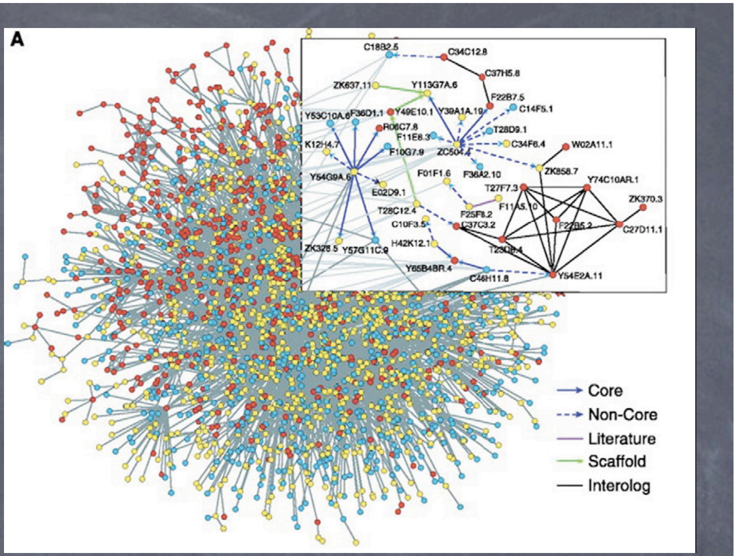
Cell is a complex system



High number of chemical species

High number of interactions

Feedbacks (non-linear reactions)

Open system: steady state (far from equilibrium, energy consumption)

