10.442/542
BIOCHEMICAL ENGINEERING
PROBLEM SET NO. 1
Due February 10, 2000

1.Assume that a microorganism has the following composition (wt. % - dry basis):
C - 47%, H - 6.5%, O - 31%, N - 10%
and that all of the available carbon-energy source is converted into cell mass, carbon dioxide, and water:

a.) Calculate the amount of O_2 required (grams) and the heat evolved (Kcal) per 100 g of cell mass synthesized (dry basis) from the following substrates. Use ammonia as the nitrogen source. Typical aerobic cell yield values (gram dry cell mass/ gram substrate) are : glucose - 0.45, hexadecane - 0.9, methanol - 0.4:

b.) What is the effect on the cell yield of replacing ammonia with nitrate as the nitrogen source when glucose is the carbon source?

c.) Plot the sensitivity of oxygen demand and heat evolution to yield on glucose.

Hint: this is a great spreadsheet problem.

2. Design a growth mediium for the cultivation of Saccharomyces cerevesiae (yeast) tht will allow the cells to reach a final concentration of 70 g/L. This strain of yeast requires the amino acid lysine and the vitamin biotin for growth. Please state your assumptioons.

3. It has been demonstrated that a *Rhodococcus* species grown with glycerol ($C_3H_8O_3$) as a carbon source in a mineral salts medium can be used as a catalyst to oxidatively remove sulfur from dibenzothiophene (DBT - $C_{12}H_8S$). This desulfurization reaction leads to the formation of hydroxybiphenol ($C_{12}H_9O$) and sulfate (SO_4^{-2}). An approach to using this biocatalyst is to grow the cells in a batch reactor, harvest the cells by centrifugation and then resuspend the cells in a well-mixed batch reactor containing a suspension of water insoluble Hexadecane/DBT in water. Please calculate the following and as always, clearly state your assumptions:

a.) If the innoculum to the batch fermentor has an optical density of 20 O.D. units (at 660 nm) and a specific growth rate of 0.4 h^{-1}, how long will the fermentation take to reach a final cell concentration of 20 g/liter? Assume the innoculum provides an initial OD of 0.5 units.

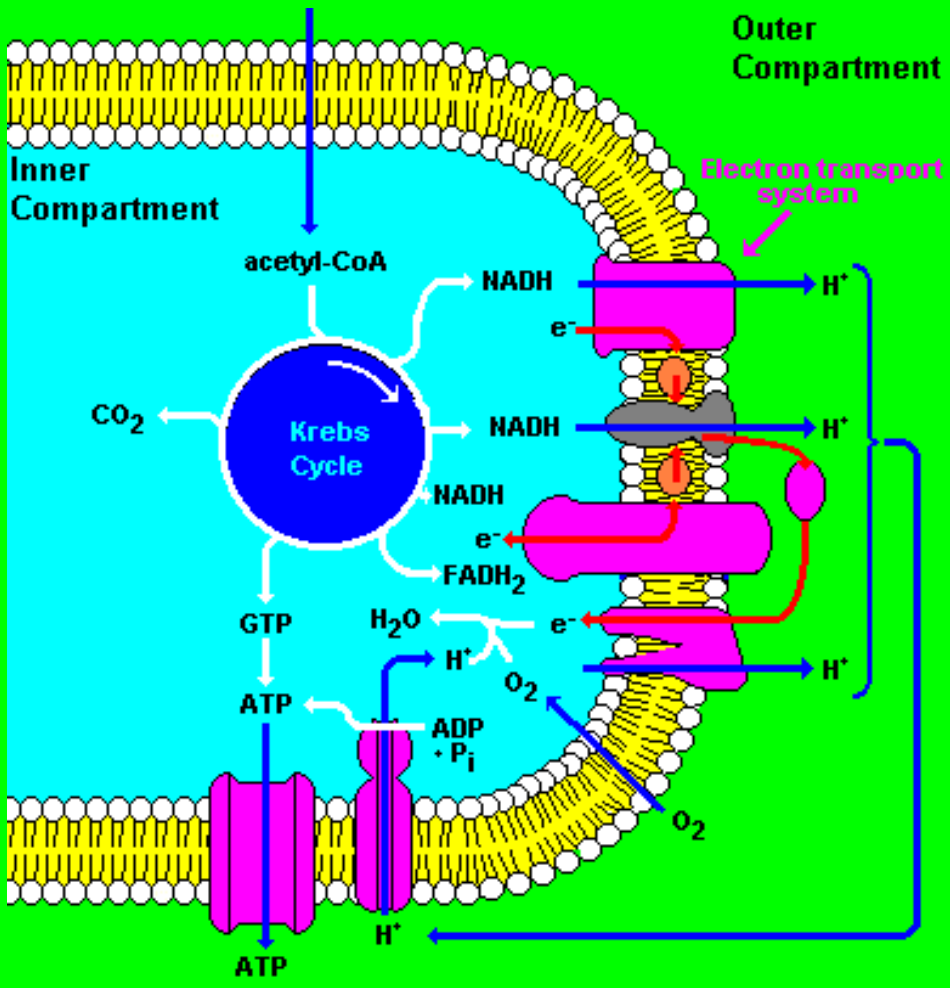
b.) What will be the maximum oxygen uptake rate and when will it occur?

