Marine Biology
(Biology 11B)

Student Guide
(otherwise known as my notes)

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Invertebrates

Kingdom Animalia:
Invertebrates: no backbone – 97% of all animals! All major groups of inverts have marine representatives, and some are exclusively marine. Insects are the major ones that invaded land. Many have larval stages that go through *metamorphosis*.
Vertebrates: backbone

Organization: animal lineages: three evolutionary lines: sponges, cnidarians and ctenophores, and all others (OH). We will discuss them in order of complexity (least to most)

I. Phylum **Proifera**: Sponges – evolutionary dead end
Simple animals "pore bearers".
a. No real symmetry, associations of loosely aggregated cells
b. Coanocytes (flagellated), collar cells, allow for food intake and O2. Osculum is excurrent pore (can have several), pore cells intake water
c. Skeleton Spicules ($CaCO_3$, or SiO_2), or spongin (household sponges)
d. Ecology: sessile, benthic, filter feeder. Encrusting and upright, and boring
e. Most are hermaphrodites: eggs and sperm. Fertilization is internal. Free swimming larvae with flagella. Cells turn inside out when settle to form coanocytes (flagella still used!)
Also have asexual reproduction: budding, re-aggregation

Radial Symmetry

II. Phylum **Cnidaria**
Diverse forms: jellyfish, corals, anemones, sea fans etc. Stinging cells = nematocysts
a. Radial symmetry with oral and aboral side. Oral side has tentacles
b. Oral/aboral. Gastrovascular cavity digestion and absorbtion of nutrients. Waste through mouth! Respiration occurs through diffusion. Medusae (free swimming) and polyp (benthic) forms. Same body organization.
c. No skeleton (hydrostatic or external $CaCO_3$)
d. Ecology: sessile and benthic, as well as free swimming (planktonic) Filter feeders and predators. Some are *colonial animals*. (corals, sea fans, gorgonians, man-o-war), with specialized *zooids*. Some like man-o-war and by the wind sailors have sails to aid in movement!
Symbiosis is common with zooxanthellae: 95% of food and formation of calcareous skeleton.

e. Sex: Two phase life cycle (polymorphism)=sessile polyp phase and mobile medusa phase. Sexual rep is usually by medusa (eggs and sperm by *broadcast spawning*, or internal fertilization). Polyp also undergoes asexual budding

A. Class Hydrozoa: Man-o-war, by the wind sailor, siphonophores, hydroids, some corals. Benthic and pelagic. Many are colonial. Filter feeders and predators. Flexible exoskeleton. Polyp. Some have powerful nematocysts.

B. Class Scyphozoa (cup animal): Jellyfish: polyp stage reduced or absent. Pelagic, can move.

C. Class Anthozoa (flower animal). Sea anemones and corals. Some have CaCO3. Many lack medusa stage and many are colonial (eg. corals), some solitary (eg. anemones). Includes sea fans/whips, sea pansies, sea pens.

III. Phylum **Ctenophora**: Comb jellies. Look like jellyfish. Not a diverse phylum (about 100 sp), all are marine.

a. Actually are bi-radial.
b. Ctenes beat in coordinated fashion to propel animal. Have two tentacles for sticking prey (no nematocysts - colloblasts) prey. Have anal pores
c. No skeleton (hydrostatic)
d. Pelagic and deep sea, predators. Many have *bioluminescence*.
e. Hermaphrodites, broadcast spawners.

Bi-lateral Symmetry (except echinoderms) Posterior, anterior, ventral, dorsal

IV. Phylum **Platyhelmenthes**: Flatworms. CNS, Brain (agg. Of nerve cells in head region). Nerve cords and muscular system. Gut like cnidarians: one opening, mouth. True organs and organ systems. 20,000 species! Many (such as flukes) are parasites (eg. tapeworms – one is 40 feet long – in sperm whales))

a. Bilateral
b. Organs and organ systems, nerves, brain, CNS, muscles
c. No skeleton
d. Variety of functions (parasites, free living etc.)
e. Sexual, most have larval stage

V. Phylum **Nemertea**: Ribbon worms. About 900 species

a. Bilateral
b. Complete digestive tract, circulatory system, proboscis for feeding.
c. No skeleton (hydrostatic)
d. All predators, free moving, benthic, often *interstitial*. Can be very long or tiny. Most are shallow marine
e. Sexual reproduction

VI. Phylum **Nematoda** (nematode worms, roundworms). 10,000 to 15,000 species

a. bilateral
b. dig tract, etc.
c. Hydrostatic
d. Huge #s in sediments, decomposers, parasites, small pointy at both ends,
e. Sexual reproduction with larvae. Can be seen in fish flesh!

