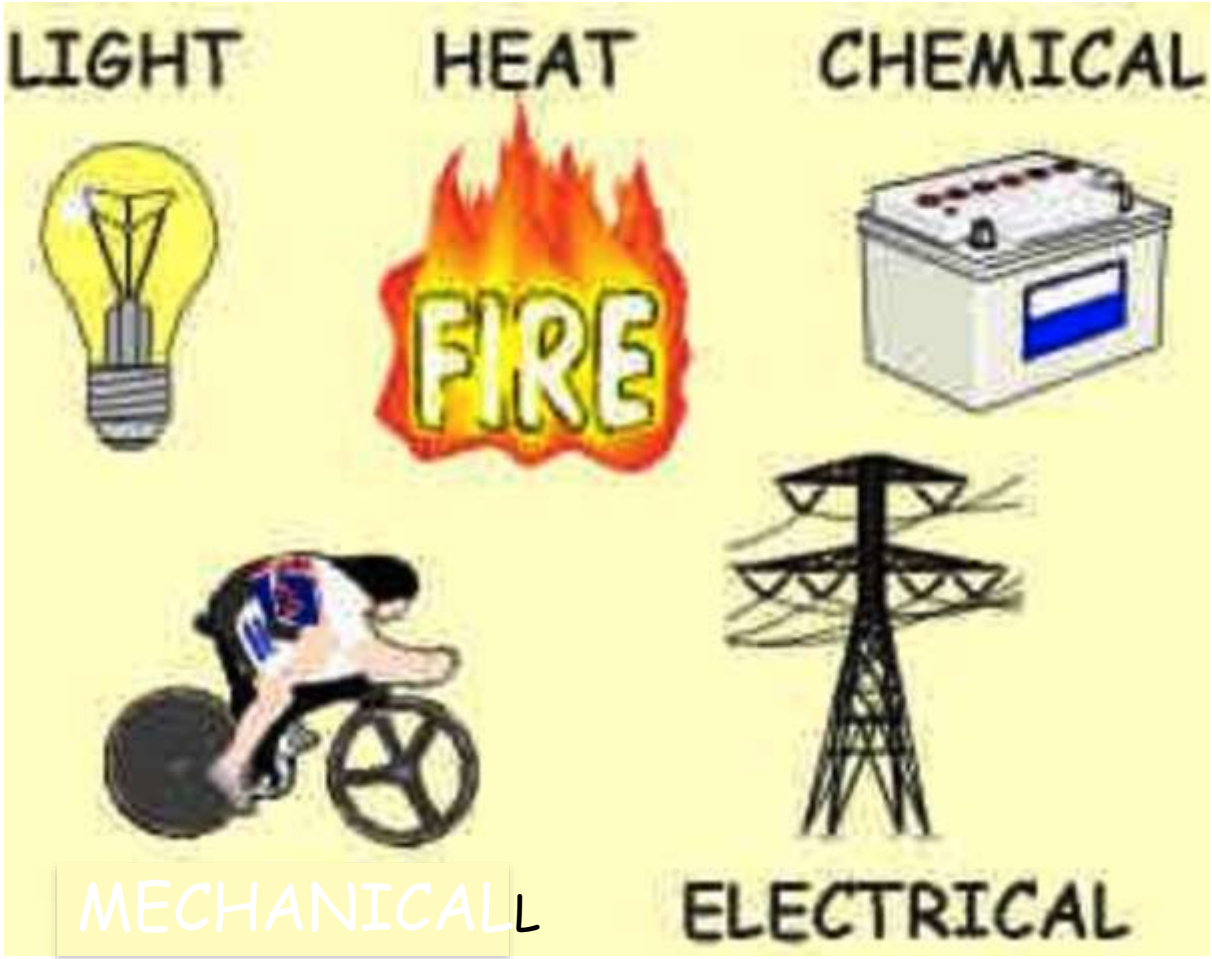
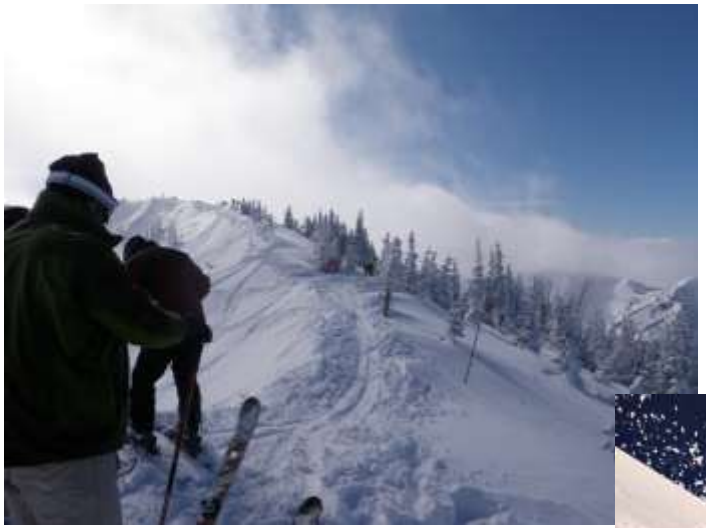
Energetics
Free Energy and Spontaneity

