Metabolism

The sum of all chemical reactions occurring inside an organism

• All metabolic reactions are carried out by enzymes

Catabolic reactions

Metabolic reactions in which large molecules are broken down to smaller molecules.

• Catabolic reactions usually generate energy

Anabolic reactions

Metabolic reactions in which small molecules are combined into larger molecules.

• Anabolic reactions usually require energy

Energy

The capacity to do work

Kinetic energy

The energy of an object due to its motion

Fig 8.2

Potential energy

Stored energy (due to the location of an substance)

Fig 8.2

Spontaneous (exergonic) reaction

Any change in a substance in which there is a decrease in the amount of potential energy.

• Spontaneous reactions can be an energy source

Fig 8.6

Non-spontaneous (endergonic) reaction

Any change in a substance in which there is an increase in the amount of potential energy

• Substances do not undergo non-spontaneous reactions unless supplied with energy.

Fig 8.6

Coupled reaction

A reaction in which a spontaneous reaction is the energy source for a non-spontaneous reaction

Energy is stored in cells in two ways:

- Concentration gradients across membranes
- Chemical potential energy (High calorie molecules)

Concentration gradient

Adjacent areas with different concentrations of a solute

Diffusion

The spontaneous movement of a solute from an area of its high concentration to an area of its low concentration.

- Substances spontaneously diffuse down their concentration gradients
- Cell membranes can block diffusion of most solutes
- A concentration gradient blocked by a membrane is a type of stored energy (potential energy)

Membrane transport proteins (also called carrier or channel proteins)

Proteins in the cell membrane that allow solutes to pass through the cell membrane

- Each transport protein is highly specific for only one solute molecule type

- Passive and active transport are the two ways the proteins move the solutes across the membrane

Passive transport (facilitated diffusion)

The spontaneous diffusion of solutes across a membrane (down their concentration gradient) with the aid of a transport protein.

- Passive transport can be coupled to ATP synthesis (making ATP from ADP and P_i)

Figs 7.17 and 9.14

Active transport ("pump")

The non-spontaneous movement of solutes across a membrane (against their concentration gradient) by a transport protein

• Active transport must have an energy source

√ ATP is a common energy source

√ Some active transport is powered by electrons from an electron transport system

Figs 7.7 and 7.18

Electron transport system

A group of molecules in a membrane that pass electrons to one another

Osmosis

The spontaneous movement of water across a selectively permeable membrane towards the side with the higher total solute concentration

- “Selectively permeable” = Water can cross membrane but solutes cannot
- “Water moves towards solutes” is a way to remember osmosis
- Hypertonic = Higher [solute] than a cell’s cytoplasm
    - √ Cells lose water when put in hypertonic solutions
- Hypotonic = Lower [solute] than a cell’s cytoplasm
    - √ Cells gain water when put in hypotonic solutions
- Isotonic = Equal [solute] to a cell’s cytoplasm
    - √ Cells don’t gain or lose water when put in isotonic solutions

Chemical potential energy

Energy stored in a molecule's covalent bonds

• Different types of covalent bonds have different amounts of energy

√ C–H is a high energy covalent bond

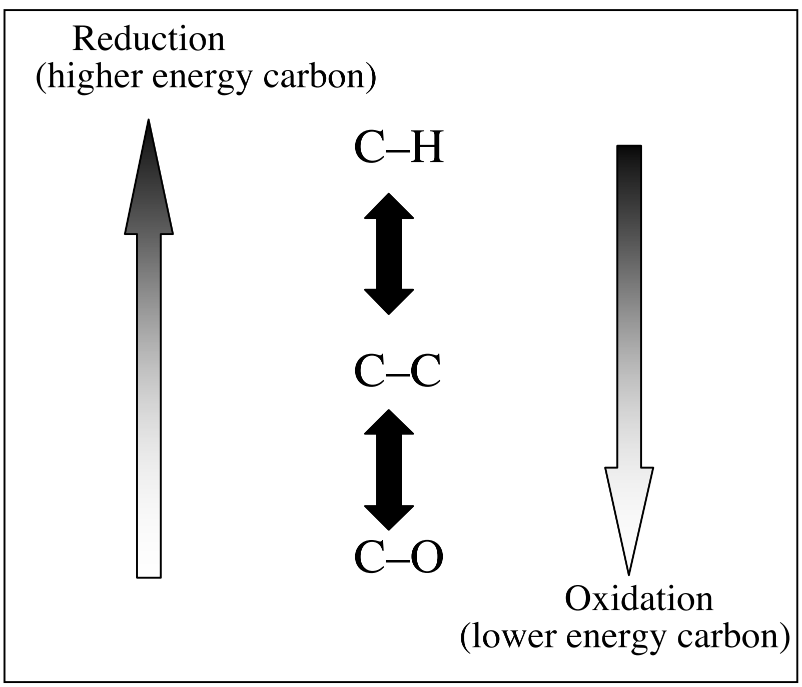
√ C–C is a medium energy covalent bond

√ C–O is a low energy covalent bond

Oxidation and reduction of carbon atoms:

