

Oceanography Final Exam!

Chapter 13:

Life in the Ocean!

Living systems - organism

- cannot exist without energy
- cannot create energy
- can transform one kind to another
- can utilize simple molecular to form complex systems.
- Some need sunlight, or use chemical reactions and what not.

Sources of Energy

1. Sunlight
 - a. Photosynthesis - chemical energy
2. Earth's internal heat
 - a. Chemosynthesis - chemical energy, which is energy converted to food.

1. Sunlight!
 - Producers use light energy to make food. (Photo-synthesizers)
 - This energy is used by consumers. (Respirers)
 - Then energy of movement, waste heat and entropy goes to space.

Energy stored by photosynthesis

- Energy = sunlight
- Pigment Chlorophyll
- $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$
- This $\text{C}_6\text{H}_{12}\text{O}_6$ is used for
 - 1. Growth
 - 2. Repair
 - 3. Movement
 - 4. Reproduction
 - 5. Breakdown process yields heat energy to space.

2. Earth's internal heat
 - a. Energy stored by chemosynthesis.
 - i. Energy = oxidation of H_2S
 - ii. No light required
 - $6\text{CO}_2 + 6\text{O}_2 + 24\text{H}_2\text{S} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 24\text{S} + 18\text{H}_2\text{O}$

Primary production

- In ocean by photosynthesis
- $\text{gC}/\text{m}^2/\text{yr}$
- = grams of carbon bound in organic matter per square meter of ocean surface per year.
- Carbohydrates in the oceans
 - 90 - 96% phytoplankton
 - 2 - 5% seaweed
 - 2 - 5% chemosynthesis.
- Diatom is phytoplankton which floats and they have chlorophyll which allows for photosynthesis.

Trophic levels

- Primary producers (plants)
 - Autotrophs
- Primary consumers (animals)
 - Heterotrophs - herbivores
- Secondary to top consumers (animals)

- Heterotroph - carnivores.
- Decomposers (primarily bacteria)
 - Release nutrients for primary producer
 - Heat energy - lost to space.

Elements of life

- Major components $> 10^5$ ppm
 - 99% of all living organisms
 - Carbon
 - Oxygen
 - Hydrogen
 - Nitrogen
- Macronutrients $> 10^3$
 - Essential
 - Na
 - Mg
 - P
 - Cl
 - K
 - Ca
 - I
 - Si
 - S
- Micronutrients $< 10^3$ ppm
 - Trace
 - Fe Cu
 - Ze
 - Mn

Biogeochemical cycles

- Carbon
- Nitrogen
- Phosphorous
- Silicon
- Iron and other trace metals

Physical and Biological factors affecting marine life

1. Light
 - a. Photic zone
 - i. Euphotic zone: about 0 - 70m
 - ii. Disphotic zone: about 70 - 200m
 - b. Aphotic zone: below 600 m.
2. Temperature
 - a. Affects metabolic rates
 - i. Ectotherms 'cold blooded': cannot regulate internal temperature, Internal T remains close to the surrounding
 - ii. Endotherms 'warm blooded': have stable and high internal temperature.
3. Salinity
 - a. Can cause damage to cells
 - b. Influence buoyancy
 - c. Organisms adapt to particular ranges
4. Dissolved Gasses
 - a. Vary strongly with temperature
5. Dissolved Nutrients
 - a. Nitrogen and Phosphate (not always available)
6. pH

- a. About 8 (slightly alkaline) average lower at depth (dissolved CO₂)
- 7. Hydrostatic pressure
 - a. Organisms adapted to pressure ranges
- 8. Diffusion
 - a. Movement of molecules from area of high concentration to lower concentration - passive process
- 9. Active transport
 - a. Pumping of molecules through a membrane from an area of low concentration to an area of high concentration (storage of sugars) requires energy)
- 10. Osmosis
 - a. Movement of water through a semi permeable membrane from high concentration to low concentration of water
 - b. Isotonic - body = ocean salinity
 - c. Hypotonic - body more saline than ocean
 - d. Hypertonic - body less saline than ocean.
- 11. Surface to volume ratio
 - a. Important for cell functions
 - b. small sphere > large sphere/object
- 12. Limiting factor
 - a. too little (not enough light)
 - b. too much (too much light, i'm assuming?)

Marine environments/zones

- littoral - intertidal
- Benthic - bottom zones
 - shelf
 - bathyal - slope
 - abyssal
 - hadal - trench
- Pelagic - water zones
 - Neritic - water above shelf
 - Oceanic - All other ocean water.
 - By depth
 - Epipelagic
 - Mesopelagic
 - Bathypelagic
 - Abyssopelagic
 - BY light: Refer to photic and aphotic zones.

Marine organisms - life in the zones

- Pelagic (most biomass on earth)
 - Plankton: floaters
 - Nekton: swimmers

1. Plankton:
 - a. Phytoplankton (autotrophic)
 - b. Zooplankton (heterotrophic)

Other plankton:

- Holoplankton
 - Entire lives as plankton
- Meroplankton
 - Part of lives as plankton
- and like, 4 other ones.

2. Nekton

- a. Swimmers
- b. Most adult fish and squid

- c. marine animals
- d. marine reptiles

Marine organisms - life in the zones

- Benthic
 - 1. Epifauna: on substrate of the seafloor
 - 2. Infauna: In substrate
 - 3. Sessile: Attached/immobile
 - 4. Mobile.
- There are more than 250,00 known marine species
- Land species: 84 and marine species: 14%
- about 2% = pelagic
- About 98 = benthic
- Most live in sunlit surface seawater
- A species' success is a function of their ability to:
 - Find food
 - Stand to predation
 - Reproduce and
 - Adapt to physical barriers and extreme environments.

Classification of Organisms

Taxonomy

- Carolus Linnaeus (1758, Sweden):
 - Developed basis of modern classification of organisms
 - Taxonomy: Systematic classification of organisms based on physical characteristics and genetic information.
 - Binomial nomenclature
 - Genus
 - species
 - Genus species

Hierarchy of organisms - Degrees of complexity

- Kingdom
 - Phylum
 - Subphylum
 - Class
 - Order
 - Family
 - Genus
 - Species
- The three life domains

The three life domains

1. Archaea Kingdom (No nucleus/prokaryotes)
2. Bacteria Kingdom (No nucleus/prokaryotes)
3. Eukarya Kingdom, which have the kingdoms of Fungi, Animalia, Plantae and Protista.

