Entropy and Order (page 10)
1. (a) Entropy is the measure of disorder in an isolated system.
   (b) There is now a disordered state at equilibrium. All components are now thermodynamically 'equal'.
2. (a) They use energy derived from the sun or a food source to drive reactions that maintain order.
   (b) Entropy decreases by increasing the sucrose concentration inside the cell. This is done by increasing the entropy of the H^+ and the ATP. Overall entropy is increased.

Energy Inputs and Outputs (page 11)
1. **Photoautotrophs** are able to manufacture their own food from simple inorganic substances using the free energy in sunlight. **Chemoautotrophs** also manufacture their own food, but they use chemical energy to do so. The oxidation of simple inorganic molecules such as sulfide or ammonia provides the energy required to fix carbon. In contrast, **heterotrophs** cannot manufacture their own food. Their energy is obtained by consuming (feeding) on other organisms.
2. The heat comes from the process of cellular respiration.
3. Chemoautotrophs fill the primary producer role in a deep sea vent environment. They can be eaten by consumers or, if in a symbiotic relationship, the chemoautotrophs provide organic molecules which are absorbed by symbiotic hosts such as the tubeworm.
4. Although chemoautotrophic bacteria can use chemical energy to fix carbon they do this via oxidation and therefore require molecular oxygen which is provided by photosynthetic organisms on the and in the surface waters of the oceans. The animals that live off the bacteria also require oxygen for respiration.
5. (a) Waste products may contain energy rich molecules and undigested matter e.g. cellulose.
   (b) Some energy from the break down of glucose is lost as heat energy to the environment.

The Role of ATP in Cells (page 13)
1. ATP production occurs in the mitochondrion.
2. ATPase.
3. (a) ATP is required for the muscular activity involved in shivering (used to heat the body when it is cool). ATP is also required for sweating to occur (used to cool the body).
   (b) ATP hydrolysis provides the energy needed to move flagella in motile cells (e.g. a sperm cell).
4. (a) In the presence of the enzyme ATPase, ATP is hydrolyzed to produce ADP plus a free phosphate, releasing energy in the process.
   (b) Like a rechargeable battery, the ADP/ATP system toggles between a high energy and a low energy state. The addition of a phosphate to ADP recharges the molecule so that it can be used for cellular work.
5. Glucose (or pyruvate)
6. Solar energy
7. Food (plants and other animals).
8. The folded inner membrane of a mitochondrion greatly increases the surface area. This allows more ATPase molecules to occupy membrane and increases the ability to produce ATP.
9. Highly active cells require a lot of energy (ATP) to move. Therefore, they have large numbers of mitochondria so that enough ATP can be produced to meet their energy demands.
10. (a) More energy is required.
    (b) It is not possible to get more energy out than you have put in, therefore, the regeneration of ATP will cost more than 30.7 kJ.

Energy Transformation in Cells (page 15)
1. Heterotrophs (strictly chemoheterotrophs) derive energy for biosynthesis from an organic energy source (other living organisms, their dead remains, or their excreted/egested products). Photosynthetic autotrophs (photoautotrophs) derive energy for biosynthesis from light energy (e.g. sunlight, which is the inorganic energy source). Chemosynthetic autotrophs (chemoautotrophs) derive energy for biosynthesis from an inorganic chemical energy source (e.g. hydrogen sulfide gas from volcanic vents).
2. (a) At this depth there is no sunlight (it is filtered out after several hundred metres). Photosynthetic organisms require a source of sunlight.
   (b) Hydrogen sulfide.
   (c) They would die due to inability to respire.
   (d) Chemosynthetic autotrophs (chemoautotrophs).

ATP Production in Cells (page 16)
1. (a) Glycolysis: cytoplasm
   (b) Krebs cycle: matrix of mitochondria
   (c) Electron transport chain: cristae (inner membrane surface) of mitochondria.
2. The ATP generated in glycolysis and the Krebs cycle is generated by substrate level phosphorylation, i.e. transfer of a phosphate group directly from a substrate to ADP. In contrast, the ATP generated via the electron transport chain is through oxidative phosphorylation, a step-wise series of reduction-oxidation reactions that provide the energy for forming ATP. Oxidative phosphorylation yields much more ATP per glucose than substrate level phosphorylation.

The Biochemistry of Respiration (page 17)
1. (a) The breakdown of glucose (a 6-C sugar) into two molecules of pyruvate (a 3-C acid) in the cytoplasm. The process is anaerobic and generates a net two molecules of ATP.
   (b) When oxygen is present, pyruvate enters the matrix of the mitochondria and CO_2 is removed. Coenzyme A (CoA) picks up the remaining 2-C fragment of pyruvate to form acetyl coenzyme A.
   (c) The acetyl group passes into a cyclic reaction (also in the matrix) combining a 4-C molecule into a 6-C molecule and releasing the CoA for reuse. CO_2 is removed and two molecules of ATP are made.
   (d) Comprises a series of reactions involving H^+ and e- along the membranes of the cristae in the mitochondria. H^+ and e- lose energy along the chain which is used to produce ATP molecules.

