SYSTEMATICS --- (Domain, Kingdom; Phylum; Class; Order; Family; Genus; Species)

PROKARYOTES:

(cells with no nucleus or other organelles; contains cell wall)

Domain Bacteria (K. Eubacteria)

(unicellular organisms; smallest type of cell (1 um); most primitive life forms; widespread; reproduction – simple cell division)

Autotrophic (photosynthesis—primary producers)-- Blue-Green algae/bacteria (cyanobacteria)
Chemosynthetic/chemoautotrophic (primary producers -- derive energy stored in chemical compounds)
Saprobic bacteria (Heterotrophic bacteria) – Important decomposers of organic matter – "decay bacteria"; key link in detritus based food webs and recycling dead org. matter; degrades pollutants, toxic wastes etc.
Pathogenic/parasitic bacteria – causing diseases in many other higher taxa (mammals, fish, invertebrates…)

Domain Archaea (K. Archaebacteria)

(more closely related to eukaryotes in their cell structures but are still prokaryotes; can be heterotrophs (Nitrogen fixers) or Chemototrophs (methanogens); Contain many species that are extremophiles

EUKARYOTES:

Domain Eukarya

(cells containing a nucleus and other organelles that are enclosed by membranes)

K. PROTISTA (protists, protozoa, & seaweeds/macroalgae--pluricellular algae)

UNICELLULAR ALGAE (PLANT-LIKE PROTISTS)

(protists --- unicellular or colonial algae with eukaryotic cells – photosynthesis within chloroplasts; mostly marine; responsible for half of the primary production on earth and half of the oxygen released into the atmosphere)

Dinoflagellates
(unicellular organisms with two flagella—one perpendicular to the other; cellulose cell membrane; imp. Phytoplankton -- mostly marine and mainly in the tropics; some are bioluminescent; major responsible for PSP – red tide; includes zooxanthellae – symbionts –"mutualisms" - with many invertebrates-mainly corals)
Diatoms
(unicellular organisms – mostly phytoplankton; silica/glass-like skeleton (frustule); imp. Primary producers in cold waters; golden-brown pigments; diatomaceous oozes)
Silicoflagellatess
(single-celled, flagellated; star shaped internal silica skeleton; very small sizes)
Coccolithophores
(small, spherical cells, flagellated, covered with button-like structures –"coccoliths" of calcium carbonate; mostly oceanic and tropical – forms calcareous oozes)

UNICELLULAR ANIMAL-LIKE PROTISTS (PROTOZOANS)

(animal-like protists; eukaryotic, unicellular; heterotrophic—ingest food; found in both marine & freshwater environments)

Foraminifera (foramineferans, forams)
(shell or test made of calcium carbonate with pores for pseudopodia extension; most live on bottom; called "forams"; forms foraminiferan ooze –Ex: cliffs of Dover in England)
Radiolarians
(shell made of silica, are spherical with radiating spines; pseudopodia are needle-like; forms radiolarian oozes; inhabit open water throughout the oceans)
Ciliates
(have hair-like "cilia" used in locomotion and feeding; most common in freshwater; includes the Tintinnids –bottom dwellers with vase-like case called "lorica")

MULTICELLULAR ALGAE (seaweeds)

(macrophytes/macroalgae/seawweds – large, multicellular algae; lack the structural features of higher plants – no true leaves, no roots, no stem; thallus; fronds or blades; holdfast; stipe; pneumatocysts)

P. Chlorophyta (green algae)
(bright, green color; many microscopic, others macroscopic; mostly in freshwater –10% marine; largest phylum of algae; coralline green algae – *Halimeda)*
P. Phaeophyta (brown algae)
(largest, most complex algae; brown pigment – fucoxanthin; produce alginates; Sargasso seaweeds; some with pneumatocysts; "kelp"; almost exclusively marine; flourish, rocky shores of high latitudes)
P. Rhodophyta (red algae)
(95% are marine; largest group of algae species within the marine environment; red pigment – phycobilins; carrageenan and/or agar; coralline red algae –encrusting algae)

K. FUNGI (molds, yeasts, mushrooms, lichens)
(eukaryotes; multicellular; superficially plant-like but lack chlorophyll – no photosynthesis; "saprobics" – decomposers – recycle dead organic matter; few marine forms; lichens: fungus+green algae symbiosis)