Energy takes various forms



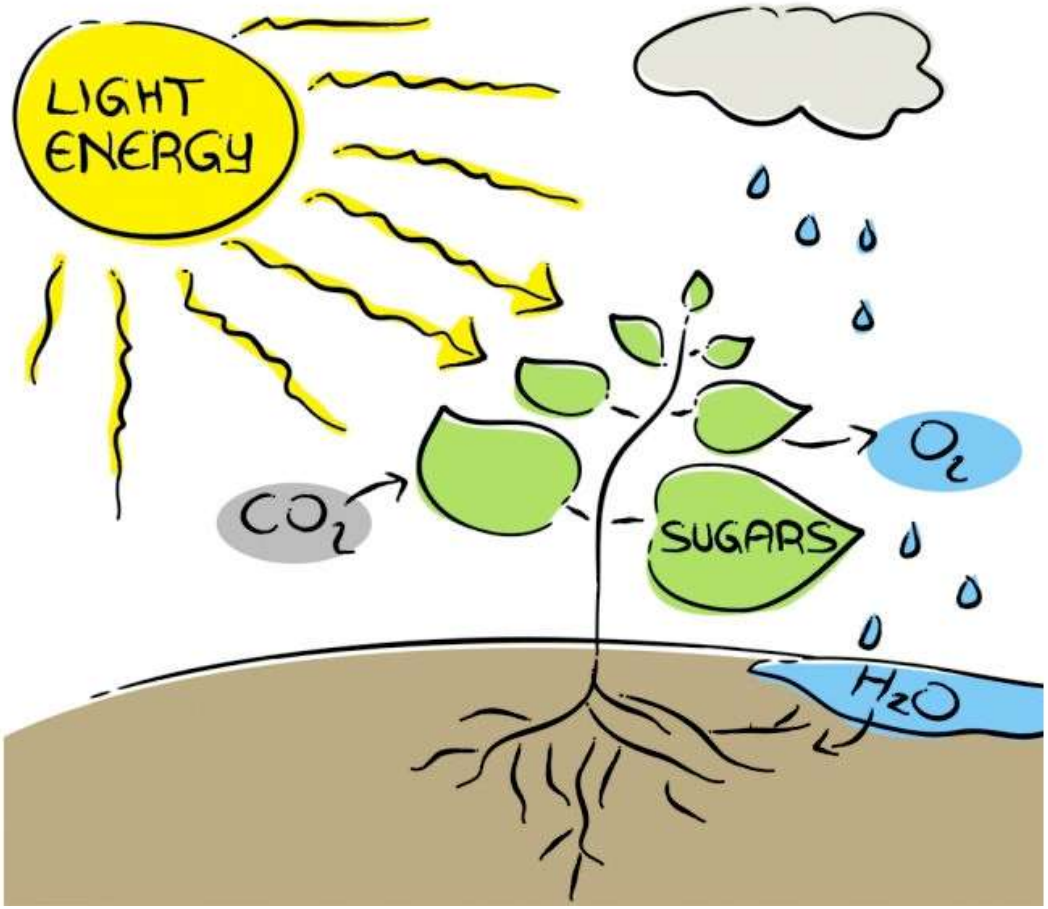
Energy, regardless of the form, can exist in two states



potential

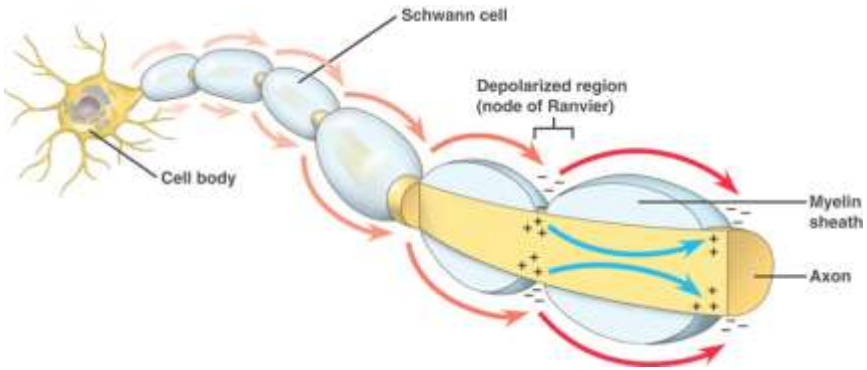
kinetic

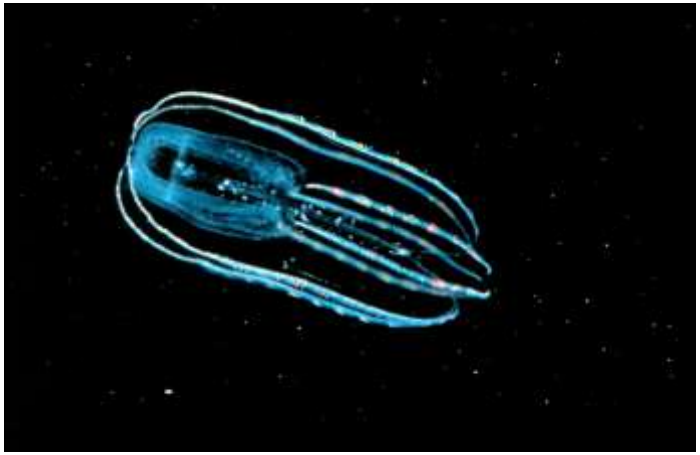
Photosynthesis makes energy available to organisms



