1.2.4 | Exchange of materials between inside and outside of cells

Molecules can cross the membrane in different ways. Passive transport happens according to the concentration gradient, namely the difference of concentration between inside and outside the cell. Molecules move from higher concentration zones to lower concentration zones without consuming energy.

Active transport occurs against the concentration gradient by using energy usually provided by ATP hydrolysis.

If the moving molecule is an ion, the distribution of charges on the two sides of the membrane has to be taken into account, since charged molecules move according to electrochemical gradient, the sum of chemical concentration and electric potential.

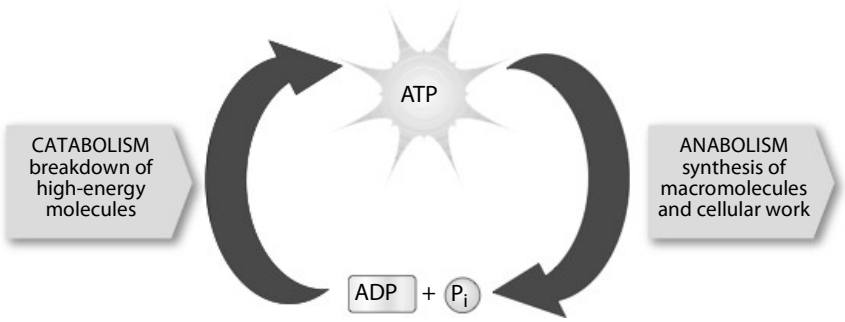
Normally, charges are unevenly distributed at the two sides of the membrane, producing an electric potential of about –70 mV called transmembrane potential.

The charge asymmetry is due to sodium (Na^+) and potassium (K^+) ions, which are 10-fold, more concentrated outside and 30-fold more concentrated inside, respectively.

A specific membrane protein called sodium-potassium pump or "Na^+/K^+–ATPase", which uses the energy provided by ATP to transfer the two ions across the membrane, creates their concentration gradient.

1.2.5 | Cell metabolism

Metabolism is the term used to define all the chemical reactions taking place inside a cell. All the reactions that transform molecules in smaller components are called altogether *catabolism*, while the synthetic reactions that produce cellular macromolecules are called *anabolism*.



The molecule of adenosine triphosphate (ATP) is used as a carrier of energy or *energetic currency* to feed all the reactions requiring energy. It consists in three phosphate groups bound to a nucleotide, the adenosine.

The bond between the first and the second phosphate and between the second and the third one are "high-energy bonds": when they are broken down, a large amount of energy is released. ATP is produced by cellular respiration and fermentation.

Catabolism of glucose

In general, cells obtain energy from oxidation of organic substances. The main source of energy is glucose break down. The first step is *glycolysis*, a series of reactions producing pyruvate plus 2 molecules of ATP and 2 of NADH.

When oxygen is present the second step is *cellular respiration*, which further oxidizes pyruvate to CO_2 and H_2O. Cellular respiration can be outlined in three stages. First, the oxidative decarboxylation of pyruvate releases a CO_2 molecule, an acetil-CoA unit and reduces a molecule of NADH. Second, a group of cyclic reactions called Krebs cycle produces one ATP and reduces three NADH molecules and one of $FADH_2$ by releasing a CO_2 molecule. The NADH and $FADH_2$ reduced in the first two stages are used in the third stage, the oxidative phosphorylation.

In this last step, the electrons are transferred from NADH and $FADH_2$ through the *electron transport chain* to O_2 as a final acceptor with production of H_2O.

2| Biology: worked solutions

1 A hydrogen bond is a relatively weak intermolecular force that occurs when a hydrogen atom, already covalently bonded to a highly electronegative atom like oxygen, nitrogen, or fluorine, is attracted to another electronegative atom nearby (correct answer: **E**). This interaction plays a crucial role in many biological and chemical processes, such as the structure of water and the stability of DNA. Although weaker than covalent bonds, hydrogen bonds significantly influence the physical properties of substances.

2 To answer the question we have to indicate which bond must be broken to form two amino acids from the proposed molecule, a dipeptide, that is formed by two amino acids joined by a peptide bond. The latter is a covalent bond that involves the -COOH group of one amino acid and the $-NH_2$ group of the other. To form the two amino acids, it is necessary to break the peptide bond, which in the scheme is indicated by number 3. Exact answer is **D**.

3 When a fatty acid reacts with glycerol one H_2O molecule is loss and the reaction is named "condensation". Since three fatty acids are reacting with the glycerol, three H_2O molecules are lost and the final formula of the triglyceride can be obtained from the sum of the three fatty acids and the glycerol minus three H_2O. For each atom:

C: $(8 \times 3) + 3 = 27$

H: $(16 \times 3) + 8 - (3 \times 2) = 50$

O: $(2 \times 3) + 3 - (3 \times 1) = 6$

C is the correct choice.

4 Cholesterol is a type of lipid, precursor of some, but not all, hormones (choice **B** is not correct) and it is also a structural component of the cell membrane, where its main function is maintaining the fluidity of the membrane by intercalating among hydrophobic phospholipid tails and preventing thus their clustering. **A** is the correct choice.

5 Glycoproteins are proteins to which a carbohydrate component is linked. Protein synthesis is based on the information contained in the nucleus (DNA); the synthesis takes place in the cytoplasm and involves the rough endoplasmic reticulum. The proteins produced in this structure are then modified in the cisterns of the Golgi apparatus. The centrioles are not involved in these processes, so the exact answer is **B**.

6 Intercellular (more precisely, intracellular) compartmentalisation is a defining feature of eukaryotic cells. These cells contain membrane-bound organelles, such as the nucleus, mitochondria, and endoplasmic reticulum, which separate different cellular processes. This organization allows for greater efficiency and specialization of functions. In contrast, prokaryotes (like bacteria) lack membrane-bound organelles and therefore do not exhibit this level of compartmentalisation. Answer: **C**.