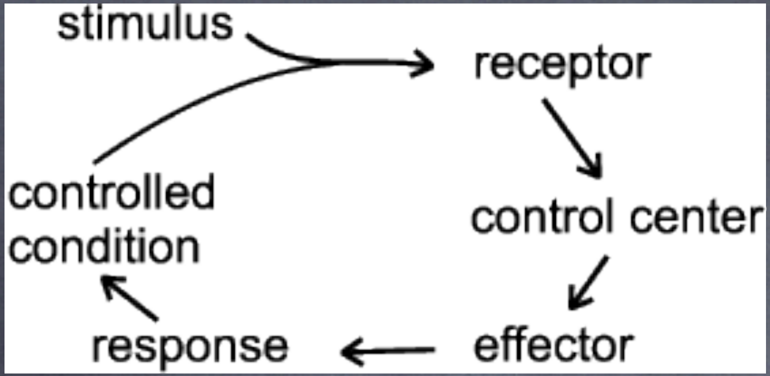
Specialization

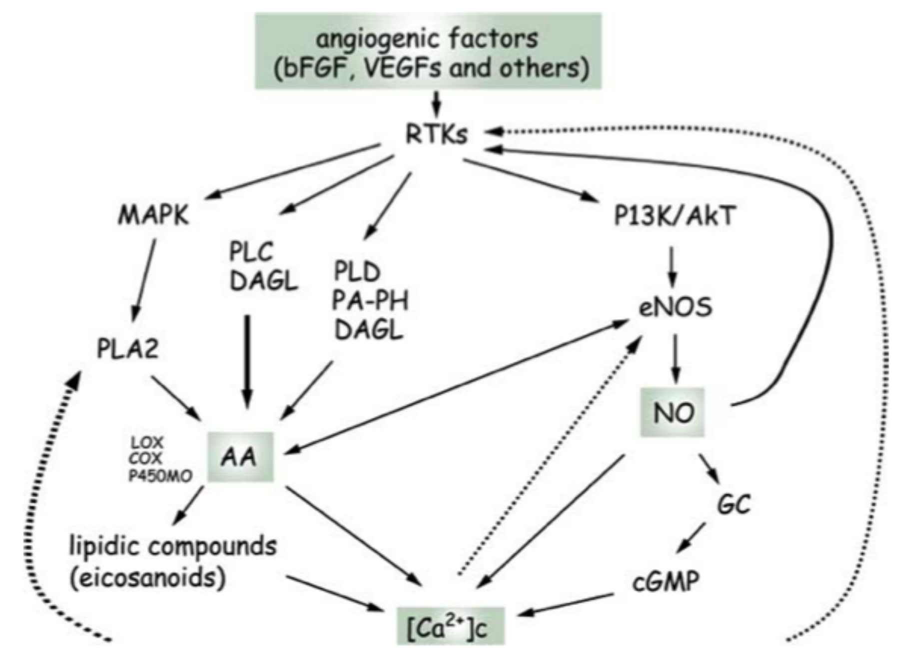
Spatial anisotropy

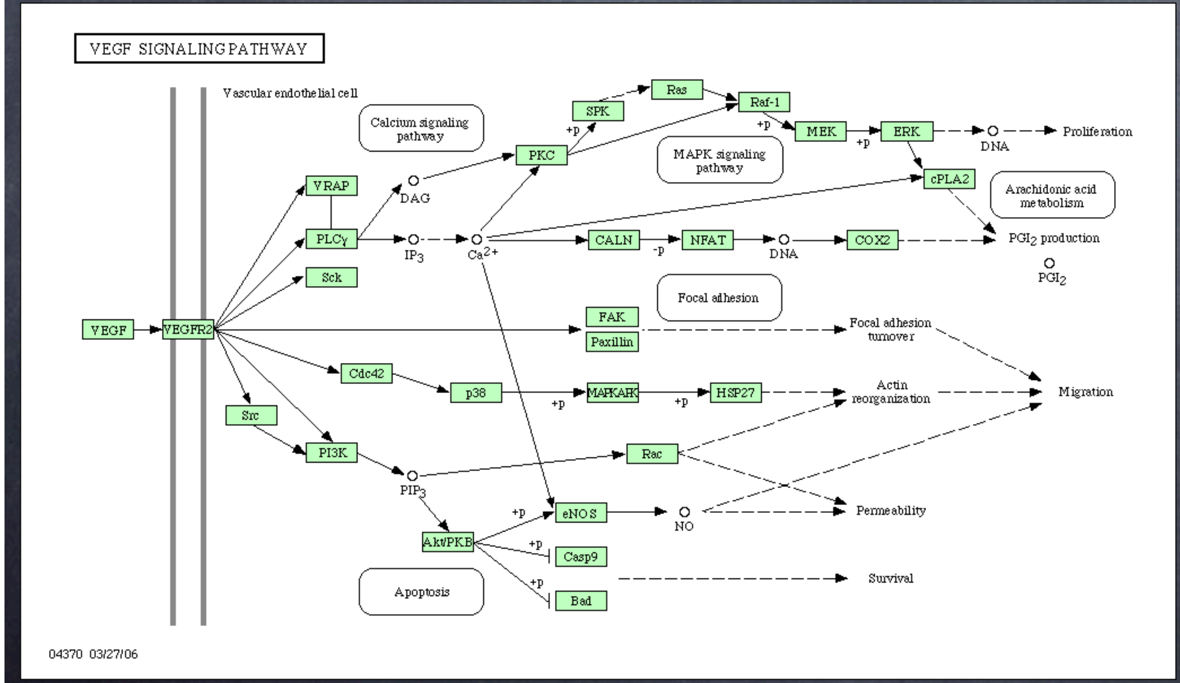
Compartmentalization (constraints to FREE DIFFUSION)

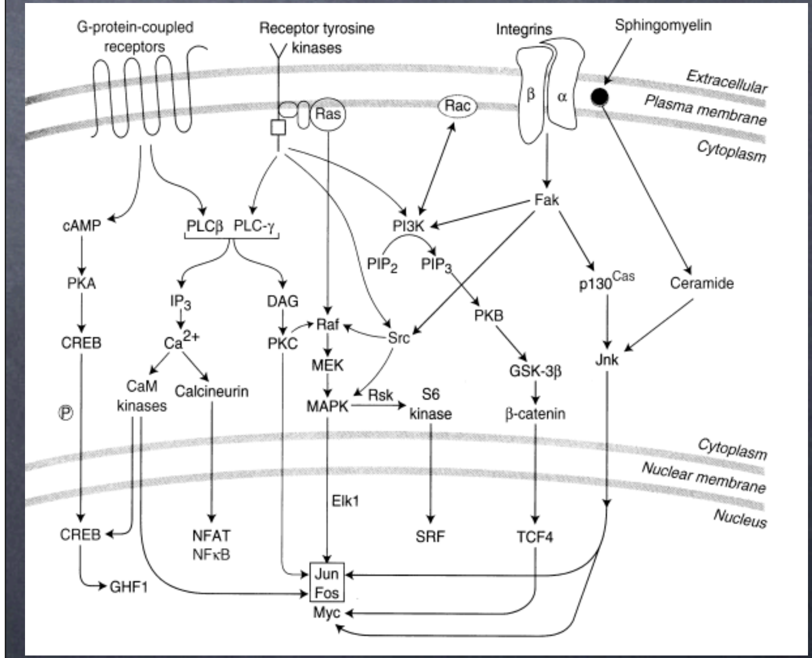
Structure-function redundancy (one structure for many functions, one function for many structures)