Radiant (light) energy transformed into chemical (CH_2O) energy

Energy is used for cell work

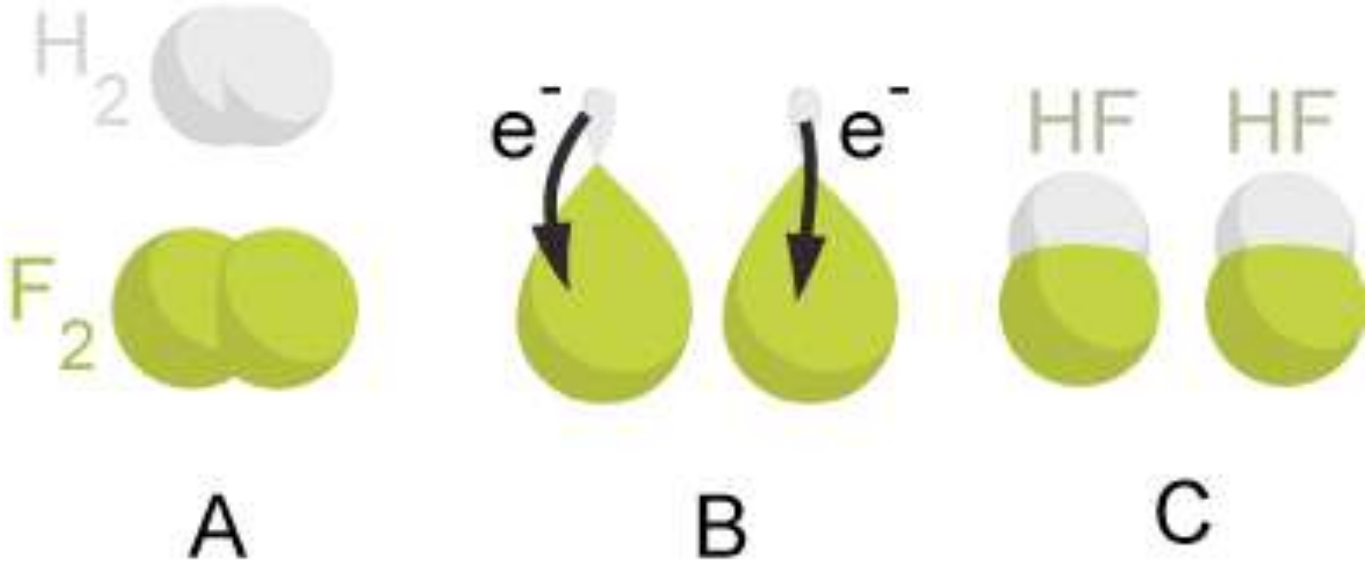




http://www.ted.com/talks/edith_widder_the_weird_and_wonderful_world_of_bioluminescence.html

In chemical rxns, energy is transferred as atoms & bonds are rearranged
aka metabolism

Ex: Redox rxns



bonds broken

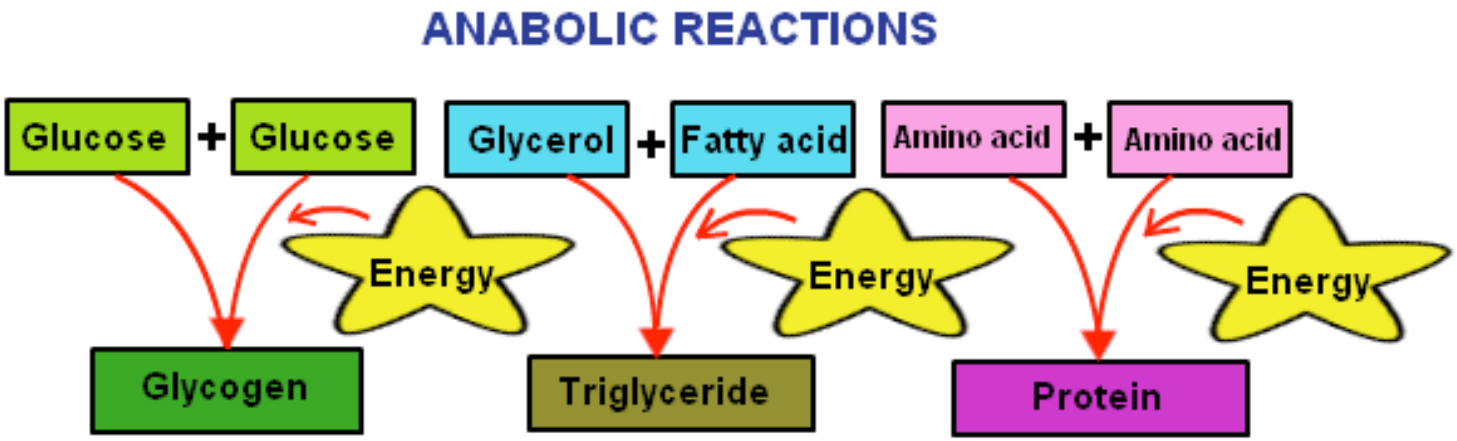
H is **oxidized** F is **reduced**
electrons transferred
energy transferred

