Energetics of body

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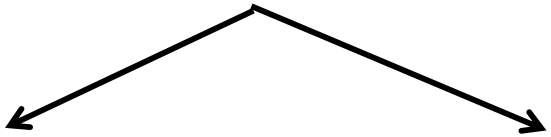
What is energy?

- Energy can be defined as the ability to do work or bring some change, the physical composition or temperature of an object.
- Energy exists in different forms but is neither created nor destroyed.
- Energy simply converts to another form.
- There are two categories of energy:
  - ***Potential energy:*** *It is stored energy or energy of position that has the potential to do* work (depends upon the relative position of various parts of a system).
  - ***Kinetic energy:*** It is the energy of motion (the motion of waves, electrons, atoms, molecules, etc.)
- The potential and kinetic energy, both are interchangeable (the difference between them is whether the energy is being transferred, or stored).

What is energy?

Forms of energy

All forms of energy fall under two categories



Potential Energy

Energy due to position or stored energy

Kinetic Energy

Energy of motion

- Potential energy – Stored energy or energy of position.

$$\boldsymbol{P = mgh}$$

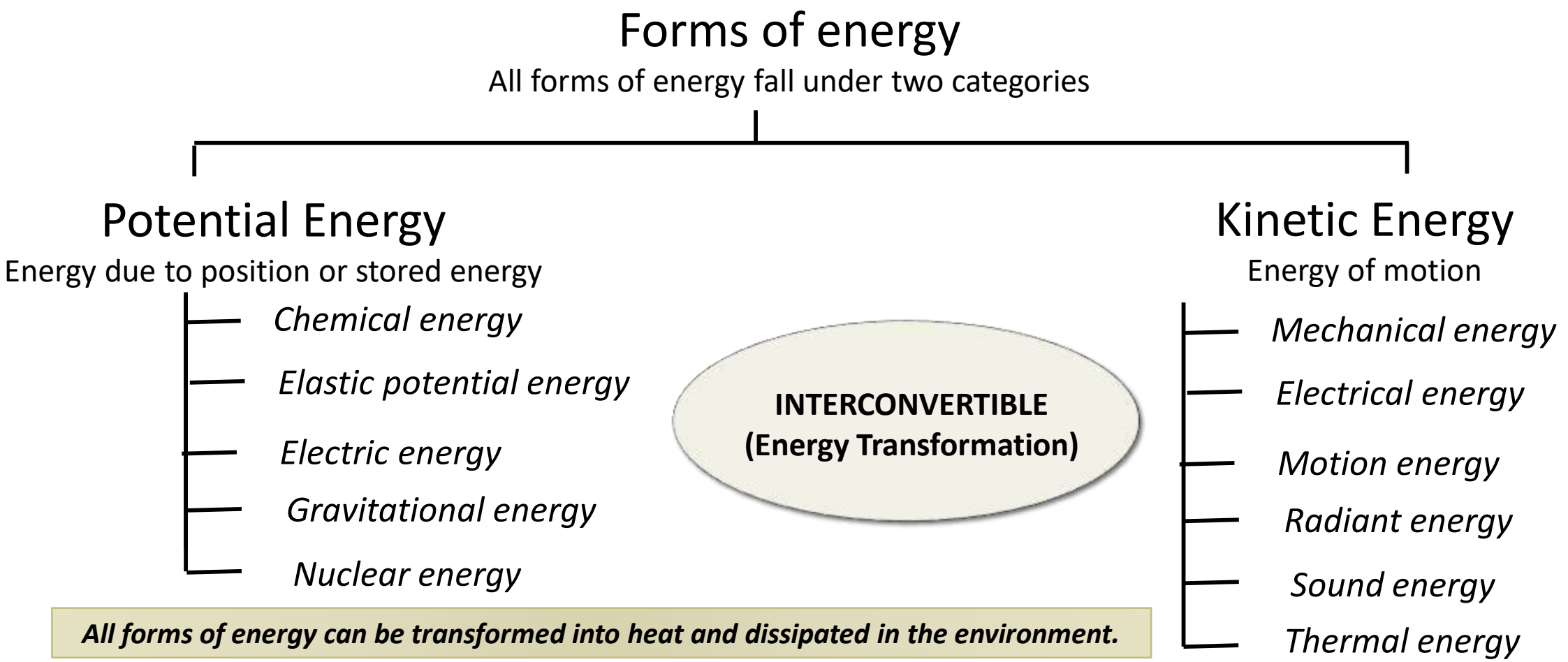
*where **P** = Gravitational Potential Energy (in Joule), **m** = mass (in kg), **g** = Acceleration due to gravity (in m/ s^2, **h** = height (in m)*

- Kinetic energy – Energy of motion.

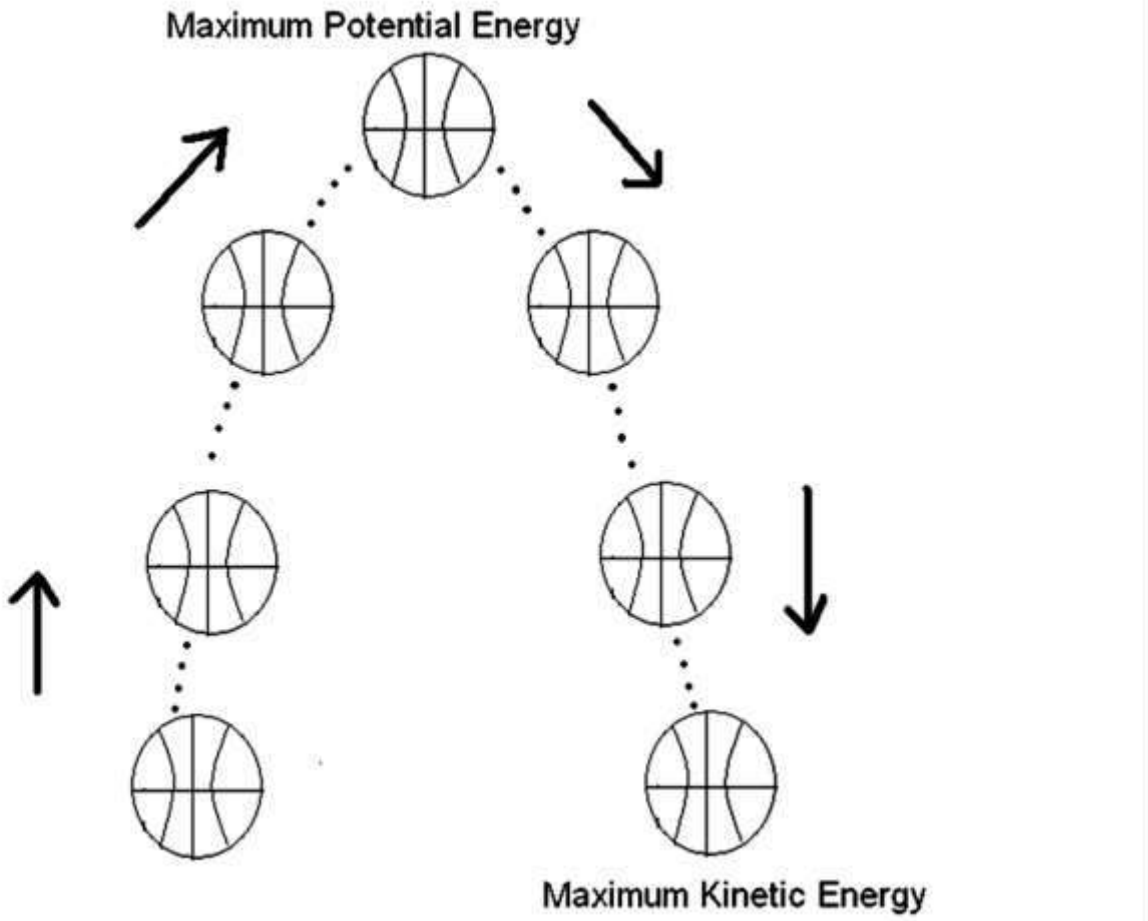
$$\boldsymbol{K = \frac{1}{2}mv^2}$$

*where **K** = Kinetic Energy in Joule), **m** = mass (kg), **v** = Velocity (in m/s)*

What is energy?