2. For maximum theoretical yield:
   (a) Glycolysis: 2 ATPs
   (b) Krebs cycle: 2 ATPs
   (c) Electron transport chain: 34 ATPs
   (d) Total produced: 38 ATPs

3. Released as carbon dioxide gas and breathed out through gas exchange surfaces.

4. (a) Hydrogen atoms supply energy in the form of high energy electrons. These are passed along the electron transport chain, losing energy as they go which is used to generate ATP.
   (b) NAD and FAD are hydrogen acceptors, transporting hydrogens to the electron transport chain.
   (c) Oxygen is the final electron acceptor at the end of the electron transport chain.
   (d) Acetyl coenzyme A, formed from pyruvate in the transition reaction, enters the Krebs cycle where CoA is released and recycled.

5. When glucose is limiting for aerobic respiration, other organic molecules e.g. fats and ultimately even protein, can provide alternative respiratory substrates.

Chemiosmosis (page 19)

1. In chemiosmosis, ATP synthesis is coupled to electron transport and movement of hydrogen ions. Energy from the passage of electrons along the chain of electron carriers is used to pump protons (H^+), against their concentration gradient, into the intermembrane space, creating a high concentration of protons there. The protons return across the membrane down a concentration gradient via the enzyme complex, ATP synthase, which synthesizes the ATP.

2. Elevating the proton concentration outside the exposed inner mitochondrial membranes would result in their flowing down their concentration gradient via ATP synthase and generating ATP.

3. A suspension of isolated chloroplasts would become alkaline because protons would be removed from the medium as ATP was generated.

4. (a) By placing chloroplasts in an acid medium, the thylakoid interior was acidified. Transfer to an alkaline medium established a proton gradient from the thylakoid interior to the medium.
   (b) The protons could flow down the concentration gradient established, via ATP synthase, and generate ATP.

Anaerobic Pathways for ATP Production (page 20)

1. **Aerobic respiration** requires the presence of oxygen and produces a lot of useable energy (ATP). **Fermentation** does not require oxygen and uses an alternative H^+ acceptor. There is little useable energy produced (the only ATP generated is via glycolysis).

2. (a) 2 ÷ 38 x 100 = 5.3% efficiency
   (b) Only a small amount of the energy of a glucose molecule is released in anaerobic respiration. The remainder stays locked up in the molecule.

3. The build up of toxic products (ethanol or lactate) inhibits further metabolic activity.

Investigating Yeast Fermentation (page 21)

1. $C_6H_{12}O_6 \rightarrow C_2H_5OH + 2CO_2$

2. Calculated rate of CO_2 production, group 1:
   (a) None: 0 $cm^3 min^{-1}$ or 0 $cm^3 s^{-1}$
   (b) Glucose: 0.443 $cm^3 min^{-1}$ or 7.4×10^{-3} $cm^3 s^{-1}$
   (c) Maltose: 0.24 $cm^3 min^{-1}$ or 4.0×10^{-3} $cm^3 s^{-1}$
   (d) Sucrose: 0.191 $cm^3 min^{-1}$ or 3.2×10^{-3} $cm^3 s^{-1}$
   (e) Lactose: 0.029 $cm^3 min^{-1}$ or 4.8×10^{-4} $cm^3 s^{-1}$

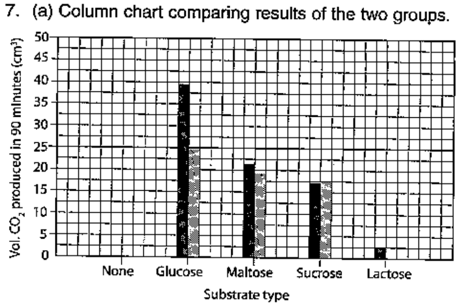
3. Calculated rate of CO_2 production, group 2:
   (a) None: 0 $cm^3 min^{-1}$ or 0 $cm^3 s^{-1}$
   (b) Glucose: 0.271 $cm^3 min^{-1}$ or 4.5×10^{-3} $cm^3 s^{-1}$
   (c) Maltose: 0.211 $cm^3 min^{-1}$ or 3.5×10^{-3} $cm^3 s^{-1}$
   (d) Sucrose: 0.194 $cm^3 min^{-1}$ or 3.2×10^{-3} $cm^3 s^{-1}$
   (e) Lactose: 0 $cm^3 min^{-1}$ or 0 $cm^3 s^{-1}$

4. The assumptions made are that 24°C and pH 4.5 provide suitable (even optimal) conditions for yeast fermentation. This is reasonable as it has been stated in the background that the literature cites warm, slightly acidic conditions as optimal for baker's yeast.

5. Graph of Group 1's results: see top of next page.

6. (a) The fermentation rates were greatest for the substrate glucose, with a CO_2 yield approximately twice that for maltose and sucrose. Maltose and sucrose were similar to each other, while the rate of fermentation on lactose was minimal.
   (b) Glucose is the preferred substrate (directly available as a fuel). Maltose (glucose-glucose) and sucrose (glucose-fructose) must first be hydrolyzed before the glucose is available (the fructose from sucrose must also be isomerized to glucose). This accounts for the lower fermentation rates on these substrates. Lactose is a poor fuel, presumably because yeast lack the enzyme to hydrolyze the galactose and glucose that form this disaccharide.

7. (a) Column chart comparing results of the two groups.



Chloroplasts (page 23)

1. (a) Stroma
   (b) Stroma lamellae
   (c) Outer membrane
   (d) Granum
   (e) Thylakoid
   (f) Inner membrane

2. (a) Chlorophyll is found in the thylakoid membrane.
   (b) Chlorophyll is a membrane-bound pigment found in and around the photosystems that embedded in the membranes. Light capture by chlorophyll is linked to electron transport in the light dependent reactions.

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