UNITY AND DIVERSITY
We can talk about Cell Biology (and Cell Physiology) because of the organizational unity of the different cell types

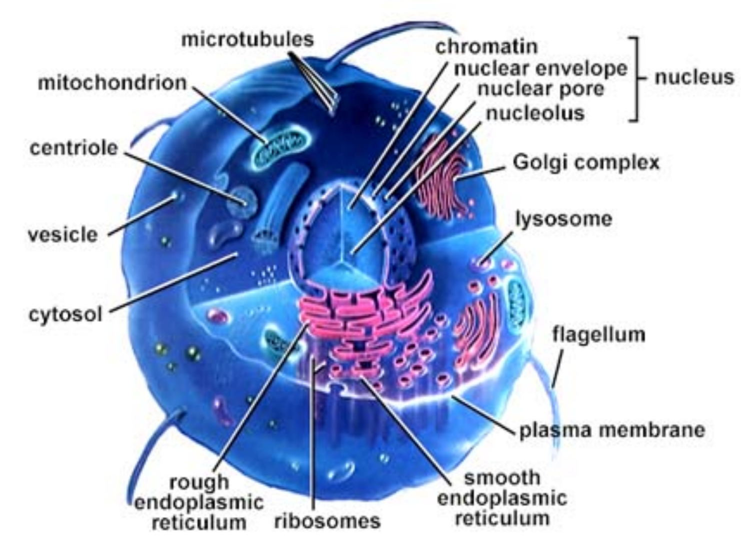

stimulus
receptor
control center
effector
response
controlled condition


angiogenic factors (bFGF, VEGFs and others)
RTKs
MAPK
PLC DAGL
PLD PA-PH DAGL
P13K/AkT
eNOS
PLA2
NO
LOX COX P450MO
AA
GC
lipidic compounds (eicosanoids)
cGMP
[Ca2+]c