new bonds made

OIL RIG

Metabolism includes anabolic rxns

energy in…

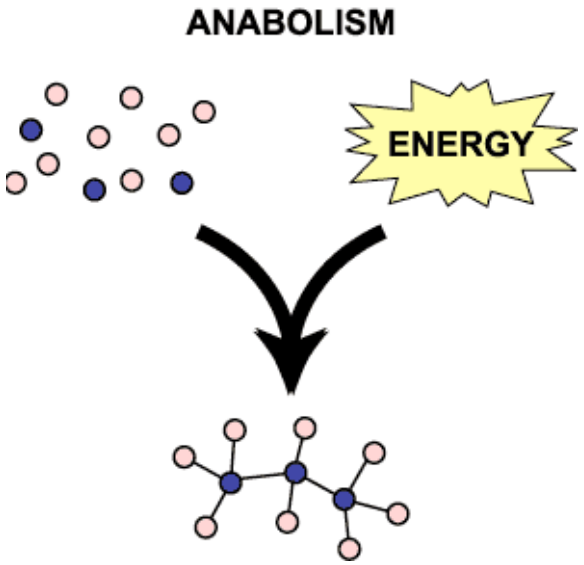


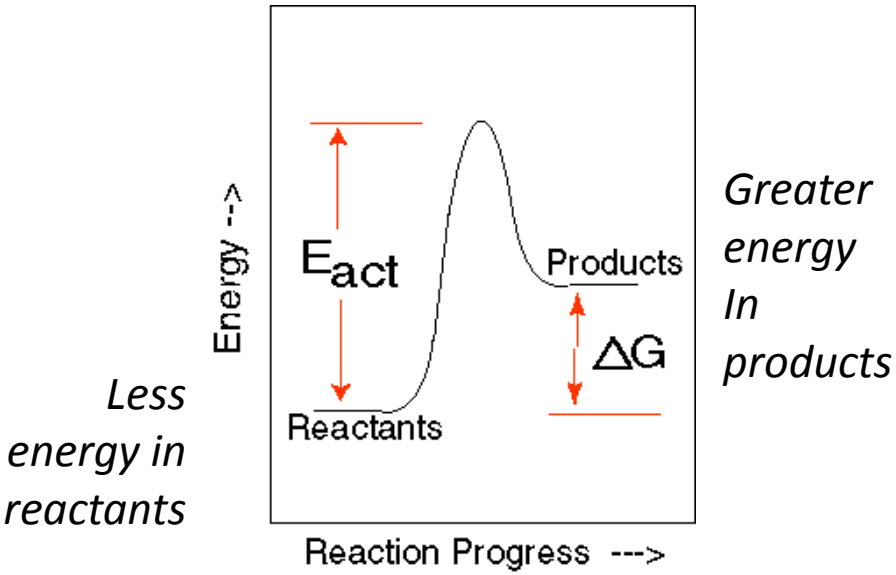
…complex, energy-rich molecules out

Anabolic rxns

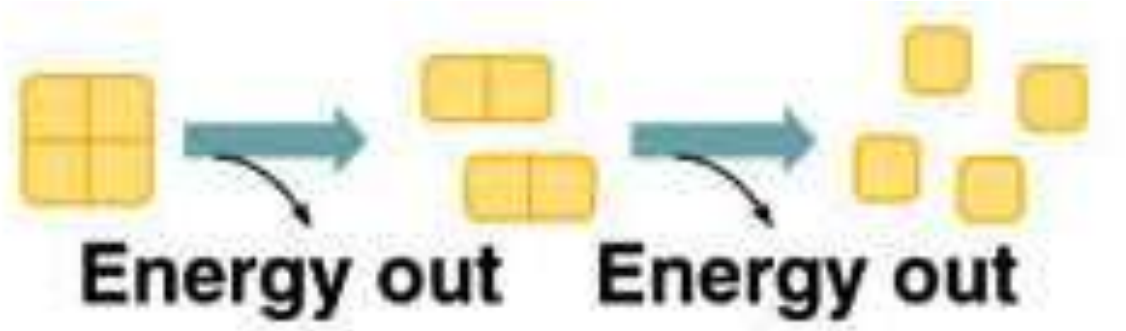
- Rxns that build molecules
  - *Ex: dehydration reactions; photosynthesis*
- Require a net input of energy
  - therefore not spontaneous
  - Energy is stored in the bonds of the molecule

aka: Endergonic





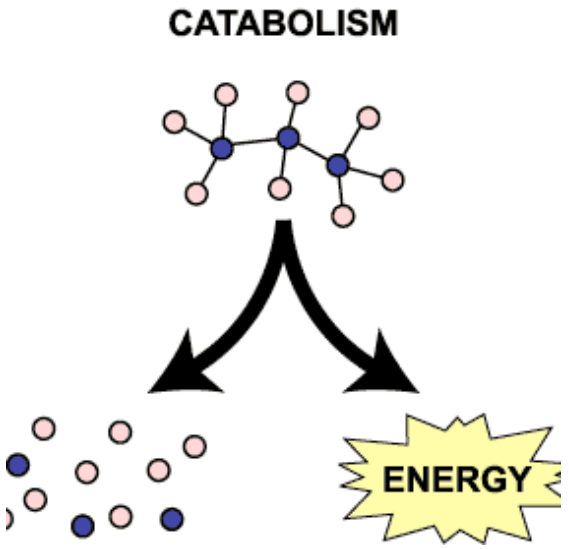
Metabolism includes catabolic rxns



simpler molecules generated; energy released

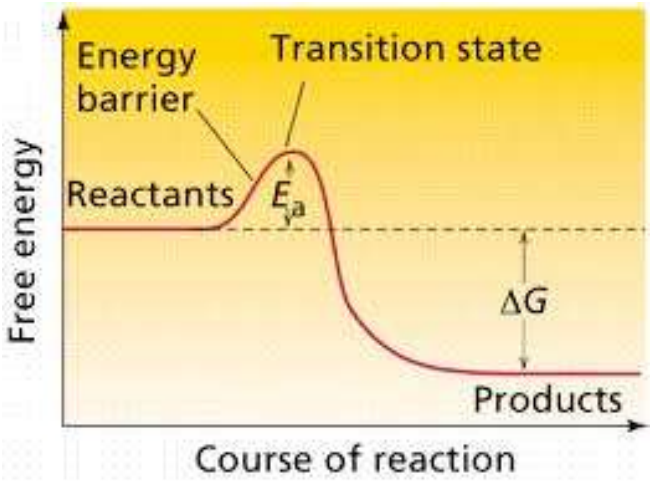
Catabolic rxns

- Rxns that **break down** molecules
  - *EX: hydrolysis reactions;*
  - *respiration*
- Stored **energy is released** as bonds are broken



