# Eucoelomates

animals having a true coelom are referred to as being **eucoelomates**

**eucoelomate** animals have a body cavity that is completely lined with mesoderm

the **mesoderm** can develop into muscle layers & internal skeletal elements

→ a large fluid filled coelom surrounded by muscle layers makes a more effective **hydrostatic skeleton** in many worms

→ mesodermal layers lead to development of arteries and veins, ie circulatory systems; better blood supply to all internal organs

→ since mesoderm lines the digestive tract, this allows for the development of much more elaborate digestive organs

eg. compare the digestive tract of earthworms to *Ascaris*.

→ mesenteries to support internal organs

most eucoelomates are **protostomes**

→ the mouth develops first in an embryo



a few eucoelomates (mainly echinoderms and chordates) are **deuterostomes**

→ the anus is the first to develop in an embryo

there are 2 main ways that a true coelom can develop in an embryo:

in most **protostomes** the coelom appears as a split in the mesoderm layer of the embryo (schizocoelous)

most invertebrate coelomates are protostomes

in most **deuterostomes**, the coelom appears as outpocketings of the archenteron (enterocoelous)

echinoderms and chordates and a few minor phyla are deuterostomes



# Animals – Molluscs

110,000 living; 70,000 fossils

second largest phylum of animals in terms of number of *known* species

some estimate there are up to 150,000 species

**most versatile body** plan of all animals

range from fairly simple organisms to some of the most complex and specialized of invertebrates

includes: snails, limpets, clams, mussels, chitons, octopus, squid, oysters, slugs, nautilus, tooth shells

the phylum is divided into 8 different classes but 90% of species are in only two: bivalves & snails

good fossil record; since most secrete a shell

all living classes were well established early in the fossil record

but did not become dominant until the brachiopods mostly died out in the Permian Extinction (~250 MY ago)

microscopic to 20 M (50-60' = giant squid) and up to 900 kg (1980 lbs; ~ 1 ton)

eg. *Tridacna* 1.5 M and 250 kg (500 lbs)



but most (80%) less than 10 cm (~4")

molluscs are mostly aquatic; found from the tropics to the polar seas

occur from the bottom of the oceans to 7000 M above sea level

typical fauna of all parts of the ocean, ponds, lakes, streams and rivers, mudflats, intertidal and terrestrial habitats

bottom feeders, planktonic, burrowers, borers, pelagic forms

one group, cephalopods, are considered the most intelligent of all invertebrates

the phylum originated in the sea and most of them remain there

→ only **bivalves** and **snails** moved to brackish and freshwaters

→ only **snails** invaded land

mollusks are closely related to segmented worms

→ same larval form = **trochophore**

## Body Plan

well developed **bilateral symmetry**

most are **unsegmented**

- a few primitive forms seem to show some segmentation.

most molluscs (except bivalves) have a well developed **head**

- bears mouth and various sense organs

in spite of wide diversity of group most share some basic features in their **body plan**:

- **mantle** - secretes shell or becomes outer body covering itself
- **visceral mass** – most internal organs are embedded in tissue rather than being surrounded by the body cavity
- **shell** - (internal or external)
- **radula** – specialized feeding organ in mouth
- **foot** - usually used for locomotion

### 1. Mantle

the body wall of mollusks consists of an outer layer of **epidermis** that extends over most of the animal as a **mantle**

often contains various **sense organs**

- eg. **ocelli, sensory papillae**



**glands** in epidermis secretes mucous, cement and sometimes a shell

in some mollusks the mantle hangs down to create **mantle cavity** around the internal organs

- houses respiratory organs; gills
- sometimes the mantle itself serves as a respiratory organ

products from the digestive, excretory & reproductive systems empty into mantle cavity before release

- a continuous current of water is created by **cilia** to bring in food and oxygen and to remove wastes and gametes

some molluscs are able to retract head or foot into mantle cavity for protection

### 2. Visceral Mass

mantle is underlain by complex layers of muscle and connective tissues

most of the body organs are embedded in a solid mass called the visceral mass rather than being located in a true cavity



the body cavity of molluscs is a true **coelom** but it is greatly reduced to a small space around the heart

- it has become part of an open circulatory system

### 3. Shell

in most molluscs the mantle secretes a **shell** which serves as a protective exoskeleton

great variation in shell form and structure

shell made of **calcium carbonate**

- calcium extracted from water, soil or food

shell is composed of 3 layers:

**periostracum** = outer

- especially thick in freshwater molluscs → protects from acidity common in fw
- in many marine forms this layer is thin or absent