1. Prokaryotes
 - a. Unicellular
 - b. lack nucleus
 - c. asexual reproduction
 - d. autotrophs
2. Eukaryotes
 - a. Unicellular or multicellular
 - b. nucleus
 - c. asexual and sexual reproduction

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d. Autotrophs and heterotrophs

1. Prokaryotes
 - a. Bacteria
 - i. single chromosome
 - ii. Blue green algae/cyanobacteria
 - b. Achaea
 - i. multiple genes
 - ii. extremophiles
2. Eukaryotes
 - a. Protista
 - i. Single and multi celled with nucleus (algae, protozoa)
 - ii. usually unicellular
 1. diatoms
 2. dinoflagellates
 3. radiolarians
 4. foraminifera
 - iii. single and multicellular seaweed (algae)
 - b. Fungi
 - i. molds, lichen
 - c. Plantae
 - i. Multicellular
 - ii. Photosynthetic
 - iii. autotrophs
 - iv. EX: Surf grass, eel grass, mangrove, marsh grasses
 - d. Animalia
 - i. Multicellular
 - ii. heterotrophs
 - iii. Ex: From simple sponges to complex vertebrates

CHAPTER 14!

Marine plants: Phytoplankton and seaweeds!

Types of photosynthetic marine organisms

1. Microscopic (small) algae = phytoplankton
2. Photosynthetic bacteria
3. Macroscopic (large) algae = seaweeds

1. Phytoplankton
 - a. Unicellular
 - b. photosynthetic
 - c. autotrophs
 - d. base of the food web
 - e. Produce food for 99% of marine animals
 - f. Golden algae
 - i. Diatoms: siliceous tests
 - ii. Coccolithophores: calcareous (calcium carbonate) plates
 - g. Dinoflagellates
 - i. Red tide (harmful algal bloom)
 - ii. toxins
 - iii. fish kills
 - iv. human illness

Diatoms

- 2 valves = frustule
- silicon (SiO₂)
- Siliceous oozes

- >5600 species
- most productive

Coccolithophores

- CaCO₃ discs
- Calcareous oozes
- Translucent (protection from too much light)
- White (Chalk) skiffs of Dover
- Great numbers in Mediterranean
- Boom forms milky water

Dinoflagellates

- 2 flagellae - whiplike projection
- some = zooxanthellae in hermatypic corals
- Some form neurotoxins → Mussels and clams → people
- red tides (seasonal bloom)
- Usually toxic
- Some bioluminescent

Bioluminescence

Luciferin + enzyme luciferase = light.

2. Photosynthetic bacteria: Picoplankton - 0.2 - 2 microns

- 1980's
- Bacteria and viruses
- Some photosynthetic
- at all depth
- absorb dim blue light in euphoric zone
- possibly great photosynthetic contributors where other phytoplankton cannot function
- Prochlorococcus = Cyanobacteria

3. Larger primary producers

- Most multicellular
- larger autotrophs
- algal seaweeds
- some angiosperms
- 2 - 5% productivity

Seaweeds

- About 7000 species are multicellular algae
- variety of sizes and shapes
- flexible
- streamlined
- strong
- Often mucilaginous covering
- lubricates
- slow desiccation
- deter grazers
- productivity can be high
- many leak carbohydrates: soup for organisms
- e.g. some sea urchins can absorb organic molecules via skin

Structure:

- Gas bladder keeps it up.
- Stipe
- Blade (leaves)
- Holdfast (roots?)
- Thallus (the whole thing)

Seaweed pigments

- Accessory pigments permit:
 - Seaweed attached to seafloor at depths > 250m into despotic zone to absorb low light and transfer

energy to chloroplast → photosynthesis

energy to chlorophyll → photosynthesis

- Accessory pigments mask underlying chlorophyll.

Chlorophyta (green algae)

No accessory pigment

- 7000 species, most freshwater
- 10% marine
- strong green colour
- some tolerate some pollution... most don't
- Generally small size.

Phaeophyta (brown algae)

- Fucoxanthin (acc. pigment)
- allow growth near bottom of euphotic zone
- 1500 species, most marine
- from small black encrusting to 60 metres
- Most large - rapid growth rates to 50cm/day
- Mucilage surface
- temperate to polar
- some gas bladders
- form Giant Kelp Forest communities
- e.g:
 - Sargassum coastal Caribbean.
 - N. Atlantic geostrophic hill
 - Sargasso Sea community
- Can grow and reproduce floating.

Rhodophyta (red algae)

- Phycobilins (acc. pigment)
- Most of the world's seaweed to about 4000 species
- Microscopic to 3/4m
- colourful - varied
- surface to about 268m
- Very slow growth at depth
- Some calcareous algae - encrusting roles as reef builders and binders.

Seaweed Zonation

- Chlorophytes = down to 10 m.
- Phaeophytes (fucoxanthin) = down to thirty m
- Rhodophytes (phycobilins) = below thirty, up to 268 m.

Seagrasses and mangrove swamps

- Wetlands of salt marshes/estuaries
- O2 poor (anoxic muds and clays absorb metals etc. pollutants)
- Spawning
- Nurseries
- Wintering
- Feeding grounds
- Fish, oysters, scallops, eel, smelt etc.

1. Seagrasses

- a. not true grasses
- b. range from tropics to 65N and S latitude
- c. about 45 species
- d. eel, turtle, manatee, surf grasses etc.

2. Mangroves

- a. Large flowering trees (like a forest)
- b. Equator to 30 N&S lat
- c. Rooted in muds
- d. smaller roots

c. need low salinities - salt secreting cells

- e. need low salinities - salt secreting cells
- f. outgrow and replace sea grass marches.

Primary productivity

- Primary productivity is the rate at which energy is stored in organic matter.
- Photosynthesis uses solar radiation
- Chemosynthesis uses chemical reactions
- 99.9% of the ocean's biomass relies directly or indirectly on photosynthesis for food.

Primary Productivity Variations

- Values varies from 1 gC/m²/year to 4000 gC/m²/year with:
 1. Nutrients
 2. Sunlight
- Limiting factors if too much or too small

Limiting factors of productivity

1. Nutrients
 - a. Used for production of C₆H₁₂O₆
 - b. Depletion: dead plankton etc. sink to deep water
 - c. Nutrients
 - i. nitrates
 - ii. phosphates
 - iii. silica
 - iv. iron
 - v. available only at upwellings.
2. Light
 - a. needed for photosynthesis
 - b. Too much or little = harmful

Compensation depth

- Photosynthesis produces C₆H₁₂O₆ and O₂
- Respiration uses these and releases CO₂
- In Euphotic zone, at about 70 m., C₆H₁₂O₆ production exceeds consumption
- as light decreases, photosynthesis decreases
- Point where production (photosynthesis) rate = consumption(respiration) rate = COMPENSATION DEPTH.

