Butler, Brown, Stephenson & Speakman, *Animal Physiology*
Solutions to numerical exercises

Chapter 2

Question 2.1

(i) Three molecules of oxygen (O_2) are needed to oxidize one molecule of ethanol (C_2H_5OH) with the formation of two molecules of carbon dioxide (CO_2) and three molecules of water (total number of oxygen molecules (O_2) needed to oxidize one molecule of ethanol = 0.5 (total number of oxygen atoms in the products of reaction (2 CO_2 and 3 H_2O molecules) – number of oxygen atoms in one ethanol molecule) = 0.5 × (4 + 3 – 1) = 3:

$$C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$$

From the text of the question we know that +174 kJ is needed to break down one mol of ethanol into component elements (C, H, O) in their most stable states (C, H_2, O_2, respectively) at 25°C and 100 kPa. From Fig 2.4 we also know that the formation of one mol of CO_2 from 1 mol C and 1 mol O_2 liberates -394.5 kJ at 25°C and 100 kPa. Also from Fig 2.4 we know that the formation of one mol of H_2O from 1 mol H_2 and one half mol O_2 liberates -237 kJ at 25°C and 100 kPa. Therefore, the net amount of (Gibbs) energy liberated from the oxidation of one mol ethanol at 25°C and 100 kPa

= energy liberated from formation of 2 mol CO_2 and 3 mol H_2O from component elements at 25°C and 100 kPa minus energy absorbed for breaking down one mol ethanol into component elements at 25°C and 100 kPa

= 2 × (-394.5 kJ) + 3 (-237 kJ) + 174 kJ = -1326 kJ.

Since the Gibbs energy, or ΔG refers to energy that is released and/or absorbed from reactions that take place at same temperature and pressure and that ΔG is the same irrespective of whether the reaction takes place at a certain temperature and pressure in one step outside the body of an animal or in many steps as it happens in an animal's body, it follows that the aerobic oxidation of one ethanol molecule in the body of an animal at 25°C and 100 kPa will liberate **1326 kJ**.

(ii) According to Figure 2.4, one mol of glucose (180 g) produces 2878 kJ when oxidized at 25°C and 100 kPa in the presence of oxygen. Thus 1 g glucose will produce 2878/180 kJ = **16 kJ** when oxidized under these conditions.

In comparison, 1 g ethanol produces 1326/46 kJ = **28.8 kJ** when oxidized in the presence of oxygen under the same conditions since one mol of ethanol has a mass of 46 g and produces 1326 kJ as shown from the answer to the first part of question 2.1.
Thus, the aerobic oxidation of one gram of alcohol (ethanol) found in alcoholic drinks liberates 80% more energy than the aerobic oxidation of 1 g glucose.

Question 2.2

(i) From Equation 2.2 it follows that the aerobic degradation of one mol of glucose (180 g) produces 6 mol of water weighing 108 g (i.e 6 × 18 g = 108 g). Therefore, the oxidation of 18 g of glucose (i.e. 1/10 mol glucose) will produce **10.8 g water** (i.e. 108 g/10 = 10.8 g).

(ii) From Equation 2.3 it follows that the aerobic oxidation of one mol of stearic acid (284 g) produces 18 mol of water weighing 324 g (18 × 18 g = 324 g). Therefore, oxidation of 18 g stearic acid, which represents 18/324 mol = 0.056 mol, will produce 0.056 × 324 g = **18 g water**.

Question 2.4

Assuming that about the same amount of energy is produced when a certain amount of oxygen is used to oxidise either carbohydrates or fats (Table 2.1), it follows that if 1 mol of oxygen was used by the mammal, then 0.6 mol oxygen was consumed to oxidise carbohydrates (60% of 1 mol) and 0.4 mol O_2 was used to oxidise fats (40% of 1 mol).

Since the amount of CO_2 produced equals the amount of O_2 consumed × RQ, it follows that 0.6 mol CO_2 (0.6 mol × 1) is produced from the oxidation of the carbohydrates and 0.28 mol CO_2 (0.4 mol × 0.7 = 0.28 mol) is produced from the oxidation of the fats in the mammal. The steady state RER value (amount of CO_2 produced /amount of O_2 consumed) will then be (0.6 mol CO_2 + 0.28 mol CO_2)/ 1 mol O_2 = **0.88**.

Question 2.5

i) Using the allometric equation from Question 2.5, the RMR **values in J s^{-1}** (rounded to the first two significant figures) for the 50 g, 250 g and 1,000 g teleost fish are: **0.013** ($0.00055 \times 50^{0.8}$), **0.046** ($0.00055 \times 250^{0.8}$) and **0.14** ($0.00055 \times 1{,}000^{0.8}$), respectively. The mass-specific RMR values are obtained by dividing the RMR values by the respective body mass: 0.013 J s^{-1}/50 g = **0.26 mJ g^{-1} s^{-1}**; 0.046 J s^{-1}/250 g = **0.184 mJ g^{-1} s^{-1}** and 0.14 J s^{-1}/1000 g = **0.14 mJ g^{-1} s^{-1}. Notice that the mass-specific RMR values decrease with the increase in body mass.**

ii) The BMR of a 1 kg (1,000 g) mammal calculated from the corresponding allometric equation is 3.0 J s^{-1} ($0.018 \times 1{,}000^{0.74}$). This compares with the RMR value 0.14 J s^{-1} calculated above for a teleost fish of same body mass. Thus, **a fish weighing 1 kg needs, on average, 21 fold less energy (3.0 J s^{-1} / 0.14 J s^{-1}) than a mammal.**