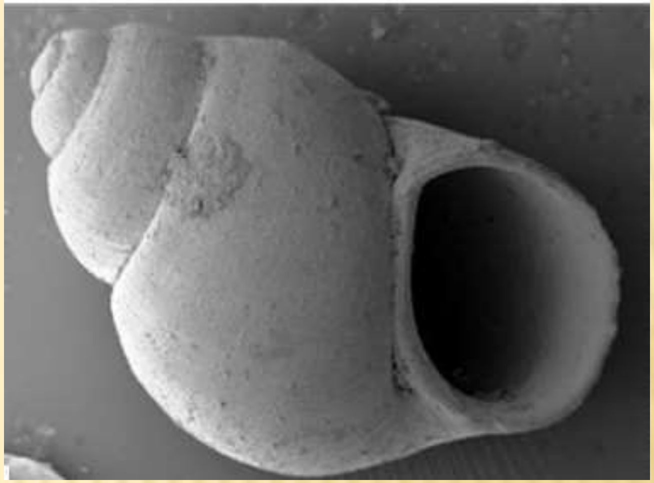
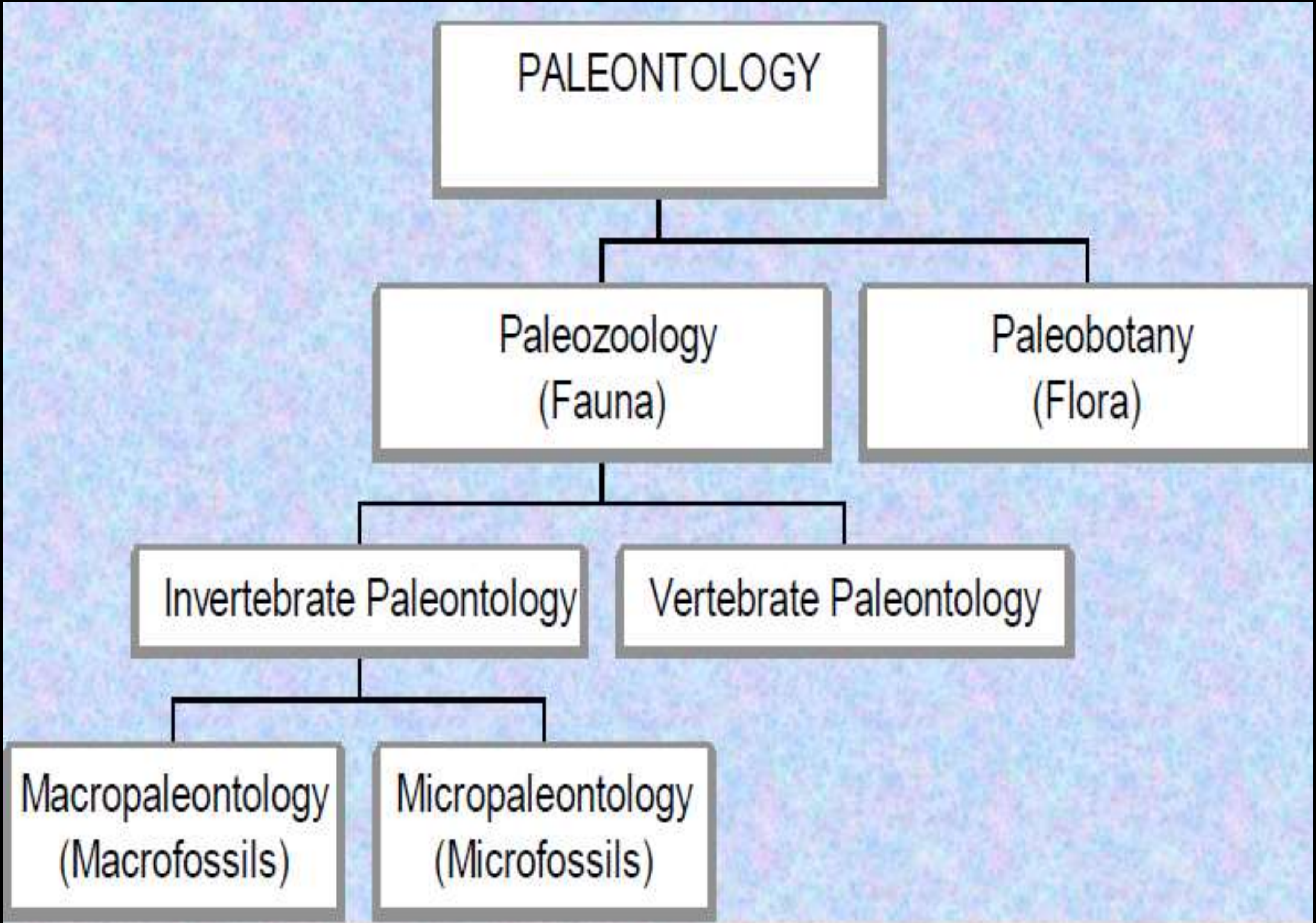
PALAEONTOLOGY

The study of fossils



Gastropod (snail) fossil

A fossil is an original material, impression (mold), cast, or track of any animal or plant that is preserved in rock after the original organic material is transformed or removed.


PALEONTOLOGY
Paleozoology (Fauna)
Paleobotany (Flora)
Invertebrate Paleontology
Vertebrate Paleontology
Macropaleontology (Macrofossils)
Micropaleontology (Microfossils)

PALEONTOLOGY

- **Paleozoology** : study of fossil animals

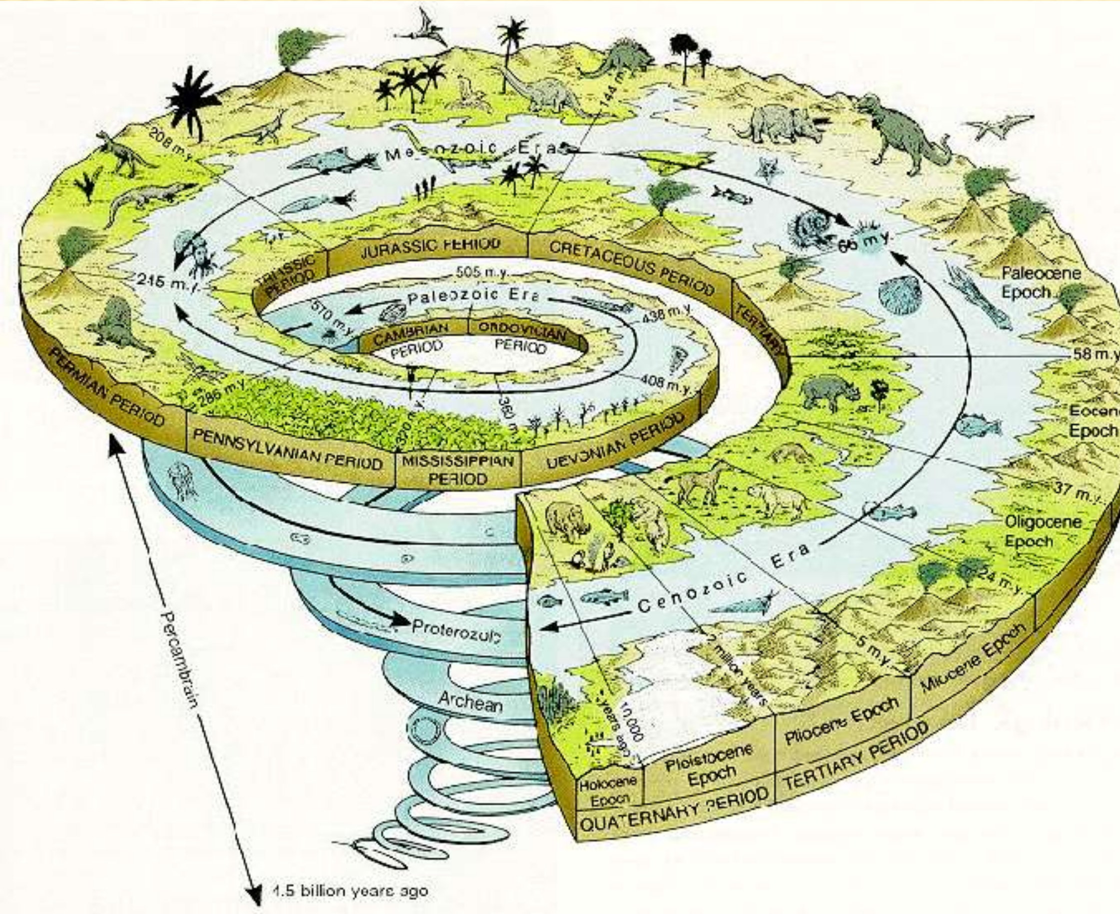
- **a**. Invertebrate paleontology - study of fossil invertebrates (animals without a vertebral column).
- **b**. Vertebrate paleontology - study of fossil vertebrates (animals with a vertebral column).

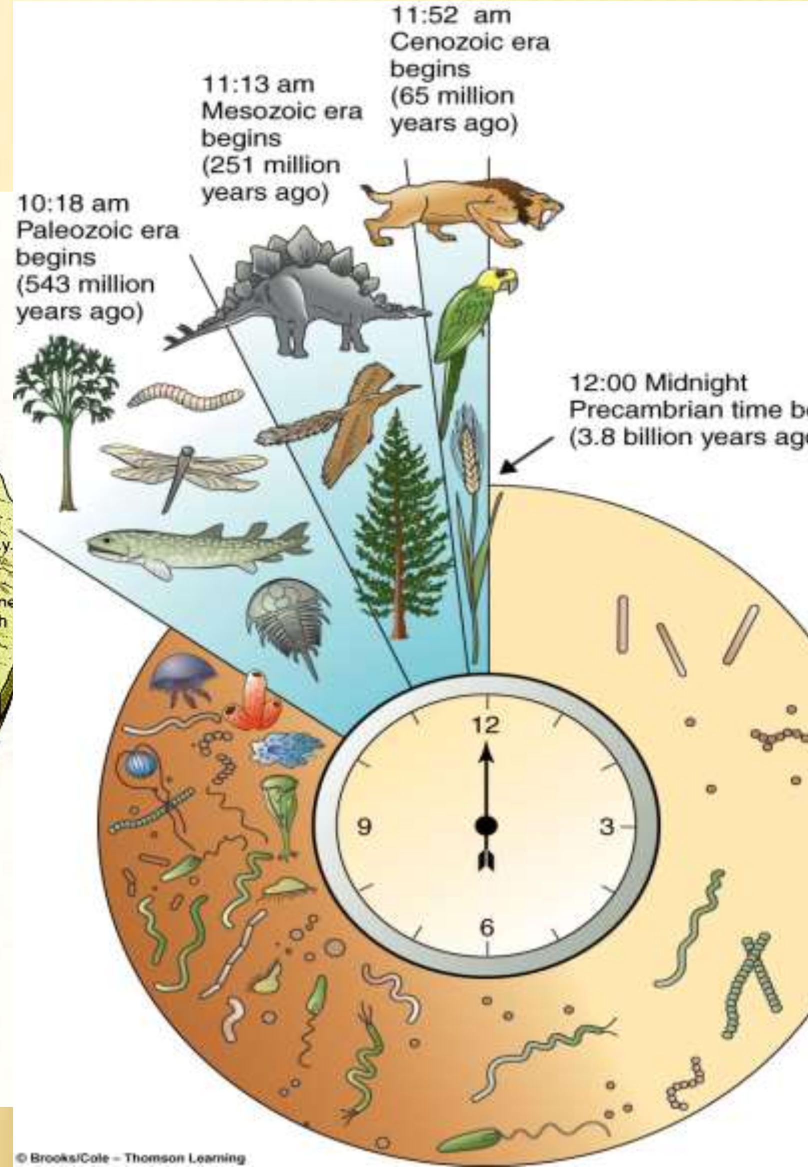
PALEONTOLOGY

- **Paleobotany** : study of fossil plants.
- Palynology : study of pollen and spores (some also include marine one celled "plants"; i.e. acritarchs, dinoflagellates, tasmanites, silicoflagellates, diatoms, ebridians, calcareous nannoplankton/coccoliths).

- **Micropaleontology** : study of small fossils (includes many groups mentioned under palynology and also foraminifera, radiolaria, chitinozoa, graptolites, pteropods (gastropods), ostracods (crustaceans), conodonts .

Evolution and the fossil record





Evolution and the fossil record

Age of Earth is ~4.6 billion years

Atmosphere had little free O_2

Included CO_2, H_2O, CO, H_2, N_2, NH_3, H_2S, CH_4.

Fossils range in age from the youngest at the start of the Holocene Epoch to the oldest from the Archaean Eon, up to 3.48 billion years old.

Stromatolites 3.4 Ga **from Western Australia**

Types of Fossils

- **Body Fossils - the actual body or body parts of an organism, whether altered or not.**

- **Trace Fossils - any evidence of past life that is not a body fossil; examples: tracks, trails, burrows borings, impressions, molds, casts.**

WHY STUDY FOSSILS?

- Fossils give clues about organisms that lived long ago. They help to show that evolution has occurred.
- They provide evidence about how Earth's surface has changed over time.
- Fossils help scientists understand what past environments may have been like.

Hard Parts: Common mineral components

Calcium carbonate $CaCO_3$ Principal mineral components of most seashells. Two common calcareous minerals in seashells:

Aragonite – unstable over geological time.

Aragonitic shells commonly are dissolved (preserved as moulds) or transform to calcite (poor preservation of primary textures).

Calcite – stable over geological time. Consequently calcitic (e.g. brachiopod) shells tends to be well-preserved.

Silica SiO_2 – Usually amorphous hydrated silica (Opal A) which commonly transforms to quartz and other silica minerals following death.

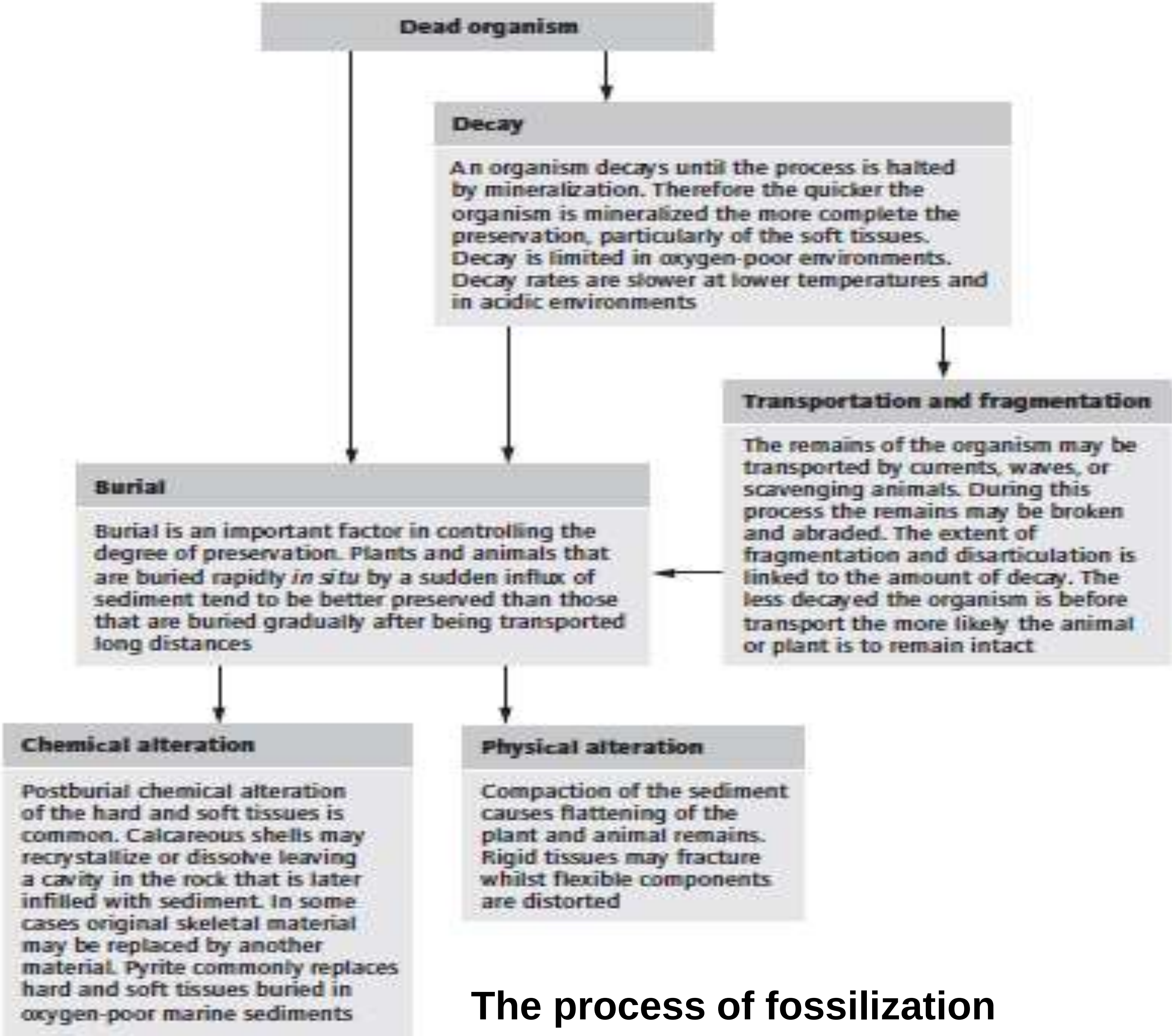
Opal may be well preserved in pelagic sediments, if deeply buried.

This is the principal “mineral” component of the skeletons of some sponges, and micro-organisms such as diatoms and radiolarians.

Skeletons may be lost or degraded through opal dissolution and obliteration of the original amorphous structure through quartz crystallization.

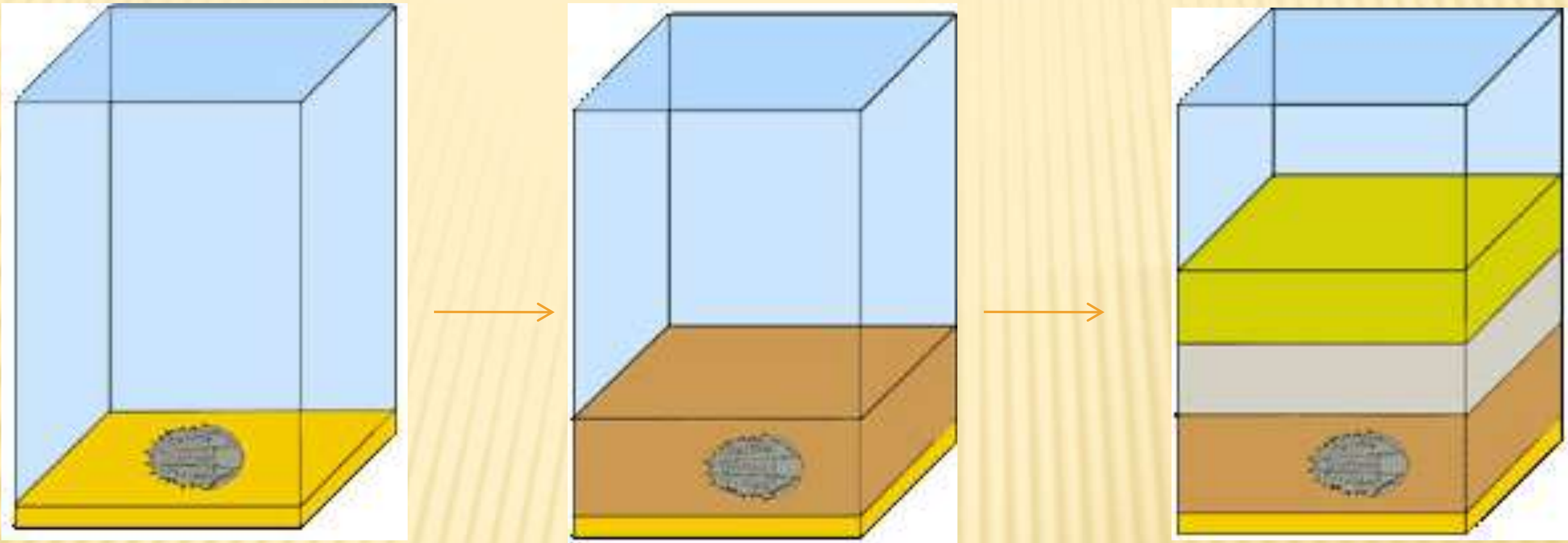
Calcium phosphate (apatite)

$Ca_3(F.Cl.OH)(PO_4)_3$ –stable over geological time (tends to be well-preserved). Principal mineral component of bones, teeth and some shells.



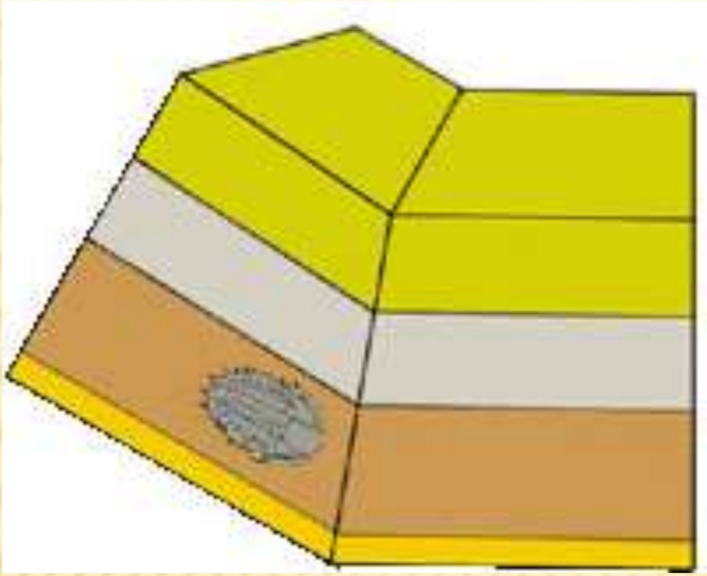
The process of fossilization

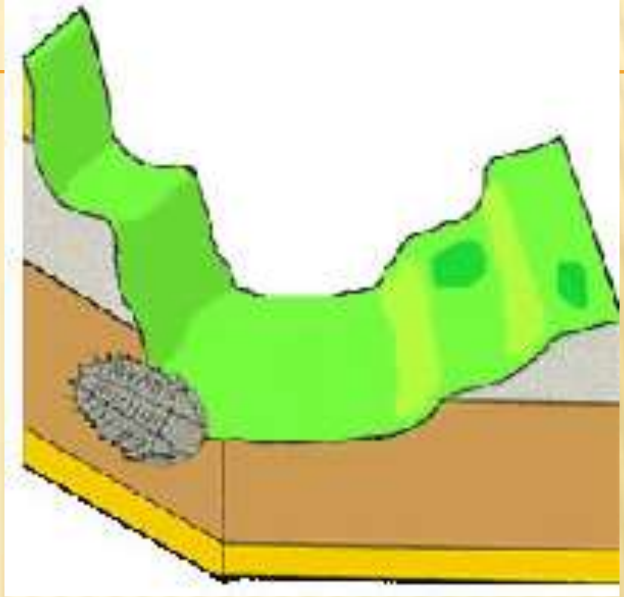
HOW IS A FOSSIL FORMED?



1. Sediment
An animal is buried by sediment, such as volcanic ash or silt, shortly after it dies. Its bones are protected from rotting by the layer of sediment.

2. Layers
More sediment layers accumulate above the animal's remains, and minerals, such as silica (a compound of silicon and oxygen), slowly replace the calcium phosphate in the bones.





3. Movement
Movement of tectonic plates, or giant rock slabs that make up Earth's surface, lifts up the sediments and pushes the fossil closer to the surface.

4. Erosion
Erosion from rain, rivers, and wind wears away the remaining rock layers. Eventually, erosion or people digging for fossils will expose the preserved remains.

WHAT ARE THE CONDITIONS THAT ARE FAVORABLE FOR PRESERVATION?

*Hard body parts such as skeletal bones or exoskeletons

*Rapid burial and/or lack of oxygen

BODY FOSSILS

- Body Fossils are the actual body or body parts of an organism that has been preserved. These fossils may or may not be altered (fossils that have gone through a chemical change or physical change). The two main types of body fossils are (A) unaltered remains and (B) altered remains…
- **Unaltered remains** of fossils means that the remains have gone through little or no chemical or physical change.

A. UNALTERED REMAINS

Original skeletal material: this means that the hard parts of

the organism are preserved as the original **material**.

- Tar impregnation
- Amber Entombment
- Refrigeration

Tar impregnation: tar pits are excellent areas to preserve life as a **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.

TAR IMPREGNATION

Fossilized water beetle, *Hydrophilus sp.,* preserved in oil-impregnated sands of a late Pleistocene (roughly 35, 000 years old) tar seep in the vicinity of the Kettleman Hills.

REFRIGERATION

- **Refrigeration--During the Pleistocene glaciations, when ice sheets cover much of the Northern Hemisphere, some animals (mammoths, for example) fell into crevasses in frozen terrain or became trapped in permanently frozen soil. Some of these animals have been discovered perfectly preserved.**

Mammoths

Ice Age wooly mammoths from the Pleistocene Epoch have been found frozen in Siberia and Alaska. Skin, hair, and soft tissue have been preserved in frozen soil.

They lived from the Pliocene epoch (from around 5 million years ago) into the Holocene at about **4,500** years ago

AMBER ENTOMBMENT-

- Amber-preserved fossils are organisms that become trapped in tree resin that hardens after the tree is buried. Small insects and other minute organism may become trapped in this resin, which after burial may harden into amber. Certain parts of the Baltic Sea coast and some of the islands in the West Indies are well known for occurrences of insects preserved in amber

Body Fossils, Altered remains

Altered remains of fossils means that the organisms have gone through chemical or physical change and must be at least ten thousand years old.

The types of altered remains of fossils are...

- Recrystallization
- Replacement
- Permineralization
- Carbonization

PERMINERALIZATION

- **Many bones, shells, and plant stems have porous internal structures. These pores may become filled with mineral deposits.**

  In the process of permineralization, the actual chemical composition of the original hard parts of the organism may not change

Permineralized Wood

- Carbonization

- **Carbonization** preserves soft tissues of plants or animals as a thin carbon film, usually in fine-grained sediments (shales). Fine details of the organisms may be preserved. Plant fossils, such as ferns, in shale generally are preserved by carbonization. Soft-bodied animals such as jellyfish or worms may also be preserved as carbonaceous films in black shales

(**leaf**)

DISSOLUTION/REPLACEMENT

- Dissolution/Replacement -- Groundwater (especially acidic groundwater) may act to dissolve a hard structure in an organism trapped in sediments and may, simultaneously deposit a mineral in its place--molecule by molecule.

Silicification

(replacement by silica)

Fossil calcareous sponge →
(originally calcitic, now siliceous)

- Depending on the chemistry of pore waters within sediment, a number of minerals can replace the original material. These transformations may occur at earlier (before or during lithification), or later (after lithification) stages of fossilization.
- Calcareous (calcitic and aragonitic) shells are commonly replaced by silica minerals (silicon dioxide), pyrite (iron sulphide), or calcium phosphate minerals.

Pyritization (replacement by pyrite)

Pyritized brachiopod

MOLD& CAST

- Mold - impression of skeletal (or skin) remains in an adjoining rock
- External mold = impression of outer side
- Internal mold (steinkern) = impression shows form or markings of inner surface
-
- Cast - original skeletal material dissolves and cavity (mold) fills with material
-
- Endocast- natural infilling of cranial cavity (may study brain evolution in fossil mammals)

CAST

- **A cast** may be produced if a mold is filled with sediment or mineral matter. A cast is a replica of the original. Casts are relatively uncommon. (A rubber mold of a fossil can be filled with modelling clay to produce a replica or artificial cast of the original object.)

Molds

Clam

1. Sediment surrounding the shell and filling the shell cavity hardens

2.Shell is dissolved

Fossil clam

Internal mould

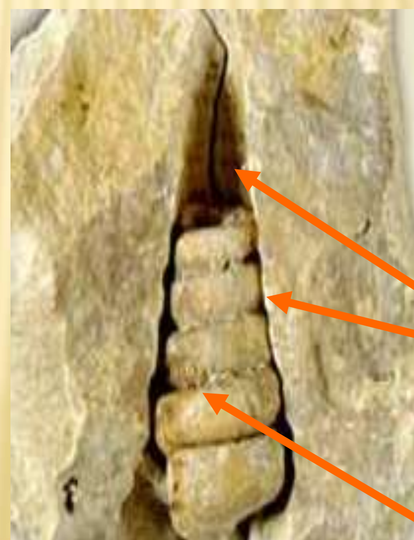
External mould

Snail

1. Sediment surrounding the shell and filling the shell cavity hardens

2.Shell is dissolved

Fossil snail



Fossil snail

External mould

Internal mould

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A mold (below) and cast (above) of a trilobite.

Ichnology

Ichnology - study of trace fossils (Ichnofossils = tracks, trails and burrows of organisms).

Burrows or borings –
Spaces dug out by living things and preserved as is or filled in

Trace Fossils

- **Burrows:** These trace fossils show how an animal such as a worm (an **annelid**) moved through the soft sediment.

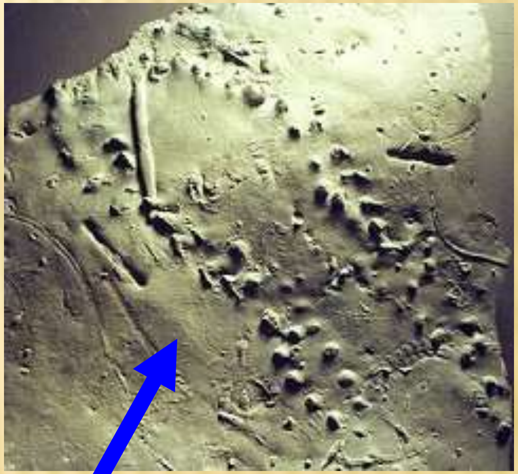
This worm tube trace fossil is hollow (the hole goes all the way through it).

Trace Fossils

2. Trace Fossils

- **Tracks**: can show how an animal moved and what its **footprint** looked like. These tracks can tell us a lot about the animal that made them in the geologic past.

(trilobite)



(trilobite tracks)

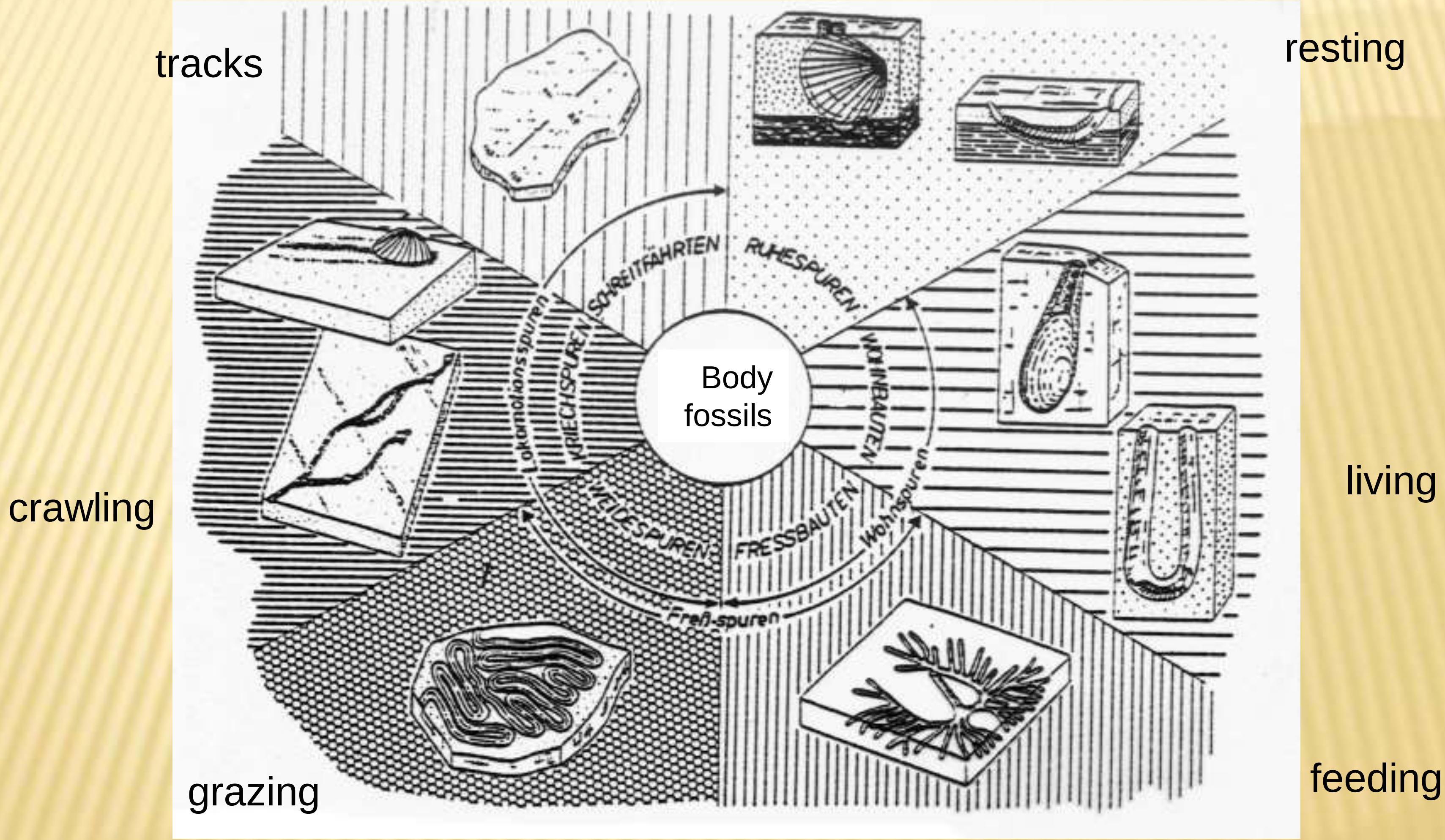
(Dinosaur tracks)

Do you see the people?

Cruziana: produced by a trilobite “plowing” along the sediment surface.

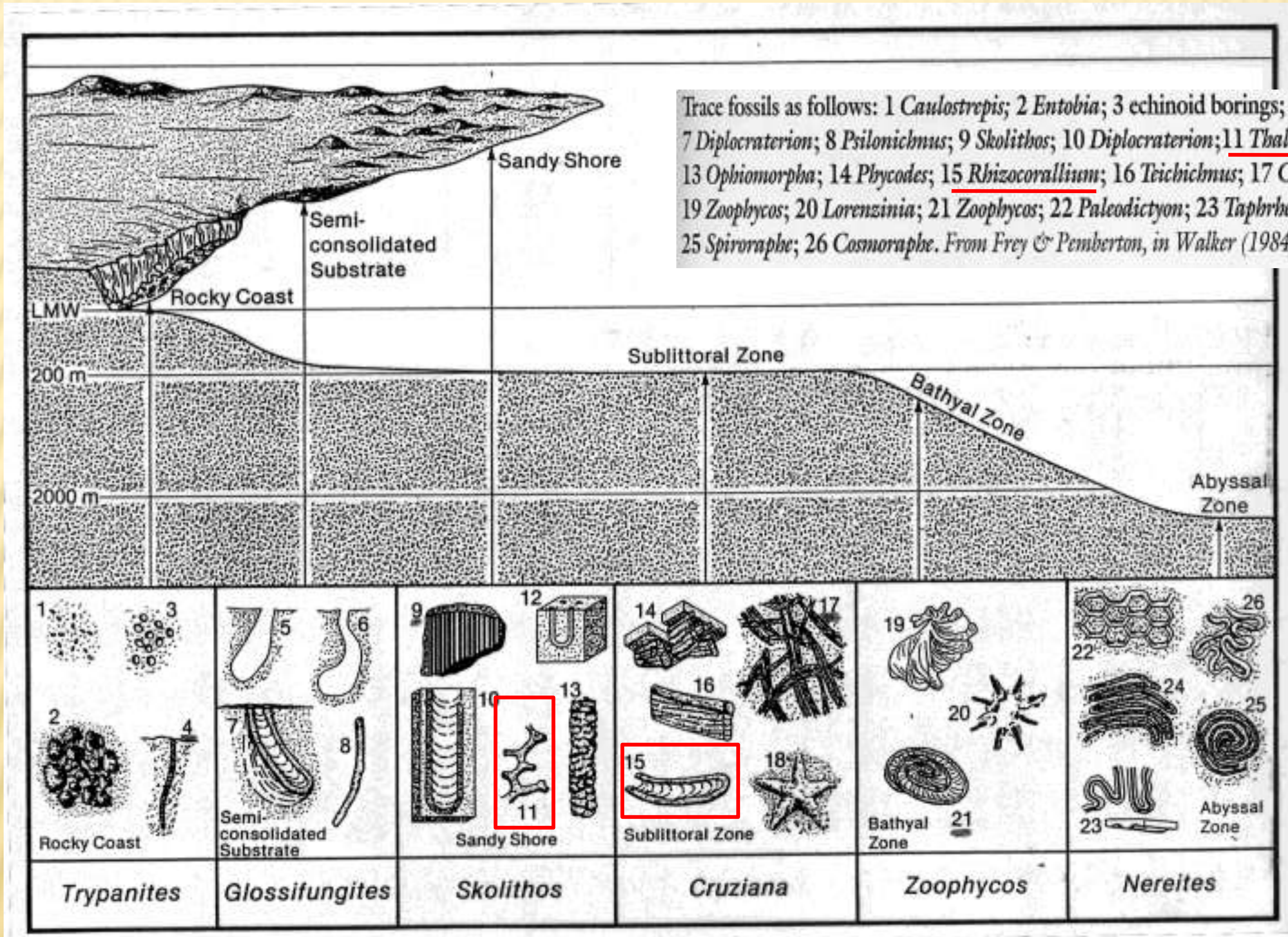
Diplichnites: produced by a trilobite walking over the sediment surface.

Trace fossils



Ziegler (1972)

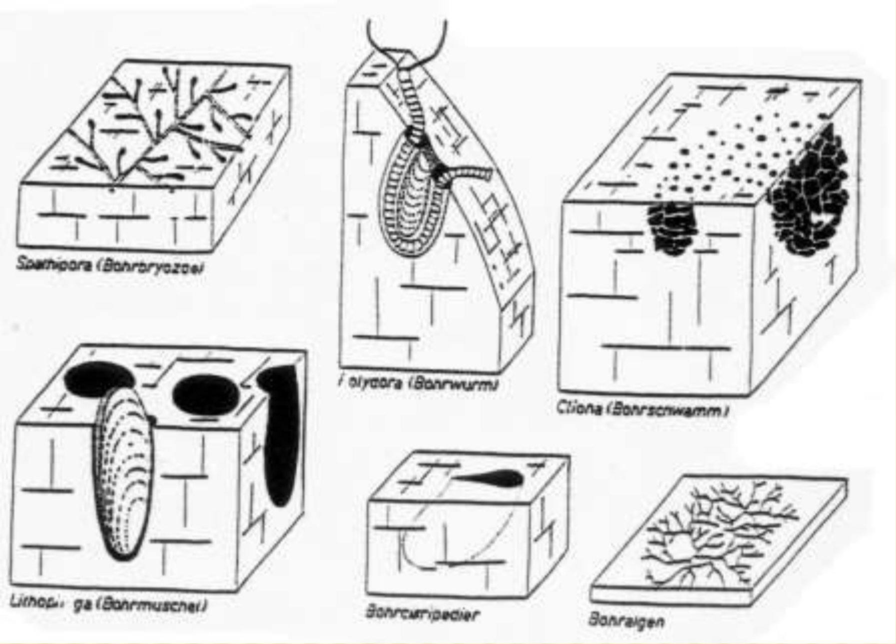
Trace fossils and water depth

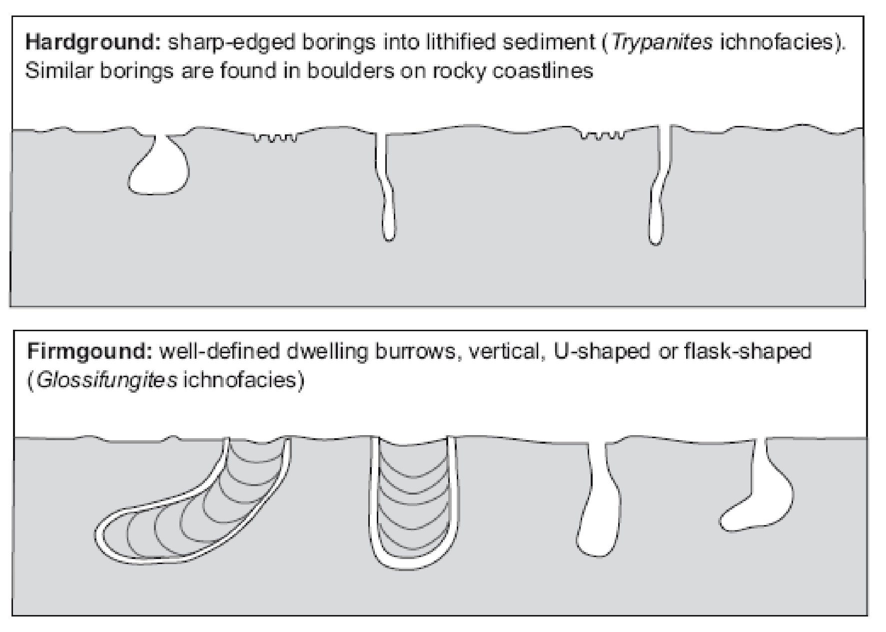


Trace fossils as follows: 1 *Caulostrepis*; 2 *Entobia*; 3 echinoid borings; 4 *Trypanites*; 5, 6 *Gastrochaenolite* 7 *Diplocraterion*; 8 *Psilonichnus*; 9 *Skolithos*; 10 *Diplocraterion*; 11 *Thalassinoides*; 12 *Arenicolites*; 13 *Ophiomorpha*; 14 *Phycodes*; 15 *Rhizocorallium*; 16 *Teichichnus*; 17 *Crossopodia*; 18 *Asteriacites*; 19 *Zoophycos*; 20 *Lorenzinia*; 21 *Zoophycos*; 22 *Paleodictyon*; 23 *Taphrhelminthopsis*; 24 *Helminthoida*; 25 *Spirorapbe*; 26 *Cosmoraphe*. *From Frey & Pemberton, in Walker (1984).*

Frey and Pemberton, *in* Walker (1884)

Borings and bioturbation





Hardground borings

- Condensation
- gaps, hiati

Firmground bioturbation (lower part)

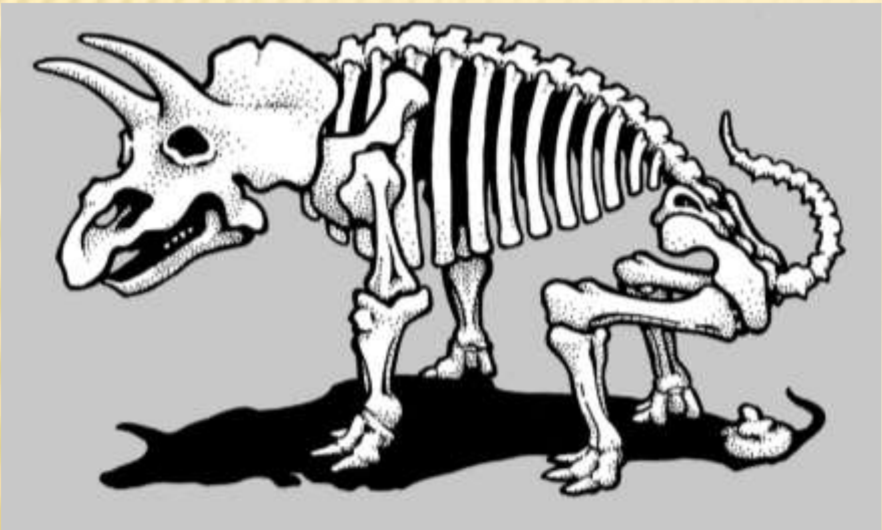
- softground
- continuous sedimentation

Ziegler (1972)

Trace Fossils

Trace Fossils

- **Coprolite:** -fossil excrement of animals; may contain undigested remains of food. usually preserved by replacement.



MORE ON TRACE FOSSILS

- Gastroliths – smooth stones from abdominal cavity of dinosaurs

MORE ON TRACE FOSSILS

- Tracks – impressions of passage of living things

Pseudofossils

Pseudofossils (meaning "fake fossils") many rocks and rock structures look like fossils, but aren't!.

(fossilized raindrops that hit soft sediment)

PSEUDOFOSSILS

The following represent a few sedimentary features that may be confused for fossils:

- 1. Differential Weathering

- weathering of rock and mineral surfaces often yield fossil-looking features

- 2. Nodules

- formed by filling voids in the sediment and incorporation of sedimentary materials within the sedimentary body

a. Chert Nodules

- microcrystalline quartz; typically found along bedding planes in limestone

b. Septaria

- large nodules with radial and concentric cracks in their centers

- Melikaria are boxwork patterns of material filling septarian cracks; may be all that is left after weathering of the septaria

c. Rosettes

- radiating macrocrystalline bodies of discoidal or spherical shape, consisting essentially of one mineral (typically pyrite, marcasite, barite, or gypsum)

- 3. Concretions

- mineral growth within sediment often forms structures that resemble bones, turtle shells, logs, etc.

- 4. Dendrites

- precipitation of manganese
- oxide along bedding plane
- creates fern-like patterns

(**dendrite** made by a mineral)

Different types of Trace Fo

Do you remember what the five types of trace fossils are?

