Energy in Marine Ecosystems

I. Food Chains, Food Webs and Ecological Pyramids
a. Food Chain- A succession of organisms in an ecological community that constitutes a continuation of food energy from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member.
   i. Begins with the primary producers
      1. They are autotrophs (‘self’-‘feeders’) - Organism capable of making organic compounds, such as carbohydrates, from inorganic material, such as carbon dioxide and water.
         a. Photoautotrophs, such as plants, use solar energy to help make these compounds in a process known as photosynthesis.
   ii. Primary producers are consumed by primary consumers
      1. Primary consumers, or secondary producers, are heterotrophs (‘other’-‘feeders’)- Organisms incapable of making organic compounds from inorganic material, they obtain their nutrition by consuming autotrophs and derive energy through respiration.
   iii. Primary consumers are consumed by secondary consumers, a.k.a. tertiary producers.
   iv. And so on…Food chains vary in length.
   v. Terrestrial Example
      1. Plant seed (primary producer) is eaten by a mouse (primary consumer) that is eaten by a cat (secondary consumer)
   vi. Marine Example
      1. Seaweed (primary producer) is eaten by sea urchins (primary consumer) that are eaten by sea otters (secondary consumer).

b. Food Web- A bunch of interconnected food chains.
   i. Primary consumers often eat more than one type of primary producer and secondary consumers often eat more than one type of primary consumer.
   ii. Leads to interrelated food chains that schematically appear as a web.

II. Decomposers
a. At each step in the food web some organic matter is not eaten by a higher-level consumer. It becomes decomposed by decomposers, who break down non-living organic matter into its original components: carbon dioxide, water and nutrients.
   i. When this matter dissolves in the water and is known as dissolved organic matter (DOM).
   ii. Dead organic matter in solid form, such as decaying seaweeds, is called detritus.
1. **Detritus** is an important energy pathway in marine ecosystems because many organisms feed on it, especially those that live below the **euphotic zone**.

iii. ** Decomposers** are important to the food web because they regenerate nutrients, which are then used by the **autotrophs**.

### III. Ecological Pyramid

a. The flow of energy through an ecosystem can be visualized as pyramid, with each level representing a different **trophic level** and the size of that level is proportional to the biomass in that **trophic level**.

i. **Trophic Level**- an energy-storing level in a food chain, or pyramid. The **primary producers** constitute the first trophic level, and the **primary consumers** constitutes the second trophic level.

ii. Because not all of the biomass of the preceding **trophic level** is used in the next **trophic level**, the higher trophic levels have less biomass.

iii. **Ecological efficiency**- percentage of energy taken in as food by one trophic level and then passed on as food to the next highest trophic level

1. **Ecological efficiency** for most ecological communities is about **10%**.
   a. 100 grams of plants will sustain 10 grams of mice, which will sustain 1 gram of cat.
   b. An ecological argument for vegetarianism…..?

### IV. The Marine Food Web

a. **Primary Producers**

   i. **Oceanic primary productivity**

   1. Light is only available for photosynthesis in the upper 100m or so of the ocean. Below that, there isn’t enough light to support ‘plant’ growth.
      a. Everything that lives below 100m in the ocean lives off of the production in the upper 100m

   2. Nutrients, such as nitrate, phosphate and silicate, are often limiting in the upper 100m.

   3. Consequently, most of the ocean tends to be **oligotrophic** (‘few’-‘food’) - Very little productivity.
      a. Not a lot of **biomass**, especially compared to land.
      b. **Biomass**: the amount (mass) of living material.

   ii. **Open Ocean or Pelagic (meaning the deep ocean).**

      1. **Phytoplankton** (‘leaf’-‘wanderer’)- planktonic photosynthesizers in aquatic habitats; the ‘plants’ of the sea.
         a. **Plankton** = any organism living in the water column that cannot swim against a current. It goes where the water goes.
            i. 1- 100µm (one millionth of a meter)
            ii. Produce ½ of the world’s oxygen
iii. Live only in the upper 100 m, or so, of the ocean
iv. Examples:
  1. Dinoflagellates
  2. Diatoms

iii. Coastal Environments:
  1. Phytoplankton
  2. Algae, Seaweeds and seagrasses
     a. Macroscopic primary producers
        i. Live attached to the substrate (bottom)
        ii. Only found in shallow areas where light can reach the bottom

b. Primary Consumers (secondary producers)
i. Open Ocean:
  1. Zooplankton (‘animal’-‘wanderer’)-planktonic animals
  2. Feed on
     a. Phytoplankton
        i. Detritus - the remains of once-living tissue
        ii. Examples
           1. Krill
           2. Copepods
           3. Larval stages of many invertebrates (crab, lobster, etc.)
           4. Larval fish
           5. Jelly fish

ii. Coastal Environment:
  1. Zooplankton
  2. Benthic Macroinvertebrates - Invertebrates you can see.
     a. Benthic, or the benthos, refers to the bottom of the sea, the mud.
     b. Feed on phytoplankton as well as Algae, seaweed and seagrass detritus
     c. Examples
        i. Worms
        ii. Clams
        iii. Sea Urchins
        iv. Limpets
        v. Some seabirds may be primary consumers
           1. Ducks eat duckweed.

c. Secondary Consumers (tertiary producers)
i. Open Ocean
  1. Nekton
     a. Animals that can swim against a current. They include fish, squid and marine mammals
  2. Large Zooplankton, small fish, some seabirds, some whales

ii. Coastal Environment
1. Large macroinvertebrates
   a. Sea stars, predatory welks
   b. Large zooplankton, bigger fish, many seabirds, some whales

V. Measuring Primary Productivity
   a. The rate of primary production, or productivity, is expressed as the amount of carbon fixed under a square meter of sea surface over time.
      i. Either measured by the amount of CO$_2$ used or the O$_2$ released, from photosynthesis.
   b. The total mount of phytoplankton in the water, or the standing stock, of phytoplankton is related to the primary productivity.
      i. The more phytoplankton, the more there is a potential for primary production.
   c. Phytoplankton contain chlorophyll (chl) so the amount of chl is a good indication of the phytoplankton standing stock, and is often used to represent it.

VI. Cycles of Essential Nutrients.
   a. Carbon Cycle
      i. Inorganic carbon is converted to organic compounds via photosynthesis
      ii. Respiration by consumers, decomposers and the producers themselves breaks down the organic compounds and makes the carbon dioxide available to producers again.
      iii. Some carbon is also deposited as calcium carbonate from the shells of organisms in the form of biogenous sediments.
   b. Nitrogen Cycle
      i. The nitrogen gas present in the atmosphere (N$_2$) is not available for use by most primary producers.
      ii. A few types of cyanobacteria are able to convert nitrogen gas into forms that can be used by primary producers.
         1. This is known as nitrogen fixation.
      iii. The most important form is nitrogen is nitrate (NO$_3^-$)
         1. Other forms include ammonium and nitrite
   c. Other nutrients
      i. Phosphate is a major limiting nutrient in aquatic systems, and is ultimately limiting in the oceans (can’t live without it), but nitrate is limiting more often.
      ii. Silicate is used by diatoms to make their casings and therefore if there is not enough of it around, diatoms can’t grow.