aka: Exergonic

Higher energy reactants



Lower energy products

Anabolism & Catabolism are linked

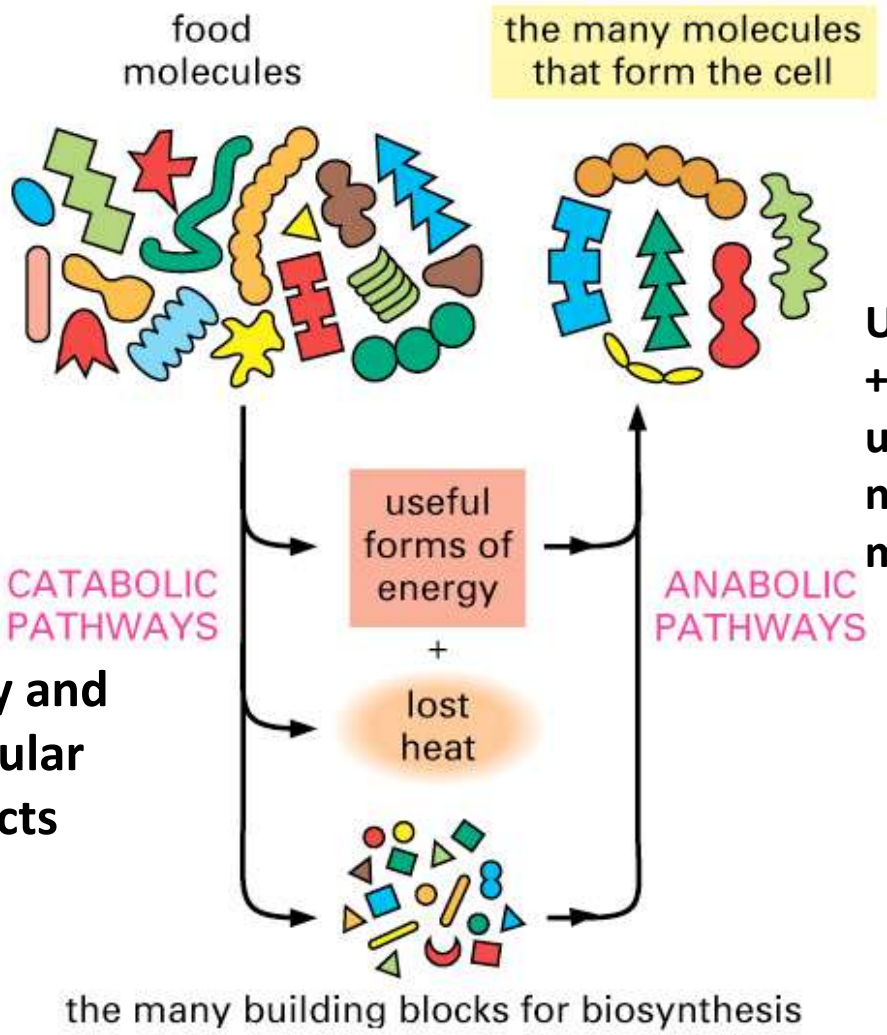
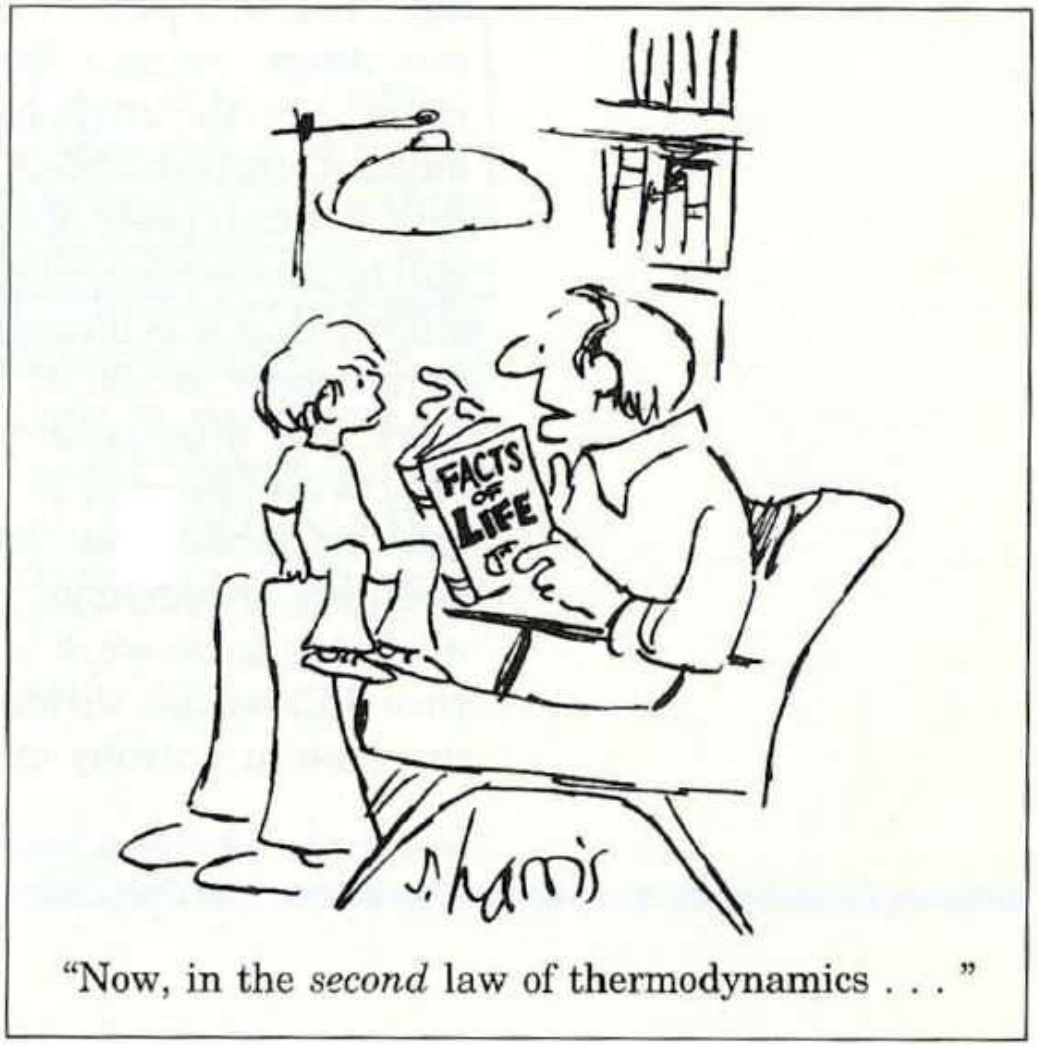