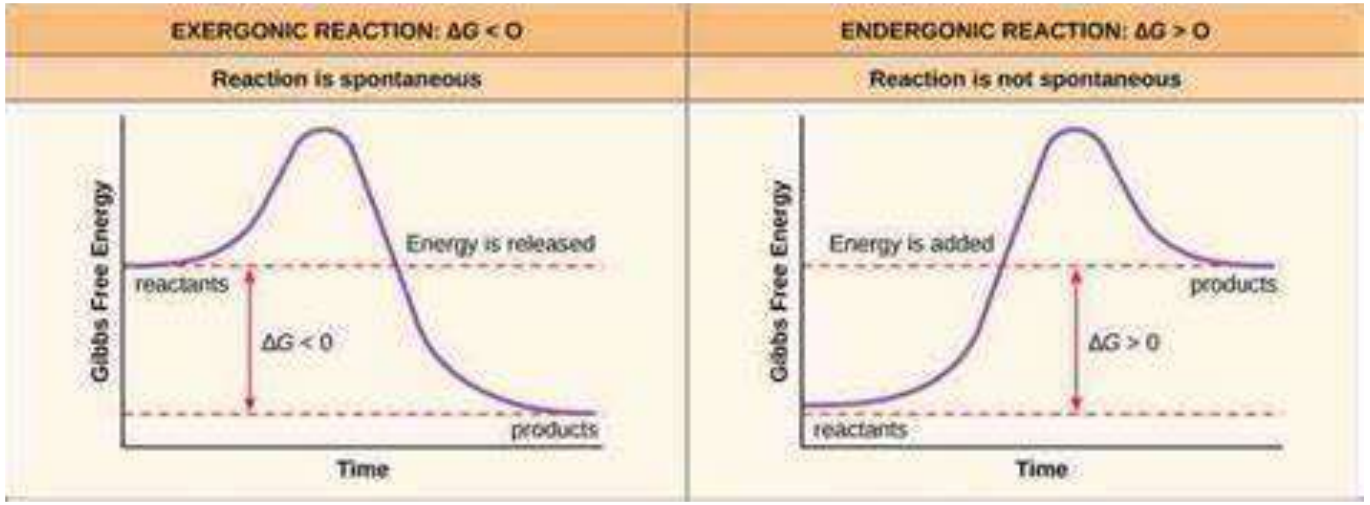


Potential vs Kinetic Energy



Energetics of Living Body

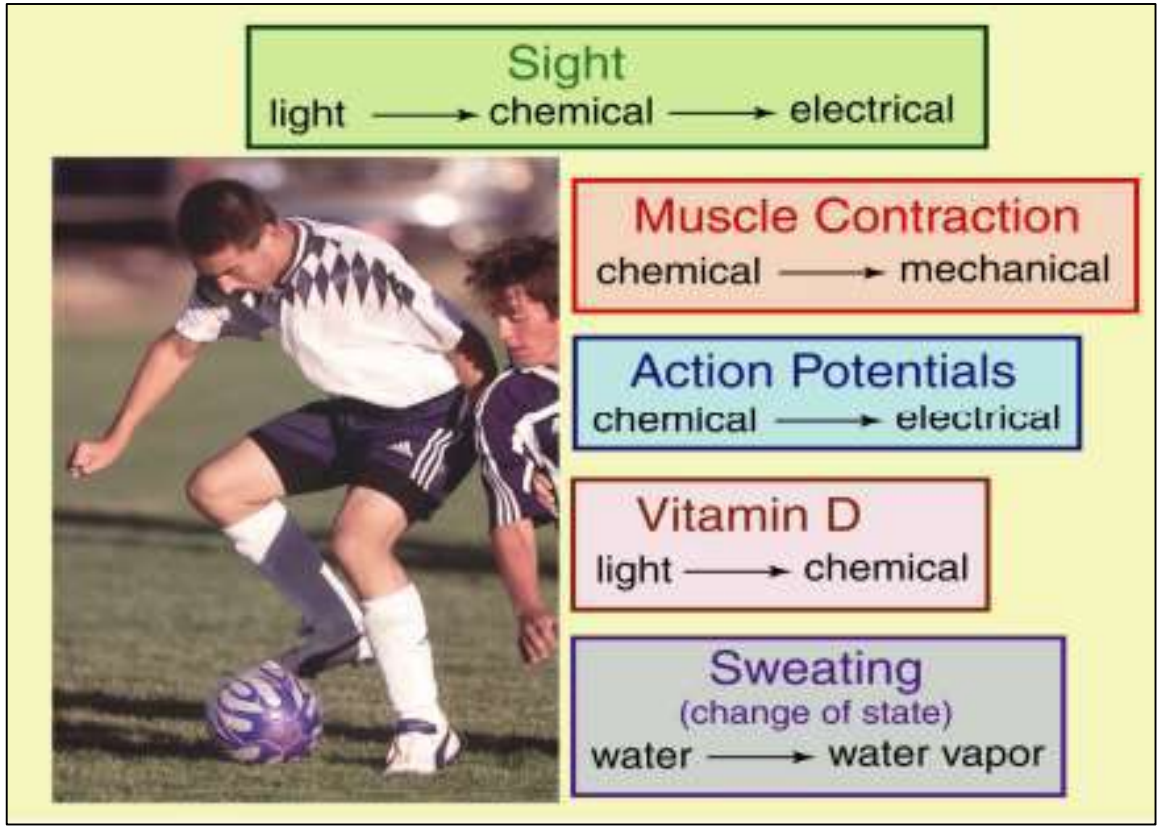
- Aims at studying the energy transfer in the living body and with the environment.
- It also follows the same laws of energetics as below - <u>laws of thermodynamics</u>
  - Energy can’t be created, but can be transferred from one form to another, and
  - Energy transfer will always proceed in the direction of increased entropy, and the release of “free energy”.



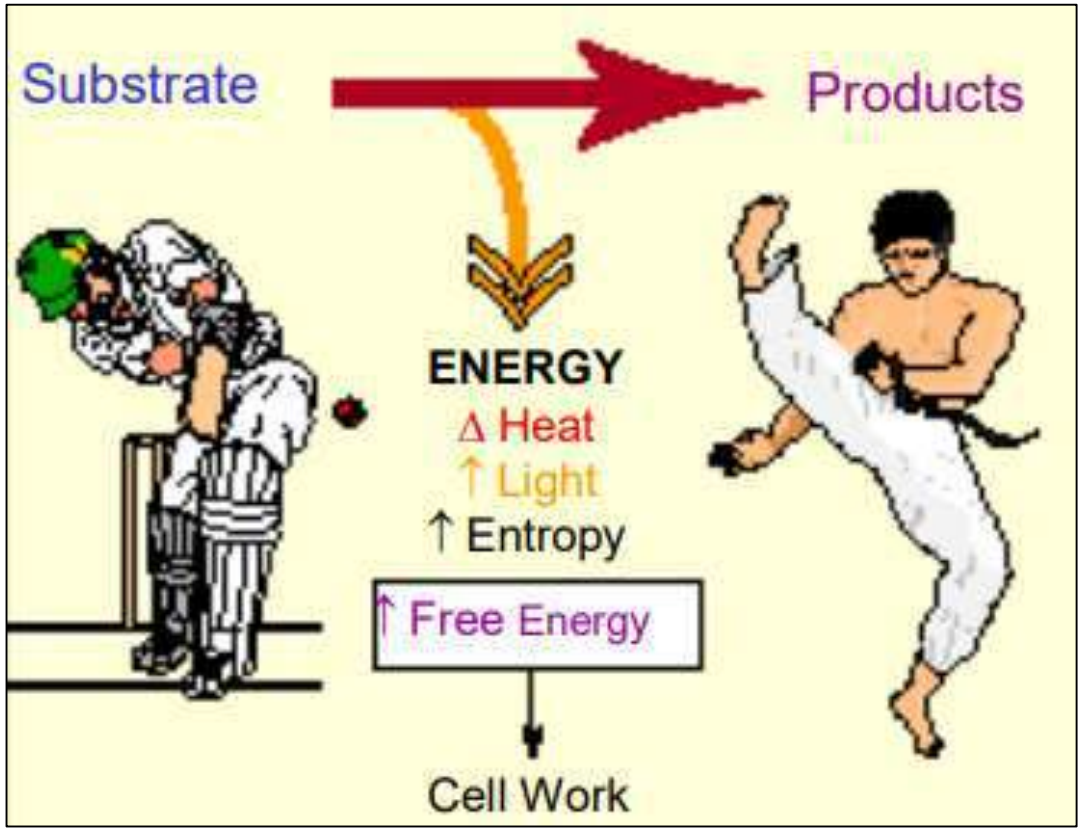
Energetics of Living Body

- Body uses energy in the form of chemical energy which is a stored form of energy.
- Body stores energy in the form of carbohydrates, protein, fats, etc., sourced from vegetarian and/or non-vegetarian food sources.
- These stored energy converts firsts into simpler forms and the simple form or monomer is then utilized in ATP generation, which is the energy currency of a cell.
- ATP (Adenosine Triphosphate) immediately transfer energy where it is needed and is converted into reduced form as ADP (Adenosine Diphosphate), and finally AMP (Adenosine Monophosphate).
- Apart from ATPs (& ADPs), NADPH2, NADPH, GTP, and creatine phosphate (in muscle cells) are also used as the energy currency of a cell.