VII. Phylum **Annelida**. Segmented worms. Many forms! 14,000 sp?

a. bilateral
b. Segmentation, Gut cavity, complex movement and systems. Makes them good crawlers and burrowers. 2 Ventral nerve cords : peristaltic movement. Each segment has 'kidneys' for nitrogenous waste, and parapodia with setae for movement. Closed circulatory system. Have gills
c. Hydrostatic
d. See ploychaeta: deposit feeders and suspension feeders: active and passive, and carniverous. Some crawl.

e. Sexual. Trochophore larvae (pg 309), often timed with phases of moon.

(leeches and oligochaets not described here)

A. Class Polycheata: most annelid species are here. 6,000 sp. Mostly marine. 5-10 cm long. Live singly or in aggregations. Build tubes made with lots of different things. Cilia and mucus aid in feeding.

VIII. Other Worms

Phylum **Sipuncula** (peanut worms). All marine. 350 sp, benthid. Most intertidal, few deep sea.

a. Bilateral
b. Unsegmented. Can curl in to look like peanut. Mouth and anus at same end
c. Hydrostatic
d. Burrows (open at one end). Calcarous tubes or burrows.
e. Sexual: gametes released through temporary gonads. External fertilization

Phylum **Echiura**: spoon worms. About 100 sp. Fat innkeeper (Urechis Caupo). Burrow with commenal creatures in mud. Sweep detritus with proboscis and urechis uses a mucus net. Pumps water through burrow and through net. Close relatives of annelids.

Phylum **Cheatognatha**: arrow worms. Only about 100 sp.

a. Bilateral
b. Unsegmented, flattened, quick movements, small body (high SA/V ration means they don't have resp. circ or excret. Systems.). Cilia serve to notify them of movements in the water (like shark lateral line system)
c. Hydrostatic
d. Predators, planktonic
e. Hermaphrodites

IX. **Lophophorates**: Lophophore=set of ciliated tentacles arranged in a horseshoe). Suspension feeders, mostly colonial (individual zooids), live in area of low sedimentation

a. Bilateral
b. Un segmented, colonial. U shaped gut
c. Exoskeleton of a variety of shapes
d. Benthic filterfeeders
e. Sexual and asexual.

Phylum **Bryozoa**: look like colonial hydrozoans. 4000 species, delicate colonies. Retractable lophophore. Zooids show task specialization.

X. Phylum **Mollusca**: animals with a full coelom. Account for more than 90% of all animal species (second to arthropods), about 110,000 species! Very successful phylum (in terms of evolution). Diversity of shapes and diversity of habitats they live in is very high. Soft bodied, with a foot, and range from microscopic to huge (giant octopus and giant squid to 2 tons!). Many have a radula.

a. Bilateral symmetry, unsegmented
b. Separate mouth and anus. Softbodied with a mantle that produces a shell (some do not have shells). Many have a radula for eating algae. Most have an open circulatory system (except

cephalopods – squid and octopus). No real brain, but clusters of nerve cells (except Cephalopods).
c. Some have shells as an exoskeleton, others have no skeleton.
d. Some are benthic, some are pelagic, and they live from the intertidal to the deep sea. Some are predators, some are herbivores (grazers), while still others are filter feeders.
e. Sexual reproduction only, some hermaphrodites. Trochophore (like annelids) and veliger (snails and bivalves) larvae. Cephalopods have no larval stage. Broadcast spawners and egg layers.