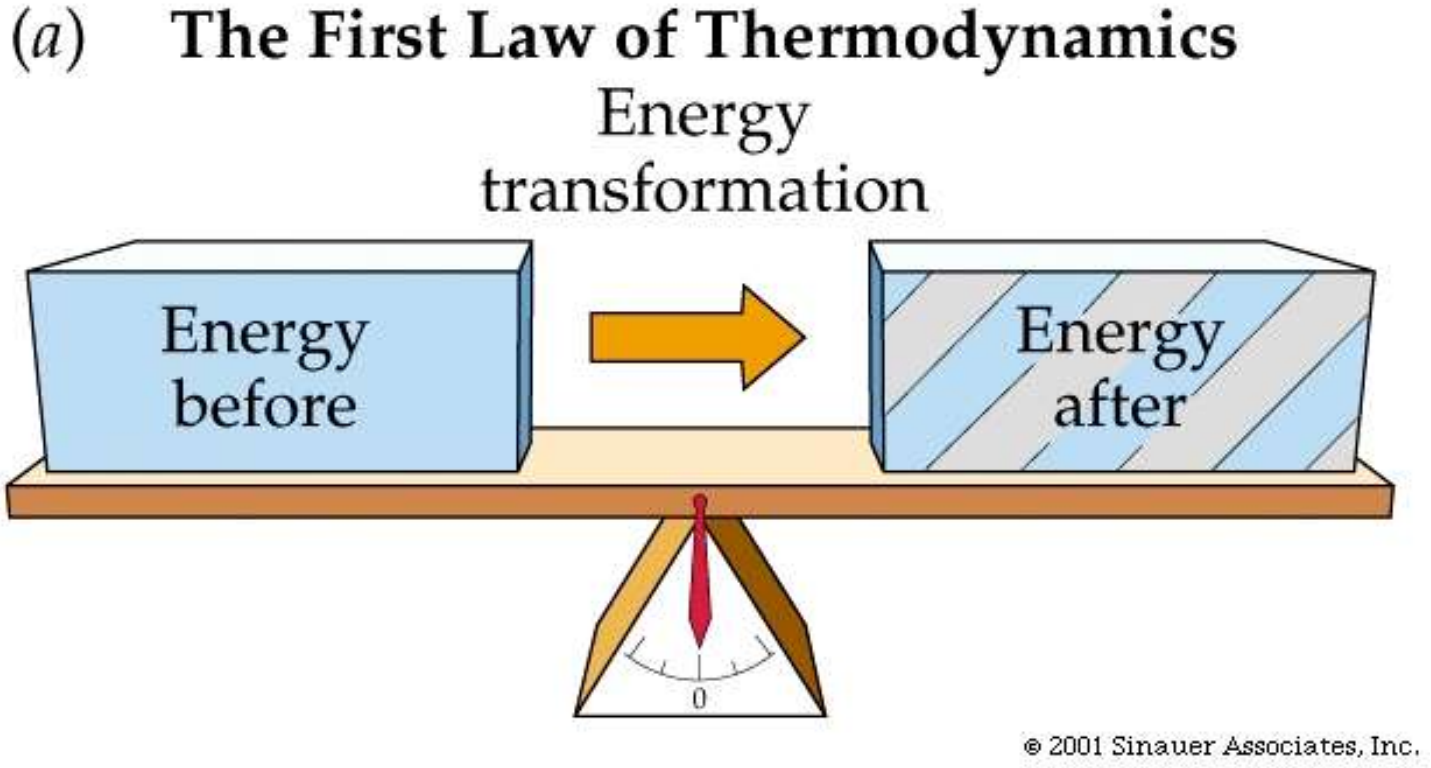
Figure 3-3 Essential Cell Biology, 2/e. (© 2004 Garland Science)

Reactions for Life Reflect the Laws of Thermodynamics*



"Now, in the *second* law of thermodynamics . . . "