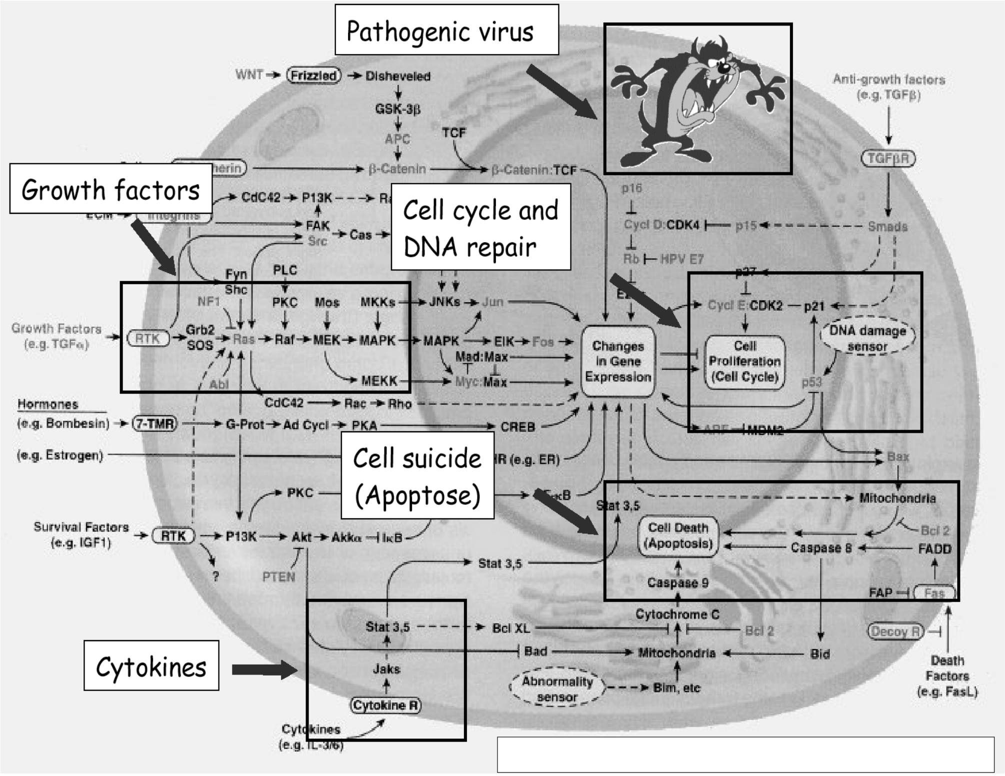

VEGF SIGNALING PATHWAY
Vascular endothelial cell
Calcium signaling pathway
MAPK signaling pathway
Arachidonic acid metabolism
Focal adhesion
Apoptosis
VEGF
VEGFR2
VRAP
PLCγ
Sck
Src
PI3K
Cdc42
p38
MAPKAPK
HSP27
DAG
IP3
Ca2+
PIP3
PKC
SPK
Ras
Raf-1
MEK
ERK
DNA
Proliferation
cPLA2
CALN
NFAT
DNA
COX2
PGI2 production
PGI2
FAK
Paxillin
Focal adhesion turnover
Actin reorganization
Migration
Rac
Permeability
Akt/PKB
eNOS
NO
Casp9
Bad
Survival
+p
-p
04370 03/27/06

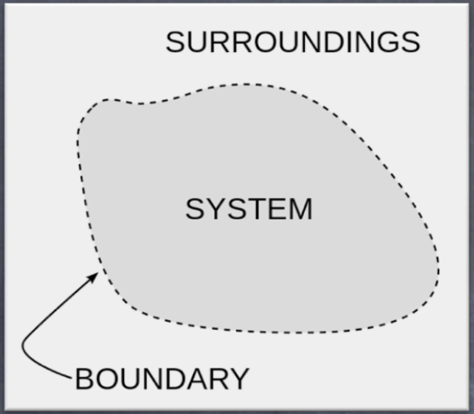

G-protein-coupled receptors
Receptor tyrosine kinases
Integrins
Sphingomyelin
Extracellular
Plasma membrane
Cytoplasm
Ras
Rac
β
α
cAMP
PLCβ PLC-γ
PI3K
Fak
PIP2
PIP3
PKA
IP3
DAG
p130Cas
Ceramide
CREB
Ca2+
PKC
Raf
Src
PKB
Jnk
MEK
GSK-3β
CaM kinases
Calcineurin
MAPK
Rsk
S6 kinase
β-catenin
Ⓟ
Cytoplasm
Nuclear membrane
Nucleus
Elk1
CREB
NFAT NFκB
SRF
TCF4
Jun
Fos
Myc
GHF1

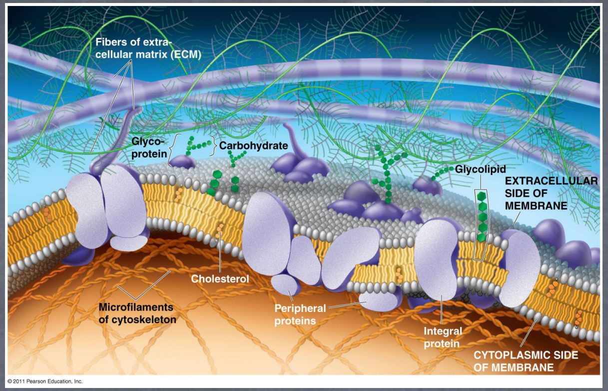
Cell is a highly biochemically and structurally compartimentalized system