Latitudinal distribution of primary productivity

1. Polar
 - No pycnocline
 - Nutrients available
 - Sunlight seasonal.
 - Limiting factor = light
2. Tropics
 - strong thermocline (pycnocline)
 - strong sunlight
 - no nutrients (except upwellings)
 - limiting factor = nutrients
3. Temperate
 - a. Spring
 - i. no pycnocline
 - ii. strong sunlight
 - iii. bloom
 - b. mid-summer
 - i. Sunlight
 - ii. pycnocline
 - iii. No nutrients = limiting factor

- iii. NO nutrients – limiting factor
- c. Late summer
 - i. pycnocline
 - ii. strong sunlight
 - iii. nutrients from bacterial decay of spring bloom above pycnocline
 - iv. second small bloom.
- d. Winter
 - i. Low sunlight
 - ii. No pycnocline
 - iii. light = limiting factor
 - iv. storms stir up nutrients available for spring bloom.

Chapter 15

Marine animals

1. Zooplankton
 - Floating animals
 - size range from 2 nanometers (heterotrophic flagellates, protists) up to several meters (jellyfish)
 - Heterotrophs
 - Primary consumer/herbivores: feed primarily on phytoplankton
 - primary consumers/carnivores: feed primarily on other zooplankton (animals)
 - Detritivores: feed primarily on dead organic matter (detritus)
 - Some unicellular protista
 - some multicellular animal.
- A. Protista
 - Foraminifera: calcareous shell composed of a series of chambers; ooze sediments; 30 nanometers to 1-2 mm; most abundant 40N and 40S
 - Radiolaria: spherical cells with silica capsule; 50 nanometers to several mm; silica ooze sediments; cold water and deep sea
 - feed on diatoms etc.
- B. Animalia
 1. Arthropods (Crustaceans)
 - a. Copepods:
 - i. about 70 percent of all zooplankton
 - ii. 0.5 mm
 - iii. most abundant and widely distributed animal in the world
 - b. Krill:
 - i. Euphasia superba
 - ii. about 2 cm - shrimp like
 - iii. feeds on diatoms
 - iv. base of antarctic ecosystem.
 - c. Jellies
 - i. Various animal groups
 - ii. transparent structure
 - iii. jellyfish (cnidaria)
 - iv. Pteropods (snails)
 - v. Salps (primitive chordates)
 2. Non-plankton
 - a. invertebrates
 - i. 90% of all living and fossil animals
 - ii. soft bodied
 - iii. no internal skeleton to support muscles
 - iv. most have exoskeletons of
 1. CaCO₃ and other ones.

Porifera

Phylum

Sponges

- Calcium Carbonate or silica spicules
- the most primitive animals
- Suspension feeders
- no digestive system, no nervous system.
- Feeds through filter, it looks like.

Cnidaria

- **Cnidoblasts** -stinging cells
 - Anemones
 - Corals
 - Jellyfish
- Medusa - free living eg. Jelly fish
- Polyp - sessile benthos eg. Coral
- Larva - Meroplanktonic stage.
- Sea wasp jelly fish are dangerous.. can kill human in 3 minutes
- 1. Corals
 - Vary in size
 - Calcium carbonate exoskeleton
 - Solitary or colonial
 - Feed at night
 - Ahermatypic corals
 - Hermatypic corals - zooxanthellae
 - Ex. Hermatypic corals
 - Warm water tropics
 - Clear water (sunlight for zooxanthella)
 - Turbidity blocks sunlight
 - Low nutrients : nutrient rich = algal blooms - block light
 - Average salinities.

Worms - Vermes (Platyhelminthes, Nematoda, Annelida)

- Bilateral symmetry
- most free living
- some parasitic

Platyhelminthes

- flatworms
- up to 3 cm
- most free living - predators/scavenger
- primitive
- no respiration system.
- Gases exchange by diffusion.

Nematoda

- Roundworms
- have mouth and anus
- all environments
- most successful of worms: about 12000 species
- microscopic to 4 cm
- most free-living, some parasitic.

Annelida

- segmented worms
- most advanced: about 5400 species
- all environments
- ex Polychaetes (many bristles)
 - most important marine annelids
 - detritus feeders
 - size from 1 - 15 cm
 - tube worms.

Mollusca

Mollusca

- Advanced invertebrates
 - large, varied group
 - advanced digestive tract
 - developed nervous systems in some.
 - Three classes
 - Gastropoda: Stomach foot
 - Pelecypoda (Bivalvia): Hatchet foot
 - Cephalopoda: head foot
1. Gastropoda (snails)
 - a. most calcium carbonate shells
 - b. single spiral unit
 - c. some grazers (herbivores) some carnivores
 - d. eg. snails, limpets, pteropods, slugs.
 2. Pelecypoda
 - a. two shells/valves
 - b. CaCO₃
 - c. Sessile benthos: live on or in the substrate epifauna or in fauna
 - d. Siphons - filter feeders
 - e. Mussels, oysters, clams, scallops
 3. Cephalopoda
 - a. Most highly developed of invertebrates
 - b. advanced nervous systems
 - c. learn/remember
 - d. many with highly developed eyes
 - e. most are carnivores
 - f. octopus: can change colour - ink
 - g. Squid - giant squid, cuttle fish
 - h. only one with exoskeleton (nautilus)

Arthropoda (crabs, shrimp, barnacles, copepods, krill.

- Joint-footed, articulating
 - rigid exoskeleton: chitin and some CaCO₃
 - Exoskeleton moults, new soft larger skeleton
 - strong, lightweight
 - striated muscles, strong, allow rapid movement.
1. Insecta
 - a. Largest subgroup
 - b. largely sub-marine
 2. Crustacea
 - a. Very large group, mainly marine
 - b. all feeding strategies
 - c. some plankton - many benthos
 - d. some sessile (barnacles), other mobile
 - e. includes: copepods, krill, lobster, shrimp, crab, barnacles.