- Mold
- Cast
- Burrow
- Track
- Coprolite

- Competition - two species vie for limited environmental resources
- Autotrophs (Producers) = manufacture their own food; "plants"; form lowest trophic level and constitute the base of the biomass "pyramid"
- Heterotrophs (Consumers) = feed on other organisms; consist of "animals" (much energy is lost cycling through higher trophic levels, and therefore with fewer organisms)

- Herbivores = feed on producers
- Predation = effect of a predator on a prey species
- Carnivores = feed on other consumers by predation
- Parasites = derive nutrition from other organisms without killing them

- Scavengers = feed on dead organisms
- Commensalism = biological association beneficial to one but does not hurt the host
- Symbiosis = mutual benefit to both participants

ORGANISM DISTRIBUTION (ESPECIALLY MARINE) DEPENDS UPON THE FOLLOWING:

- a. Seawater Properties - Density and Viscosity
- Density of aquatic organisms typically equals water density
- Viscosity - influences shape and feeding (there are many "filter feeders" in aquatic environments, due to the viscosity of water allowing food to be held in suspension)

- b. Salinity
- - usually measured in parts per thousand (0/00); average seawater salinity is 35 0/00 but varies from 0 to 270 0/00
- - in Geochemical Studies of Paleosalinity use boron (greater in saltwater); other trace elements; type of organic matter; carbon and oxygen isotopes [freshwaters depleted in heavy carbon (C-13) and heavy oxygen (0-18)]
- - in Biological Studies use stenohaline (restricted by salinity; organisms internal "salinities" equals surrounding water salinity; if rapid change cells may not function) versus euryhaline (salinity tolerant) organisms

C. TEMPERATURE

- - water moderates temperature
- - in cold-blooded organisms, an increase in temperature of 10°C often causes metabolic activity to double
- - in warm-blooded organisms there is little metabolic change with temperature change
- - temperature influences reproductive cycles
- - in Geochemical Studies of Paleotemperature use 18O/16O (less with greater temperature; most important for determining paleotemperatures); boron and bromine greater if greater temperature; Calcium/Magnesium and Calcium/Strontium ratios are less if the temperature is increased
- - in Biological studies of paleotemperature use stenothermal (temperature intolerant) versus eurythermal (temperature tolerant) organisms; also may look at species diversity (greater in warmer environments) or morphology (body form reflects environmental factors)

- d. Dissolved Gases
- \- concentrations depend on atmospheric concentration; solubility of gas; water temperature and salinity
-
- d1. Nitrogen (N) - most abundant dissolved gas; required by plants in ionic form
-
- d2. Oxygen (O) - enters sea by photosynthesis, river water, atmosphere; all organisms use oxygen during respiration; oxygen at maximum near surface, minimum at about 700-1,000m Oxygen; approximately 6 to 10 ppm; warmer, saltier or organic debris-rich water with less oxygen

- d3. Carbon Dioxide (CO_2) - enters sea from organism respiration, atmosphere and rivers; removed by plants for photosynthesis and used by organisms to make shells; increases to approximately 1,000m; increased CO_2 leads to Greenhouse Effect (increase temperature)
-
- d4. Hydrogen Sulfide (H_2S) - produced by anaerobic bacteria
-
- e. Light
- - Photic zone = zone of light penetration
- Euphotic zone = upper illuminated layers of water in the photic zone; receive sufficient light to support photosynthesis; usually 10-60 meters but clear tropical waters may be greater than 100 meters
- - Aphotic zone = zone in which light does not penetrate
-

- f. Pressure
- - pressure increases approximately 1 atmosphere per 10 meters
- - affects vertical migration of organisms, bacterial decomposition, production of shells (CCD = carbonate compensation depth)
-
- g. Depth
- - deep water stores carbon, nitrate, phosphate
-
- Paleobathymetry - the ancient water depth may be determined by type of body fossils and trace fossils present
-
- h. Water energy, turbidity and sedimentation rates
- - affects distribution of food and nutrients; types and morphology of organisms present
- - amount of suspended sediment especially affects filter-feeders
- - nature of substrate affects type of infauna (live in substrate) or epifauna (live on substrate; sessile or vagile benthonic) present

- Biostratigraphy ("Stratigraphic Paleontology")
-
- 1. Biostratigraphic distributions are controlled by:
-
- a. Evolution
- b. Paleoecology - <u>no</u> organism inhabits all environments
- b1. Facies-controlled organisms = restricted to particular sedimentary environments (often with slow evolutionary change)

- b2. Biofacies = facies distinguished on the basis of their fossils (Ex. = reef biofacies - may have corals, coralline algae, stromatoporoids, rudist bivalves)

- 2. Biostratigraphic Units

- body of rocks delimited from adjacent rocks by their fossil content
- often use fossils for Correlation (matching stratigraphic sections of the same age)

- a. First appearances of fossils may be due to 1) evolutionary first occurrence 2) immigration

FAD = First appearance datum   FOD = First occurrence datum

b. Last appearance of fossils may be due to 1) extinction event 2) emigration

LAD = Last appearance datum   LOD = Last occurrence datum

Biozone

- - basic unit of biostratigraphic classification
- - based on the distribution of Index Fossils (fossils characteristic of key formations; should have short time span, wide geographic range, independent as possible of facies, abundant, rapidly changing and with distinctive morphology)

Principle types of biozones

A. Taxon-range biozone

B. Concurrent-range biozone

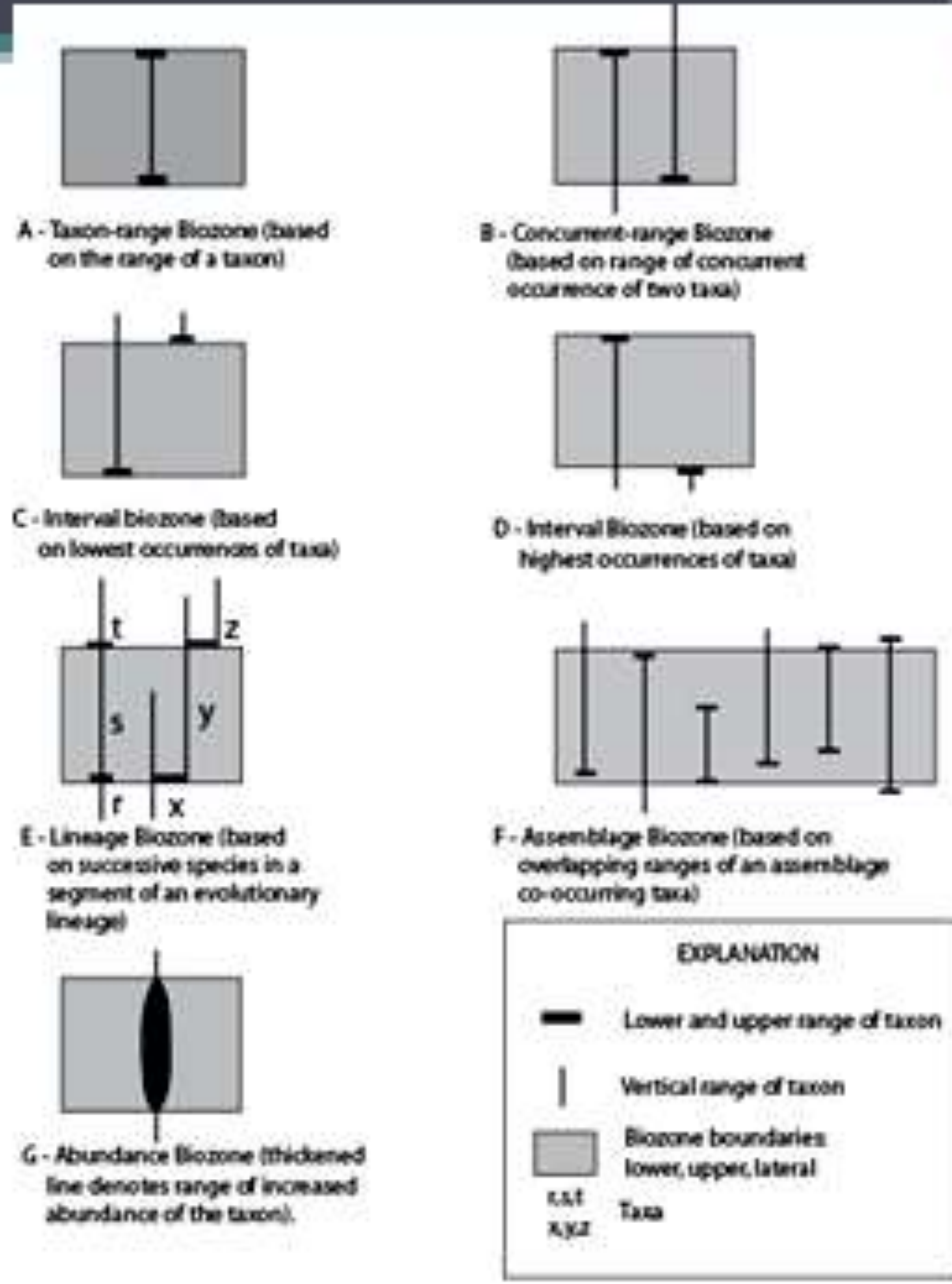
C. Interval biozone (lowest occurrences of taxa)

D. Interval biozone (highest occurrences of taxa)

E. Lineage biozone

F. Assemblage biozone

G. Abundance biozone



Biological Classification of Fossils

As fossils clearly represent the the remains of ancient biological organisms, it only makes sense that they should also be classified in the same manner as living organisms.

The fundamental unit of biological classification is the species. Members of a species are able to interbreed and give rise to fertile offspring. Palaeontologists, lacking evidence of reproductive isolation of ancient "species", focus on morphological definitions of species. Above the species level are increasingly more inclusive groups which are defined by certain characteristics possessed by all their members. These various groupings are as follows:

Kingdom: (e.g. Animalia)
Phylum: (e.g. Chordata)
Class: (e.g. Mammalia)
Order: (e.g. Primates)
Family: (e.g. Hominidae)
Genus (e.g. Homo)
Species: (e.g. Homo sapiens)

This classification heirarchy applies mainly to body fossils. As you will see, trace fossils classification is more limited in this respect.

INVERTEBRATE GROUPS

- **Sponges (Phylum Porifera)**
- **Cnidarians (Phylum Cnidaria)**
- **Phylum Brachiopoda:** (both articulates and inarticulates)

Bryozoans

- **Mollusks (Phylum Mollusca):**

- Class Bivalvia

-Class Cephalopoda (Subclass Nautiloidea)

-Class Gastropoda

-Class Monoplacophora

INVERTEBRATE GROUPS

- **Arthropods (Phylum Arthropoda):**

-Class Crustacea (Subclass Ostracoda)

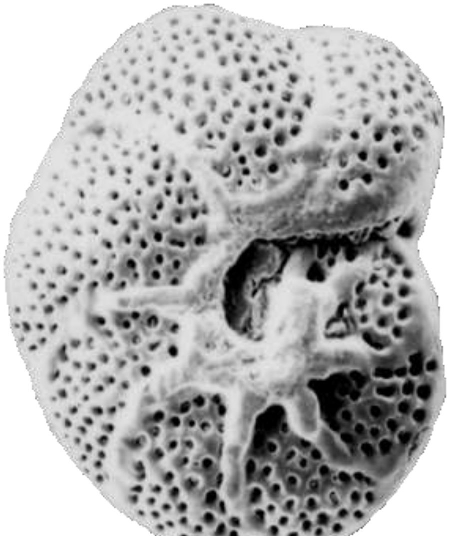
-Class Trilobita

- **Echinoderms (Phylum Echinodermata)**

  -Starfish

  -Echinoids (sea urchins sand dollars, and sea biscuits)

FORAMINIFERA
&
IT'S APPLICATIONS



INTRODUCTION

- Microfossils are very small remains of organisms 0.001mm(1 micron) to 1mm, that require magnification for study.
- They are abundant , can be recovered from small samples.
- It provides the main evidence for organic evolution through time.
- They are classified into two groups:
- **Organic walled:** Acritarchs, Dinoflagellates, Spores ,Pollen etc.
- **Inorganic walled:** Diatoms, Silicoflagellates, Ostracods, Conodonts and Foraminifera

Kingdom: PROTOZOA
Phylum : SARCODINA
Class : RHIZOPODA
Order : FORAMINIFERA

- Most abundant can be studied with simple techniques and low power microscopes.

- Their shells are called **tests** which consist of single or multiple chamber(s).

- Each chamber is interconnected by an opening (*foramen)* or several openings *(foramina)*

- Known from Early Cambrian to Recent times and has reached its acme during Cenezoic

MORPHOLOGY

•Shell morphology and mineralogy form the prime basis for identification of species and higher categories of Foraminifera.

•Most have a shell or test comprising chambers, interconnected through holes or foramina.

•The test may be composed of a number of materials but three main categories have been documented:

•Organic

Consist of tectin, which is protinaceous

•Agglutinated

Fragments of extraneous material bounded by variety of cements

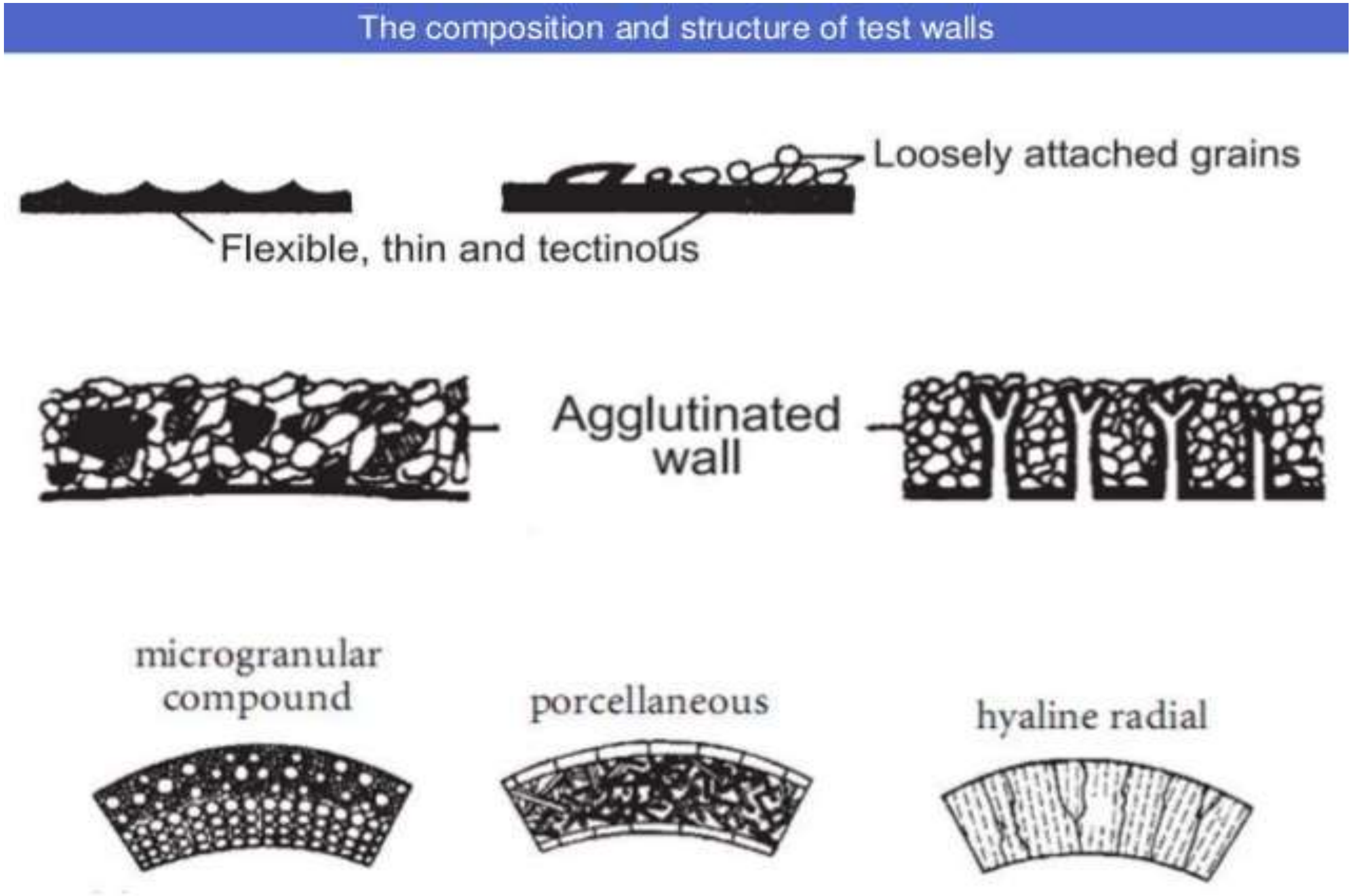
•Calcareous

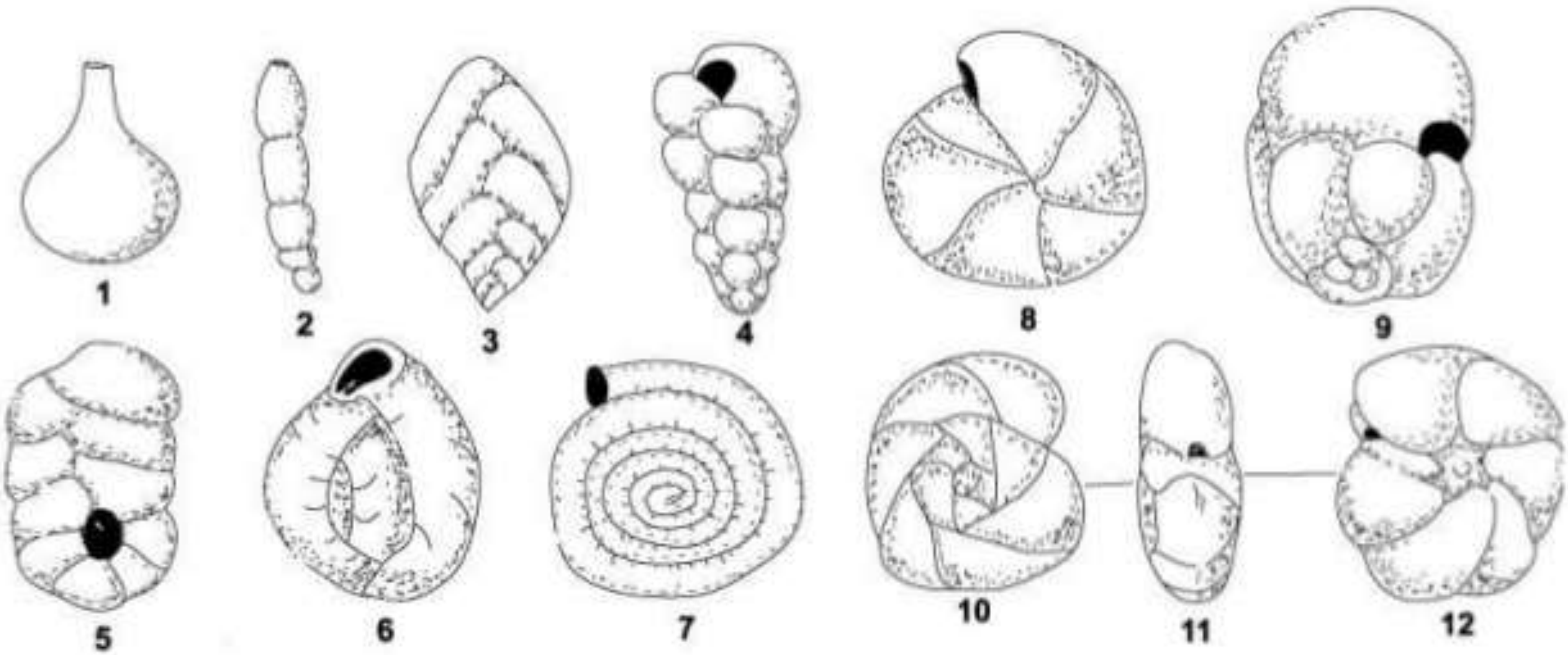
Subdivided into three sub-groups:

I. Microgranular consists of tight packed, similar size grains of crystalline calcite

II. Porcellaneous tests are formed of small, randomly oriented crystals of high Mg calcite

III. Hyaline tests are formed of larger crystals of low magnesium calcite and have a glassy appearance, this test can be radial or granular.





Principle types of chamber arrangement. 1, single chambered; 2, uniserial; 3,biserial; 4, triserial; 5, planispiral to biserial; 6, milioline; 7, planispiral evolute; 8, planispiral involute; 9, streptospiral; 10-11-12, trochospiral (10, dorsal view; 11, edge view; 12, ventral view). Redrawn from Loeblich and Tappan 1964.

ECOLOGY

•Foraminifera have a wide environmental range, from terrestrial to deep sea and from polar to tropical.

•Species of foraminifera live in particular environments which help in studies of recent and ancient environmental conditions.

•Changes in the composition of foraminiferal assemblages used to track changes in the circulation of water and depth.

•Most are marine they can tolerate only in very small variations in salinity of the water.

•Certain groups having a porcelaneous test can live equally in hyperhaline environments lagoons with a salinity > 35 ppm

- Some groups such as the agglutinates and hyalines prefer water with a low salinity e.g. brackish lagoons and estuaries.

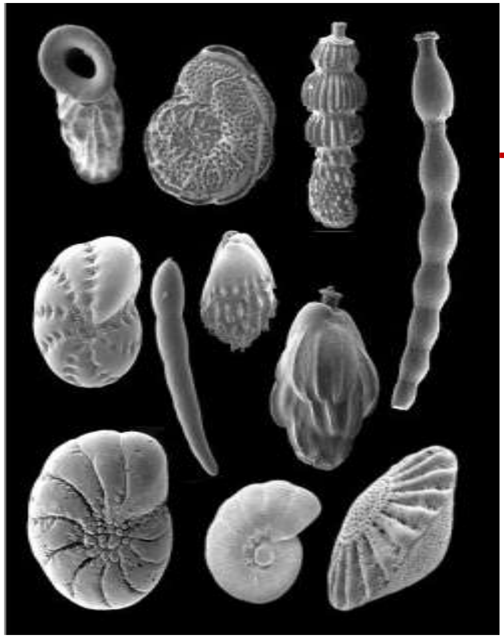
- **Food:** They feed on small bacteria, algae, protests and invertebrates.

- **Light:** Primary production of nutrients by planktonic and benthonic algae render this zone attractive to foraminifera.

- **Salinity:** The majority of foraminifera are adapted to normal marine salinities about 35 ppm.

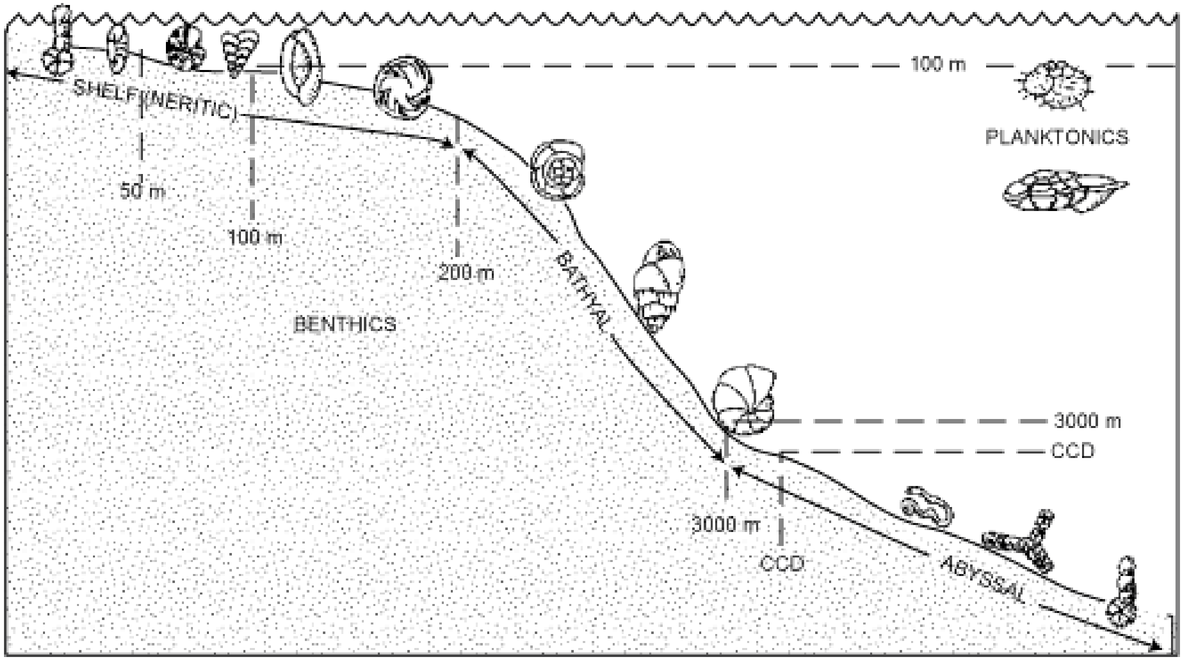
- **Temperature:** Each species is adapted to a certain range of temperature conditions.

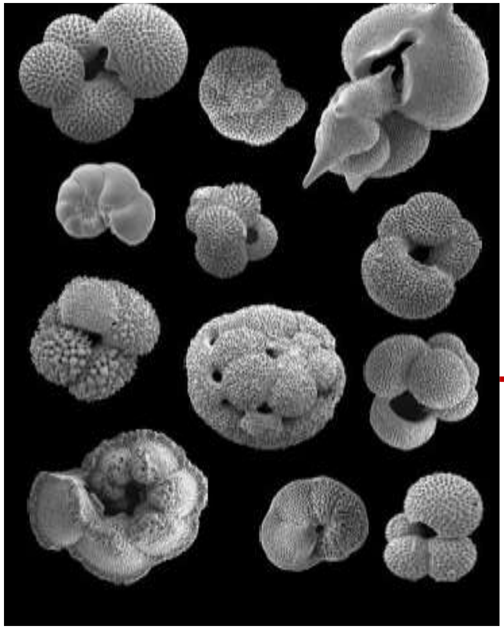
APPLICATIONS OF FORAMINIFERA



Benthic foraminifera is the bottom dwellers. They live all along and beneath the ocean floor in the sediments.

Two Groups of Foraminifera





Planktonic foraminifera live in the upper zone of the ocean. They are found only in the open ocean. When they die, they settle to the bottom of the ocean.

BIOSTRATIGRAPHY

•Biostratigraphical indicators for marine rocks of Late Palaeozoic, Mesozoic and Cenozoic.

• **Foraminifera provide evidence of the relative ages of marine rocks**

• They show fairly continuous evolutionary development, so different species are found at different times.

• Foraminiferas are abundant and widespread, being found in all marine environments.

.

PALEOECOLOGY

- **Foraminifera provide evidence about past environments.**

- Foraminifera have been used to locate ancient shorelines, and track global ocean temperature changes during the ice ages.

- If a sample of fossil foraminifera contains many extant species, the present-day distribution of those species can be used to infer the environment at that site when the fossils were alive.

- If samples contain all or mostly extinct species, there are still numerous clues that can be used to infer past environments.

- These include species diversity, the relative numbers of planktonic and benthic species, the ratios of different shell types, and shell chemistry.

PALAEOBIOGEOGRAPHY

• The chemistry of the shell is useful because it reflects the chemistry of the water in which it grew.

• For example, the ratio of stable oxygen isotopes depends on the water temperature, because warmer water tends to evaporate off more of the lighter isotopes.

• Measurement of stable oxygen isotopes in planktonic and benthic foram shells from hundreds of deep-sea cores worldwide have been used to map past surface and bottom water temperatures.

• This data helps us understand how climate and ocean currents have changed in the past and may change in the future.

OIL EXPLORATION

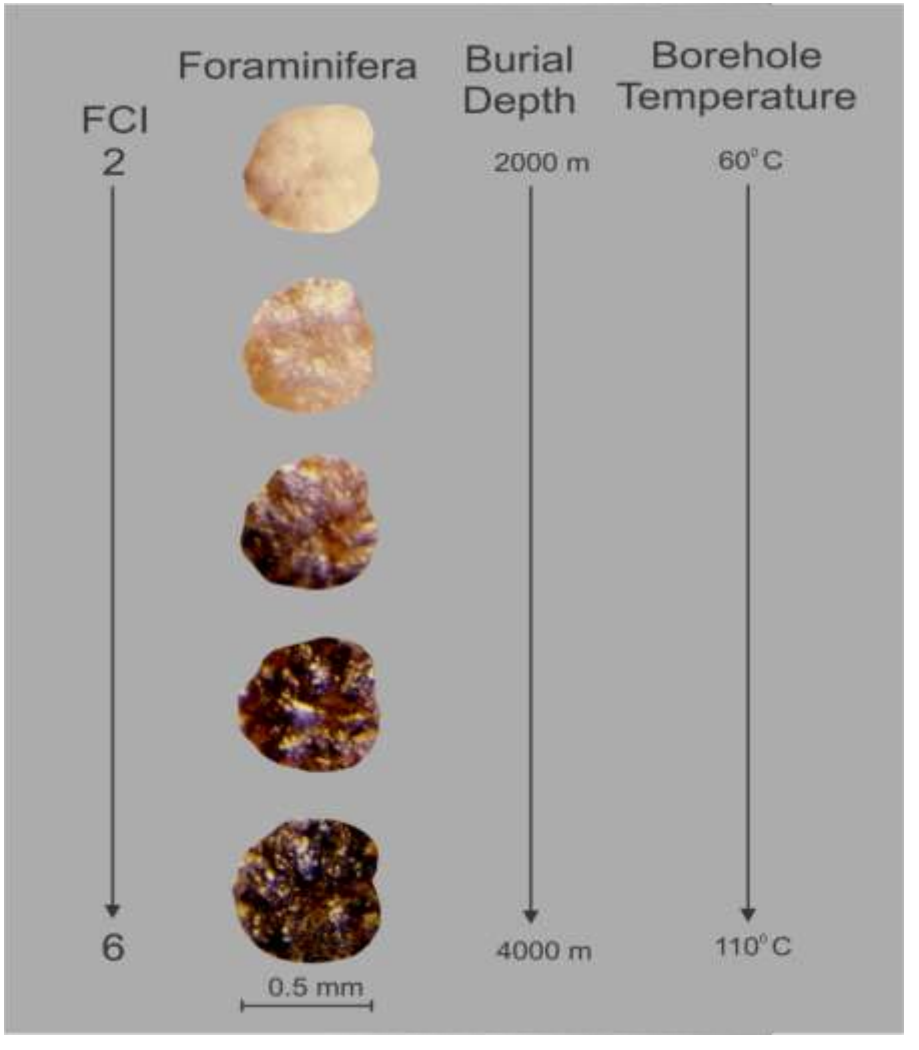
Foraminifera are used to find petroleum

- Some species are geologically short-lived and some forms are only found in specific environments.

- Therefore, a paleontologist can examine the specimens in a small rock sample like those recovered during the drilling of oil wells and determine the geologic age and environment when the rock formed.

- Stratigraphic control using foraminifera is so precise that these fossils are even used to direct sideways drilling within an oil-bearing horizon to increase well productivity.

• **Foraminiferal Colouration Index** (FCI) is a tool for assessing the thermal alteration of organic matter buried in sedimentary rock. It uses temperature-controlled colour changes in the organic cement of agglutinated foraminifera (microfossils) to estimate thermal alteration.



CONCLUSION

- Foraminifera are abundant in most marine environment so only small sediment samples are needed to obtain statistically significant numbers of microfossils to perform environmental analysis.

- They are sensitive to environmental change and their mineralized shell normally get preserved in the sediment after the death of the organism

- Foraminifera extremely useful in determining palaeoclimate, stratigraphy and oil prospecting.

- Foraminiferal analysis of dated sediment cores represent a quick and cost efficient way to evaluate possible differences between present and reference conditions without previous knowledge of the area being examined.

FOSSILS:

NODOSARIA

I. PHYLUM : Protozoa

II. CLASS : Gymnomyxa

III. ORDER : Foraminiferida

IV. FAMILY : Nodosaridae

V. MORPHOLOGY:

i. Test wall: Calcareous, finely perforate.

ii. Chamber: Multichambered, uniserial, straight, symmetrical rounded in section.

iii. Suture: Straight and perpendicular to the axis of the test.

iv. Ornamentation: Smooth or with granules, spines or ribs.

v. Aperture: Terminal.

VI. AGE: Silurian to Recent.

TEXTULARIA

I. PHYLUM : Protozoa

II. CLASS : Gymnomyxa

III. ORDER : Foraminiferida

IV. FAMILY : Textularidae

V. MORPHOLOGY:

i. Test wall: Agglutinated and elongated.

ii. Chamber: Biserial, circular in cross section, numerous in numbers.

iii. Aperture: Single, low arc at the base of the flat chamber.

VI. AGE: Upper Silurian to Recent.

LAGENA

I. PHYLUM : Protozoa

II. CLASS : Gymnomyxa

III. ORDER : Foraminiferida

IV. FAMILY : Nodosaridae

V. MORPHOLOGY:

i. Test wall: Calcareous, finely perforate.

ii. Chamber: Unilocular, flask shaped.

iii. Ornamentation: Smooth or spinose or ribbed or striated.

iv. Aperture: round or oval on elongate neck which may have phialine lip.

VI. AGE: Jurassic to Recent.

AMMONIA

I. PHYLUM : Protozoa

II. CLASS : Gymnomyxa

III. ORDER : Foraminiferida

IV. FAMILY : Rotaliidae

V. MORPHOLOGY:

i. Test wall: Calcareous, perforate.

ii. Coiling: Trochospirally coiled with 3 to 4 whorls. Evolute on dorsal side and involute on ventral side.

iii. Suture: Curved, thickened on dorsal side and depressed on ventral side.

iv. Umbilicus: Umbilical surface with irregular granules along sutures and umbilical regions. Umbilicus may be with umbilical fissures with numerous fused pillars and bosses.

v. Aperture: Slit shaped at the base of the final chamber.

VI. AGE: Miocene to Recent.

GLOBIGERINA

I. PHYLUM : Protozoa

II. CLASS : Gymnomyxa

III. ORDER : Foraminiferida

IV. FAMILY : Globigerinidae

V. MORPHOLOGY:

i. Test wall: Calcareous, perforate.

ii. Coiling: Trochospirally coiled.

iii. Chamber: Spherical to ovate.

iv. Ornamentation: Pitted or Cancellated.

v. Aperture: Umbilical.

VI. AGE: Paleocene to Recent.

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•Howard A., Armstrong and Martin D. Brasier (2005), Microfossils, Blackwell Publishing, 2nd Edition, 296 p.
•Michael J. Benton and David A.T. Harper (2009), Introduction to Palaeobiology and the Fossil Record, A John Wiley & Sons, Ltd, 592 p.
• Jones, R.W (1996): Micropaleontology in Petroleum Exploration. Oxford University Press, Oxford.
• http://www.ucmp.berkeley.edu/fosrec/Wetmore.html

PHYLUM PORIFERA

SPONGES

Introduction

→Porifera (po-rif -er-a) (L. porus, pore, fera, bearing)

→ Most primitive of all animals

→Among the approximately 15,000 sponge species are mostly marine; a few exist in brackish water, and some 150 species live in freshwater

→ Sessile; Draws food and water into its body

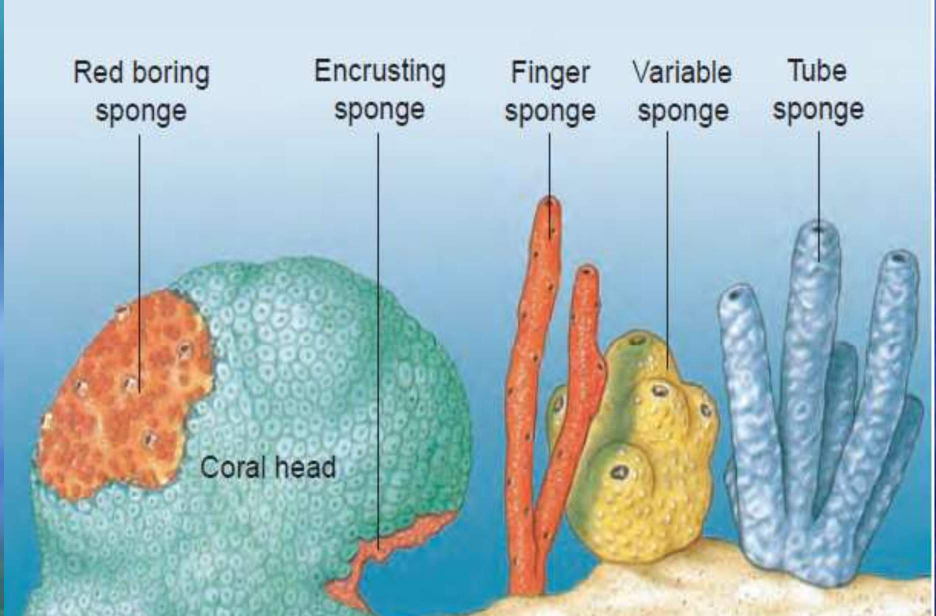


Figure 1. Some growth habits and forms of sponges.

Characteristics

→ Multicellular

→Body with pores (ostia) where water, canals, and chambers that form a unique system of water currents on which sponges depend for food and oxygen

→Radial symmetry or none

→No organs or true tissues; digestion intracellular

→Excretion and respiration by diffusion

→ Has choanocytes, flagellated "collar" cells which help pump water in and out of the sponge

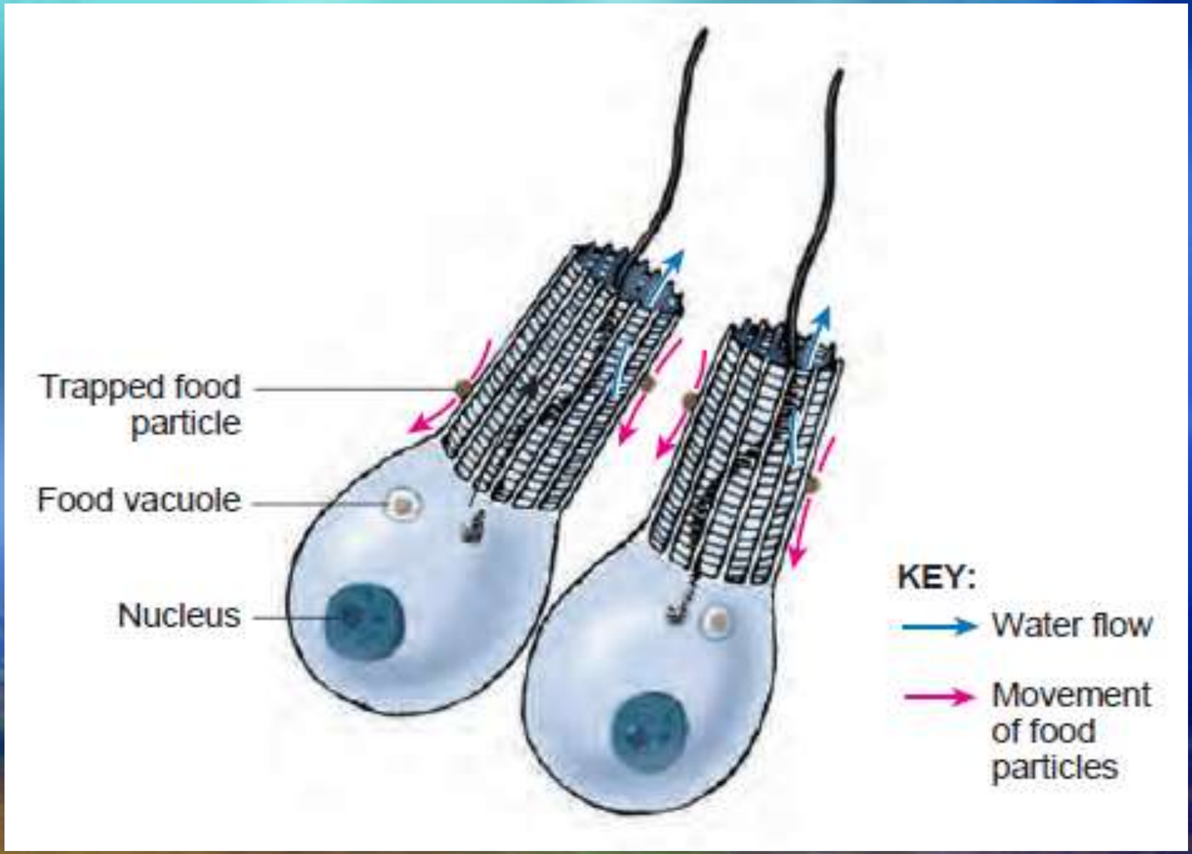


Figure 2. Sponge choanocytes have a collar of microvilli surrounding a flagellum. Beating of the fl agellum draws water through the collar (blue arrows) where food is trapped on microvilli (red arrows).

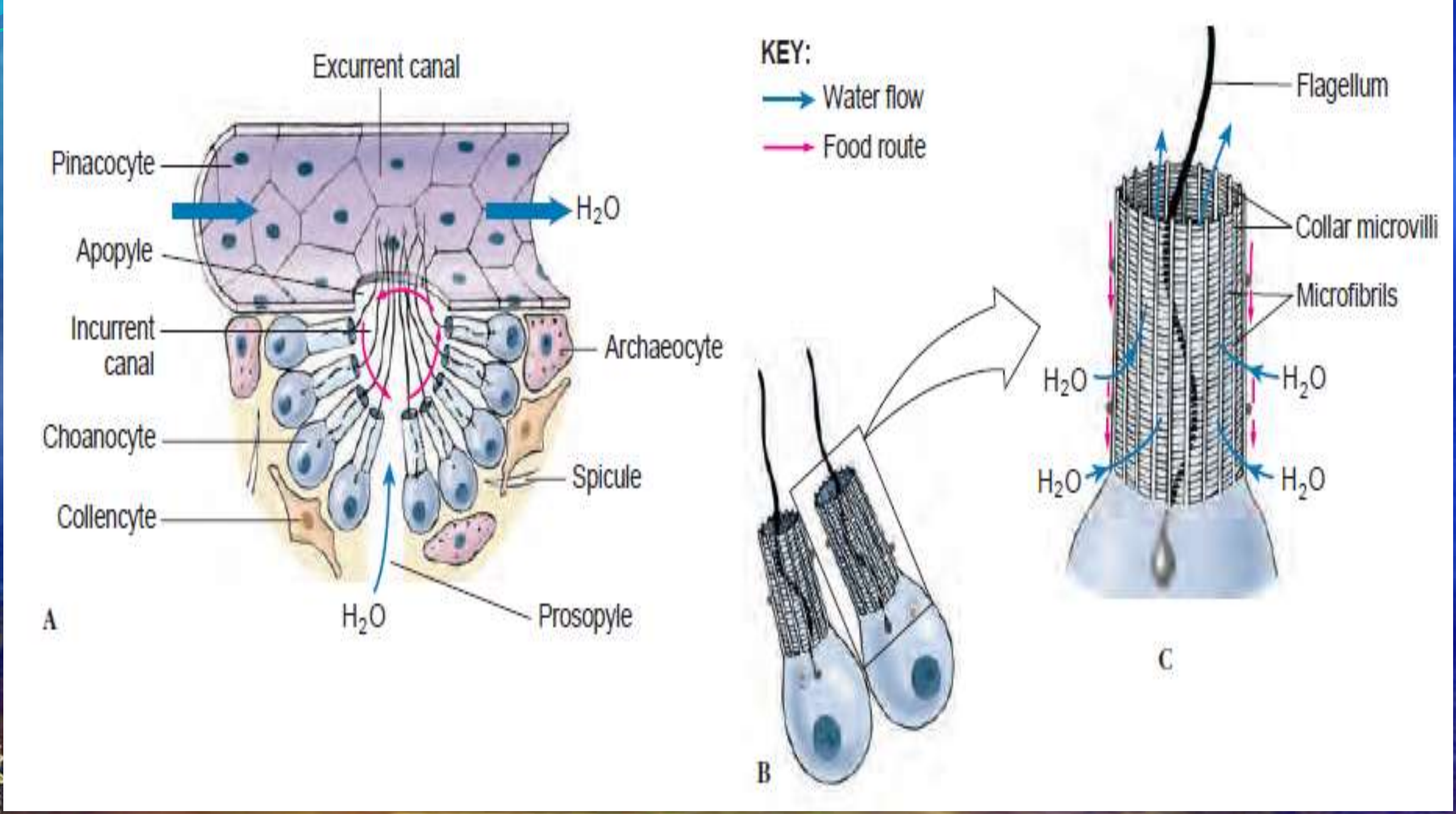


Figure 3. Food trapping by sponge cells. A, Cutaway section of canals showing cellular structure and direction of water flow. B, Two choanocytes and C, structure of the collar. Small red arrows indicate movement of food particles.

Characteristics

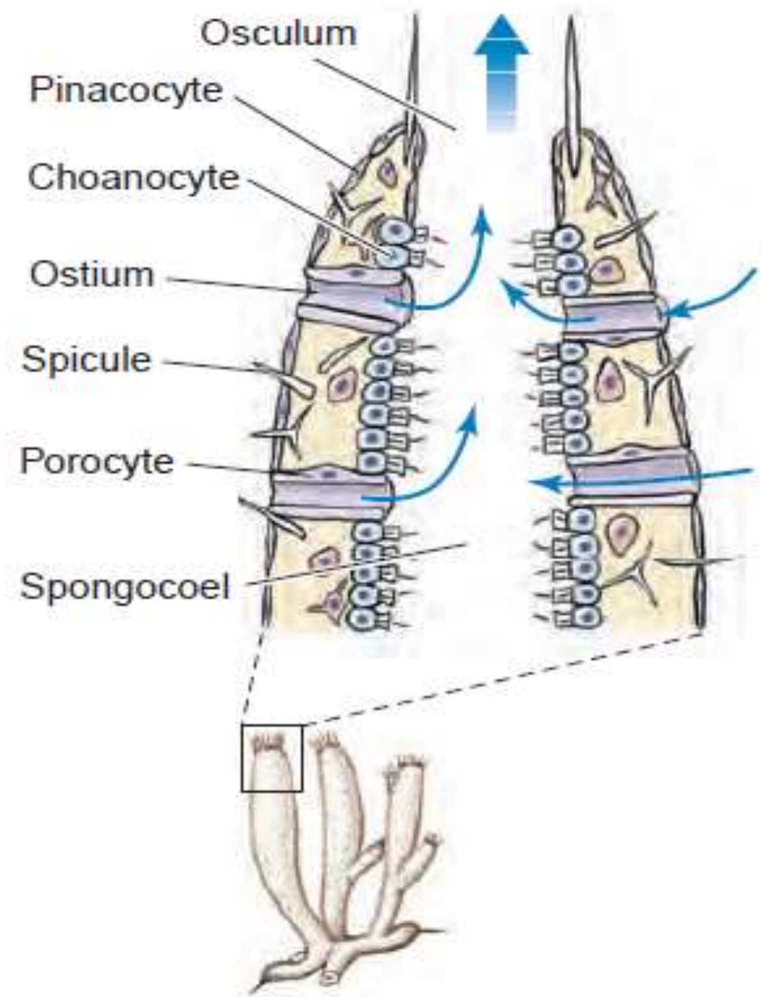
→Reactions to stimuli apparently local and independent in cellular sponges;

→ Nervous system probably absent

→Asexual reproduction by buds or gemmules

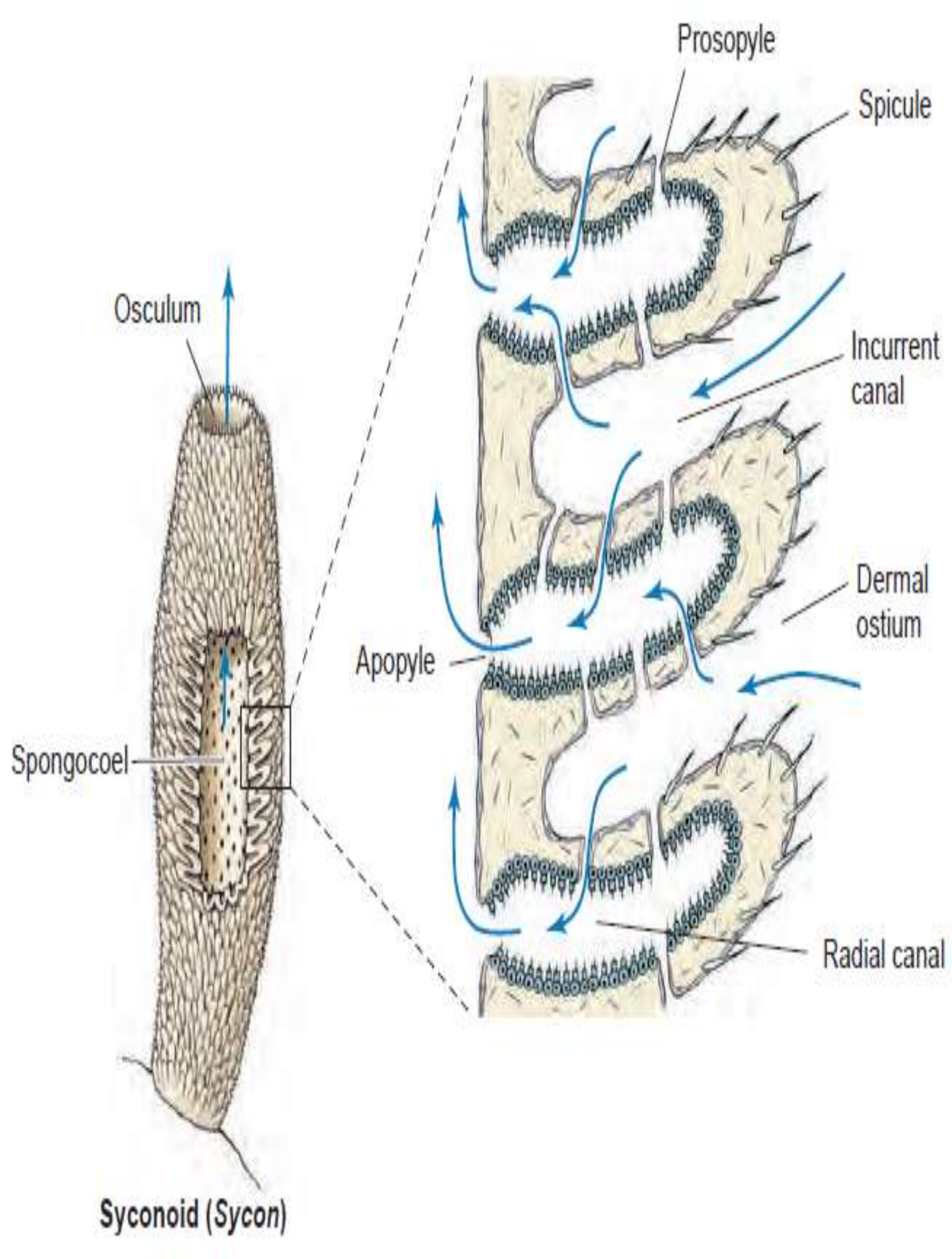
→Sexual reproduction by eggs and sperm; free-swimming flagellated larvae in most

3 Types of Canal Systems



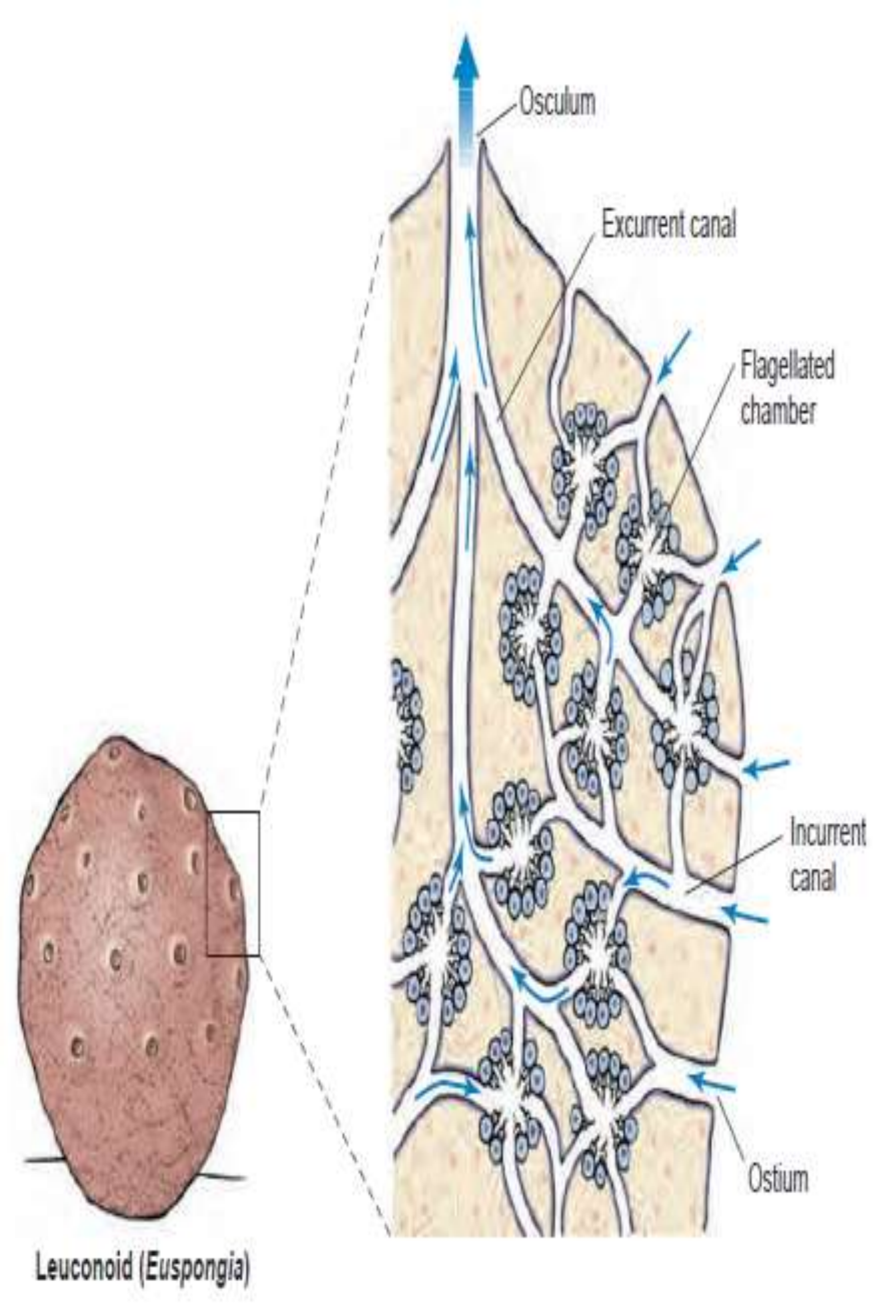
Asconoid (*Leucosolenia*)

→**Asconoid**- simplest type among canal systems the choanocytes lie in a large chamber called the ***spongocoel***



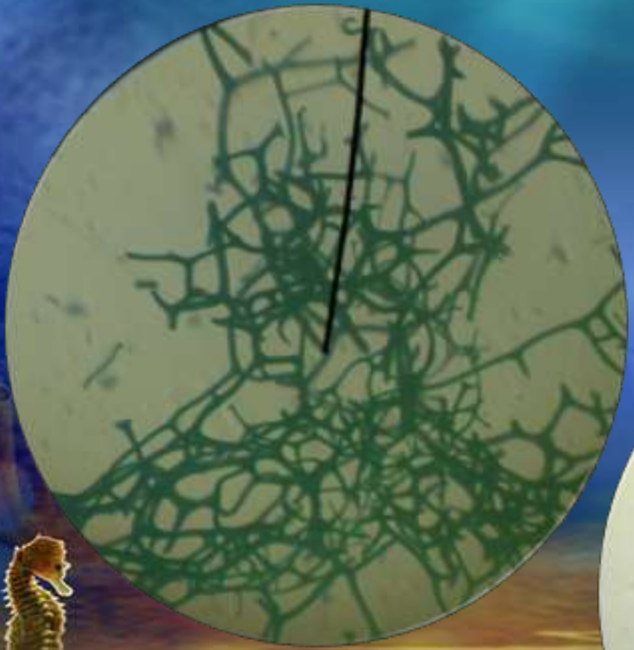
→ **Syconoid**- choanocytes lie in canals

→ **Leuconoid**- considered the major plan for sponges, for it permits greater size and more efficient water circulation.



