Metabolism, RQ, and Power Problems[i]

Biology 390 -- Physiology

1. Calculate the RQ for the aerobic metabolism of ethanol, CH_3CH_2OH.

Balance the equation for complete oxidation of ethanol to water and CO_2: $C_2H_6O+3O_2 \text{----->} 2CO_2 +3H_2O$

$RQ = M_{CO2}$ / (obviously molar amounts can be used just as well as M_{O2} volumes since both are gases and 22.4 / 22.4 = 1)

thus, **RQ = 2/3 = 0.66**

2. Suppose that a migrating Monarch butterfly has a mass-specific oxygen consumption of 10 $mlO_2\ g^{-1}\ h^{-1}$ and it is <u>using stores of fat</u> as fuel since there are no flowers.

(a) Calculate its $\dot{V}_{CO_2}$.

Since the RQ for fat is about 0.71, then:

V_{CO_2} = 0.71*10 ml/(g*h)=**7.1ml CO_2 /(g*h)**

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(b) Calculate its mass-specific power (watts g^{-1}) (see table of RQ energy equivalents). *For the purpose of practice, I urge you to make the calculation using the Kcal equivalent of O_2, not the KJ equivalent.*

From the table, if RQ = 0.71, then 1 LO_2 = 4.69 Kcal or **1 ml = 4.69 cal** We need to convert ml O_2 /(g*h) to calories/(g*h) to watts. Thus:

V_{O_2} * cal/mlO_2 * joules / cal * h/s

10 mlO_2 /(gh) * 4.69 cal/mlO_2 * 4.184 J/cal * 1 h/ 3600 s

= **0.055 w/g (55 milliwatts/g)** *(rounded values)*

(c) Suppose that the costs of flight are always constant but that now the <u>Monarch is able to feed on flowers and its RQ shifts to 1.0</u>. What is its $\dot{V}_{O_2}$? $\dot{V}_{CO_2}$? (keep all of these mass specific). *For the purpose of practice, I urge you to make the calculation using the Kcal equivalent of O_2, not the KJ equivalent.*

This one is a bit tougher but it is simply the reverse of the last process. The main thing to keep in mind is that we learned the metabolic cost of flight in the last problem -- it is 0.055 w/g. This will not change when the fuel changes from fat to carb.

$\dot{V}_{O_2}$ in mlO_2/(g*h) at RQ =1: energy cost (w/g)*sec * s/h * cal/J / volume O_2 per cal so:

0.055 w/g (*i.e.*, J/(g*s)) * 3600s/h * 1 cal/ 4.184 J / 5.05 mlO_2/cal

3. A typical value of $\dot{V}_{O_2}$ for a resting adult human is 220 ml O_2 min^{-1}. Calculate her $\dot{M}_{O_2}$.

This one's a cinch -- just convert to mols. Let's assume that V_{O_2} is already

at STPD (that is how it is normally reported). So, 1 mol O_2 = 22.4 LO2:

M_{O_2} = 0.22LO_2 /min/22.4L/mol=**0.0098mlO_2 /minor9.8mmols/ min**

4. A running tarantula used a total amount of oxygen during its run of 22.4 ml O_2.
At the start of the exercise, it had a total body d-lactic acid concentration of 1 millimols; at the finish of exercise the total body lactate was 11 millimols.

To do this problem, assume that all hexose comes from glycogen. Look in the notes on anaerobic metabolism to find the net energetic yields of ~P for each process starting with glycogen.

How many total mols of ˜P were synthesized during the exercise?

The synthesized ATP is the sum of ~P synthesized in aerobic plus that synthesized in anaerobic metabolism.

Aerobic If we start from glycogen, we know that we conserve 37 mols of ~PinATPpermolofhexoseandweuse6molsofO_2 to do this(see aerobic metabolism notes). Thus, **for each mol of O_2 used, we get 37 / 6 = 6.17 mols ~P**.

Now, our spider used 22.4 ml O_2 in its run -- *i.e.* 0.0224 L O_2. Since there are 22.4 liters in a mol, then M_{O_2} **for the spider was 0.0224 / 22.4 = 0.001**

mols or 1 millimol.

Therefore, the total aerobic production of ~P is M_{O2} * mols~P / mols O_2 = 1 millimol O_2 * 6.17 millimols ~P/millimol O_2 = **6.17 millimols ~P**

Anaerobic: Starting with glycogen, we get 3 ~P per hexose and two molecules of lactic acid (see anaerobic metabolism notes). Put another way, 3/2 = 1.5 mols of ~P are made per mol of lactic acid that accumulates.

Total lactic acid accumulation is the difference between what we started with and finished at -- in this case 11 - 1 = 10 millimols.

Thus, 10 millimols lactate produced * 1.5 millimols ~P per millimol lactate produced**= 15 millimols ~P via anaerobic metabolism**

Total: anaerobic plus aerobic = 15 + 6.17 = 21.2 millimols of ~P

What proportion of this animal's exercise was fueled by anaerobic metabolism?

15 from anaerobic / 21.2 total **= 0.71 or 71% -- 2.4X more ~P was generated aerobically than**

anaerobically

How many mols of glucose were converted to lactate during the exercise?

Two lactates are produced per hexose (glucose) derived from the glycogen. Since 10 millimols of lactate accumulated, then **5 millimols of hexose were used**

How many mols of glucose were burned aerobically?

To do this problem, assume that all hexose comes from glycogen. Look in packet #3 to find the net energetic yields of ˜P for each process starting with glycogen.

One mol of glucose is oxidized by per 6 mols of O_2 -- that is, mols of glucose used = 1/6 * M_{O2}

M_{O2}(mols) = 0.0224 (L O_2) / 22.4 (L/mol) = 0.001 mols of O_2 used (see earlier problem)

Mols of hexose used = 0.001 / 6 = **0.17 millimols**

Thus, the total hexose used was 5.17 millimols (5 + 0.17). Notice that 5/5.17 = 97% of this hexose was used by anaerobic glycolysis even though it accounted for 70% of the ATP production! This is a useful demonstration of the energetic differences of the two processes.