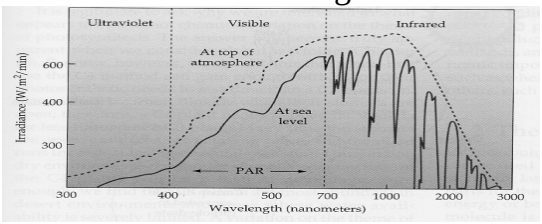
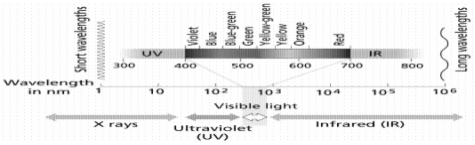
Ecosytem Energy

- Where does the energy you use to walk and breath ultimately come from?
- Where does the energy you use to propel your car ultimately come from?
- ALL organisms MUST acquire energy to be successful
- All organisms oxidize carbon compounds (i.e., fixed carbon) to acquire energy.
- Autotroph: self-feeding organisms that can make their own fixed carbon using energy from light or chemicals
- Heterotrophs: organisms that depend on other sources of fixed carbon for their energy.

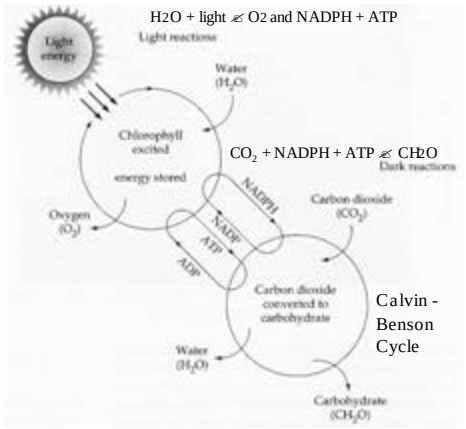
Irradiance reaching Earth





Basic Biochemistry

- Photosynthesis - plants, protists, and bacteria
  - $6H_2O + 6CO_2 + light ---> C_6H_{12}O_6 + 6O_2$
  - Light reactions: in chloroplasts; electron transfer membranes produce some ATP and NADPH
  - Dark reactions: in protoplasm; ATP and NADPH used to " fix" CO_2 to CH_2O; RUBISCO
  - C_3, C_4, CAM
- Respiration - all 5 kingdoms
  - reverse of photosynthesis
  - $CH_2O + O_2 ---> CO_2 + H_2O$ + energy
- Energy transfer in living systems is carried out by the carbon cycle

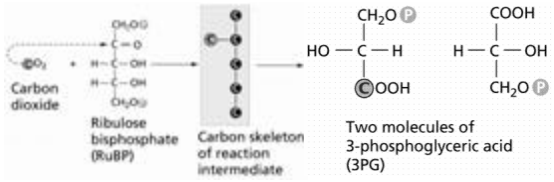


Photosynthesis: converting solar energy to biologically - useful chemical energy

C3 Photosynthesis: All plants have this biochemistry (even the C4 and CAM plants)

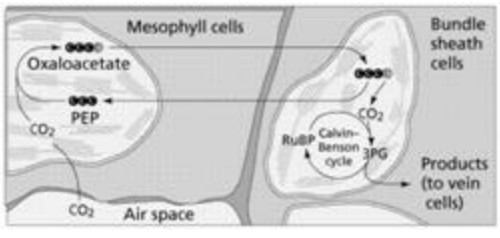
CO2 + C5 ⇙ 2C3 These C3 molecules are what give C3 photosynthesis its name

Calvin Cycle x 6



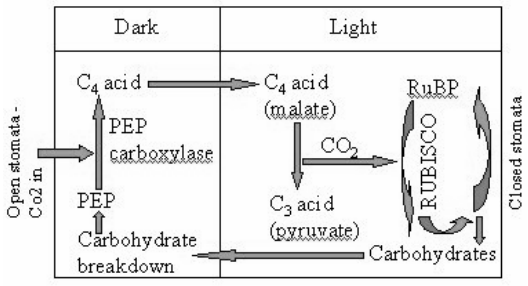
C4 photosynthesis: a mechanism to pump CO_2 into the C3 pathway

CO_2 + PEP(C3) ⇙ Oxaloacetate (C4)



CAM Photosynthesis: a mechanism to conserve water and/or CO_2

CAM is C4 biochemistry, but with different timing



Comparison of Photosynthetic Systems

	C3	C4	CAM
Enzyme used	RUBISCO	PEPcase/RUBISCO	PEPcase/RUBISCO
Optimum Temperature	15-25oC	30-40oC	25oC
Leaf structure	bundle sheath cells	bundle sheath cells	mesophyll cells with
	lacking chloroplasts	having chloroplasts	large vacuoles
Efficiency in light	can be sun or shade	ineffective in shade	
	plants		
Typical habitat	requires relatively	arid or tropical	arid environments or
characteristics	moist habitats	regions	where CO2 is limited
Productivity	med	high	low

Ecosystem Transfer of Energy

- Gross primary productivity (GPP): total amount of photosynthesis carried out by plants
- Net primary productivity (NPP): GPP minus plant respiration; is the amount of energy available to the rest of the food web
- Photosynthetic efficiency: the proportion of light energy that plants convert to chemical energy (typically 0-4.5%)
- Ecological efficiency: the proportion of energy from one trophic level that gets passed on to the next higher trophic level (typically 1-20%)
- Exploitation efficiency: the proportion of a trophic level that is consumed by the next higher trophic level

Why is ecological efficiency so low?

- 1st Law of Thermodynamics: energy is neither created nor destroyed
- 2nd Law of Thermodynamics: when energy is converted from one state to another, its quality declines
- Therefore, energy is not "lost" from the ecosystem (this would violate the first law), rather it is degraded to a useless form
- Reasons for inefficiency
  - entire organism is not consumed
  - entire organism is not digested
  - respiration (endotherms vs. ectotherms; aquatic vs. terrestrial)
- Secondary production: amount of animal biomass produced
  - dependent on ecological efficiency
  - length of food web

Ecological efficiency (%) of various consumers

Birds	1.29
Small mammals	1.51
Other mammals	3.14
Fish	9.77
Non-insect invertebrates	25
Insects	40

from Begon, Harper, and Townsend 1986

Length of Food Webs

- Short in terrestrial systems
- Ecosystems have small number of large apex predators b/c there is not enough energy to support a bunch of them
- Longer in aquatic ecosystems, especially open ocean
  - the size of phytoplankton is an important determinant for the number of trophic links, as organisms tend to feed on organisms just slightly smaller than themselves (optimal foraging theory)
- Number of trophic levels in ecosystems influences the biomass of large animals that is supported by a given amount of 1^o production