A. Class Gastropoda: 'stomach footed'. (90,000 species!). Snails (some with no shell), nudibranchs (no shell – and with exposed gills) and limpits (many of which are grazes and very territorial). Most feed with a radula. A few are benthic and sessile, but most are mobile and either benthic or pelagic (such as the pteropod or flying snail). This class includes the abalone which are grazers, and the cone snails which have a harpoon loaded with toxin which they use to kill and eat larger prey.

B. Class Bivalvia: Two shells: clams, mussels, and oysters. About 3000 species. No radula. Most are filter feeders using an incurrent and excurrent siphon for drawing and expelling water. Feed mostly on diatoms and dinoflagellates (hence the danger of eating these shellfish during a 'red tide'. Most are benthic and many can move a bit. Broadcast spawners. Some bore into rocks and wood ('ship worms'), some burrow, some attach to hard substrate (eg. mussels). Some produce pearls.

C. Class Cephalopoda: 'head-foot'. Squid (10 arms, 2 tentacles), cuttlefish (8 arms 2 tentacles) and Octopus (8 arms). These animals have a 'true brain', while the other classes just have 'brain clusters'. Tiny to huge, deep sea to intertidal. Some are very toxic (like the blue ringed octopus). They have tentacles with sucker pads, and paired beak-like (like a parrot beak) jaws. Well developed eyes and jet propulsion make them good predators. About 600 species, all are marine. The octopus is considered quite intelligent, and can also change color. They are egg layers, and the female (in squid the male too) die after the eggs are hatched or laid (in squid). Important food for humans and many marine mammals (especially squid).

D. Class Polyplacophora: Chitons, about 600 species, including the gumboot chiton. Most like the ancestral or 'old' mollusc. They have 8 section jointed shell plates. Feed with a radula. All are marine, intertidal and subtidal.

XI Phylum **Arthropoda**: 'jointed leg'. 1 million species! (most numerous phylum). Includes the insects. Very successful phylum in terms of diversity of species and habitats they live in. They have an exoskeleton of chitin, and the molt their skeleton periodically (like snakes).

Subphylum **Crustacea**: 35,000 species, Includes the copepods, crabs, lobsters, krill, and barnacles.
a. Bilateral symmetry
b. Segmented bodies. Paired appendages (jointed legs). Dorsal (on the back) heart, and ventral (on the stomach) nerve cord. They (crustaceans) have a simple brain, and an open circulatory system.
c. Exoskeleton of chitin which they molt

d. Since there are so many, we'll focus on the Crustaceans (class Crustacea) here. Some are planktonic (like copepods) while others are benthic scavengers and predators (like shrimp and lobsters), and still others are filter feeders (like copepods).
e. They (crustaceans) have separate sexes. Male transfers sperm to female, and she holds the eggs. They have a planktonic nauplius larvae

A. Class Copepoda (oar foot): copepods. Small and planktonic. Major consumers of phytoplankton (mostly diatoms).

B. Class Decapoda (10 feet). Largest class. Crabs, shrimp and lobsters. All (even crabs) have a 'tail' like in the lobster. In the crab it is curled under. You can use it to sex a crab (in the male it is thin while in the female it is wide). Crabs have a high diversity of forms. Decapods are an important food source for humans.

C. Class Isopoda (equal feet): Pill bugs (terrestrial) and kelp isopods are examples of this class. Some are parasitic on fish gills. Others can be seen just above the high tide mark running like big pill bugs with large feet (they are actually marine – species *ligia*).

D. Class Amphipoda (double feet): sand fleas, caprellids (you'll see these later in our float lab), whale lice, and the little organisms that gray whales feed on are amphipods. They can occur in great numbers. Many (like the ones gray whales eat) are benthic and live in soft sediment. Laterally compressed bodies.

E. Class Cirripedia (curled feet): barnacles. Sessile and hermaphroditic. They have the longest penis relative to body size of any animal on earth (over 6 times their body length!). Sessile, filter feed with their feet.

