Microbiology Name: ___________________________

Glycolysis and Cellular Respiration Homework

The physiological processes of living cells involve complex sequences of chemical reactions, most of which are catalyzed by globular (and sometimes quaternary) protein molecules called ______________________________. The term ______________________________ is used to describe these chemical reactions, and includes both anabolism (building or synthesis reactions) and catabolism (breakdown reactions). Whenever chemical reactions occur, energy is exchanged, and according to the laws of thermodynamics, some energy is lost (escapes the organism). Heterotrophic microorganisms (fungi, protozoa and many prokaryotes) replace this lost energy by taking in and breaking down organic compounds (carbohydrates, proteins, lipids, etc.). The energy stored in these molecules does not drive metabolic processes directly, but is "captured" briefly in the form of small, high-energy, triphosphate molecules such as _________ (a single eukaryotic cell uses approximately two million of these molecules per second). Chemical reactions resulting in the formation of nucleoside triphosphate molecules are called ______________________________ reactions and are of two types in chemoheterotrophs as indicated below.

Since carbohydrates are the primary source of energy for many cells, the catabolism of carbohydrates is often used to demonstrate basic metabolism. Carbohydrates often enter cells as monosaccharides (most often glucose) because exoenzymes have been used to break down polysaccharides outside the cells. Glucose ($C_6H_{12}O_6$) can be completely catabolized to yield six molecules of carbon dioxide through a process called ____________________________________ ____. This process involves three stages or steps as described below. The catabolism of glucose to pyruvic acid with the associated production of two ATP molecules and the reduction of two NAD molecules can occur under either aerobic or anaerobic conditions and is called ______________________________. The two ATP molecules produced are the result of ________________________________ phosphorylation, which means the energy involved was released when the substrate molecules were being catabolized. Two types of enzymes involved in this metabolic pathway are ________________________ enzymes (that catalyze the transfer of phosphate groups between organic compounds), and ______________________________ enzymes (that catalyze reactions converting specific molecules into their chemical isomers). The pyruvic acid resulting from the above pathway can be further catabolized to carbon dioxide by entering into a cyclic series of chemical reactions known as the __________________ cycle (citric acid cycle or TCA cycle). During this series of reactions, carboxyl groups ($COOH^-$) are removed from various keto acids, resulting in the release of ______________________________________ (considered a metabolic waste product), and the reduction of NAD to NADH + H^+. NAD is a ____________________________, i.e., an organic "helper" molecule that can interact with an apoenzyme, forming a ______________________________ (the active form of a conjugated enzyme). There are four NAD molecules and one _________ molecule reduced during the catabolism of each pyruvic acid.

The coenzymes reduced just prior to and during the citric acid cycle have considerable amounts of potential energy stored within them. This energy is released (in stages) when the coenzymes pass their extra electrons to the ____ chain, a series of oxidation-reduction reactions involving membrane-bound proteins (mostly). The ATP produced in association with this last set of reactions is the result of _________________________________ phosphorylation. There are a maximum of ______ (#) ATP molecules produced for each NADH + H^+ oxidized via the ETC, and ______ (#) ATP molecules produced for each $FADH_2$ oxidized via the ETC. As electrons travel down the ETC, various integral proteins, most of which are ____________________________ (pigmented enzymes with iron prosthetic groups), transport hydrogen protons across membranes (the cristae of mitochondria or cell membranes) generating a concentration and electrical gradient known as the proton motive force.

When hydrogen ions pass back across these membranes (down their concentration and electrical gradients), they pass through an enzyme complex called _________ ___________________________, and provide the energy required to bind ADP with PO_4 generating ATP. The total number of ATP molecules generated during cellular respiration are formed in part through substrate-level phosphorylation reactions and in part by oxidative phosphorylation reactions. Eukaryotic organisms can generate a maximum of _______ (#) ATP molecules per glucose catabolized, while prokaryotic cells can generate a maximum of ________ (#) ATP per glucose catabolized. The primary reason for the difference is the location of glycolysis enzymes in eukaryotic organisms (outside the mitochondria). The coenzymes reduced in association with glycolysis cannot pass electrons directly to the ETC because they are outside a double-layer of membrane. Prokaryotic cells carry out all of these metabolic reactions within their cytoplasm, and they have ATP-synthase enzymes in their cell membranes. The last enzyme in the electron transport chain is called cytochrome c oxidase, and can pass electrons from cytochrome c enzymes (four of them) to molecular _____________________________. This final electron acceptor picks up four electrons and four hydrogen protons and forms two molecules of water. Without this final electron acceptor, the coenzymes required for glycolysis and the Krebs cycle could not be oxidized, ATP could not be made, and metabolism would stop (which is why respiratory organisms suffocate rather quickly under anaerobic conditions).

Many of the reactions involved in glucose catabolism are also involved in the catabolism of proteins and lipids as well as in the synthesis of these compounds. This is one reason why gaining an understanding of glucose metabolism is essential to understanding cellular function at the biochemical level.