Echinodermata

- spiny skin
- all marine
- pentamerid symmetry .. 5-fold
- form most of benthic deep sea biomass
- unique water vascular system
- include:
 - sea stars (starfish)
 - Brittle stars (deep sea)
 - Sea urchins (voracious predators)
 - Sea cucumbers (eject viscera)

Chordata

- Stiff dorsal notochord

- tubular nervous system
- gill slits behind the oral opening
- notochord embryonic only
- Tunicates
 - Sponge-like
 - suspension feeders
 - sea squirts.
- Amphioxus (genus)
 - Transitional between invertebrate and vertebrates
 - dorsal tubular nerve tube
 - notochord
 - semi transparent.
- Fish to amphibians, to reptiles, to birds to mammals.

B. Chordates (vertebrate)

- Chordates with bony , articulated structure around notochord/nerves = backbone

Fish

1. Agnathids (most primitive) (jawless)
 - a. Hagfish
 - i. Worm-like shape (up to 1m)
 - ii. Infauna
 - iii. lime glands
 - iv. feed on soft tissue inside dead /living prey
 - v. knot for betting 'footing'
 - b. Lamprey
 - i. Excellent parasite, does not kill
 - ii. similar to hagfish in size and shape
 - iii. toothed sucking mouth
 - iv. Attaches to fish or whales.
2. Chondrichthyes (cartilage skeletoned fish)
 - a. Sharks
 - i. Most < 2,
 - ii. Great white to 7m - dangerous
 - iii. sense vibrations in water
 - iv. sense of smell
 - v. some filter feeders (whale shark) No gas bladder
 - vi. few are aggressive to humans
 - vii. about 350 species
 - b. Rays
 - i. Specialized pectoral fins
 - ii. Giant manta ray to 7m
 - iii. Largest are plankton feeders
 - iv. small rays crush mussels for food.
 - v. about 250 species
3. Osteichthyes (Bony fish, both primitive and modern types)
 - i. About 27 00 species both fresh and marine
 - a. Lion fish
 - b. Moray eel
 - c. Weedy seadragon
 - d. scrawled cowfish

Amphibians

- Frogs
- Salamanders
- Toads
- None are exclusively marine
- Skin is permeable to seawater.

Reptiles

- Few marine
 - lungs breath air
 - Skin more or less impermeable to seawater
 - Salt glands excrete excess salt
 - Ex: Turtles, crocodiles, snakes.
1. Turtles
 - a. Forelimbs modified flippers
 - b. 8 species, all except one, tropical
 - c. cannot retract into shell
 - d. most are herbivorous (algae, turtle grass)
 - e. Some are carnivorous (crabs, molluscs)
 - f. Atlantic leather back is the biggest, can be bigger than 2m and heavier than 600Kg.
 2. Crocodiles
 - a. One marine species
 - b. Tropics, west Pacific/Australia
 - c. Carnivorous
 - d. Hunt in packs
 - e. > 7m long
 - f. Florida versions are not marine
 - g. Smaller
 3. Sea snakes
 - a. Advanced
 - b. 50 species
 - c. Indian Ocean and West Pacific
 - d. Skin impermeable to seawater/permeable to gas exchange.
 - e. All very venomous
 - f. Dive to 100m

Birds/Aves

- Birds evolved from reptiles about 160 m.y.a
 - Endotherms
 - Lightweight/ hollow bones/ beaks
 - Lay eggs
 - Marine birds:
 - About 270 species = 3% of all birds
 - Most southern hemisphere
 - salt-excreting glands in head
 - oiled feathers
 - most return to land for breeding.
1. Tubnoses
 - a. All latitudes
 - b. 15 000 km trips at 80 km/hr
 - c. beaks highly sensitive
 - d. Albatross - 3.6 m wing span about 10 kg
 - e. eat fish and squid and breeds on remote islands
 2. Pelicans and relatives
 - Throat pouches
 - webbed feet
 - tropical coastal birds
 - wings fold back for diving
 - amazing flyers
 3. Gulls, terns and puffins
 - a. Shore birds (marine and terrestrial)
 - b. > 115 species
 - c. Some migrate (Arctic tern 24, 000km round trip)
 - d. Puffins do not fly well - good swimmers

4. Penguins
 - a. Southern hemisphere
 - b. to Galapagos, S. America. S. Africa
 - c. Duck - size to > 1m
 - d. Cannot fly: wings = flippers
 - e. Adapted to cold water
 - f. fat insulated - neutral buoyancy.

Marine mammals

- Mammals evolved from common ancestor with reptiles about 200 m.y.a.
 - No marine mammals in fossil record until about 50 - 60 m.y.a
1. Cetacea (Whales, porpoises, dolphins)
 - a. Entirely marine
 - b. Cigar-shaped body
 - c. Forelimbs - modified to flippers
 - d. hind limbs - internal, unattached
 - e. elongate skull
 - f. blowholes on top
 - g. vertical motion for propulsion
 - h. Carnivora (Seals, sea lions, walruses, sea otters)
 - i. Sirenia (Manatees, dugongs)
 - a. Odontoceti (toothed whales)
 - i. Predators
 - ii. deep divers to 200 m
 - iii. Echo-sounding - food, socializing
 - iv. low frequencies travel great distances
 - v. high frequencies - short sonar-like clicks
 - vi. Sperm Whale can detect... far?
 - vii. Examples: Beluga whale, killer, narwhale, squid, sperm whale.
 - b. Mysticeti (Baleen whales)
 - i. Horn-like material
 - ii. Press tongue against baleen to strain food.
 - iii. Filter feeder - krill and other plankton (can't bite)
 - iv. Not deep divers, near surface
 - v. great blue - largest living animal on Earth
 - vi. Eat up to 3 metric tons of krill a day.
 - vii. Complex sounds
 - viii. blow bubbles in circles to trap krill
 - ix. Migrate singly or in pods to 18 000 km
 - x. to high latitudes for summer feeding
 - xi. to low latitudes for breeding and calving.
 - xii. Examples: Humpback, minke, blue, fin and gray whales.
2. Carnivora
 - a. Pinnipeds
 - i. Evolved from land bears
 - ii. Seals, sea lions, walrus
 1. Seals
 - a. No external ears
 - b. short hair and soft underfur
 - c. front flippers
 - d. hind limbs fused and point backward for propulsion
 - e. great swimmers
 - f. poor walkers
 2. Sea lions
 - a. Have external ears
 - b. Hind limbs (flippers) are not fused
 - c. Can move about on land

- 3. Walrus
 - a. 1800 kg
 - b. Tusks and whiskers
 - c. dig for clams
 - d. tusks good for climbing on floes
- b. Fissipeds
 - i. Sea otter
 - 1. Smallest marine mammal - 120 cm long
 - 2. warm dense fur
 - 3. intelligent
 - 4. feeds on molluscs, crustaceans, echinoids.
 - ii. Polar bears
 - 1. Stalk prey
 - 2. Predators
 - 3. Worlds largest bears 2.5 m and 800 kg.
 - 4. Swim from floe to floe
 - 5. to 1000 km in open water
 - 6. Travel to 3200 km/yr
- 3. Serenia
 - a. Gentle
 - b. Small-brained
 - c. Large to 4.5m - 680 kg
 - d. Herbivores - sea grass - algae
 - e. In tropical estuaries
 - f. Some in freshwater/brackishw ater
 - g. Dugongs and manatees

Marine adaptations

Fins!!