**prismatic layer** = middle

- dense prisms of calcium carbonate crystals in protein matrix

**nacreous layer** = inner

- glossy film of calcium carbonate sheets
- secreted continuously through live



- thickens
- produces irridescent "mother of pearl"

shell appears in embryo

- grows throughout life → often **growth lines**

usually used for **protection**

- but some bivalves use shell to rasp into wood or rock

in some such as squid and octopus the shell is internal and greatly reduced

- the **mantle** serves as the animals outer covering

### 4. Radula

in mouth is tongue-like rasping organ = **radula**

- found in all groups except bivalves and aplacophora (solenogastres)

hardened file-like, up to 250,000 tiny teeth

- the numbers and pattern of teeth are used to identify certain species
- new rows of teeth are continually added to the back of the radula ad the front teeth are worn down

the radula is supported by a cartilage-like rod (=odontophore)

used to scrape, pierce, tear or cut food

radula also acts as a conveyor belt to move food toward the digestive tract

**5. Foot**

all molluscs have a thick muscular **foot**

variously modified for **locomotion**:

**creeping movements** - produced by waves of muscular contractions that move through foot

or by creating a **slime trail** from mucous glands in the foot

eg. snails → gliding movement

or **digging** into sediment
being extended from body into sediment
hydraulically by engorging with blood to anchor
then draw rest of body into sediment

eg. bivalves
eg. scaphopoda

or for **attachment**:

may secrete mucus to adhere to solid substrate

eg. limpets, chitons, land snails



the foot of many bivalves contain a gland that produces **byssal threads** (sea silk) for attachment

silky filaments of keratin and other proteins

attached to substrate by extremely effective cement

in some molluscs a portion of the foot is modified into a long tubular **proboscis** for feeding

**Feeding and Digestion**

detritus feeders, burrowers, borers, grazers, carnivores, filter feeders, etc

in mouth is tonguelike rasping organ = **radula**

most internal organs, including the digestive system are embedded in solid tissue called the **visceral mass**, instead of being free inside a body cavity (coelom)

**complete digestive tract** divided into discrete, functionally specialized regions:

**foregut**

**buccal cavity**
**mouth**, **radula**, **salivary glands, esophagus**
receives and prepares food

**midgut**

**stomach** and associated **digestive glands**
sorting region, crushing region



**crystalline style** in some to grind food
some digestion takes place in digestive gland

**hindgut**

**intestine** usually long and coiled
absorption of nutrients
formation of feces (undigested residue)

**Respiration**

most mollusks have folded, ciliated **gills** (=ctenidia)

→thin feathery sheets of tissue covered with cilia

also used for feeding in bivalves

some mollusks breath through their skin

many terresrial snails lack gills (=pulmonates)

→mantle is modified into a saclike "lung" for breathing air

**Circulation**

**open circulatory system** in most

→ blood not entirely contained within vessels

works good for slow moving animals

→ the most active molluscs, the cephalopods, have a closed circulatory system



simple heart with a few vessels

heart with 2 auricles and 1 ventricle

extending from heart is **aorta**

reduced coelom becomes a **haemocoel** surrounding heart

blood contains several kinds of cells:

oxygen carrying cells with pigments to improve efficiency of oxygen transport:

**haemocyanin** (Cu) - most - blue
some with **hemoglobin** (Fe) - red

some white blood cells

no clotting agents or thrombocytes

cephalopods have a closed circulatory system

**Endocrine Systems**

well developed **endocrine system**

→ controls egg laying and growth

**Nervous System**

CNS is a ring of **ganglia** in head area with paired nerves and ganglia extending to other parts of the body

eg. pedal ganglia → control foot

although the molluscs have a relatively simple nervous system

cephalopods are considered the most "intelligent" of all invertebrates

rival some mammals in ability to reason & learn

unlike most molluscs, cephalopods are active predators

→ can recognize prey with sharp eyes

→ can learn by watching

**Excretion**

usually 1 pair of **nephridia** (=metanephridia)

often called kidneys (not really true kidneys)

(**metanephridium** consist of a tube that opens into body cavity at one end and drains to the outside)

in many species the nephridial tubule also acts as **gonoduct**



some molluscs have several pairs of nephridia

some excretion also occurs through body wall and gills

**Reproduction & Development**

most molluscs are **dioecious**; some, especially gastropods, are **monoecious** (hermaphrodites)

many marine forms produce characteristic larva = **trochophore**

same larval form is found in some flatworms, annelids and a few other minor phyla

in some gastropods and bivalves a second larval form develops = **veliger**

it is also free swimming and has a foot, shell and mantle

in many molluscs the trochophore larvae develops in the unhatched egg and a veliger hatches to become the only free swimming larva in these species

some freshwater bivalves produce a parasitic larva = **glochidium**

it attaches to gills of host fish and feeds on blood

in cephalopods, many freshwater snails and some bivalves



development is **direct**, ie. no larval stage

**Evolution of Molluscs**

new molecular evidence indicates an evolutionary relationship between Molluscs, Flatworms, Rotifers and Annelids