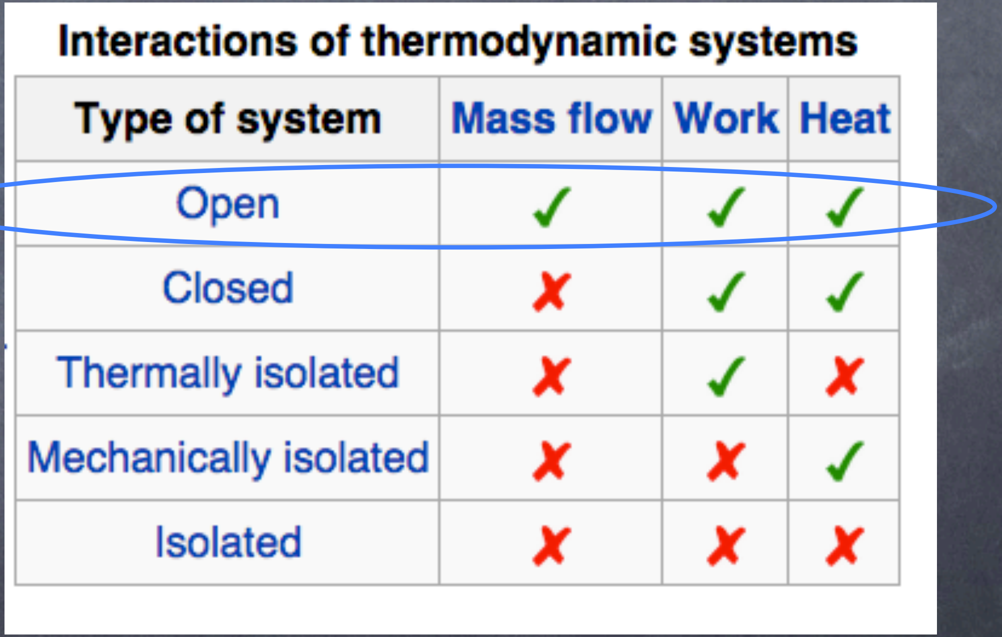
The Integration of Biochemical Networks







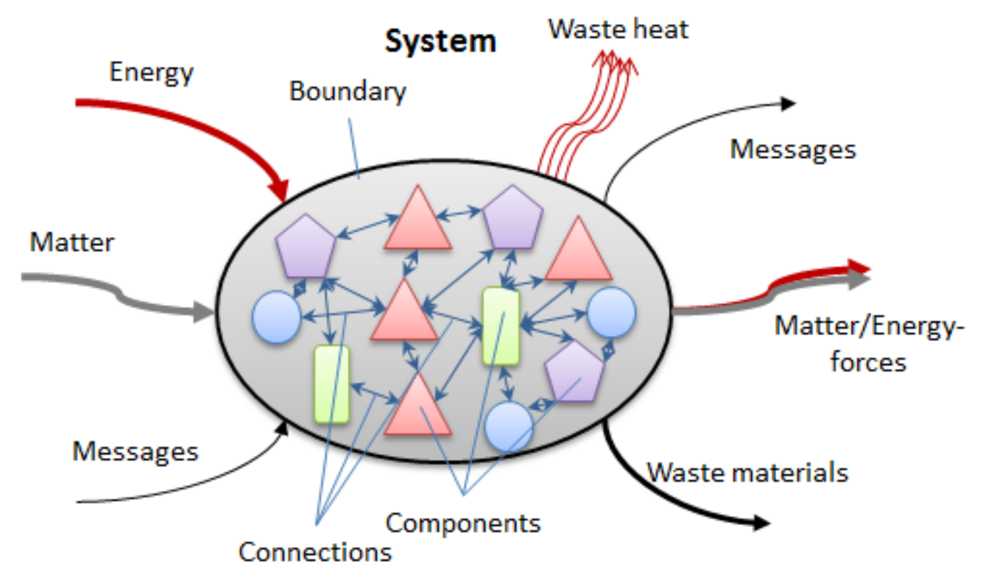
Living beings →


Interactions of thermodynamic systems

Type of system	Mass flow	Work	Heat
Open	✓	✓	✓
Closed	✗	✓	✓
Thermally isolated	✗	✓	✗
Mechanically isolated	✗	✗	✓
Isolated	✗	✗	✗

An open system can maintain (and eventually increase) its internal stability and organization

A dissipative system is a thermodynamically open system which is operating out of, and often far from, thermodynamic equilibrium in an environment with which it exchanges energy and matter.



NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

The zeroth law of thermodynamics involves some simple definitions of **thermodynamic equilibrium**. Thermodynamic equilibrium leads to the large scale definition of temperature, as opposed to the small scale definition related to the kinetic energy of the molecules.