- 1. Locomotion
 - a. In eel-like fish
 - i. Muscle segments, myomeres
 - ii. Contract and relax alternately casing forward thrust
 - b. In more advanced fish
 - i. Propulsion depends on caudal fin aspect ratio.
- Pectoral fins (two near the front)
 - Different function for different fish.
 - Flying fish = uses to glide
 - Rays = swimming
 - Gurnard = walking?
- Caudal fin (in the back)
 - Fin shapes are classified according to aspect ratio = $[(\text{fin height})^2]/\text{fin area}$
 - Low aspect ratio
 - Quick manoeuvrability
 - Lunge for prey and from predator
 - High aspect ratio
 - Strong propulsion chase prey
 - Low manoeuvrability.
 - Rounded: 1 flounder
 - Truncate : 3 salmon
 - Forked : 5 herring
 - Lunate: 7+ tune
 - Heterocercal: shark.
 - ASPECT RATIO: $[(\text{fin height})^2]/\text{fin area}$

2. Muscle fibre

- a. White muscle fibre
 - i. Large
 - ii. Flat
 - iii. Fatigues easily
 - iv. Short energy burst
- b. Red muscle fibre
 - i. Myoglobin O₂ retention
 - ii. Smaller
 - iii. Holds energy for long term
 - iv. Short strong bursts
- 3. Fish - Individual swimming behaviour
 - a. Lungers
 - i. Low aspect ratio caudal fin
 - ii. wait for prey
 - iii. short burst of energy
 - iv. mainly white muscle fibre.
 - b. Cruisers
 - i. Chase prey for long distances
 - ii. predominately red muscle fibre
 - iii. Lunate and heterocercal caudal fins (high aspect ratio)

Some general adaptations to the marine environment.

- 1. Temperature
 - a. Surface temperatures vary from 2C to 32C to 40C in tropical estuaries
 - b. In temperate zone, temperatures fluctuate seasonally
 - c. in the tropics and the poles: less range
 - i. Endotherms
 - 1. Regulate their body temperature
 - 2. Migrate because they tolerate broad temperature ranges
 - 3. They have high metabolic rates
 - 4. they need more food and more oxygen
 - 5. mammals, seabirds, some large fish
 - ii. Ectotherms
 - 1. Most marine organisms
 - 2. Inter and external temperatures are equal
 - d. In the tropics/warm waters
 - 1. They have higher metabolic rates
 - 2. they need more food and more oxygen
 - e. In high latitudes/cold waters
 - i. They move slower
 - ii. larger
 - f. Exceptional temperature adaptations
 - i. e.g.. Prolobus bacteria
 - 1. Tolerate 90C to 113C temperatures
 - 2. Hydrothermal vents
 - 3. Fish are generally ectotherms
- 2. Light/colour
 - i. Light in the ocean depends on:
 - 1. The sun's angle, latitude
 - 2. depth of penetration of light
 - 3. suspended particles - nutrients
 - a. Plants - photic zone
 - i. Some adaptations to deal with light
 - Translucent
 - b. Animals: Eyes vary from very large to non
 - i. bioluminescence common - aphotic zone

- ii. Photophores = light producing organs
 - iii. dinoflagellates
- 3. Sound
 - a. lateral line system for sound = pores in skin - canals around eyes, over head and down sides connected to nerves
- 4. Pressure
 - a. Deep sea
 - i. Organisms adapted to particular depths
 - ii. Compact, no gas bladders
 - b. Verticle moers
 - i. Birds and mammals
- 5. Salinity
 - a. Euryhaline - broad tolerance
 - b. Stenohaline - narrow tolerance
 - c. Hypotonis - body less saline
 - d. Hypertonic
 - e. Isotonic - same salinity
- 6. Buoyancy
 - a. Organisms stay at required depths by various strategies:
 - i. Gas bladders - kelp
 - ii. Gas control in Chambers
- 7. Migration
 - a. Anadromous
 - i. Lives in marine water, breeds in fresh seater, salmon
 - b. Catadromous
 - i. Lives in fresh waters
 - ii. Breed in marine water
 - iii. American Eel!
- 8. Schooling - Group behaviour
 - a. >2000 species of fish squid etc.
 - b. Few to thousands move together
 - c. Same size - same direction - equal spacing
 - d. Possible value
 - i. Continuous motion may confuse
 - ii. One large entry
 - iii. not all consumed
 - iv. Reduce ocean distribution to predators.
- 9. Osmosis
 - a. Water moves from high con to low con
 - b. Water moves through semi-permeable membrane
 - c. Fish either dehydrate (hypotonic) or burst with water (hypertonic) without osmo-regulation
 - d. Chondrichthyes (sharks etc) are more or less isotonic with seawater by producing urea in tissues.

Chapter 16

Marine Communities

Marine organisms live in communities

- Organisms are distributed in the marine environment in groups sharing a common living space
- A **community**: many populations of organisms of the same species occupying a specific area
- A **population** is a group of organisms of the same species occupying the same area.
- The largest marine community = most sparsely populated = little food... lies in the mass of dark water
- The smallest marine communities are established against solitary rocks

Communities consist of interacting producers, consumers and decomposers

- The energy is passed from organism to organism in a food web = food webs define communities

– There are different places to live and different jobs for organisms within the community

1. Habitat

a. Address of organism within its community = its physical location

2. Niche

a. The organism's occupation (job) in the community

3. Biodiversity

a. the variety of species in a community

b. High biodiversity (coral reef) has complex physical and biological relationships

c. Low biodiversity = less variety.