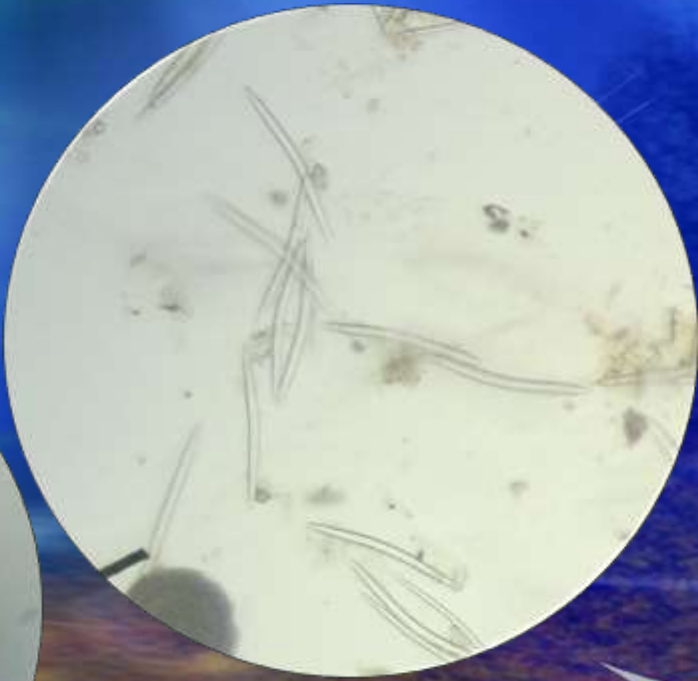
→Body wall with two layers of loosely arranged cells and a mesenchyme in between

→ Body has an endoskeleton made up of spicules which can be calcareous, siliceous and spongin.



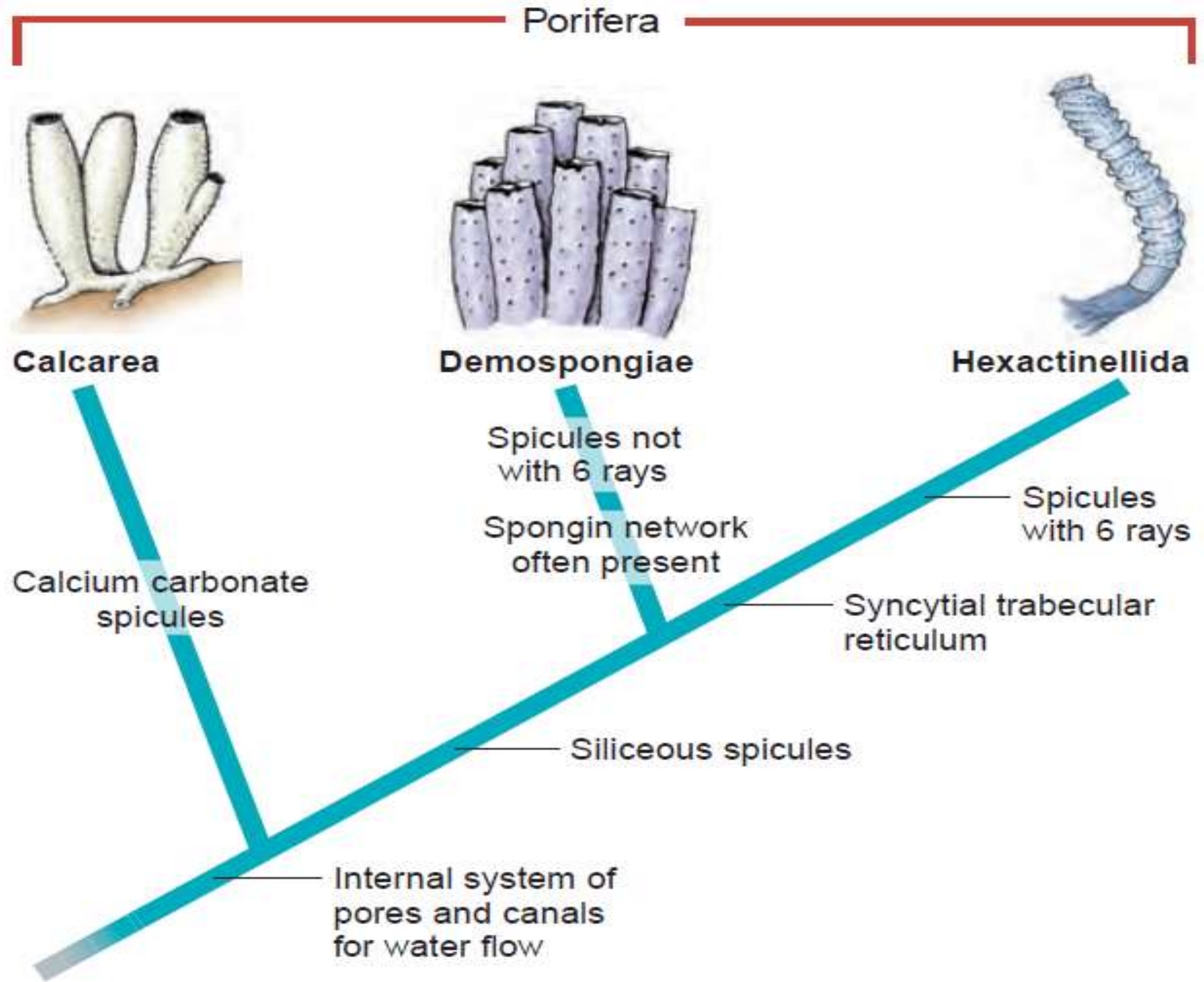
Spongin

Siliceous



Calcareous


Classification


Porifera
Calcarea
Demospongiae
Hexactinellida
Spicules not
with 6 rays
Spongin network
often present
Spicules
with 6 rays
Calcium carbonate
spicules
Syncytial trabecular
reticulum
Siliceous spicules
Internal system of
pores and canals
for water flow

Class Calcarea

Calcareous Sponges

→ (cal-care-a) (L. calcis, lime) (Calcispongiae).

→Have spicules of calcium carbonate that often form a fringe around the osculum (main water outlet); spicules needle-shaped or three or four rayed

→ all three types of canal systems (asconoid, syconoid, leuconoid) represented

→ALL marine.

Examples: ***Scypha, Leucosolenia, Clathrina.***

Scypha

(Syconoid sponge)

→Marine; Usually found in shallow water

→ Lives in fine detritus material and a variety of planktonic organisms in water

→Solitary sponge that may live singly or form clusters by budding

→ Vase-shaped typically 1-3cm long with a fringe of straight spicules around the osculum

→The soft body wall consists of 3 layers:

- ❖ thin flat cells which comprise the outer epidermis, the *pinacocytes;*
- ❖ inner lining of choanocytes;
- ❖ gelatinous mesohyl which bear undiffrentiated amoeboid cells, *amoebocytes*

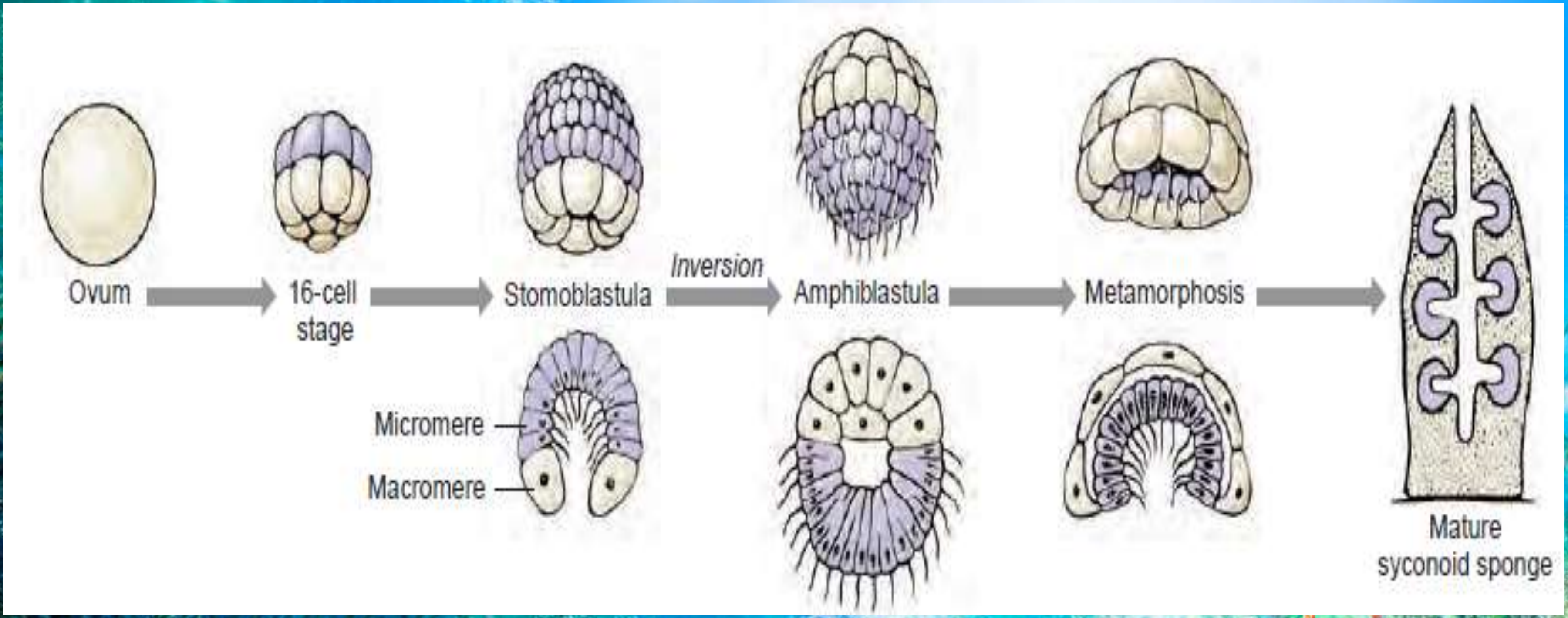


Figure 4. Development of calcareous syconoid sponge, *Scypha*

Leucosolenia

(Orange Pipe Sponge)

→ small asconoid sponge

→grows in branching colonies

→ usually arising from a network of horizontal, stolon like tubes

Clathrina

(Yellow Network Sponge)

→ Has similar characteristics with *Leucosolenia* but only differ with a kind of tube it has, an intertwined tube.

Class hexactinellida

Glass Sponges

→Have six-rayed, siliceous spicules extending at right angles from a central point

→ spicules often united to form network

→ body often cylindrical or funnel-shaped

→ flagellated chambers in simple syconoid or leuconoid arrangement

→habitat mostly deep water; all marine.

Example: *Euplectella*.

Euplectella

(Venus Flower Basket)

→They range from 7.5 cm to more than 1.3 m in length.

→ Distinguishing feature: skeleton of six-rayed siliceous spicules bounded together into a network of glass-like structure.

→ Tissues are syncytial network of fused amoeboid cells called a trabecular reticulum.

Class demospongea

Common Sponges

→Contains 95 % of living sponge species including most large sponges

→ Have siliceous spicules that are not six-rayed

→ Spicules may be bound by spongin or maybe absent

→ All members of the class are leuconoid and all marine except for members of freshwater family Spongillidae

Examples: ***Carterispongia, Spongia.***

Carterispongia

(Elephant's Ear Sponge)

→Shape like an expanded vase

→ Its main body consists of a broad leathery plate

→ Its skeleton is made up of only spongin and no spicules

→ It has numerous ostia in its surface and root spicules for attachment to host

Spongia

(Bath Sponge)

→Size frequently over 10 cm in diameter.

→ Globular-massive, quite variable in shape.

→ Oscules few in number, on the upper side, up to 1 cm in diameter.

→ Consistency spongy-elastic, compressible, supple.

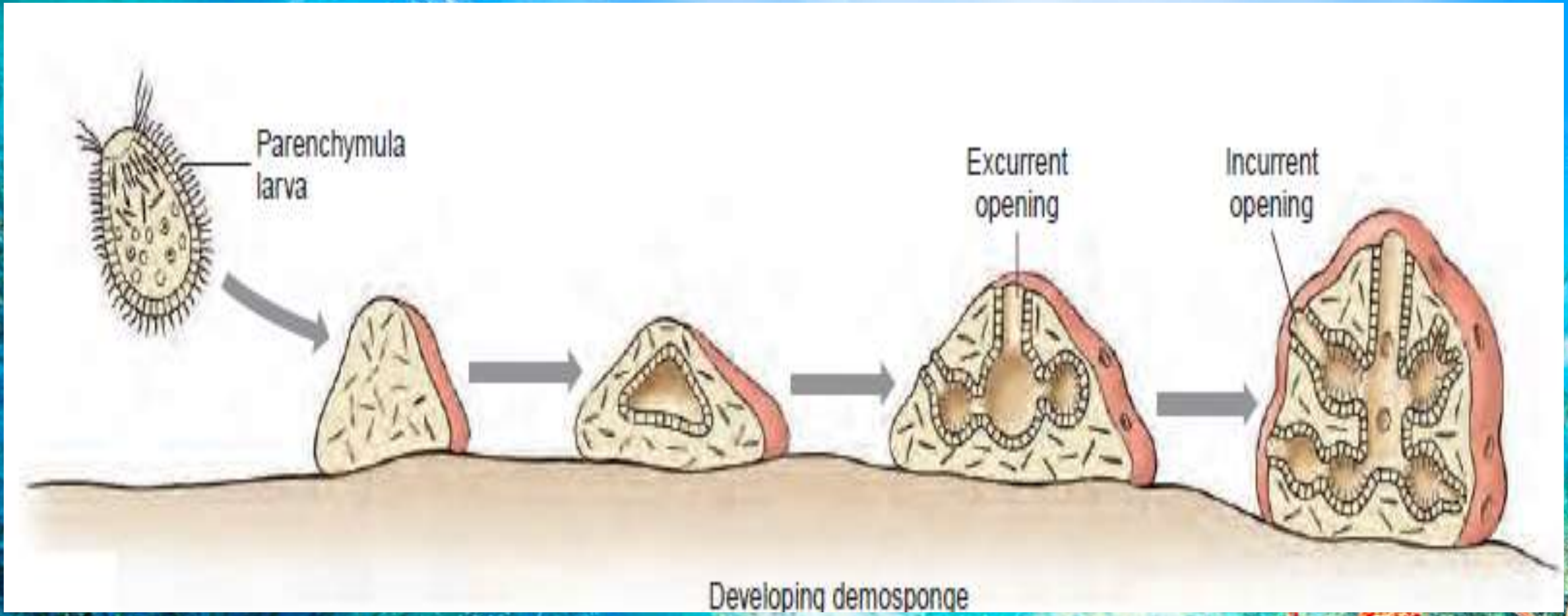


Figure 4. Development of common sponge, Demospongea

FOSSILS:

SIPHONIA

I. PHYLUM : Porifera

II. CLASS : Desmospongia

III. ORDER : Lithistida

IV. MORPHOLOGY:

   i. Shell form: pear, apple or fig shaped with a long or short stalk.
   ii. Incurrent canals: small, curved and arranged radially from centre.
   iii. Excurrent canals: large and parallel and open into spongocoel by ostia.
   iv. Spicules: Four rays with bifurcated.

V. AGE: Upper Cretaceous.

VENTRICULITES

I. PHYLUM : Porifera

II. CLASS : Hexactinellida

III. MORPHOLOGY:

   i. Shell form: Simple, cup shaped, funnel shaped or cylindrical.
   ii. Spongocoel: large and deep.
   iii. Walls: Folded.
   iv. Canals: Sycanoid.
   v. Spicules: Six rayed and form a mesh work.
   vi. Root: Consisting of siliceous fibres.

IV. AGE: Cretaceous.

references

Hickman, Cleveland Jr. P., et al. 2008 Integrated Principles of Zoology 14th ed. New York, USA. Mc-Graw Hill Companies, Inc.

PRESENTATION ON

- Phylum: Coelenterata

Define marine invertebrates:

In general invertebrates are those animals which have no notochord as opposed to vertebrates. Who could adapt themselves in marine environment are considered as marine Invertebrates.

There is a huge diversity in marine invertebrate species.

Example: crabs, sponges , snails , shrimps , oysters etc

Define Coelenterata:

The coelenterate may be define as diploblastic metazoan with tissue grade of construction having nematocysts and a single gastrovasculer cavity or the coelenterons. The coelenterate are tentacle bearing, aquatic, either sedentary or free swimming, radically or biradially symmetrical metazoan without head organs or systems and with a low but definite cells tissue grade of organization . They posses nematocysts of intrinsic origin and only one internal cavity opening only by the mouth.

Why it is called coelenterata:

- The name of coelenterate comes from two Greek words koilon means hollow and Enteron means intestine, that means hollow intestine . But the terms hollow bodies or hollow inside convey the name coelenterates better the literal translation because coelenterates prosses a true intestine. All the coelenterates process a sigle large central cavity. The coelenterons are gastrovasculer only one openion to outsides.

General characters of coelenterata :

- *Coelenterates are metazoa or multicellular animals with tissue grade of organization.
- * They are aquatic, mostly marine. Except few fresh water from like hydras.
- * Individuals are radially or biradially symmetrically with a central gastrovuscular cavity communicating to the exterior by the mouth.
- * Acoemolate animals because they do not posses a second body cavity the coelom

- * The tentaclesr provide with nematocysts; tentacles surve for capture;its injestion are for defence ,these are also presents on body layer
- * they are usually carnivorous , digestion is extra cellular as well as intra cellular , anus is not found .
- * Nervous system consists of one of more networks.It is located in the ectoderm and endoderm .
- * Reproduction is both sexual and asexual methods.
- * A ciliated plnula larva usually present in the life history.
- * The life history exhibits the phenomena of alternation of generations or metagenesis .

>>A list of 15 genera of coelentereta:

A. Hydra
B. Obelia
C. Aurelia
D. Metridium
E. Cunina
F. Plumumaria
G. Tomoya
H. Cynaea
I. Tubularia

J. **Millepora**
K. pericolpa
L. periphylla
M. charybdaea
N. Heliclytus
O. Lucernaria

hydra

Jelly fish

metdrium

obelia

Classify coelentereta upto order at least three characters and one examples :

- The classification followed here is given by Hyman, L.H 1940 according to him phylum coelentereta has been devided into 3 classes; hydrozoa , Scyphozoa , Anthozoa .
- Class- 1: hydrozoa
- >> Body wall consists of an outer ectoderm and inner endoderm separated by non cellular mesogloea.
- >> They exibit tetramerous or polymerous radial symmetry .

>> Gastrovascular cavity without stomodaeum , septa or nematocyst bearing gastric filament .
Example >: millepor , stylaester etc

- 

- millepora

Order 1 : hydroida

- >> Solitary or colonial forms .
- >>sense organs of medicine ocella and statocystes and exclusively ectodermal in origin
- example : hydra , tubuairia

Order 2: milleporina

- >>colonial coral like hydrozoa without perisarea
- >> Massive calcareous skeleton is secreted by ectoderm provide with poros through which polyps protrude out
- Example: millepora

Order 3: stylasterina

- >>Larva is livarated as planulla .
- >>gastrozooids dactylozooids are small, solid without tentracles .
- Example: stylaster .
- Order 4: trachylina
- >>Polypoid stage reduce or absent.
- >>medusa are large.
- Example: solmaris , geryonia

Order 5 : siphonophyra

- >>Medusa always incomplete and rarely freed.
- >>they are polymorphic free swimming or floating colonial hydrozoa.
- Example: diphyes , physalia .

Class 2: Scyphozoan .

- >>scyphozoan includes a large jellyfish or truemedusa are exclusively marine.
- >> Mesogloea is usually cellular.
- >>Gastrovascular system without stomodaeum with gastric
- Filaments may or may not be devided interradial packet.
- Example: tamoya , periphylla

Order 1: Lucernaridae

- >>Body is globet or trumpet shapped.
- >>Gastrovascular system is devided into central stomach and 4 per radial poches .
- Exm: lucernaria , haliclystus

Order 2: Carybdeida

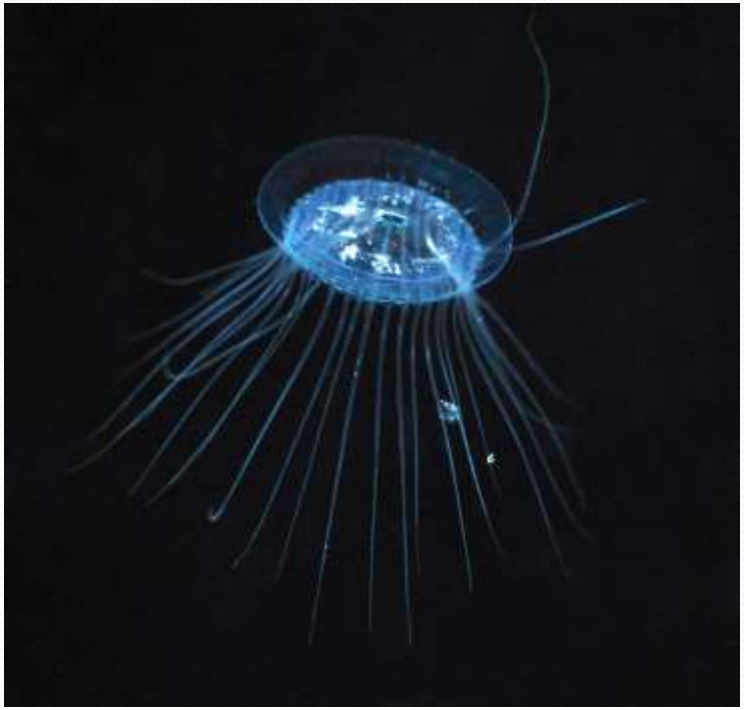
- >>Body cubical with 4 flates sides.
- >>four per radial tentaculocysts or rhopalia are present and gonads are leaf like.
- Exm : tomoya , charybdaea

Order 3: coronate

- >>Body colonial, conical, dome shaped and grooved .
- >>Mouth is cruciform.
- Exm : periphyla , pericolpa .

Order 4: semacostomeae

- >>Mouth is square
- >>Gastric pouches and filaments are absent.
- Exm: Aurelia, cynaca .



Order 5; Rhizostomae

- >> Free swimming schyphozoa found in shallow water of tropical and subtropical ocean.
- >>4 subgential pits are generally present.
- Exm : Cassiopeia , rhizostoma .

Class 3: Anthozoa .

- >>Solitary and colonial exclusively marine forms .
- >>They are exclusively polypoid .
- >> The stomodaeum is present, often provided with one or more ciliated grooves the siphonoglyphs .
- Exm: telesto , alcyonium .

Order 1: stolonifera

- >>Inhabit in shallow water in trophic oceans.
- >>Skeleton consists of loose spicules or of compact tubes and plateformes .
- Exm :tubipora , clavularia

Order 2: Eelestacea .

- >>Eatch steam is very elonged polyp bearig lateral polypes .
- >>Skeleton contains of spicule fused by calcarieus or horny secration .
- Exm: telesto ,

Order3: Alcyonacea .

- >>Skeleton consist of separate calcarious spicules not axial
- >>Colony mushroom shaped or branched into stout blunt process
- Example: xenia ,alcyonium

Order4: coenothecalia

- >>Commonly known as blue erect terminal tubes,called as coral reffs in indo pacific.
- >>Skeleton is perforated by neumorous larger and smaller erect cavities.
- Example: heliopora

Order5:Gorgonacea

- >>The axial skeleton compossed of calcarious spicules or horn like material.
- >>The colony is plant like consistof a main stem arising from basal plat of stolons and number of brances bearing polyps.
- Example:gorgonian,corralium

Order6: Pennatulaceae

- >>Peduncle is embedded in the mud and sand.
- >>The main stem is supported by calcarious and or horney skeleton.
- Example:pennatula,renilla
-

- *Representative*

Jelly fish {Aurelia aurita}

systematic position:

P:colenterata

C:scyphozoan

O:semaeostomeae

F:ulmaridae

G:Aurelia

S: Aurelia aurita

Habit and Habitat:

- Aurelia is a common jelly fish or moon jelly ,occurs in coastal waters of tropical and temparate ocean in the world close to the surface of the waters.It is cosmpolon in distribution .It lives either singly or in large groups found floating or swimming freely.It is carnivorous and reproducts both by sexual and asexual methods.

Respiration and Excreation :

- There are no specialized organs for respiration and excreation . These process are presumably performed by the whole body surface . The gastrovascular system brings about respiration since the current of water carries oxygen in its circulation and removes co2 .The 2 reguiement of the medusa is very small compared to its weight , because the jelly fish contains about 96% of water . The gastrovascular
- system also removes excreatory matter

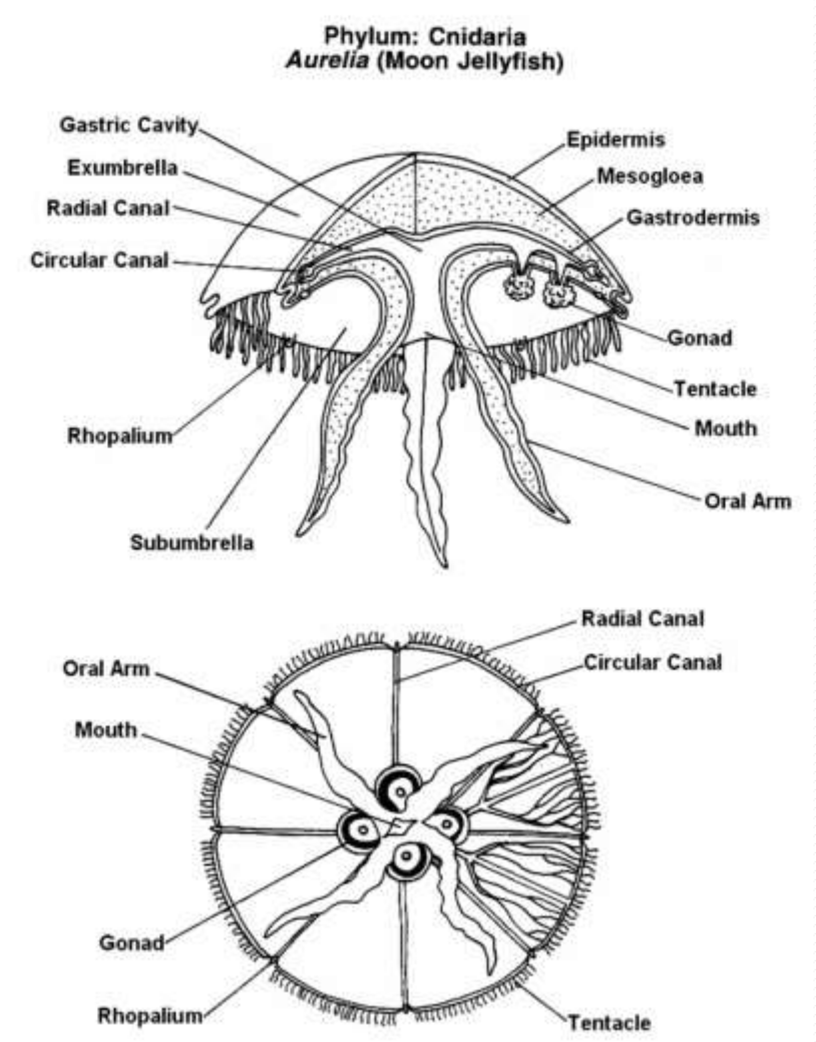
Gastovascular canal system :

- The mouth leads into a short gullet within the manubrium which finally opens into a 4 lobed spacious stomach . The stomach occupies a greater part of the center of ball in the form of 4 extensionscalled gastric pouches , situated inter radially .At the 4 corners of the mouth are 4 per radial canal . Situated at right angle to each other, 4 inter radial canals are present in between the per radial canal . These 8 canals are much branched . 8 unbrached ase 2 form adradial canels arise 2 form each gastric pouch . Between the inter radial and per radial canals . All these 16 canels open in the circulation or ring canal situated at the mergin of the umbrella thus the gullet , stomach with gastric pouches and all the canal constitute The gastrovascular canal . As mentionedearlier , the enteron cavity except 8 gullet is lined by ciliated endodermal cells

The Anatomical structure of Aurelia aurita with leveled diagram :

- Size , shape and Colour :

The medusa of Aurelia is flattened , bowl or saucer shaped gelatinous stricter called the bell or umbrella . It exhibits tetramerous radial symmetry . It usually measurs (7.5 to 10)cm in diameter . It is also transparent having bluish white body with pinkish gonad.

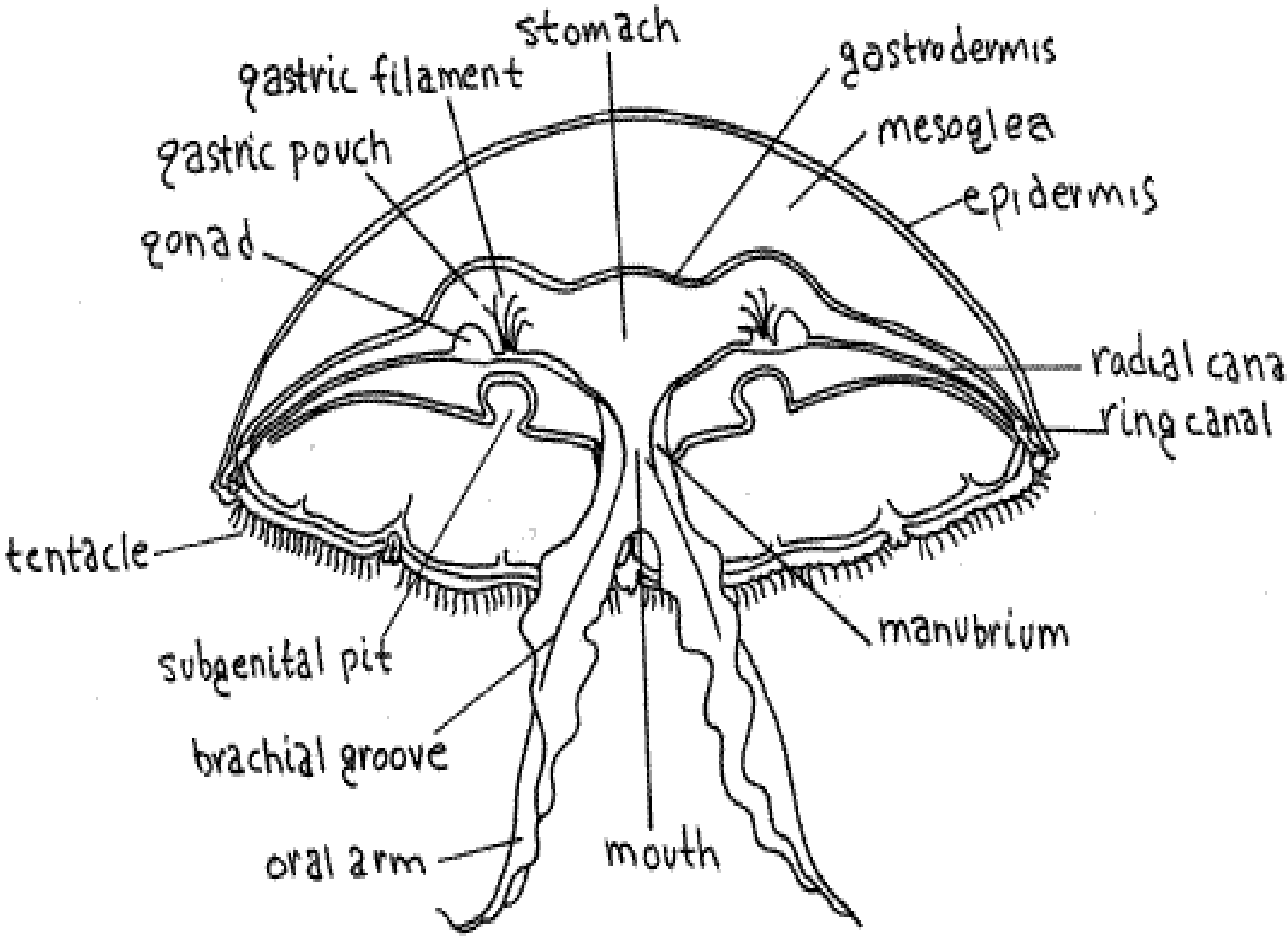

Phylum: Cnidaria
Aurelia (Moon Jellyfish)
Gastric Cavity
Exumbrella
Radial Canal
Circular Canal
Epidermis
Mesogloea
Gastrodermis
Gonad
Tentacle
Mouth
Oral Arm
Rhopalium
Subumbrella
Radial Canal
Circular Canal
Oral Arm
Mouth
Gonad
Rhopalium
Tentacle

External structurs :

- The umbrella is distinctly divided into a slightly convex upper surface and a concave lower surfac . The margin is circular , which is broken by 8 notches . Each notch is provided with a pair of marginal lappeds enclosing sense organ.The margin of umbrella bearing marginal lappets which is thin and ridge like , called velarium . A true velam like those of hydrozoan medusa is absent in aurilla, cause it lacks muscle and nerve ring.

The subumbrellar surface bears the followings:

- Manubrium :
- In the center of subumbrella surface there is a well developed but short and inconspicuous manubrium bearing a large squarish mouth.
- Oral organ:
- All the 4 corners of the mouth are drawn out into 4 long , mobile delicate frilled and tapering and processes called the oral arms . which provided with a ciliated groove one its inner side and they are also provived with neumerous nematocysts .


stomach
gastric filament
gastrodermis
gastric pouch
mesoglea
epidermis
gonad
radial canal
ring canal
tentacle
manubrium
subgenital pit
brachial groove
oral arm
mouth

Gonads and subgenital pits:

- 4 horse shoe shaped pinkish gonads which later become circular are situated between oral arms. In the center of the subumbrella surface . gonads are in fact internal line into the gastric pouches but they are visible just bellow each gonad in the subumbrella surface is a circular aperture called subgenital pits of unknown function . The gonads are provided with delicate fin thresd like gastric filaments bearing nematocyst in the gastric pouce . asystem of fin branched or unbranched radiating canels clear in visible on the surface of umbrella . these are per radial , interradial and radial in position .

The corners of mouth are oral arms are per radial in position while gonads and subgenital pits are interradial in position. Marginal notches of aper radial and interradial both are 4 in position.

What do you mean by Coelom

- Animals that have true coelom are called Eucoelomates such as phylum Annelida, Arthropoda, Mollusca, Echinodermata, Hemichordata and Chordata. The fluid filled body cavity is lined with peritoneum, which is derived by embryonic mesoderm, and separates the digestive tract and outer body cell wall. Internal organs are suspended in the body cavity and help to develop those. According to the embryology, Coelom is derived from two different ways. One way is through the splitting of the mesoderm, and the other way is out pocketing of archenteron fusing together to form the coelom.

What do you mean by **Pseudocoelom**

- Animals that have pseudocoelom or false coelom are called pseudocoelomate such as phylum Nematoda, Acanthocephala, Entoprocta, Rotifera, Gastrotricha1. Although they have a body cavity, it is not lined with peritoneum or partially lined with peritoneum , which is derived by embryonic mesoderm. This body cavity is filled with fluid, which suspends the internal organs and separates the digestive tract and outer body cell wall. As embryology implies, the pseudocoelom is derived from the blastocoel of the embryo.

What is the difference between Pseudocoelom and Coelom?

Pseudocoelom	Coelom
1. pseudocoelom is not lined with the peritoneum, 2. • Pseudocoelom is derived from the blastocoel of the embryo. 3. pseudocoelom does not aid in the formation of a circulatory system. 4. In Psudocoelom, nutrients circulate through diffusion and osmosis . 5. pseudocoelom is not segmented. 6. Pseudocoelom lacks muscles or supporting mesenteries	1. coelom is lined with the peritoneum. 2. coelom is derived from two different ways. 3. Coelom allows the formation of an efficient circulatory system. 4. coelom, nutrients circulate through the blood system. 5. Coelom is segmented. 6. Coelom has muscles or supporting mesenteries

CORAL REEF

Coral reefs are underwater structures made from calcium carbonate secreted by corals. Coral reefs are colonies of tiny animals found in marine waters that contain few nutrients. Most coral reefs are built from stony corals, which in turn consist of polyps that cluster in groups. The polyps belong to a group of animals known as Cnidaria, which also includes sea anemones and jellyfish. Unlike sea anemones, coral polyps secrete hard carbonate exoskeletons which support and protect their bodies. Reefs grow best in warm, shallow, clear, sunny and agitated waters

PROCESS OF CORAL REEF FORMATION

Fringing reef :

A fringing reef is one of the three main types of coral reefs recognized by most coral reef scientists. It is distinguished from the other two main types (barrier reefs and atolls) in that it has either an entirely shallow backreef zone (lagoon) or none at all. If a fringing reef grows directly from the shoreline (see photo, right) the reef flat extends right to the beach and there is no backreef. In other cases (e.g., most of The Bahamas), fringing reefs may grow hundreds of yards from shore and contain extensive backreef areas with numerous seagrass meadows and patch reefs.

This type of coral reef is the most common type of reef found in the Caribbean and Red Sea. Darwin believed that fringing reefs are the first kind of reefs to form

Process of lagoon reef formation

On the coast, longshore drift carries sediment parallel to the coast. Where the coast has a concave shape , such as a bay or cove, longshore drift carries and deposits sediment across the entrance of the concave coastline, overtime, blocking the water in the concave coastal formation from the rest of the ocean/sea. The isolated water body is a lagoon. Across river mouths, sediment carried by the river, along with sediment carried by longshore drift, build up at the mouth, cutting off the river water from the sea; this is also considered a lagoon; an estuarine lagoon, to be exact, where salt water from the sea mixed with the river water before isolationl.

. In terms of coral lagoons, according to Darwin's theory, coral reefs are formed around volcanic islands. Over time, the volcanic islands sinks into the ocean, but the reef around it builds to form a ring of accumulated coral skeletons. Eventually, the island is no longer there, and the ring of above-surface coral left behind is known as an atoll. Within the atoll, where the island had sunk, an isolated water body is left behind. This is a lagoon as wel

PROCESS OF ATOLL REEF FORMATION

Corals (represented in tan and purple) begin to settle and grow around an oceanic island forming a fringing reef. It can take as long as 10,000 years for a fringing reef to form. Over the next 100,000 years, if conditions are favorable, the reef will continue to expand. As the reef expands, the interior island usually begins to subside and the fringing reef turns into a barrier reef. When the island completely subsides beneath the water leaving a ring of growing coral with an open lagoon in its center, it is called an atoll. The process of atoll formation may take as long as 30,000,000 years to occur.

FOSSILS:

ZAPHRENTIS

I. PHYLUM : Coelenterata
II. CLASS : Anthozoa
III. ORDER : Zoantharia
IV. MORPHOLOGY:
   i. Shell form: Simple coral, conical, curved as horn shaped.
   ii. Calyx: Deep, rounded, well marked cardinal fossula present.
   iii. Marginal character: Margin thin with transverse line of budding.
   iv. Septa: Numerous.
   v. Columella: Absent.
V. AGE: Devonian and Carboniferous.

MONTIVALTIA

I. PHYLUM : Coelenterata
II. CLASS : Anthozoa
III. ORDER : Alcyonaria
IV. MORPHOLOGY:
   i. Shell form: Simple coral, cylindrical in shape.
   ii. Epitheca: Well developed thin and folded.
   iii. Calyx: Deep, ovate.
   iv. Septa: Numerous, strong showing Exsert condition pseudo septae also present.
   v. Columella: Absent.
   vi. Dissepiments: Abundant.
V. AGE: Triassic to Cretaceous.

CALCEOLA

I. PHYLUM : Coelenterata
II. CLASS : Anthozoa
III. ORDER : Zoantharia
IV. MORPHOLOGY:
   i. Shell form: Simple coral, conical and slipper shaped.
   ii. Epitheca: Very thick.
   iii. Calyx: Deep and closed by an operculum.
   iv. Septa: Numerous and well developed.
   v. Columella: Absent.

AGE: Middle Devonian.

BRACHIOPODS

INTRODUCTION

- Group of bilaterally symmetrical, coelomate organisms.

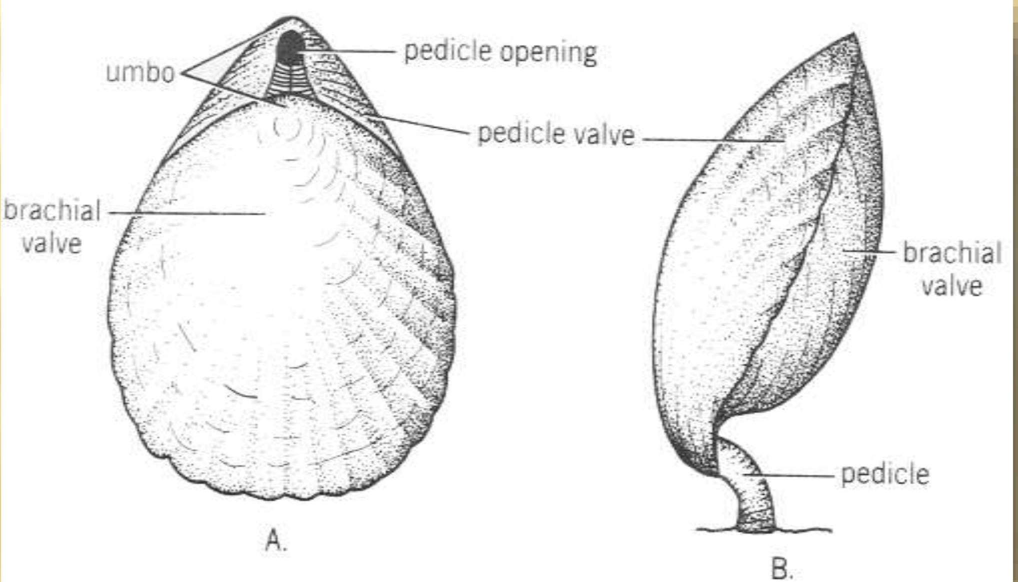
- They have two dissimilar hard **valves**(shell or test) often made up of **Calcite($CaCO_3$)** and/or **Chitin + Calcium phosphate.**

- Brachiopods are of two divisions(Classes)
  - ARTICULATE BRACHIOPODS
  - INARTICULATE BRACHIOPODS

•All known brachiopods are Solitary, benthic marine animals.

•They are normally attached to rocks, shells or other objects by a flexible stalk- The **PEDICLE.**

•Larger and shorter valves are commonly termed as **PEDICLE VALVE** and **BRACHIAL VALVE** respectively.



•Pedicle is attached to inner surface of PEDICLE VALVE by muscles and protrude through a **PEDICLE OPENING.**

•Line along which the valves are in contact is the COMMISURE.

•Edge of valve along which both are in permanent contact is termed **HINGE LINE** or **CARDINAL MARGIN.**

GEOLOGIC HISTORY

•Brachiopods have an extensive fossil record, first appearing in **Cambrian** Period.

•They flourished during the **Devonian** period.

•At the end of the **Paleozoic** however, they were decimated in the mass extinction that marks the end of the **Permian** Period.

- Only about 300 to 500 species of brachiopods are existing today, a small fraction of the perhaps 15,000 species (living and extinct) that make up the phylum Brachiopoda.