* The study of energy transformations

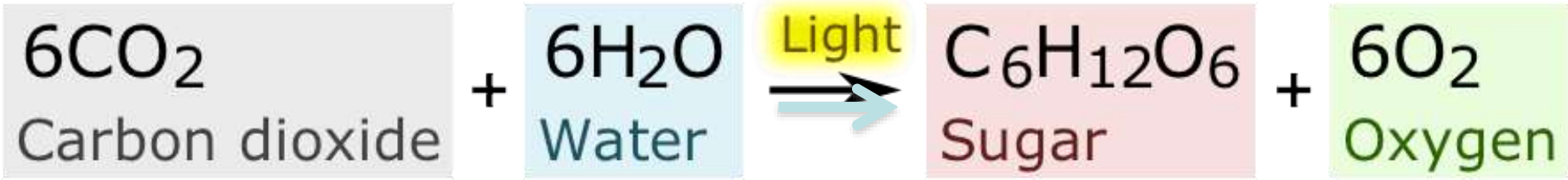


Energy amount is constant

The energy into a rxn = the energy at completion

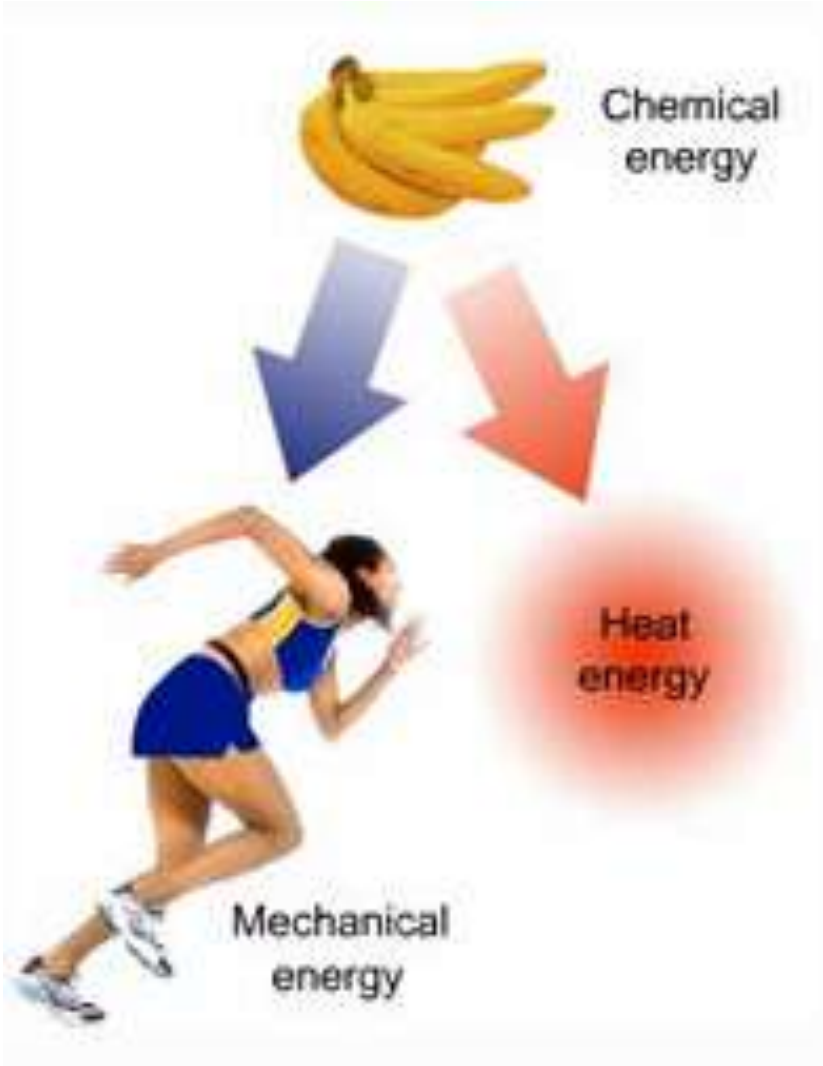
Ex: Photosynthesis

Energy in = energy out



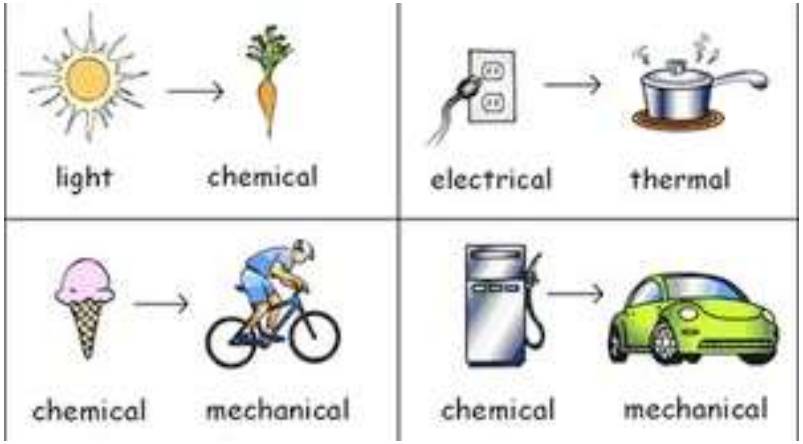
Matter in = Matter out

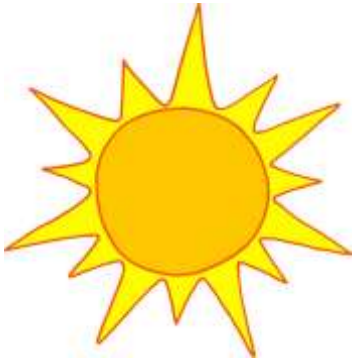
Matter & energy are conserved



Energy form however, is not constant

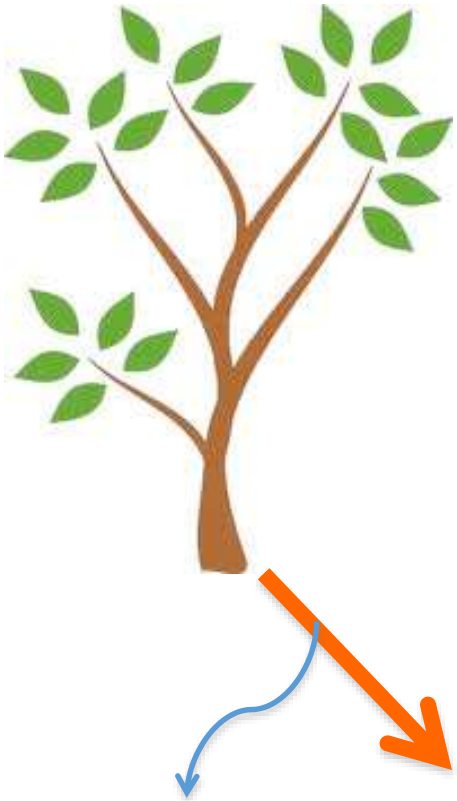
Energy is transformed at every step





heat

Free energy



Free energy *useful to life*

\+ Energized atoms *not useful*

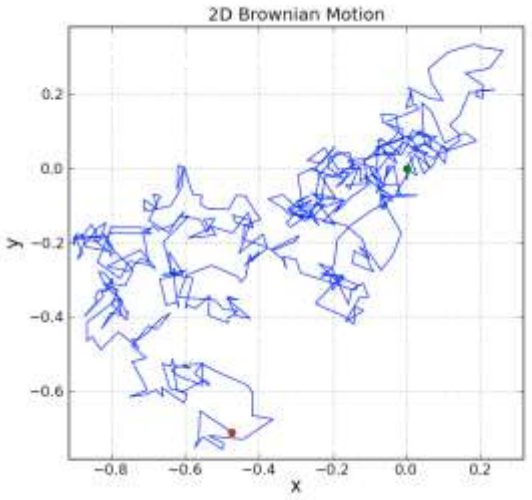
= Total Energy

This is why there are not 15 trophic levels in a food web

Second Law of Thermodynamics

- No physical process finishes with as much available, or useful, energy as it started with **FREE ENERGY**

- unavailable energy reflects the random kinetic energy of molecules, allowed to spread out; **ENTROPY**



- Often, this means that:
  - the change in energy includes transformation to heat
  - small molecules result from the break down of larger ones
  - an ordered system becomes more disordered

Entropy happens it’s the Law!

QUANTIFYING ENERGY

total energy = useable energy* + unusable energy

available for work *random atomic motion*

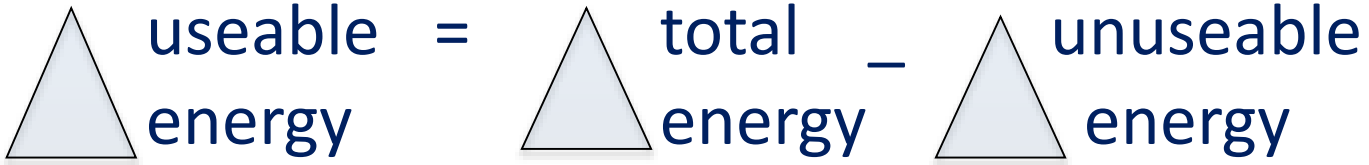
*point of interest for biologists

OR

useable energy = total energy - unusable energy

available for work *random atomic motion*

This relationship can be used to determine the energy change of a rxn: exergonic or endergonic?



