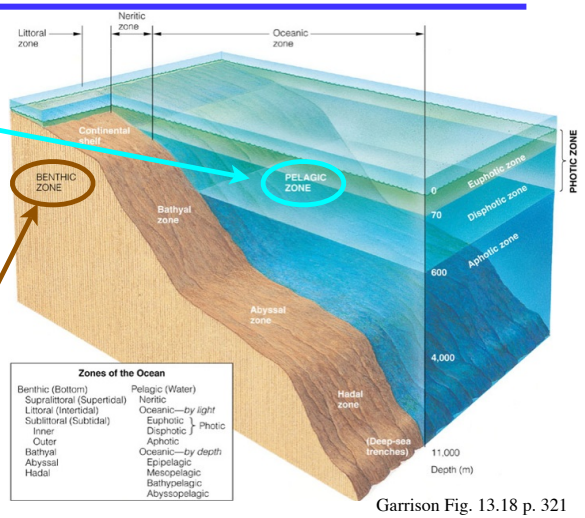
Marine Environments

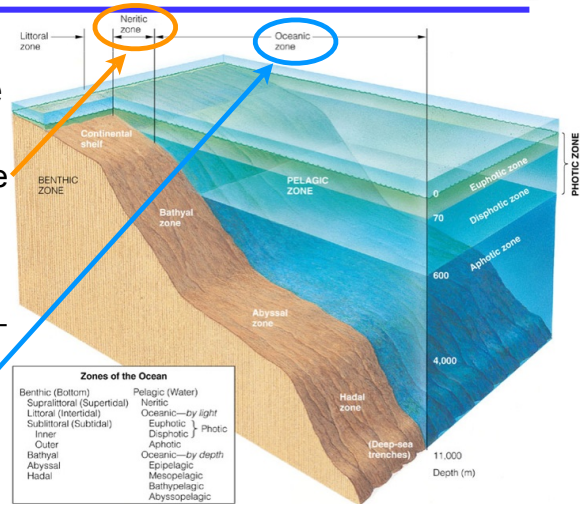
- Water column habitat = pelagic zone
  - Our focus
- Bottom habitat = benthic zone



Garrison Fig. 13.18 p. 321

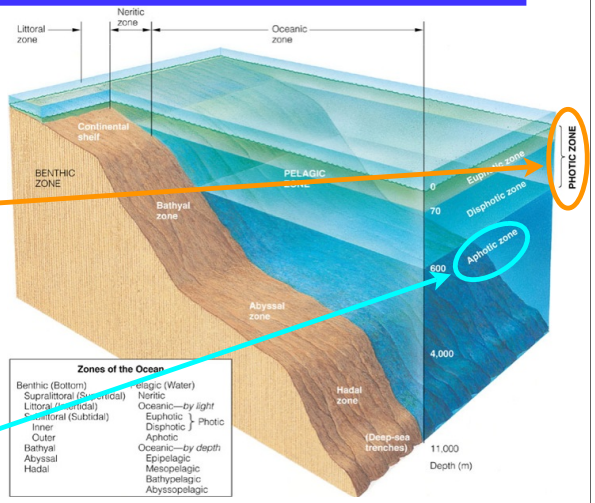
Pelagic Environments

- Classified by distance from shore
  - Near shore shallow = neritic
    - Over the continent-al shelf
  - Far from shore = oceanic



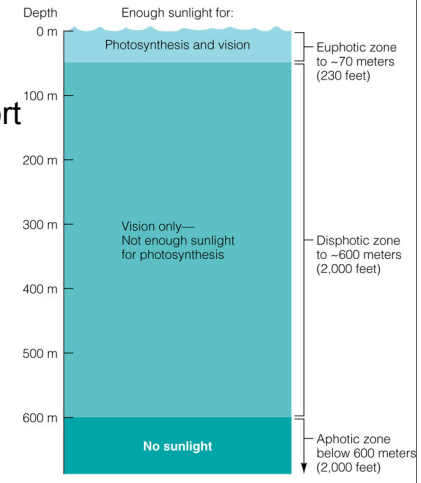
Pelagic Environments

- Classified by depth
  - Near surface = photic
    - Euphotic brightly lighted
    - Disphotic dimly lighted
  - Deep = aphotic