Factors affecting communities

– Physical and biological factors determine the location and composition of a community

1. Physical factors: (Temperature, salinity, light, pressure) affect the success of an organism

2. Biological factors: (crowding, predation, grazing, parasitism, etc)

– Physical or biological factor could limit the success of an organism in a community = limiting factor

– A limiting factor prevents an organism from feeding growing, producing, etc.

– Organisms have different tolerances to specific factors

1. Eury = tolerance to broad range of

a. Salinities as in euryhaline

b. Temperatures as in eurythermal

2. Steno = tolerance to a narrow range of

a. Salinities as in stenohaline

b. Temperatures as in stenothermal.

– In all communities various interdependent relationships exist

– Types of Symbiosis:

1. Mutualism - both benefit more or less

2. Commensalism - symbiont benefits... hosts aren't hurt.

3. Parasitism: Symbiont benefits - hosts suffers

Communities

1. Coastal

a. Rock shore (supralittoral)

b. Sandy shore. (littoral)

i. These two are supra littoral and littoral

2. Shelf

a. Coral reef - tropics

b. Kelp Forest - mid latitudes

i. These two are sublittoral

3. Oceanic Pelagic

a. Epipelagic

b. Mesopelagic

c. Bathypelagic

4. Benthic Abyssal

a. Deep sea floor

b. Whale falls

5. Benthic Mid-Ocean Rift

a. Hydrothermal vents

1. **Rocky Intertidal Communities (Rocky shores):**

a. Interface between coast and ocean

b. intertidal zone = band between high tide and lowest low tide

c. Densely populated zone

d. Zonation well developed in temperate latitudes .

i. Zones

a. Supralittoral/supratidal zone

i. Above normal high tide

- ii. Exposure >>>>> water
- iii. Harsh
- iv. Limited nutrients
- v. Dehydration

1. **Organisms:**

- a. Encrusting
 - i. Lichen
 - ii. Blue green algae
 - b. Grazer/predator (snails)
 - i. Periwinkles
 - ii. Limpets
 - c. Scavengers
 - i. Hermit crabs
 - ii. Rock crabs
 - iii. Other arthropods
- b. High tide zone
- i. Between highest high and lowest high tide
 - ii. Exposure >>>> water
 - iii. Strong waves
 - iv. Nutrients with tide - organic debris
1. Organisms:
- a. Macro algae
 - i. Thick walled (dehydration)
 - ii. Leathery
 - iii. Flexible stripes
 - iv. Firmly attached
 - b. Buckshot barnacles
 - i. Suspension feeders with high tide withdraw (Dehydration and protection)
 - ii. Periwinkles
 - iii. Encrusting blue green algae
 - iv. Crabs.
- c. Mid tide (intertidal)
- i. Between lowest high and highest low tides
 - ii. Water >> exposure
 - iii. Strong currents - waves
 - iv. Nutrients with tide - organic debris.
1. Organisms:
- i. Mussels
 - NO macro algae = replaced by mussels
 - ii. Goosneck barnacles
 - Other barnacles
 - Crabs
 - Some low tide organisms move with tide.
- d. Low tide
- i. between highest low tide and lowest low tie
 - ii. Water covered - rarely exposed
 - iii. Nutrients available.
1. Organisms
- a. Macro algae
 - i. Normal benthic sub tidal community
 - ii. Filter feeders, carnivores
 - iii. Fish, Shrimp
 - iv. NO mussels = predated by starfish. :(

2. **Sandy shore**

- a. Interface between coast and ocean
- b. Intertidal areas could be sandy, muddy or consist of gravel and cobbles

- c. not well zoned.
 - i. Organisms
 - 1. Intertidal
 - a. Epifauna (crabs and shrimp)
 - b. Infauna (worms)
 - 2. Subtidal
 - a. Normal benthic infauna and epifauna
- 3. Coral reef community
 - a. Coral reefs form in area of high energy
 - b. Balance between construction and destruction
 - c. In addition to corals, reef residents are calcareous algae, encrusting, producing and consuming creatures.
 - i. Framework builders
 - 1. Hermatypic corals
 - a. Clear water
 - b. 18 - 28 C
 - c. Strong light
 - d. Stenohaline
 - e. Low nutrients
 - 2. Encrusting organisms (encrusting calcareous algae)
 - 3. Their secretion help cement the reef together
 - ii. Grazers
 - 1. Destructive to reef
 - 2. snails
 - 3. fish pick on shells
 - 4. other dig to make homes
 - iii. Dwellers
 - 1. Passive organisms
 - 2. Do not contribute to or destroy reef structure
 - 3. Complex community about 3000 species.
- 4. Kelp forest community
 - a. Seaweed
 - i. Macro algae - brown kelp to 30 metres in length
 - ii. Cooler than 20C
 - iii. High nutrient - upwelling
 - iv. Solid firm substrate for holdfast.
 - b. Other organisms live in shelter of Kelp Forest:
 - i. Sea urchins eat kelp
 - ii. Sea otters eat sea urchins
 - iii. Killing sea otters (oil spills and hunting)
- 5. Epipelagic zone
 - a. 0 - 200m depth
 - b. Light and Oxygen
 - c. Photosynthesis
 - d. 83% marine/oceanic biomass
 - e. Most of the fishes and plankton are primary producers.
- 6. Mesopelagic
 - a. 200 - 1000 m
 - b. Dim to no light
 - c. No photosynthesis
 - d. High nutrients
 - e. Dead organisms from epipelagic zone
 - f. Fish, squid, other nekton.
 - i. Organisms in this zone.
 - 1. Often red coloured
 - 2. Sensitive eyes which permit to feed by detecting the shadows of prey above