Molluscs branched off the main animal line about 545 MY ago

plant and animal life on land would not arise for another 100 MY



## Classification of Phylum Mollusca

**Class: Aplacophora: now Caudofoveata & Solanogastres**

**Class: Monoplacophora**

**Class: Polyplacophora** (chitins)

**Class: Scaphopoda** (tusk shells, tooth shells)

**Class: Bivalvia** (mussels & clams)

**Class: Gastropoda** (snails & slugs)

**Class: Cephalopoda** (octopus and squid)

## Class: Aplacophora

(sometimes divided into 2 classes; Caudofoveata & Solenogastres)

means "no plate or shell'

~370 sp

features may be closer to ancestral mollusc than any other modern group

all marine; most are small; 2-140mm long

soft bodied, wormlike, **no shell**, no distinct head

body covered with calcareous **scales** or **spicules**

some are burrowers in muddy sediments

→feed on protozoa & microorganisms and detritus

others don't burrow and live on the sediment and feed on larger organisms including cnidaria

**radula** is present in some, absent in others

some have **gills** for respiration

no nephridia

monoecious or dioecious



## Class: Monoplacophora

means: "one plate"

25 species

small; 3mm to 3 cm

fossils known from Cambrian

→was believed to be an extinct group until discovered near Costa Rica in 1952

small, single, low rounded shell with ventral creeping foot

superficially resemble limpets (gastropods)

unlike other molluscs; show some evidence of **segmentation**

some organs are serially repeated in body:
3-6 pairs of gills
8 pairs of muscles
3-7 pairs of kidneys (nephridia)

[it was once believed that the mollusc ancestor was a segmented wormlike animal but current research has discredited that hypothesis]

have **radula** for scraping food

ladderlike nervous system similar to flatworms

eg. *Neopilina* sp.



## Class: Polyplacophora
**(chitons)**

means "many plates"

1000 species

body is flattened with convex upper surface

most 2-5 cm; some to 30 cm

prefers rocky intertidal zones;

but found to 4000 M deep

all marine

clings to rocks or hard surfaces

fairly sedentary; may move short distances to feed

head and cephalic sensory organs reduced

**shell** contains 8 overlapping plates on dorsal surface

if detached, can roll up like pill bugs/armadillo

**mantle** forms a girdle around margins of plates

sometimes covers part or all of plates



broad ventral **foot** attaches firmly to substrate

the grooves along sides of foot form closed "tubes" open at each end

**<u>Feeding</u>**

most feed on algae using **radula** to scrape algae from surface

one predatory species (*Placiphorella velata*) captures small invertebrates by "jumping" on them

**<u>Respiration</u>**

**gills** suspended in mantle cavity along sides of thick flat muscular foot

water is pumped across gills within the "tube"

at low tide when exposed, can breath air to some degree

**<u>Nervous System</u>**

2 long nerve cords extend along body

**osphradia** in mantle cavity near anus

→ samples chemical in water

**Reproduction**

sexes separate (dioecious) in most

often with complex courting behaviors

produce **trochophore** larva



## Class: Scaphopoda
**(tusk shells, tooth shells)**

means "trough foot"

~900 species

slender bodies in tubular shell, open at both ends

most 2.5-5 cm; some up to 25 cm

marine molluscs

subtidal to 6000 M deep

esp Atlantic coast

sedentary (not sessile),

→ burrows into mud or sand

mantle wrapped around viscera and fused to form a tube

foot protrudes through larger end of shell

→used to burrow into sediment

as it burrows it always leaves the small end exposed to water



**Feeding & Digestion**

feeds mainly on detritus and protozoa caught by **cilia** on foot

or using tentacle-like **captacula**

→mucous covered tentacles extending from head

captacula may also serve a sensory function

**radula** carries food to **gizzard** for crushing

**Respiration**

no gills

**mantle** wraps around viscera and fuses to form tube

movement of foot and cilia pump water through tubular mantle cavity

→gas exchange occurs across surface of mantle

**Nervous system**

no eyes

captacula may serve some sensory function

**Reproduction**



dioecious

produces **trochophore** larva

# Class: Bivalvia

means: "two valves"

old name for class was pelecypoda = "hatchet foot"

includes mussels, clams, scallops, oysters, shipworms

1 mm to 1.5 M (*Tridacna*)
up to 500 lbs

all are aquatic
mostly marine,
many brackish,
some freshwater

most are filter feeders

no head, no radula, almost no cephalization

**Shell**

shell is laterally compressed; 2 valves (right & left)

