Unit 6 Notes: Cellular Respiration

I. An Overview of Cell Respiration

A. Cell respiration is a decomposition pathway that provides energy (ATP) by oxidizing organic foods into CO_2 and H_2O.

1. In aerobic respiration, oxygen is the oxidizing agent that gets e^- from the decomposed food.

a. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy

b. One glucose releases more energy than is needed for a single reaction, so many ATP are formed instead.

2. Anaerobic respiration occurs without O_2, using a waste product, a N compound, or a S cmpd. instead.

a. The food is not fully decomposed so it does not release as much energy.

b. Many organisms can store the reduced, energy rich waste products for use later.

B. There are four main stages of aerobic respiration that take place in two parts of the cell.

1. Glycolysis (in cytoplasm) partially oxidizes glucose into two 3-C compounds, releasing a small amount of ATP.

2. The 3-C compounds enter mitochondria, lose a CO_2 (now 2-C) and are bound by coenzyme A.

3. Coenzyme A delivers the 2-C compounds to the Krebs cycle in the matrix of mitochondria.

a. The 2-C compounds are completely oxidized into CO_2.

b. The energy released is used to form some ATP and to reduce NAD^+ into NADH and FAD^+ into $FADH_2$.

4. Still in the mitochondria, NADH & $FADH_2$ drop off e^- and protons at an electron transport chain.

a. High energy e^- are used to actively transport H^+ ions across a membrane (diffusion for lots of ATP).

b. Oxygen accepts the e^- at the end of the e.t.c. and combines with hydrogen to form water.

c. Lack of oxygen as an e^- acceptor backs up (shuts down) both Krebs cycle and the e.t.c.

II. The Reactions of Respiration

A. Glycolysis begins both aerobic and anaerobic respiration.

1. Two enzymatic steps each use an ATP to modify glucose.

2. The 6C molecule now splits into 2 – 3C sugar phosphates. (PGAL may enter here; carbon skeletons available)

3. More enzymatic reactions partially oxidize the two sugar phosphates into two molecules of pyruvate (3C).

a. 2 NADH and 4 ATP are formed.

b. Net yield: 2 NADH and 2 ATP.

4. If sufficient O_2 is present, each pyruvate will go on to a mitochondrion.

5. Insufficient O_2 causes fermentation of pyruvate.

a. NAD^+ is needed for the ATP yielding steps of glycolysis to occur.

b. NADH reduces pyruvate into lactate, alcohol, or acetic acid (vinegar), providing the needed NAD^+.

B. Once inside a mitochondrion, pyruvate must be converted before any carbon is added to the Krebs cycle.

1. Enzymes cause pyruvate to release a molecule of CO_2, forming acetic acid (2C).

2. Acetic acid is oxidized (reducing NAD^+), forming acetate.

3. Coenzyme A binds to acetate (now acetyl-CoA) and delivers it to the Krebs cycle in the matrix.

C. The Krebs cycle completely oxidizes acetate.

1. CoA drops acetate off which is picked up by a 4C compound (oxaloacetate), forming the 6C compound citrate.

2. A series of enzymatic reactions form the following:

a. 2 CO_2

b. 3 NADH and 1 $FADH_2$

c. 1 ATP

3. 2 acetate from each glucose → double products above

4. The end of the Krebs cycle regenerates oxaloacetate.

D. The electron transport chains use NADH and $FADH_2$ to produce ATP.

1. Cytochromes (e^- transport proteins) imbedded in the inner mitochondrial membrane separate H atoms into protons (left in the matrix) and electrons.

2. As e^- are passed down the chain, the energy they release allows enzymes to actively transport protons. ⇑$[H^+]$

3. The H^+ diffuse through ATP synthetase → ATP.

4. Each NADH provides enough energy for 3 ATP while each $FADH_2$ yields 2 ATP.

5. O_2 is the final e- acceptor – if it is not available, the e.t.c. clogs up and will not operate.

E. Various species have varying needs for O_2.

1. Obligate aerobes (us included) can't survive long w/o O_2.

2. Obligate anaerobes use glycolysis and/or fermentation for all their energy needs (O_2 can be poisonous).

3. Facultative aerobes generally prefer to use aerobic resp., but can go for long periods of time w/ anaerobic resp.

III. Respiration and Cellular Activities

A. Fats and proteins may also be used to generate ATP.

1. When lipids are broken down, glycerol enters glycolysis while the fatty acids are converted into acetate.

a. Glycerol can contribute to anaerobic processes.

b. The fatty acids must have O_2 available to become oxidized in the Krebs cycle.

2. Before they are used for energy, proteins must be broken into amino acids and have the amine group removed.

a. NH_3 is formed and is usually converted to urea or uric acid before excretion from the body.

b. The resulting 4C (oxaloacetate) or 5C (ketogluterate) acids can enter the Krebs cycle.

B. Like glycolysis, compounds can be removed from the Krebs cycle to provide carbon skeletons for biosynthesis.

C. Many organisms use respiration for heat production.

1. Warm blooded animals release enough heat to keep their body temperature fairly stable.

2. Alternate respiration pathways in specialized mitochondria release more heat and less ATP than normal.

a. Brown fat (LOTS of mito's) can rapidly raise the temperature of hibernating, small, and/or hairless animals.

b. Some plants have an alternate e.t.c. branch which raises their temp. for producing odors (pollination) or melting snow.

D. The rate of respiration is controlled by supply and demand.

1. When energy demands are low, excess blood glucose is converted to glycogen or fat.

2. When demands are high, glycogen is broken down to supply blood glucose (fats and proteins may also be used, especially when glycogen supply runs low).