K. PLANTAE -- METAPHYTA

Flowering plants (Angiosperms – Division/Phylum: Magnoliophyta or Anthophyta)
(dominate land, only few marine representatives; true leaves; true stems; true roots)

Seagrasses
(all adapted to live at sea; able to live and reproduce while completely submerged in seawater; have rhizomes; around 40 species in 2 families; most species are found in shallow, protected waters, and form extensive meadows; forming highly productive ecosystems; important role in stabilizing sediment; habitat for many animals)

Salt-marsh plants
(mostly found intemperate and higher latitudes; true grass families; are "halophytes" (salt tolerant); like mangrove, form very important ecosystems)

Mangroves
(found in intertidal zones of tropical/subtropical zones; around 100 species; very important – filters the water; holds toxic wastes; holds sediments; nursery grounds; prevents coastal erosion; important primary productivity; are halophytes)

K. ANIMALIA-- METAZOA (multicellular animal)

(Eukaryotes, multicellular heterotrophs – over 2 million described species into >30 phyla)

INVERTEBRATES (97% of all species of animals)

CELLULAR LEVEL OF ORGANIZATION

P. Porifera (sponges) ("pore-bearing")

(Asymmetric; sessile; nearly all marine; filter feeders; ostia; oscula; choanocytes/collar cells; spicules-glass or calcium carbonate; spongin; reproduction asexually by budding & sexually; commercial value—bath sponges)

[C. Calcarea; C. Desmospongiae; C. Sclerospongiae; C. Hexactinellida]

TISSUE LEVEL OF ORGANIZATON

P. Cnidaria

(radial symmetry; polyps and medusa forms with oral and aboral surfaces; nematocysts; 2 layers of tissue (diploblastic)– ectoderm & gastroderm/endoderm with mesoglea in between; blind gut – mouth serve equally as anus; both sexual and asexual reproduction)

C. Hydrozoa (hydrozoids; siphonophores, fire corals…)
(Colonial polyp stage-specialize feeding, defense, reproduction; feathery/bushy; small; include Portuguese-man-of-war which is a siphonophore; fire corals)

C. Scyphozoa (jellyfish)
(Medusa-dominant phase; solidary; planktonic; painful sting; some deadly – case of box jellyfish)

C. Anthozoa (corals and sea anemones, sea whips, sea pens…)
(polyp form only; 60% of the phylum are colonial – corals, sea fans, sea pens..; the others are solitary –anemones)

P. Ctenophora (comb jellies)

(radial symmetry; 2 tissue layer (diploblastic) with mesoglea; 8 rows of ciliary combs; all marine; most planktonic; colloblast cells – sticky cells; carnivores)

ORGAN LEVEL OF ORGANIZATION

P. Platyhelminthes (flatworms)

(bilateral symmetry with anterior/posterior end; dorsal/ventral surface; dorsoventrally flattened; true organs; Acoelomates; 3 tissue layer (triploblastic)-ectoderm, endoderm/gastroderm, mesoderm; gut with single opening—no anus; cephalization (head); gas and waste exchange through tissue – explain why they are flat – larger surface area)

C. Cestoda (tape worms)
(parasites, repeated proglottis & modified head with suckers, hooks for attachment to host)

C. Trematoda (flukes)
(parasites; feeds on animal host's tissue, blood, or intestinal contents)

C. Turbellaria

(free living; almost all benthic; carnivores; many have striking colors; has eyes—sensitive to changes in light intensity; movement—muscular contraction forming undulating waves; high capacity of regeneration)

P. Nemertea (Ribbon worms or Proboscis worm)

(Acoelomates; triploblastic; complete digestive tract, true circulatory system; long proboscis to capture prey)

P. Nematoda (roundworms)

(Pseudocoelomates; triploblastic; small; abundant; live in mud or sand; circular in cross section; elongated, wormlike shape, typically pointed –tapered-at both ends)

P. Annelida (segmented worms)

(Coelomates—gut lies in a cavity; body consisting of similar segments called metamere/somites; mostly benthic; large number of species)

C. Polychaeta

(widespread in marine environment; head-prostomium and tail/pygidium are specialized segments; all other segments are similar and have lateral, flattened extensions, called parapodia with bristles/setae; various feeding habits – filter feeders; deposit feeders; carnivores; includes the "pogonophores" or beard worms – linked to the hydrothermal vents)