As entropy increases, free energy decreases

To Know

$\Delta G = \Delta H - (T \Delta S)$

Gibbs = entHalpy - (Temp K) diSorder

If G < 0, the reaction is exergonic; occurs spontaneously; disorder is increased *G is negative*

If G > 0, the reaction is endergonic; order/complexity is increased *G is positive*

* usually ATP -> ADP + P

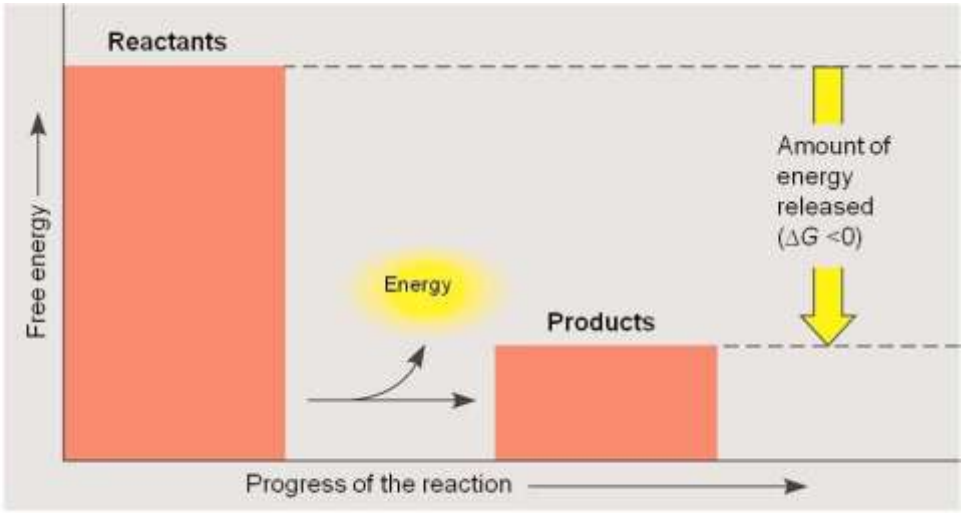


Figure 8.6 (a) Exergonic reaction: energy released

Energy released
Spontaneous
Exergonic
G is negative

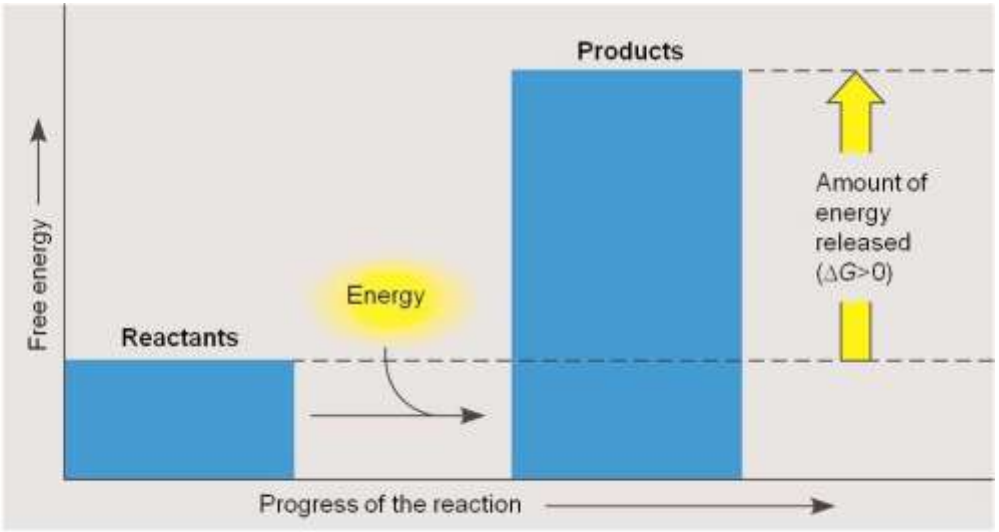


Figure 8.6 (b) Endergonic reaction: energy required

$2H_2O_2 \rightarrow 2H_2O + O_2$

Building or breaking down molecules?

Decreasing or increasing complexity?

Catabolic or anabolic?

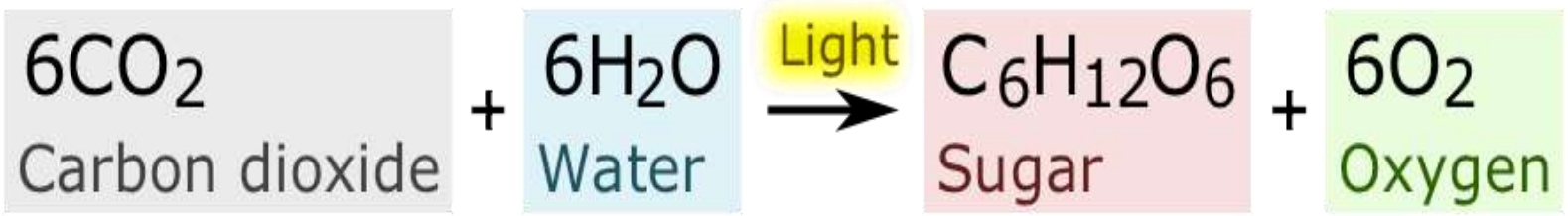
Energy stored or released?

Endergonic or exergonic?

Increasing or decreasing disorder?

Change in G positive or negative?

Spontaneous or coupled with ATP?



Building or breaking down molecules?

Decreasing or increasing complexity?

Catabolic or anabolic?

Energy stored or released?

Endergonic or exergonic?

Increasing or decreasing disorder?

Change in G positive or negative?

Spontaneous or coupled with ATPrxn?