3. Upward turned eyes.
 4. Bioluminescent organs that cast dim blue light downward that masks their own shadows.
 5. Home of **Deep Scattering Layer** (DSL): dense aggregates of fishes, squid, and other animals that migrate up and down in synchrony with day light.
7. Bathypelagic zone
 - a. 1000 - 4000 m depth (Abyssopelagic = > 4000 m)
 - b. totally darkness
 - c. cold except at hydrothermal vents
 - d. High pressure
 - e. >75% empty
 - f. Food patchy dead organisms decal droppings
 - i. Organism adaptations
 1. Red colour
 2. Eyes absent, large, greatly reduced
 3. Bioluminescence is important in feeding and mate attraction
 4. Jaw unhinge: extendable jaws (Gulper eel)
 5. Stomachs expand to consume larger prey
 6. Low metabolic rates
 7. need less food
 8. live longer.
 8. Deep sea floor
 - a. Same conditions as Bathypelagic
 - b. Some adaptations:
 - i. Blind tripod fish feel prey with gills and fills
 - ii. Some fish bury in ooze with open mouth at surface.
 9. Whale Fall
 - a. Whale carcasses are spaced at around 25km intervals across area like the North Pacific
 - b. Source of food for bathypelagic and benthic organisms
 - c. Up to 5068 animals feed on one animal.
 10. Hydrothermal Vent community
 - a. Organisms can withstand extremes of temperature and pressure
 - b. Primary producers anoxic bacteria
 - c. Chemosynthesis
 - i. $H_2S, O_2, CO_2 \rightarrow C_6H_{12}O_6$
 - ii. Organisms feed on bacteria or live in symbiotic relationships with bacteria
 - iii. Most die when vent stops.
 1. Organism Adaptations:
 - a. Red flesh
 - b. Hemoglobin need for oxidation of hydrogen sulphide and tissue production
 - c. Clams - huge and fast growing - 4cm/yr
 - d. Tube worms 3m, basic taxon, no mouth, gut filled with bacteria
 - e. Anemones, worms, barnacles, limpets
 11. Deep Rock Communities
 - a. Extremophiles
 - b. Anoxic
 - c. Bacteria living between sediment grains of many rocks, fractures at drilling depth to 1220 m and temperatures 100C to 400C
 - d. >800 m below sea bed
 - e. Ultramicrobacterial ecosystem.

Chapter 16

Marine Resources

- Rapid growth and interest
- Oceans are used for:
 - Food = biblical resources
 - Drinkable water

- Drinkable water
- Highways of trade
- Recreation: coasts
- Energy and mineral resources
- Waste disposal: bad for ecosystem and survival
- Highly profitable.

1. Petroleum: hydrocarbons
2. Methane Hydrate = Potential source of hydrocarbon
3. Sand and gravel
4. Evaporites
5. Hydrogenous sediments
6. Water (potable)
7. Energy
8. Biological.

1. Petroleum
 - a. Hydrocarbons: oil, natural gas
 - b. Offshore: large deposits are found offshore in sediments under ocean water
 - c. Floating platforms
 - d. Drill > 1000 m in depth in substrate.
 - i. Formation
 1. Source rock: Organic shale buried in anoxic shallow sediments (continental margins)
 2. Reservoir rock: Sand and limestone (should be porous)
 3. At certain temperature and pressure, we have an oil window and gas window where oil and gas form.
 4. Once formed, the liquid and gas move upward through porous rocks (sealed rock)
 5. If there is no impermeable rocks, then the oil-gas leak out in the environment and can seep.
2. Methane Hydrates - Hydrocarbons Potential resource
 - a. Greatest hydrocarbon reserve on Earth
 - b. CH₄: Crystalline solid methane in ice cage (Canada Mackenzie river permafrost)
 - c. ~500 m depth
 - d. Low temp
 - e. In thick layers in continental slope sediments
 - i. Origins unknown
 1. Methane fizzes as it escapes at surface
 2. Burns readily when ignites
 3. Powerful greenhouse gas.
3. Sand and gravel
 - a. Second in value to petroleum
 - b. Seafloor dredging on continental shelf
 - c. Uses: landfill, cement, roads, beaches
4. Evaporites
 - a. Various salts evaporated from seawater
 - b. Manganese (Mn) salts: used for aircraft metals
 - c. 50% of the world's Mn metals come from seawater evaporation
 - d. NaCl (Sodium chloride: table salt)
5. Hydrogenous Sediments precipitated from sea water
 - i. Hydrogenous sediments are precipitated from sea water predominantly as manganese and phosphorite nodules
 - a. Metallic Sulphides
 - i. Potential resource
 - ii. Spreading centres
 - iii. Convergent boundaries - volcanism
 - iv. Red sea - muds
 - v. Boats of sun hide rich brine muds

- v. Pools of supercritical brine fluids
 - 1. Zn, Pb, Ag, Cu, etc.
- b. Phosphorite nodules
 - i. Continental margin
 - ii. Upwelling areas
 - iii. Form nodules and crusts
 - iv. Dissolved vertebrate skeletons
- c. Manganese Nodules
 - i. Potential
 - ii. Deep sea floor and slopes and seamounts
 - iii. Mainly in Pacific ocean.
 - iv. Harvesting, endangers deep sea floor.
- 6. Potable water (desalination)
 - a. Distillation
 - i. it takes energy to vaporize
 - ii. Expensive
 - iii. Viable where energy (oil) is cheap
 - b. Freezing
 - i. Ice crystals expel salts
 - ii. Multiple freezing increases purity
 - iii. Expensive.
 - c. Solar still
 - i. Coastal areas
 - ii. Sunny locations
 - iii. Fairly small scale
 - iv. Works well
 - d. Reverse osmosis
 - i. Down in more than 30 countries
 - ii. Less energy than freezing or distillation
 - iii. Water molecules are passed under pressure through a semi-permeable membrane.
- 7. Marine energy
 - a. Wind
 - i. Offshore wind power system (OWPS)
 - ii. Denmark and north Germany
 - iii. Floating wind farms
 - iv. Immense potential
 - v. fastest growing alternate energy.
 - b. Waves
 - i. Oscillating water column system
 - ii. Solid/rocky shore - high energy
 - iii. Potential
 - iv. Not economical yet.
 - v. Experimental plant off Scotland
 - vi. Other coastal systems
 - vii. Offshore floating devices
 - viii. Several models
 - ix. Also deep water waves
 - x. Rotating drum in trough translates orbital motion to a system that drive turbines.
 - c. Ocean Currents
 - d. Tidal currents
 - i. Dams
 - 1. Structures used to capture the energy from water moving in and out due to tidal currents
 - 2. Large tidal range
 - 3. Turbines work with incoming and outgoing tides
 - 4. Dams: St. Malo
 - ii. Fence
 - 1. Series of vertical turbines mounted

