The Energetics of Aerobic Metabolism[1]

Now it's time to try to figure out how much energy was conserved in ATP in aerobic metabolism. The first step is simply to add up all the ~P formed by various reactions or processes; in economics this would be the equivalent of a **gross output**. Then we subtract the ATP required to get things started (essentially the initial **cost or "investment"** in glycolysis). The **net** will then be the **gross minus the cost**.

We'll divide the sources of ~P according to the reactions where they were produced and **we'll express everything on a per hexose basis**. You should try to **fill in the numbers as we go along; an overall answer will be given at the end.**

Starting with one molecule of glucose:

1. Glycolysis:

(a) **COST** of Activation ______ ~P

(b) **GAINS**

(i) **Redox** (from NADH) -- per glucose there are _____ NADH produced these are oxidized in the ETS and yield __ or ___ ~P each for a total of _______ ~P from redox reactions

(ii) **Substrate Level phosphorylations** -- per 3 C fragment there are ___ substrate-level phosphorylations. This gives a total of _____ ~P from glycolysis substrate level phosphorylations starting with one glucose

(iii) **Subtotal GROSS GAIN from glycolysis _____ ~P**

(c) **NET GAIN IN ~P from Glycolysis ________ ~P**

2. Bridge Reaction

Each bridge reaction produces ____ pairs of high-energy electrons that are carried by _______ to the ETS. The number of ~P that result are _______. There are _______ substrate level phosphorylations for each bridge reaction for a total of ___ from bridge reaction substrate-level phosphorylations. The bridge reaction occurs ___ times for each glucose that entered respiration; there fore the **total number of ~P generated via the bridge reaction per glucose is _____.**

3. Krebs (citric acid) Cycle:

The Krebs cycle will turn ___ times per glucose that enters aerobic glycolysis.

So, per turn,

Redox: the number of NADH generated are _____, the number of $FADH_2$ generated are __ and the total number of ~P generated from all of these electrons (both those that went to NADH and $FADH_2$) is _______.

There are _____ substrate-level phosphorylations per turn of the Krebs cycle.

Total -- the sum of ~P generated per single turn via redox and substrate level phosphorylations are ________; therefore per glucose that entered respiration the total number of ~P generated via the Krebs cycle was ________ .

4. **Totals:** **Net from glycolysis (see above)** ________
Net from "bridge reaction" _________
Net from Krebs cycle ___________

Total ____________

You should have gotten **36 or 38** depending on what you assumed happened to the **glycolysis-produced NADH** (see last set of notes).

Net total of ~P from substrate-level phosphorylations _______
Net total of ~P from redox _________

How Much Energy Was Transferred from Glucose to ATP-- *i.e.*, How Much Energy Was *Conserved* in a Useful Form Instead of Lost as Heat?

To do this calculation, we need to know how much energy is released if mol of ATP is hydrolyzed to ADP and Pi. The amount depends in large part on how far the ratio of [ADP]*[Pi]/[ATP] is displaced from equilibrium. The further the reaction is displaced from equilibrium (*i.e.*, the more ATP relative to ADP and Pi) the more molecules that can be broken down per mol of ATP present at the start of the reaction.

Under what are called standard conditions where the concentrations of ATP, ADP, and Pi are all 1 Molal and the temperature is $20^{o}C$, at one atmosphere of pressure and a *p*H of 7 (whew!) then:

1. ATP + H_2O ---------> ADP + Pi - 7.3 Kcal

However, these are far different from cellular conditions where the concentration of ATP is typically 10X that of ADP. Under cellular conditions, more ATP would break down before equilibrium is reached and so more energy is released:

2. ATP + H_2O ---------> ADP + Pi - 10.7 Kcal

We'll do the calculation with both of these measurements.

So, the total amount of energy conserved in ~P will equal the total number of mols of ~P produced times the energy yielded when that mol of compound is allowed to react to equilibrium. Let's figure that per glucose there are 36 mols of ~P produced (nearly all as ATP from ADP and Pi). Thus:

2a. Energy Conserved -- Standard Conditions = 36 ~P * 7.3 Kcal/mol ~P
= 262.8 Kcal

2b. Energy Conserved -- Normal Cell Conditions = 36 ~P * 10.7 Kcal/mol ~P
= 385.2 Kcal