Importance of Light

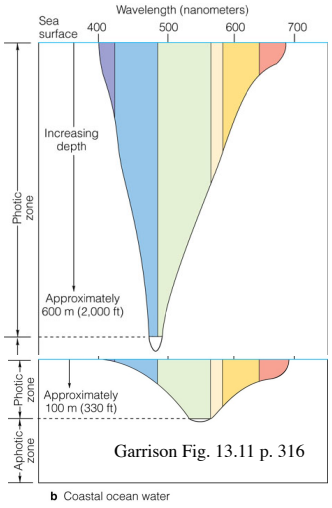
- Photosynthesis
  - Euphotic zone has adequate light to support net photosynthesis
  - Upper 50-100 m depending on location
- Vision to see prey, predators, mates
  - Disphotic zone has adequate light
    - To ~600 meters



Garrison Fig. 13.12 p. 316

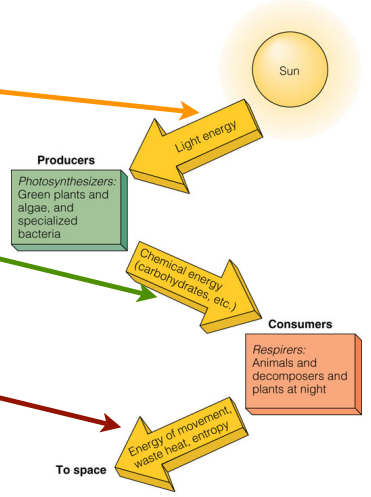
Importance of Light

- Penetration differs by color
  - Red, yellow absorbed first
    - Long wavelength
    - Infrared (heat) also
  - Violet absorbed near surface
    - Short wavelength
    - Ultraviolet also
  - Blue, green reach deepest
  - Deeper photic zone offshore
    - Coastal waters more turbid
    - More green/yellow
      - Plankton & sediments



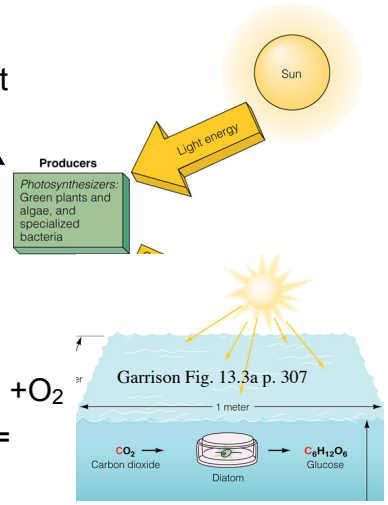
Pelagic Production: Energy

- Energy source = sun
  - Energy as light
- Primary production = photosynthesis
  - Energy stored mainly as carbohydrates $(CH_2O)_n$
- Respiration
  - $(CH_2O)_n$ burned with O_2 to release energy for movement, etc.
    - Mostly given off as heat



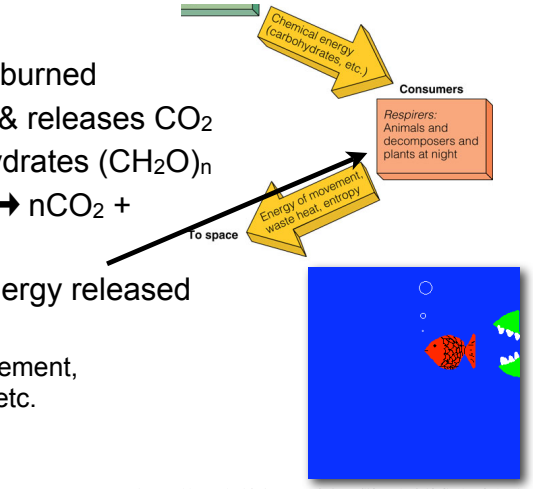
Pelagic Production: Energy

- Photosynthesis
  - Chlorophyll captures light energy
    - Transferred for chemical storage
  - Consumes CO_2 & releases O_2
  - Product = carbohydrates $(CH_2O)_n$
  - $nCO_2 + nH_2O \rightarrow (CH_2O)n + O_2$
  - Glucose (carbohydrate) = $(CH_2O)_6 = C_6H_{12}O_6$