Energetics of Living Body

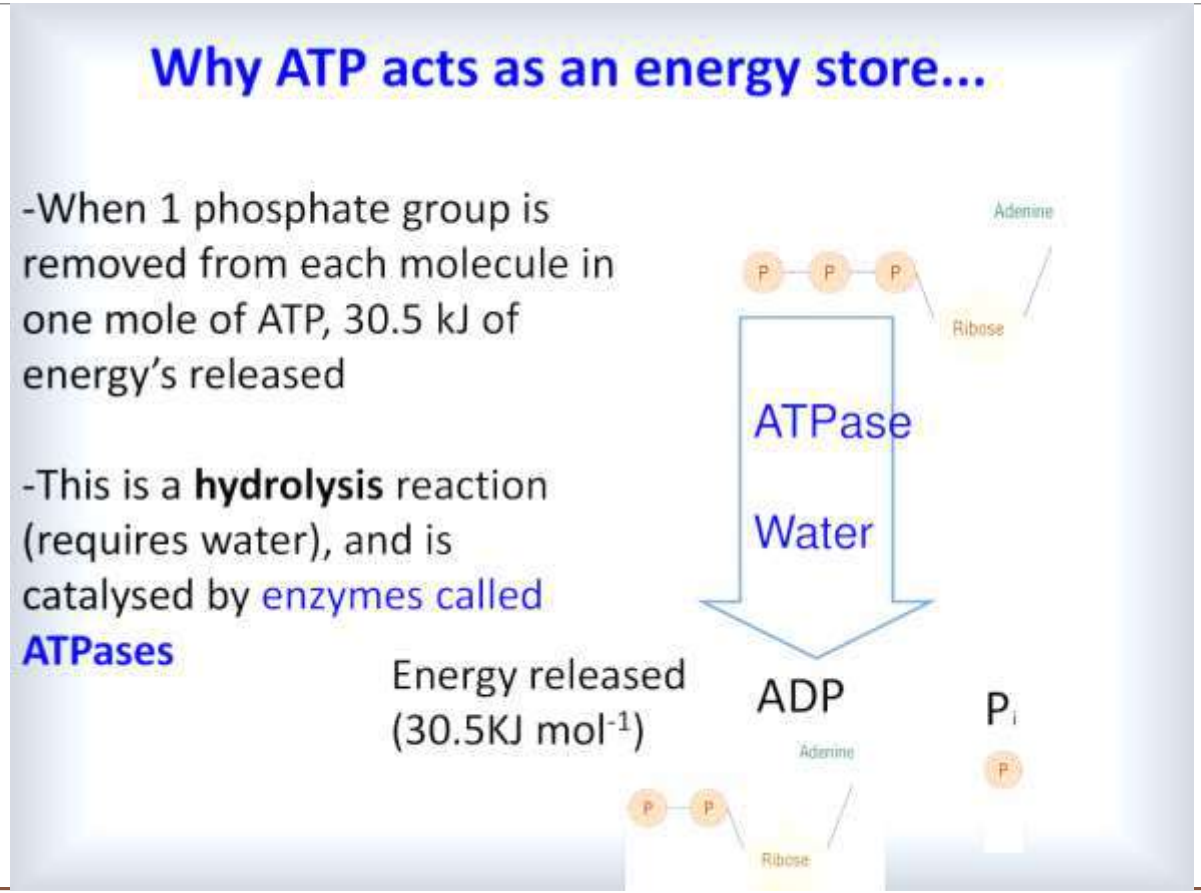


First Law of Energetics



Second Law of Energetics

Energetics of Living Body

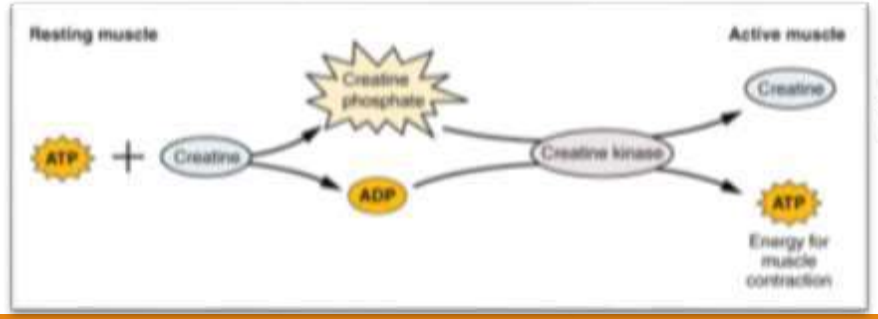


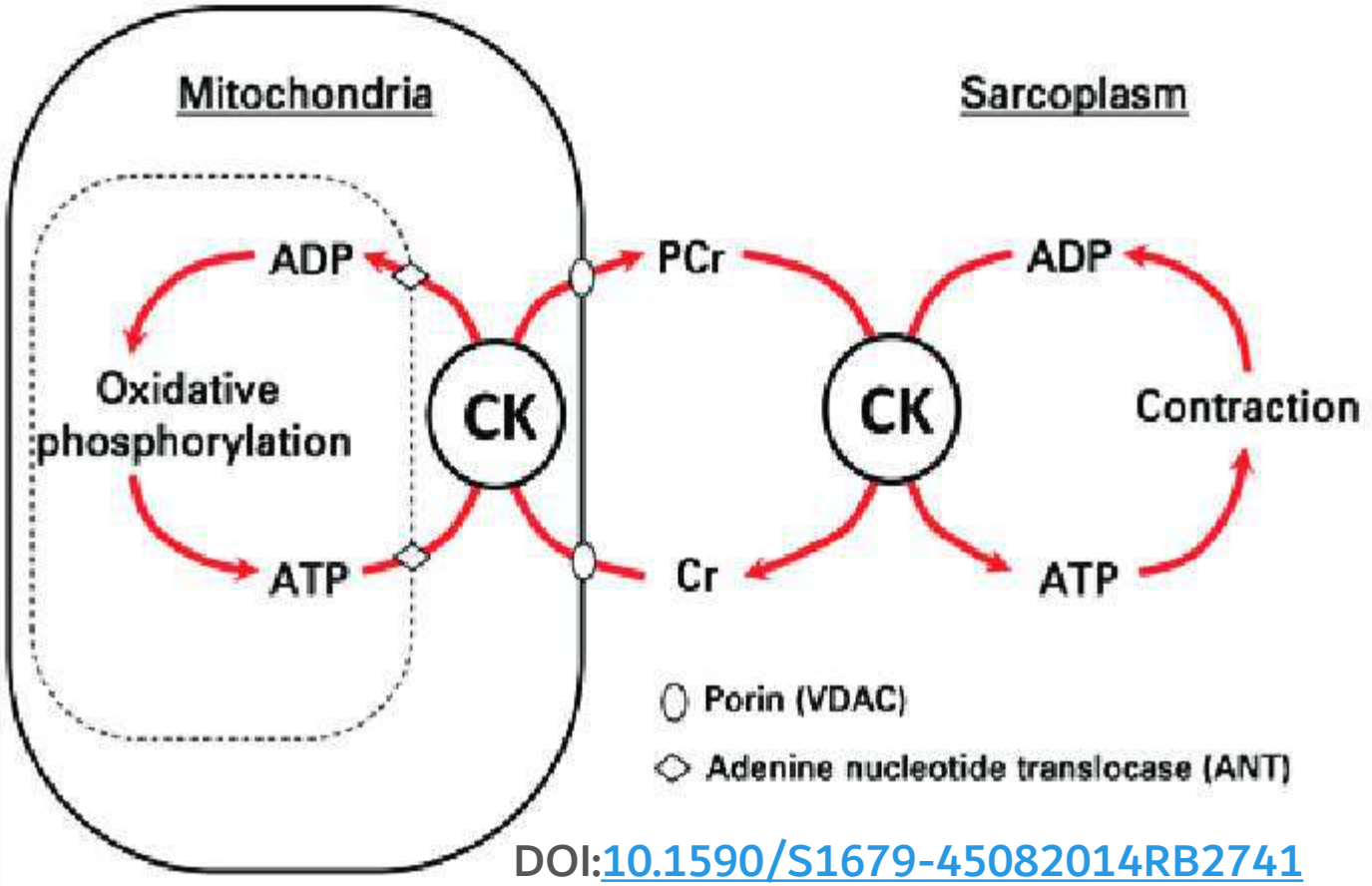
ATP is not a storehouse of energy, it is used as soon as it is available.