- It is the Brachiopod valves that are often found fossilized.

PALAEOECOLOGY

- Brachiopods seems to have a free swimming larval stage and a stagnant benthonic forms.

- They can tolerate different water environments (muddy, saline, etc..), but a fresh water brachiopods are not known to be lived.

Extinct brachiopods lived on bottom of oceans with considerable environmental conditions.

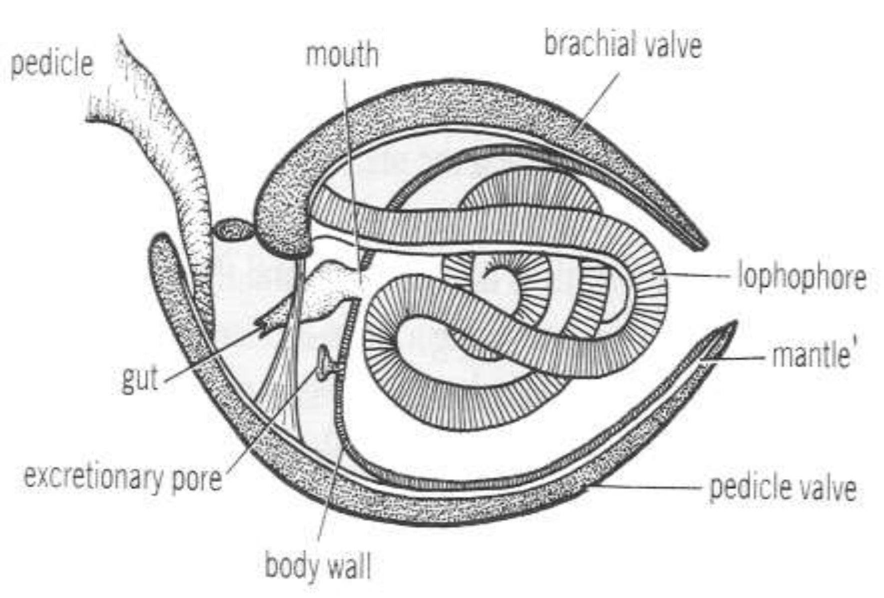
GEOGRAPHIC RANGE

- Brachiopods are found throughout the world's marine environments most abundant in warmer seas.

MORPHOLOGY of SOFT PARTS

•The soft parts of the brachiopod animal are contained between the two valves.
They are divided into 5

- BODY
- MANTLE
- LOPHOPHOR
- PEDICLE
- MUSCLES



1. THE BODY

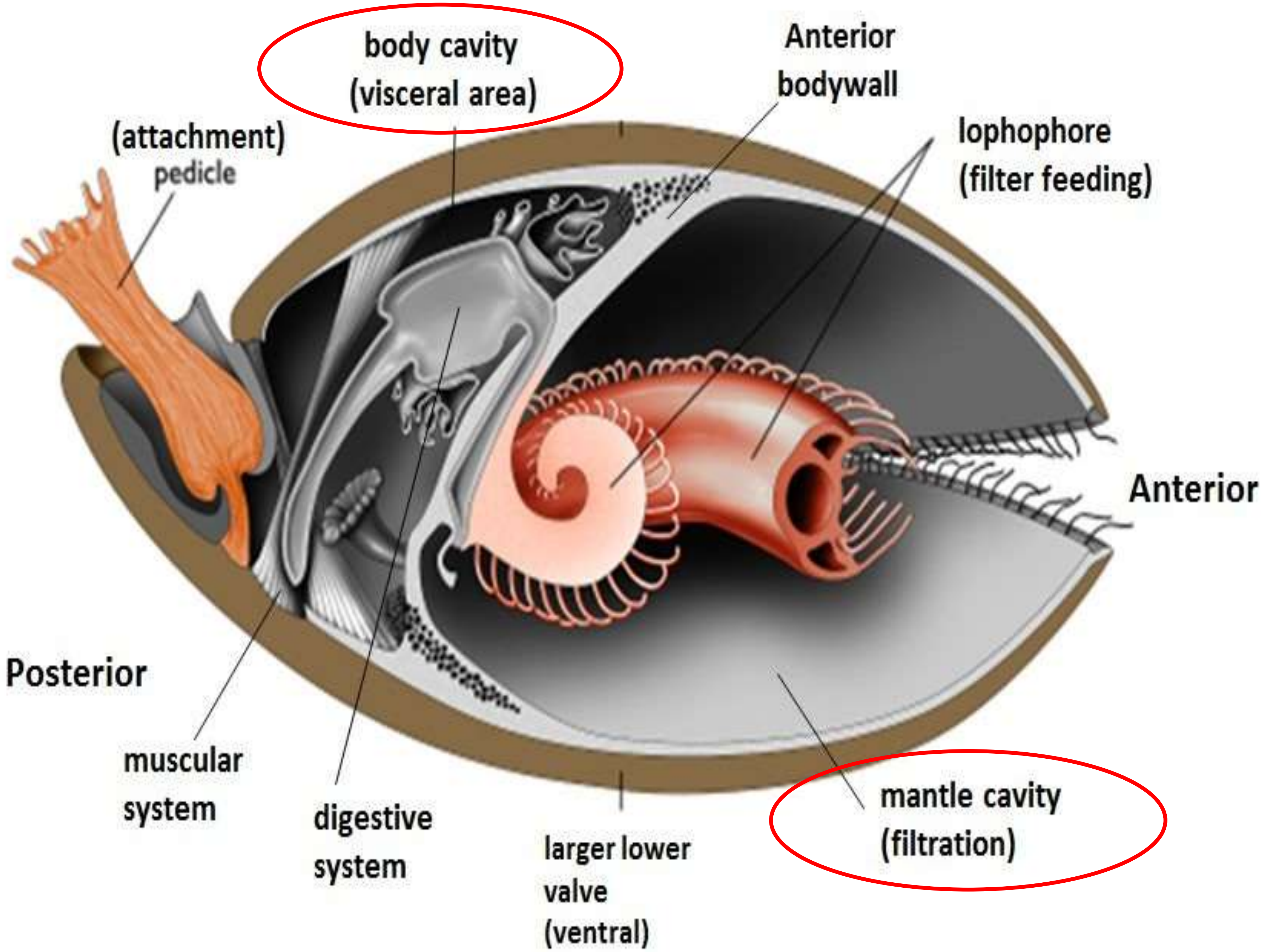
- The Body inside the shell is divided into two portions by a vertical membrane.

❑ **VISCERAL CAVITY** or **COELOM**

-Seen in the posterior region.
-Chief visceral organs are located here.

❑ **MANTLE CAVITY** or **BRACHIAL CAVITY**

-Mostly occupied in Brachiopod interior.
-Seen in the anterior region.


body cavity
(visceral area)
Anterior
bodywall
(attachment)
pedicle
lophophore
(filter feeding)
Anterior
Posterior
muscular
system
digestive
system
larger lower
valve
(ventral)
mantle cavity
(filtration)

2. MANTLE

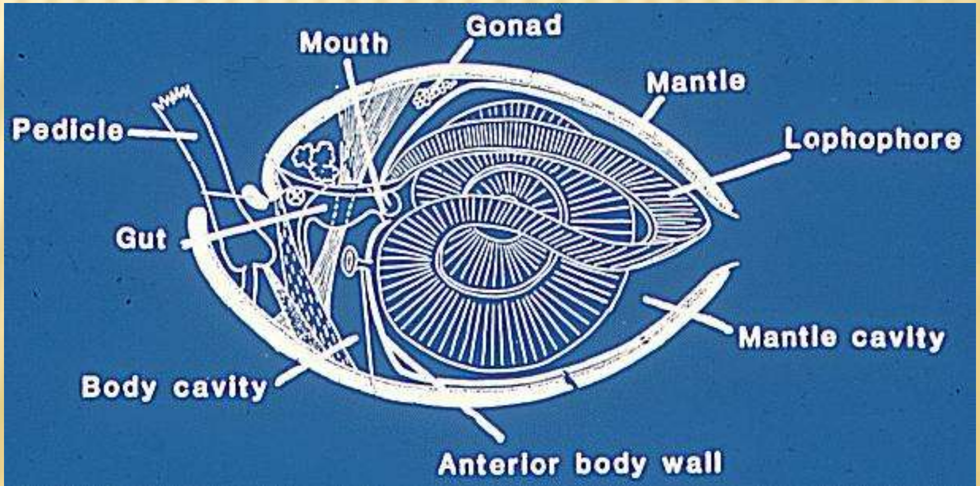
- MANTLE or PALLIUM is a thin double layered membrane which lines the interior of the shell.

- They contain the cells secreting the shell material

- In certain places they are separated to accommodate slender tabular extensions called **Vascular sinuses**.

3. LOPHOPHORE

- Variously shaped appendage attached to the anterior surface at body and Mouth at middle.
- It occupies a large space within the Brachial cavity.
- It creates water currents for Respiration, food capturing, carry away rejected substances.



•The Lophophore exhibit considerable morphological variations in different families and genera.

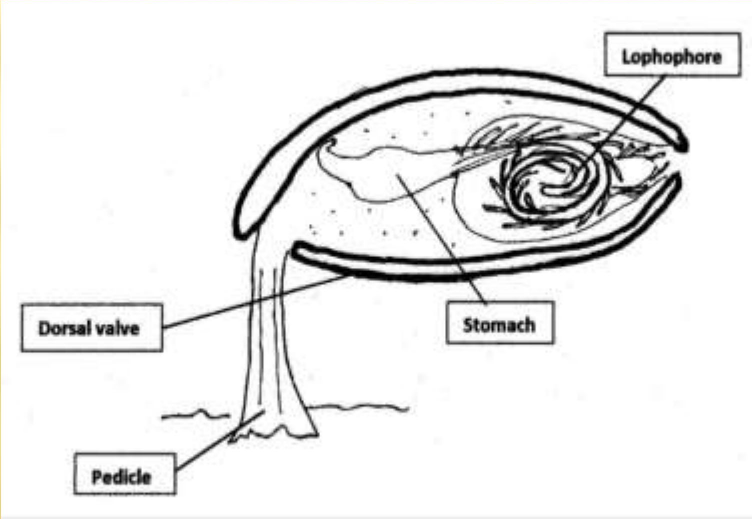
•Some Brachiopod lophophore contain a single lobed disc or a pair of elongated arms called **Brachia** (folded, coiled or spiraled).

•Edges of Brachia bear long and slender tentacles called **Cirri.**

•The Cirri bears numerous fine cilia and a beat of these construct currents in water.

4. PEDICLE

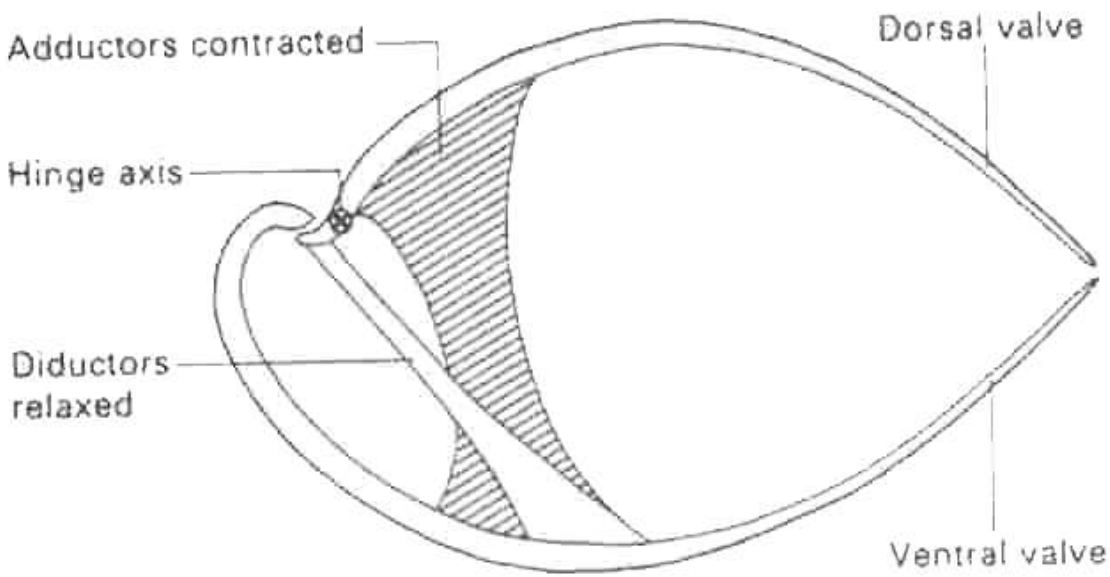
- **PEDICLE** or **PEDUNCLE** is the organ by which most brachiopods attach themselves to the substratum.
- Tough, Flexible cylinder like that is attached to pedical valve comes out from posterior opening.
- In some cases it also comes out through opening of valves.



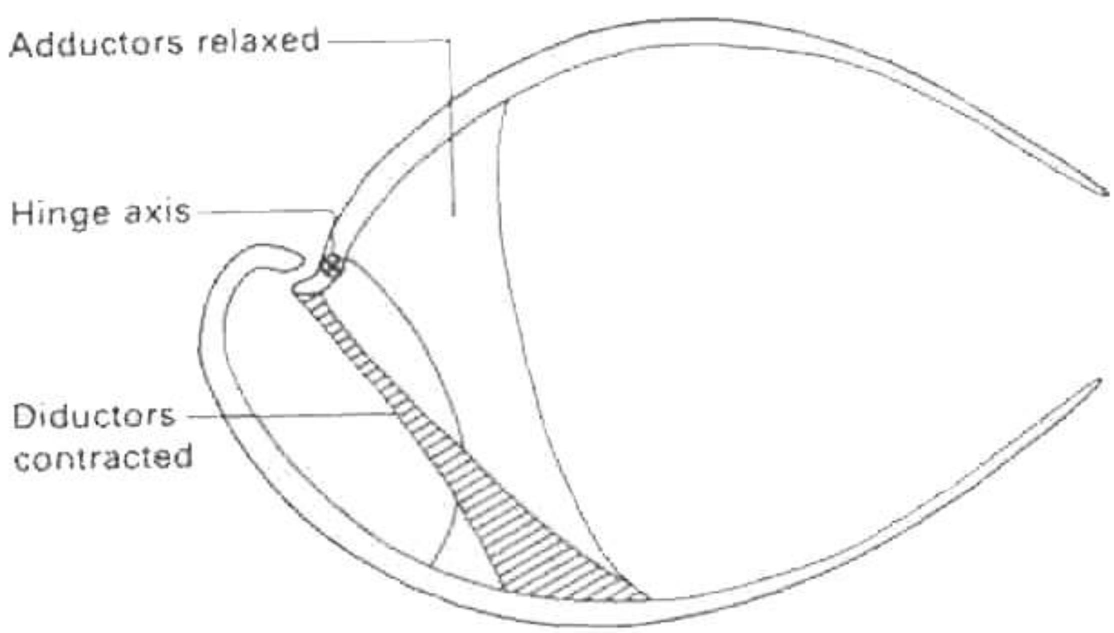
5. MUSCLES

NAME OF MUSCLES	NUMBER	FUNCTION
ADDUCTORS	2	Close the shell by contraction; They are stretched when the shell is open, relaxed when it is closed.
DIDUCTORS	4	Open the shell by Contraction; they are relaxed when the shell is closed.
PEDICLE MUSCLES	5	Adjust the shell up and down on the pedicle, or twist on the pedicle.

A

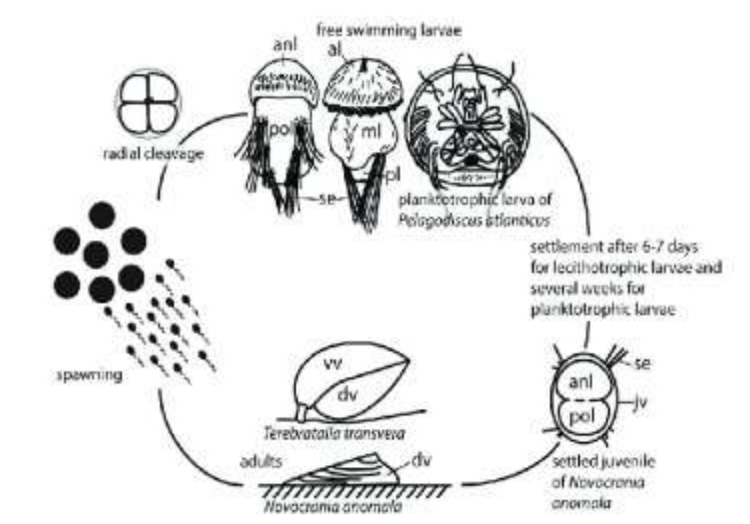

Adductors contracted
Dorsal valve
Hinge axis
Diductors
relaxed
Ventral valve

B


Adductors relaxed
Hinge axis
Diductors
contracted

REPRODUCTION

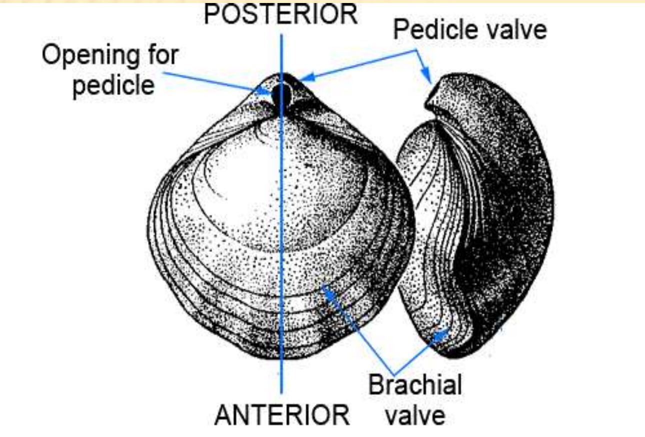
- Brachiopods reproduce sexually.
- Eggs and Sperms are produced and are released into the open sea water.
- After fertilization it develop as a free swimming ciliated larva.
- After a short period, settles down and get attached to the substratum.



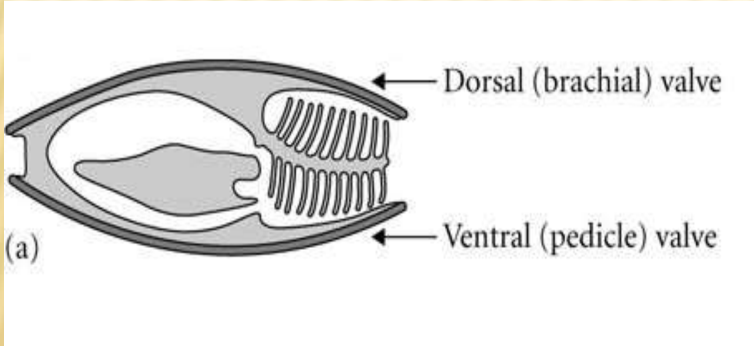
THE SHELL

❑ORIENTATION

1. ANTERIOR AND POSTERIOR – The shell margin where the valves separate and open is **ANTERIOR.**Direction of shell growth .Opposite direction defined by the position of Hinge line or Pedicle opening is the **POSTERIOR.**



2. DORSAL AND VENTRAL - During life pedicle valve is commonly larger and situates in a superior position and Brachia valve in a lower position. The direction away from Pedicle valve is termed **VENTRAL** and away from Brachial valve is termed **DORSAL**

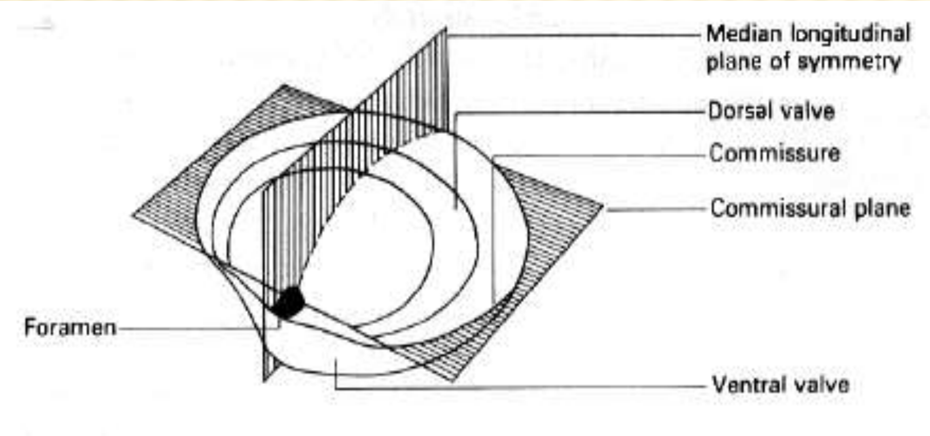


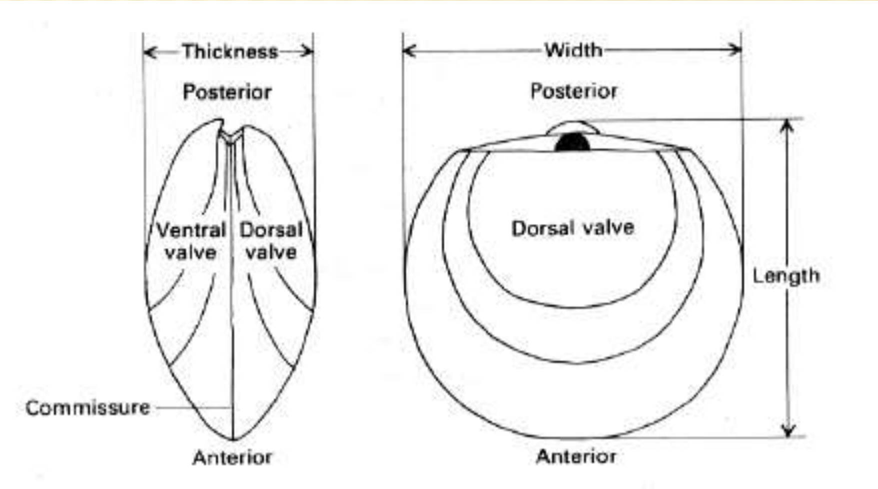
❑DIMENSION

1.LENGTH or HEIGHT-Linear distance along plane of symmetry from anterior extremity to posterior margin of beak.

2.WIDTH or BREADTH-Linear distance from farthest opposite points on surface of shell measured normal to plane of symmetry.

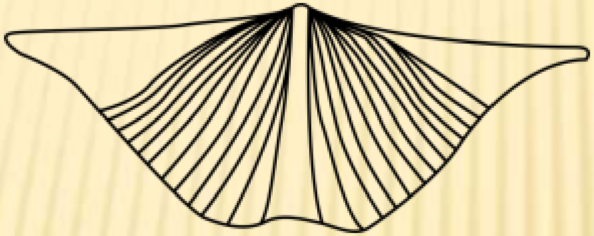
3.THICKNESS- Linear distance between farthest opposite points on surface of two valves measured a plane perpendicular to the valves passing through the centre.



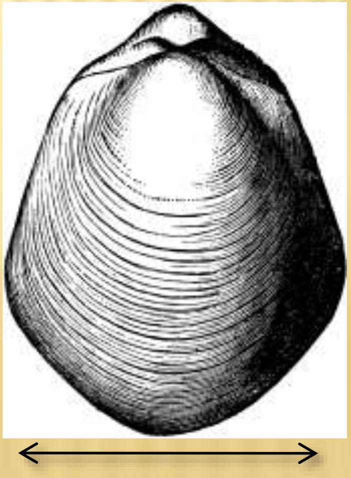


❑SHAPE

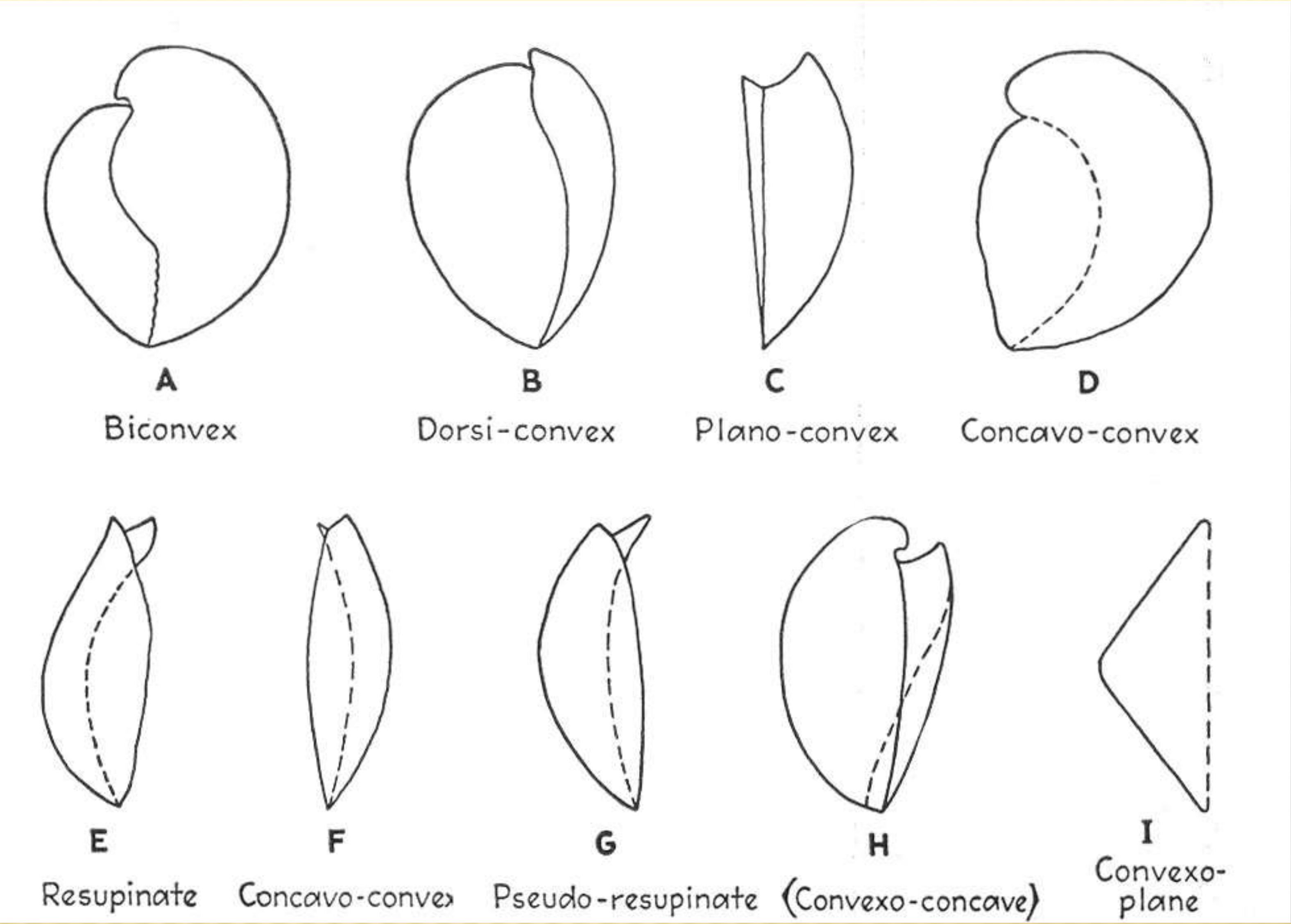
1.OUTLINE - Brachiopod shells have diverse shapes. Simplest forms are **ELLIPTICAL SUBCIRCULAR or-SEMIELLIPTICAL**



*Some show a tendency to transversely widen along the hinge line.
E.g.. PENTAMERUS



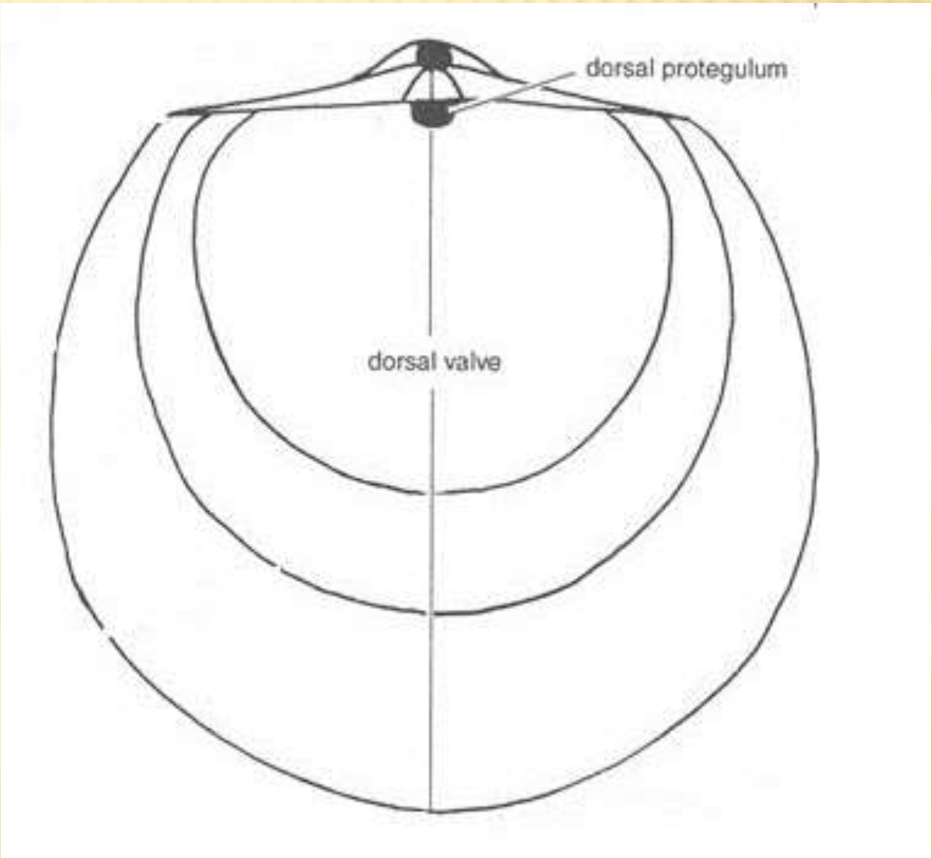
2. PROFILE -Shape of shell in longitudinal profile



** RESUPINATE – The Pedicle valve which is convex shows opposite concave shape near the hinge line.*

❑DEVELOPMENT OF SHELLS

As soon as the larvae settles down to attach on strata, mantle secretes a horny shell called PROTEGULUM. This grows along with shell material until natural shape is obtained.



*Three types of shell growth are observed.

1.HEMIPERIPHERAL	Addition of shell material takes place along lateral and anterior margins of the valves.
2.HOLOPERIPHERAL	Shell growth takes place all around the margins of the protegulum
3.MIXOPERIPHERAL	Growth takes place all sides of Protegulum but shell is not enlarged in backward direction

INTERIOR OF PEDICLE VALVE

1. HINGE TEETH	-The Hinge line of Articulates is divided into two by median pedicle opening called DELTHYRIUM. -Primary articulation is by means of Teeth and Sockets(each 2) -Teeth are in pedicle valve fit into dental sockets in Brachial valve.
2.DENTAL LAMELLAE	The Cardinal shelf in Articulate brachiopods is supported by pair of plates the inner edges called Dental lamellae

3.PEDICLE OPENING	Generally found in the Pedicle valve or Ventral valve. In some both valves are shared.
4.SPONDYLIUM	When two DENTAL LAMELLAE converge along midline of the pedicle valve to form a 'V' shaped chamber is called SPONGDYLIUM
5.MUSCLE SCARS	The term is used for any mark that Indicates muscular attachment.
6.PALLIAL MARKS	Mantle folds which contain tabular extensions for passage of fluids leave marks on interior of both valves. Typically dendritic in pattern.

INTERIOR OF BRACHIAL VALVE

1.DENTAL SOCKETS	Pair of depressions along the hinge line receive the hinge teeth.
2.HINGE PLATE or **CARDINAL PLATE**	Simple or derived plate that lies along the cardinal plate generally bearing the Hinge sockets

SURFACE ORNAMENTATION

Ornamentation of a shell is an Important character in identification of the animals.
They develop with respect to their age

Grouped into two types

1. RADIAL TYPE
2. CONCENTRIC TYPE

RADIAL	**1.STRIAE**	Very fine radial ridges.
	2.COSTAE	Prominent radial ribs that extend from beak and not involving any kind of folding of the inner surface of the shell.
CONCENTRIC	**1.GROWTH LINES**	Fine to coarse ridges running sub parallel edges of valve margins.
	2.LAMELLAE	Overlapping concentric fills which may extend from millimeter to more in length from shell surface.

******When RADIAL and CONCENTRIC ornamentation are present it is called* ***RETICULATED***

SIGNIFICANCE IN HUMAN LIFE

Beyond the potential for scientific research, there are no positive effects of brachiopods on humans.

Phylum Mollusca

Phylum Mollusca

- It is one of the main group of invertebrates in the standpoint of Palaeontology.
- They are marine freshwater and terrestrial snails.

Distinguishing Properties

- Complete absence of segmentation
- Elongated bilateral symmetry except in Gastropods
- Contain body wall of which lower part is modified for locomotion and upper part is called mantle which is folded.
- The free space enclosed by the mantle is called mantle cavity. The mantle contains cells which secrete the shell.
- In all molluscs, the shell consists mainly $CaCO_3$ in the form of calcite or aragonite.

Three important classes

- Pelecypoda or Lamellibranchia
- Gastropoda
- Cephalopoda

Class: Lamellibranchia





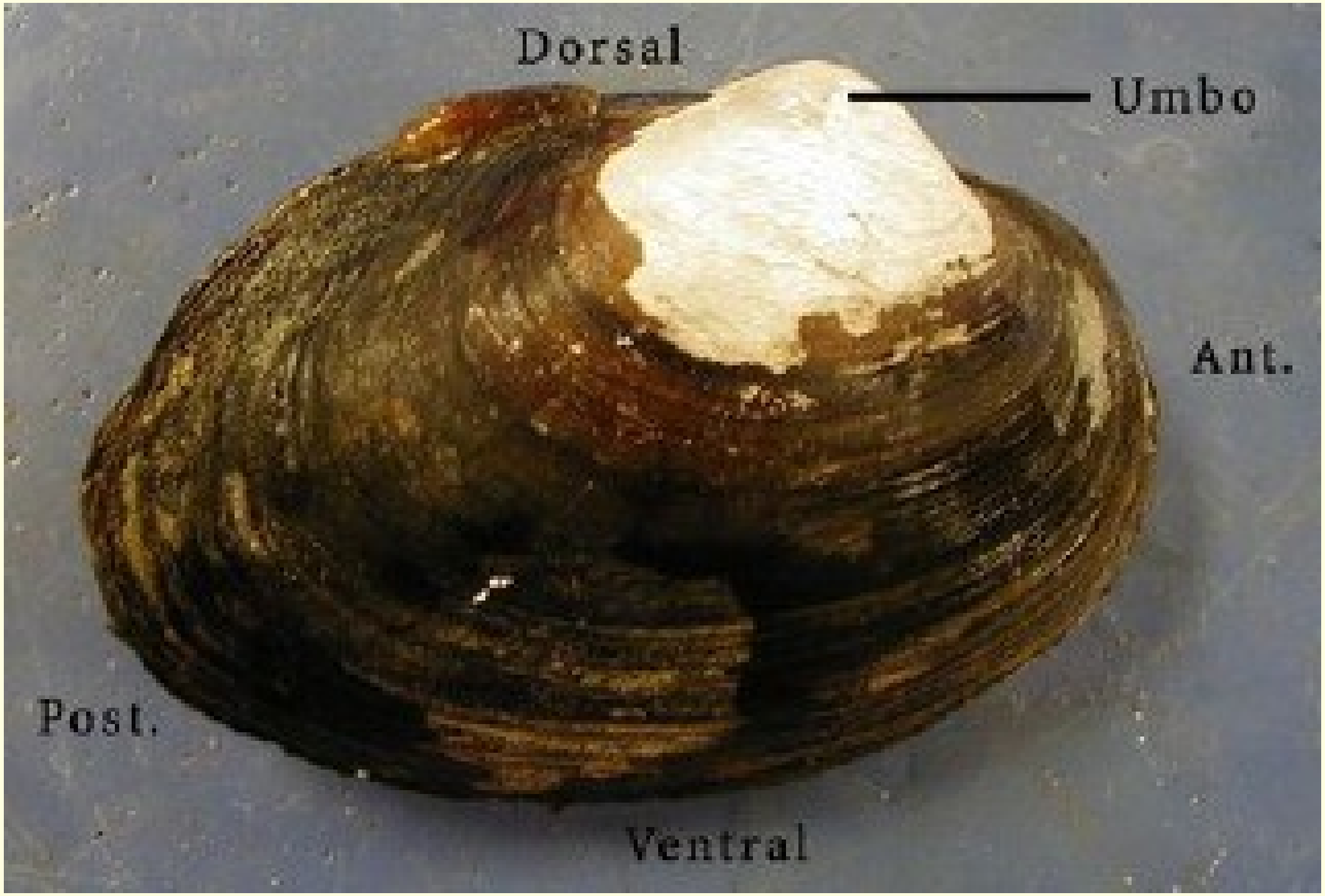

Class: Lamellibranchia or Pelecypoda

- Animals of this class started their life from Cambrian and continued to Present day.
- They possess wide geographical and geological distribution.
- Living forms are exclusively aquatic (marine or freshwater) forms with a wide range of adaptability for all depth ranges from shore lines down to the depth of about 6000m.

Morphology

- In a typical Lamellibranch, the body is enclosed in a calcareous bivalve shell.
- These valves are joined by means of hinge on the dorsal side of the animal.
- One valve is placed on the right side, the other on the left side of the body, unlike that of the Brachiopods.

External Shell



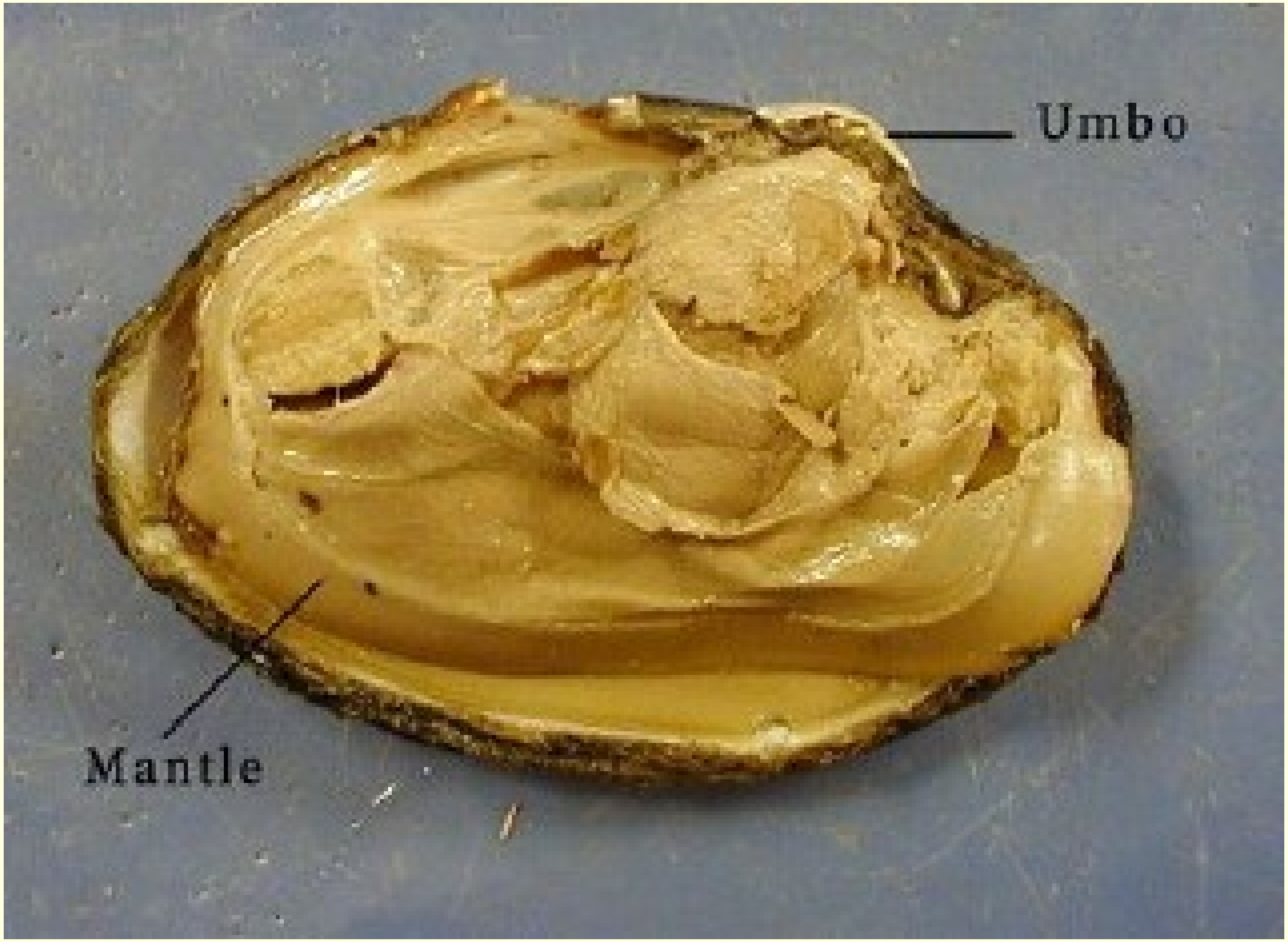
Morphology

- The interior of the shell is lined by a fold of skin known as mantle, which is divided into two lobes, each one being placed in each valve.
- The cavity enclosed by this mantle is called as mantle cavity.
- The valves are alike, compressed laterally with prominent plough shaped foot projecting from the mantle at the ventral surface
- (pelecy means plough shaped, poda means foot – word meaning plough shaped foot).

Morphology

- In genus Trigonia, the foot is used to jump a considerable distance.
- In genus Mytilus, the foot is considerably reduced.
- In ostrea, foot is totally absent .
- In some animals there is a gland on the foot.
- This will secrete a viscous substance which will harden to form a bundle of fibres known as byssus.
- Byssus is helpful for the animal to attach themselves to the foreign bodies.

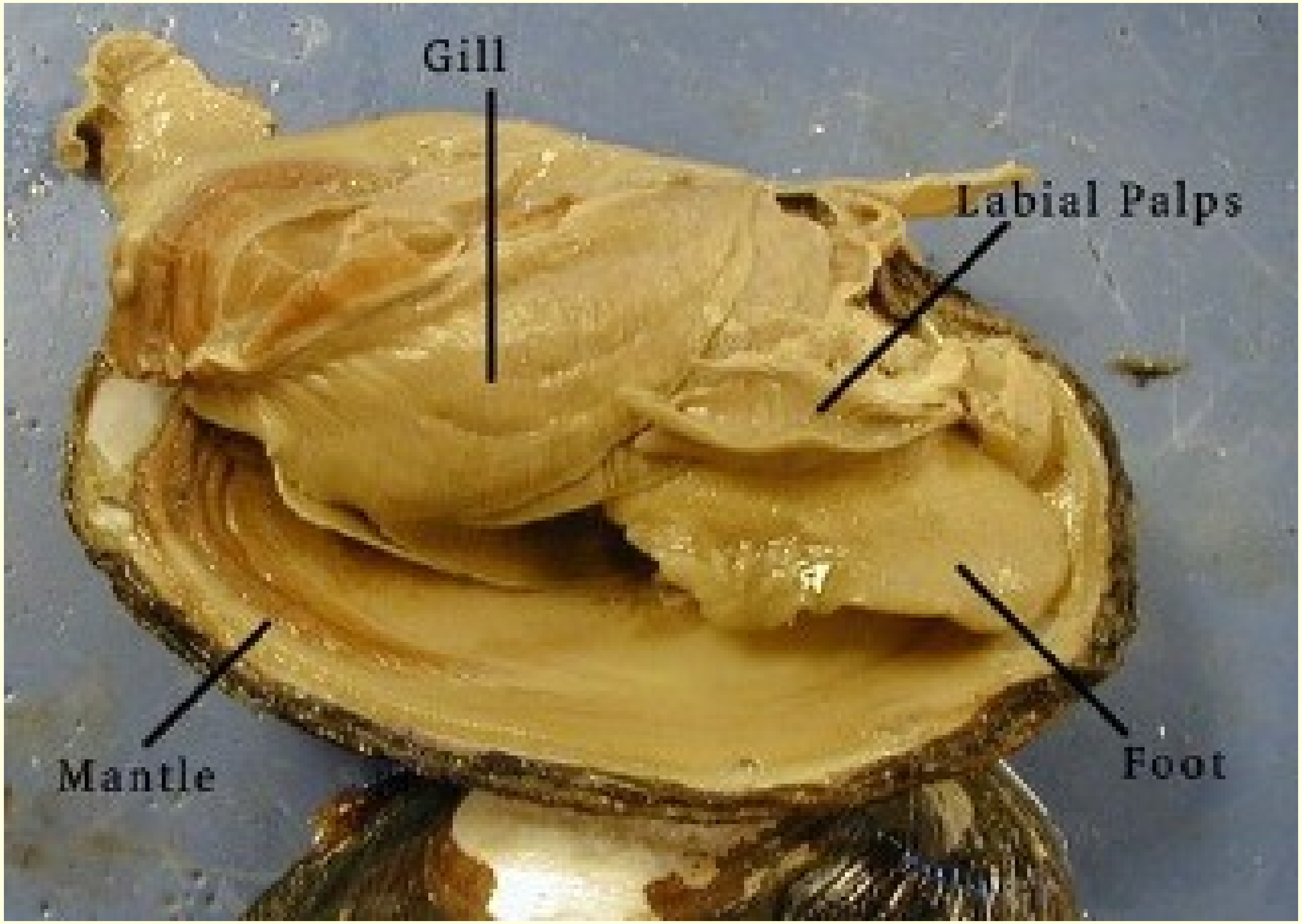
Mantle



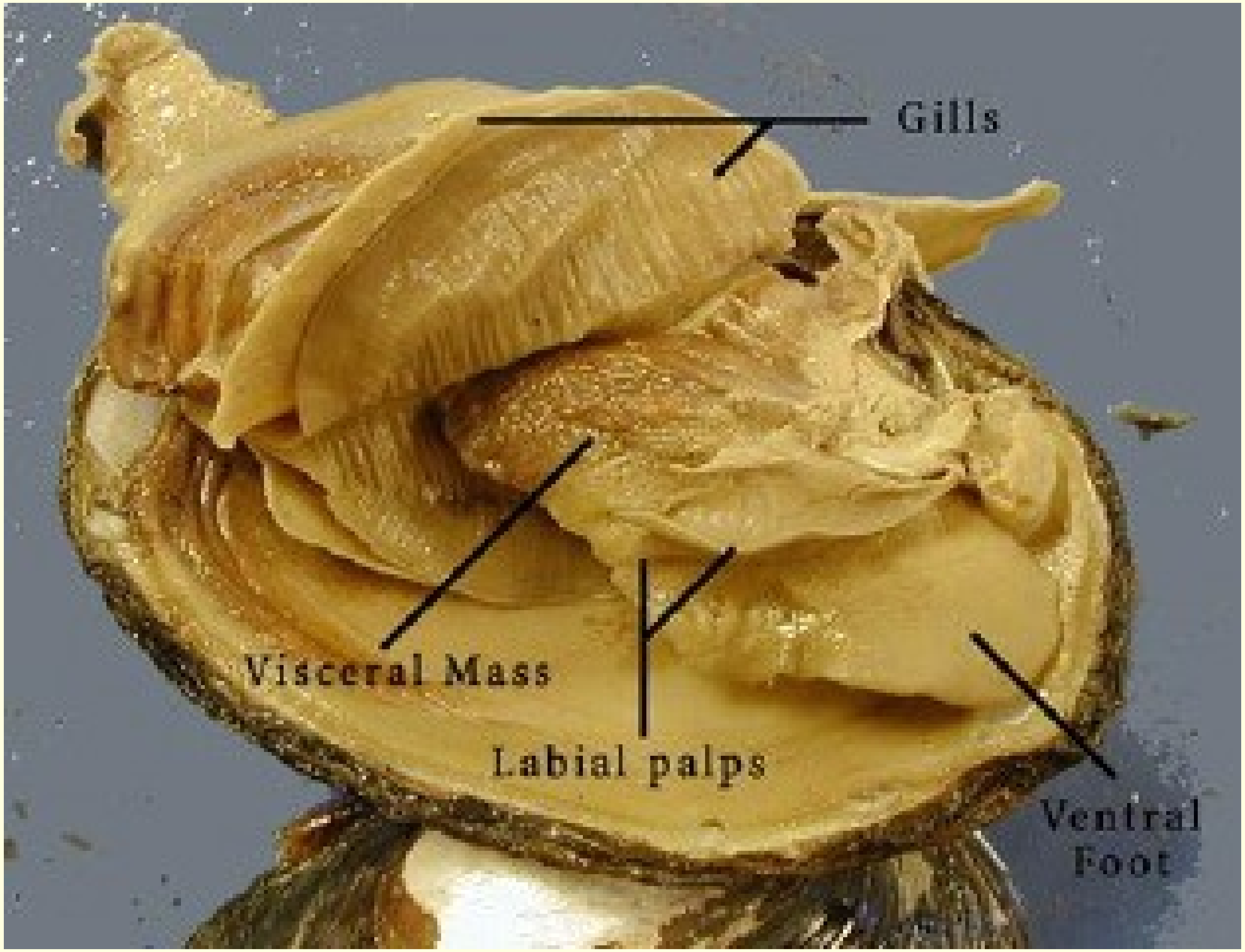
Morphology

- Respiration is by means of a pair of gills attached to the body dorsally between foot and the mantle on each side.
- The gills are plate like or leaf like. Therefore, the name Lamellibranchia meaning leaf-like gills.
- These animals do not posses head hence the class is also known as Acephala (A = absent + cephala means head).
- This class is also called as bivalvia.