Pelagic Production: Energy

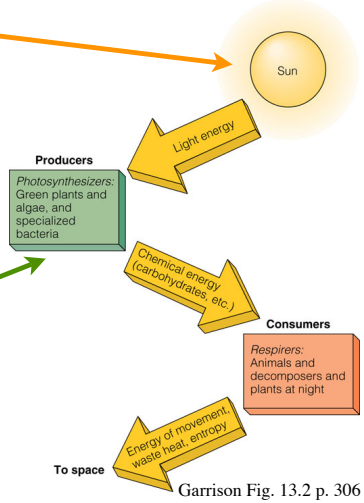
- Respiration
  - Stored energy burned
  - Consumes O_2 & releases CO_2
  - Fuel = carbohydrates $(CH_2O)_n$
  - $(CH_2O)_n + O_2 \rightarrow nCO_2 + nH_2O$
  - Much of the energy released as heat
    - Some for movement, reproduction, etc.



www.acocksgreen.bham.sch.uk/sciencezone/science/lifecycles/LifeCycleInfo.html

Pelagic Production: Organisms

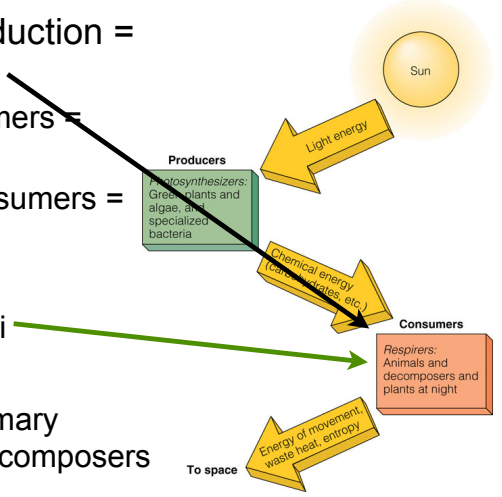
- Energy source = sun
  - Supports all life in the sea, even in unlighted waters
  - EXCEPT hydrothermal vent communities
- Primary production = photosynthesis
  - Photosynthetic bacteria
  - Algae (micro- & macro-)
  - A few higher plants



Garrison Fig. 13.2 p. 306

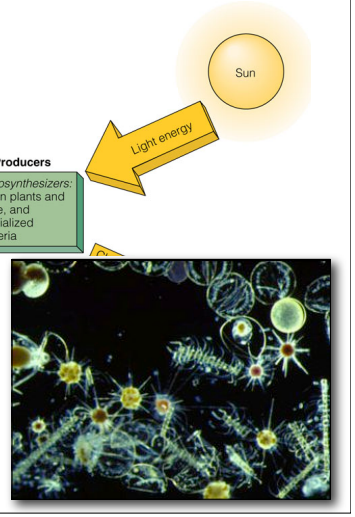
Pelagic Production: Organisms

- Secondary production = consumption
  - Primary consumers = herbivores
  - Secondary consumers = carnivores
- Decomposers
  - Bacteria & fungi
- Respiration
  - All animals, primary producers & decomposers



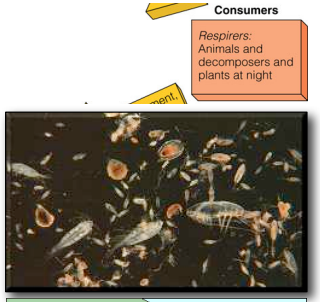
Pelagic Production: Organisms

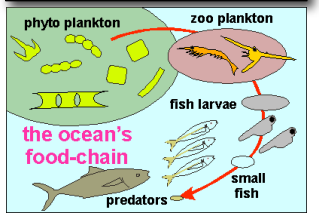
- Primary producers
  - Phytoplankton (∅P)
    - = Free-floating
    - Single-celled & microscopic
    - Photosynthetic bacteria + microalgae
  - All seaweeds (macroalgae) + seagrasses (higher plants) = 4-10% of total ocean primary production
    - Attached to bottom
    - Limited to coastlines