Energetics of Living Body

Phosphagen system

Creatine phosphate is an energy currency of skeletal muscles, cardiac muscles, and brain.





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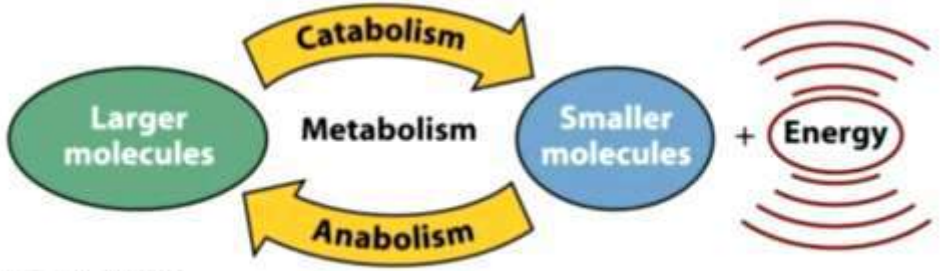
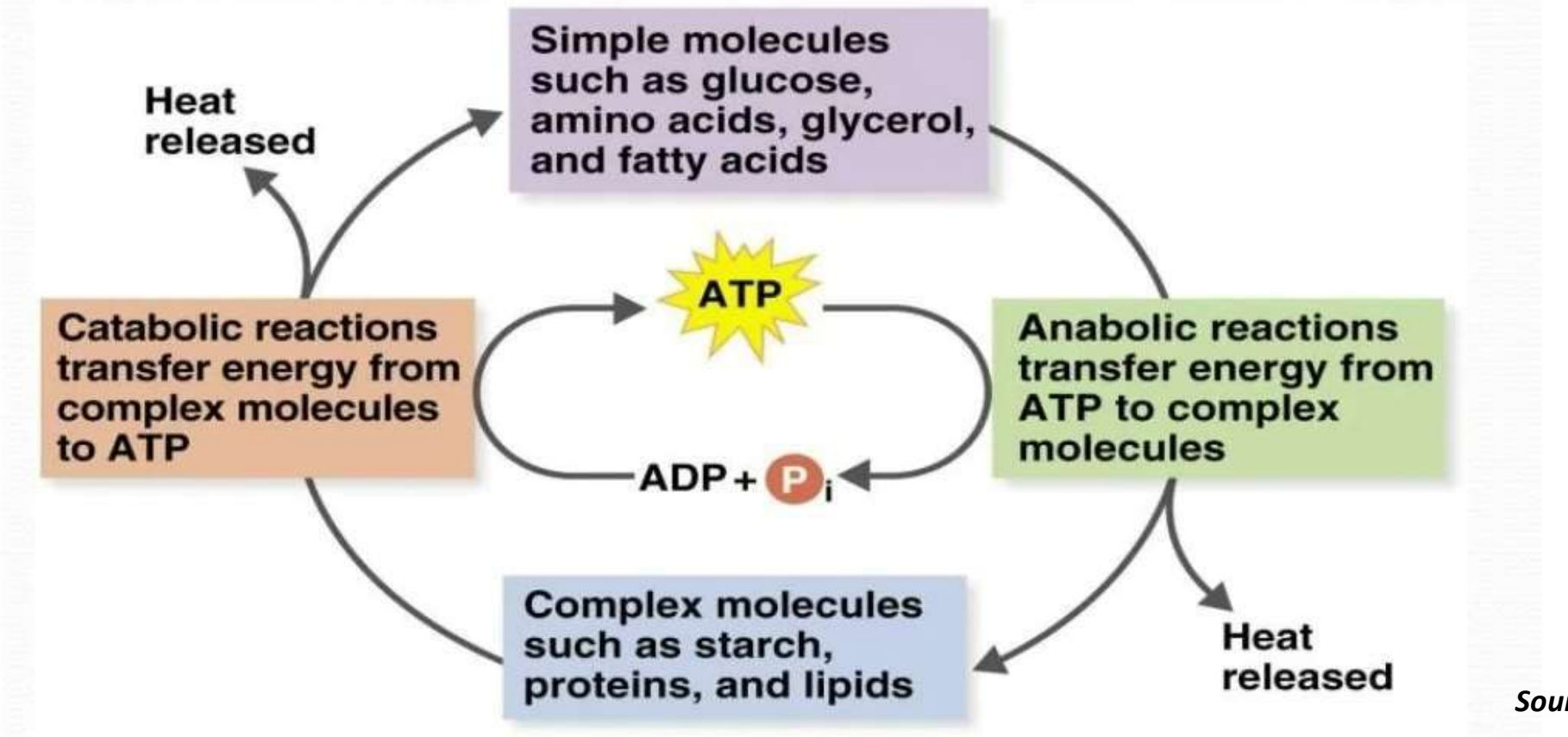
Energetics of Living Body

- The energy currency is produced by various metabolic processes in the body – the sum of chemical reactions required for maintaining the living condition of the cells in an organism.
- It is a sequence of enzymatically catalyzed chemical reactions in a cell.
- All these metabolic pathways are determined by enzymes.
- It is of two types; catabolic process and anabolic process.
  - ***Catabolism or catabolic reaction –*** It is a breakdown process that provides energy and building blocks for the anabolic process.
  - ***Anabolsim or anabolic process –*** It is a synthesis process that uses energy and building blocks to build larger molecules.



Energetics of Living Body

Role of ATP in Coupling Reaction

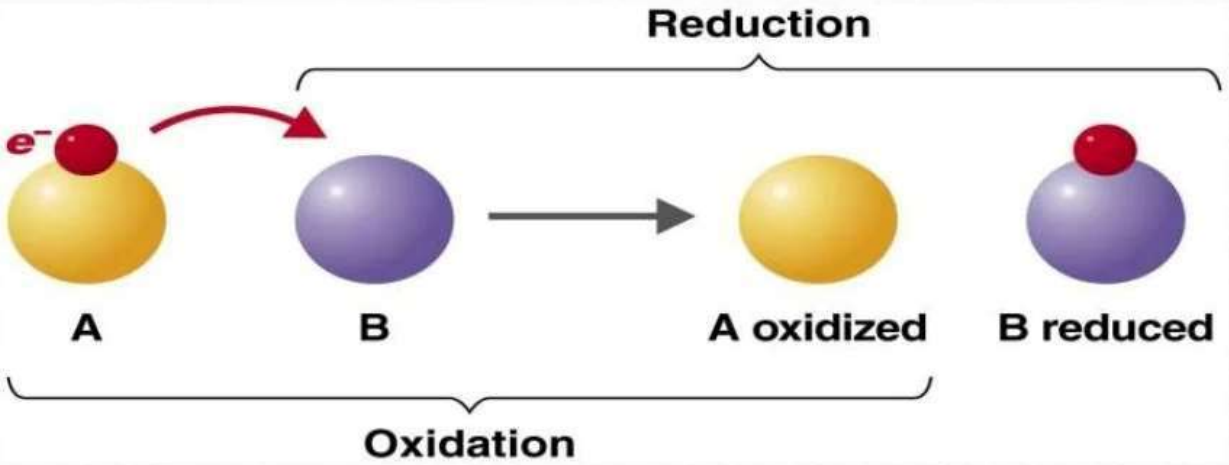


Source: slsdeshare.com

Energetics of Living Body

Oxidation-Reduction Reaction

- **Oxidation**: Removal of electrons
- **Reduction**: Gain of electrons
- **Redox reaction**: An oxidation reaction paired with a reduction reaction



