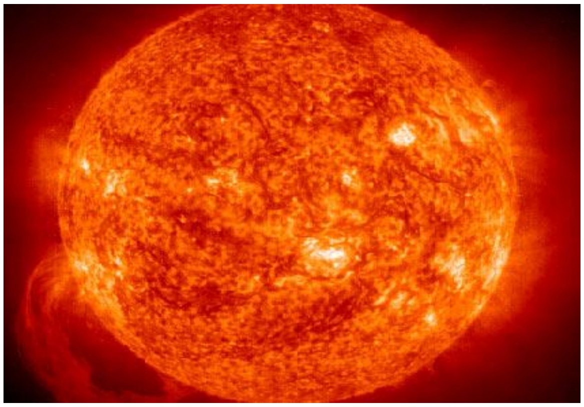
BIOENERGETICS



Bioenergetics

The study of energy transfer within the living things.

Why Study Bioenergetics?

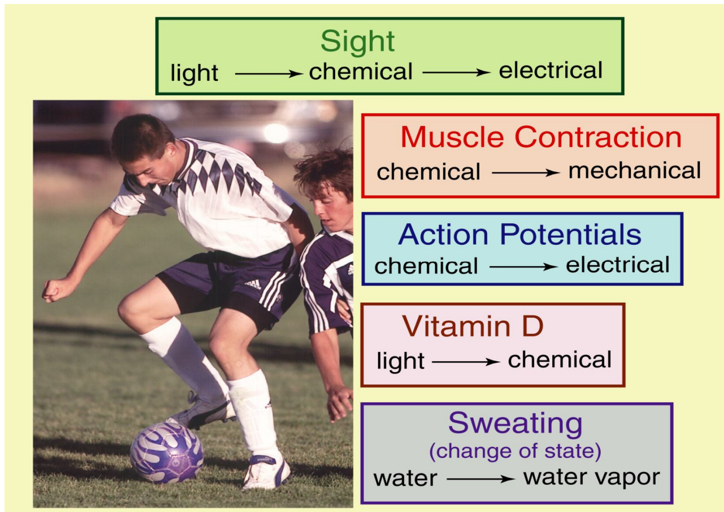
The understanding of metabolism provides the directions to better understand how skeletal muscles generate energy, and how and why the body responds to exercise the way it does.

The study of metabolism is aided by studying bioenergetics

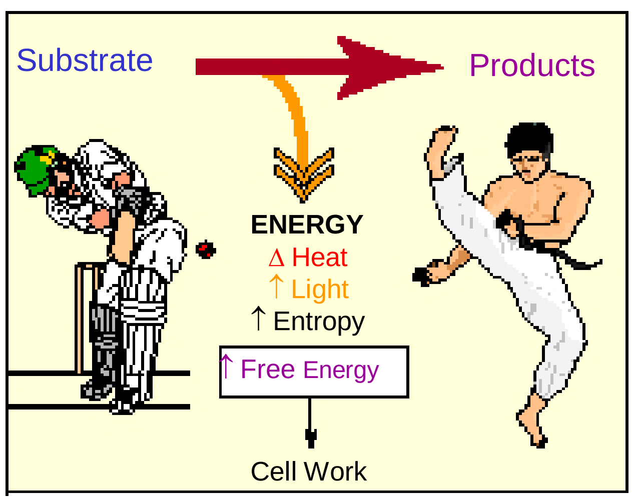
The **Laws of Bioenergetics** provide the rules upon which metabolism functions

There are two laws of bioenergetics.

1) *Energy cannot be created or destroyed, but can be changed from one form to another.*



2) *Energy transfer will always proceed in the direction of increased entropy, and the release of "free energy".*



What are other examples of energy transfer within the human body or other biological systems?

Eye sight: light to electrical impulses (action potentials)

Muscle contraction: chemical energy to mechanical energy

Vitamin D formation: light energy to chemical energy

Photosynthesis: light energy to chemical energy in plants

The laws of bioenergetics can enable you to understand why these energy transfers occur.

Lessons to learn from the 1st law of bioenergetics

1. The main forms of energy within the body are;

heat **light** **mechanical** "**free energy**"
chemical **entropy**

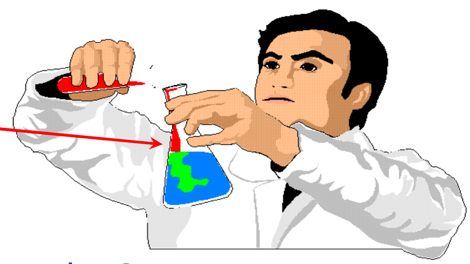
2. Entropy is a form of energy that cannot be re-used in chemical reactions, and is defined synonomously with **increased randomness** or **disorder**.