"bulging" part of shell on dorsal side near hinge
= **umbo**

is the oldest part of shell; grows from edges

shell held together dorsally by **hinge** and **adductor muscles** extending between shells



shell is mainly used for **protection** but does have some other uses in some species:

eg. shipworms use shell to burrow into wood and then feed on wood particles

eg. some clams are able to bore into rock and concrete with spiny valves

eg. scallops use shell for propulsion by quickly closing them together to force out water

→ can swim in any direction

**Mantle**

shell is secreted by **mantle**

their mantle can also produce "**pearls**"

pearl production is a protective action toward some foreign body between shell and mantle

eg. sand grain, parasite, etc

mantle secretes layers around object

commercial pearls are produced by some oysters & some freshwater bivalves

posterior portions of mantle come together to form **incurrent and excurrent siphons**

in some bivalves the siphons can be quite long

**Foot**



thick muscular foot used for locomotion

changes in blood pressure as hydrostatic skeleton allow foot to dig in and anchor itself in sediment

then muscles constrict and pulls rest of animal in

some mussels are sessile and attach to substrate by **byssal threads** secreted by glands in the foot

**Feeding & Digestion**

**most** bivalves are **filter feeders:**

**gills** are used to filter food out of water

food is strained out as water passes over gills

trapped in **mucous** and moved by **cilia** to mouth

some bivalves are **deposit feeders:**

use long proboscis like organ formed from modified **foot** to collect food in sand or mud

some bivalves use their **shell** to bore into solid objects to extract food:

eg. **shipworms** "termites of the sea"
have long, wormlike appearance; long siphons
use small valves as rasping organs to drill through wood and eat wood particles excavated
bacteria in gut digest the wood and fix nitrogen for host



some bivalves are **predators:**

eg. **septibranchs** slurp up tiny crustaceans by creating a strong suction in mantle cavity to draw in prey

eg. **razor clams** thrust proboscis between shells of other bivalves to kill and eat them

some bivalves get most of their food from symbiotic algae (**dinoflagellates**) that live in mantle tissue

eg. *Tridachna*

food enters mouth and enters stomach

in stomach, food is sorted

a gelatinous rod (= **crystalline style**) spins slowly (by cilia) & dissolves to release digestive enzymes

particles are **sorted** by size:
→larger particles move to intestine
→smaller particles move to digestive gland

**Respiration**

**gills** used for respiration

**cilia** on gills create incurrent and excurrent flow

oxygen is extracted from water passing over gills

**Circulatory System**

3 chambered **heart** (2 atria, 1 ventricle) in **pericardial cavity**

wraps around intestine

beats slowly

pumps blood to gills for oxygenation and to kidney for excretion

**Nervous System**

sense organs poorly developed

**statocysts** in foot

**tactile** cells in mantle cavity

**eyes** in scallops along mantle edge
→ each has cornea, lens, retina, pigment layer

**Reproduction**

usually dioecious;

some (eg some oyster species) are prodandrous

gametes discharged into mantle cavity and out excurrent siphon



in most → fertilization is external

eggs develop into characteristic **trochophore larva**

in some marine forms a second free swimming larval form is produced = **veliger**

(has shell, foot and mantle)

**eg. oyster:**

50 Million eggs released per season

embryo develops into trochophore
→ veliger
→ spat

freshwater bivalves have internal fertilization

gills become brood chambers

bivalved **glochidia larvae** (specialized veliger) are released

some moms can "shoot" larvae into water column

others produce a structure that looks like a small fish to entice predatory fish

when fish bites the "bait" it gets a mouthful of glochidia which then attach to the lungs

they parasitize gills of fish for 1 - 3 weeks generally causing little harm to their host but dispersing far and wide

then release and sink to bottom to become filter feeders



# Class: Gastropoda

means "belly foot"

