Problem Set #1 Key - *Fermentations*

*Problem set is due at the beginning of class, Tuesday 16 September 2004.*

**Problem 1**

Consider a balanced, **mixed-acid** fermentation of the compound Nonositone (see pathway below), a 9-carbon compound that is degraded after activation by ATP by the NonK enzyme, and a substrate-level phosphorylation performed by a transketolase yielding 1 glucose-6-P and 1 dihydroxyacetone-P. For this question, discount all electron flow and use of carbon compounds for biosynthetic purposes.

**A.** For 1 mole of nonositone, predict the amounts of each carbon-containing product you expect to be produced (including moles of ATP) for a balanced fermentation performed at **pH 6.5**.

Excrete ethanol to balance NAD\(^+\) pools; make acetate to increase ATP yield.

Nonositone + 2 ATP + Pi + 2 NADH + 2 H\(^+\) → 3 Glyceraldehyde-3-P + 2 NAD\(^+\)
3 Glyceraldehyde-3-P + 3 Pi + 3 NAD\(^+\) + 6 ADP → 3 Pyruvate + 6 ATP + 3 NADH + 3 H\(^+\)
3 Pyruvate 3 HS-CoA → 3 Acetyl-CoA + 3 Formate
½ Acetyl-CoA + ½ NADH + ½ H\(^+\) → ½ Acetylaldehyde + ½ HSCoA
½ Acetylaldehyde + ½ NADH + ½ H\(^+\) → ½ Ethanol
2 ½ Acetyl-CoA + 2 ½ Pi → 2 ½ Acetyl-P + 2 ½ HS-CoA
2 ½ Acetyl-P + 2 ½ ADP → 2 ½ Acetate + 2 ½ ATP

Nonositone + 6 ½ ADP + 6 ½ Pi → 3 Formate + ½ Ethanol + 2 ½ Acetate + 6 ½ ATP

**B.** For 1 mole of nonositone, predict the amounts of each carbon-containing product you expect to be produced (including moles of ATP) for a balanced fermentation performed at **pH 4.0**.

Excrete ethanol to balance NAD\(^+\) pools. Can not make acetate at low pH; can not make ethanol or lactate or succinate since this would unbalance NAD\(^+\) pools. Since pKa of pyruvate is lower than 4.0, it may be excreted.

Nonositone + 2 ATP + Pi + 2 NADH + 2 H\(^+\) → 3 Glyceraldehyde-3-P + 2 NAD\(^+\)
3 Glyceraldehyde-3-P + 3 Pi + 3 NAD\(^+\) + 6 ADP → 3 Pyruvate + 6 ATP + 3 NADH + 3 H\(^+\)
½ Pyruvate ½ HS-CoA → ½ Acetyl-CoA + ½ Formate
½ Acetyl-CoA + ½ NADH + ½ H\(^+\) → ½ Acetylaldehyde + ½ HSCoA
½ Acetylaldehyde + ½ NADH + ½ H\(^+\) → ½ Ethanol

Nonositone + 4 ADP + 4 Pi → ½ Formate + ½ Ethanol + 2 ½ Pyruvate + 4 ATP

It is possible to use lactate, although this is not **required** at low pH; it is merely possible.

Nonositone + 2 ATP + Pi + 2 NADH + 2 H\(^+\) → 3 Glyceraldehyde-3-P + 2 NAD\(^+\)
3 Glyceraldehyde-3-P + 3 Pi + 3 NAD\(^+\) + 6 ADP → 3 Pyruvate + 6 ATP + 3 NADH + 3 H\(^+\)
1 Pyruvate + 1 NADH + 1 H\(^+\) → 1 Lactate

Nonositone + 4 ADP + 4 Pi → 1 Lactate + 2 Pyruvate + 4 ATP
Problem 2

Consider an ethanol fermentation of nonositone, as would be performed by yeast. Predict what products would be formed. Comment on any virtues or difficulties regarding this fermentation when compared to the mixed-acid fermentation detailed above.

In contrast to the mixed acid fermentation, 1 mole pyruvate is consumed to balance the NAD⁺ pools. More ethanol cannot be made and the pyruvate must be excreted. One may conclude that yeast are less flexible in what carbon sources they can use efficiently, since a mixed acid fermentation at most pH’s provide a greater energetic yield.

Nonositone + 2 ATP + Pi + 2 NADH + 2 H⁺ → 3 Glyceraldehyde-3-P + 2 NAD⁺
3 Glyceraldehyde-3-P + 3 Pi + 3 NAD⁺ + 6 ADP → 3 Pyruvate + 6 ATP + 3 NADH + 3 H⁺
1 Pyruvate → 1 Acetylaldehyde + 1 CO₂
1 Acetylaldehyde + 1 NADH + 1 H⁺ → ½ Ethanol

Nonositone + 4 ADP + 4 Pi → 1 CO₂ + 1 Ethanol + 2 Pyruvate + 4 ATP