The first law of thermodynamics relates the various forms of kinetic and potential energy in a system to the work which a system can perform and to the transfer of heat. This law is sometimes taken as the definition of internal energy, and introduces an additional state variable, enthalpy. The first law of thermodynamics allows for many possible states of a system to exist. But experience indicates that only certain states occur.

$$dU - dQ + dW = 0$$

$$dQ = TdS$$

$$dW = PdV$$

$$dU - TdS + PdV = 0$$

This leads to the second law of thermodynamics and the definition of another state variable called entropy.

The second law stipulates that the total entropy of a system plus its environment can not decrease; it can remain constant for a reversible process but must always increase for an irreversible process.

Entropy $dS = dQ/T$

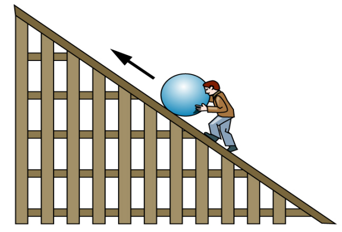
Enthalpy $H = U + PV$

In an isolated system $\frac{dS}{dt} \geq 0$

the Gibbs free energy is a thermodynamic potential that measures the "usefulness" or process-initiating work obtainable from a thermodynamic system at a constant temperature and pressure (isothermal, isobaric).

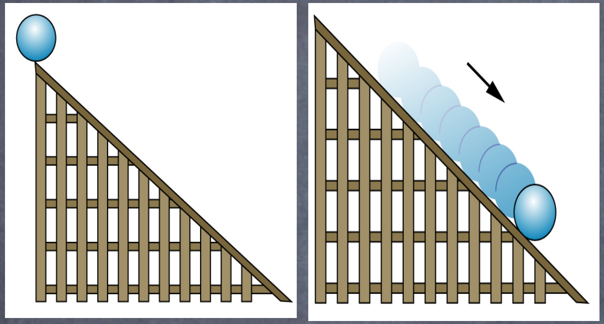
$G = H - TS = U + PV - TS$

$dG = 0$ equilibrium

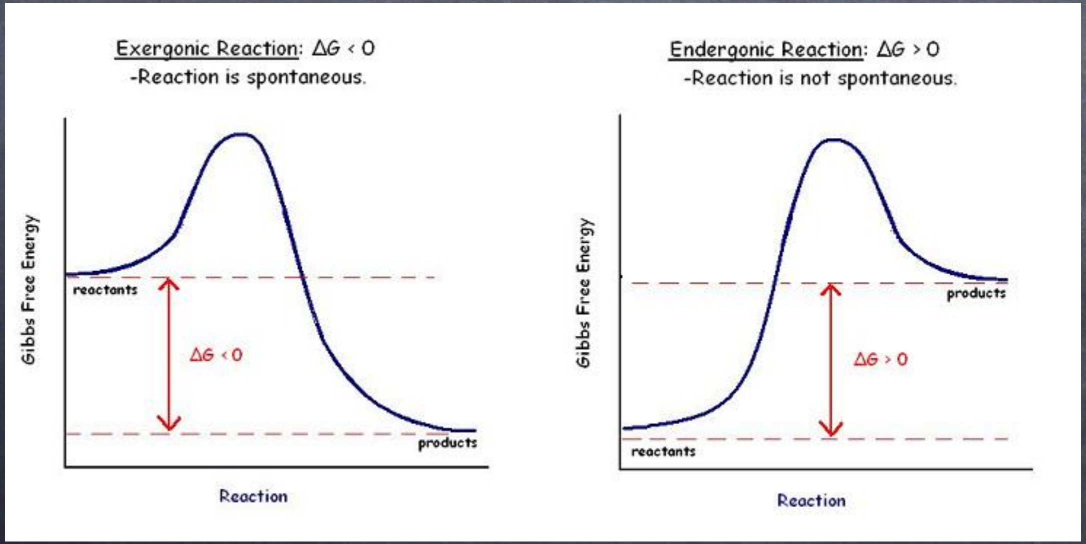


Work is used to push a ball up a ramp.

Endoergonic reaction
dG>0



Esoergonic reaction
dG<0



COUPLED REACTIONS

$A + B \rightleftarrows AB$ $\Delta G = 5 Kcal / mole$

Endoergonic

$ATP + H_2O \rightleftarrows ADP + Pi$ $\Delta G = -7.3 Kcal / mole$

Esoergonic

GLOBALLY:

$\Delta G = -2.3 Kcal / mole$

Esoergonic