XII. Phylum **Echinodermata**: 'spiny skinned'. Includes the starfish, brittle stars, sea urchins, sand dollars, sea cucumbers, sand dollars. There are about 6,000 species living from the intertidal to the very deep sea.

a. Radial pentamerous (5 part) symmetry as adults. Bilateral symmetry as larvae. Unique in that they are complex animals with radial symmetry. Other radially symmetrical animals are the more simple sponges (porifera), jellyfish/sea anemones (cnidaria), and ctenophores.
b. 3 body cavities (coelomic cavities). One serves as a water vascular system for movement, feeding and attachment. Simple nervous system with no cephalization (brain area).
   Water vascular system: exterior aboral madreporite (water intake) connected to a ring canal, connected to radial canals, connected to tube feet. This is a hydraulic system that works with water pressure to move all those tiny tube feet!
   Pedicellaria on some keep them clean.
c. Body (in most, except sea cucumbers where it is present but reduced) is enclosed in hard CaCO3 (calcium carbonate) ossicles (pieces) with openings. (exoskeleton)
d. Most are benthic as adults (feather stars – crinoids, are free swimming). They range from filter feeders (some sea cucumbers, sand dollars) to grazers (many sea urchins), to predators (some sea stars) to scavengers and detritivores (some sea stars and brittle stars)
e. Most have separate sexes. Some are broadcast spawners, some brooders. All reproduce sexually. Have a larval stage (bipinnaria larvae). Some (eg. sea stars) can regenerate body parts if they are lost. This is not really asexual reproduction.

A. Class Asteroidea (star-like): Sea stars (starfish). About 1600 species. Some have as many as 50 arms! Stomach sticks out from body for external digestion. They can stick this stomach into a bivalve (clam) shell and begin digesting it!

B. Class Echinoidea (hedgehog like). Sea urchins and sand dollars, about 900 species. Very much like sea stars (in terms of body organization), but have no 'arms'. In some urchins, the mouth (Aristotle's lantern), is adapted for grazing on algae. Sand dollars live in soft sediment and filter feed with tube feet and move with their spines (opposite from other echinoderms).

C. Class Ophiuroidea (snake form). Brittle stars and basket stars, about 2000 species. Their arms an wave and move like a snake. They use them for movement and filter feeding (the tube feet do the actual feeding).

D. Class Holothuroidea. Sea cucumbers. These lack actual spines, but have soft spiny projections. Many are eaten (there is quite a large fishery for them). There are about 1,100 species, and some are found very deep. They are filter feeders and deposit feeders (literally eat the mud or sand and digest organic matter out of it).

XIII. Phylum **Chordata**. Humans are in this Phylum too. Of the invertebrates, they are most like 'us' and other vertebrates. The invertebrates in this group (that we will discuss) are the **urochordates** (subphylum), and include tunicates, larvaceans and salps. During development we share:

1) nerve cord – along dorsal length of animal

2) gill – pharyngeal gill slits – small opening at end of gut or pharynx

3) notochord – flexible rod support between nerve cord and gut

4) ventral heart and tail (sometimes only during larval stage)

5) most chordates have a backbone, but tunicates (subphylum **urochordata**) are invertebrates and do not.

a. Bilateral symmetry (very obvious in larvae)
b. reduced segmentation. A complete digestive tract, and a closed circulatory system
c. No skeleton (hydrostatic or water filled)
d. Tunicates are benthic and sessile as adults, while salps and larvaceans ar pelagic. Some are filter feeders and some are predatory.
e. ???

A. Class Ascidiacea (little bags): These are the tunicates or sea squirts. Free swimming larvae (look like tadpoles), sessile adults. When they settle they lose their nerve cord, and develop a U shaped digestive tract. They filter water in an incurrent siphon and out an excurrent siphon. Some are solitary and some are colonial. Some deep sea tunicates are predatory.

B. Class Larvacea (larva). This is a very interesting group of animals. Adults resemble the larvae (tadpoles). They are planktonic and clear (no color). Larvaceans build huge (3 feet wide compared to a one inch long animal) clear mucus houses which they constantly keep clean,

eating the organic matter that settles on the house. At a sign of danger they will jettison out of their house and swim away. The houses then remain as mucus blobs which continue to collect organic matter, slowly sinking. This is a major part of 'marine snow', and eventually settles to the deep sea where the houses (with their load of organic yummies) become someone elses food!