70,000 living species; 15,000 fossils

→ 1/3rd of all molluscs

largest and most successful class of molluscs

extremely diverse group: snails, slugs, abalones, limpets, whelks, conchs, periwinkles, sea slugs, sea hares

microscopic to 1 M long; most 1-8 cm

marine, freshwater and terrestrial representatives

→ virtually every mode of life except aerial

marine: littoral to deepest ocean
some pelagic in open ocean
some brackish

freshwater: rivers, lakes, streams ponds, etc
tropics to poles

terrestrial: woodlands, pastures, mosses, cliffs,
some specialized for climbing

usually sluggish and sedentary

some sea slugs are brightly colored



**Body Plan**

unlike clams, snails and slugs have a distinct **head** with brain, sense organs and mouth

sense organs: simple eyes
tentacles
chemical receptors

mouth with **radula**
→ rasps and scrapes algae

elongated body with **foot** below for gliding

**mantle** secretes shell and forms dorsal surface of animal

in slugs the mantle forms a hollow breathing chamber

**Shell**

most have a single heavy shell for defense

some shells with **operculum**

a few have no shell

snails are very well **protected**:

→generally secretive habits

→strong shell, some with door

→some can produce toxic secretions

→some can deliver an active blow with sharp operculum to deter attack

→some can even redeploy stinging cells from cnidarian prey

still many are eaten by insects, fish, birds & mammals

and parasitized by a variety of helminths

**slugs** have lost their shell

(but still produce one temporarily during embryonic development)

most shells show some degree of **coiling**; a few do not

coiling occurred early in the fossil record of gastropods

all living gastropods, whether coiled like snails or uncoiled like limpets and slugs, descended from coiled ancestors

in addition to coiling, some animals also show **tortion**

**tortion** was a separate evolutionary event from coiling; occurred later in evolution

animal begins with basic bilateral symmetry but becomes assymetrical due to **tortion**



tortion

→ brings gills up front for better gas exchange

→ makes more room in shell for retraction

→ but puts anus over head; greater chance of fouling mouth

some shells also show **spiral** winding instead of straight coil

makes shell more compact

but unbalanced → shell tipped over

gills, auricle, and kidney on right have been lost

this assymetrical loss helped reduce fouling of tortion

→ water is brought into left front side of shell and out right side of shell

**<u>Locomotion</u>**

unlike other molluscs, gastropods glide on their "foot" by secreting a mucus trail

a wave of muscular contractions propels them along



it takes a lot more energy to move this way than it does to run, walk, swim or fly

the "most expensive" part is mucus production

many snails follow the mucus trail of other snails to conserve their own mucus

**<u>Feeding & Digestion</u>**

wide variety of feeding types in the group

1. most gastropods are **herbivores**

   a. use **radula** to scrap algae off of hard surfaces such as rocks

      eg. aquarium snails

   b. some are **browsers**

      eg. abalone holds seaweed with foot and breaks off pieces with radula to eat

   c. some are **plankton feeders**

      they drift in plankton as they eat algae

2. some are **filter feeders**

   **eg. limpets** use gill cilia to draw in water current with food particles then filters out food

3. others are **scavengers**



feed on dead and decaying organisms

4. some are **carnivores**

   feed on a variety of animals

   eg. other mollusks, especially bivalves; soft corals, fish, worms, etc

   some carnivores can follow chemical trails to locate their prey

   often have a long tubelike **proboscis** that they can thrust between the shells of bivalves and kill and digest prey

   some use **venom** to subdue their prey

   **eg. cone shells**

   one of the most specialized of the group

   **radula** consists of individual teeth; each charged with a highly toxic **venom**

   when prey is located the snail extends wormlike **proboscis** to attract prey, eg a fish

   its proboscis is loaded with one of its toxic teeth

   when close enough, the tooth is expelled like a harpoon to paralyze the prey

   this allows a slow moving predator to catch often a much faster prey such as fish

the stings of some species are lethal to humans

**eg. moon snail** (*Polinices*) **& oyster borer** (*Urosalpinx*)

uses **radula** to help bore hole through bivalves

also secretes digestive chemicals to help drill through shell

once hole is complete, snail thrusts **proboscis** through hole and spends hours or days feeding on prey

using its radula to cut and tear off pieces of flesh

some predatory gastropods are pelagic or swimming forms that have lost their shells = **Nudibranchs**

**eg. sea slugs**

nearly all are marine

widely distributed, mostly shallow waters some pelagic

brilliant colors; some contain toxins to subdue their prey

unique coloration may be warning

some feed on sea anemones and corals

→ draw color from their prey

→ the undischarged nematocysts of their prey are preserved and transported to the surface of their bodies and used for defense

**eg. sea butterflies**

some secrete a mucus net to capture zooplankton

then draw their web into their mouth and eat web and all trapped food



some sea slugs are able to harvest chloroplasts from the algae they eat and use them temporarily for **photosynthesis**

new data indicates that not all such slugs are able to do photosynthesis with the "stolen" chloroplasts. What are they used for?