3. "Free energy" is referred to as **Gibb's free energy**, and is abbreviated "**G**". Typically, during energy transfers there is a change in energy forms, which is indicated by the "Δ" symbol. Thus, a change in Gibb's free energy is expressed as a "**ΔG**".

Calculating Gibb's Free Energy

1. Standard Free Energy Release - $\Delta G°'$

[S] = 1 M
[P] = 1 M
pH = 7.0
T = 25 °C



What can happen to the reaction?

1. **[P] will increase** — ***Exergonic reaction*** $-\Delta G°'$
2. **[S] will increase** — ***Exergonic in the reverse direction***
3. **[S] and [P] do not change** — ***Equilibrium reaction*** $\Delta G°' = 0$

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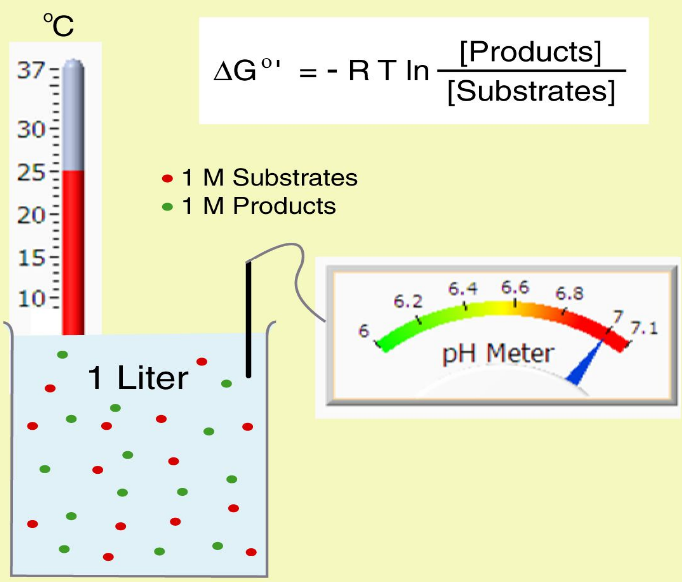
Standard Gibb's Free Energy Change

$$\Delta G°' = - R T \ln \frac{[Products]}{[Substrates]}$$



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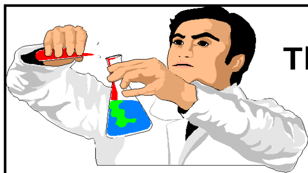

The $-\Delta G°'$ for a reaction can be calculated

$$-\Delta G°' = -R\ T\ \ln([P] / [S])$$

Where; **R = Molar gas constant = 0.001986 Kcal/M/°K**

T = Absolute temperature (°K)

Keq = [P] / [S]

Note; the Keq is the [P] and [S] that results once a new equilibrium has occurred.

The $\Delta G°'$ is a measure of the innate directionality and theoretical free energy release of a chemical reaction under standard conditions.

PROBLEM: ***Inside a muscle fiber during exercise, pH can decrease to ~6.3, and temperatures can vary from ~35 - >40° C***

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Examples of $\Delta G°'$ for some Important Intermediary Molecules of Catabolism

Phosphorylated Compound	Free Energy*	
	Kcal/mol	kJ/mol
Phosphoenolpyruvate	-14.8	-61.9
1,3 bisphosphoglycerate	-11.8	-49.3
Creatine phosphate	-10.3	-43.0
ADP	-7.3	-30.5
ATP	-7.3	-30.5
Glucose-1-phosphate	-5.0	-20.9
Fructose-6-phosphate	-3.8	-15.9
AMP	-3.4	-14.2
Glucose-6-phosphate	-3.3	-13.8

*For the removal of 1 phosphate group, standard conditions

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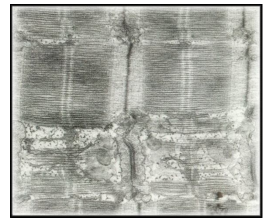
2. Absolute Free Energy Release - ΔG



The ΔG is a modification of the $\Delta G^{\circ\prime}$ to account for in vivo [S] and [P], pH and T.