Pelagic Production: Organisms

- Primary & secondary consumers
  - Zooplankton (ZP)
    - = Free-floating
    - Weak swimmers
    - Uni- & multi-cellular
    - Micro- & macro-scopic
    - Wide variety of animals
  - Nekton
    - Strong swimmers
    - Fish, marine mammals





Primary Productivity

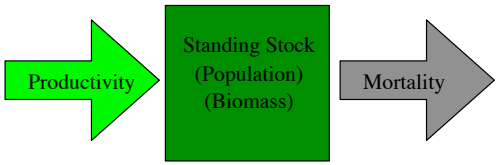
- Primary production = process of creating living from nonliving material
  - Fixing of energy as carbohydrate, etc.
  - Photosynthesis or chemosynthesis
- Primary productivity=rate of primary production
  - Per unit time & area
- Carbon is the currency of production
  - Grams carbon fixed as carbohydrate per year
    - Per square meter of ocean surface
    - gC/m2/year
  - Range 75-150 gC/m2/year (average ~120)

Productivity vs. Standing Stock

- Standing stock is the amount of living matter
  - Usually per unit area, i.e. per square meter
  - Usually separated by types of organisms
    - E.g., primary producers
- Several common ways to report
  - Population = number of individuals per m^2
  - Biomass = mass of living tissue
    - Wet weight = fresh tissue mass
    - Dry weight = tissue with water removed
    - Carbon = gC/m^2
    - Chlorophyll = used for primary producers
      - Easy way to separate from consumers

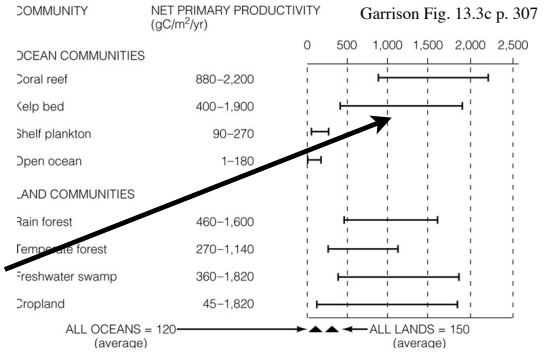
Productivity vs. Standing Stock

- Standing stock is an inventory
- Productivity is a rate of change of that inventory
  - Production increases the inventory
  - Death (mortality rate) decreases the inventory
  - Standing stock results from the balance of the two rates



Ocean Primary Productivity

- Ocean is generally less productive than land
  - Varies by type of environment
  - Greater proportion of area is “desert”
  - Garrison does not give productivity of upwelling areas
    - 1000+ $gC/m^2/year$



Ocean Standing Stock

- Ocean has generally less biomass than land
  - Because it sinks!
    - No trees or shrubs
  - 0.1 - 0.3% of terrestrial biomass
- Much faster rate of turnover of biomass
  - Primary producers live a few days instead of years

Table 13.1 Comparison of Global Net Productivity and Living Biomass in Marine and Terrestrial Ecosystems

Ecosystem	Net Primary Productivity (10^{15} grams/year)[a]	Total Plant Biomass (10^{15} grams)	Turnover Time (years)
Marine	35–50	1–2	0.02–0.06
Terrestrial	50–70	600–1,000	9–20

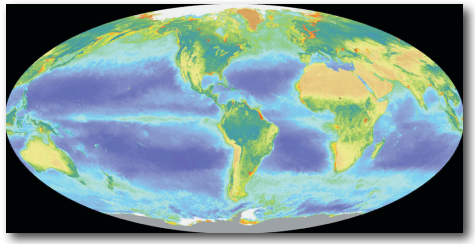
Source: Falkowski and Raven, 1997.
[a] 10^{15} grams is equivalent to 1 billion metric tons.