C. Oligochaetes (earth worms…)

(basically freshwater; includes the earthworms

C. Hirudinea (leeches --- "blood suckers")

(some are parasitic; body has suckers for attachment and blood-sucking – ectoparasites)

P. Sipuncula (peanut worms)

(soft, unsegmented bodies; long anterior portion contains a mouth with small lobes or branching tentacles; shallow waters; detritus feeders)

P. Echiura (Echiurans)

(large, soft, unsegmented, sausage-shape worm; large spoonlike or forked proboscis extending from head; live in sand, mud, or under rocks; detritus/deposit feeders)

P. Mollusca

(soft, unsegmented body, prominent foot; mantle which secretes a shell; radula; 2nd largest animal phylum; complete digestive tract with salivary and digestive glands; herbivores, carnivores and filter feeders; nervous system and behavior show a range of complexity; gonochoric (separate sexes) and hermaphrodites; fertilized eggs develop into a trochophore and veliger larvae; >200,000 species; varied habitats –marine, freshwater, and land)

C. Monoplacophora

(Limpet-like; mostly in deep-water; not many species)

C. Polyplacophora (chitons)

(all marine; solidly cling to solid substrate with a massive flat foot; 8 overlapping plates; radula well developed; most are herbivores)

C. Gastropoda (snails, cones, cowries, whelks, abalone, nudibranchs…)

(coiled dorsal shell and a ventral creeping foot; 75% of all mollucs; includes the nudibranchs which have no shell; radula well developed and used for various functions – rasping tongue in herbivores; and harpoon in carnivores; some can use radula to drill holes; many species have commercial value—important fisheries)

C. Bivalvia (Pelecypoda) (2 valves) (clams, oysters, mussels, scallops…)

(2 valve shells, filtering gills, shovel-like foot; sessile—burrow in mud, sand; or attach with byssal threads; most are marine; no radula; giant clam have symbiosis with zooxanthellae; pearl oysters – pearl production; top shell – *Trochus*- button production; many have commercial value—important fisheries)

C. Cephalopoda (octopus, squid, cuttlefish, chambered nautilus)

(possess a foot modified into arms that surround the head; voracious predators; highly developed brain; sense organs highly developed; radula is present; jaws modified as "beak" in mouth cavity; squid – has a chitinous "pen" ; cuttlefish – calcified internal shell-"cuttlebone"; octopus – no shell; chambered nautilus – has a well developed external calcium carbonate shell; movement by jet propulsion via a siphon/funnel; ink sac; "giant squid" – largest of all invertebrates; some octopus can equally attain 300 lbs; important source of food and important fisheries)

C. Scaphopoda (tusk shells)

(Elongate shell, open at both ends and tapered like an elephant tusk; live in sandy, muddy bottoms; mainly deep water)

P. Arthropoda ("jointed foot")

(segmented animals with paired jointed limbs; bilateral symmetry; exoskeleton – made of protein-based chitin; to grow animal must discard/shed its exoskeleton—process called molting/ecdysis; open circulatory system; respiration using gills (crustaceans); book lungs (arachnids) or trachea (insects & arachnids); sexes are separate, and fertilization is internal; most abundant (successful) of all animal phyla; >1 million species)

S.P. Crustacea

(adapted to live in water; two pairs of antennae, gills to obtain oxygen; calcified exoskeleton—chitinous with calcium carbonate; wide habitats; head – fusion of first 5 segments; pair of compound eyes; body – includes thorax and abdomen – sometimes some

carapace parts are fused to form the "cephalothorax"; appendages specialized for walking, feeding, defense, swimming, gas exchange, reproduction.)

C. Branchiopoda (brine shrimp; fairy shrimp; and *Daphnia*-water fleas)

C. Ostracoda (*Cypris*)

C. Copepoda (copepods)

(mostly marine; major part of the zooplankton; small 1-5 cm; shape like a cylinder; abdomen is reduced with no appendages; thorax 2-5 segments; first pair of antennae are long and used for swimming; *Calanus* – most important copepod)

C. Cirripoda (barnacles)

(all marine; filter feeders, live attached to surfaces; body enclosed by heavy calcareous plates; filtering appendages or cirri; acorn barnacles; gooseneck barnacles)

C. Amphipoda (amphipods)

(beach hoppers, amphipods; laterally (side to side) compressed, curved bodies; most < 2cm length; beach hoppers – spring about –detritus of beach)

C. Isopoda (fish lice)

(Flat from top to bottom; legs that are similar to each other; fish lice – parasites of fish and crustaceans...)