C. Class Thaliacea (chamber): These are the salps, some solitary and some colonial forming long chains. They too are translucent and planktonic. They have a chamber through which they draw water to filter feed. Some have developed close symbiotic relationships with parasites which live inside them and eat them alive.

FISH! Phylum Chordata, Subphylum Vertebrata

Jawless Fish: Class. Agnatha

- Lack jaws
- Feed by suction with a round mouth with teeth
- Long thin bodies (like eels)
- Lack paired fins and scales
- Includes 2 orders
  1. Hagfish: Marine only. Feed on dead or dying fish. Can live quite deep, in muddy bottoms. Used to make wallets! ~30 species
  2. Includes Lampreys: most are fresh water, some are anadramous (feed at sea). Blood suckers. ~30 species

Cartilagenous fishes – Class Chondrichthyes

- 12 orders, 45 families
- They have paired fins and biting jaws.
- Cartilaginous skeletons: means they have to be big and most are.
- Many use fat (not air) for buoyancy
-

Sharks –

some with teeth – numerous and spares, some filter feeders
scales small and sand paper like
swim constantly (most) – force water over gills
variety of shapes =great white, cookie cutter, hammer head, whale and basking
large livers (with fat) for buoyancy
fins – fleshy, stiff for guiding tail force

Rays and Skates –

flattened bodies, body shape
demersal, bottom dwellers and feeders, mouth on bottom
pectoral fins expanded and sometimes fused to head
electric rays –(Torpedo) shock to 200V from organ on head, swimmers
Sting rays – stingers + eagle rays
Manta rays – large

Ratfishes – deep water, long tails

Bony fishes – Class Osteichithyes

19 orders, 206 families (23,700 species)

- gill cover = operculum
- fin rays – bony spines that are connected by a membrane = flexible, for swimming
- teeth fused to jawbone
- swim bladder in many

NEKTON

WHAT ARE NEKTON?

Unlike plankton, nekton NOT at mercy of currents: free swimmers.
Most are vertebrates (except squid), but no amphibians

FLOTATION

Animal flesh (protein & bone) is heavier than water
Lightening bodies:
- -air layer under feathers & fur
- -fats: blubber in mammals, fats in enlarged liver of sharks
- -lungs & air sacs in mammals & birds

REPRODUCTION

STRATEGIES:

	example	**#young**	**PI**	**juv. mort.**	**lifespan**	**repro age**
r	Sunfish	many (300 mil)	low	high	short	younger
K	Shark	few (most w/ live young)	high	low	long	older

BIRDS
-breed on isolated islands to avoid predators
-form large colonies
-migrate 1000s of kms between feeding & breeding grounds

REPTILES
-turtles only on land to breed
-large nesting aggregations, eggs harvested w/ poles
-snakes: live young in water, eggs on land
-migrate 1000s of kms.

MAMMALS
-Seals & Sea Lions (Pinnipeds) give birth on small beaches & ice flows.
-often **polygamous** (harem master), & sexually dimorphic.
-migrate 1000s of kms.
-nurse in **rookeries**, milk w/ high fat content for fast growth.

FEEDING ECOLOGY

MOST NEKTON EAT OTHER NEKTON
Fish & squid are main food items
Correlation of predator-prey size
Sperm whale eats largest prey - giant squid sucker marks
Orcas hunt whales like wolf pack, but also eat pinnipeds & cetaceans.
Porpoises eat fish & squid, often specialize
Sharks eat anything
Some eat zooplankton…

Tetrapods (animals with four feet)

MARINE REPTILES – Class reptilia

Ectotherms
Lay eggs on land
8 species turtles – all threatened or endangered
50 species snakes
1 species iguana (marine)

Turtles:

a. Invaded sea ~150 mya
b. Long generation time - >20 years @maturity
c. Oceanic existence (many)
d. shell length ranges from 70-183cm
e. live throughout tropics and subtropics throughout the world
f. can stay UW up to 50 min
g. Long migrations: green turtles travel from Ascension island to Brazil, 2000 Km
h. Females have site fidelity.