c.) The conversion of hydroxybiphenol (HBP) from dibenzothiophene (DBT, $C_{12}H_8S$) requires oxygen. If the specific rate of DBT conversion is 50 mg DBT per gram cell per hour, then what is the expected specific oxygen demand?

d.) After fermentation, the cells are harvested by centrifugation. The resulting slurry is mixed with hexadecane containing 15% by weight DBT. Both DBT and hexadecane ($C_{16}H_{34}$) are insoluble in water. The phase ratio of the resulting mixture of cell slurry and hexadecane/DBT is 1 to 4. Estimate the maximum expected rate of DBT conversion and be sure to state all assumptions.

Diagram of Electron Transport Portion of Energy Metabolism

Within the Mitochondrial Inner Membranes



Animation of electron transport from U. Connecticut.

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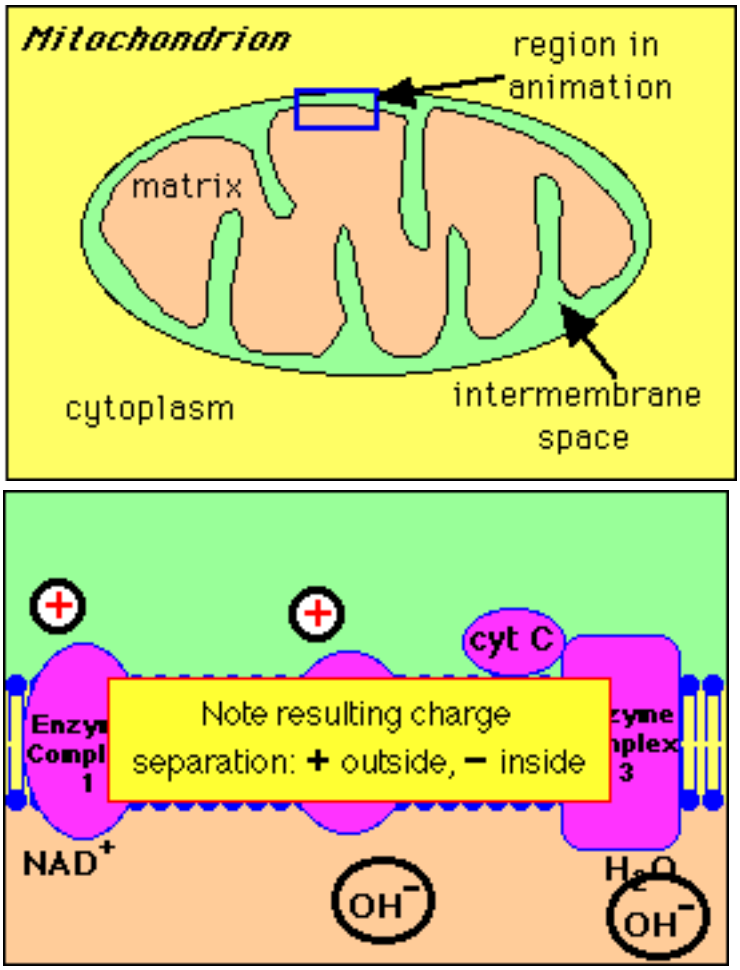
Animation of Electron transport in Mitochondria



Go to Animation of ATP synthesis in Mitochondria

The schematic diagram above illustrates a mitochondrion. In the animation, watch as NADH transfers H^+ ions and electrons into the electron transport system.

Key points:

1. **Protons** are translocated **across** the membrane, from the matrix to the intermembrane space
2. **Electrons** are transported **along** the membrane, through a series of protein carriers
3. **Oxygen** is the **terminal electron acceptor**, combining with electrons and H^+ ions to produce **water**
4. As NADH delivers more H^+ and electrons into the ETS, the **proton gradient increases**, with H^+ building up outside the inner mitochondrial membrane, and OH^- inside the membrane.

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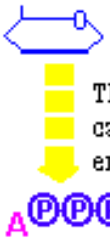
An Overview of Cellular Energy Metabolism

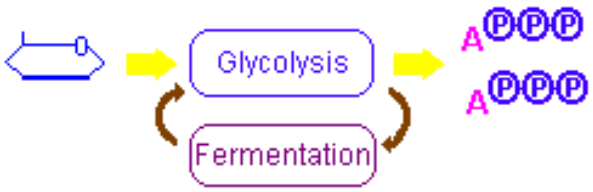
All organisms derive their chemical energy from molecules such as glucose