C. Euphausiids (krill)

(Shrimplike; 2-3 cm; filter feeders; Krill – extremely important in polar waters – mainly Antarctic waters – major food source for baleen whales, penguins, many fish…)

C. Malacostraca

O. Decapoda (shrimp, lobster, crabs)

(5 pairs of walking legs, first of which is heavier and usually has claws used to obtain food and in defense; carapace well developed with cephalothorax (head and thorax are fused) and abdomen/tail; abundant; 1/3 of all crustaceans; high commercial value/ important fisheries)

S.P. Chelicerata (spiders, scorpions, ticks, mites, sea spiders, horseshoe crabs)

C. Merostomata (horseshoe crabs)

(all marine; 4 species (*Limulus*); living fossils; horseshoe-shaped carapace that encloses a body provided with 5 pairs of legs; soft sandy, muddy bottoms; effective burrowers—feed on polychaete worms)

C. Pycnogonida (sea spiders)

(all marine; 4 or more pairs of jointed legs stretch from a small body; widely distributed)

C. Arachnida (scorpions, spiders, ticks, mites)

(all terrestrial)

S.P. Uniramia [Insects, centipedes, millipedes]

C. Insecta (insects)

(distinguish from crustaceans by having 3 pairs of legs as adults; most diverse animal group; mostly terrestrial, some aquatic – few marine; water strider—surface of ocean)

C. Chilopoda --- centipedes

C. Diplopoda --- millipedes

P. Bryozoa (lophophores, bryozoans)

(marine; lophophore – feeding structure with ciliated tentacles arranged in a horseshoe shape, circular, or coiled fashion; filter feeders; form delicate colonies of interconnected individuals – zooids -- on seaweeds, rocks, and other surfaces; small, sessile)

P. Chaetognatha (Arrow worms)

(Planktonic, transparent; streamlined worms; narrow body and lateral fins; voracious predators-using the spines on the head as jaws; all marine)

P. Echinodermata

(radial symmetry-pentamerous, as a secondary characteristic; endoskeleton with ossicles; unique water vascular system/ambulacral system that connects to the outside by the madreporite; with tube feet used for respiration, locomotion, and food acquisition; sexes separate; oral and aboral surfaces; all marine; high regeneration capacity)

C. Asteroidea (starfish)

(most have 5 arms with central disc; active carnivores; water vascular system is well developed)

C. Ophiuroidea (brittle stars, basket stars)

(5 arms radiating from a central disc; arms are thin and brittle and articulated; most active of the echinoderms – move rapidly; water vascular system well developed; lack and anus; filter feeders, scavengers)

C. Echinoidea (sea urchins, sand dollars, heart urchins)

(body spherical or flattened, covered with spines; skeletal ossicles are plates intricately fused into a shell called test; water vascular system well developed; remarkable jaws called Aristotle's Lantern; herbivores and detritus feeders)

C. Holothuroidea (sea cucumbers)

(body elongated into a cucumber shape with 5 bands of tube feet running down it's length; skeleton reduced to a series of microscopic ossicles; body flaccid, with warty skin; water vascular system well developed; large whorl of tentacles around the mouth for feeding; deposit feeders; defense system – sticky filaments and evisceration)

C. Crinoidea (sea lilies, feather stars)

(body plan described as an upside-down brittle star with the mouth directed upwards; tube feet are used to filter feed; sessiles – sea lilies; free living – feather stars; common in tropical waters)

VERTEBRATES

P. Chordata

(At least during part of their development, all share: (1) a single, hollow tubular nerve chord (becomes the spinal nerve); (2) a notochord (becomes the spinal column-backbone; (3) gill slits/pharyngeal slits; all chordates also have a ventral heart; divided into 3 major Sub Phylum)

PROTOCHORDATES (Lack a backbone)

SP. Urochordata

C. Ascidiacea (tunicates, ascidians)

(highly modified chordates; only show the chordate characteristics in the larval stages; sac-like bodies; sessile; body is composed of a large pharynx perforated with small slits; filter feeders; body has 2 openings or siphons—incurrent and excurrent siphon; tunicate covering or tunic made of cellulose – thick, leathery, or gelatinous; solitary or colonial)

SP. Cephalochordata

C. ---------- (lancelets)

(laterally compressed and elongate like that of a fish; 3 basic chordate characteristics are well developed; inhabit soft bottoms; filter feeders using gill slits)