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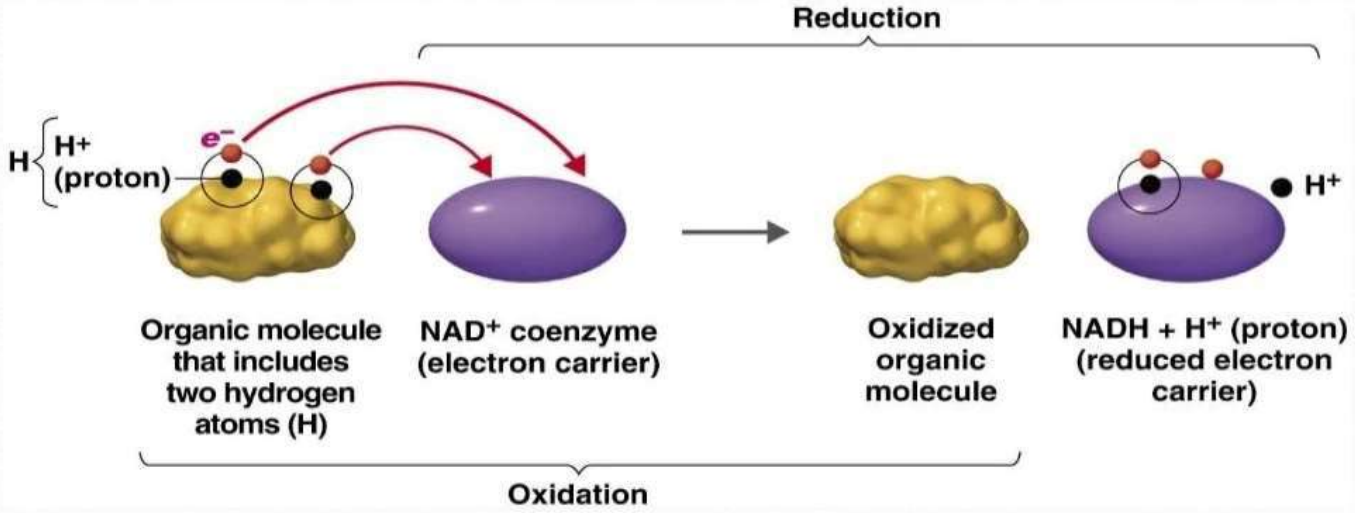
Energetics of Living Body

Oxidation-Reduction Reaction

- In biological systems, the electrons are often associated with hydrogen atoms. Biological oxidations are often **dehydrogenations**



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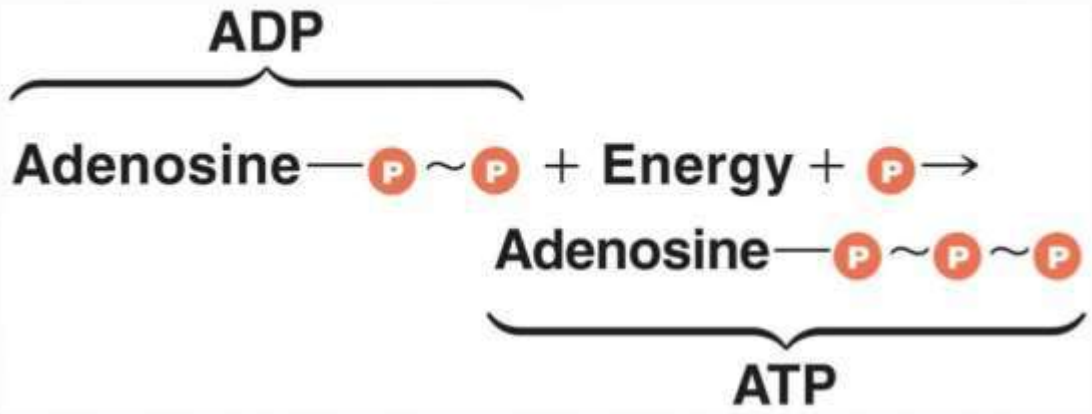
Energetics of Living Body

Generation of ATP

- ATP is generated by the **phosphorylation** of ADP



Substrate Level Phosphorylation

- Energy from the transfer of a high-energy PO_4– to ADP generates ATP

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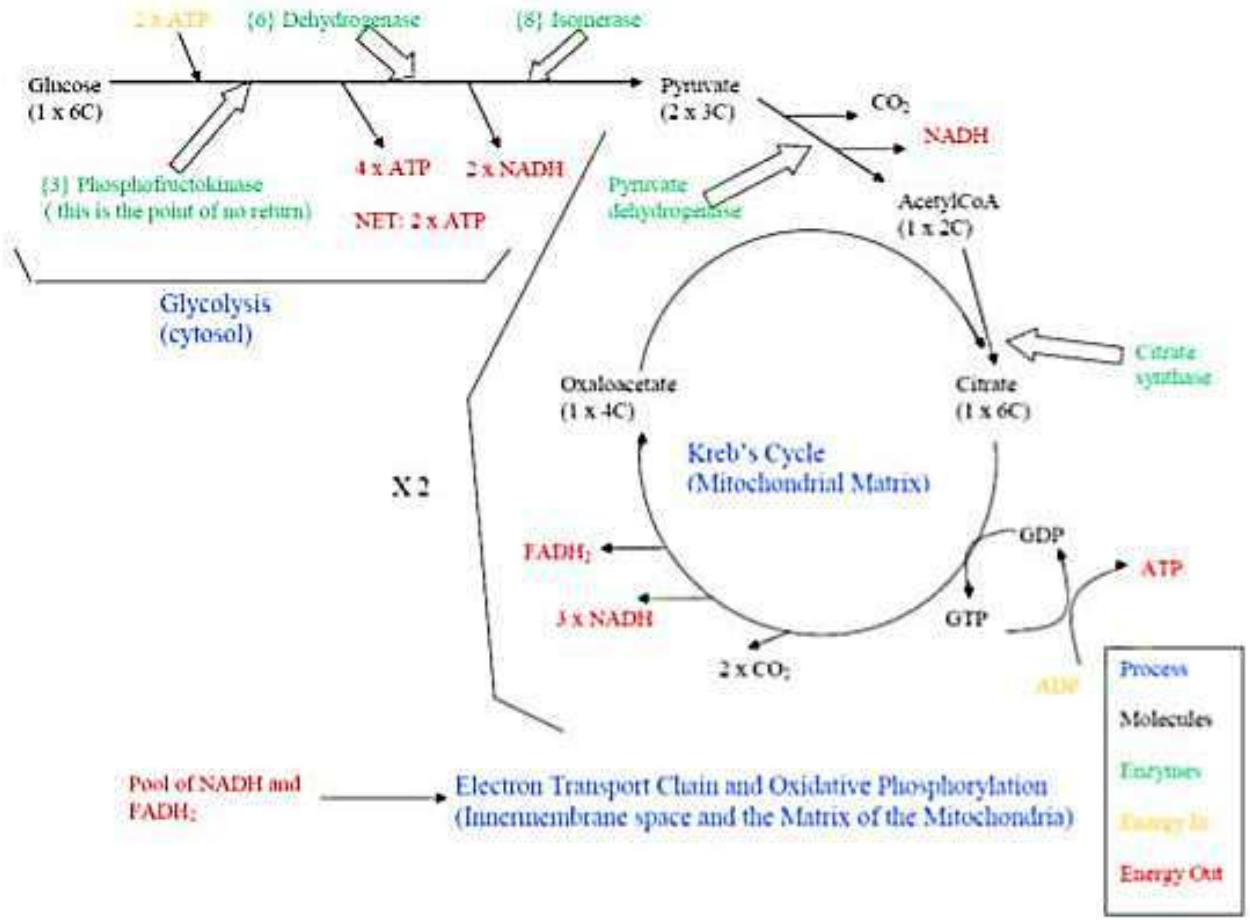
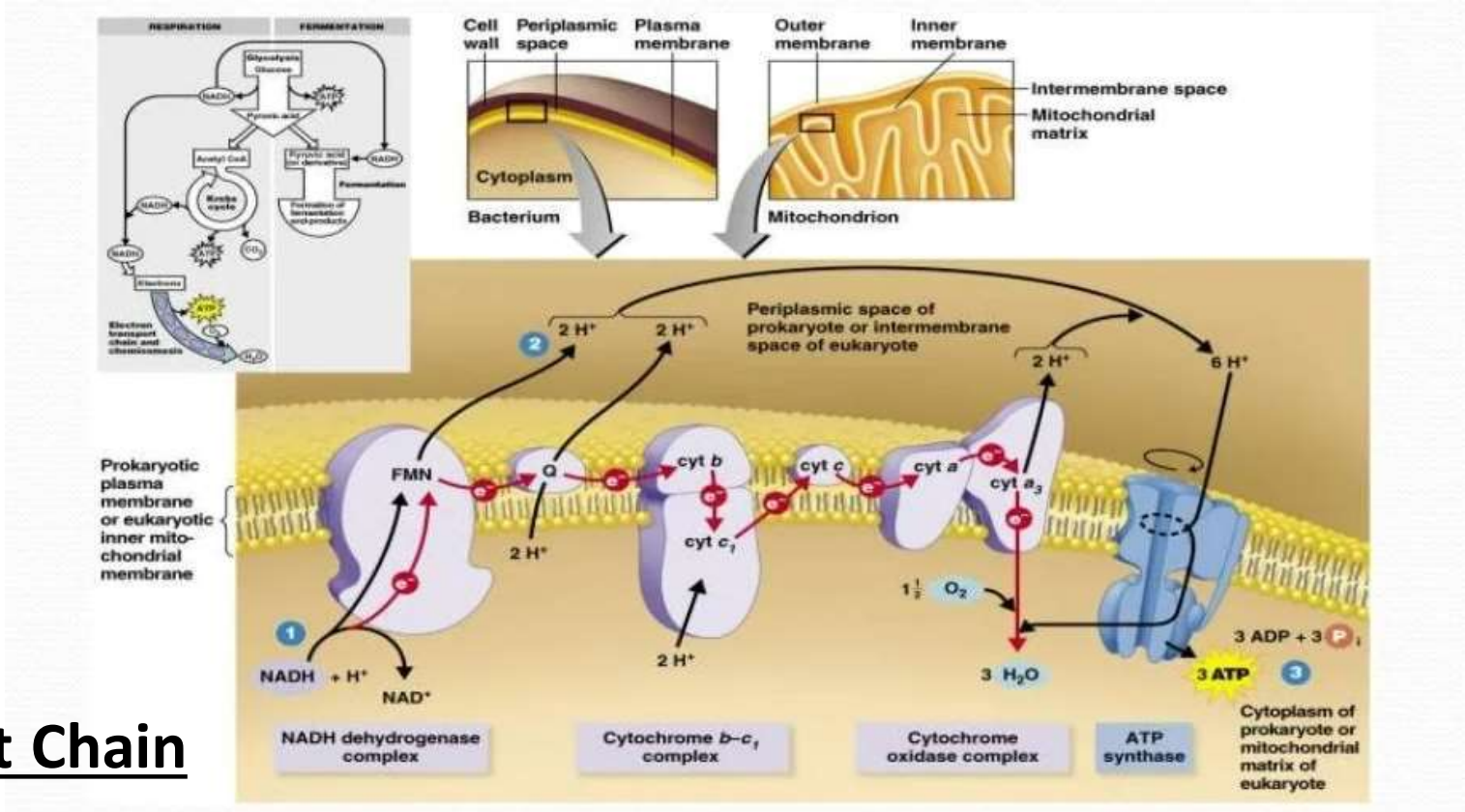
Energetics of Living Body

