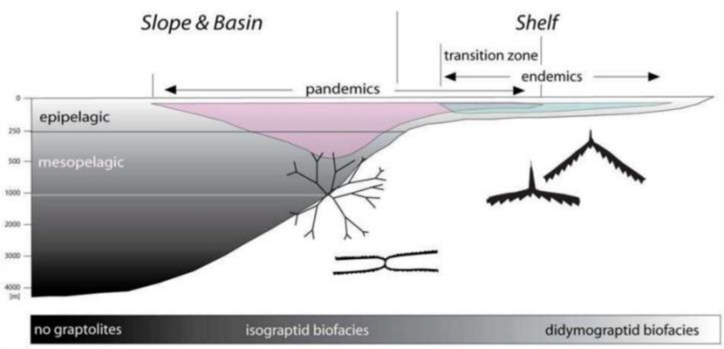
- **Dendroid graptolites** (**Dendroidea**): dendritic or branched types, lived in cone-shaped colonies that were attached by the pointed end to the sea floor
  - sessile animals (attached to the sea-floor by a root-like base)

- **Graptoloidea**: with few branches & derived from the dendroid graptolites, is pelagic & planktonic, drifting freely on the surface of ancient seas or attached to floating seaweed by means of a slender thread colonies with single branch (monograptids)

7.3 Index Fossils

- Graptolites important index fossils for Paleozoic rocks as they evolved rapidly with time & formed many different species
- Graptolites are common fossils & have a worldwide distribution
- The preservation, quantity & gradual change over a geologic time scale of graptolites allows the fossils to be used to date strata of rocks
- Graptolites used to estimate water depth & T during the graptolites lifetimes

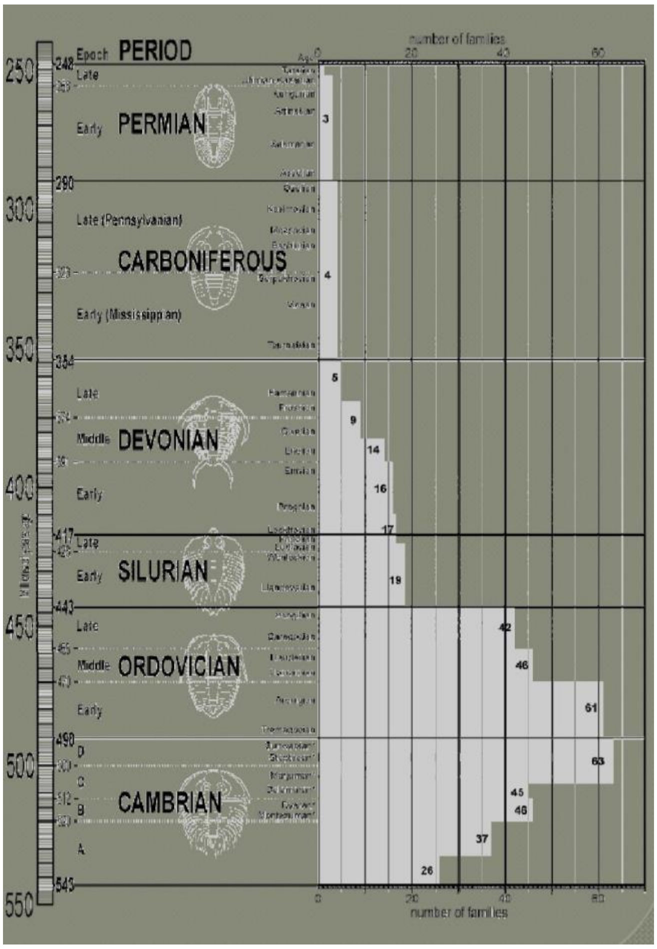




CHAPTER EIGHT: TRILOBITES

- Trilobites are a fossil group of extinct marine arthropods that form the class Trilobita
- Like other arthropod, trilobitomorph characterized by numerous jointed & paired appendages
- The calcitic & chitinous exoskeleton consists of 3 lobes: a central axial lobe, & 2 lateral pleural lobes
- Trilobites remarkable, hard-shelled, segmented creatures that existed over 520 Ma in ancient seas