Garrison Table. 13.1 p. 307

Measuring Phytoplankton

- Biomass (standing stock)
  - Capture using a bottle or a net
  - Count numbers of cells, weight or volume
  - Fluorometer measures chlorophyll
    - Rapid surveys pumping water
  - Ocean color by satellite

Garrison Fig. 13.4 p. 308

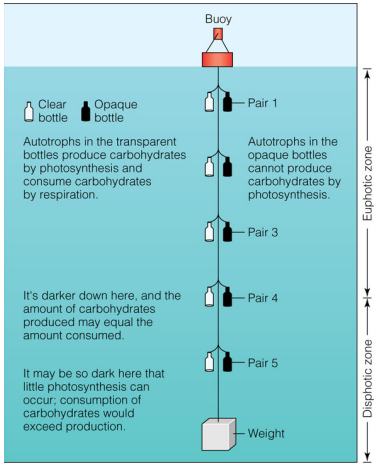


Measuring Primary Productivity

- Production (photosynthesis)
  - Time rate of change of biomass
    - Measure biomass at same location at two times
    - Subject to huge errors because water is moving
    - Does not measure productivity or mortality rates
- Use radioactive carbon-14 (^{14}C) tracer
  - Capture phytoplankton in a large bottle
  - Incubate in small bottles with added ^{14}C
  - Collect & measure amount of ^{14}C fixed
    - Use ^{14}C/total CO_2 ratio to estimate total C uptake
  - Sum uptake over depth & duration to estimate gC/m^2/day
  - Repeat at different seasons to estimate annual productivity

Measuring Primary Productivity

- ^{14}C incubation
  - To estimate productivity vs. depth
    - Resuspend at different depths *-or-*
    - Use screens to simulate various light levels corresponding to different depths
  - Calculate *net* productivity
    - Subtract respiration
    - Dark bottles
    - C that becomes biomass



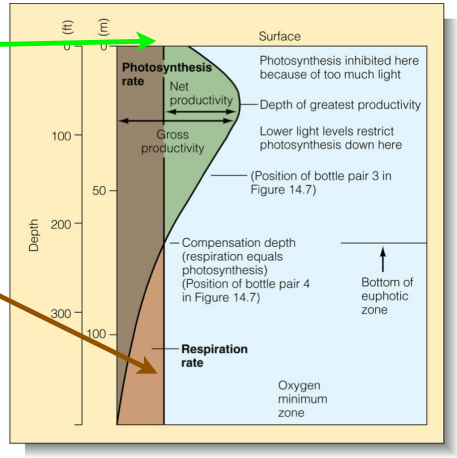
Garrison Fig. 14.7 p. 342

Photosynthesis vs. Depth I

- How does photosynthesis depend on light alone?
  - Assume nutrients are plentiful
  - Not enough light: bad
    - Little photosynthesis below ~100 m
    - Absolutely none below 268 m
  - Too much light: bad
    - Photo-inhibition at surface in tropics
- Key indicator: *net* photosynthesis
  - Respiration roughly constant with depth
  - Net photosynthesis = C uptake (gross) - respiration

Photosynthesis vs. Depth I

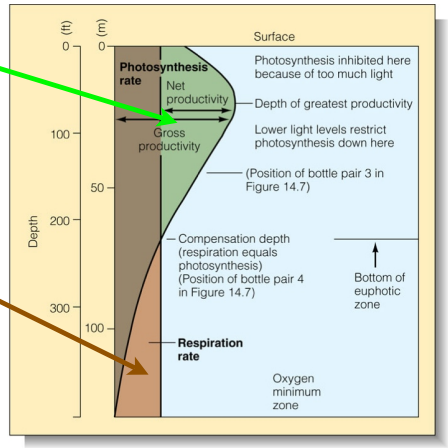
- Green area = gross photosynthesis
  - Maximum below the surface here
  - Not so at high latitudes & early or late in the year
- Brown = respiration
  - Roughly constant with depth



Garrison Fig. 14.8 p. 343

Photosynthesis vs. Depth I

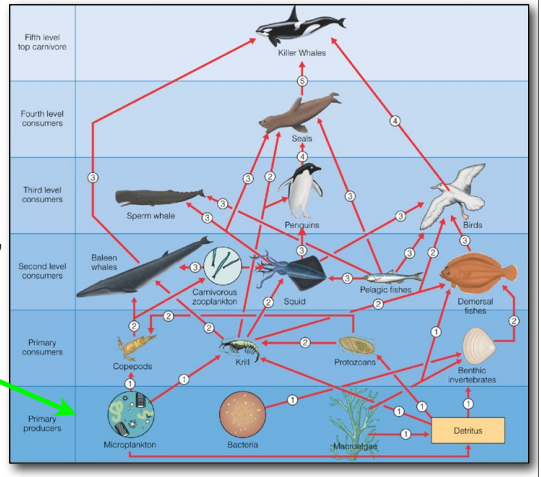
- Net PS = excess of green over brown
  - Gross PS - respiration
- Depth at which gross = respiration
  - Zero net PS
  - Bottom of euphotic
  - Compensation depth
  - Rule of thumb: 1% light level