TRUE CHORDATES (have a well developed backbone)

SP. Vertebrata

C. Agnatha (Cyclostoma) (jawless fish -- hagfish, lamprey)

(lack jaws; body cylindrical and elongated; lack paired fins; lack scales)

C. Chondrichthyes (cartilaginous fishes --sharks, skates, rays, ratfish)

(skeleton made of cartilage; mouth almost always ventral; well-developed teeth; paired lateral fins; placoid scales—gives a rough skin texture; gill slits)

C. Osteichthyes (bony fish)

(bony skeleton; about 96% of all fishes are bony fishes; account for almost half of all vertebrates; cycloid or ctenoid scales; gills are covered by an operculum or gill cover; caudal fin generally homocercal; fin with 'fin rays" either bony or smooth; mouth are mostly terminal; protrusible jaws; presence of swim bladder in many species; fins are highly maneuverable; all land vertebrates evolved from early bony fishes)

Land-dwelling Vertebrates ("tetrapods")

(have lungs as breathing apparatus)

C. Amphibia (frog, toads, salamanders)

(terrestrial, freshwater organisms—must always keep themselves moist; none are strictly marine)

C. Reptilia (snakes, turtles, crocodiles, lizards)

(Reptiles are air-breathing, ectothermic, poikilothermic vertebrates; their skin is covered with dry scales; nearly all lay their eggs on land – "oviparous")

C. Aves (birds)

(birds are endothermic, homeothermic vertebrates that have feathers and light hollow bones as adaptations for flight; Seabirds spend a significant part of tier lives at sea and feed on marine organisms; true seabirds have webbed feet for swimming; seabirds nest on land but feed entirely or partially at sea; comprise about 3% of the total bird species)

Pelicans and related types – pelicans (pouch below their large beak0; cormorants (long-necked, usually black birds); frigatebirds (narrow wings and a long, forked tail); boobies…

Gull groups – gulls (are predators and scavengers – proliferated form human wastes); jaegers and skuas—predators; terns – graceful flyers; have slender beaks; puffins; razorbill

Penguins – flightless; wings modified into flippers to swim; adapted to cold weather; except for 1 species, all live primarily in Antarctica—exception – Galapagos penguin)

Tubenoses – large group of seabirds with distinctive tube-like nostrils and heavy beaks usually curved at the tip; include albatrosses, shearwaters, and petrels; skillful flyers

Shorebirds—wading shorebirds; most do not have webbed feet – common in estuaries and marshes – plover, sandpipers… or groups include – rails, coots, herons, egrets, and ducks.

C. Mammalia (mammals)

(air breathing vertebrates, endotherms and homeotherms; skin with hair; with few exceptions, they are viviparous; mammary glands to feed newborn; large brain to the body size—more complex than any other vertebrates

O. Cetaceans (whales dolphins, porpoises)

("convergent evolution" – bodies are streamlined much like those of fish—air breathing; endotherms; have hair – though scanty; and produce milk for their young; have a pair of front flippers; many cetaceans have a dorsal fin, muscular tail

ends in a pair of fin-liked, horizontal flukes; blubber for insulation; nostrils are modified to an opening at the top of the head, the blowhole; about 90 species of cetaceans

SO. Mysticeti (baleen or toothless whales) – filter feed with their baleen plates

SO Odontoceti (toothed whales)

(toothed whales, which include the dolphins and porpoises, lack baleen and feed mostly on fish and squid)

O Pinnipeds (seal, sea lions, walruses)

(have flippers and blubber; need to breed on land)

O. Sirenia (manatees, dugong)

(called sea cows or sirenians; have a pair of front flippers but no rear limbs – replaced by a paddle-shaped, horizontal tail; strict vegetarians—seagrasses—4 species of sirenians, all in danger of extinction)

O. Carnivora (sea otter, polar bear)

Important (Ref: Castro & Huber 2012):

- **Refer to Table 7.1 (p.148) – "Some of the most important characteristics of the major Animal phyla"**
- **Refer to Table 8.1 (p.175) – "Most important characteristics of Marine Fishes"**
- **Refer to p.178 – Class Mammalia; Class Reptilia; Class Aves; and to Table 9.3 (p.209) "Most Important Characteristics of the Marine Reptiles, Seabirds, and Marine Mammals"**