Food:
Many juveniles are omnivores (eat plants and animals)
7 species are carnivores and eat:
sponges (hawksbill - can eat sponges!)
jellies (leatherbacks0
crabs
fishes
urchins
gastropods

green turtle eats grasses and algae

reproduction/life cycle:

- every few years female goes to shore (nesting grounds)
- eggs on shore (~130 eggs)
- migrate to natal beaches (where they were born)
- female makes one nest, goes to water for 2 weeks, back to beach for up to 7 batches.
- Temperature of nest is imp: low temp = females
- male stays in water (whole life at sea)
- after last batch of eggs they go hundreds of miles away to feeding areas for 2-4 years.
- sex determined in part by abiotic factors (temperature of nest)
- turtles hatch after 9-10 weeks. Dig to surface. Best to emerge at night when predators are fewer. They are about 5 com long when they hatch!
- until 30 cm (approx one year) where do they go? We don't know. 20-50 years to maturity!!!!

Conservation:
- Humans eat eggs
- shrimp trawlers – turtles get caught in nets: TEDs (Turtle Excluder devices)
- 3 turtles are endangered (kemps ridleys, leatherback and Hawksbill) all others are threatened.

Snakes (family Hydrophiidae, related to cobras-Elapidae)
Live in indo west pacific from East Africa to NE Australia and N to Japan.
Indonesia-Malaysia to Indochina most sp of sea snakes.
Some hunt in water, reproduce on land (have enlarged scales on ventral surface for movement on land)Tail flattened in vertical plane used for swimming.
3/4 snakes never leave water. No large scales, very flattened tail
are ovoviviparous
.5 to 3 meters long

other marine reptiles:
salt water crocodiles (endangered)
marine iguanas (Galapagos)

Sea Birds

Class Aves
Order Sphenisciformes: Penguins
Order Porcellariiformes: tubenoses
Order: Anseriformes: Ducks
Order Charadriiformes: gulls and shore birds
Order Ciconiiformes: Herons
Order Pelicaniformes: pelicans and cormorants

- 28 orders, 8600 species
- descended from landbirds – re-entry into the ocean
- Endotherms
- High metabolism
- Can Fly (not all!)
- Light hollow bones for flight
- Water retaining eggs (resist water loss)
- All seabirds still breed on land, but rely on the sea for food.
- Some seabirds spend virtually their whole life at sea except for a brief nesting period
- Conservation implications (island nesting)
- ~ 250 species of seabirds, cosmopolitan distribution.
- Importance of guano

Adaptations to water, some have:
√ webbed feet
√ countercurrent heat exchangers
√ oil in feathers
√ air in feathers
√salt secreting glands (tubesnouts)
√ ability to glide or swim or plunge dive

Feeding: most are carnivores. many diving birds feed on krill and larval fish. others feed on baitfish (the plungers)

Types of lifestyles:

Shorebirds (waders)
Long legs (some), specially adapted bills. Important in estuaries!
Herons, egrets, avocets, stilts, godwits, curlews, sanderlings, plovers, oystercatchers (rocks)

Divers
some can dive very deep
Cormorants, auklets, murres, puffins, penguins

Plungers
Pelicans, terns, gulls sometimes, shearwaters (pursuit plungers), boobies

Skimmers and wanderers
albatross, boobies, frigatebirds (cleptoparasites!), tropicbirds

Scavengers
Gulls

Nesting and breeding: colonies, behavior, egg adaptations

Arctic tern breeds in arctic summer, 10,000 miles to antarctica for antarctic summer

MARINE MAMMALS

We know comparatively little about marine mammals. Most of 'what they do' happens underwater.

Marine mammals are air breathing mammals with mammary glands, hair, warm blood, and live birth. They all 're-entered' the water and developed adaptations for an aquatic existence. In general they are large (for thermoregulation purposes), and need to maintain a constant internal environment like humans (eg. salinity and temperature).

Other adaptations:
Vision, sound, fins for stability, fusiform body, blubber, heat retention/dumping capabilities, decreased respiratory rates, low reproductive rates, high maternal investment.