Garrison Fig. 14.8 p. 343

Pelagic Production: Food Web

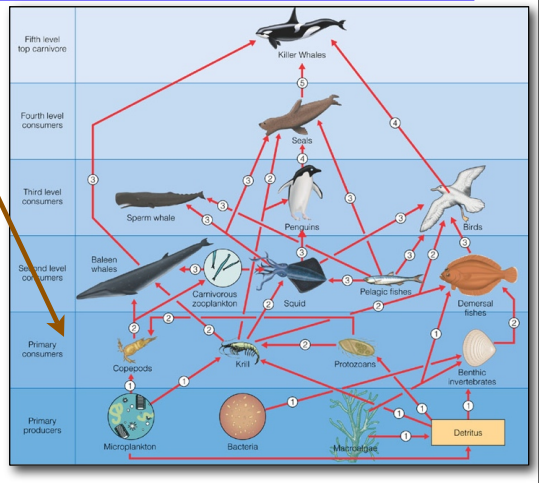
- Trophic levels
  - Denote hierarchy of feeding relationships
  - By convention, drawn from bottom up
  - Trophic level 1 = primary producers



Garrison Fig. 13.6 p. 310

Pelagic Production: Food Web

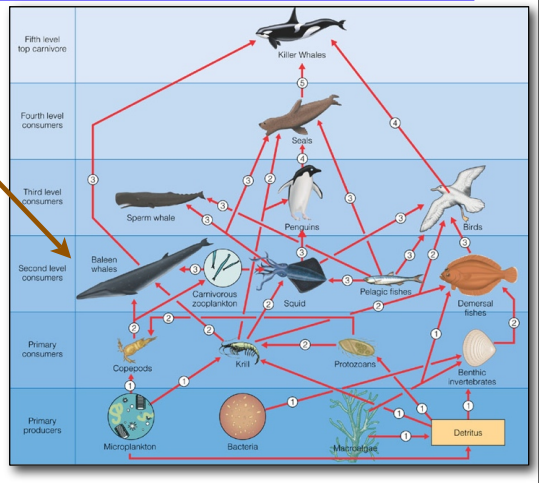
- Primary consumers = zooplankton
  - Trophic level 2
  - Herbivores & detritivores
  - 1-celled Protozoa to krill (small crustaceans)
    - 0.1 mm to ~5 cm



Garrison Fig. 13.6 p. 310

Pelagic Production: Food Web

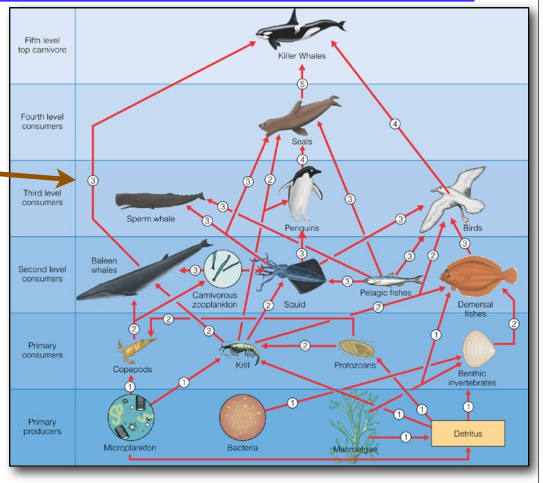
- Secondary consumers = zooplankton & nekton Level 3
  - Carnivores
  - Large zooplankton
  - Fish larvae & juveniles
  - Small adult fish, squid, birds, whales