Carbohydrate metabolism



Energetics of Living Body

Chemiosmotic Generation of ATPs



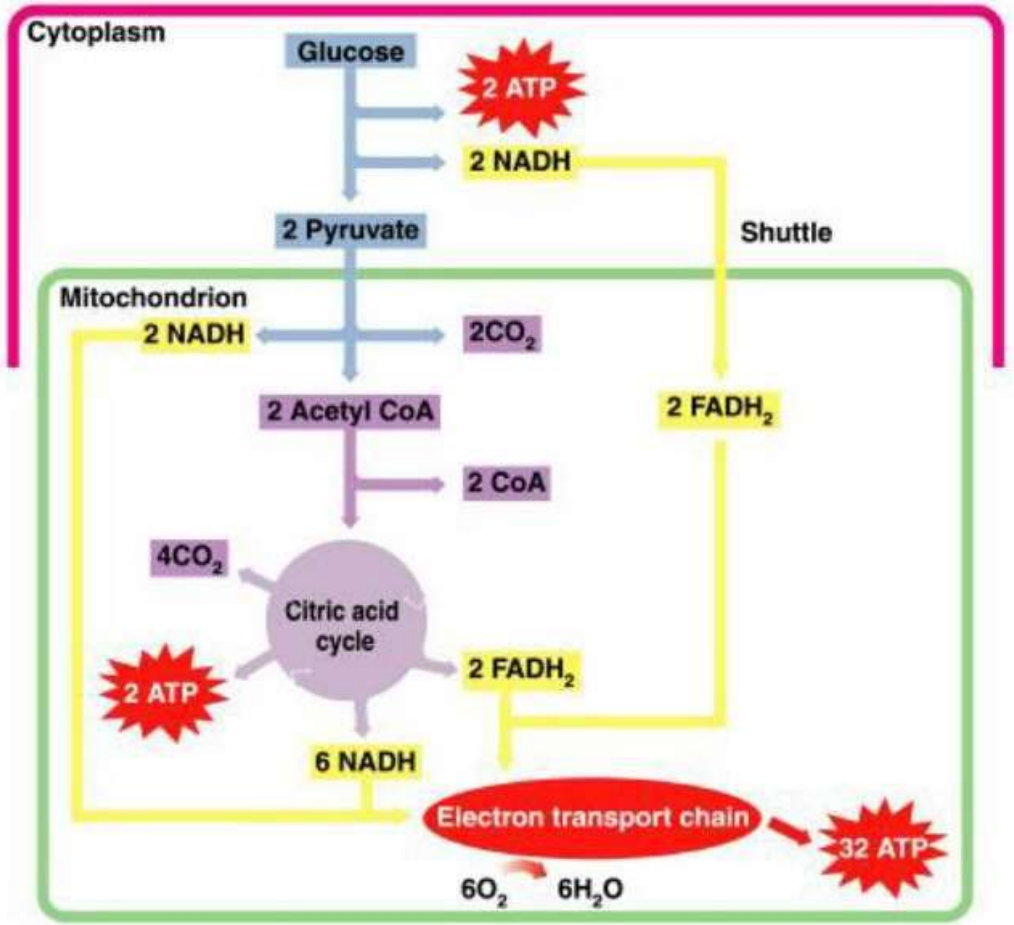
Electron Transport Chain

Energetics of Living Body

A

The complete oxidation of glucose yields

- 6 CO_2
- 6 H_2O
- 36-38 ATP



Generation of ATPs from Carbohydrate Metabolism

One GTP is also produced.

Energetics of Living Body

Production of Various Energy Currency in Carbohydrate Metabolsim

- Energy produced from complete oxidation of one glucose using aerobic respiration

Pathway	ATP Produced	NADH Produced	$FADH_2$ Produced
Glycolysis	2	2	0
Intermediate step	0	2	0
Krebs cycle	2	6	2
Total	**4**	**10**	**2**

Source: slsdeshare.com

Energetics of Living Body

Production of Various Energy Currency in Carbohydrate Metabolsim

- ATP produced from complete oxidation of one glucose using aerobic respiration

Pathway	By Substrate-Level Phosphorylation	By Oxidative Phosphorylation	
		From NADH	From FADH
Glycolysis	2	6	0
Intermediate step	0	6	0
Krebs cycle	2	18	4
Total	**4**	**30**	**4**

Source: slsdeshare.com

Energetics of Living Body

Production of Various Energy Currency in Carbohydrate Metabolsim

- 36 ATPs are produced in human (in eukaryotes)

Pathway	By Substrate-Level Phosphorylation	By Oxidative Phosphorylation	
		From NADH	From FADH
Glycolysis	2	6	0
Intermediate step	0	6	
Krebs cycle	2	18	4
Total	**4**	**30**	**4**