## Respiration

simple gills (=ctenidia) are variously modified in aquatic forms

terrestrial snails (=**pulmonates)** lack gill but have highly vascularized mantle cavity that serves as an air breathing "lung"

lung opens to outside through a small opening (= **pneumostome)**

draw air in over moist surface of the mantle to extract oxygen

many pulmonates have returned to water and therefore must surface periodically to breath

## Nervous System

sense organs:

simple **photoreceptors** that detect light and dark

a few have image forming **eyes** with cornea and lens



**statocysts** for balance

**tactile organs** – one or two pairs of tentacles one pair usually contains the eyes

**chemoreceptors** – especially in incurrent areas of respiratory system

## Reproduction

**monoecious** or **dioecious**

many gastropods perform elaborate **courtship ceremonies**

in some, courtship can last up to 20 hours

some use a syringe-like stylet to inject their paretner's brain with 'manipulative' chemicals while mating to enhance their success

many terrestrial snails eject a **dart** from dart sac into partners body to heighten excitement before copulation

some hold onto the dart and use it as a dagger, stabbing their partner up to 3000 times during mating

it contains a chemical that improves chances of their sperm fertilizing the other's eggs

as hermaphrodites, they often cross fertilize each other



after cross copulation, each partner deposits its eggs in shallow burrows

some sea slugs have a "disposable penis"; after copulating, the penis just falls

it takes 24 hours to regrow a replacement

a few snails (eg *Crepidula*) are **protandrous**

they live stacked on top of each other

each begins life as a male

the original male reproductive tract degenerates and the animal regenerates either a female or another male tract

→ if attached to a female males will remain males

→ if too many males in the "pile" then some will become females

once female, they remain female for life

a few primitive gastropods eject sperm and eggs into water

in aquatic forms eggs may be attached to substrate or float freely in plankton

some marine forms enclose eggs in wide variety of

tough **capsules**

eg. welk

a few freshwater forms brood their eggs in oviduct or bear live young (ovoviviparus)



# Class: Cephalopoda

800 living species; 10,000 fossil species

means "head foot" the main mass of the animal

with a cluster of prehensile arms and tentacles extending from one end

include squid, octopus, nautilus, cuttlefish

extensive fossil record back to Cambrian

dominant life in ancient oceans after trilobites declined

all marine

2 cm to 60' (giant squid, weighs almost a ton)

giant squid is most massive invertebrate

recent genetic analysis indicates that giant squid (*Architeuthis dux*) anywhere in the world are all members of a single global population.

the young apparently disperse globally the settle as adults in one place

most active & most advanced of all molluscs

→ some argue: most advanced of all invertebrates

**Shell**



most fossil forms (eg. ammonites common in Texas) had very large heavy shells kept buoyant by gas filled inner chambers

today only *Nautilus* has a large external shell

**eg. *Nautilus***

shell spiral as some gastropods

but divided into chambers

chambers not found in gastropods

chambers connected by cord of living tissue = **siphuncle**

can adjust gas in chambers for neutral buoyancy

some have **internal shell** completely enclosed by mantle

**eg. cuttlefish, squid**

some have completely lost shell and mantle encloses and protects animal

**eg. octopus**

shell was sacrificed for speed to avoid predation

**Mantle**

in most cephalopods the **mantle** serves as the animals outer covering



much thicker and more muscular than in other groups

protects internal organs

most cephalopods are excellent swimmers

can forcefully expel water from the mantle cavity through a ventral **funnel** (siphon) creating "jet propulsion"

allows them to maneuver quickly to flee predators

the funnel can be pointed to quickly move in any direction

squid are streamlined and have **lateral fins** that greatly improve their swimming ability

octopus is better adapted to crawling than swimming

crawls over rocks and corals & into crevices using suction discs on its tentacles to pull or anchor itself

some deep water octopi have webbed tentacles and swim like jellyfish

the surface of the mantle and the rest of animal is covered by pigment cells called **chromatophores**

chromatophore is an elastic **pigment cell**

tiny muscles surround each one

contraction expands chromatophore and changes color of body

allows animal to rapidly change color

under nervous and hormonal control

can produce general darkening and lightening flashes of pink, yellow, lavender

can form bars, stripes, spots and blotches

the ability to change color quickly offers considerable protection (in lieu of a shell) – provides instant camoflage

also can be used for communication

can indicate danger, protection, or used during courtship

many deep sea forms are **bioluminescent**

**Head & Foot**

in cephalopods, the **head** is indistinguishable from the **foot**

the "head-foot" is elongated into 8 or 10 **arms** (up to 90 in nautilus) and 2 longer **tentacles**