Garrison Fig. 13.6 p. 310

Pelagic Production: Food Web

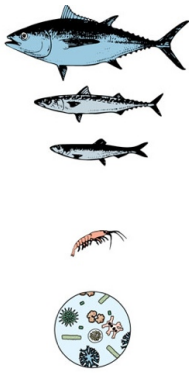
- Tertiary consumers = nekton
  - Level 4
  - Carnivores that feed on lower carnivores
  - Large adult fish
  - Whales, seals, birds



Garrison Fig. 13.6 p. 310

Food Web Efficiency

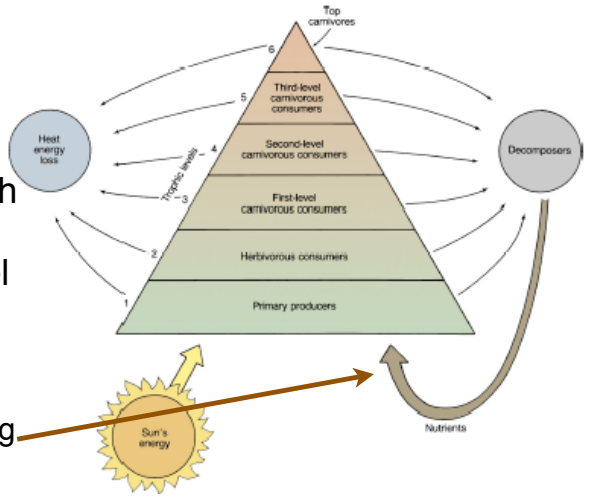
- Recall that only about 10% of food consumed by animals becomes biomass
  - 90% is burned by respiration, eliminated as waste, lost as gametes (egg & sperm), etc.
  - Result: each trophic level has less productivity than the one below it



Garrison Fig. 13.6 p. 310

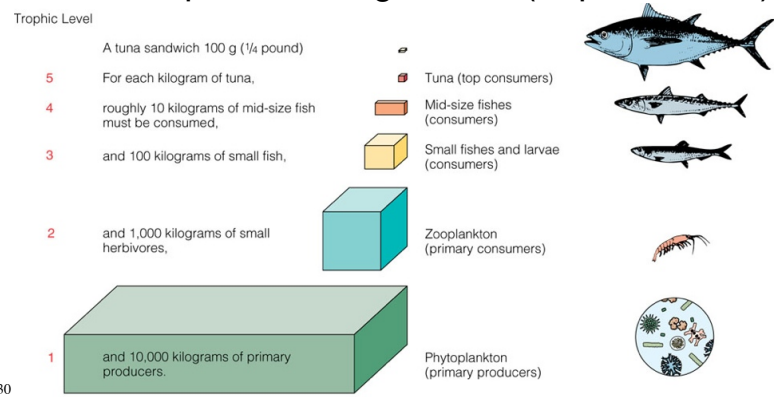
Trophic Pyramid

- Rule of thumb: productivity decreases 90% at each higher trophic level
  - System recovers some loss by recycling waste



Food Web Production

- Note 10^5 kilograms of primary production needed to produce 1 kg of tuna (trophic level 5)



Garrison Fig. 13.5 p. 309

Food Web Production

- Sets a limit on the total fish production of the oceans
  - Feed the starving masses?
- Estimated total ocean primary production = 3.5–5 * 10^{13} kg/yr
  - 35–50 billion metric tons/yr

Table 13.1 Comparison of Global Net Productivity and Living Biomass in Marine and Terrestrial Ecosystems

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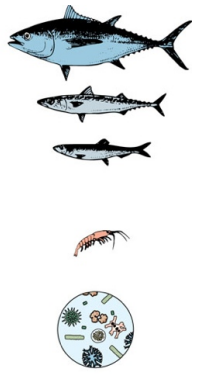
Source: Falkowski and Raven, 1997.
[a] 10^{15} grams is equivalent to 1 billion metric tons.

Garrison Table. 13.1 p. 307

Food Web Production

- Level 1 3.5–5 * 10^{13} kg/yr
  - Level 4 3.5–5 * 10^{10} kg/yr mid-size fish
  - Level 5 3.5–5 * 10^9 kg/yr large fish
  - 3.5–5 million metric tons/yr of tuna-sized fish vs. 35–50 billion metric tons/yr phytoplankton
  - Global fish harvest ~100 million metric tons/yr



Garrison Table. 13.1 p. 307