Source: slsdeshare.com

Energetics of Living Body

4 Steps of β-oxidation

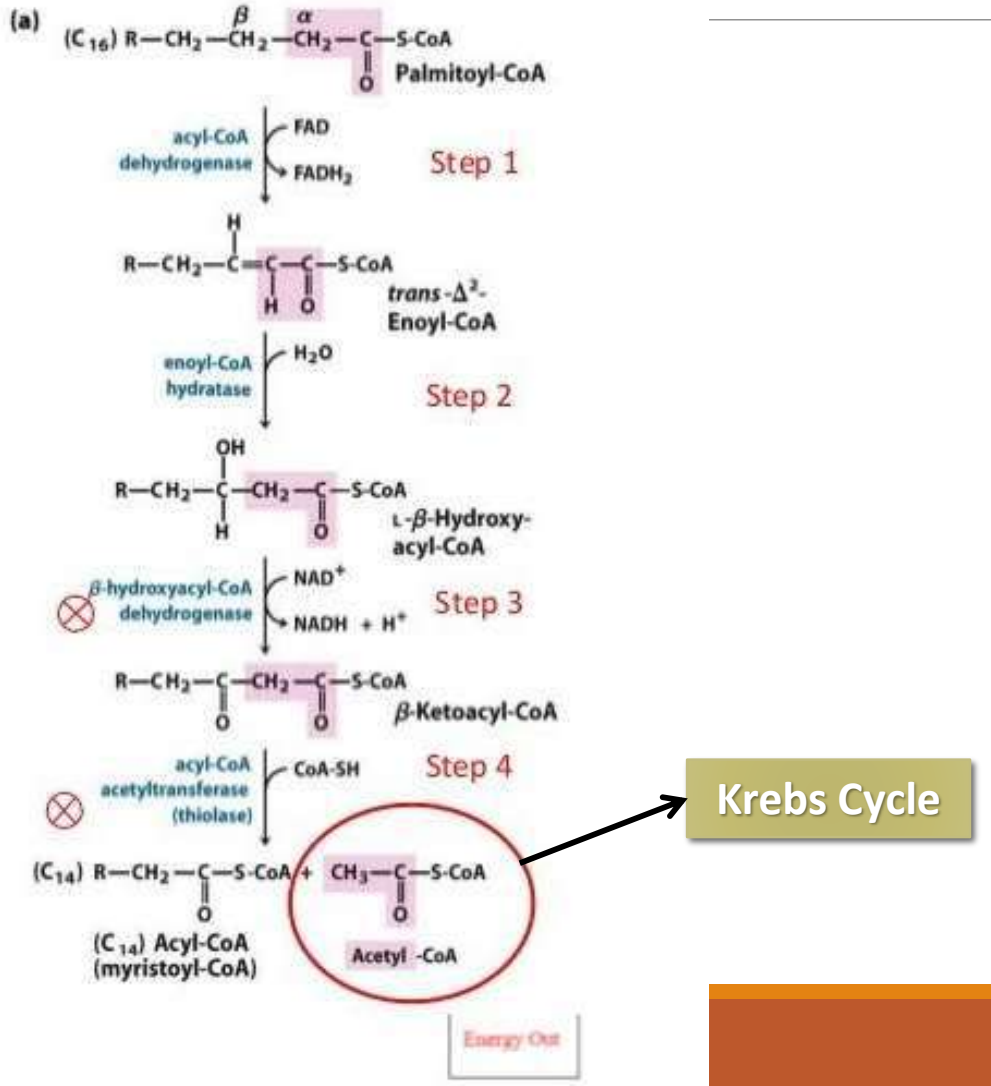
1. Dehydrogenation of the fatty acyl-CoA to make a trans double bond between α and β carbon.
   - Short, medium, and long chain acyl-CoAdehydrogenases
   - e^- removed transferred to FAD
2. Hydration of the double bond

1. Dehydrogenation of the β-hydroxyl group to a ketone

   - e^- removed transferred to NAD^+

1. Acylation – addition of CoA and production of acetyl-CoA

β-Oxidation



Energetics of Living Body

From one palmitate molecule

- Complete β-oxidation of **palmotyl CoA** (16 carbons) produces :
  - **8** acetyl CoA ----- Kreb Cycle TCA cycle ------ 8 X 12 = **96** ATP
  - **7** NADH ---------- ETC ---------- 7 X 3 = **21** ATP
  - **7** FADH2--------- ETC ---------- 7 X 2 = **14** ATP
- ----------
- All yield ----------**131 ATPs**

- Activation of fatty acid requires **2 ATP**

- **Net energy gained**: **129 ATPs** from **one molecule of palmitate**

Energetics of Living Body

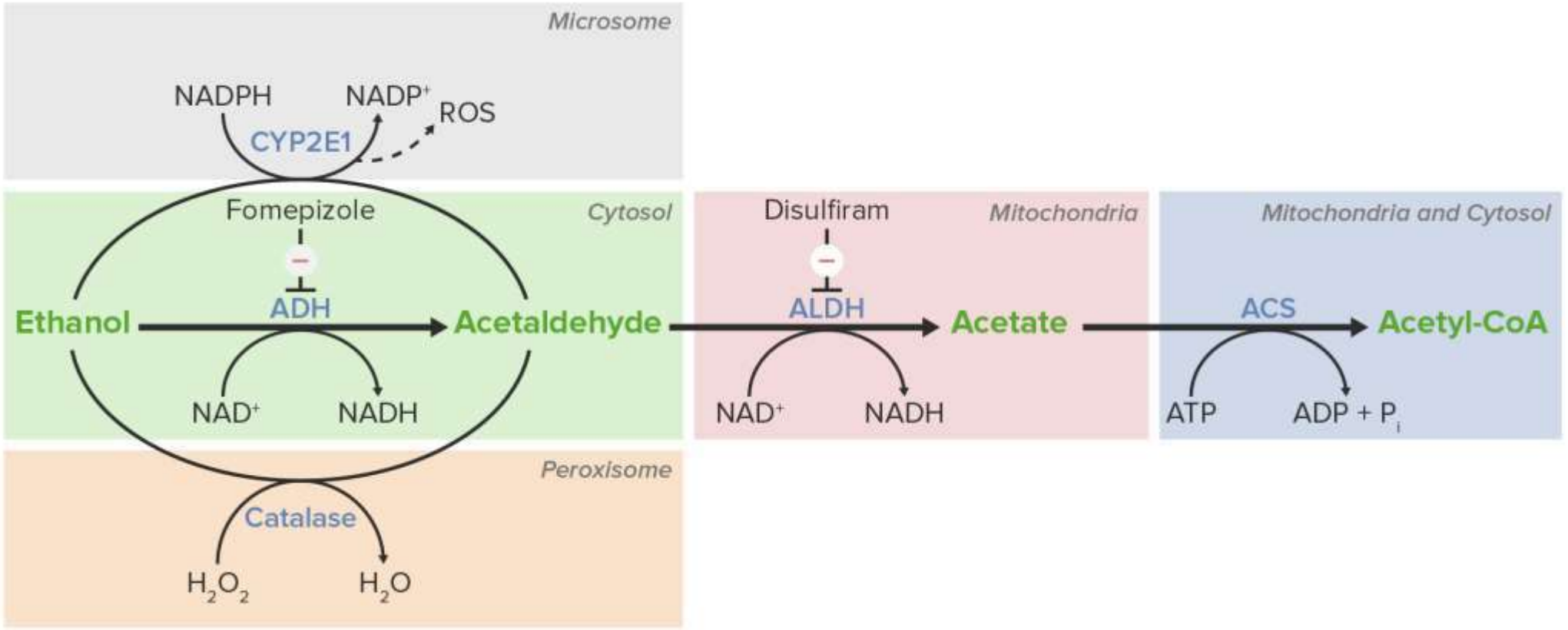
Chemical Energy of Body

- Fats store the most energy.
  - 80% of the energy in our body.
  - about 146 ATP from a triglyceride.
- Proteins are least likely to be broken down to make ATP.
  - amino acids are not usually needed for energy.
  - about the same amount of energy as a carbohydrate.