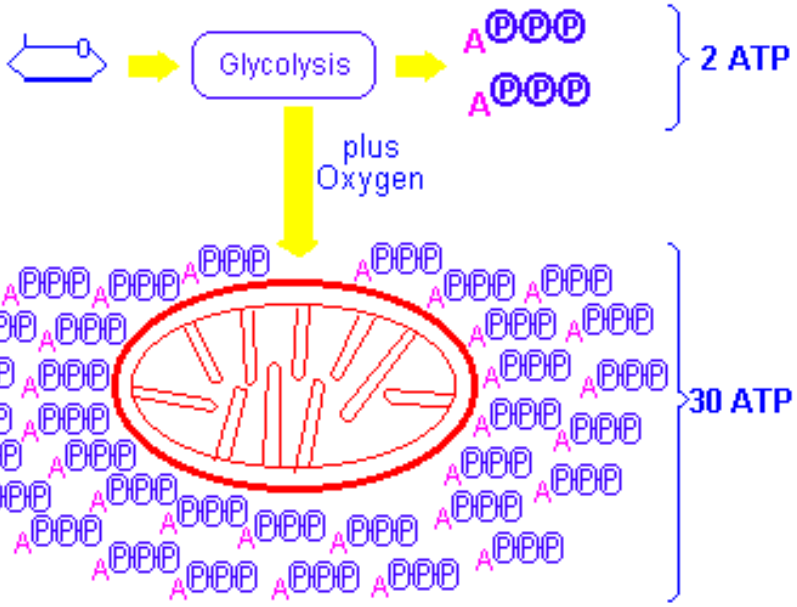
The cells of an organism break down glucose and capture the released energy in the form of high energy bonds in molecules such as ATP.

Glycolysis is the first step in the breakdown of glucose and results in the capture of two ATP molecules.

Glycolysis does not utilize oxygen to release energy from glucose but does require a process known as fermentation in order to recycle a required intermediate. When oxygen is limited, cells can derive energy from glycolysis and fermentation.



In the presence of oxygen, most cells have the ability to further metabolize the products of glycolysis producing carbon dioxide and water as the end products. This process of aerobic respiration can result in the production of an additional 30 molecules of ATP.



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BIOL 121: Human Biology Web Site

The Human Biology course as developed by Robert J. Huskey and Fred A. Diehl was not offered during the Fall Semester of 1999. Huskey was the teacher of record for the Human Biology course and the creator of the web site for the course. He was re-assigned for Fall, 1999, to teach the Introductory Biology course (BIOL 201) along with Reginald H. Garrett.

It is anticipated that Huskey will again be teaching Human Biology in the Fall Semester of 2000. A decision will be reached in the early part of 2000. Stay tuned for the Phoenix-like re-appearance of Human Biology.

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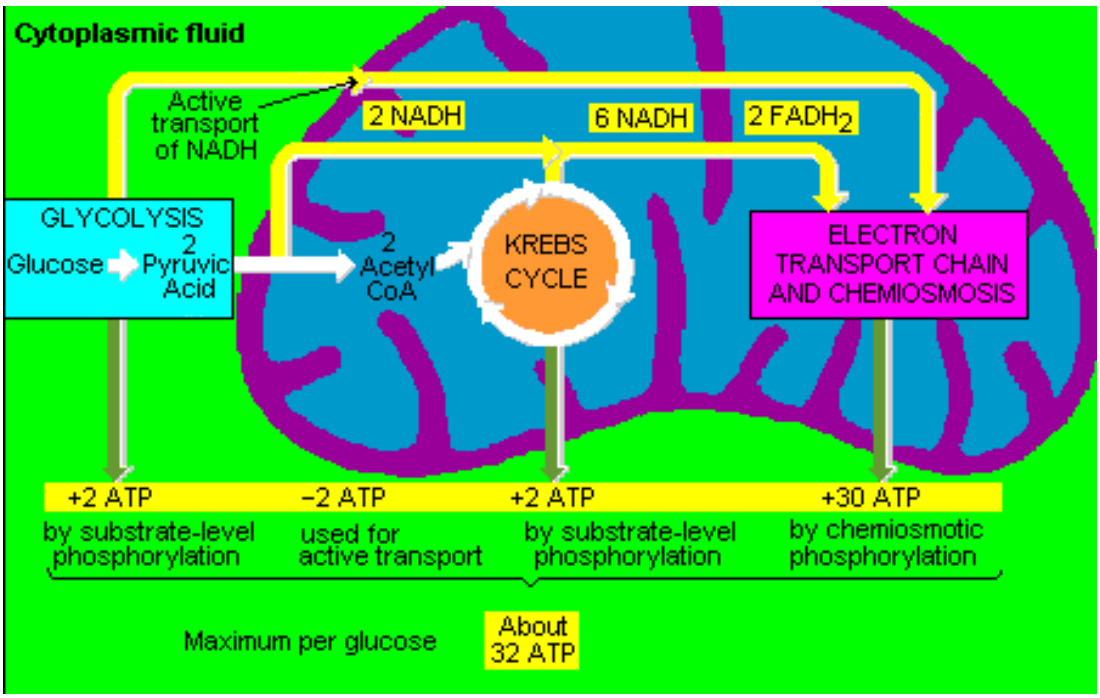
ATP Yield from Metabolism of Glucose



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