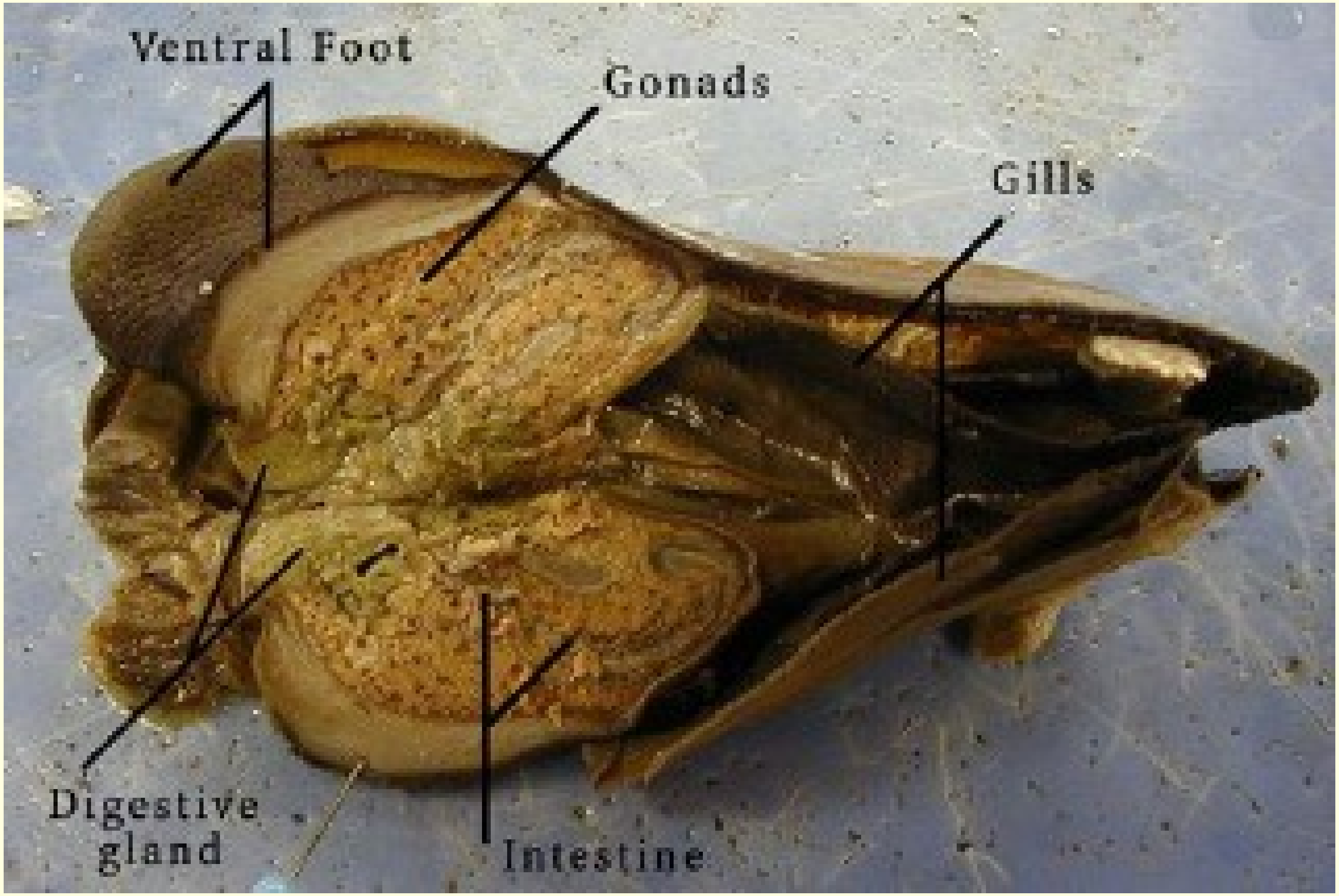
One side of mantle removed



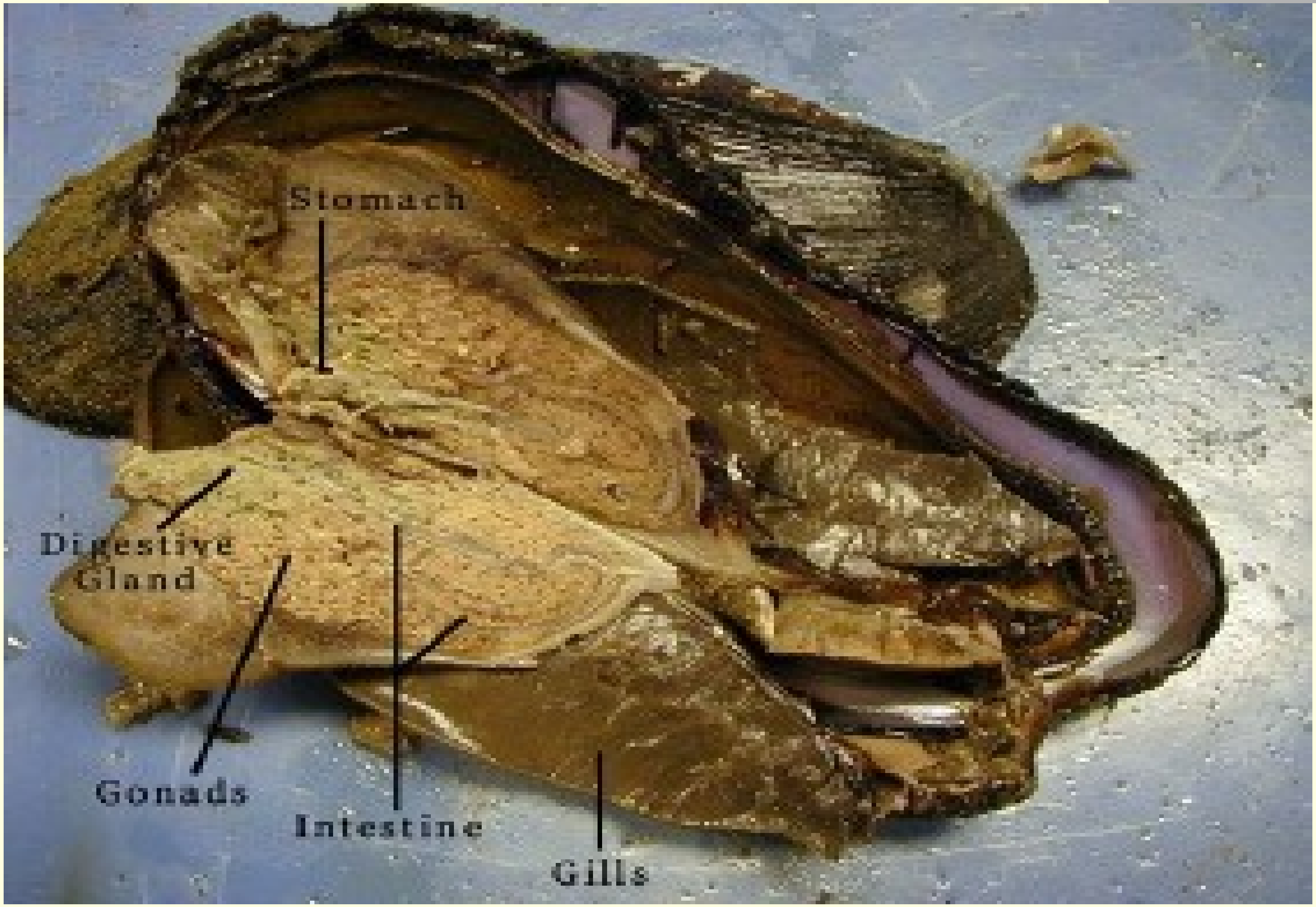
Visceral Mass



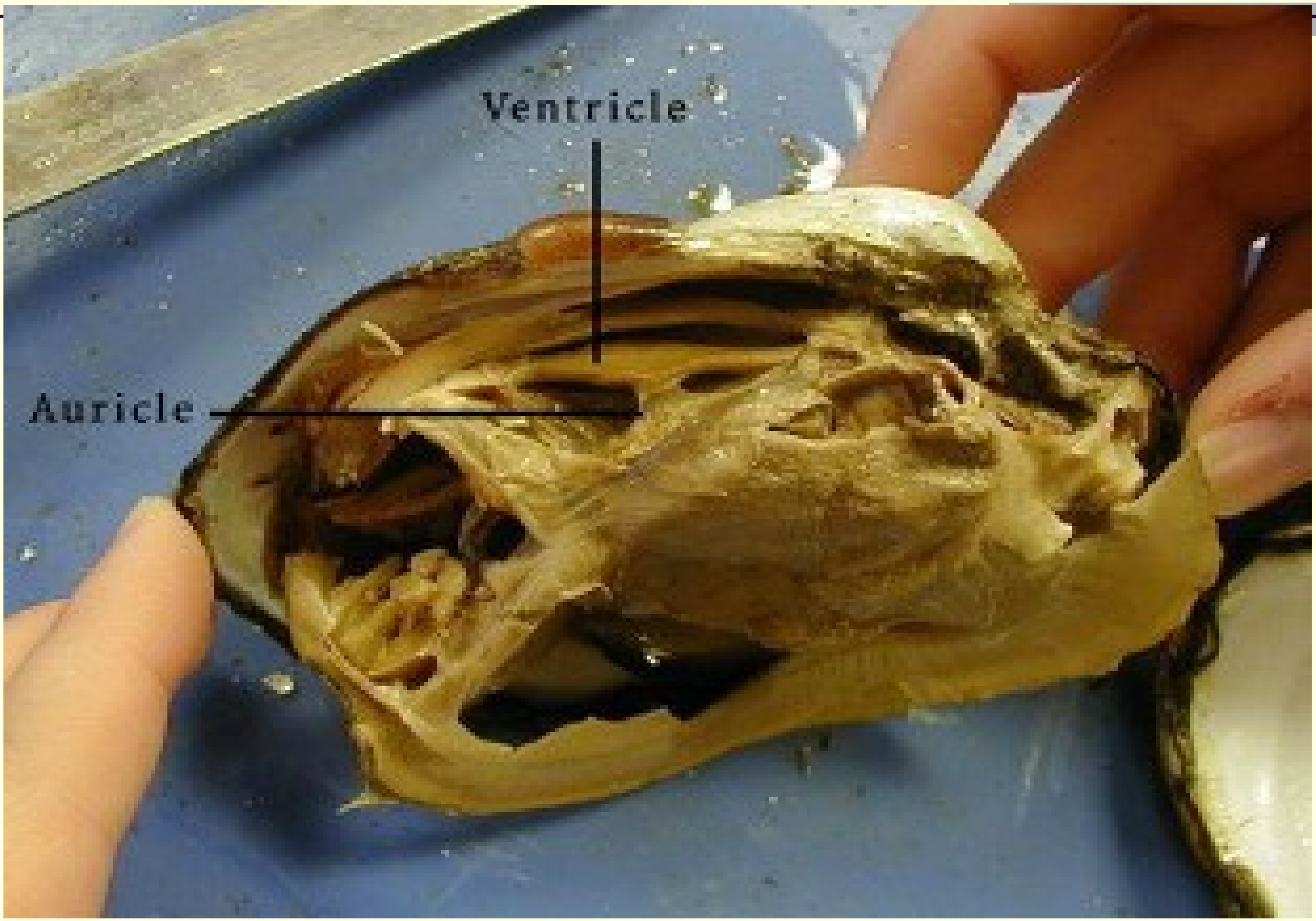
Dissected Visceral Mass (I)



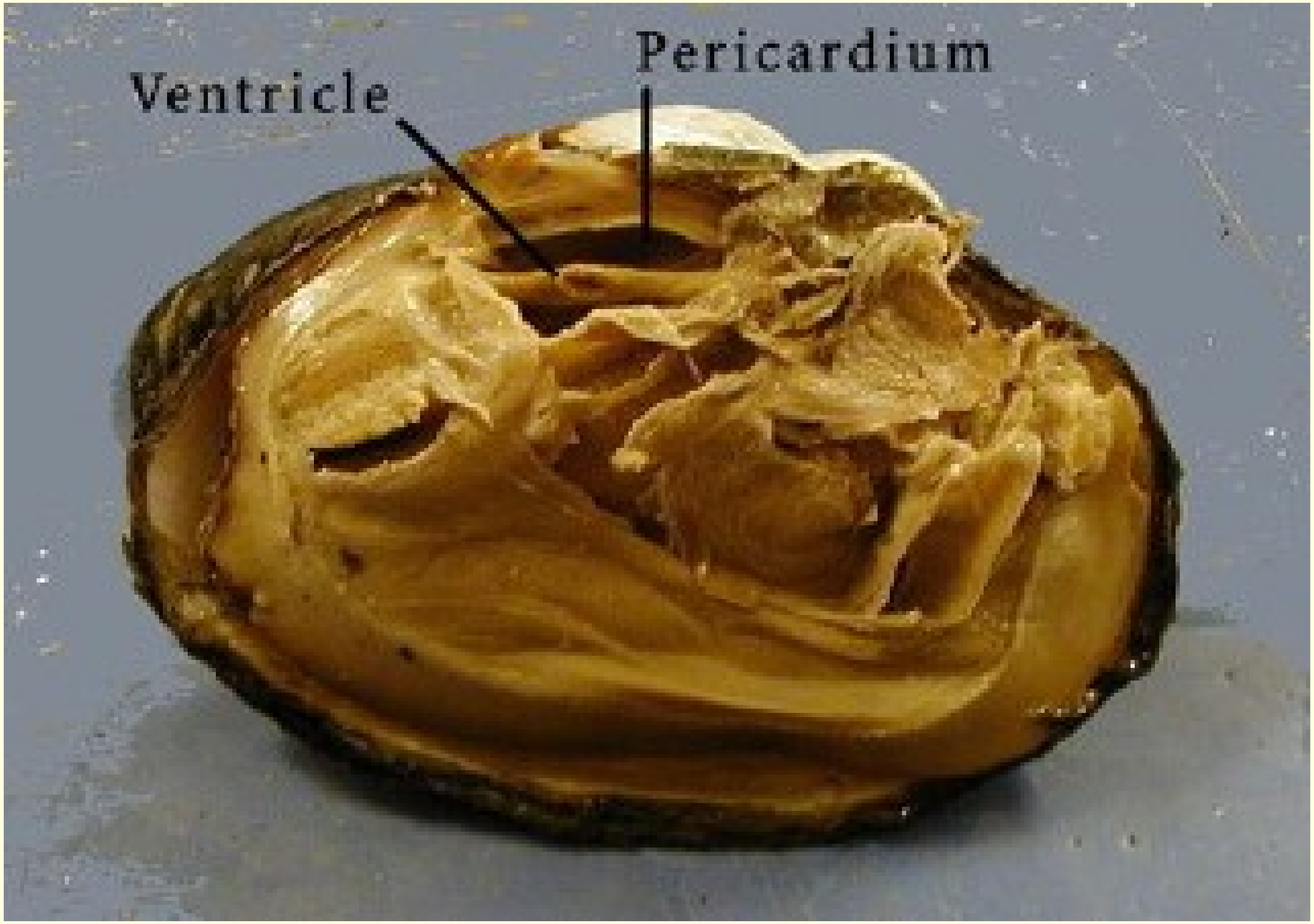
Dissected Visceral mass (II)



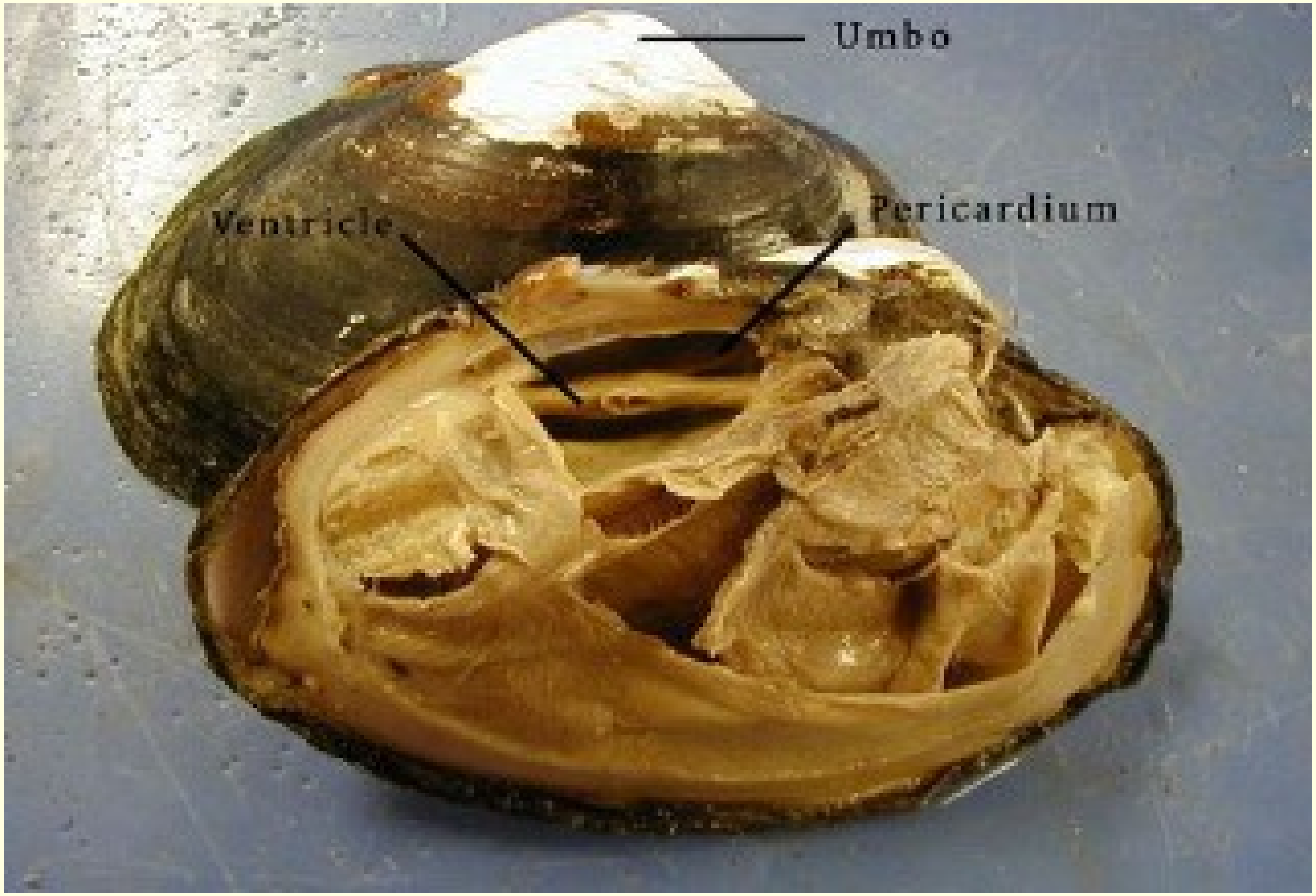
Dorsal Heart I



Dorsal Heart II



Dorsal Heart III



Morphology

- In some forms the margins of the two mantle lobes do not unite. In this case, on the posterior margin, two openings are present.
- They may be produced into lubes known as siphons. There are two siphons – inhalent or brachial siphon and exhalent or anal siphon.
- In many forms siphons can be withdrawn into the shell by means of muscles.
- The shell can be closed by means of adductor muscle which passes from interior of one valve to the other.

Adductor Muscles

- If there are two adductors, the forms are called dimyaria. E.g.Cardita, Arca etc.
- If only one adductor is present, the forms are called monomyaria, where the posterior adductor only is present.
  E.g. Pecten, Ostrea, Gryphaea.
- In the case of two adductor muscles, the posterior adductor muscle is generally large and the anterior muscle is small and this type is known as Anisomyaria.
  E.g.Mytilus.
- If both adductor impressions are equal in size, then they are called Isomyaria.
  E.g.Venus.

Muscular Impressions.

- Markings were produced by the union of the muscles - muscular impressions.
- Adductor forms oval, rounded or sometimes elongated impressions. In dimyaria, there are two depressions in each valve but in monomyaria – only one.
- Linear depression, caused by the attachment of the muscle of the mantle to the shell - pallial line.
- In some cases, the line runs between the adductors are parallel with the margins of the valve - simple or cutine pallial line.
- In others, the line which runs between the adductors, which possess retractile siphon, the pallial line bend inwards just before reaching the posterior adductor.
- This curve is known as pallial sinus.

Shell Margins

- The margin near the hinge is dorsal, the opposite where the valve open is the ventral.Near the mouth is anterior and near the siphon is the posterior.
- In majority of the cases, the two valves are generally equal or almost equal in size and is generally inequilateral.
- In some, the shell is nearly equilateral (as in Glycymeris) and in others like Ostrea, it is inequivalve.
- When the shell is equilateral, the direction of greatest growth is perpendicular to the hinge line,
- When inequilateral, the direction of growth is oblique to the hinge line.
- Each valve is regarded as a greatly depressed hollow cone, the apex of which forms the umbo or beak.
- The umbo represent the earliest formed part of the shell.

Umbo

- If the umbo is pointing towards anterior side as in Arca and Venus, it is called as Prosogyre or Prosocline.
- Umbo pointing towards posterior side as in Trigonia, is called Opisthocline or Opishtogyre.
- Umbo pointing towards each other as in Pecten, is called as acline or orthogyre.
- Sometimes anterior to the umbo, a circular depression, shared by both the valve is known as lumule.
- Similarly posterior to the umbo, an elongated biconvex depression shared by both the valves is known as escutcheon.

Ligaments &Teeth

- Opening of the lamellibranch shell is by means of the ligament -composed of horny substances , placed at the hinge margin.
- The ligament may be made up of simple layers of muscles - alvincular or multivincular ligament.
- Bundle of layers of muscles or cylindrical muscles - paravincular ligament.
- The hinge is formed by the projection – teeth.
- Seen alternate in two valves, the teeth of one valve fitting into the depression between those of the other.
- To ensure that the valves should be closed perfectly.
- The margin of the valve where teeth occur is known as hinge line.
- Generally it is curved but in some genera like arca, it is straight.

Types of Dentition

- Taxodont – Hinge line straight with numerous small similar sized and shaped teeth, radiating from the center of the valve. E.g. Arca, Glycymeris.
- Dysodont –Numerous small similar sized and shaped teeth are placed on the hinge line and they are seen to radiate from the umbo. E.g.Mytilus.
- Isodont - Two or three teeth- strong and equal size, seen in each valve on both sides of the central triangular ligamental pit. Teeth and sockets are symmetrical. E.g.Spondylus.
- Schizodont – very few, strong, thick and grooved teeth appear to diverge from the umbo towards inside of the valve. E.g.Trigonia.
- Heterodont – This dentition represents the highest development in Lamellibranchs. The teeth are few in number and are not of uniform size and shape.
- The smaller teeth occurring just below the umbo are known as cardinal teeth and the other larger teeth away from the umbo either on the posterior and anterior lateral teeth. E.g. Cardita, Venus.
- Desmodont - True teeth and hinge line are replaced by one or more smooth laminae or ridges. Developed at the higher margins. E.g.Ostrea, Gryphaea.

Cardinal area or Hinge area

- In some genera in which the hinge line straight (E.g. Arca) , there is in between the hinge line and the umbo of each valve , a flattened triangular portion of the shell known as cardinal area or hinge area .
- When area is present, umboes of the two valves are widely separated. The area is due to the more extensive growth of the hinge line.
- In some lamellibranches with a straight hinge line may have on each side of the umbo, a triangular wing like extension known as ears (E.g.Pecten)

Shell valves

- Shell of lamellibranch is equivalve (unlike brachiopods) and inequilateral (unlike equilateral in brachiopods).
- In Ostrea, Gryphaea, Exogyra, Hippurites, one valve is cup like and the other is lid like giving rise to inequivalve condition.
- A line drawn from umbo to the ventral margin divides the valve into two unequal parts giving rise to inequilateral nature. But in pecten the shell is equilateral and equivalve.

Layers of shells

- The shell is secreted by the mantle and its structure varies in different groups. Usually three layers have been distinguished.
- On the external surface – a green or bluish layer formed of horney material known as periostracum. This is not preserved in fossils.
- In the middle – is the prismatic layer, usually consists of calcite.
- Inner thin layer – of aragonite called as Naere.

Measurements

- Length of the lamelibranch is measured from anterior to the posterior margin.
- Height is measured from umbo to the ventral margin.
- The thickness is from one valve to the other at right angles to the line of length and height.

Difference from Brachiopods

- The valves are right and left instead of dorsal and ventral.
- Lamellibranchs are generally inequilateral and equivalve.
- Teeth occur in both valves.
- A ligament is present.
- Umboes are never perforated for the passage of pedicles.
- Microscopic structure of the shell is entirely different.

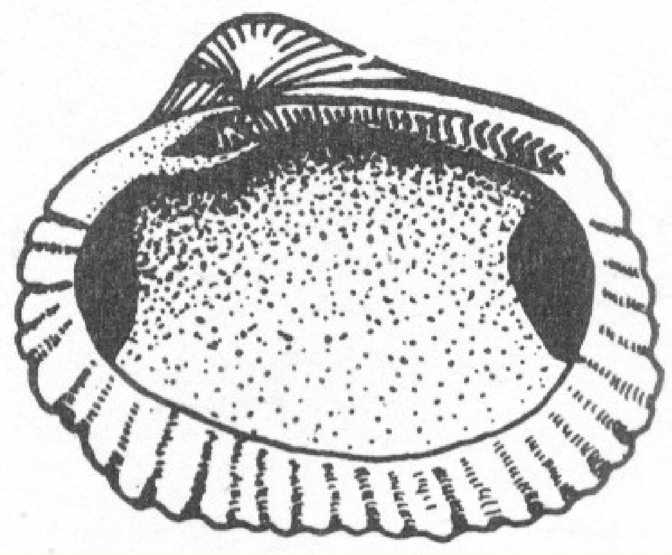
Classification

- Classification of the lamellibranches are mainly based on the characters of the hinge. Three main divisions are recognized:

  1. Taxodonta
  2. Anisomyaria
  3. Eulamellibranchia.

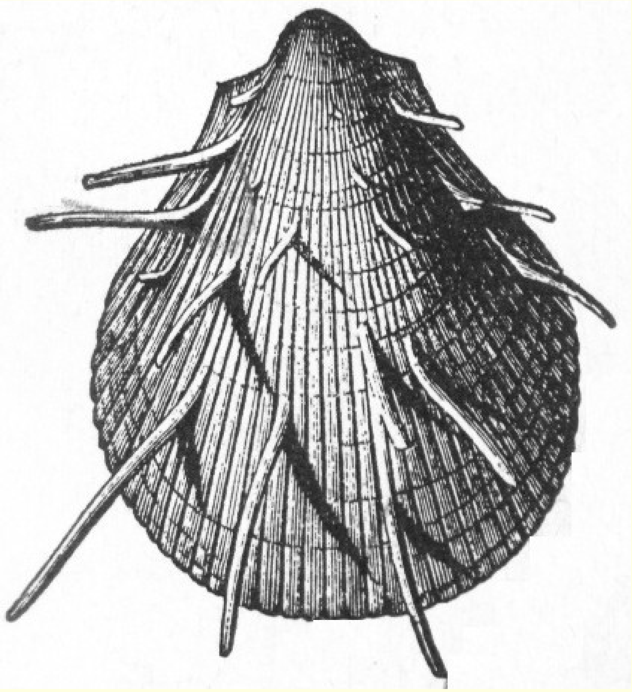
Arca

Shell equivalves, sub-quadrangular, ventricose, with a carina from the umbo to the postero-ventral angle. Surface with radiating ribs and concentric striae: margins smooth or dentate; gaping ventrally. Hinge straight, with numerous small, similar, transverse teeth. Umbones prominent, separated the large areas which have numerous ligamental grooves. Adductor impressions nearly equal, the anterior rounded, the posterior divided. Pallial line simple.



Spondylus

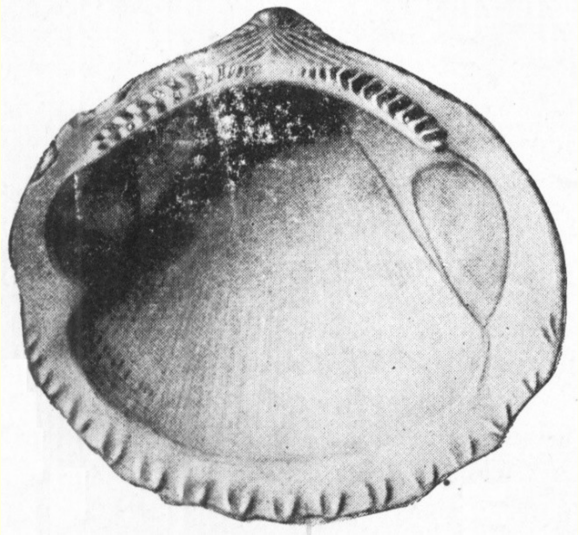
Shell irregular, with ears and straight hinge line, attached by the right valve; surface with radiating ribs which are spiney or foliaceous. Right valve larger and more convex than the left, with a triangular area. Ligament internal, in a deep triangular pit. Adductor impression large. The strong teeth in each valve fit into corresponding sockets in the other valve. Jurassic to Present Day.



Glycymeris

Shell thick, sub-orbicular, equivalve, almost equilateral. Surface smooth or radially striated. Ligament external, on the area. Umbones central, slightly curved posteriorly. Hinge arched or semicircular, with a row of numerous, small, strong, transverse teeth. Adductor impression sub-equal - the anterior sub-triangular and the posterior oval or rounded. Pallial line with very small sinus.

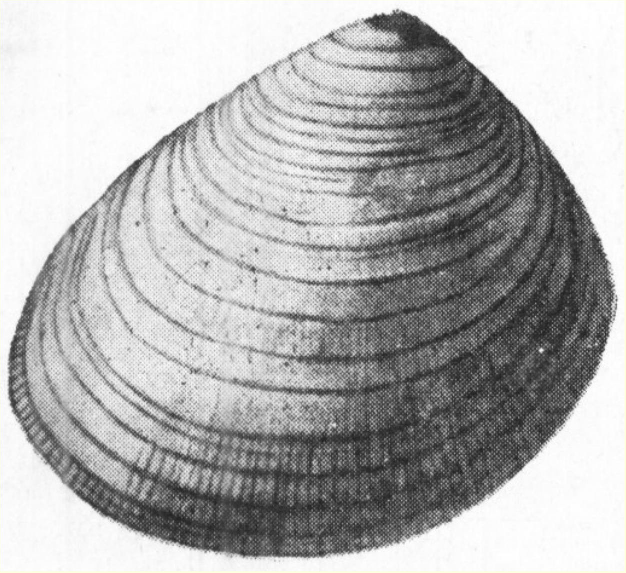
Stratigraphic Range : **Cretaceous to Present Day.**



Nucula

Shell equivalve, trigonal or oval, closed, posterior side very short. Umbones directed posteriorly. Surface smooth or with fine radial lines. Interior nacreous. Magmas of valves smooth or crenulated. Hinge line angular, with a mediun internal triangular ligament-pit, and numerous sharp teeth. Adductor impression nearly equal. Pallial line simple. The character of the hinge, the simple type of the gill strucutre.

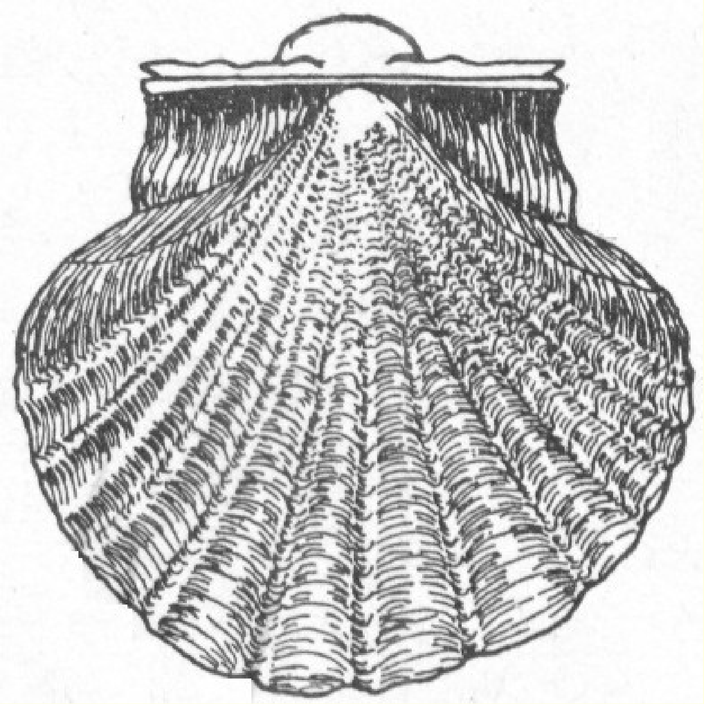
Stratigraphic Range : Silurian to Present Day



Pecten

Shell sub-circular, ovate or trigonal, closed, almost equilateral, inequivalve or nearly eqiuvalve. Surface frequently with radiating ribs or striae, sometimes smooth or with concentric ridges. Hinge line straight; with well developed ears, with or without a byssal sinus. A central, triangular pit for the internal ligament. Adductor impression large, a little excentric.

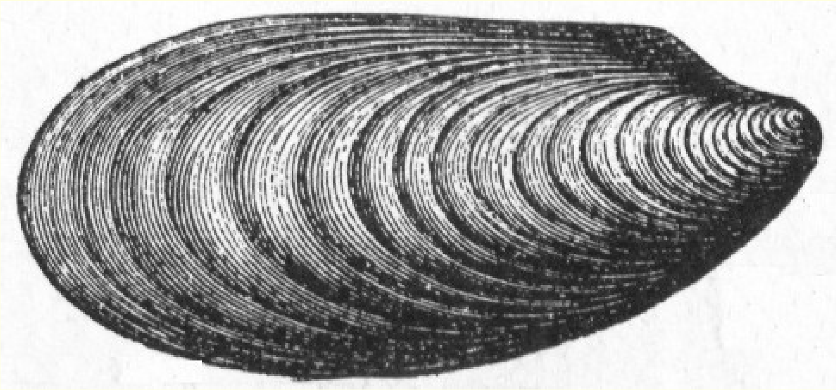
Stratigraphic Range : **Carboniferous to Present Day**



Inoceramus

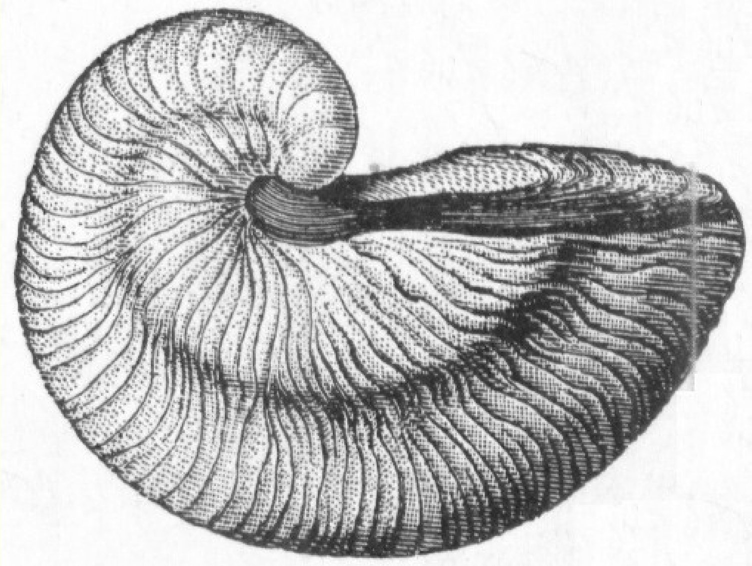
Shell variable in form, circular or oval. Inequilateral, inequivalve, ventricose or compressed, with ears indistinctly limited. Umbones prominent, rather anterior. No teeth. Surface with concentric furrows. Hinge line straight with numerous parallel, close set, transverse ligament pits. Adductor impression rarely visible. Inner layer of shell thin and nacreous, outer layer thick, formed of large prism.

Stratigraphic Range : **Upper Cretaceous**

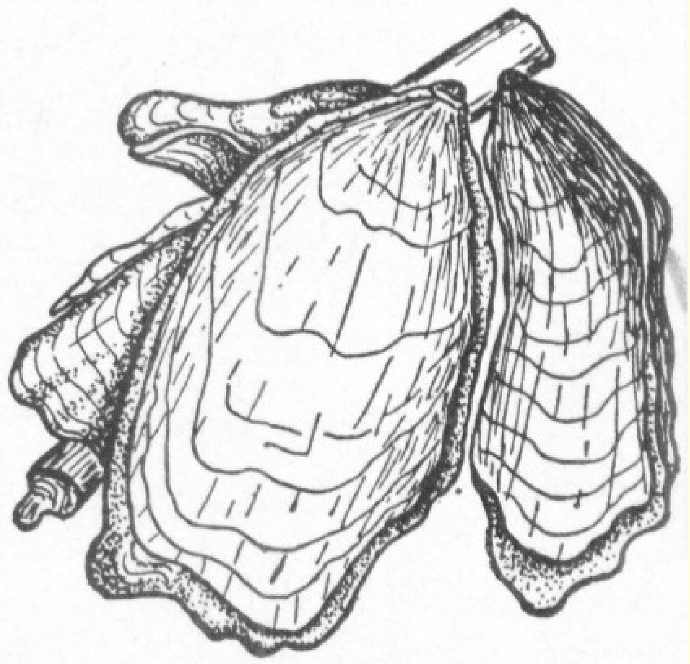


Gryphaea

Shell with lamellar structure, irregular, inequivalve, slightly inequilateral fixed by the left valve. Left valve large and convex, with a prominent incurved umbo. Right valve flattened or concave.
Stratigraphic Range : **Jurassic.**



Ostrea



Shell with lamellar structure, irregular inequivalve, slightly inequilateral, fixed by the left valve which is convex, often with radiating rib as striae. Umbo prominent, sometimes directed anteriorly, sometimes posteriorly. Right valve flat or concave, often smooth. Ligament pit triangular or elongated. Hinge short without teeth. Adductor impression sub-central; pallial line indistinct.

Stratigraphic Range : **Triassic to Present Day.**

Exogyra

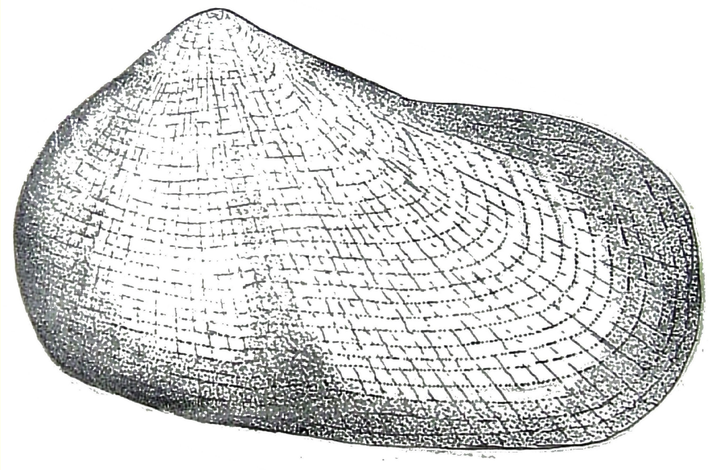
Shell with lamellar structure, irregular, inequivalve, slightly inequilateral, fixed by the left valve. Right valve flat, resembling an operculum. Umbones more or less spiral, directed posteriorly.

Stratigraphic Range : **Upper Jurassic to Cretaceous..**

Unio

Shell thick, oval or elongated, with a thin peri-ostracum. Surface smooth, tuberculate, strated, or folded. Umbones more or less anterior, often corroded. Ligament external, elongated. In right valve one or two thick, irregular teeth infront of the umbo, and a long lamellar posterior tooth; in the left valve, two long lamellar posterior lateral teeth. Anterior adductoe impression very deep, the posterior shallow. Pallial line simple.

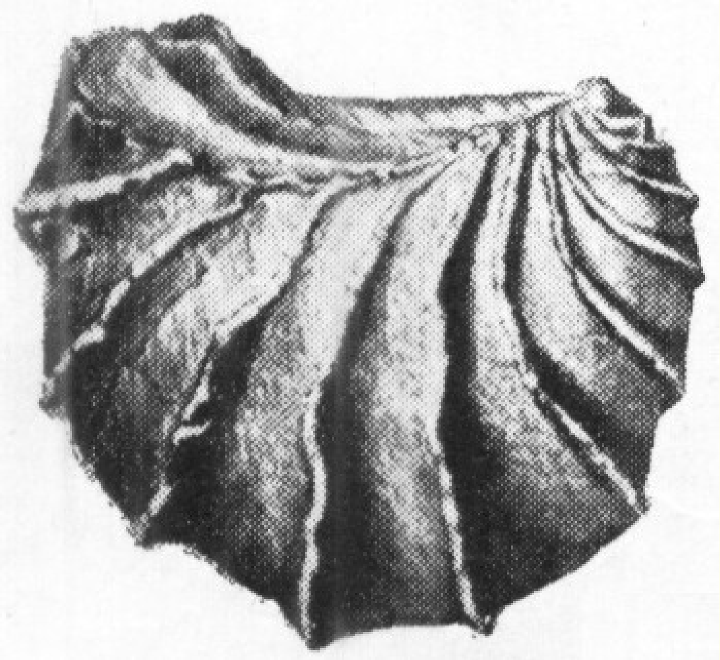
Stratigraphic Range : **Triassic to Present Day**



Trigonia

Shell thick usually ornamented with concentric rows of tubercles or with concentric ribs, trigonal, very inequilateral, anterior margin rounded, posterior produced and angular. Generally with ridge extending from the umbones to the posterior end, cutting of a portion which has a different ornamentation. Umbones anterior, directed posteriorly. Teeth strong, grooved; in the right valve two teeth diverge from below the umbo. Ligment marginal, thick. Adductor impression deep. Pallial line simple.

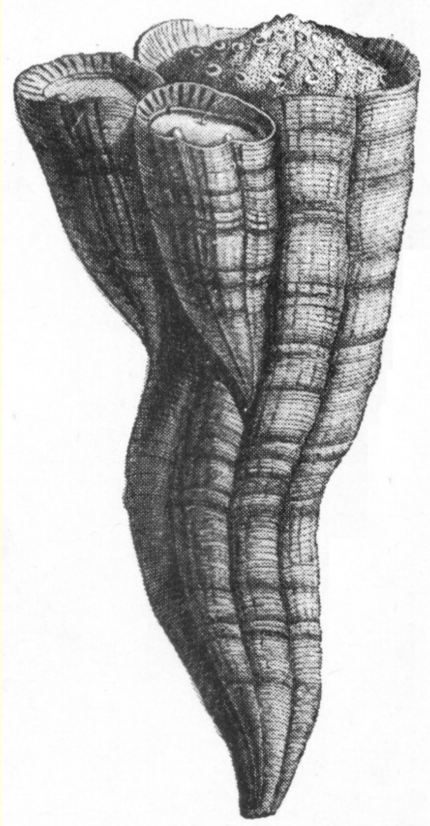
Stratigraphic Range : **Triassic to Present Day.**



Hippurites

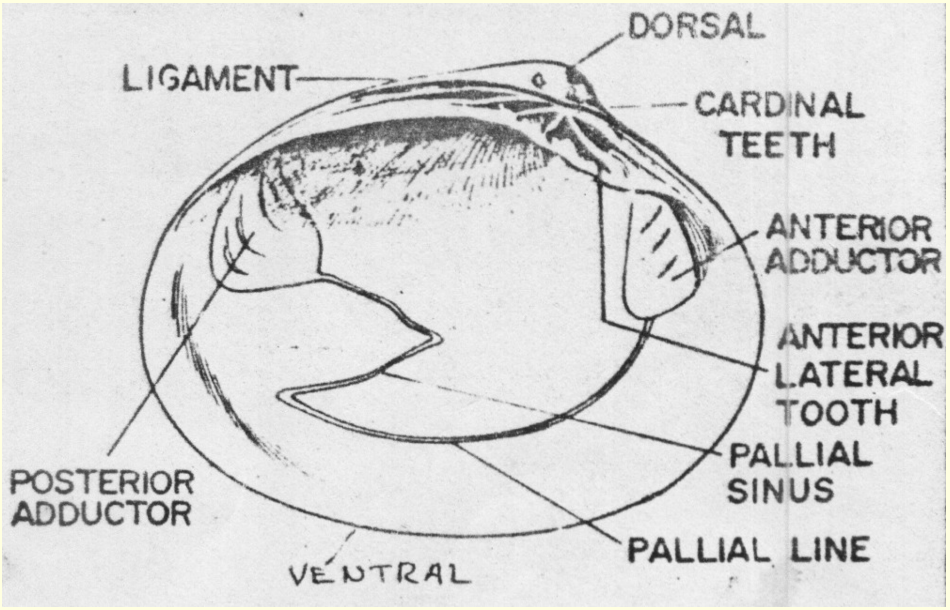
Shell very large and massive, very inequivalve, fixed by the apex of the large valve. The large valve elongated, conical, striated or smooth, with three parallel furrows extending from the apex to the cardinal margin, due to fold in the shell wall, which give rise to three corresponding ridges in the interior. Hinge consists of a small cardinal tooth and of cardinal pits. Anterior adductor impression large and divided into two separate parts.

Stratigraphic Range : **Upper Cretaceous.**



Venus

Shell thick, oval, convex, ornamented with concentric lamellae, sometimes with radial ribs: lunule distinct. Margins of valves finely crenulate. Hinge-plate thick, with three thick cardinal teeth, no lateral teeth. Ligament external, prominent. Pallial sinus short, angular. Stratigraphic Range : Miocene to Present Day.



FOSSILS:

ARCA

I. PHYLUM : Mollusca

II. CLASS : Pelecypoda

III. ORDER : Taxodonta

IV. MORPHOLOGY:

   i. Shell form: Inequilateral, equivalved.
   ii. Umbo: Prosogyral or nearly Orthogyral.
   iii. Ornamentation: Surface is ornamented with radial ribs and concentric striations.
   iv. Margin: Crenulated or dentate. Posterior margin elongated and anterior margin rounded.
   v. Hinge line: Straight.
   vi. Dentition: Taxodont.
   vii. Adductor Scars: Dimyarian and Anisomyarian.
   viii. Pallial line: Simple or Entire.
   ix. Diagnostic Features: Cardinal area present in which 'v' shaped grooves called "Chevron grooves" present. Taxodont dentition, straight hinge line.

V. AGE: Jurassic to Recent.

SPONDYLUS

I. PHYLUM : Mollusca

II. CLASS : Pelecypoda

III. ORDER : Anisomyaria

IV. MORPHOLOGY:

   i. Shell form: Equilateral, equivalve.
   ii. Umbo: Orthogyral.
   iii. Ornamentation: Surface is ornamented with concentric growth lines and spiny radial ribs.
   iv. Margin: Smooth and finely striated.
   v. Hinge line: Straight, hinge ear present.
   vi. Dentition: Isodont.
   vii. Adductor Scars: Monomyarian, Sub-central.
   viii. Pallial line: Nil.
   ix. Diagnostic Features: Isodont dentition, straight hinge line, and spiny radial ornamentation, hinge ear present.