1gm alcohol = 7 cal/mg

Molecule	Energy
Carbohydrate	4.30 calories/mg
Lipid	9.45 calories/mg
Protein	5.65 calories/mg

Energetics of Living Body



Alcohol metabolism

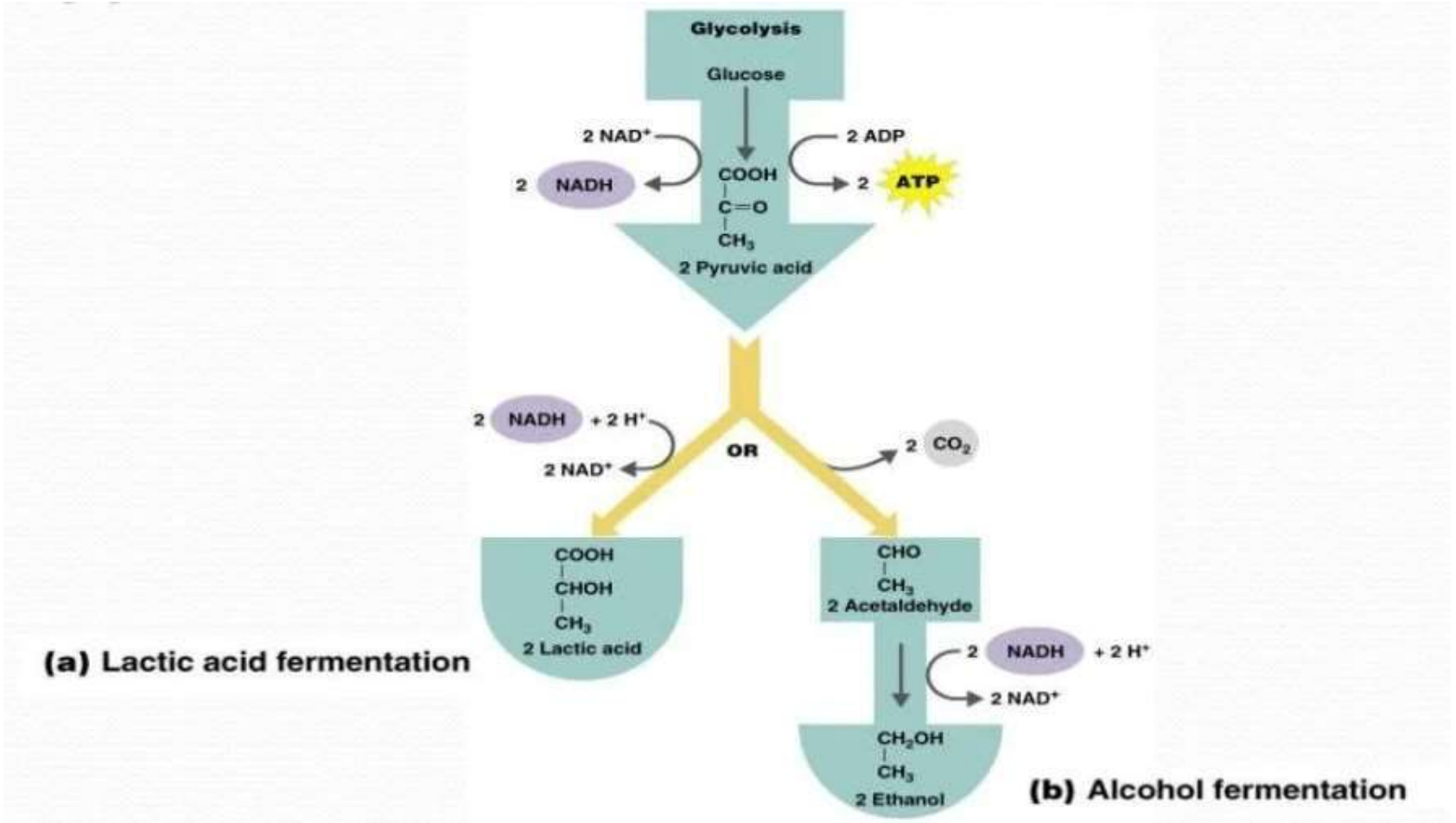
Energetics of Living Body

Fermentation

- Process in which pyruvate is subsequently metabolized in the absence of oxygen.
- The result of the need to recycle the limited amount of NAD by passing the electrons of reduced NAD to other molecules.
- It can be categorized into two: homolactic acid fermentation and alcoholic fermentation.
  - ***Homolactic acid fermentation:*** Pyruvate is converted directly to lactic acid, using electrons from reduced NAD.
  - ***Alcoholic fermentation:*** Carbon dioxide is released from pyruvate to form acetaldehyde, which is reduced to ethanol.
- Releases energy from the oxidation of organic molecules.
- Does not require oxygen and Kreb's cycle or ETC, uses an organic molecule as the final electron acceptor.

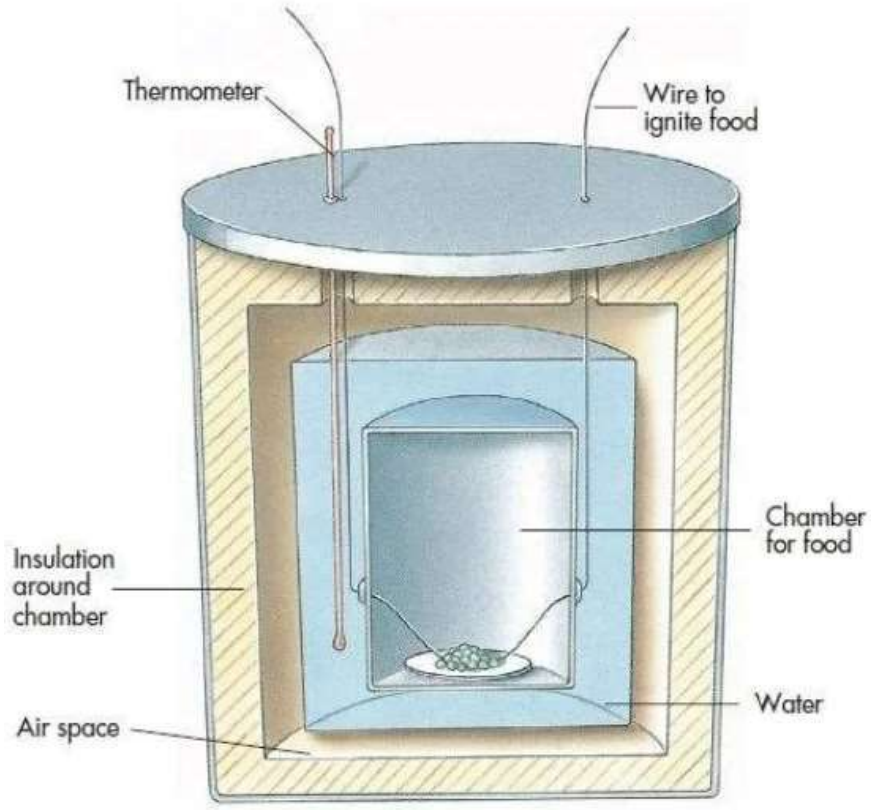
Energetics of Living Body

Fermentation



Calorimeter

Used to measure the energy content of a given substance



- The food in the calorimeter is combusted via electrical ignition.
- The heat (Calories) given off by the food raises the temperature of the water, thereby providing data about the caloric content of specific foodstuffs.
- The process is called calorimetry.

Calorimetry techniques

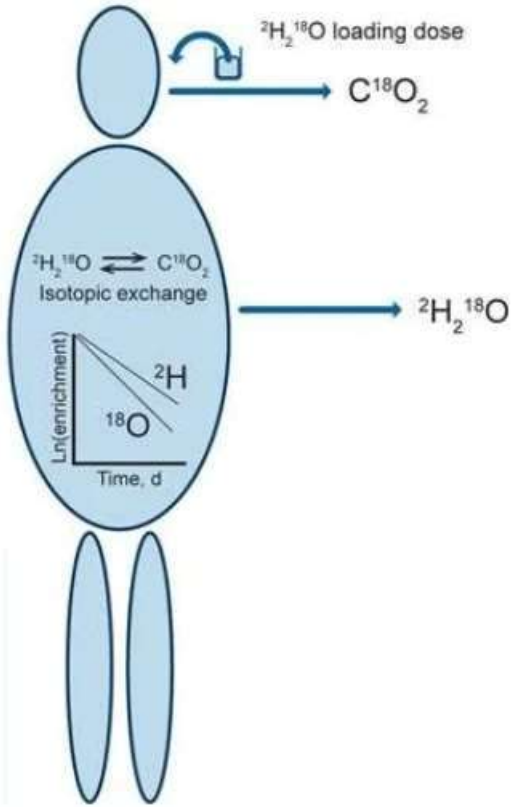
Two types; indirect calorimetry technique and doubly labeled water (DLW) technique.

- **Indirect calorimetry technique**
  - It is based on determining the amount of oxygen an individual consumes.
  - It may also be used to measure VO_{2Max} and other measures of cardiovascular and respiratory function.

Calorimetry techniques

Two types; indirect calorimetry technique and doubly labeled water (DLW) technique.

- **Doubly labeled water (DLW) technique:**
  - **It is a type of calorimetric technique in which stable isotopes of hydrogen and oxygen in water $^{2}H_{2}{}^{18}O$ are ingested.**
  - **Analysis of urine and blood samples provides data on ^{2}H and excretion.**
  - **The labeled oxygen is eliminated from the body as water and carbon dioxide, whereas the hydrogen is eliminated only as water.**



Thank you