• Oxidation = Carbon atom gains bonds to oxygen or loses bonds to hydrogen

• Reduction = Carbon atom gains bonds to hydrogen or loses bonds to oxygen



• CO_2 is the most oxidized (lowest energy) a carbon atom can become in a living thing

Cells store potential energy by making organic molecules with many reduced carbons

- Examples: Making glucose from CO_2 (photosynthesis)
  - √ Metabolic reactions that reduce carbon require energy (a non-spontaneous reaction)

Cells release energy by oxidizing the carbon atoms in organic molecules

- Example: Oxidizing glucose carbons into CO_2 (respiration)
  - √ Metabolic reactions that oxidize carbon produce energy (a spontaneous reaction)

Activation energy (E_A)

The energy that must be added to start a spontaneous reaction

Fig 8.15

Catalyst

Any substance that speeds up a reaction by lowering E_A but which is not consumed in the reaction.

- Enzymes are the catalysts of all metabolic reactions

- Enzymes need an energy source (usually ATP) to catalyze non-spontaneous reactions

Metabolic pathway

A series of enzymes that bring about large changes in substrate molecules by each individual enzyme making a small change.

• Substrate = the molecule that enters a metabolic pathway

• Endproduct = the molecule that exits a metabolic pathway

• Intermediates = all the molecules between the substrate and the endproduct

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Cycle

A circular metabolic pathway

Fig 9.12

Enzymes can be regulated (activated or inhibited) to fit the cell's needs

Competitive inhibitors

Molecules that slow an enzyme down by fitting into the enzyme's active site, so that the enzyme's substrate cannot bind

• Competitive inhibitors are able to enter the active site because they are similar in shape to the substrate molecule

Fig 8.19

Allosteric inhibitors

Molecules that slow an enzyme by binding to a site on the enzyme that is not the enzyme's active site

• Allosteric inhibitors change the shape of the active site such that substrate molecules no longer fit

• Feedback inhibition = When the endproduct of a metabolic pathway is an allosteric inhibitor of one of the first enzymes in the pathway

√ Feedback inhibition stops the pathway if too much endproduct is being made

Figs 8.19, 8.20, and 8.21

Allosteric activators

Molecules that speed an enzyme by binding to a site on the enzyme that is not the enzyme's active site

• Allosteric activators change the shape of the active site such that substrate molecules can fit into it

Fig 8.20

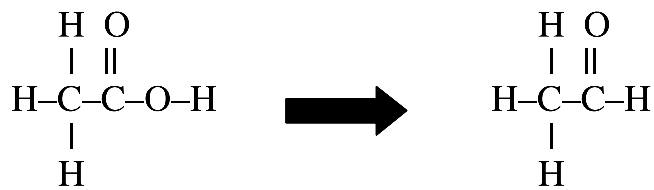
Phosphorylation

Some enzymes are activated when a phosphate group is added to their amino acids

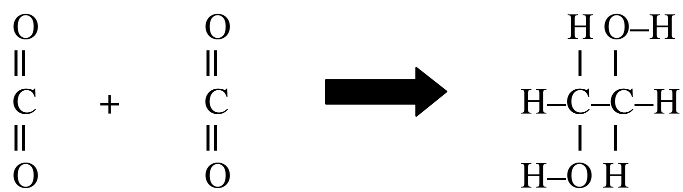
Extra questions on oxidation and reduction of organic molecules:

For each chemical reaction shown below, state (a) whether the molecule was oxidized or reduced, and (b) whether the molecule gained or lost potential energy.

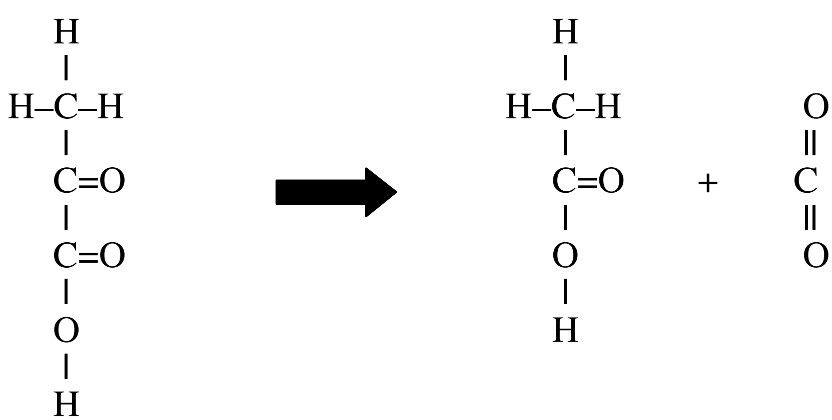
(a)



(b)



(c)



(d) $C_3H_6O_3 \rightarrow 3CO_2$

Answers: (a) reduction/gained energy, (b) reduction/gained energy,
(c) oxidation/lost energy, (d) oxidation/lost energy