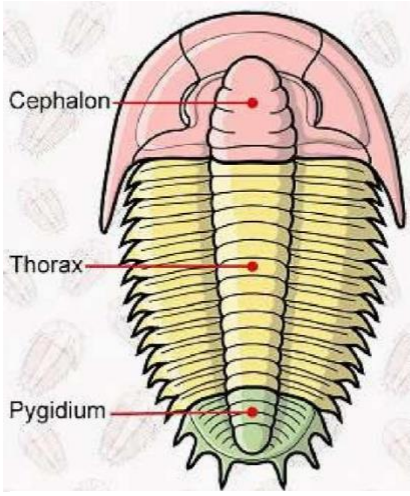
Kingdom	Animalia
Phylum	Arthropods (Arthropoda)
Class	Trilobites (Trilobita): Cam – Per
Order	Polymerida, Agnostida

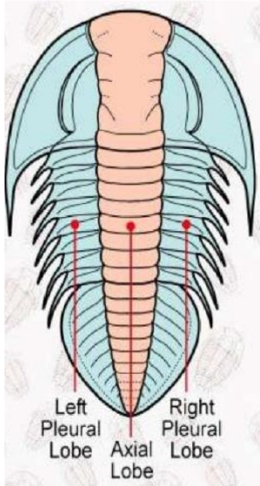


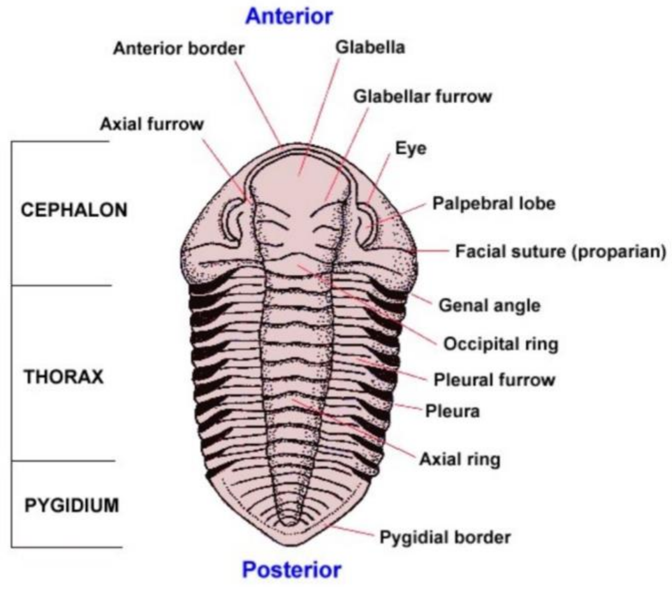
- most common during the Cam, Ordo & Silurian
- they have no modern equivalents & understanding of their soft parts has to be based on modern day arthropod that show some similarity (crustaceans)

8.2 Morphology

- all trilobites bear a long central axial lobe, flanked on each side by pleural lobes (pleura = side, rib)
- 3 lobes run from the cephalon to the pygidium are what give trilobites their name, & common to all trilobites despite great diversity of size & form
- The exoskeleton divided lengthwise into 3 regions:
  1. a cephalon (fused head segment)
  2. a segmented thorax
  3. a pygidium (tail piece), sometimes bears spines







8.3 Taxonomy

- According to some texts, trilobites are considered to have phylum status & are divided into 8 Orders
- A less radical classification treats trilobites as a Superclass or Class with 2 orders: the Polymerida & the Agnostida
- **Polymerida** are the most diverse in regards to species diversity, morphologic, & ecologic types
- The Polymerids can be identified by their larger size, a well defined cephalic region with eyes, facial sutures, & a large number of thoracic segments.
- An easier way to identify **Polymerids** is by default; if its not a agnostid then it's a Polymerid
- **Agnostid** trilobites are recognizable by small size, few thoracic segments (usually 2), & a cephalon without eyes which is superficially similar in morphology to the pygidium, & lack facial sutures

8.3 Paleoecology & Life Habits

- Trilobites very common in marine limestones & shales of the early Paleozoic, from Cambrian Period
- Most trilobites were epifaunal crawlers. & they occupy a wide variety of exclusively marine habitats, specific life habits are difficult to discern by morphology alone.
- several aspects of trilobite morphology can indeed provide some clue as to the life habit or activity
- most trilobites are considered to have been benthic, the small size & non-descript morphology of agnostid trilobites suggests that these (along with some others) may have been nektonic or nekto-benthic