**ENERGY TUTORIAL: Bioenergetics**

**1)** Which ONE of the following statements is TRUE concerning the cell's nucleus:

A. It is the small region at the centre of an atom, consisting of protons and neutrons.
B. It is the powerhouse of the cell.
C. It contains membrane proteins responsible for cell-cell communication.
D. It contains the cell's (primary) genetic information.

**2)** Name THREE key biological functions of the cell membrane and TWO features that enable to carry out these functions.

**3)** In Lecture 13, Example Problems 1 (see page 109 of the course book), we calculated the energy converted by photosynthetic organisms over one year as $6.6 \times 10^{20}$ J. Redo the calculation from scratch to calculate how many PW.h of energy are photosynthesized over 2 years. (Note: P = peta = $10^{15}$).

**4)** Each cell only has one nucleus. Does each cell only have one mitochondrion? Do some cells have more or less mitochondria? If no, what would you expect might predict how many mitochondria different cell types have?

**5)** A large, 140g 'study bar' has been developed. It contains 2g of protein, 20g of fat and 118g of carbohydrate. Suppose that studying for ENGGEN140 while sitting takes 140 kcal/h. Given that carbohydrate contains 16 kJ/g, fat contains 37 kJ/g and protein contains 23 kJ/g, determine how long you could study for ENGGEN140 by eating TWO study bars. One calorie = 4.184 J.

**6)** A 65g 'power bar' developed for endurance athletes contains 4.5g of fat, 47g of carbohydrate and 8.5g of protein. The energy densities of the food constituents are as follows: fat contains 39 kJ/g, carbohydrate contains 16 kJ/g, protein contains 18 kJ/g.

A. What is the total energy content of the power bar?

B. Jogging requires a total energy expenditure of 570 kcal/h, as measured using indirect calorimetry. Given the chemical energy provided by the energy bar above, determine how long you could jog for after eating the energy bar. One calorie = 4.184 J.

**7)** The enzyme 'catalase' catalyses the following reaction of $H_2O_2$ (hydrogen peroxide) in cells:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

A. Which product is produced at the same rate as hydrogen peroxide is consumed?
B. Is oxygen produced at the same, half or twice the rate that hydrogen peroxide is consumed?

**8)** The average rate of combustion of a candle made of beeswax is $2\times10^{-4}$ mol/s. The molar mass of beeswax is about 677.2 g/mol. You want the candle to burn for 6 hours. Determine the smallest candle, to the nearest 10g, that you would need.

**9)** Suppose that the (change in) Gibbs free energy of a reaction is $\Delta G = -40$ kJ/mol. Is this exergonic or endergonic? Spontaneous or non-spontaneous? What is the maximum amount of chemical work that you can do (per mol) using this reaction?

**10)** The free energy available from glucose is $\Delta G = -2862$ kJ/mol under standard conditions. In cellular respiration 38 ATP molecules are synthesised for each glucose molecule. Under standard conditions each ATP can provide $\Delta G = -29$ kJ/mol to drive other reactions in the cell. What is the energetic efficiency of cellular respiration?

**11)** Write down the reaction for the hydrolysis of ATP.

**12)** Which ONE of the following statements about the molecule adenosine triphosphate (ATP) are FALSE?

A. ATP drives cellular work by transferring a phosphate group to a recipient molecule.
B. Almost 100% of the chemical energy in food molecules is converted into ATP to carry out cellular work.
C. When an ATP molecule is used for cellular work, the remaining ADP and phosphate can be recycled to make another ATP.

**13)** The reaction for sucrose formation in sugar cane is as follows:

$$\text{glucose} + \text{fructose} \rightarrow \text{sucrose} + H_2O \ (\Delta G = +23\text{kJ/mol})$$

ATP hydrolysis reaction is as follows:

$$\text{ATP} + H_2O \rightarrow \text{ADP} + \text{phosphate} \ (\Delta G = -29\text{kJ/mol})$$

In sugar cane, both reactions can be coupled together as follows:

$$\text{glucose} + \text{fructose} + 2\text{ATP} \rightarrow \text{sucrose} + 2\text{ADP} + 2\text{P}$$

(I've ignored the $H_2O$ terms - we didn't balance these properly in the original reactions anyway).

A. What is the Gibbs free energy of the coupled reaction?
B. Is this reaction spontaneous or non-spontaneous?

**14)** We know that glycolysis directly produces 2 ATP (net). The enzyme that catalyses the formation of ATP in the final step of glycolysis is called pyruvate kinase. This facilitates the transfer of a phosphate group from phosphoenolpyruvate (PEP) to ADP in the combined reaction:

$$\text{PEP} + \text{ADP} \rightarrow \text{pyruvate} + \text{ATP}$$

A. This reaction results from coupling a reaction involving PEP, pyruvate and P to the phosphorylation of ADP to ATP. Write down the two component reactions you think are involved.
B. What do you think the $\Delta G$ of the reaction involving the phosphorylation of ADP to ATP is? (Hint: see previous question for a start, but remember to take into account the reaction direction).
C. If the Gibbs free energy of the reaction involving the PEP $\rightarrow$ ? reaction (you determined/guessed the details of this in A) is $\Delta G$ = -62kJ/mol, what is the $\Delta G$ of the overall reaction?
D. Is this reaction spontaneous or non-spontaneous? Exergonic or endergonic?

**15)** The Gibbs free energy provides the 'potential energy' to drive chemical reactions. Describe, using a labelled diagram, the role played by *enzymes* in biochemical reactions. Do these affect the overall change in Gibbs free energy of a reaction?

**16)** Sketch figures illustrating how you would expect A) substrate concentration and B) enzyme concentration to affect enzyme-mediated (i.e. enzyme assisted) reactions.

**17)** List how many ATP are produced in each of the key stages of cellular respiration (name the stages too!).

**18)** Which ONE of the following statements is FALSE with regard to the electron transport chain?

A. The electron transport chain occurs along the inner wall of the mitochondria
B. ATP Synthase uses the energy of the hydrogen ion gradient to generate ATP from ADP
C. Electrons are accepted by $NAD^+$ at the end of the transport chain
D. Potential energy stored in the hydrogen ion gradient is released when the hydrogen ions re-enter the mitochondria
E. The high energy electrons carried in NADH and $FADH_2$ are passed from molecule to molecule in the electron transport chain in a series of redox reactions

**19)** Which of the following TWO statements about cellular respiration are TRUE?

A. Glucose is oxidised during cellular respiration.
B. Fermenting yeast cells produce lactic acid during bread making.
C. The Krebs Cycle produces the majority of the ATP by direct synthesis.
D. Glycolysis requires an initial input of energy to split glucose.

**20)** Choose the ONE TRUE statement about cellular respiration:

A. Most of the ATP from cellular respiration is produced by the electron transport chain.
B. Under standard conditions, nearly 100% of chemical energy in food molecules is converted into ATP to carry out cellular work.
C. When no oxygen is present, glycolysis cannot proceed.
D. Glucose is reduced in cellular respiration.