- 1. Series of vertical turbines mounted
 - iii. Turbine
 - 1. Underwater 'windmills'
 - 2. Located in shallow coastal areas
 - 3. Efficient
 - 4. Some problems with organisms
 - e. Thermal
 - i. Ocean thermal energy conversion (OTEC)
 - ii. The thermal gradient between the warm surface water and the cold deep water
 - iii. System utilizing warm water, pressured to steam (turbines) and cooled by the water.
 - iv. Poor efficiency
 - v. **Best in tropics**
 - vi. Difficulties - cyclones - organisms etc.
 - vii. Experimental 1930
 - viii. Environmental concerns: Ammonia escape, CO2 etc
8. Biological resources
- a. Drugs
 - i. 10% of marine organisms yield clinically useful compounds
 - ii. Antiviral: Sea sponge - Herpes Infection
 - iii. Anti-inflammatory: sea fans - arthritis
 - iv. Eleutherobin: Soft Coral - disrupts tumour growth
 - v. Anticancer: bryozoans
 - vi. Antibiotics and anticancer agents - deep sea bacteria.
 - b. Fish, Crustaceans, Molluscs
 - i. Most valuable living marine resources
 - ii. 10 major groups supply 95% commercial marine catch
 - iii. > 15 million employed through fishing!
 - a. Some issues:
 - i. Satellite imaging used to generate fish-finding charts (concentrations of plankton and desirable fish)
 - ii. Over fishing: not enough breeding stock to replenish the species
 - iii. Trawling: Fishing using a a fishing net through the water behind one or more boats
 - iv. Drift net fishing: using vertically suspended nets
 - v. Bykill: Animals unintentionally killed while desirable organisms are collected
 - c. Whaling
 - i. 4.4 millions large whales in 1900 and now little more than 1 million
 - ii. 1986 International Whaling Commission: manage whale stocks.
 - iii. Place a moratorium on large whale slaughter except 'scientific' purposes
 - iv. Japan never stopped! Argh.
 - d. Mariculture
 - i. Farming of marine organisms in estuaries, bays, nearshore environments
 - ii. Plaice and salmon, shrimp, oysters
 - iii. Rapid growth - expanding industry
 - iv. Problems:
 - v. Escape of engineered species
 - vi. Reduce the genetic diversity of wild fish
 - e. Fur - bearing mammals
 - i. 400 00 seals, sea lions are hunted for fur/yr
 - f. Botanical resources
 - i. Marine algae are exploited
 - ii. Algin is the most important commercial product extracted from seaweed mucus.
 - iii. Multiple uses: ice cream, salad dressings, paint, printers ink.
9. Non-Extrative Resources
- a. Commerce: trade - shipping
 - b. Tankers
 - c. Recreation - cruises etc.
 - d. Coastal - real estate

v. Coastal Real Estate.

Chapter 18:

Environmental Concerns.

1. Marine pollutants
 - a. Marine pollution = energy or substances, directly or indirectly introduced to the marine environment that change the quality of water
 - b. Or affect the physical chemical or biological environment.
 1. 44% runoff and discharges from land: land sources:
 - a. Estuaries - ports - urban - industrial wastes
 - b. Coastal things.
 - c. Rivers - vast Drainage areas to oceans
 - d. Organics - sewage
 - e. Pesticides
 - f. Fertilizers
 2. 33% airborne emissions from land: atmospheric
 - a. Particulate.....
 3. 12% shipping and accidental spills
 - a. Cargo of toxic substances
 - b. Oil spills from tankers
 4. 11% offshore inputs
 - a. 1% offshore resource exploitation: oil, gas, sand/gravel
 - b. 10% ocean dumping.
2. Characteristics of pollutants
 - a. Quantity and Toxicity
 - i. Some pollutants are toxic in tiny concentrations.
 - ii. Others are harmless
 - iii. Crude oil interferes with the feeding structures of zooplankton
 - b. Persistence
 - c. Some pollutants reside in the environment for a very long time.
3. Main types of Pollutants
 - a. Oxygen - Demanding wastes (ODW)
 - i. ODW = Pollutants which reduce the amount of dissolved oxygen in water
 - ii. Biochemical Oxygen demand (BOD) = amount of oxygen consumed if all the organics in one liter of water were oxidized by bacteria
 1. Sewage and/or fertilizer run-off from farms
 2. Enriched nutrient content in rivers and lakes.
 - b. Conservative pollutants
 - i. Persist for long time
 - ii. Magnify, Concentration higher once we move on food chain.
 - iii. Do not biodegrade
 - iv. Bioaccumulate
 - v. Biomagnify
 - i. Heavy metals... Human activities 5 times as much mercury and 17 times as much lead
 - ii. 2 more examples.
 - c. Particulate pollutants
 - i. Plastic and other solids
 - ii. Tremendous quantities and growing
 - iii. Illegal to dump plastics off N. American coast.
 - d. Thermal Pollution
 - i. Local
 - ii. Devastating to local benthic fauna
 - iii. Coastal industries, nuclear factories
 - e. Oil Pollution
 - i. Light components - Volatiles, evaporate
 - ii. Water - solubles

iii. Water - oil

iii. Dissolve

iv. immiscibles emulsify

1. Oil in water - bacterial decay
2. water in oil (chocolate mousse) - turbulence - takes longer
3. Heavy crude - tar balls, sink.

Law of the sea

- To protect the ocean
- seaward boundary is = 5 km = distance a cannonball could be fired from shore.
- After WW2, continental shelves oil and gas sources discovered.
- In the draft convention: territorial waters extend 18.2 km from shore.
- US claimed everything within 200 miles = US exclusive economic zone.
- Exclusive economic zone
 - Sovereignty over marine resources
 - No high seas sharing
 - The US EEZ was signed on March 10, 1983 by Reagan
 - About 40% of ocean un EEZ.
 - Rest > 45% high sea is shared

ERTH2403 FINAL EXAM:

1. Date: April 16th, 2015 from 7 - 9.
2. Lecture 10 to lecture 13.
3. Chapters 13 - 18.
4. 13 = definitions
5. 14 = questions
6. Marine Animals = know the examples

Possible short answer questions:

Chapter 14:

Plankton, algae, and plants

- The characteristics of the different type of marine algae
- Lack of nutrients and light can limit the primary productivity (limiting factors)
- Variation in the oceanic primary productivity by season and latitude (in the tropics, the temperate, and the polar zones)

Chapter 15: marine animals

- Amphioxus (Genus) and the transition between invertebrates and vertebrates
- Adaptations of fish to the marine environment (caudal fins, aspect ratio, muscle fibre types, and life mode (lungers and cruisers)
- ^ What is aspect ratio.. draw different fins and give number

Chapter 16: Marine Communities

- Characteristics and the organisms of the zones of the Rocky Intertidal Communities (rocky shore)
- Definition and illustration of the deep scattering layer

Chapter 17:

Marine resources

- tidal currents are used as a source of marine energy.