ORDER PINNIPEDIA (suborder of carnivora)-winged foot: seals, sea lions, walruses
Families: Phocidae (seals), otariidae (sea lions) and odobenidae (walruses)

Evolution:
- Debated!
- Derived from terrestrial carnivores such as dogs, bears (seal lions and walrus), and weasels (seals).
- Re-entered the water about 22 million years ago (25 million years ago for seals, 8 million years ago for sea lions)

Adaptations:
- Fat (blubber) though not large reserves
- Counter current heat exchange to help cool off and stay warm.
- Many of them 'haul out' on land or ice
- Molt 1 or 2 times per year

Reproduction:
- Extremely rich milk for young
- Delayed implantation
- Migrations for feeding and breeding
- 2 major mating strategies: on land and in the water
- Give birth to one pup, at 1 to 2 year intervals
- Sexual dimorphism (male often much larger than female)
- Some wean in as short as 4 days (some seals)!! Others stay with their young longer (sea lions)
- Seals: fast (no food) during breeding/pupping. Sea lions feed and spend more time with pups.
- Females sexually mature in 3-5 years, males 5-9 years
- Phocids (seals) and odobenids (walrus): internal testes in males
- Otariids (sea lions): external testes

Feeding: feed on a diverse assemblage of animals.
- Predators
- Many feed in the deep scattering layer (squid etc.)

Diving Physiology
- Large blood volume
- Phocids (seals) have some extreme adaptations such as: cartilaginous lower ribs for compression, ability to reduce nitrogen absorption, high concentration of red blood cells (for oxygen), myoglobin for efficient oxygen transport, high stores of oxygen, ability to lover heart rate to extreme low levels (to 6 beats per minute!), ability to reduce peripheral blood flow,

Conservation/exploitation:
- Elephant seals hunted for blubber – thought extinct. Now beginning to see increase in south america and north america numbers.
- Caribbean monk seal is extinct, Hawaiian is endangered
- Fur seals and harp seals have been heavily hunted for fur
- Harp seals, hooded seals, and ring seals are harvested in 'sustainable' numbers today

- Nets and fishing line have taken their toll.
- Genetic bottle necks (define)

Phocidae - seals
Internal testes
Hind flipper propulsion
No external ears
Can't really 'walk' on fore flippers like sea lions can
Deeper divers
Squid eaters (primarily)

Otariidae – sea lions
Long fore-flippers
Can walk and maneuver well on their fore flippes
Swim underwater with fore flippers
External ears (pinnae)
External testes
More recently evolved
Fish eaters

Odobenidae - walruses
Internal testes
No external ear flaps
Flippers like a sea lion (large fore flippers)
Use their large teeth (tusks) to dredge the bottom for molluscs and other invertebrates

ORDER SIRENIA: manatees and dugongs.
These are herbiverous aquatic mammals. They tend to be placid, slow moving, and non-aggressive mammals. Manatees live in rivers (fresh water) and ocean.
They spend their entire life in the water (do not haul out). Known as 'sea cows'. Steller sea cow is extinct. 4 species (3 manatees and 1 dugong) and 2 genera (manatees and dugongs). Dugongs live in the indo west pacific and E. Africa/madagascar.
Evolution: they evolved about 40 million years ago from elephant-like animals.
Characteristics and adaptations: fat/blubber, paddle shaped flukes (tail) which has been fused. Large dexterous fore flippers.

Reproduction:
- 2 teats at the base of each fore flipper
- 12-15 month gestation
- >5 years to mature, 2-5 year intervals between single offspring births
- nurse young for 1-2 years

Feeding: ruminating herbivores (eat plants). Enlarged hindgut with microflora to help break down cellulose (eat sea grasses and hyacinth).
Teeth are continually replaced.

Conservation/exploitation: very engangered, still exploited. Steller sea cow extinct. Boats are a problem (hit and kill them with propellers), nets and hunting for meat and blubber (still).

Family MUSTELIDAE: sea otters (*Enhydra lutris*)
This is a subfamily of the weasels and skunks which the otter is closely related to.

Evolution: about 15 million years ago they returned to the sea.