$$\Delta G = \Delta G^{\circ\prime} + R\,T \ln([P] / [S])$$

Where; **R = Molar gas constant = 1.98589 cal/M/°K**

= 0.001986 Kcal/M /°K

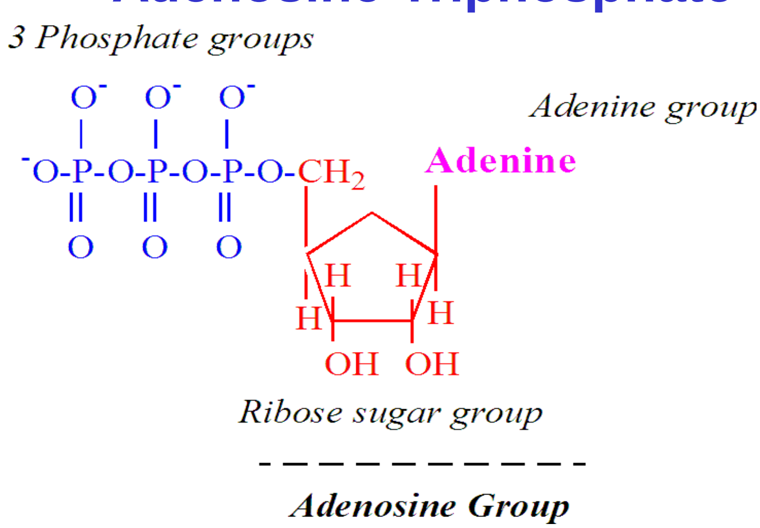
T = Absolute temperature (°K)

Mass Action Ratio (L) = [P] / [S]

Note; L differs to the Keq as the [P] and [S] are those that are present at any given time inside a cell.

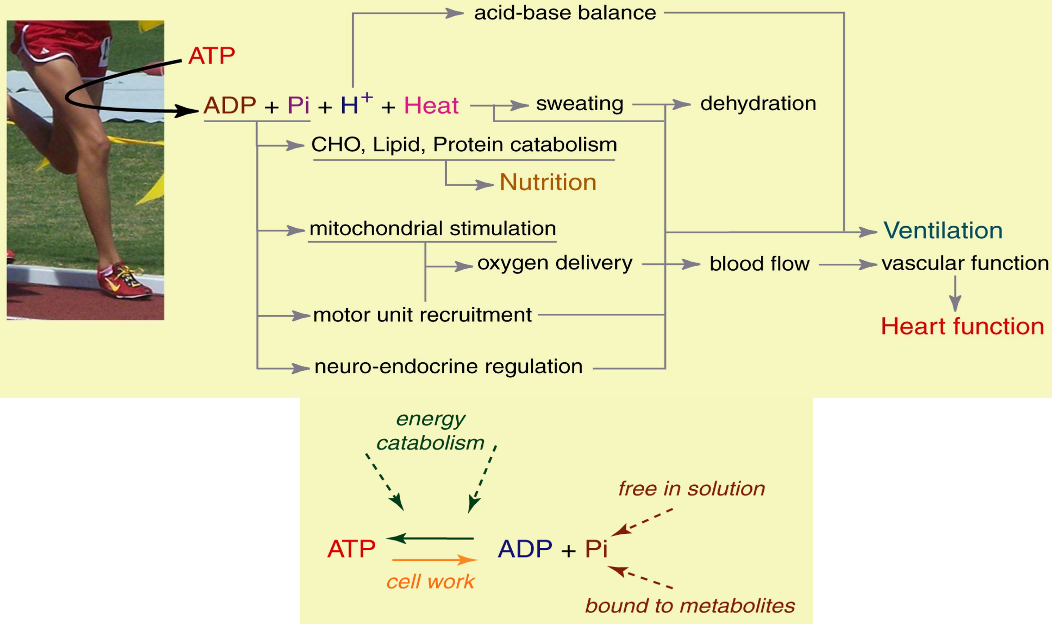
ΔG is not a constant, as it changes continually with changes in the metabolic state of the cell.

Adenosine Triphosphate



*Remember, for this reaction to occur inside a muscle cell, about **9.7 Kcal/Mol** of energy is needed to add the phosphate group to ADP to reform ATP, not 7.3 Kcal/Mol.*

ATP Demand Stimulates Exercise Physiology



Lessons to learn - 2nd law of bioenergetics

1. All reactions proceed in the direction of:

a) ↑ **entropy** *b)* a release of free energy (**-ΔG, (Kcal/Mol)**)

2. The more negative the **ΔG**, the greater the release of free energy during a chemical reaction.

3. Chemical reactions that have a **-ΔG** are termed **exergonic reactions**.

4. By convention, reactions that require free energy input to proceed are termed *endergonic reactions*, but there are no such reactions in the human body!

5. The free energy not used to do work is expressed as heat.

6. Reactions that have no net change in substrate or product are termed **equilibrium reactions**, and have no change in free energy (**$\Delta G=0$**).

7. All reactions are potentially reversible.

8. The directionality and amount of free energy release of a chemical reaction can be modified by ***altering substrate and product concentrations***

- ↑'ing products may reverse the direction of the reaction

- ↑'ing substrates can make the ΔG more negative

Of course, if the reaction is reversed, what were the products are now the substrates, and vice-versa