Physiological Dynamics in Animals and Plants - Lecture 4a - Cellular Respiration

I. The major catabolic process of cells is cellular respiration.

   A. Cellular respiration is common both to animals and plants.

   B. Cellular respiration and photosynthesis are complementary processes.

II. Cellular respiration is three connected processes: Kreb's cycle, electron transport, and oxidative phosphorylation (oxygen-dependent ATP synthesis).

   A. The fuel for cellular respiration can be carbohydrates, lipids, or proteins.

   B. Most cells use glucose as fuel; glucose must be partially degraded (catabolized) before it can be used in cellular respiration.

   C. Complete metabolism of glucose: Glucose + $O_2 \rightarrow CO_2$ + H_2O + energy

III. Pathways for the catabolism of glucose

   A. The first pathway discovered was glycolysis = the Embden-Meyerhoff pathway

      1. Conversion of glucose to lactate in anaerobic cells such as oxygen-deprived muscle cells.

   B. In anaerobic yeasts, glucose is converted to ethanol and CO_2.

   C. In aerobic cells, glucose is converted to CO_2 and H_2O through its connection to cellular respiration

   D. Glycolysis in anaerobic cells = fermentation.

IV. Characteristics of glycolysis

A. Occurs in the cytosol of eukaryotic, aerobic cells

B. Occurs in 2 stages: in the first stage ATP is consumed, in the second stage ATP is produced

C. Three types of chemical reactions occur during glycolysis: rearrangements of carbon skeletons; phosphate transfers; oxidation-reduction reactions

D. The 6-carbon molecule, glucose, is converted to two copies of the 3-carbon molecule pyruvate (pyruvic acid).

E. Per glucose molecule, glycolysis uses 2 ATP in stage I and produces 4 ATP molecules in stage II for a net gain of 2 ATP molecules per glucose.

F. There is one oxidation-reduction reaction in glycolysis in which 2 molecules of NAD^+ are reduced to 2 molecules of NADH + H^+.

G. Overall, per glucose molecule, glycolysis yields 2 pyruvate molecules, 2 NADH molecules, and 2 ATP molecules.

H. Other sugars can be metabolized by glycolysis including fructose, maltose, lactose, and sucrose.

V. To begin cellular respiration there is a transition reaction by which pyruvate enters Krebs cycle.

A. The reaction takes place in the mitochondrion.

1. Pyruvate (3C) $\rightarrow$ CO_2 (1C) + acetyl functional group (2C) + e^-.

2. NAD^+ is reduced to NADH.

3. Acetyl group + coenzyme A = acetyl CoA → Krebs cycle

VI. Krebs cycle = tricarboxylic acid (TCA) cycle = citric acid cycle

A. Occurs in matrix of mitochondrion.

B. Three types of chemical reactions: rearrangement of carbon skeletons, phosphate transfer, and oxidation-reduction

C. Each 2-C acetyl fragment is converted to 2 x CO_2 which leaves cells

D. Electrons are removed from intermediates of Krebs are used to reduce the coenzymes, NAD^+ and FAD^+

E. One ATP is formed from each acetyl fragment.

F. Per pyruvate, a combination of the transition reaction and Krebs cycle yields 3 CO_2 molecules, 4 NADH, 1 $FADH_2$, and 1 ATP per pyruvate; twice those amounts per glucose.

VII. Electrons from NADH and $FADH_2$ are used to reduce a series of enzymes in a mitochondrial electron transport chain (ETC).

A. The ETC is located in the inner mitochondrial membrane.

B. The final (terminal) electron acceptor is O_2.

C. The first few enzymes of the ETC contain organic coenzymes (vitamin derivatives); the last few contain metal ions.

D. As electrons move through the ETC, H^+ accumulate in the space between the inner and outer mitochondrial membranes.

E. The difference in pH on the two sides of the inner mitochondrial membrane activates ATP synthase.

1. ADP + Pi ---→ ATP

2. ATP synthase has two components: F_o and F_1.

3. Proton-dependent ATP synthesis = chemiosmosis.

4. Oxygen-dependent ATP synthesis = oxidative phosphorylation.

F. NADH → e^- + O_2 = 3 ATP: $FADH_2$ → e^- + O_2 = 2 ATP

VIII. In bacteria, complete oxidation of one molecule of glucose yields 38 ATP; in animal and plant cells, complete oxidation of one glucose molecule yields 36 ATP.

IX. Fatty acids can be metabolized to acetyl CoA in the matrix of the mitochondrion; the pathway is called Knoop's beta oxidtion of fatty acids.

X. Carbon skeletons of amino acids can be metabolized through Krebs cycle as well.

XI. Metabolism is regulated by "energy charge."