tentacles and arms have rows of **suction discs**

arms have suckers along their entire length

tentacles have suckers only at distal end

as cephalopod gets closer to prey it can shoot out tentacles to quickly capture it

a mouth is at center of arms
contains chitinous **beak** or **jaws**

the rest of the foot is modified into a **funnel** for directed movement

**Digestive System**

almost all cephalopods are **predators**

only the "vampire squid" is not a predator

it is a filter feeder using tiny mucous lined filaments to fish for organic matter

it lives in low oxygen zones where predators could not survive

use tentacles and arms to capture and handle prey with its suction cups

strong beaklike **jaws** enclose tongue-like **radula**

octopus and cuttlefish have **poison glands** to help subdue prey



the **beak** bites pieces of prey off and the **radula** further tear it into pieces

from the **mouth**, food travels through a long thin **esophagus** to a small **stomach**

secretions from **pancreas** and **liver** help digest the food into a mush

food is then passed to the **cecum** where digestion is completed and nutrients are absorbed into the hemolymph (blood) for distribution

undigested wastes are passed to the **rectum** and out the **anus**, and finally out the **siphon**

**Excretion**

**Kidneys** extract wastes from the hemolymph and release wastes through the funnel

**Respiration & Circulation**

since the cephalopods are so active they require more oxygen than other molluscs

most have 1 pr of large gills; no cilia

mantle cavity expands and contracts to draw water over gills → more efficient than cilia

**1-way valves** allow water to enter along edges of



mantle but force water to exit through funnel for locomotion

**closed circulatory system**
→ more efficient for gas exchange and transport

accessory (brachial) **hearts** at base of each gill improves pumping efficiency even more

**Nervous System and Senses**

largest brain of any invertebrate

several lobes with millions of nerve cells

more elaborate than in other classes

much of our current knowledge of nerve cell function is based on studies of the large nerve fibers of the squid

**brain** is located behind mouth

octopus and cuttlefish actual "think & plan"

learn and react to their environment

level surpassed only by some vertebrates

generally considered the cleverest of all invertebrates and rival mammals in some ways

masters of disguise

most versatile use of **chromatophores** in the animal kingdom, esp. cuttlefish

great curiosity; can solve problems

can easily learn behaviors by reward/punishment

if they see another rewarded for a particular choice they will do the same thing to hopefully get the same reward

one octopus would short circuit the light over her tank by squirting water at it if someone forgot to turn it off at night

can use rudimentary tools

biologists have recently (2010) reported the first example of "tool use" by an invertebrate:

a species of octopus in Australia has been observed carrying around coconut shells and using them for cover when threatened

European Union has recently (2012) offered them the same protections as lab rats

**sensory organs are** better developed in cephalopods than in other mollusk classes

**eyes**: most have very well developed eyes with cornea, lens retina

eyes show remarkable convergent evolution to vertebrate eye; cornea, lens, retina, etc

differences:

verts: adjust shape of lens to focus image on retina
cephs: lens is rigid, adjust shape of eyeball to focus



verts: receptors point away from light source, are behind several layers of nerve cell and have "blind spot" where optic nerve exits the eye

cephs: receptors are in front of the "wiring", no blind spot, more light reaches receptors

**statocysts**: large and more complex than in other classes important in controlling eye position

**tentacles**: use tentacles for tactile exploration

**Protection: Ink Sac**

most cephalopods have an **ink sac** for protection

along the side of rectum

**melanin** pigment (same as in our skin)

→ creates smoke screen to facilitate escape from danger

**Reproduction**

cephalopods are **dioecious**

in the male:

**sperm** are produced in a single large testis and pass to the vas deferens for storage

the male packages sperm in a packet called a



**spermatophores** and stores it in mantle cavity

each spermatophore can contain up to 10 M sperm

in squid a spermatophore is about the size of a rice grain

in the female:

a single large **ovary** produces eggs

2 large **nidamental glands** produce a hard, foul tasting (to deter predation) capsule that encloses the eggs

males often fight for the attention of a female

courtship sometimes includes numerous color changes & body movements

the female typically chooses her mate

a specialized arm of male is used to transfer sperm to female
= **hectocotylus arm**