V. AGE: Jurassic to Recent.

TRIGONIA

I. PHYLUM : Mollusca

II. CLASS : Pelecypoda

III. ORDER : Eulamellibranchia

IV. MORPHOLOGY:

i. Shell form: Trigonal, inequilateral, bivalve.

ii. Umbo: Opisthogyral.

iii. Ornamentation: A ridge extending from the Umbo to the posterior margin divides the shell into two parts with different ornamentation. The anterior portion possesses concentric growth lines as deep grooves or furrows and ridges. The posterior portion is ornamented with radiating striae.

iv. Margin: Anterior margin rounded and posterior margin angular.

v. Hinge line: Curved.

vi. Dentition: Schizodont.

vii. Adductor Scars: Dimyarian, and Anisomyarian.

viii. Pallial line: Entire.

ix. Diagnostic Features: Trigonal shape and double ornamentation.

V. AGE: Jurassic to Recent.

VENUS

I. PHYLUM : Mollusca

II. CLASS : Pelecypoda

III. ORDER : Eulamellibranchia

IV. MORPHOLOGY:

i. Shell form: Inequilateral, Oval, and Convex.

ii. Umbo: Prosogyral.

iii. Ornamentation: Ornamented with concentric growth lines.

iv. Margin: Smooth Posterior margin elongated and anterior margin rounded.

v. Hinge line: Curved.

vi. Dentition: Heterodont dentition.

vii. Adductor Scars: Dimyarian and Isomyarian.

viii. Pallial line: Pallial Sinus short angular near the posterior adductor scar.

ix. Diagnostic Features: Pallial Sinus present, Heterodont dentition.

V. AGE: Miocene to Recent.

MERETRIX

I. PHYLUM : Mollusca

II. CLASS : Pelecypoda

III. ORDER : Eulamellibranchia

IV. MORPHOLOGY:

i. Shell form: Inequilateral, Convex, Trigonal shape.
ii. Umbo: Prosogyral.
iii. Ornamentation: Surface is smooth and ornamented with concentric growth lines with coloured enamel.
iv. Margin: Smooth. Posterior margin elongated and anterior margin rounded.
v. Hinge line: Curved.
vi. Dentition: Heterodont dentition.
vii. Adductor Scars: Dimyarian and Heteromyarian.
viii. Pallial line: Pallial Sinus rounded.
ix. Diagnostic Features: Pallial Sinus rounded Heterodont dentition.

V. AGE: Cretaceous to Recent.

EXOGYRA

I. PHYLUM : Mollusca
II. CLASS : Pelecypoda
III. ORDER : Anisomyaria
IV. MORPHOLOGY:

i. Shell form: Inequilateral, inequivalve.
ii. Umbo: Opisthogyral and spiral like fashion.
iii. Ornamentation: Surface is smooth with fine lamellar structure.
iv. Margin: Smooth.
v. Hinge line: Short and curved.
vi. Dentition: Edentulus.
vii. Adductor Scars: Monomyarian, Sub-central.
viii. Pallial line: Nil.
ix. Diagnostic Features: Cahew nut shape and spiral umbo.

V. AGE: Upper Jurassic to Cretaceous.

OSTREA

I. PHYLUM : Mollusca
II. CLASS : Pelecypoda
III. ORDER : Anisomyaria
IV. MORPHOLOGY:

i. Shell form: Inequilateral, convex.
ii. Umbo: Opisthogyral.
iii. Ornamentation: Surface is ornamented with platy lamellar structure.
iv. Margin: Irregular in outline.
v. Hinge line: Short and curved. Ligament pit triangular.

vi. Dentition: Desmodont.
vii. Adductor Scars: Monomyarian, Sub-central.
viii. Pallial line: Nil.
ix. Diagnostic Features: Shell convex, ornamented with desmodont dentition.

V. AGE: Triassic to Recent.

GRYPHAEA

I. PHYLUM : Mollusca
II. CLASS : Pelecypoda
III. ORDER : Anisomyaria
IV. MORPHOLOGY:

i. Shell form: Inequilateral, convex.
ii. Umbo: Opisthogyral and incurved nature.
iii. Ornamentation: Surface is ornamented with platy foliated lamellar structure.
iv. Margin: Irregular in outline.
v. Hinge line: Short.
vi. Dentition: Desmodont.
vii. Adductor Scars: Monomyarian, Central.
viii. Pallial line: Nil.
ix. Diagnostic Features: Incurved umbo, platy lamellar ornamentation, monomyarian adductor scar.

V. AGE: Triassic to Recent.

ALECTRYONIA OR LOPHA

I. PHYLUM : Mollusca
II. CLASS : Pelecypoda
III. ORDER : Anisomyaria
IV. MORPHOLOGY:

i. Shell form: Inequilateral.
ii. Umbo: Opisthogyral.
iii. Ornamentation: Surface is ornamented with coarse angular folds.
iv. Margin: Highly crenulated with spine like projection. Posterior margin concave and anterior margin convex.
v. Hinge line: Short and curved.
vi. Dentition: Desmodont.
vii. Adductor Scars: Monomyarian, Sub-central.
viii. Pallial line: Nil.
ix. Diagnostic Features: Spinose margin.

V. AGE: Upper Jurassic to Cretaceous.

Difference between Pelecypoda and Brachiopoda

S.NO	PELECYPODA	BRACHIOPODA
1.	It consists of two valves namely right and left valve.	It consist of brachial and pedicle valve.
2.	Muscle scars are same.	Muscle scars are different.
3.	Brachial skeleton is absent.	Brachial skeleton is present.
4.	Dentition pattern present.	Dentition pattern is absent.
5.	Pedicle opening absent.	Pedicle opening is present.
6.	They are vagrant benthos.	They are sessile benthos.
7.	Shell layer consist of three layers.	It is made up of multi layers.
8.	Orientation is uniform.	Orientation differs

CONTENTS

Introduction Phylum Mollusca

- The Phylum Mollusca [Molluscum=soft bodied] includes soft bodies , triploblastic, unsegmented and coelomate invertebrate animals.
- These animals are bilaterally symmetrical and unilateral symmetry.

CLASS-GASTROPODA

- The Gastropoda [Gr. Gastros=stomach+podas=foot] is one of the main class of phylum Mollusca including snails, whelks, limpects etc.
- Some of the Gastropos are terrestrial, some are freshwater while all others are marine.

The phylum Mollusca is classified into seven classes-
But only three classes are important by the Geological overview.
They are-

- Lamellibranchia,
- Cephalopoda,
- Gastropoda

MORPHOLOGY

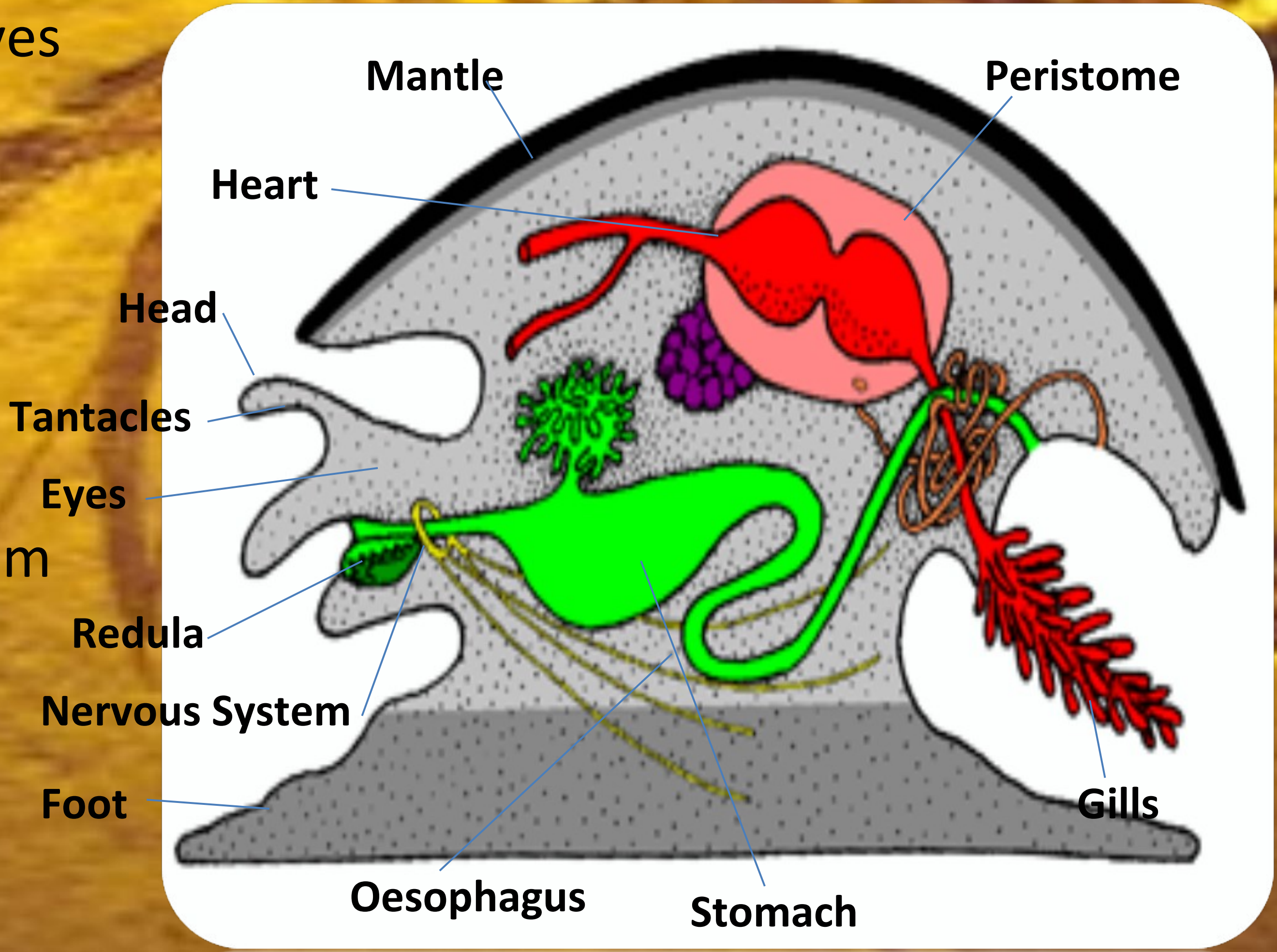
A Gastropods shell is long, conical tube like structure closed at one end open at the other end. The open anterior end is known as aperture.

Morphology of Gastropodes have been divided into two parts

- Soft parts
- Hart parts

SOFT PARTS

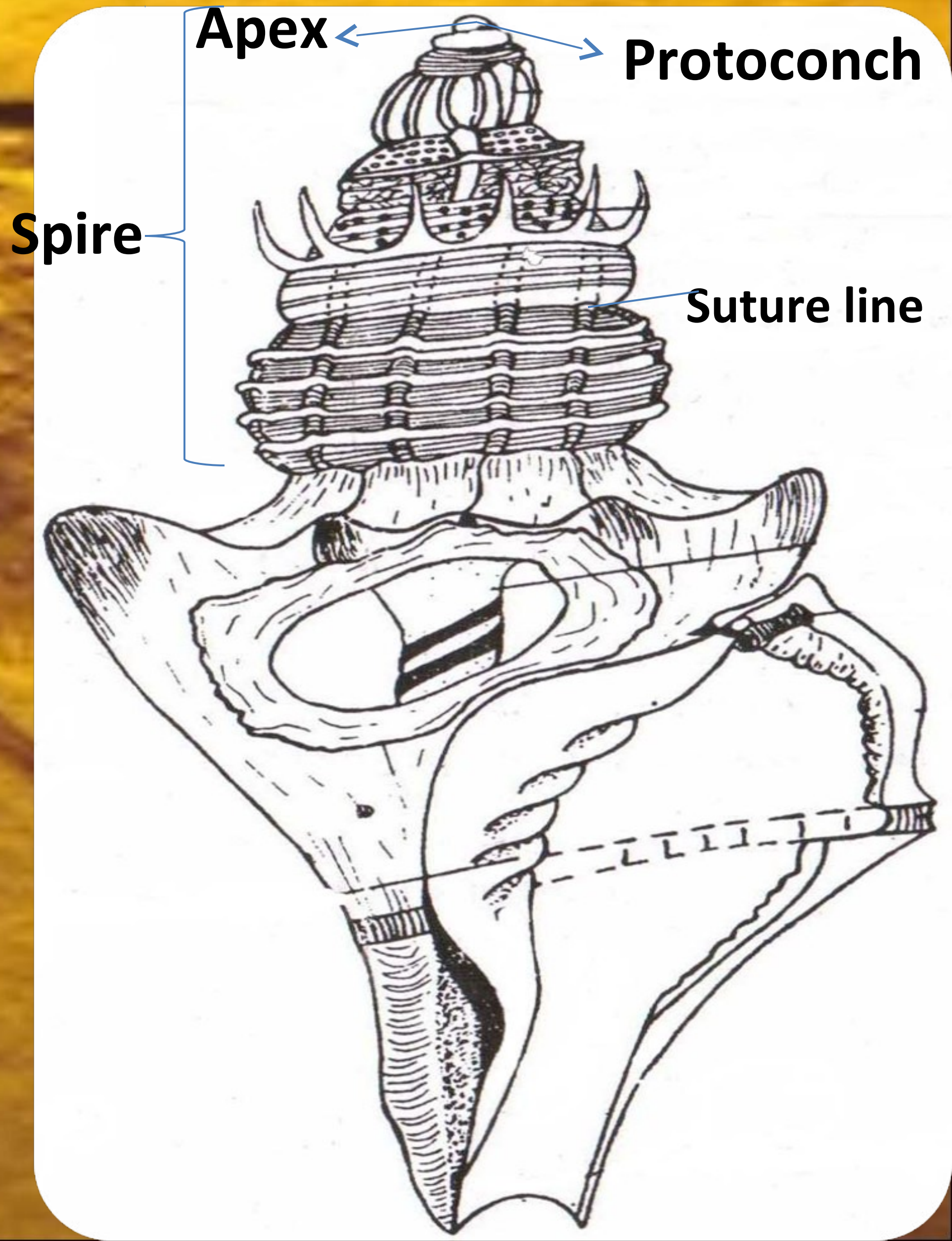
- Head with tantacles& eyes
- Mouth cavity
- Foot
- Gills or lungs
- Heart
- Peristome
- Redula
- Nervous system
- Mantle
- Oesophagus
- Stomach



HARD PARTS

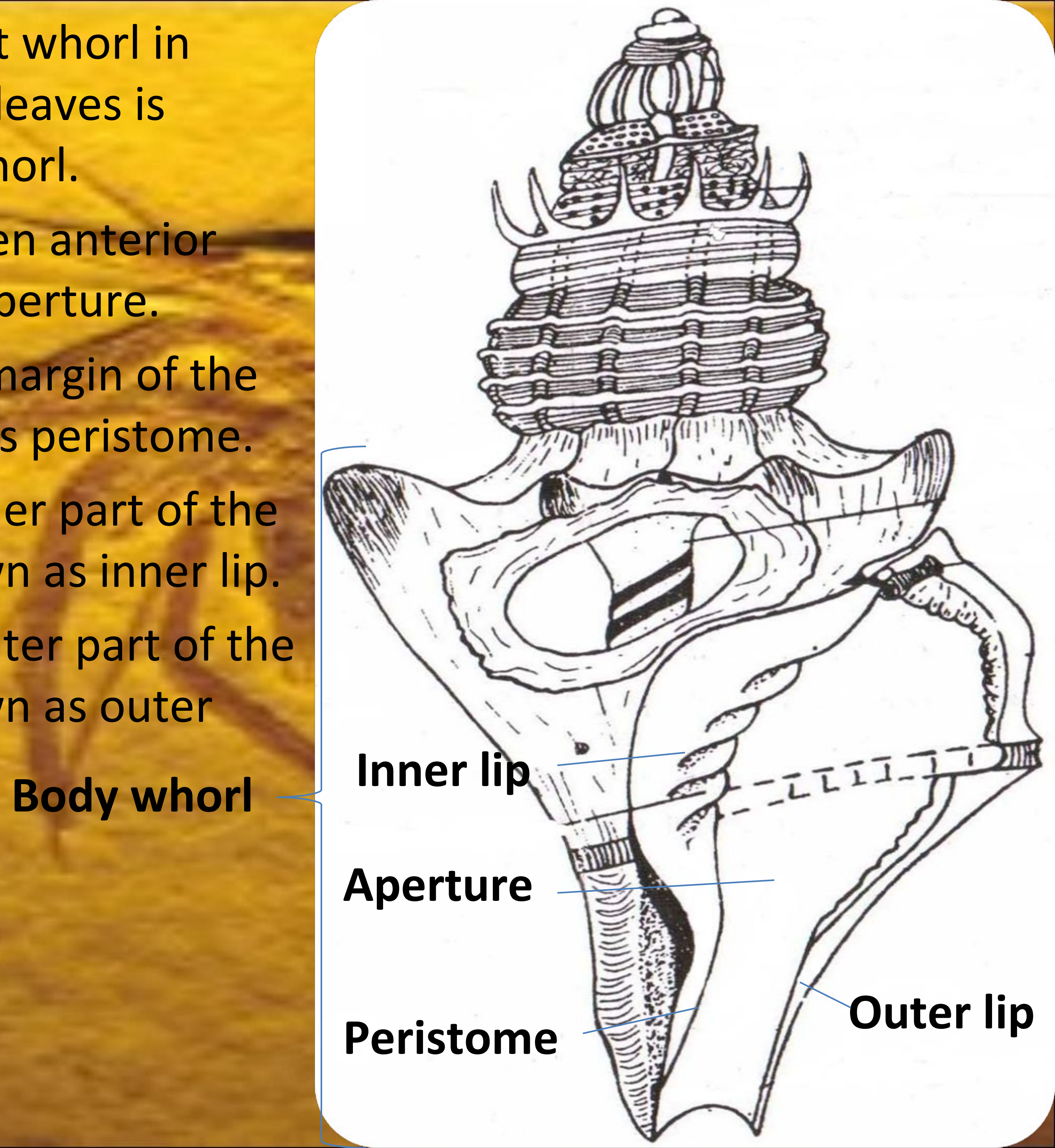
1. **Spire**-All The whorls except the last whorl constitute the spire of the shell.

- **Protoconch**- The closed posterior end is known as protoconch.
- **Suture line** – The whorls are separated by a slight depression which is known as the suture.
- **Apex**- The terminal whorl of the spire forms the apex.

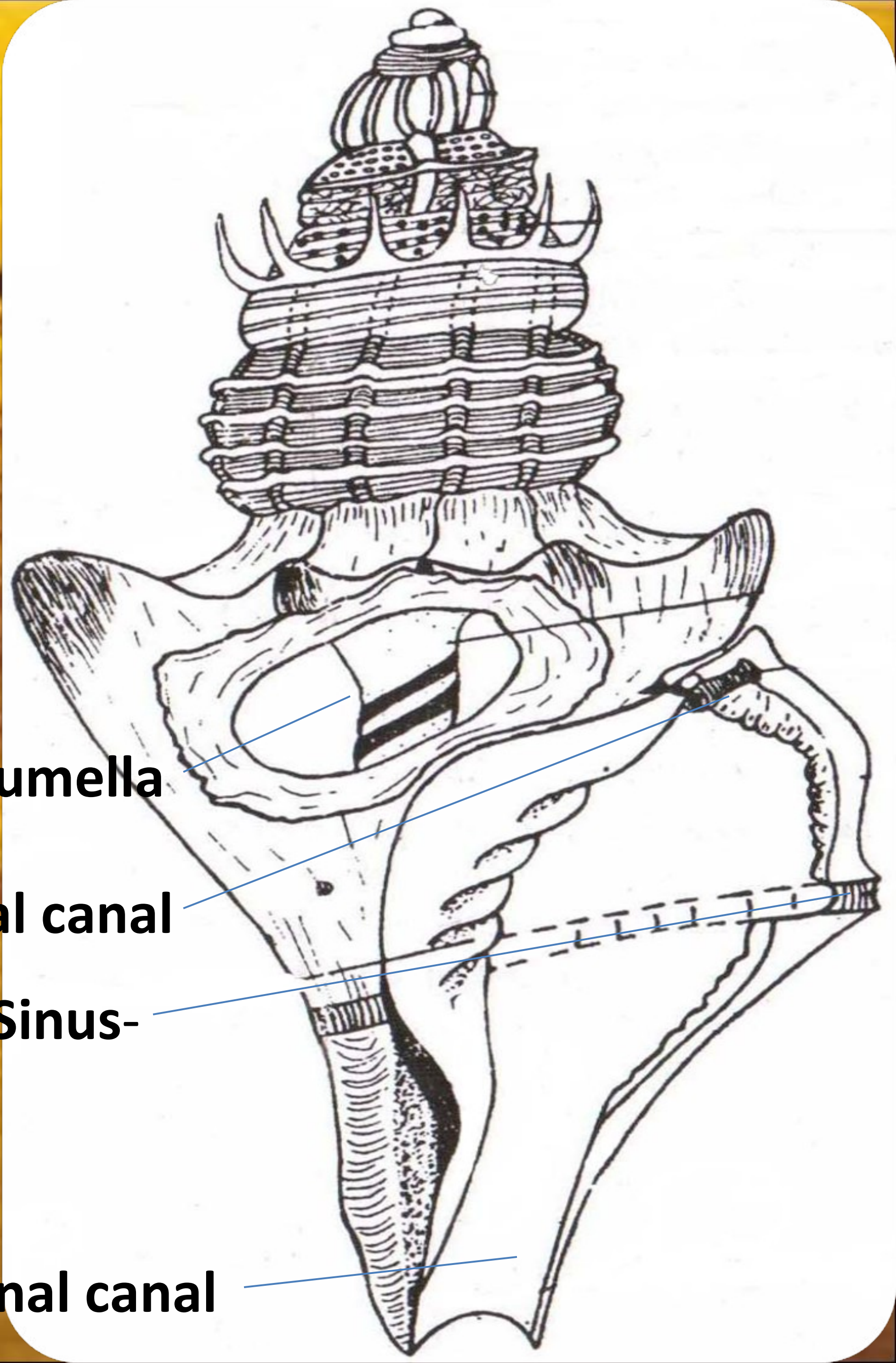


2.Body whorl- The last whorl in which the animal leaves is known as body whorl.

- **Aperture-** The open anterior end is known as aperture.
- **Peristome** – The margin of the aperture is term as peristome.
- **Inner lip** – The inner part of the peristome is known as inner lip.
- **Outer lip** – The outer part of the peristome is known as outer lip.



- **Columella**- A central pillar like axis extending form apex to the base of the shell called as columella.
- **Siphonal canal**- The anterior tube is the anterior or siphonal canal .
- **Anal canal**- The posterior tube is the posterior or anal canal.
- **Operculum**- The aperture of the shell may be covered by a plate known as operculum.
- **Sinus**-



ORNAMENTATION

Two types of ornamentation present in Gastropoda they are- Spiral and Transversive ornamentation.

- **Spiral**-parallel to suture line, includes ***pitted sculpture*** and ***raticulate sculpture*** .
- *Transversive-It* includes ***axial coastae***,***smooth sculpture***, ***spine***, ***spiral coastae***.

FORMS OF THE SHELL

- The forms of the shell depend on the –
  - Spire angle,
  - Number the whorl
  - Shape of the whorl
  - Size of the last whorl

The following are the forms of the shell.

1. ***Discoidal***-The shell is planispirally coiled. The whorls are in one plane so that the entire arrangement can be seen. ex- *Planorbis*.

2. ***<u>Trochiform</u>***- The spire is sharp and acute. the whorl in the spire increase in diameter gradually. The body whorl is small and the base of the shell is flate. ex-*Trochus*.

3. ***<u>Turbinate</u>***- The spire is sharp and acute. the whorl in the spire increase in diameter gradually. The base which is convex. ex- *Turbo.*

4. ***<u>Turreted-</u>***The spire is long with numerous whorls and acute sharp apex. The body whorl is very small. ex-Turritella.

5. ***<u>Cylindrical</u>***-After gradual increase in the diameter of the spire, the diameter remains containt or it may reduce near the base. ex-*Voluta.*

6. ***Globular***-The spire is small and sharp. The body whorl is large and round with round aperture. *ex-Natica.*

7. ***<u>Fusiform</u>***-The shell is spindle-shaped. The body whorl is thick in the middle and tapering near the bottom and the top. ex- *Fusinus*.

8. ***Convolute***-The last whorl of the shell covers all the previous whorls. The aperture, with crenulated outer lips, is a long as the shell. ex-*Cypraea*.

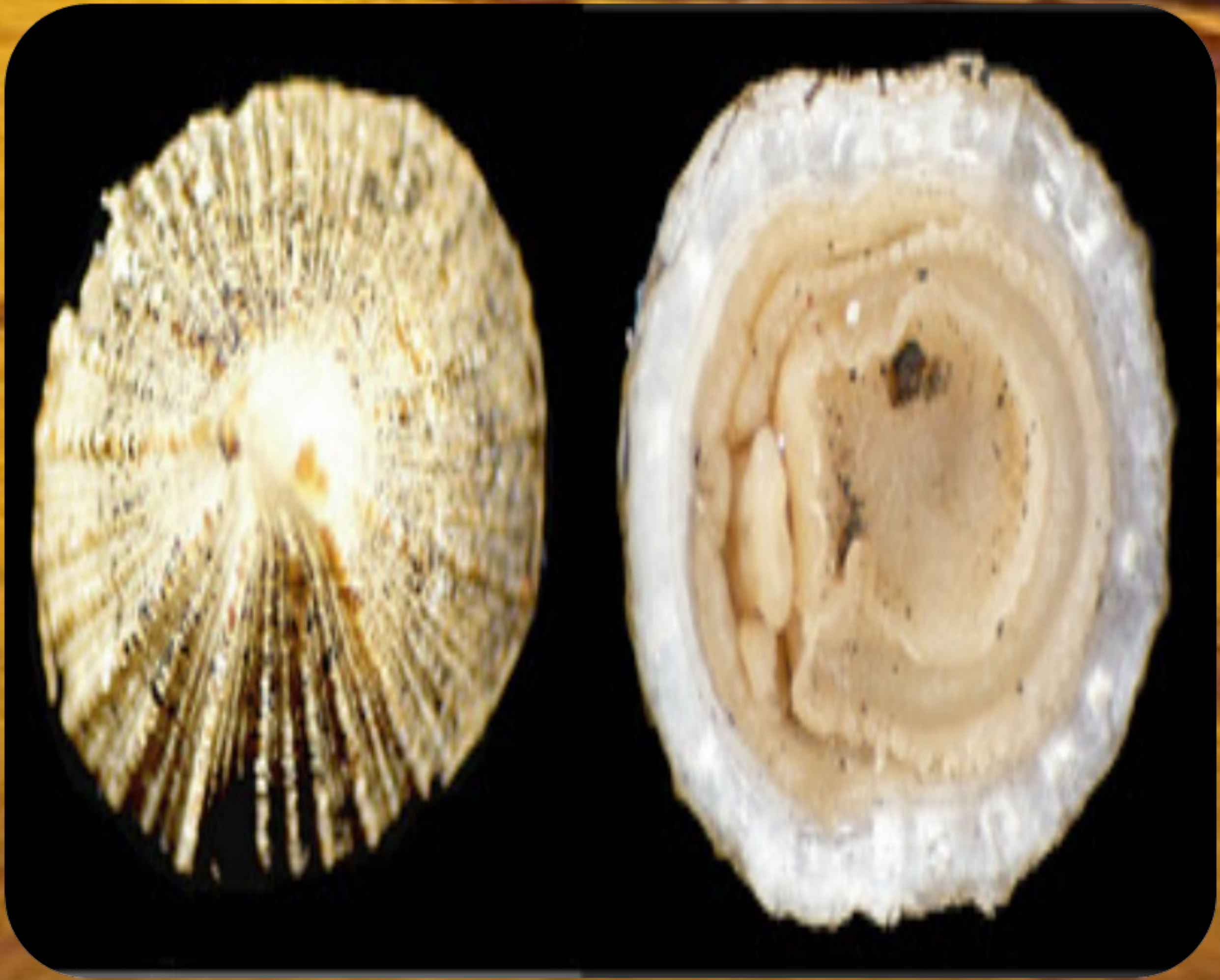
9.***Auriform***-The shell has very short spire and the aperture is very large. Ex-H*aliotis*.

10. ***<u>Conical</u>***-The spire is short, apex is sharp, the body whorl is large. conical with parallel lips. ex-*Conus.*

11. ***Vermiform***-the shell is worm like and twisted.

Ex-*vermicularia*.

12. ***Patelliform***-The apex is sharp and shell is cap like. *Ex-patella*.



13. ***<u>Pupaeform</u>***-the apex is convex and rounded, whorl increase in size in spire, all whorl are uniform in diameter and the aperture is rounded. *Ex-Pupa*

EVOLUTIONARY TRENDS IN GASTROPODES

- The evolutionary trends in Gastropoda are both progressive and retrogressive.
- Uncoiled simple cap shaped shale started developing helicoids coiling; planispiral coiling was restricted to pelagic forms while helicoid coiling observed in benthonic forms.

PROGRESSIVE ADAPTATION DUE TO MODE OF LIFE IN GASTROPODA INCLUDE-

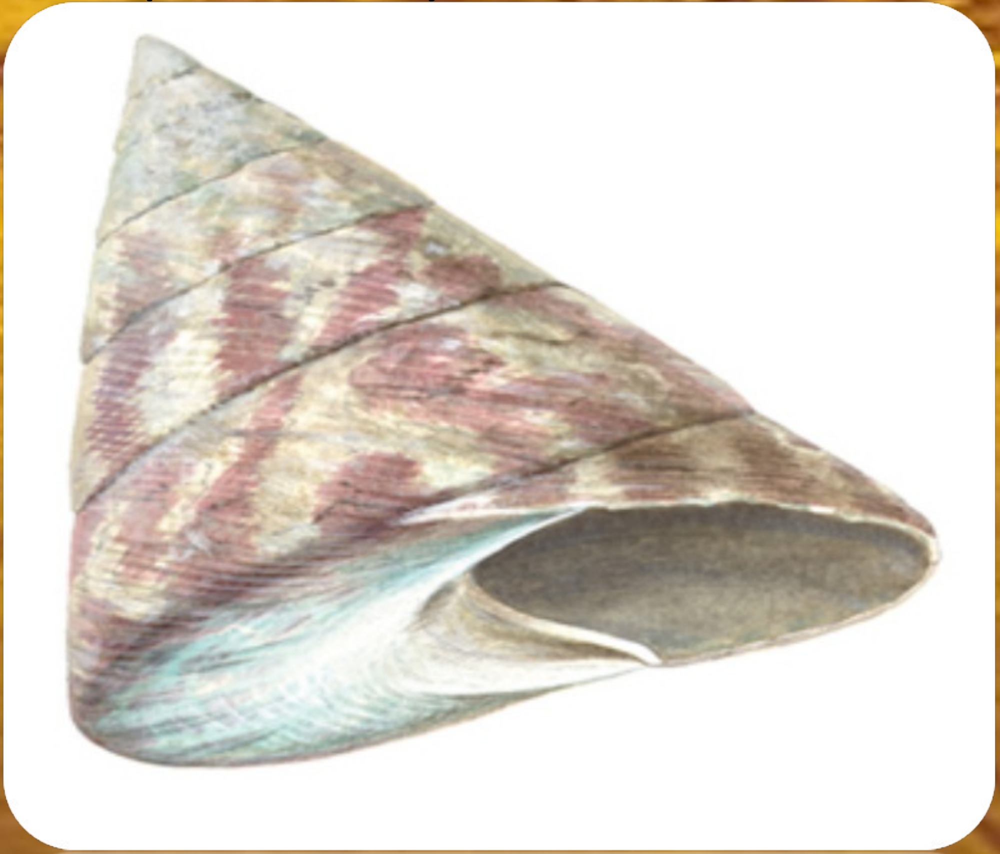
- 1. increase in tightness of coiling.
- 2. increase in evolution of the apex with respect to the last whorls,
- 3. development of discoidal shell,
- 4. increase in the size of the whorls,
- 5. development of trochiform and biconical shells,
- 6. development of fusiform shells,
- 7. modification around the aperture,
- 8. development of loss of ornamentation and
- 9. loss of operculum.

SOME IMPORTANT FOSSILS-

- **Dextral forms-**

  1***. Trochus***-Trochiform Shell, smooth spire, sharp apex.

Age-Triassic to present day.



2. ***Turbo***- Turbinate shell. Age-Jurassic to present day.

3. ***Turitella***-long, turreted shell, long spire, sharp apex, small body whorl. Age-cretaceous to present day.

5. ***<u>Natica</u>***- shell globular, small and sharp spire, large body whorl, round aperture umbllicus present. Age- Trias to present day.

6.**Cyprea**-convolute shell, outer whorl covers all other whorls, lips crenulated. Age-Eocene to present day.

7. <u>***Conus***</u>-conical shell, short flat spire, long body whorl, lips parallel. Age-Upper cretaceous to present day.

8***. Voluta***- short spire, cylindrical shell, long aperture. Age- Eocene to present day.

9.***Murex***- Shell with nodes, spine, large whorls, long aperture.
Age- Eocene to present day.

- **Sinistral forms-**

1. Plaorbis- discoidal shell.

Age – Jurassic to present day.

2.Physa- short spire, globular body whorl, helicoid coiling.
Age-Intertrappeans.

FOSSILS:

PHYSA

I. PHYLUM : Mollusca

II. CLASS : Gasteropoda

III. ORDER : Pulmonata

IV. MORPHOLOGY:

i. Shell form: Globular.

ii. Spire: Medium spire angle, limited whorls.

iii. Suture: Inclined.

iv. Body whorl: Large.

v. Aperture: Sub-oval.

vi. Peristome: Holostomatous.

vii. Umbilicus: Present.

viii. Ornamentation: Smooth.

ix. Coiling: Sinistral.

V. AGE: Triassic to Recent.

TROCHUS

I. PHYLUM : Mollusca

II. CLASS : Gasteropoda

III. ORDER : Prosobranchiata

IV. MORPHOLOGY:

i. Shell form: Trochiform.

ii. Spire: Medium, numerous whorls, spire angle may be 60°-120°.

iii. Suture: Inclined.

iv. Body whorl: Small.

v. Aperture: Sub-circular.

vi. Peristome: Holostomatous.

vii. Columella: Present.

viii. Ornamentation: Surface is smooth with distinct growth lines.

ix. Coiling: Dextural.

V. AGE: Triassic to Recent.

TURRITELLA

I. PHYLUM : Mollusca

II. CLASS : Gasteropoda

III. ORDER : Prosobranchiata

IV. MORPHOLOGY:

i. Shell form: Turrilitic cone.
ii. Spire: Long, numerous whorls, acute spire.
iii. Suture: Inclined.
iv. Body whorl: Small.
v. Aperture: Oval shape.
vi. Peristome: Holostomatous.
vii. Columella: Present.
viii. Ornamentation: Spiral ribs and striations.
ix. Coiling: Dextural.

V. AGE: Cretaceous to Recent.

FUSUS

I. PHYLUM : Mollusca
II. CLASS : Gasteropoda
III. ORDER : Prosobranchiata
IV. MORPHOLOGY:

i. Shell form: Fusiform.
ii. Spire: Numerous whorls, acute spire.
iii. Suture: Inclined.
iv. Body whorl: Large.
v. Aperture: Oval with elongated anterior siphonal canal and posterior sutural canal.
vi. Peristome: Siphonostomatous, outer lip inflected and inner lip reflected.
vii. Columella: Present.
viii. Ornamentation: Spiral ribs and striations.
ix. Coiling: Dextural.

V. AGE: Cretaceous to Recent.

Reference

- *Dr. P.C. Jain*
- *Dr. M.S. Anantharaman*
- *H.S. Woods*

PHYLUM – MOLLUSCA

CLASS - CEPHALOPODA

- **They are highly organized than other molluscs .**
- **They are equipped with highly developed eyes and other sensory organs.**
- **They had an efficient method of locomotion.**
- **The term Cephalopoda obviously refers to the arrangement of the pedal tentacle about the head. Hence the name Cephalopoda meaning head footed.**

- They are exclusively marine animal and started their life from Cambrian.

- Present day forms include the cuttle fish and nautilus.

- The extinct types cephalopods are Belemnites, Ammonoids and Goniatites.

- They are bilaterally symmetrical freely moving Molluscs. Typically possessing a univalve shell divided into several chambers.

The Cephalopodes are divided into three subclasses or orders

1. Nautiloidea,
2. Ammonoidea,
3. Coleodea Dibranchia

Order Nautiloidea

- **Nautiloids are the oldest of the Cephalopodes and may have provided the ancestral stock from which the Ammonoidea and Dibranchia were derived.**

- **Most of them all extinct, the several of the Nautiloids in the tropical region of Asia give us an opportunity to examine the anatomy of the primitive Cephalopods.**

- The shell is always external and consists of a tube which tapers to a point at the end and may be straight, arched or spiral.
- In the spiral form the whorls may be separated or in contact through out.
- Commonly the shell is helicoids spiral.
- In plani-spiral coiling the whorls are in one plane.

- **The anterior of the shell is divided into a number of chambers by means of transverse partitions called *Septa*.**

- **The chambers usually increase in size towards the aperture of the shell.**

- **The body of the animal occupies the last chamber and called as *body chamber*.**

- **All the chambers except the last chamber or body chamber are gas filled.**

- **The shell grows by addition of materials at the margin of the aperture.**

- **After certain period the body of the animal moves forward and a new septum is secreted behind it.**
- **In nautilus the last air filled chamber is somewhat smaller than the proceeding one.**
- **All the chambers are transverse by a small cord like prolongations of the posterior end of the body containing arterics and known as *Siphuncle*.**
- **The position of the siphuncle varies in different genera.**

. In nautilus, it pierces the septa at or near the centre

- **in others it may be near to either external or internal margin of the whorl.**
- **It commences from the first chamber as a closed tube.**
- **In many fossil nautiloids, the siphuncle is completely replaced by a calcareous tube.**

•Septa are often prolonged in the form of funnel around the siphuncle. These funnels are termed as *Septal Neck*.

•In all the nautiloids, the septal necks are directed backwards.

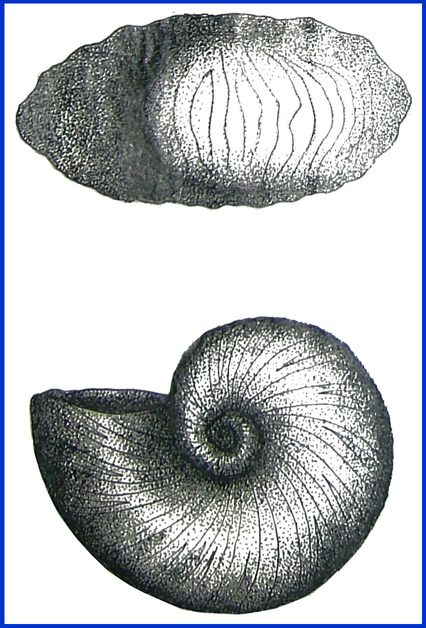
•The aperture of the shell has in some cases a simple margin, straight or slightly curved. In nautilus there is a sinus at the extreme margin and the lines of growth on the shell are correspondingly curved.

- **The lines were the edge of the septum touches the wall is known as the *Suture line*.**
- **The suture line can be seen only when the shell is removed.**
- **Fossil form occurring as cast shows the suture lines clearly.**
- **The simple form of the suture line is the chief characteristics feature in nautiloidea.**
- **The shell which covers the embryo in the cephalapoda is known as the *Protoconch*. It may have different forms in different genera.**

Orthoceras :- Shell straight or occasionally slightly curved. Transverse section circular. Septa concave. Suture line straight. Siphuncle cylindrical and central.

Age - Late Cambrian to Triassic.

Nautilus :- Shell more or less globose, spiral, whorls few, coiled in one plane, body chamber much larger than proceeding one. Aperture simple with an external sinus, septa concave, suture line more or less undulating. Siphuncle central. Septal neck short and directed backwards. Surface of the shell smooth or ornamented with striae.



Distribution of Nautiloids

- At present, nautiloids are represented only by few species like nautilus found in Indian Ocean and East Indian Archipelago.
- They lived in benthonic shallow water condition.
- They first appeared in Upper Cambrian period and their number increased during Ordovician and Silurian periods.

- **Earliest forms were having highly curved shells but later o the shell become straight or slightly curved.**
- **Between Devonian and Carboniferous periods, the decline of the nautiloids started.**
- **During Permian only Orthoceras and Nautilus continue to Present Day.**

Order Ammonoidea

- Ammonoids are the most important member of stratigraphically among the cephalopods.
- They become extinct completely after Mesozoic.
- The structure of ammonoid shell is very similar to that of nautiloidea.
- The shell is usually coiled in plani spiral but in some forms the shell is partially uncoiled or wounded into helicoids spiral.

- In ammonoids the suture line shows complicated pattern
- The siphuncle is at the margin of the shell, generally near to the outer margin
- The septal neck is usually directed forward except in some of the earliest chamberss.

Suture lines in Ammonoidea

- The main distinguishing feature of ammonoid is the fom of suture line, which is the line of intersection of septa to the outer shell wall.

- It may be remembered that in the case of nautiloids, the suture is simple, smooth

- But in ammonoids it is sinus, because the other part of each septum are filled or plicated.

- **The suture line become more complicated during the evolution of ammonoids.**

- **The form of suture line constitute the important diagnostic character in the identification**

- **The portion of the suture line which are convex towards the mouth of the shell is termed *Saddle.***

- **The intervene portion is termed as the *Lobes***

- The saddles and lobes form some secondary foldings, resulting a dendriculate appearance of the suture.
- They are nearly similar on both the sides of the shell.
- Commonly there is an external lobes at the external margin
- Then the superior and inferior lateral lobes on the side of the whorl and near the inner margin.

- **The saddles are also arranged in the similar manner**
- **Prominent lobes that arises in some shell from the subdivision of the first lateral saddle or lobes are termed as *Adventitious saddle and lobes.***

The suture line ammonoids are primarily grouped into three baisc types

1. **Goniatite suture**

- **Consists of simple lobes and saddles.**
- **The individual lobes saddles are not further divided**
- **This type of suture line is mostly characters the Palaeozoic ammonoids.**

Eg: Goniatite – Middle Carboniferous

2. Ceratite suture

- **This is characterised by smooth, rounded saddle and much divided lobes.**
- **Ammonoids with ceratite type suture lines are known to have appeared first in the Carboniferous and persisted upto until the Triassic**

2. Ammonite type of suture

- This suture have both the saddle and lobe were mutely divided in some varieties.
- Shell with ammonite type suture line appeared first in Permian and disappeared in with the extinction of ammonid in general at the close of the Cretaceous.

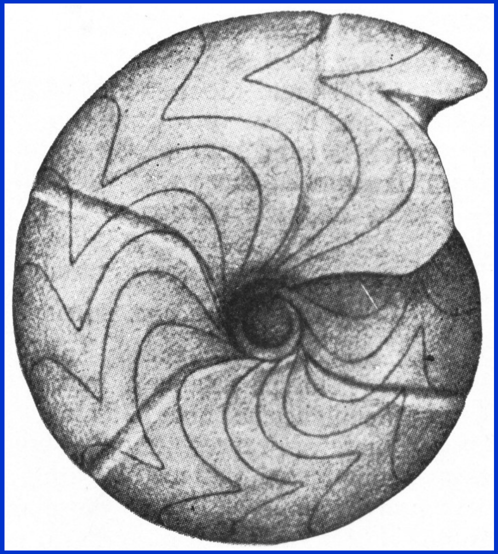
- The actual function of these minute folding in the septa of the ammonoid shell is not clearly understood.
- it is believed that the in the septa enabled ammonoids to resist high hydrostatic pressure on the shell.
- The surface of the shell amy be smooth or ornamented with striae, ribs, tubercles or spines
- Ornamentation is more developed in the Mesozoic than the Palaeozoic genera.

- **In some ammonids the external margin of the shell is provided with a ridge or keel and in these forms the ribs of the two sides are not continuous**
- **Many ammonoids possess an operculam (aptychus) by which they could close the aperture when they are retreated into the shell since in many genera, this is of calcite.**

Goniatite

Shell smooth or striated, whorls generally wide and embracing, with rounded external margins. Umbilicus small or closed. Septal neck short, directed backward but usually with a small part projecting forwards. External lobe divided by a small saddles. External saddle narrow, lateral lob angular or deep. Lateral saddle broad, rounded and undivided.

Age: Middle Carboniferous.



Ceratite

Shell discoidal, on the sides are ribs which often bears tubercles near the umbilical and external margins, margin broad, convex or flattened. Umbilicus moderately large, body chamber short. Saddles rounded, lobes denticulate. External lobes broad and short.

Phylloceras

Shell smooth or with fine striae or gentle folds, never with tubercles. External margin rounded, umbilicus very small or closed. Saddle and lobs numerous, saddles divided, the extremities being rounded.

Age : **Jurassic to Cretaceous.**

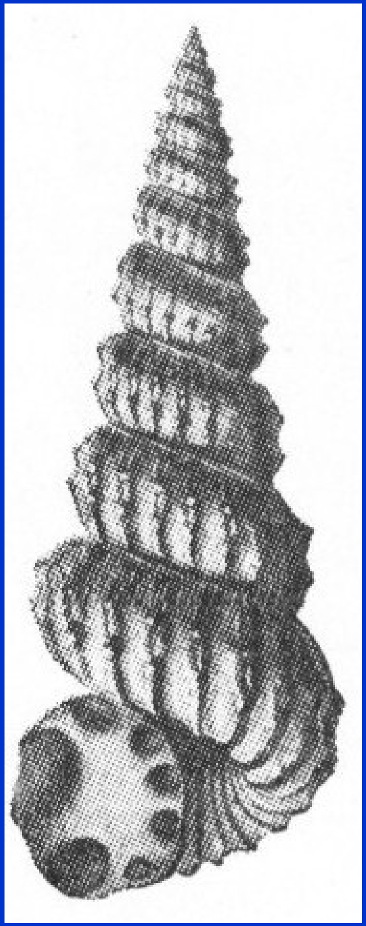
Schloenbachia

Shell with small umbilicus, external margin has smooth. Surface has strong ribs and tubercles and lobes. The shell superficially resembles to a gasteropode but distinguished in fact that the former is chambered.

Turrilites

Shell helicoids-spiral, turreted, usually sinistral. All the whorls are in contact, surface ornamented with transverse ribs or tubercles.

Age : **Middle and Upper Cretaceous.**



Acanthceras

Whorls thick, umbilicus large, ribs simple or bifurcated, with rows of tubercles at the sides and margin. External margin broad with a median row of tubercles. Saddle broad.

Age : Cretaceous.

Baculites

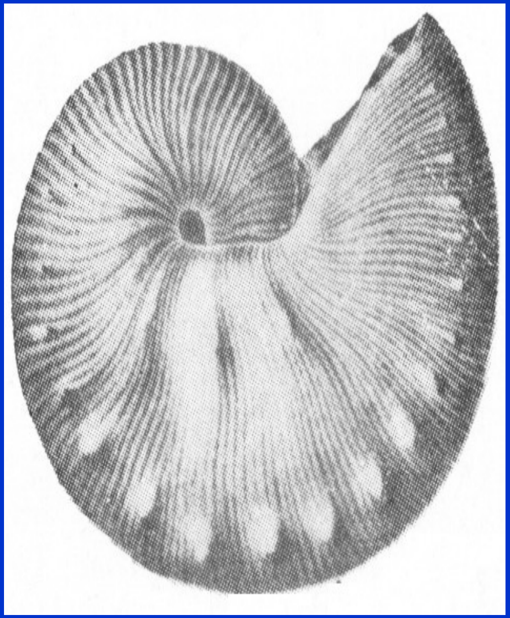
Shell straight, but the first formed part i.e. the apex is spiral, elliptical in section; suture line with the lobes symmetrically divided.

Age : Upper Cretaceous.

