Chapter 18

Question 18.9

As indicated in Section 18.1.5, the force produced by a skeletal muscle is directly proportional to the number of myofibrils that act in parallel to produce force, meaning that more myofibrils will be present in muscles (of same type) that have a larger cross-sectional area and, therefore, muscles of larger cross-sectional area will produce more force.

In contrast, the velocity of shortening of a skeletal muscle is proportional to the number of sarcomeres in series in the respective muscle, meaning that a longer muscle will have more sarcomeres in series and, therefore, will display faster shortening velocity than a shorter muscle of same type, as explained in Section 18.2.5. Also as explained in Section 18.5.2, the maximal power produced by skeletal muscles is proportional to the intrinsic shortening velocity between its actin and myosin filaments and the total mass of the muscle. This means that a faster muscle type (where the actin and myosin filaments slide past each other more quickly) has the capacity of producing more power than a slower muscle type (where the actin and myosin filaments slide past each other more slowly) of same mass; a heavier (larger mass) muscle will produce more power than a lighter (smaller mass) muscle of same type. With this in mind, the answers to the specific questions i) to iv) are:

(i) ***Force:*** **20 N** because the cross-section of the 20-cm-long muscle is the same (1 cm^2) as that of the 10-cm-long muscle used for comparison. ***Power:*** **4 W** because the mass (volume × muscle density) of the 20-cm-long muscle (20 cm × 1 cm^2 × muscle density) is twice the mass of the 10-cm-long muscle (10 cm × 1 cm^2 × muscle density) used for comparison.

(ii) ***Force:*** **10 N** because the cross-section of the 20-cm-long muscle is half (0.5 cm^2) that of the 10-cm-long muscle used for comparison. ***Power:*** **2 W** because the mass of the 20-cm-long muscle is the same (20 cm × 0.5 cm^2 × muscle density) as the mass of the 10-cm-long muscle (10 cm × 1 cm^2 × muscle density) used for comparison.

(iii) ***Force:*** **40 N** because the cross-section of the 5-cm-long muscle is twice (2 cm^2) that of the 10-cm-long muscle used for comparison. ***Power:*** **2 W** because the mass of the 5-cm-long muscle is the same (5 cm × 2 cm^2 × muscle density) as the mass of the 10-cm-long muscle (10 cm × 1 cm^2 × muscle density) used for comparison.

(iv) ***Force:*** **10 N** because the cross-section of the 10-cm-long muscle is half (0.5 cm^2) that of the 10-cm-long muscle used for comparison. ***Power:*** **1 W** because the mass of the 10-cm-long muscle is half (10 cm × 0.5 cm^2 × muscle density) that of the mass of the 10-cm-long muscle (10 cm × 1 cm^2 × muscle density) used for comparison.

The largest force is produced by the 5 cm long and 2 cm^2 cross-section muscle (iii) because it has the largest cross-sectional area of all other muscles considered. The greatest power is produced by the 20 cm long and 1 cm^2 cross-section muscle (i) because it has the largest mass.

Question 18.10

The distance travelled by the bird (in km) = Energy used for flying (in kJ) / Energy cost for flying of the 1 kg (in kJ km^{-1}) bird.

The energy used by the bird for flying is 200 g fat × Energy content per g fat

= 200 g × 35.5 kJ g^{-1}

= 7.1×10^6 J

= 7.1×10^3 kJ

The energy cost for flying of the 1 kg bird is

$16 \times (1000)^{-030}$ J g^{-1} km^{-1} × 1,000 g

= 16 × 0.126 × 1000 J km^{-1}

= 2.02 kJ km^{-1}.

Consequently, the **distance travelled by the bird was 7.1×10^3 kJ × (2.02 kJ $km^{-1})^{-1}$ = 3515 km**.

Question 18.11

Running distance (in km) = Energy available for running from the consumption of two slices of toast/ Energy cost for running of the 70 kg person (in kJ km^{-1}).

Energy available for running from the consumption of two slices toast is 90% of total 590 kJ energy content in the two slices of toast = 531 kJ.

The Energy cost for running of the 70 kg person is $120 \times (70{,}000)^{-0.32}$ J g^{-1} km^{-1} × 70,000 g = 120 × 0.02816 J g^{-1} km^{-1} × 70,000 g = 236.5 kJ km^{-1}.

Running distance necessary for ‘burning’ the energy gained from the consumption of the two slices of toast by an average 70 kg person is 531 kJ × (236.5 kJ $km^{-1})^{-1}$ = **2.25 km**.