(proximal suckers are longer and thinner than on its other arms)

male plucks spermatophore from its own mantle cavity and inserts it into females mantle cavity



male must be careful since female will often escape so quickly that she rips the arm off the male

not too serious since male dies soon after mating

after several matings the female can select which sperm to use to fertilize her eggs

eggs are fertilized as female lays them

eggs attached to stones in long strings of 1000's of eggs

or in some species, eggs are brooded by the female

female squid dies after laying her eggs

direct development; no free-swimming larvae

juveniles hatch from eggs

generally, cephalopods don't show parental care but a few cases are known:

eg. one group of deep water squid carries and protects and egg sac carrying up to 3000 eggs for several months

eg. some octopuses spend months caring for the eggs they have laid

protecting them from predators and keeping them clean

by the time the eggs hatch the mothers are so exhausted that they die outright or easily succumb to predators

**Major Groups of Cephalopods**

1. nautiloids
2. ammonoids -all extinct
3. coleoidea - all living forms except nautilus



# Ecological Impacts of Molluscs

1. important in **food webs** in aquatic ecosystems and even in terrestrial ecosystems

   mollusks are eaten by a large number of animals

2. snails are major source of calcium for birds

3. oysters are **keystone species** since they tend to form reefs nearshore

   the cracks and crevices provide homes for a large variety of animals creating a complex community of interactions

4. threatened & endangered mollusks

   freshwater bivalves are now the most threatened group of invertebrates in the US

   some can live up to 50 years

   once >300 species in rivers, lakes, etc

   today: ~24 are extinct
   >160 endangered or threatened

   11 species in Texas about to be listed in the endangered list (2010)

   especially due to:



**hunting and harvesting & poaching**

were actively harvested by native americans for food, tools, jewelry

early settlers collected massive quantities for food and pearls

even today 1000's are collected for pearls & meat often sold as pet food; some human consumption

**damming rivers**

**pollution, sedimentation**

since they filter the water they are especially sensitive to pollutants and sediment

they are often the first species to disappear or decline when environmental conditions change

due to mining, industry & agriculture

5. Bioinvasives

eg. asian clam

**eg. zebra mussel**

named for distinctive striped shell pattern

arrived in US in 1986 via ballast water from Eiuropean freighter into Lake Erie



now found throughout the Great Lakes

voracious eaters that disrupt food chains by competing for same food as native species

extremely fertile and can disperse at any stage of life

able to strongly attach to any hard surface by tough byssal threads

→ have found 15000 attached to a single 4" clam

able to completely bock water inlet pipes of water treatment plants and power plants

highly costly to remove

have been found clinging to boats and are quickly spreading throughout the US

not yet in Texas but already have been found in Oklahoma

# Human Impacts of Molluscs

**1. currency**: tusk shells used as money (=wampum) by native Americans

**2. as food**: oysters, scallops, mussels, octopus, squid

eg. >2 Billion pounds of oysters are eaten each year

oysters first cultivated for food for 2000 yrs

oyster middens are found from ancient roman times and are common at coastal archaeological sites

certain species consumed cooked or raw

eg. octopus, squid & cuttlefish: 3 million tons/yr are consumed; an industry valued at >$6 Billion

eg. (1990): each night 1000 SE Asian boats set out ~25,000 miles of nylon drift nets that extend about 30 ft down from the surface to catch red squid

the bycatch from this nightly activity;
~2000 dolphins
~300,000 tons of pomfret (a kind of fish)
→ these are discarded
1000's tons of tuna, swordfish, salmon
→ are kept and sold on the black market

**3. precious "stones"**

shell nacre → buttons, cameos, etc

some species of oysters and some fw clams produce **pearls**

generally produced when a parasite gets between the shell and mantle of the animal



natural pearls take many years to grow and are very expensive

cultured pearls use "blank" of polished shell placed under mantle of oyster, then allows layers to deposit for 3-6 years

much quicker process, much cheaper, preferred today

**4. ink** → sepia dye

**5. cuttlebone** from cuttle fish

**6. Pharmaceuticals**

eg. medication derived from cone snail venom alleviates some kinds of chronic pain that even morphine can't control

**7. Materials Science Research**

eg. mussels have an amazing ability to attach to rocks. their glue is made from protein strands that can attach strongly to even teflon

applications to develop aquatic glues, antifouling paints, stronger sutures

**8. shell collecting**

**9. pollution control**

oysters consume nitrates and ammonia helping to clean & purify eutrophic waters



a project in Chesapeake Bay is using oyster reefs to remove 19 million pounds (8.6 M kg) of nitrogen compounds/yr from the bay waters

**10. destructive species**

snails and slugs → gardens

boring snails destroy oyster beds

shipworms → damage wooden ships and warves

some are not deterred by creosote treatment

some bivalves can even bore into concrete

**bioinvasions**; eg zebra mussel

intermediate hosts to parasitic helminths