Scaphites

Shell coiled in a plane spiral; the whorls in contact and embracing, except the last, which is free from the spiral and then recurved in the form of a hook. Surface ornamented with bifurcated ribs which often bear tubercles. Suture line generally much divided.

Age : **Cretaceous.**



Geologic Distribution

- The earliest representative of ammonoids are found in Lower Devonian and later in Cretaceous

- The ammonids constitute valuable index fossil for the stratigraphic studies due to various reasons.

- They evolved quickly and split into a large number of genera, each having limited stratigraphic range.

- **Most of them are free swimmers and had wide ecological tolerance and hence they were quickly and widely distributed geographically.**
- **They are relatively more commonly fossilised and easily identified because of their distinct characters.**
- **Because of all these factors, ammonids are used as dependable index fossils especially for marine Mesozoic strata.**

- **Another important ammonoid is that some of the specific genera among them are known to provide illustrative examples of the ‘Biogenetic Law’, ‘Ontogeny recapitulates phylogeny’, when the shell of a particular individual of ammonoid is studied.**

- **The earliest sutures are relatively simple ones.**

- **but as successively the later sutures studied, they are found to be advanced in complexity.**

- **In many specific genera, this change towards complexity is due to the evolutionary development.**

Order Dibranchia

- **Living form of dibranchia is Cuttle fish**
- **They are much less important geologically than ammonoids and nautiloids.**
- **The only common fossil form is Belemnites**
- **It comes under suborder *Decapoda***
- **Belemnites consists of shell of three parts**

Belemnites consists of shell of three parts

1. The Guard or Rostrum
2. Phragmocone
3. Pro-ostracum

- The guard is small solid and is much more commonly preserved than the other parts

- It varies considerably in size and shape being cylindrical, conical or fusiform

- The end which was directed away from the mouth is always pointed and at the other end there is a conical cavity called *Alviolus*

- The guard varies in length from 1 to 15 inches

- When sliced transversally or longitudinally it is seen to be formed of number of layers arranged concentrically around an axial line

- The layers become somewhat thicker towards the pointed end and thinner towards the broad end of the guard

- Each layer is formed of minute prisms of calcite which are placed perpendicular to the axial line, thus produce a radiating fibrous appearance in cross section

- The surface of guard may be smooth or granular

- The phragmocone is a hollow cone part which fit into the alviolus at the broad end of the guard

- **It is divided into number of chambers by transverse septa which are concave in front**
- **At the pointed end of the phragmocone, there is a globular or ovoid prtotoconch formed of calcareous materials.**
- **In well preserved specimen, the upper part of the belemnites is produced in front into a large lamellar expansion. This prolongation is termed as *Pro-ostracum***

- **The head of the belemnites is in front of the pro-ostracum**

- **Stratigraphic range of belemnites is from Jurassic to Cretaceous and are especially abundant in argillaceous beds.**

FOSSILS:

CERATITE

I. PHYLUM : Mollusca
II. CLASS : Cephalopoda
III. ORDER : Ammonoidea
IV. MORPHOLOGY:
    i. Shell form: Conispiral or Discoidal.
    ii. Coiling: Evolute.
    iii. Umbilicus: Large.
    iv. Body chamber: Small.
    v. Aperture: Simple and elongated.
    vi. Siphuncle: Cylindrical, placed at the external margin.
    vii. Ornamentation: Ornamented with ribs, nodes, Tubercles, costae, bifid.
    viii. Suture: Ceratitic (rounded saddles and dentate lobes).
V. AGE: Triassic.

NAUTILUS

I. PHYLUM : Mollusca
II. CLASS : Cephalopoda
III. ORDER : Nautiloidea
IV. MORPHOLOGY:
    i. Shell form: Planispiral or Globular.
    ii. Coiling: Convolute / involute .
    iii. Umbilicus: Small.
    iv. Body chamber: Larger than other whorls.
    v. Aperture: Simple with an external sinus.
    vi. Siphuncle: Dorsal margin.
    vii. Ornamentation: Smooth.
    viii. Suture: Nautilitic (slightly undulating).
V. AGE: Triassic to Recent.

GONIATITE

I. PHYLUM : Mollusca
II. CLASS : Cephalopoda
III. ORDER : Ammonoidea
IV. MORPHOLOGY:
    i. Shell form: Globose.

ii. Coiling: Involute .
iii. Umbilicus: Small.
iv. Body chamber: Large.
v. Aperture: Simple with deep external sinus.
vi. Siphuncle: At external margin.
vii. Ornamentation: Surface is smooth.
viii. Suture: Goniatitic (rounded saddles and angular lobes).

V. AGE: Permo-carboniferous.

ACANTHOCERAS

I. PHYLUM : Mollusca
II. CLASS : Cephalopoda
III. ORDER : Ammonoidea
IV. MORPHOLOGY:
   i. Shell form: Conispiral or Coiled.
   ii. Coiling: Involute .
   iii. Umbilicus: Sealed.
   iv. Body chamber: Large.
   v. Ornamentation: Ribs two rows at the periphery.
   vi. Suture: Ammonitic.

AGE: Cretaceous.

BELEMNITES

I. PHYLUM : Mollusca
II. CLASS : Cephalopoda
III. ORDER : Coeloidea
IV. MORPHOLOGY:
   i. Shape: Cigar shaped.
   ii. Parts: Three parts namely (1) Phragmocone (2)Guard or Rostrum (3)Pro-ostracum.
   iii. Phragmocone: It is a chambered shelly cone. The chamber is formed by septa. Septa necks are retrosiphonate. Siphuncle is at the ventral.
   iv. Guard: More or less conical, lower end pointed growth lines distinct.
   v. Pro-ostracum: Extention of the free end of guard and wing like.
   vi. Suture: Ammonitic.

AGE: Cretaceous.

Evolutionary Trends in Trilobites

Contents

Introduction

What are Trilobites ?

Trilobites are an ***Extinct Group*** of Invertebrate (Arthropoda) Which occupy a dominant role in the early part of the Stratigraphic / Paleontological record. They are exclusively marine organisms and especially in some shallow sea deposits of ***Cambrian and Ordovician*** age, their remains are abundant widely distributed .

Average ***size*** of Trilobita was a small creature , usually 50-75 mm in length but some were also quite tiny less than 10mm & rarely measures even half a meter. Exoskeleton in nature, a few examples are success even in Recent (Recent example Cockroaches).

General Morphological Features

- Head or Cephalon part of the Exoskeleton which covers the head of animal is know as HEAD SHIELD or CEPHALIC SHIELD. It is commonly Semi circular in outline.
- Head shield is one the most important parts of skeleton, because morphological features of the segment can be classified through this.

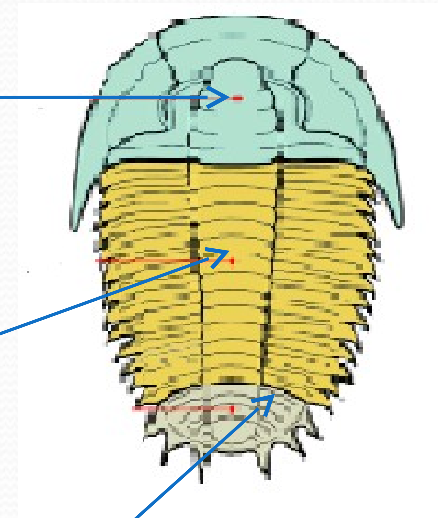
CEPHALON

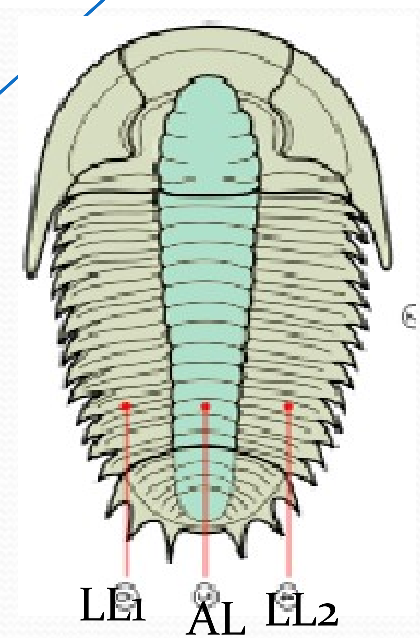
- THORAX is the part of body behind the cephalon which consist of series of segments ranging from 2-40.The segment are same ,except in size, becoming narrow towards PYGIDIUM.
- Each segments is divided by AXIAL FARROWS by 3 LOBES. They are LL1,AL,LL2

THORAX

- The posterior or tail part of the exoskeleton in know as pygidium.
- They have Circular/Triangular shield which composed or segments together .Segments varies from 2-6upto 30.
- Some of trilobites the posterior end of PYGIDIUM end with a spine is know as TELSON.
- Pygidium may be larger or smaller

PYGIDIUM





Cephalon Region

❖**Eye** :The majority of trilobites bore a pair of **compound eyes** (made up of many lensed units). They typically occupied the outer edges of the **fixigena** (fixed cheeks) on either side of the **glabella**, adjacent to the **facial sutures**.

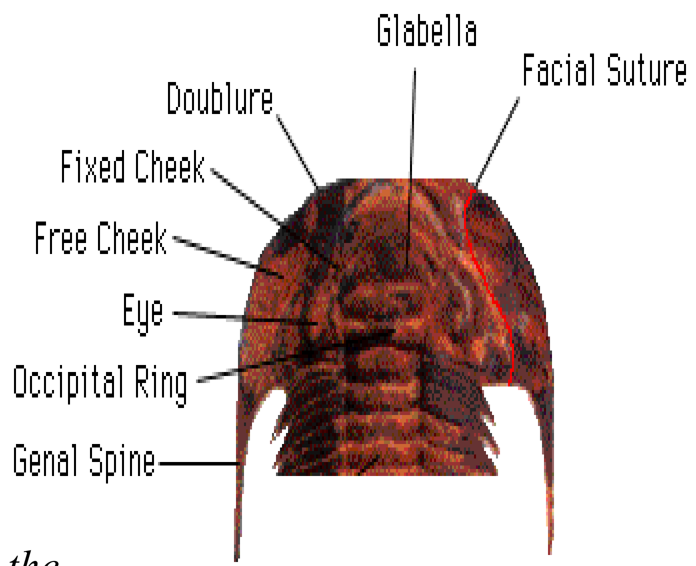
❖**Genal angle**: The angle formed by the meeting of the lateral (side) and posterior (rear) margins of the cephalon; the angle is important in trilobite taxonomy.

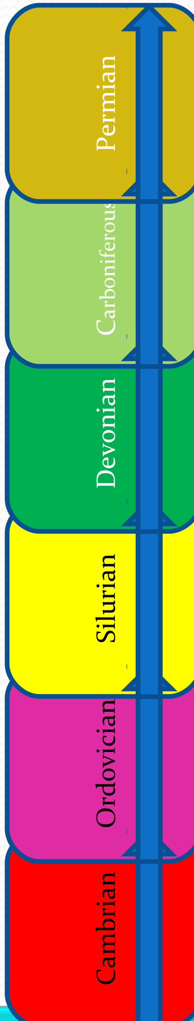
❖**Genal spine**: A spine anywhere on the gena (i.e., cheek) of the cephalon, typically pointing at the genal angle.

❖**Glabella**: That middle (axial) portion of cephalon that is typically convex and/or lobed.

❖**Fixed Cheek**: the fixed cheek Cephalic shell surrounding Glabella inside of facial sutures. Also see gena and librigena.

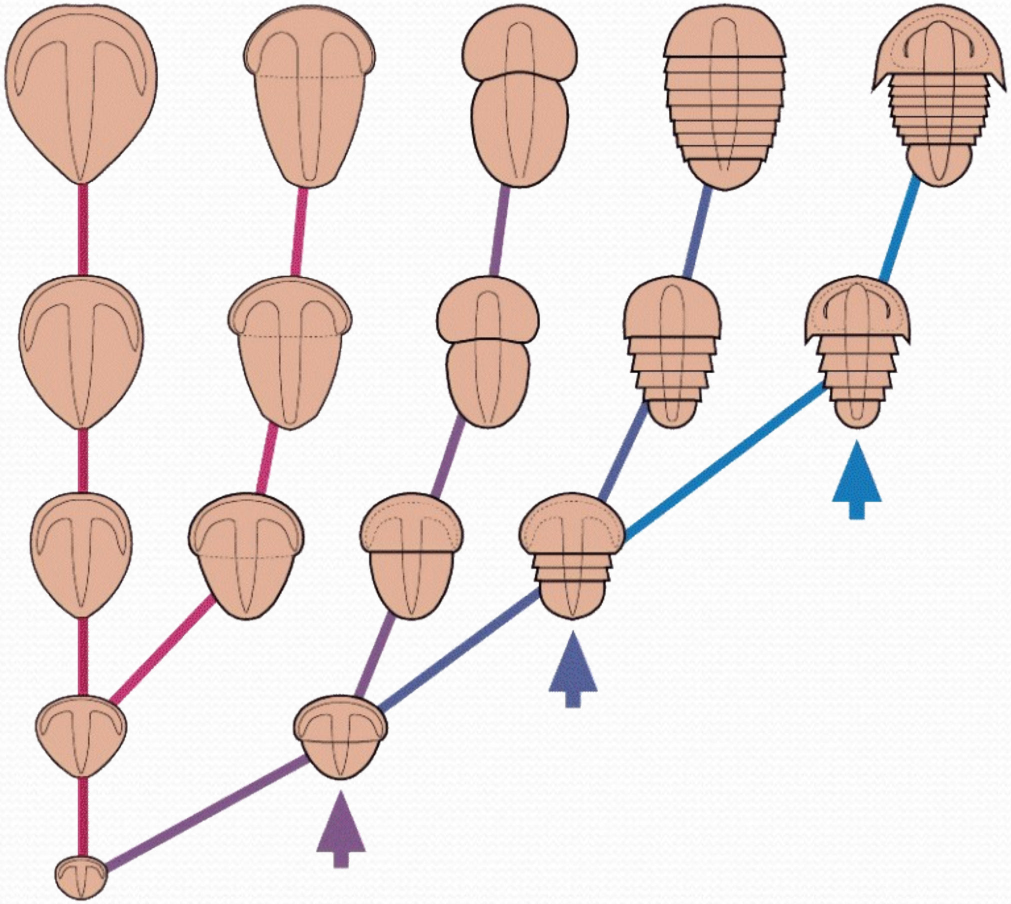
❖**Facial Suture** :*They are lines on the Cephalon along which the parts of the cephalon separate when the trilobite molts. They typically run from somewhere along the anterior edge of the cephalon and around the edge of the eye and continue from there to end at either the side or rear of the cephalon.*





Evolutionary Trends in Glabella , Eyes, Thorax , Pygidium & Spinosity of Trilobites .

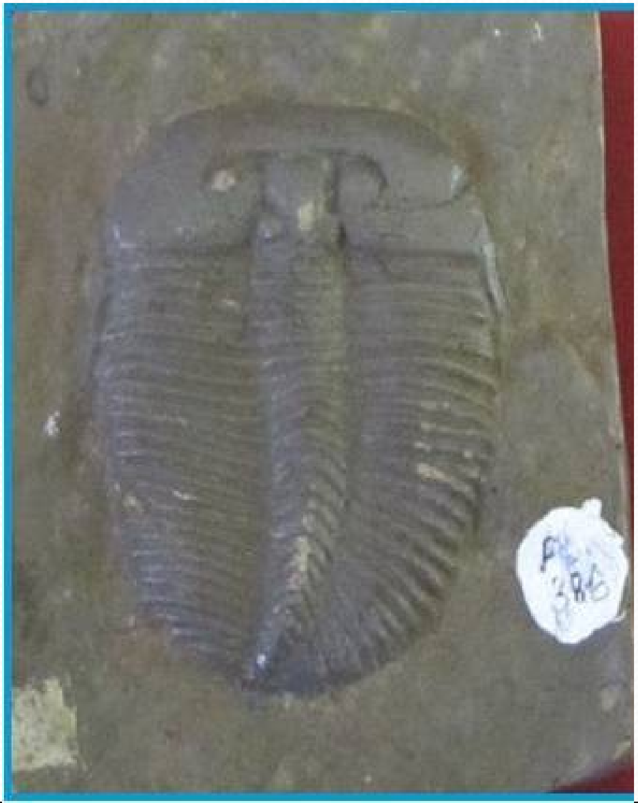
EVOLUTIONARY TRENDS IN



The exoskeleton as the cephalon which is the widest part ,semicircular with rounded genal angel into long .Glabella is convex with furrows Eyes are small ,facial suture is extended to anterior ,Thorax is tapering towards pygidium pluera, Pygiduim is small (5-15) segments.
Order: Proparia
Age : Ordovician to Devonian

CALYMENE

OLENELLUS



The exoskeleton is large elongated with semicircular cephalon in which the genal angles are extended backwards as long spines. Glabella is broad ,eyes are large ,thorax is small with(2-8) segments.
Order: Opisthoparia
Age: Middle Cambrian

PARADOXIDE

OLENELLUS

The Exoskeleton has the cephalon which is semicircular in outline with elongated g.spine more than the length of thorax rounded genal angle. The glabella is prominent, eyes are large kidney shaped, thorax contains 11 segments, pygidium is small triangular shaped.
Age : Silurian to Devonian
TRINUCLES

The exoskeleton is large, prominent semicircular cephalon, well marked glabella, indistinct furrows, large eyes, eleven thoracic segments, small prominent truncated pygidium.
Order: Proparia
Age : Ordovician to Devonian
PHACOPS

Stratigraphic Application of Early Trilobita

- Oldest Trilobites are found in Lower Cambrian rocks roughly ***525–530 m y age***. The first records may be in Baltica (present day Scandinavia and the eastern European platform).
- However, shortly on the heels of these occurrence records, Trilobites also appear in Lower Cambrian rocks from Siberia and China.
- One interesting aspect of the early history of Trilobite is that straight away Trilobite shows a prominent pattern of ***bio geographic differentiation.***

Youngest Fossil Record of Trilobites
Where the Trilobita species alive?

- **Owens (2003) reviewed the youngest record of Trilobites are extinct during the Permian and revealed that five genera of Trilobites persisted until the great extinction crisis at the end of the Permian. This event was perhaps the largest extinction and one of the BIO event in Earth's history.**

- **Trilobites fossil record reveals two crises during the Permian age, one during the Middle Permian (Guadalupian Epoch) and Late Permian (Ochoan Epoch).**

- **Only five persisted to the end Permian event: *Cheiropyge* (an aulacopleuroid in the family Brachymetopidae), *Kathwaia* (a proetoid in the family Phillipsiidae, subfamilyBollandiinae), *Paraphillipsia*(Phillipsiidae, Cummingellinae), *Acropyge***
- **(Phillipsiidae, Ditomopyginae), and *Pseudophillipsi* (also Ditomopyginae).**

- **The mentioned genera of the Trilobites are found in various localities today including *Pakistan, China, Russia, Hungary and Japan.***

Geological Distribution

- Trilobites had world wide distribution are considered as Index Fossil like AGNOSTUS,OLENELLUS,PHACOPS,DALMANITES & CALMENE have been found useful for inter continental correlation.
- The Stratotype from WENLOCK limestone of Silurian age have yield CALYMENE BLUMENBACHI,SPHAEREXOCHUS MIRUS,DALMANITES MYOPS, PYOCTUS Sp. & ENCRINURUS PUNCTATUS.
- A some of these have been recorded from India. It is useful to know Stratigraphical distribution of some important Genera of Trilobite.
- Trilobites of the Cambrian age are know from 3 area salt range, **Pakistan, Kashmir & in Spiti Himalayas.**

  Records from Neobolus beds of Salt Range *are Ptychoparia sakesarensis, Redlichia, Chittidillia plana. (Reported :Indian species)*
- Records from Kashmir are *Ptychoparia dadpurensis*, *Saukia vagons.*
- Records from Spiti region of Himalayas *Redlichia noetlingi, Ptychoparia spitiensis, Agnostus spitiensis, Oryctocephalites memor*.

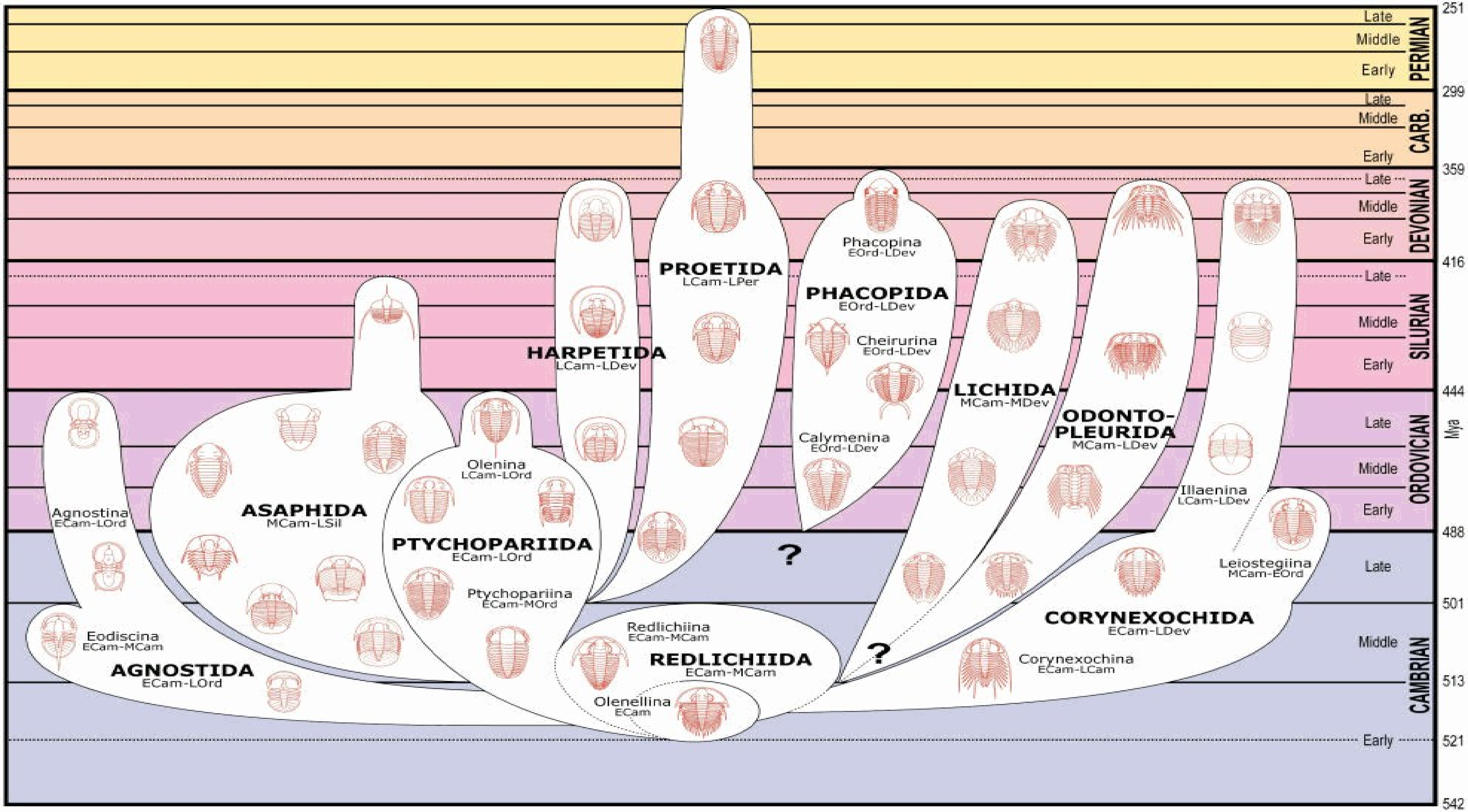
  (The existence is from middle to upper Cambrian age).
- Ordovician Age Trilobites are know from Spiti & Burma

  (Naugkangyi beds of Burma).

BIGGEST KNOWN

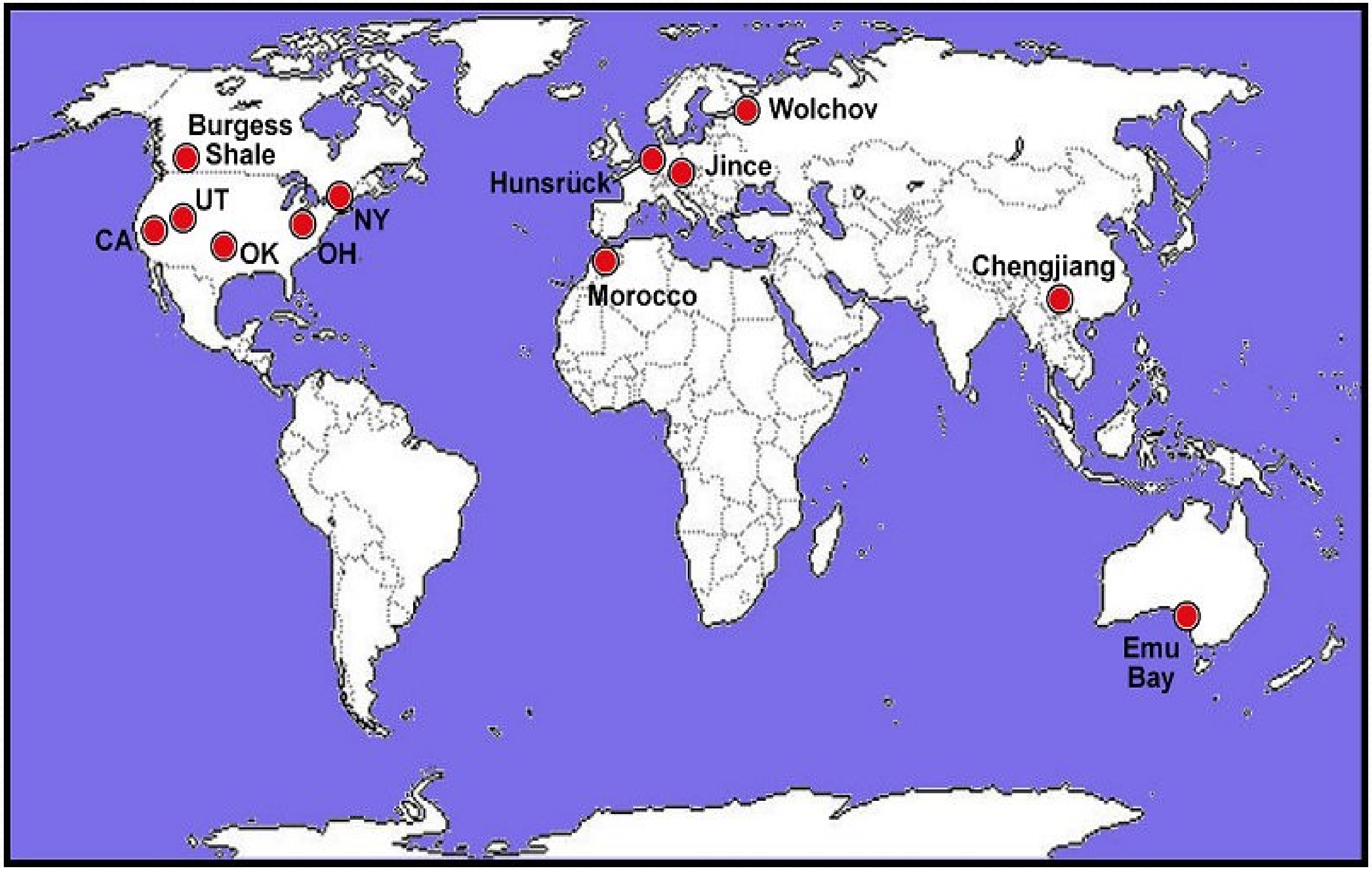
World’s biggest known trilobite, holotype of *Isotelus rex n. sp. (MMMN I-2950), articulated dorsal exoskeleton showing broken posterior* margin of pygidium; Late Ordovician (Richmondian), Churchill River Group, near Churchill, northern Manitoba, CANADA

Trilobites **DURING** Palaeozoic



Class Trilobita: Paleozoic Era: Image above ©2009 by S. M. GonIII, created using Macromedia Freehand and PaintShopPro

World Distribution of Trilobite



Conclusion

Early thinking was forerunner for Vertebrate. This theory was ruled out because its total extinction after the Permian Age.

Total Span of Geologically from ***Cambrian – Permian (550-245 m.y)*** exhibits in Fossil Record is every parts evolved in ***305 my***

To understand its significant evolution and the Age for the sediments ***(in the absence of Absolute method)***.

FOSSILS:

PARADOXIDES

I. PHYLUM : Arthropoda
II. CLASS : Crustacea
III. SUB-CLASS : Trilobita
IV. MORPHOLOGY:
   i. Cephalon: Shape and margin broad. Border is semicircular in outline.
      a) Facial suture: Opisthoparian
      b) Glabella: Broad infront with prominent furrows.
      c) Cheeks: Nearly equal in size.
      d) Eyes: Large and arched.
      e) Genal angle: Long and extended into long genal spine.
   ii. Thorax: Shape triangular. Pleural spine directly attached to the axis.
   iii. Pygidium: Rudiment.
V. AGE: Middle Cambrian.

CALYMENE

I. PHYLUM : Arthropoda
II. CLASS : Crustacea
III. SUB-CLASS : Trilobita
IV. MORPHOLOGY:
   i. Cephalon: Semicircular.
      a) Facial suture: Gomatoparous.
      b) Glabella: Inflated, 3 lateral furrows whiuch are incompleted and look like knobs.
      c) Cheeks: Fixed cheek larger than free cheek.
      d) Eyes: Small and prominent.
      e) Genal angle: Rounded.
   ii. Thorax: There are 13 sesments, axial lobe prominent, Pleurae are grooved and blunt.
   iii. Pygidium: Small and possess 6 to 12 segments.
V. AGE: Ordovician and Silurian.

References :

- P. C. Jain and M.Sanantharaman (2010), Paleontology Evolution and Animal Distribution,Vishal Publisher, 7th edn. (Revised), pp.159-167.
- Moore(1952), Invertebrate Fossils, McGraw-Hill Book company(USA), pp.475-519.
- Henry Woods, Paleontology Invertebrate, CBS Publisher Delhi,8th Edition, pp.353-376.
- Web Sites : www.trilobites.info

  www.wikipedia.com

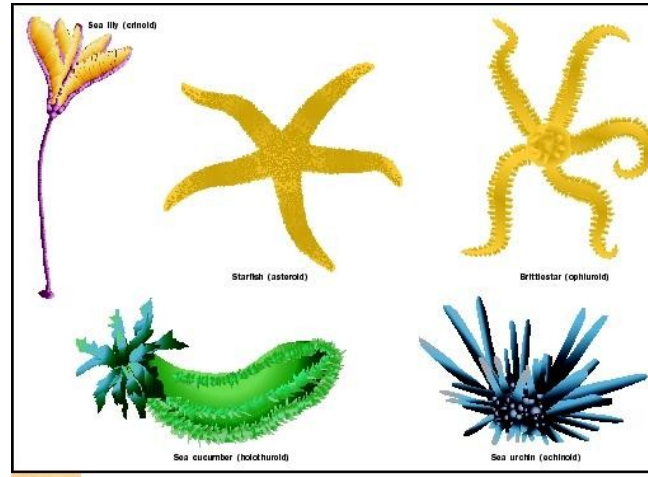
Phylum Echinodermata

Ex. Sea stars, sea cucumbers, feather stars, sea urchins, sand dollars

Phylum Echinodermata

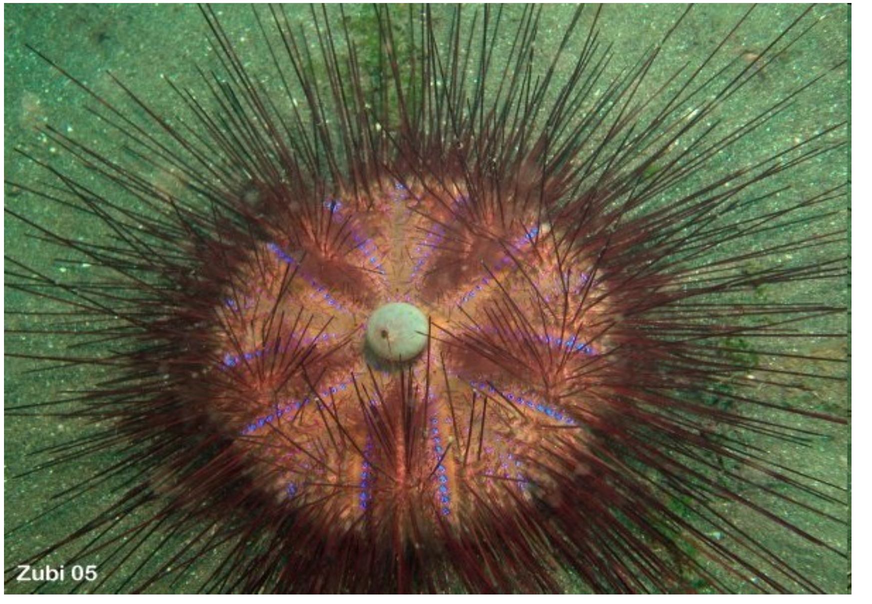
4 main classes:

- Class Asteroidea
- Class Ophiuroidea
- Class Echinoidea
- Class Holothuroidea



Echinoderms:

- Name means "spiny skin"
- Sea stars, sea cucumbers, sea urchins, etc.
- All marine
- All found on the bottom of the sea



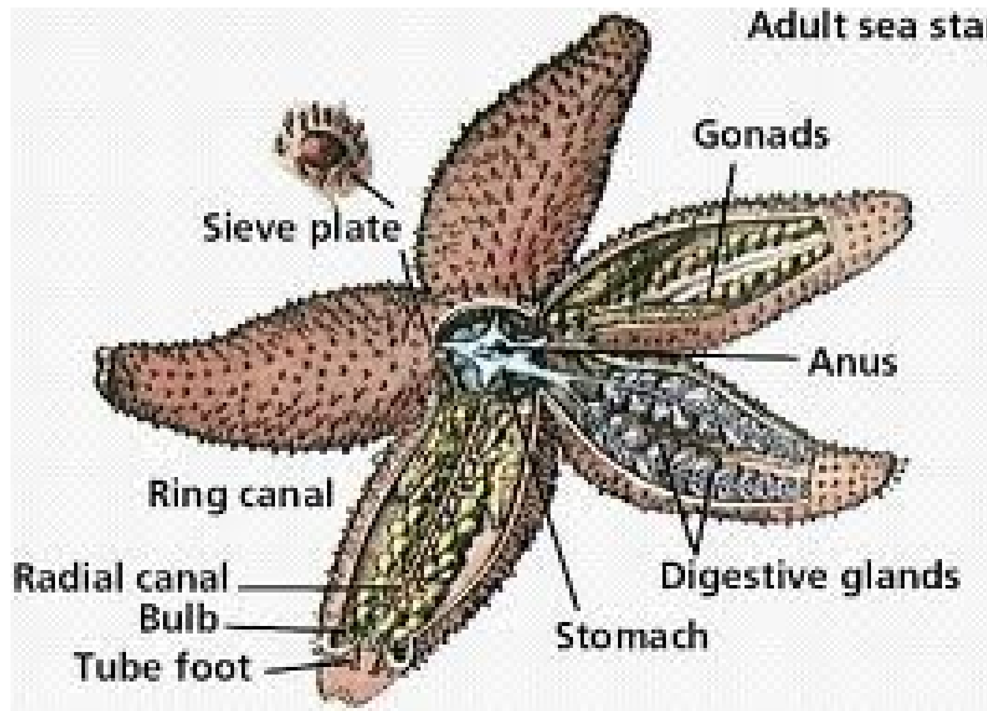
Characteristics Phylum Echinodermata:

- Body type: pentamerous radial (body radially symmetrical in 5 parts multiples of 5)
- Body organization:

  3 layers: endoderm, mesoderm, ectoderm
- Body cavity: coelom
- Ecological roles:
  - Food source
  - Predator – control populations
  - Recycle nutrients
  - Chemicals-anticancer, antiviral

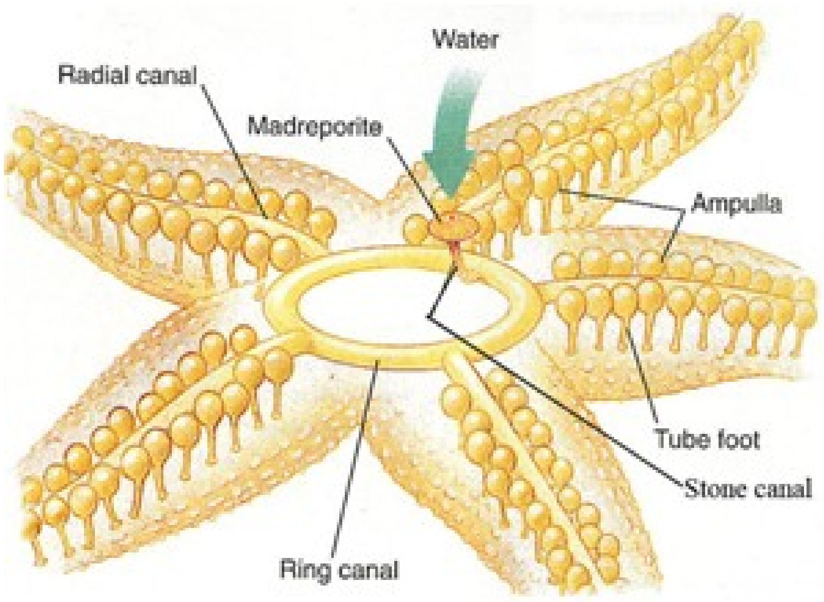
Characteristic continued:

- Digestive system:
  - **Complete** – mouth & anus
- Reproduction:
  - *Sexual:* - dioecious
  - *Asexual:* regeneration – if lost an arm or guts



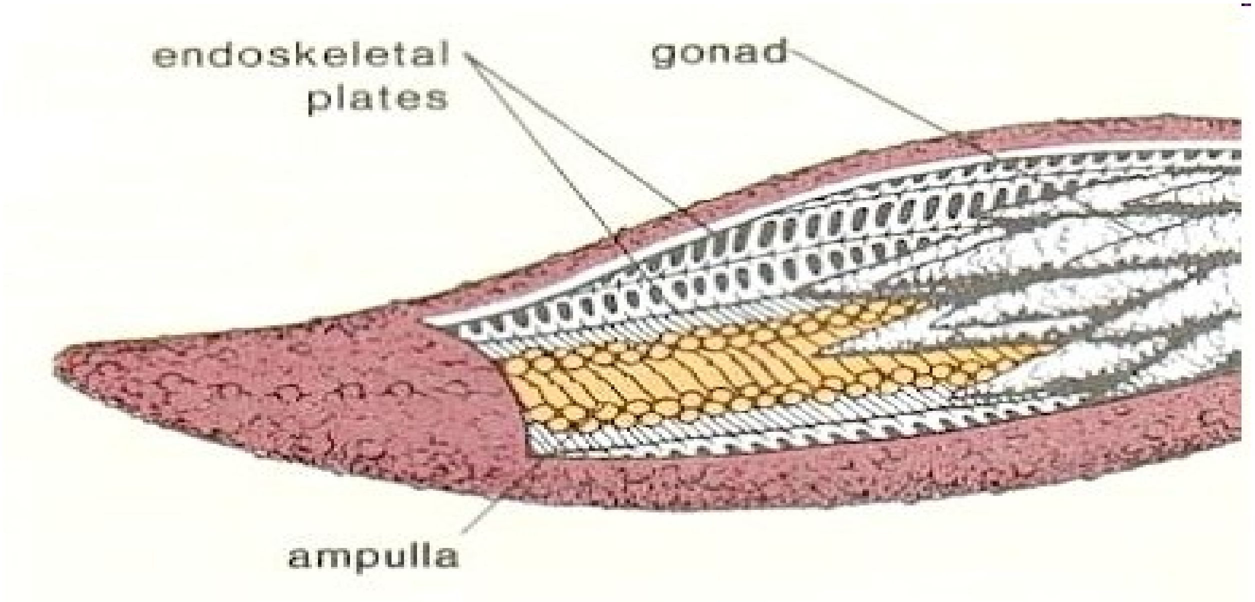
Characteristics continued:

- Circulation: **closed**
- Nervous system:
  - nerve cords
  - ***No*** brain
  - Tube feet sensory
- Respiration: tube feet & skin gills - diffusion
- Excretion: diffusion, tube feet
- Habitat: water - ocean



Endoskeleton:

- Internal skeleton found within the tissues
- It is always covered by a thin layer of tissue
- Spines and bumps give reference to their name which means “spiny-skinned”

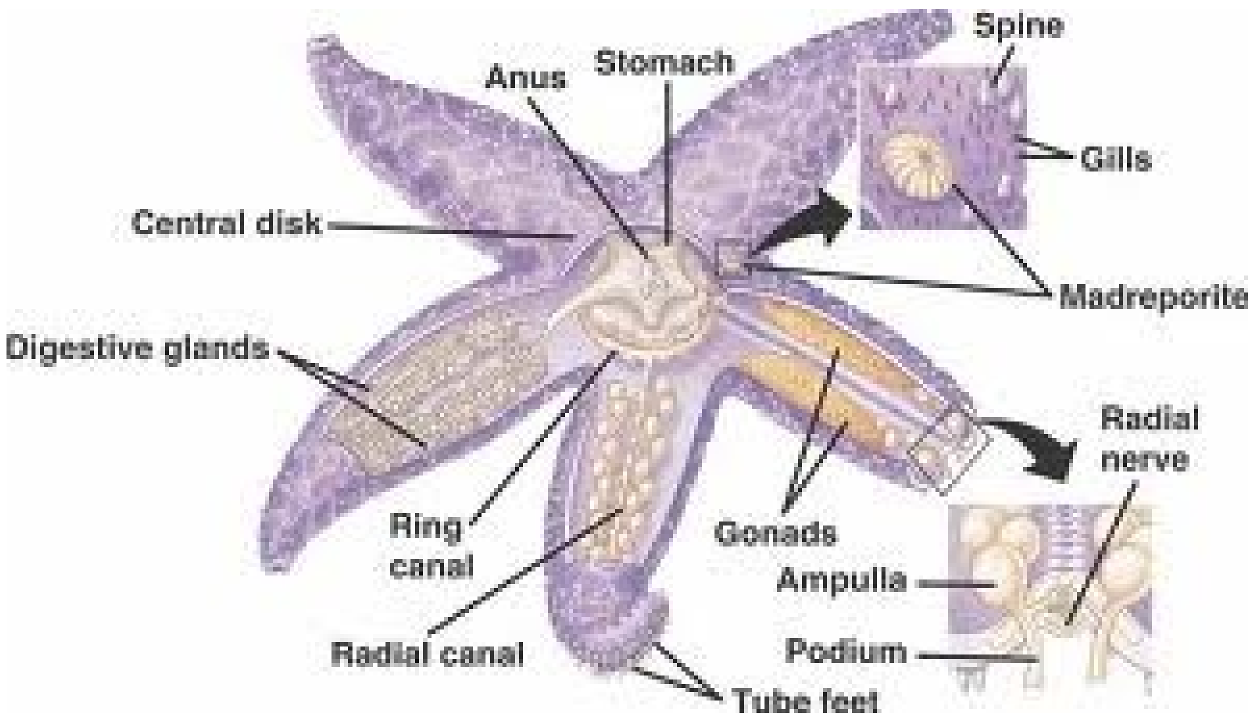


Dermal Branchiae

- Soft bumps on the body that absorb oxygen from the water

Water Vascular System:

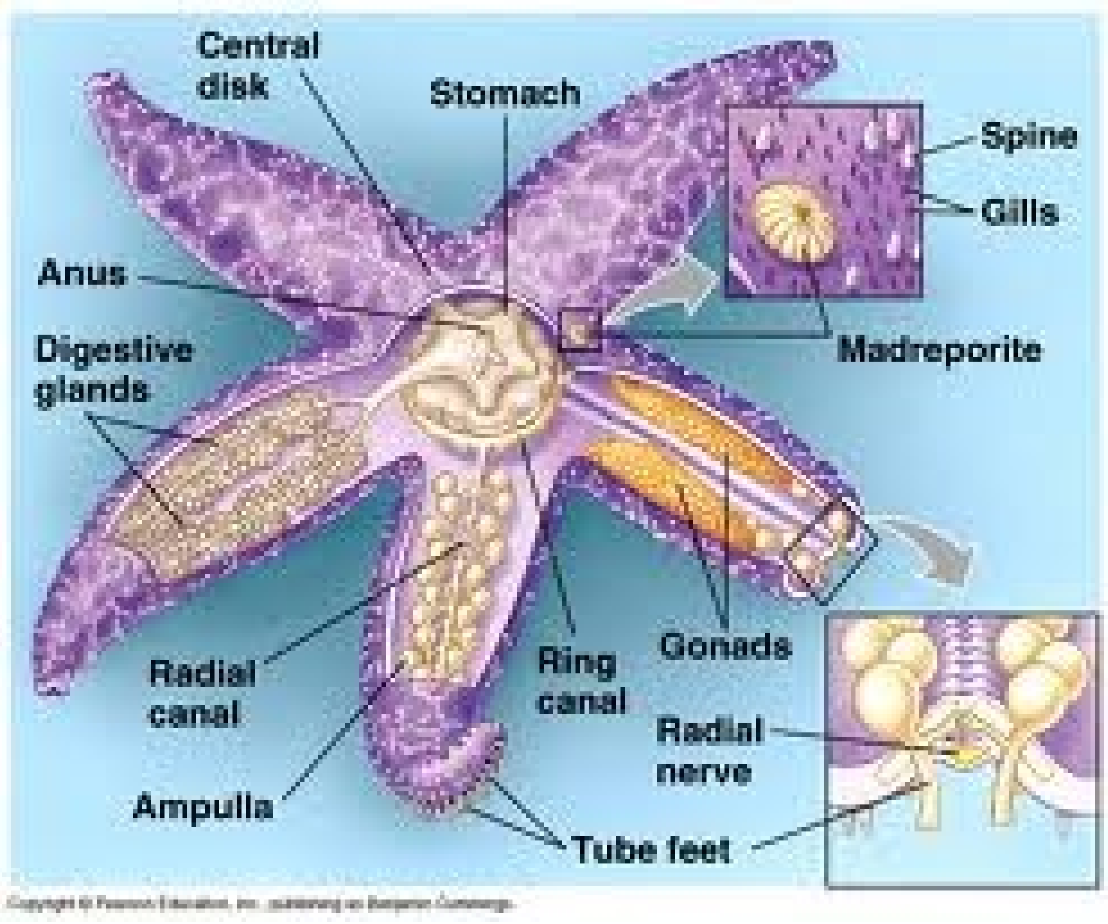
- Has a ***water vascular system*** for movement, & structure (internal skeleton = endoskeleton)



Water vascular system

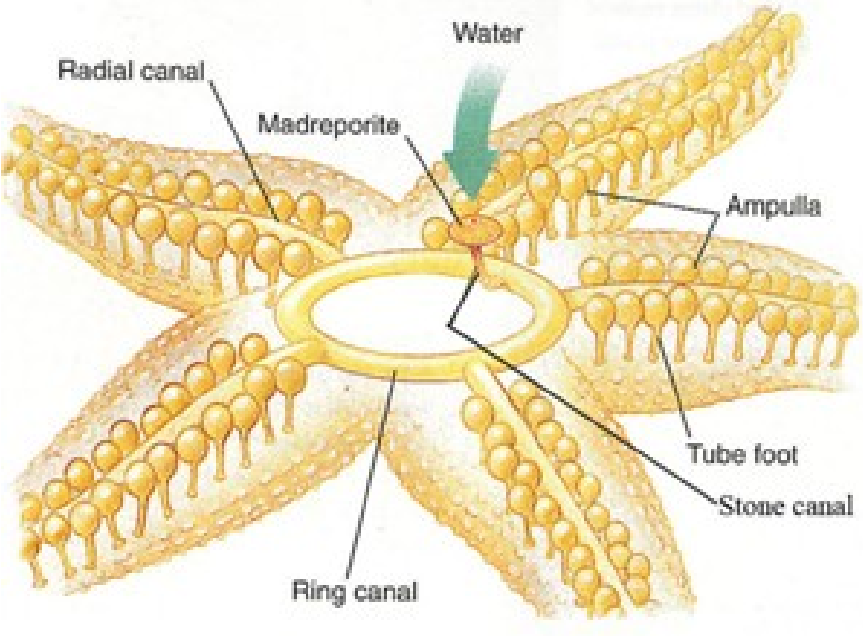
- network of canals which sea water circulates through = hydrostatic skeleton