Adaptations/characteristics: dense fur for warmth (not much blubber), air in fur for warmth, webbed feet. Small size (relatively), very high metabolism (need to eat ALOT). Males weigh about 90 lbs, females about65 lbs. They have retractable claws on fore flippers. A flap of skin (like a pouch) extends across their chest to help hold food. They have external ears. Males and females are segregated in the social structure. They live about 10-15 years (oldest 23 years).

Reproduction:
- Males sexually mature at 5-6 years, females at about 4-8 years.
- 8 month gestation for one pup
- delayed implantation
- pups can swim at about 4-6 weeks. They can forage on their own at about 6 months
- Mom spends about 1 year with her pup
- She gives birth every 1-2 years

Conservation/exploitation:
- heavily hunted for fur. Last remaining central coast population found in Big Sur California.
- Now there is a central coast and Northern (Alaska) population. Still recovering. Relocation project to channel islands
- Role of sea otters as keystone species.
- Killer whales and otters in Alaska

ORDER CETACEA: Whales, dolphins and porpoises
ketos (greek), cetus (latin) = whale
Sub orders: Archaeoceti (extinct), mysticeti, odontoceti

Evolution:
- fossil record not good
- modern forms present 10-12 mill yrs ago late miocene
- 23 mya ancestral forms (early miocene)
- 45-55 mya archaeoceti (gave rise to the extant orders?)
- mysticeti and odonotoceti mono or poly phyletic origin?
- 55mya ancestors ventured back into the ocean :prob even toed ungulates

adaptations and general design: internal mammary glands, heat retention, blubber, vision, sound, fins for stability, decreased resp rates, born large, high maternal investment, low reproductive rates

Reproduction:
- Rich milk
- Mating strategies (permiscuous, male competition, sperm competition)
- Gestation and parental investment
- Migrations (some) for reproduction/feeding

Migrations:
- most mobil creatures on earth
- some rorquals 48 mph!
- poles in summer, tropics in winter
- 10,000 mile round trip migrations!

Stranding: why?

Conservation
- IWC: 1979 closure of factory ship whaling
- cetacean sanctuaries: indian ocean and antarctic
- problems: non member nations and scientific whaling
- minkes in Antarctic: Norway has resumed whaling
- gray whales: native whaling
- river dolphins: damming of the rivers
- blue whales

Suborder Mysticeti: Baleen Whales 10 species
- no teeth (baleen
- 2 blowholes
- largest: 30 m 160 tons
- smallest is the minke and the pygmy right whale: 10 and 7 meters respectively

Feeding:
- gulp feeding
- straining while swimming
- suction using tounge
- Food: krill to fish to amphipods

3 Families
Balaenidae - the right whales
no ventral grooves or pleats, no dorsal fin
Bowhead - B. mysticetus
N Right Whale - Eub. glacialis
S Right whale - Eub. australis
Pygmy R. Whale - Caperea marginata
Balaenopteridae - the Rorqual whales
numerous ventral grooves and dorsal fin
blue whale Balaenoptera musculus
fin whale B. physalus
Sei B. borealis
Bryde's B. edeni
Minke B. acutorostrata
Humpback - Megaptera novaeangliae
Eschrichtiidae - gray whale E. robustus
few ventral grooves, dorsal knuckles

Suborder odontoceti: toothed whales 65 species, 6 families

- Have teeth
- generally smaller (except sperm whale)
- highly social
- sophisticated sonar (acoustics)
- some are very deep divers
- 1 blowhole

Physeteridae: sperm Whales

- Deep divers
- Matriarchial societies
- Largest of the odontocetes
- Temperate waters

Monodontidae: narwhales and white whales (beluga)

- Flexible head
- Cold Arctic waters

Ziphiidae: beaked whales

- Least known group
- Very deep divers
- In some only the males have teeth
- Some known only from strandings

Delphinidae: dolphins (and killer whales)

- Highly social
- Sophisticated sonar
- Includes killer whales and dolphins

Phocoenidae: porpoises

- Less social than delphinidae
- travel in smaller groups
- tend to be small in size

Platanistidae: river dolphins

- Highly endangered
- poor eyesight
- long rostrum (beak)
- good sonar
- small groups