  - unique to Echinoderms



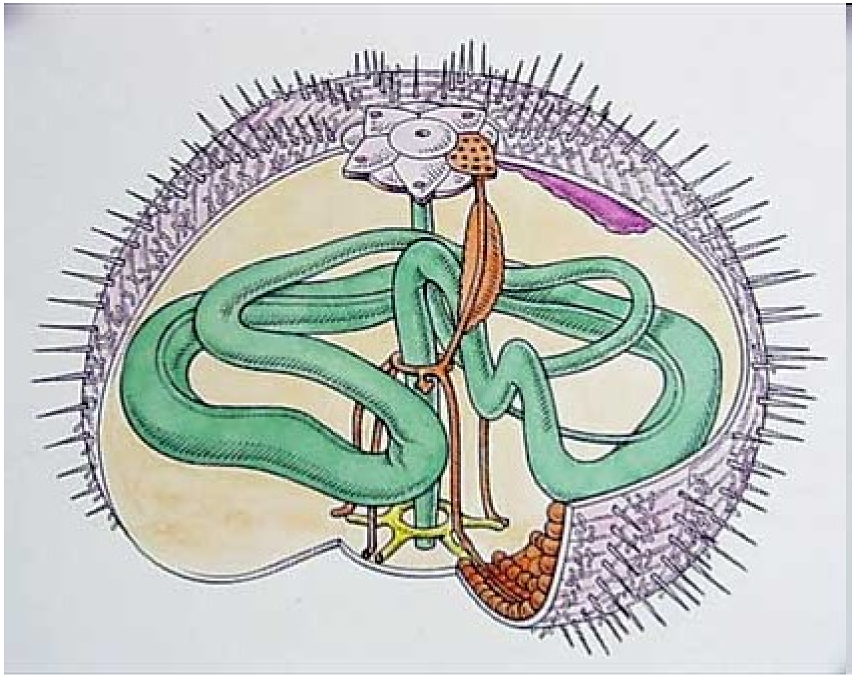
WATER VASCULAR SYSTEM OF A SEA STAR:

- Madreporite/ sieve plate: water enters vascular system
- Ring canal: surrounds mouth & leads to radial canals
- Radial canals: 5 of them – one down each arm
- Ampulla: muscular sac that controls tube feet by forcing water into it.
- Tube feet: create suction to adhere to substrate
  - Movement, feeding ,excretion, respiration, sensory organ

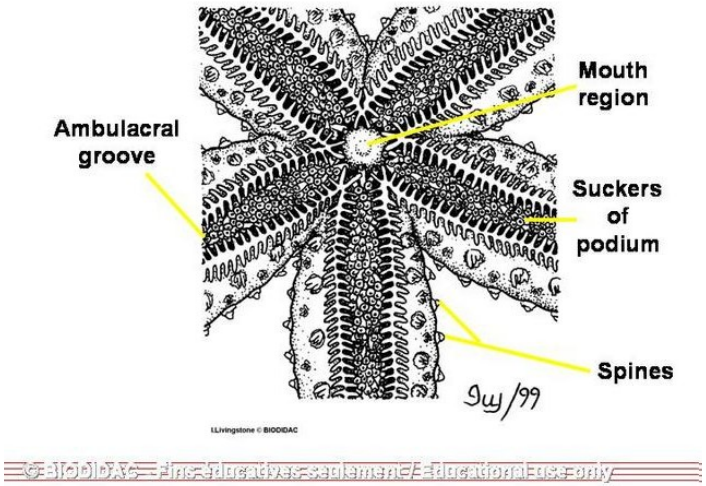


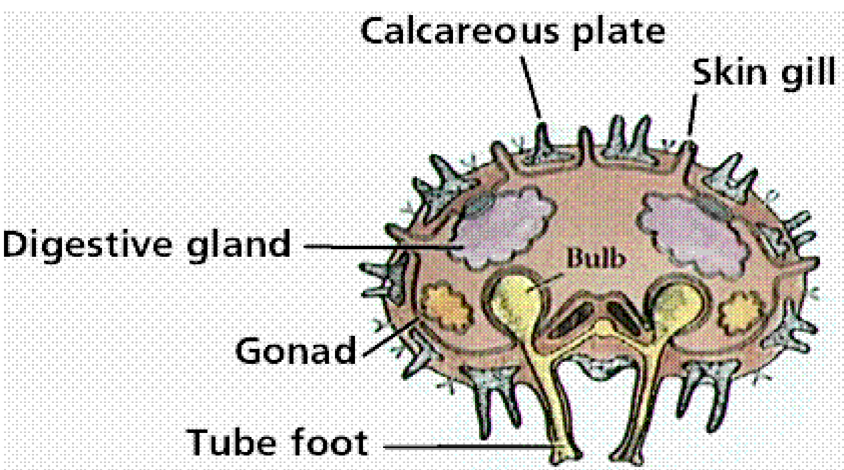
Digestive System:

- Sea urchins have a longer coiled intestine to allow time for the digestion of plant material
- Sea cucumbers have a similar section to absorb nutrients from the sediment it ingests



Digestive System:



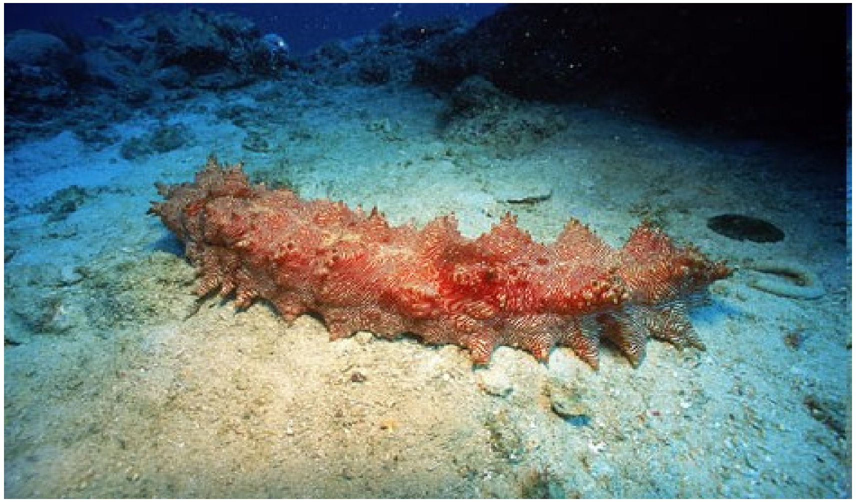


- Sea and brittle stars can evert a portion of their stomach out of there mouth to engulf food
- Digestive enzymes located in glands that extend into the arms

Regeneration/Autonomy:

- The ability to grow lost or damaged body parts
- Some times a severed arm can grow into a new organism if 1/5 of the central disc is present

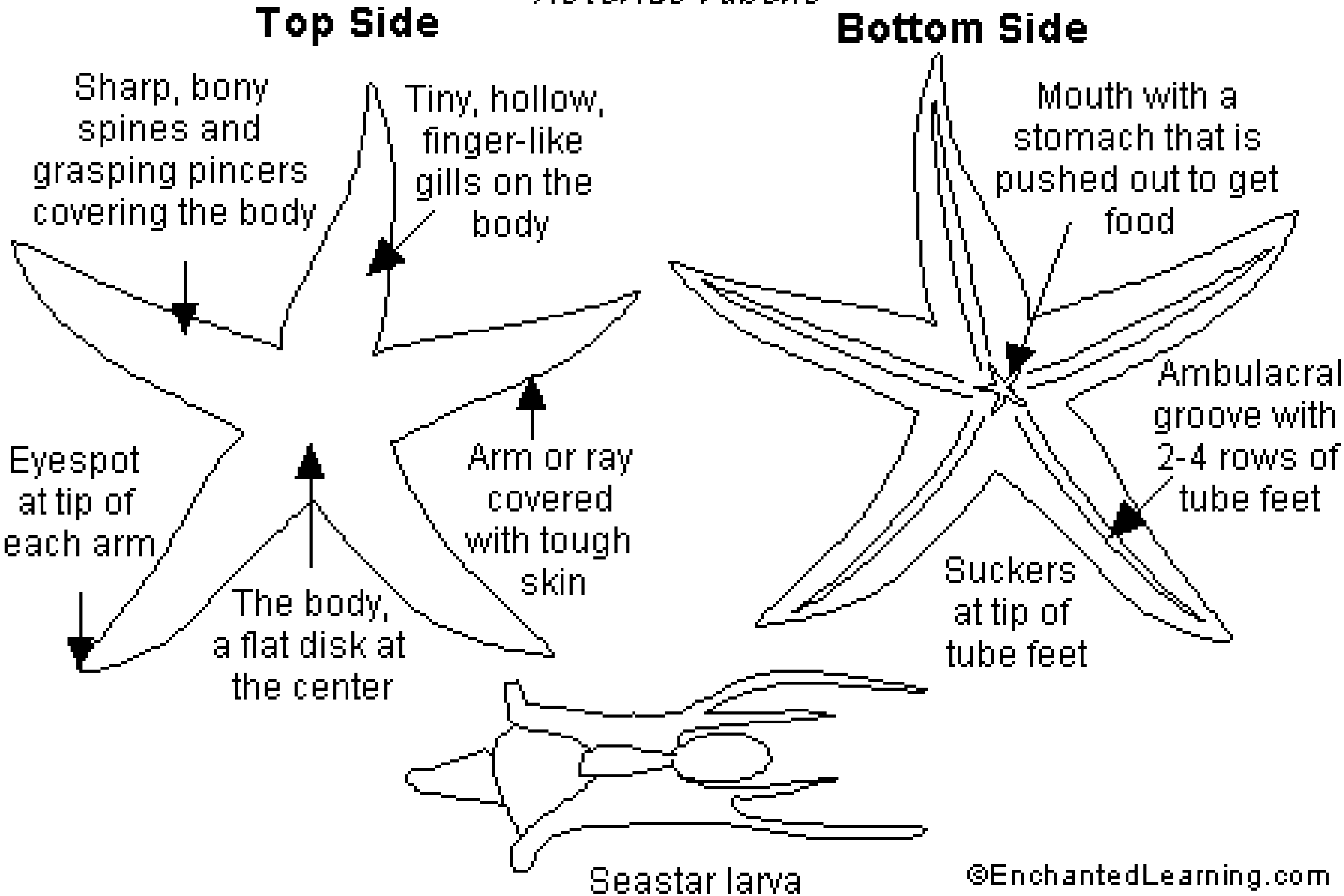
Nervous System:

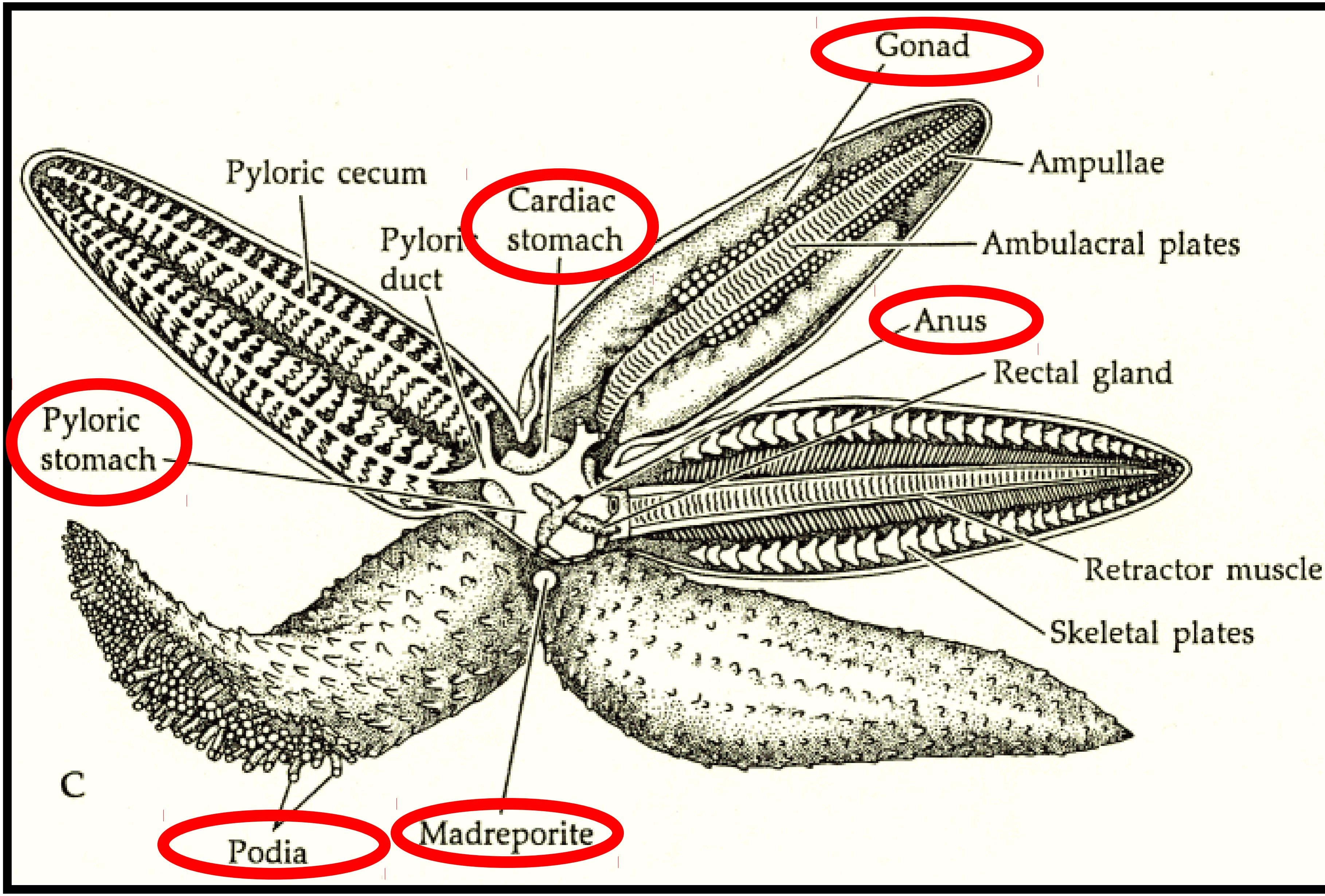


- Limited knowledge on this aspect except for the presence of a nerve net
- Ocelli – microscopic pigment spots on sea stars that can detect light and dark

Common Sea Star

Asterias rubens



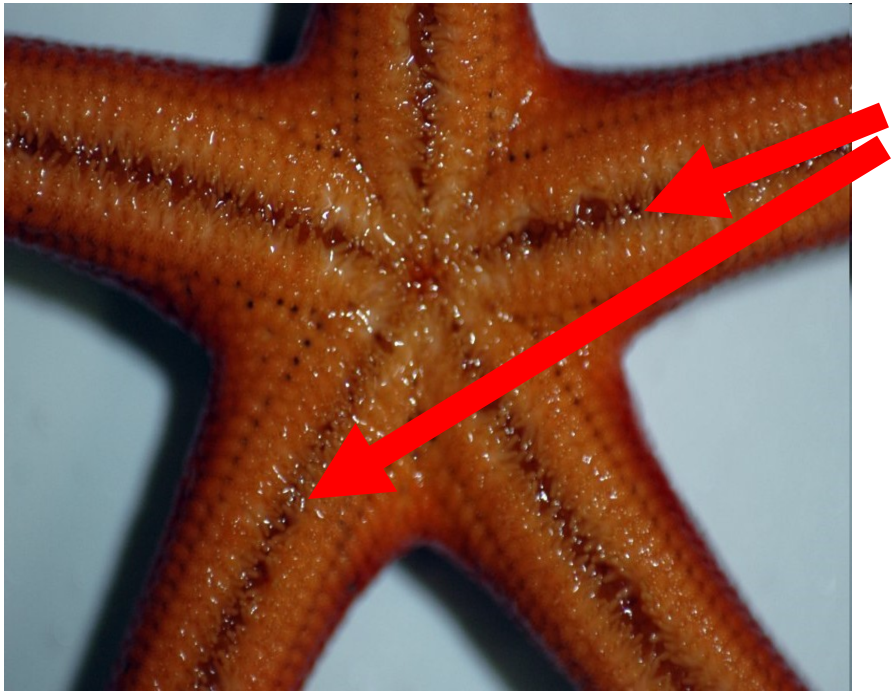


Gonad
Pyloric cecum
Cardiac stomach
Pyloric duct
Ampullae
Ambulacral plates
Anus
Rectal gland
Pyloric stomach
Retractor muscle
Skeletal plates
C
Podia
Madreporite

Class Asteroidea

- Includes: sea stars or starfish
- Most have 5 arms from a central disk, though can have up to 50
- Each arm carries an equal share of organ systems

Class Asteroidea



- Ambulacral grooves contain the tube feet on the arms

Class Asteroidea

- Pedicellariae
- Tiny pincer-like organs on the aboral side keep the surface clean
- Most sea stars are predators of bivalves, snails, or other attached or slow moving animals

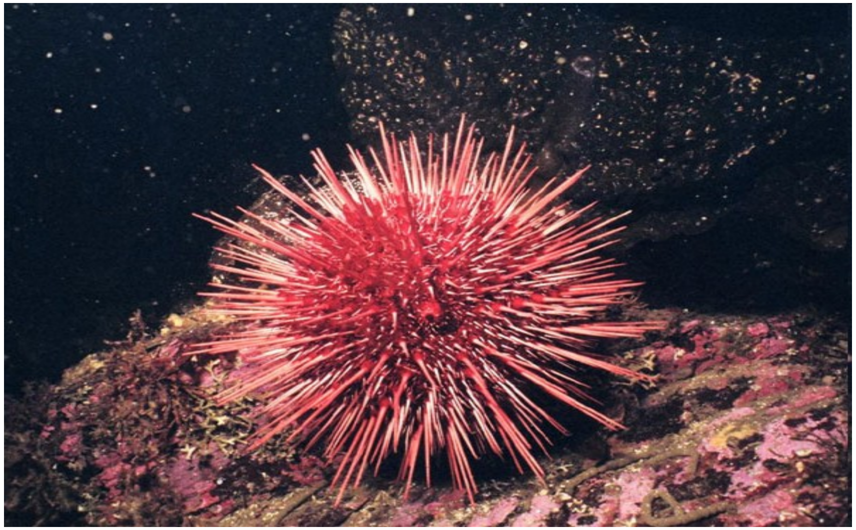
Class Ophiuroidea

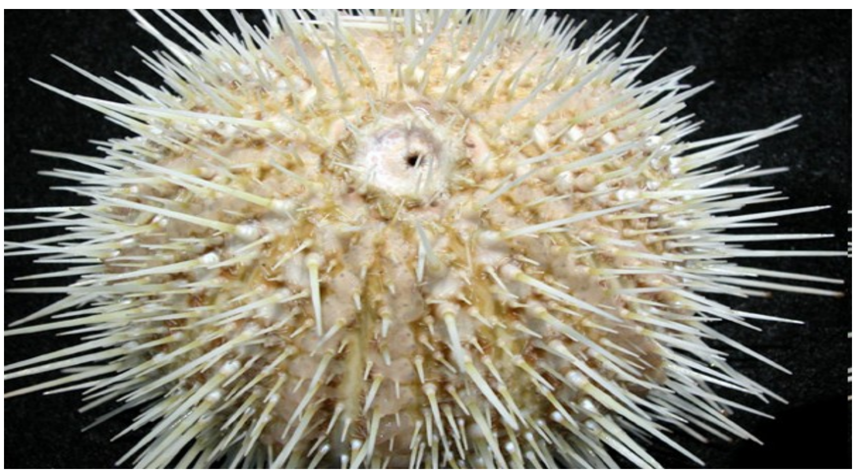
- Includes: Brittle Stars
- Legs proportionally longer and thinner than sea starts
- Allows for better movement
- Organs in central disc
- Tube feet lack suckers

Class Ophiuroidea

- Eat organic matter and small animals they find on the bottom
- Passed from tube foot to tube foot till it reaches the mouth

Class Echinoidea





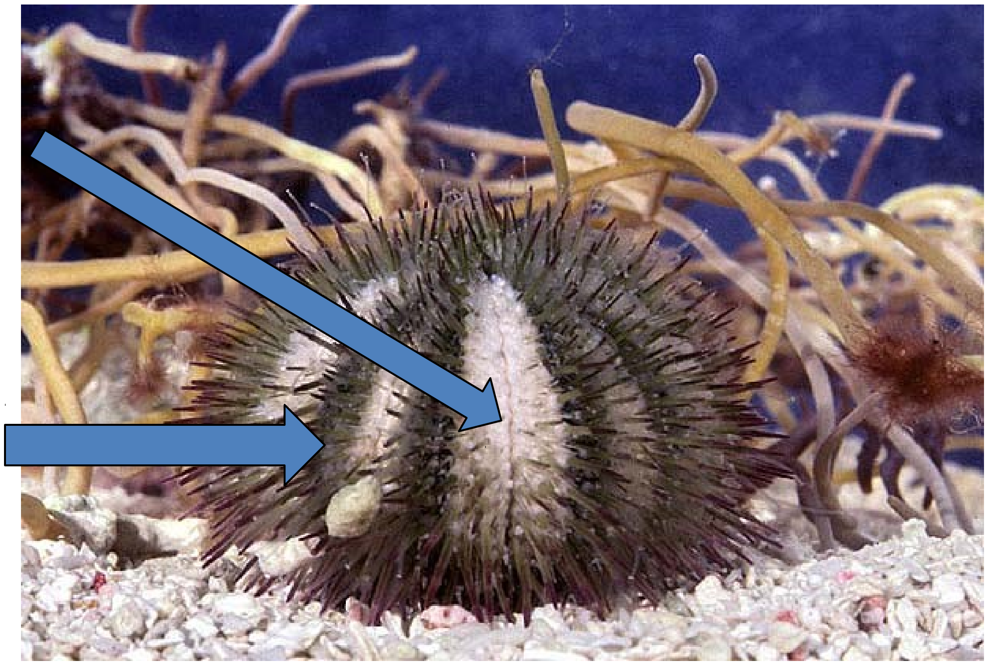
- Includes: Sea Urchins & Sand Dollars
- Body structure forms a round, rigid body with movable spins and pedicellarie
- Locomotion achieved by movable spines

Class Echinoidea

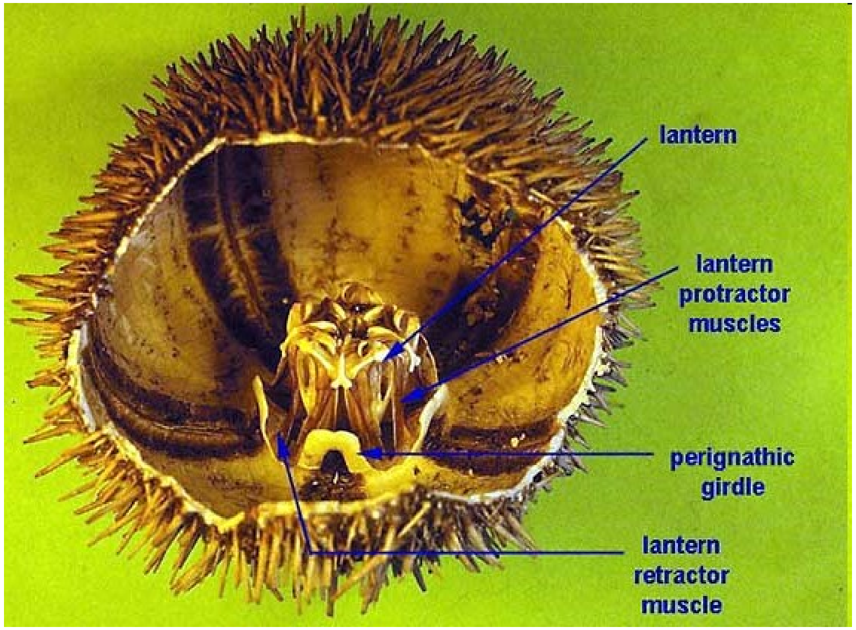
- Body plan of sea stars repeated by moving arms upward and connecting them at the tips
- Mouth is on the bottom, anus on the top
- Spines: sharp, hollow and sometime contain venom

Plates:

- 10 plates
- Alternating abulacral (have openings for tube feet) and interambulacral (bumps for spines)



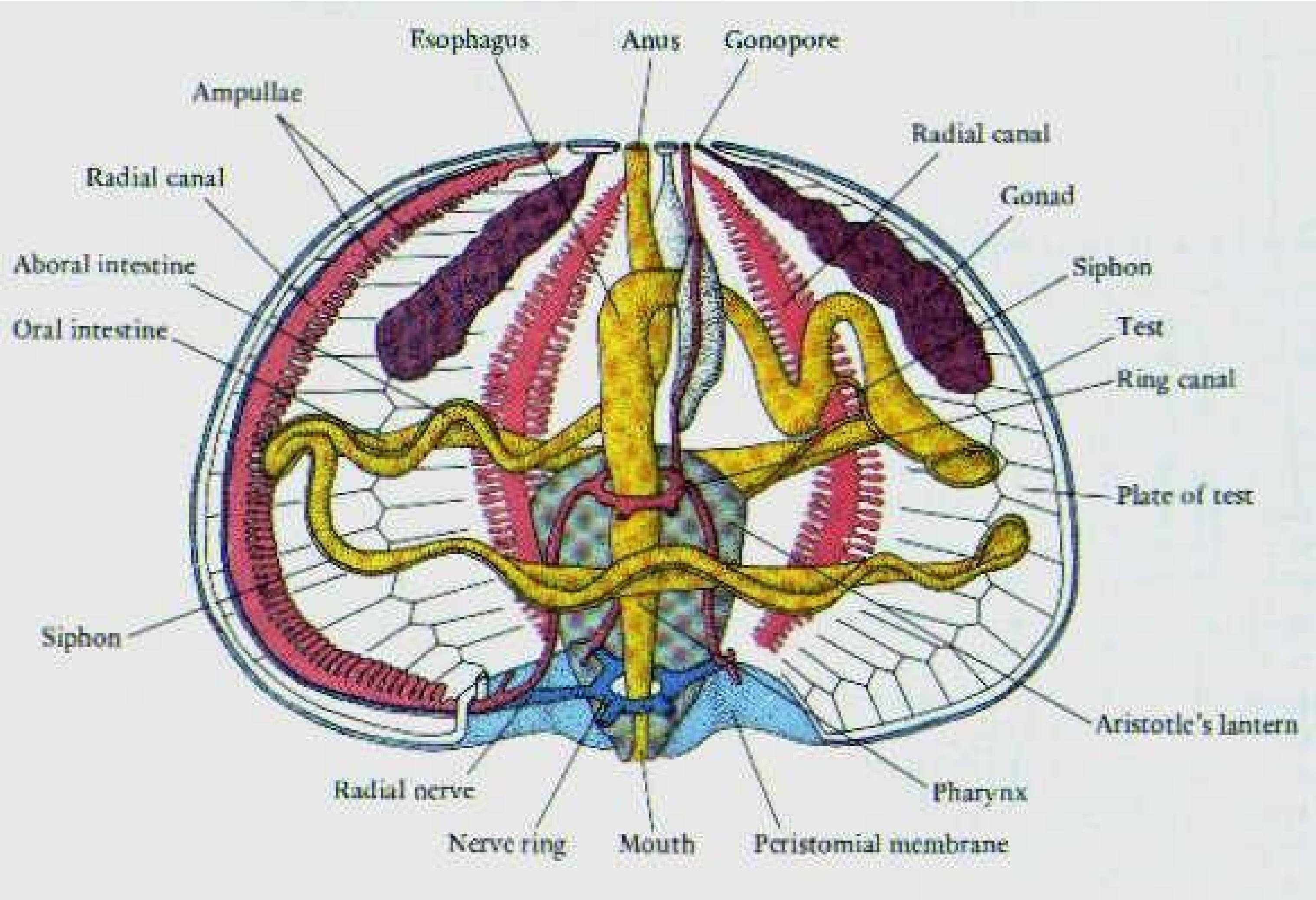
Class Echinoidea



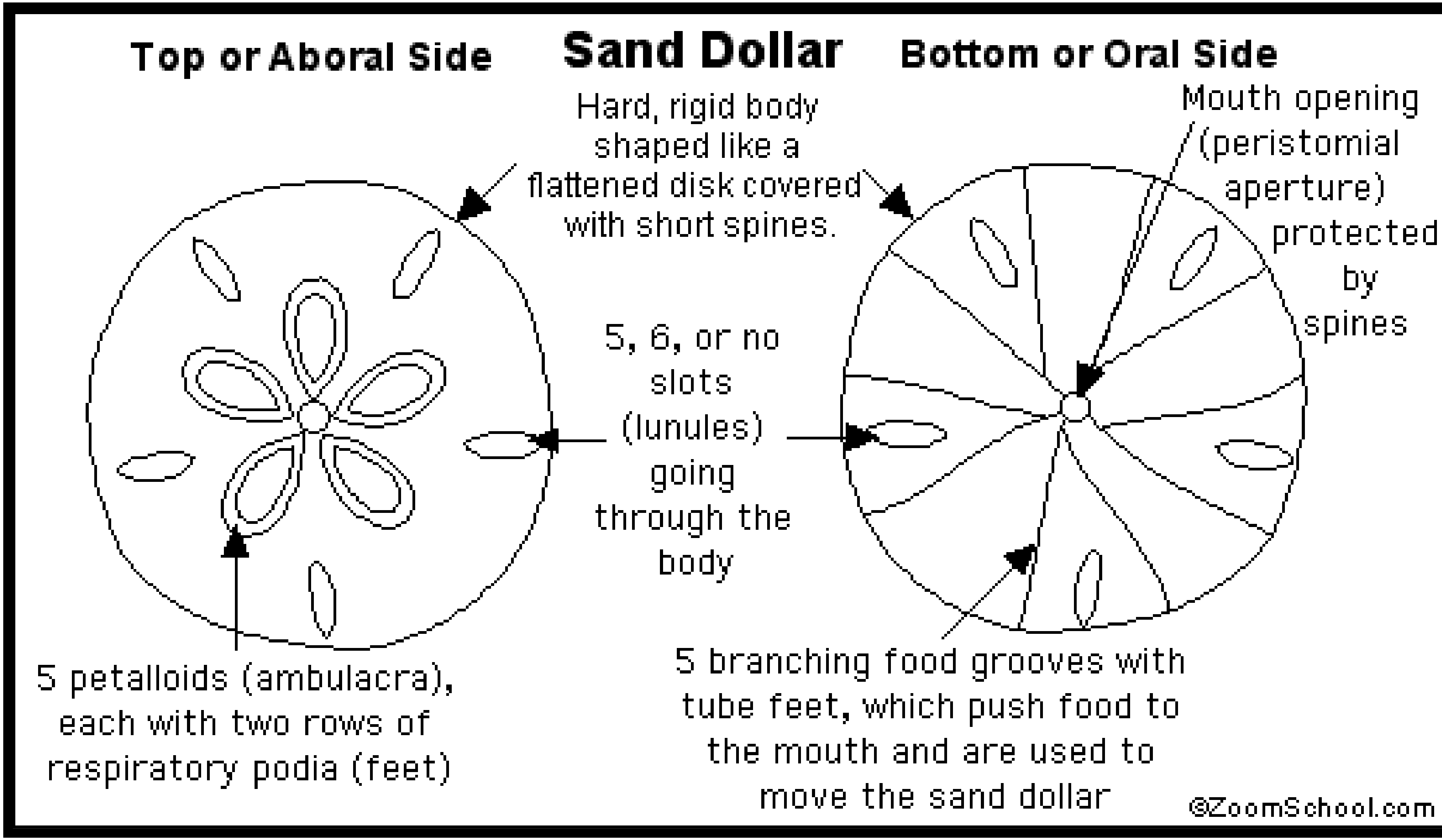
- The mouth has an intricate system of jaws and muscles called Aristotle's Latern
- Used to bite off algae and other bits of food from the bottom

Class Echinoidea

- Heart Urchins and Sand Dollars are adapted for the soft bottom of the ocean
- Flat bodies and short spines

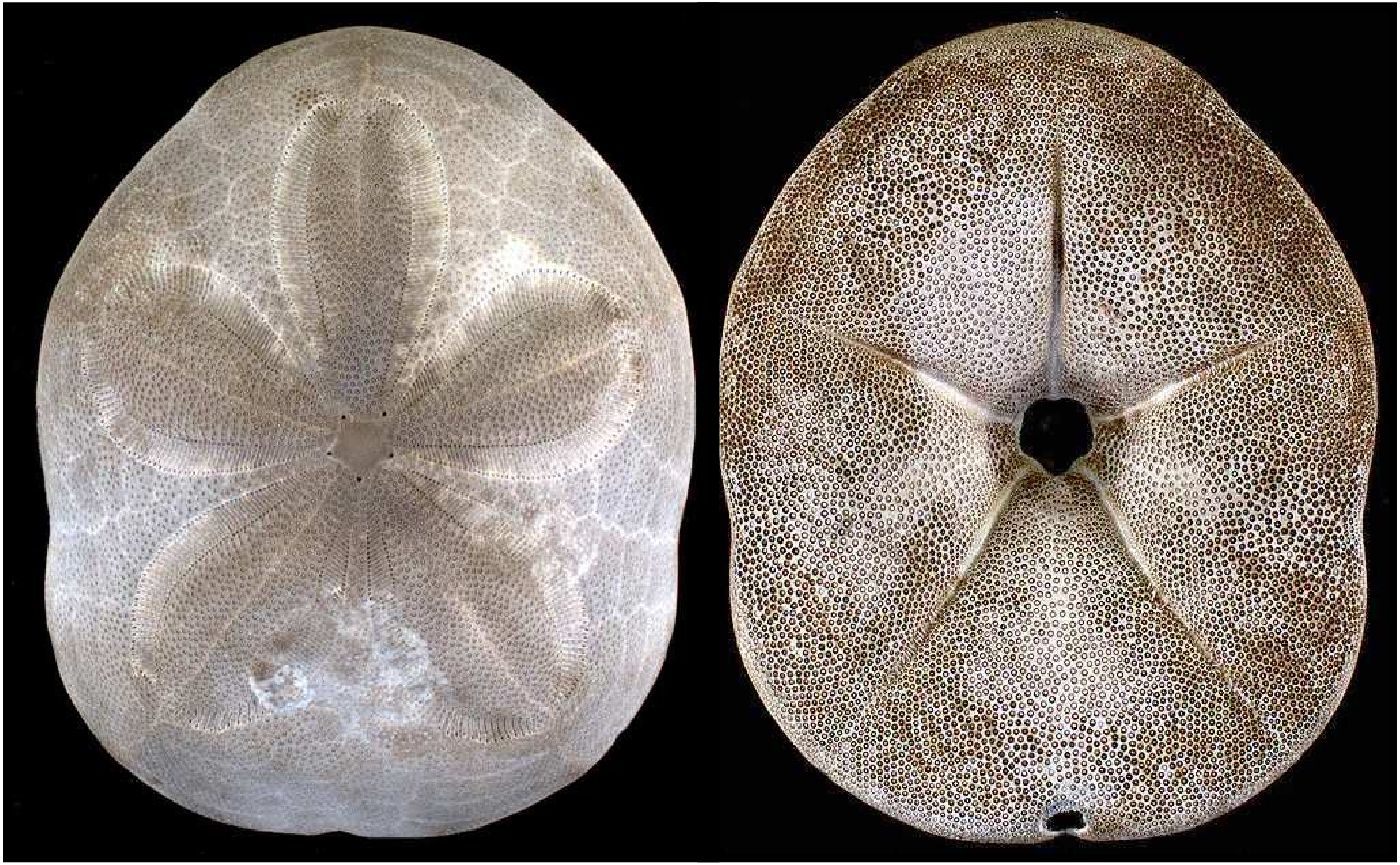


Esophagus
Anus
Gonopore
Ampullae
Radial canal
Radial canal
Gonad
Aboral intestine
Siphon
Oral intestine
Test
Ring canal
Plate of test
Siphon
Aristotle's lantern
Radial nerve
Pharynx
Nerve ring
Mouth
Peristomial membrane



Top or Aboral Side
Sand Dollar
Bottom or Oral Side
Hard, rigid body shaped like a flattened disk covered with short spines.
Mouth opening (peristomial aperture) protected by spines
5, 6, or no slots (lunules) going through the body
5 petalloids (ambulacra), each with two rows of respiratory podia (feet)
5 branching food grooves with tube feet, which push food to the mouth and are used to move the sand dollar
©ZoomSchool.com



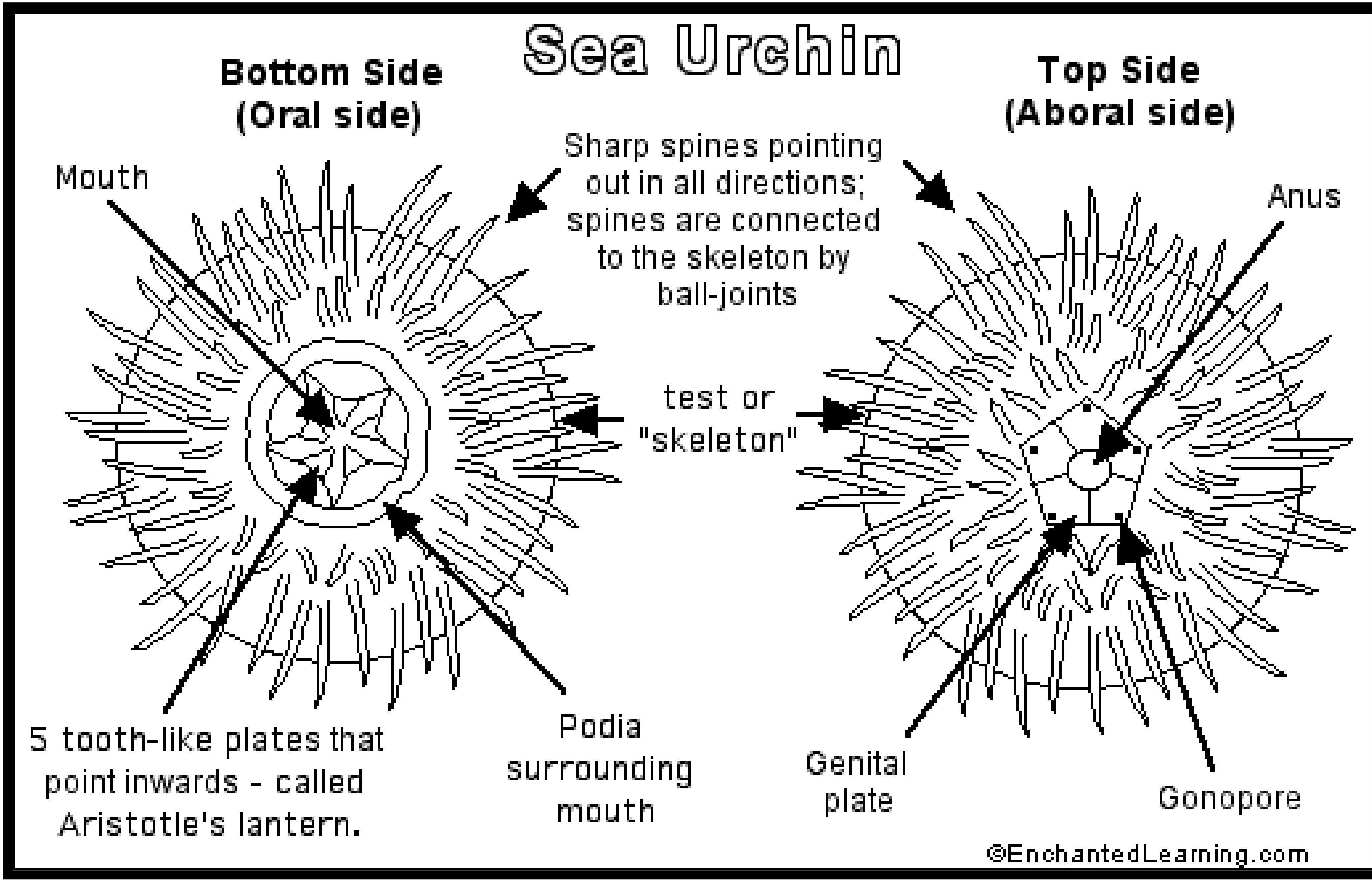


SAND DOLLAR

Mellita quinquiesperforata

Their trails are visible on the beach at low tide, as they plow furrows in the sand while feeding on tiny particles of detritus. Food items are carried to their mouth on the underside of their body using thousands of tiny spines, moving them down channels. When they die, their spines disappear, leaving only the bleached white shell behind. Live specimens produce an antibiotic substance called "Echinochrome" which stains your fingers yellow.

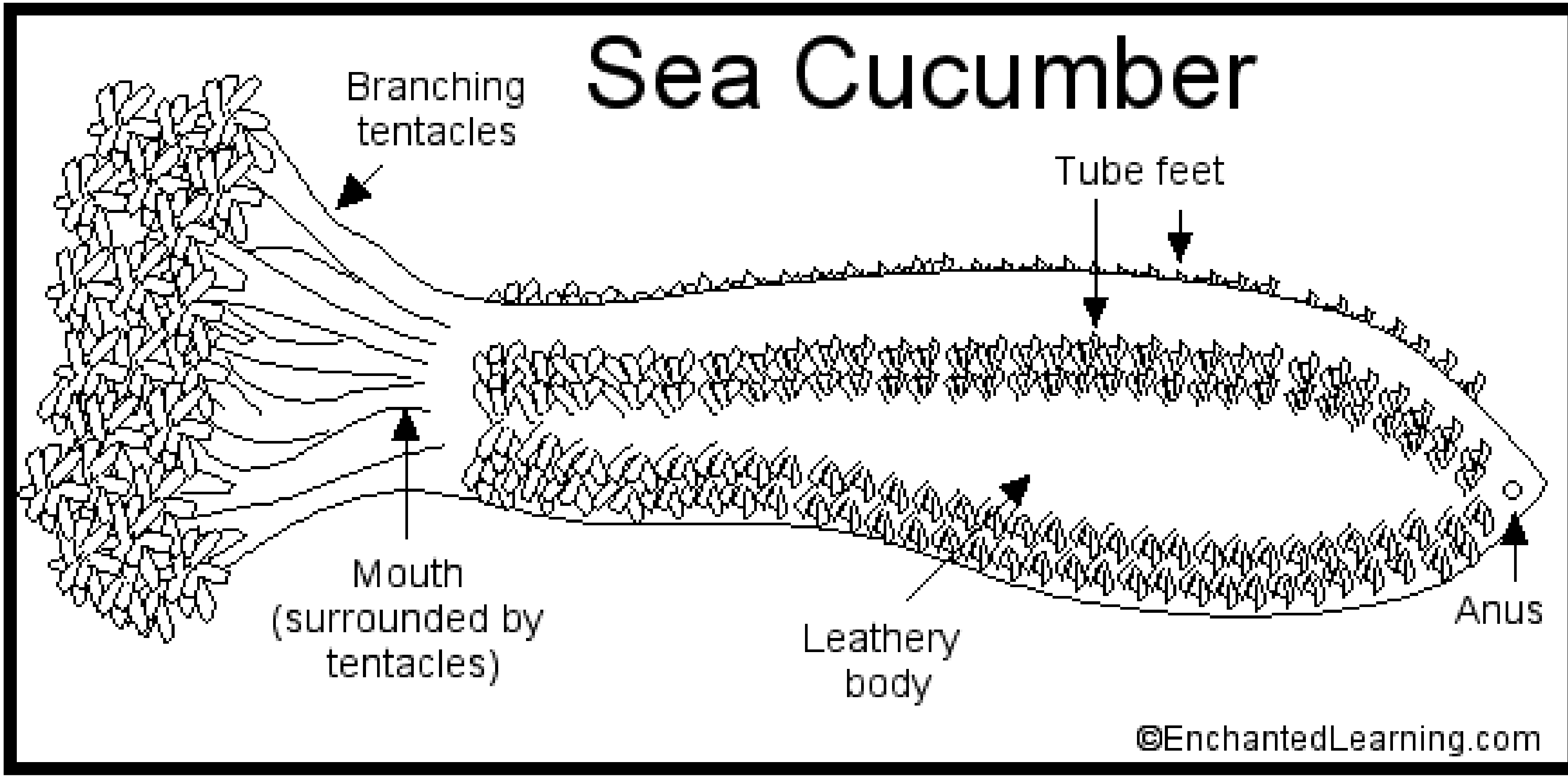
Class: Echinoidea



Sea Urchin
Bottom Side
(Oral side)
Top Side
(Aboral side)
Mouth
Sharp spines pointing out in all directions; spines are connected to the skeleton by ball-joints
Anus
test or "skeleton"
5 tooth-like plates that point inwards - called Aristotle's lantern.
Podia surrounding mouth
Genital plate
Gonopore
©EnchantedLearning.com

Class Holothuroidea

- Sea Cucumbers
- Similar body plan to a sea urchin, just stretched out from mouth to anus
- Lies on sides, oral and aboral surfaces are at the ends


Sea Cucumber
Branching tentacles
Tube feet
Mouth (surrounded by tentacles)
Leathery body
Anus
©EnchantedLearning.com

Sea cucumber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FOSSILS:

MICRASTER

I. PHYLUM : Echinodermata
II. CLASS : Echinoidea
III. ORDER : Irregularia
IV. MORPHOLOGY:
   i. Shell form: Oval or heart shaped. Truncated behind.
   ii. Symmetry: Radial.
   iii. Corona: Ambulacra sub-petaloid. Five umbulacra and interambulacra plates are distinct. Ambulacrum shows trivium character in the posterior part and bivium character in the anterior part. Tubercles are small.
   iv. Oral / aboral system: Mouth and anus are in different axis. Apical disc is small.
V. AGE: Cretaceous.

HEMIASTER

I. PHYLUM : Echinodermata
II. CLASS : Echinoidea
III. ORDER : Irregularia
IV. MORPHOLOGY:
   i. Shell form: Oval or heart shaped. Truncated behind.
   ii. Symmetry: Radial.
   iii. Corona: Ambulacra sub-petaloid. Ambulacrum shows trivium character in the posterior part and bivium character in the anterior part. Tubercles are small.
   iv. Oral / aboral system: Mouth and anus are in different axis. Apical disc is small.
   v. Faciole:
V. AGE: Cretaceous.

STIGMATOPYGOUS

I. PHYLUM : Echinodermata
II. CLASS : Echinoidea
III. ORDER : Irregularia
IV. MORPHOLOGY:
   i. Shell form: Cap shaped. Flat at the base.
   ii. Symmetry: Radial.
   iii. Corona: Ambulacral and inter ambulacral areas are petaloid type. Surface is smooth.
   iv. Oral / aboral system: Mouth and anus lie in different axis.
V. AGE: Upper Cretaceous.

PLANT FOSSILS

GLOSSOPTERIS

I. DIVISION : Pteropsida
II. CLASS : Gymnospermae
III. ORDER : Pteridospermae
IV. GENUS : Glossopteris
V. MORPHOLOGY:

The frond is large and varies in shape and size. Generally it is lenticular in shape with smooth margin, obtuse or spatulate apex. Midrib is present. Venation is reticulate. Length varies from 30-40cm. The rhizome of glossopteris is called vertebraria.

VI. AGE: Upper Carboniferous to Lower Triassic (Lower Gondwana).

GANGAMOPTERIS

I. DIVISION : Pteropsida
II. CLASS : Gymnospermae
III. ORDER : Pteridospermae
IV. GENUS : Gangamopteris
V. MORPHOLOGY:

The frond is large and varies in shape and size. Generally it is lenticular in shape with smooth margin, obtuse or spatulate apex. Midrib is absent. Venation is sub-parallel. Length varies from 30-40cm.

VI. AGE: Upper Carboniferous to Lower Triassic (Lower Gondwana).

PTILOPHYLUM

I. DIVISION : Pteropsida
II. CLASS : Gymnospermae
III. ORDER : Pteridospermae
IV. GENUS : Ptilophylum
V. MORPHOLOGY:

The main frond is divided into number of lenceolate pinnules with entire margin acute apex. The pinnules have midrib and veins arched. Pinnules overlap each other and attach to the main rachis in an oblique manner.

VI. AGE: Jurassic to Cretaceous (Upper Gondwana).