

# Cellular energetics study guide

[Science](#), [Chemistry](#)



Cellular Energetics Study Guide 1. Overall Metabolism a. Oxidation — a molecule **LOSSES** hydrogen, energy is **RELEASED** b. Reduction — a molecule **GAINS** hydrogen, energy is **GAINED** and stored (the more reduced a molecule is, the more energy is stored in its **COVALENT BONDS**) \*\*\* Always occur in a coupled pair (**RED-OX**)\*\*\* c. Electron Carriers i. Oxidizing Agents: are **REDUCED** to **OXIDIZE** another molecule 1.  $\text{NAD}^+$  - oxidizes glucose to 2 pyruvate in glycolysis, oxidizes pyruvate to  $\text{CO}_2$  in the Krebs's cycle (gets reduced to  $\text{NADH}$ ) 2.  $\text{NADP}^+$  - oxidizes  $\text{H}_2\text{O}$  to  $\text{O}_2$  during the Light Dependent Reactions of photosynthesis, final electron acceptor from chlorophyll (PSI) (gets reduced to  $\text{NADPH}$ ) 3.  $\text{FAD}^+$  - oxidizes  $\text{NADH}$  to  $\text{NAD}$  during glycolysis and transported to the mitochondrion (gets reduced to  $\text{FADHs}$ ) ii. Reducing Agents: are **OXIDIZED** to **REDUCE** another molecule 4.  $\text{NADH}$  - reduces 2 pyruvate to 2 lactic acid in fermentation, reduces  $\text{O}_2$  during the respiratory chain (gets oxidized to  $\text{NAD}$ ) \***CANNOT** pass through the mitochondrion\* 5.  $\text{NADPH}$  - reduces  $\text{CO}_2$  to form carbohydrates (Calvin Cycle) in the Dark Reactions of photosynthesis (gets oxidized to  $\text{NADP}$ ) 6.  $\text{FADH}_2$  - reduces  $\text{O}_2$  during the respiratory chain (gets oxidized to  $\text{FAD}$ ) \***CAN** pass through the mitochondrion\* 2. Phosphorylation: Formation of ATP ( $\text{ADP} + \text{P} \rightarrow \text{ATP}$ ) d. Substrate-level: direct enzymatic transfer of a phosphate to ADP \* Only occurs during glycolysis when  $\text{O}_2$  is not needed to function \* Only a small amount of ATP is produced this way e. Electron Transfer /Chemiosmosis: the movement of protons ( $\text{H}^+$ ) down a concentration gradient through ATP synthase that can **HARNESS THE ENERGY OF THAT GRADIENT** (proton-motive force) to bond ADP and phosphate to create ATP through oxidative phosphorylation \* Occurs during the Light Dependent Reaction \* 90% of ATP

is produced this way 3. Photosynthesis f. Balanced Net Reaction:  $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$  g. Light Dependent Reaction — occurs on the thylakoid lumen iii. Photolysis — oxidation of  $\text{H}_2\text{O}$  to release electrons used to return PSII to ground state iv. NADP Reduction — NADP receives an electron from PSI as it passes through electron transfer chains, reducing it to  $\text{NADPH}^+$ . Electrons are passed from excited atoms that gain energy from a photon. v. ATP Synthesis — ATP is produced by chemiosmotic phosphorylation. Proton gradient (within the thylakoid interior) is made as electrons from photosystems are passed through proton pumps. h. Light Independent Reaction — occurs in the stroma vi.  $\text{CO}_2$  fixation:  $\text{RuBP} + \text{CO}_2 \rightarrow 2 \text{PGA}$  (a form that can be easily reduced). The reaction is catalyzed by RUBISCO. 7. In the presence of oxygen,  $\text{RuBP} + \text{O}_2 \rightarrow \text{Bad Sugar}$ ; process is called photorespiration. Plants overcome this by keeping a HIGH concentration of  $\text{CO}_2$ . Land plants must compromise opening the stroma to maintain high  $\text{CO}_2$  concentration with loss of  $\text{H}_2\text{O}$ . There are 2 additional adaptations that evolved: a. C-4 Pathway — formation of Oxaloacetate (C-4) from  $\text{CO}_2 + \text{PEP}$  (C-3). Occurs in outer cells (mesophyll). Calvin cycle occurs in inner cells only (closer to supply of  $\text{CO}_2$ , bundle sheath). b. CAM Pathway — like C-4, but fixation only occurs at night, when water loss is minimal. Found in desert plants, like cacti. vii. Calvin Cycle 8.  $\text{PGA}$  is reduced to  $\text{PGAL}$  using the products of the light dependent reaction,  $\text{NADPH}$  (oxidized) and  $\text{ATP}$  (provides energy) 9. One-sixth of the  $\text{PGAL}$  produced is used to create glucose for the cell to grow and repair. 10. Five-sixths of the  $\text{PGAL}$  is used to produce  $\text{RuBP}$ , completing the cycle (energy requiring). 4. Cellular Respiration i. Balanced Net Reaction:  $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$  j.

Glycolysis — occurs in the cytoplasm. All organisms carry out this process.

viii. Glucose is double phosphorylated by 2 ATP and broken up into two three carbon phosphorylated molecules called PGAL ix. Each PGAL is phosphorylated by a free phosphate and ADP to form Biphosphoglycerate (BPG) while NAD is reduced to NADH. x. Each BPG aides in Substrate Level Phosphorylation of two ADP's to form 2 ATP's. Water is released. The remaining 3 carbon molecule is pyruvate. k. Fermentation — when pyruvate is used to oxidize NADH to replenish NAD<sup>+</sup>. Only produces 2 ATP per glucose through glycolysis. Some organisms (anaerobic) do it exclusively. Occurs regularly in all cells, but products can build up when NAD supplied through reduction of pyruvate is not available. 2 Forms: xi. Alcoholic — produces ethanol and CO<sub>2</sub> from reduction of pyruvate. xii. Lactic acid — produces lactic acid from the reduction of pyruvate. l. Kreb's Cycle — NAD required to begin. Takes place in the matrix of the mitochondria or in the cytoplasm of prokaryotes. xiii. Pyruvate is oxidized to Acetyl CoA, Reduced by \_\_\_\_\_, Releases 1 NADH. xiv. Acetyl CoA is added to Oxaloacetate to form Citrate. xv. Citrate is broken down releasing 2 H<sub>2</sub>O and is oxidized 4x: by NAD<sup>+</sup> thrice and once by FAD<sup>+</sup>. One Substrate Level phosphorylation occurs producing ATP. Oxaloacetate is the product and continues the cycle by being added to the next available acetyl CoA. m. Electron Transport and Oxidative Phosphorylation — takes place on the cristae (inner mitochondrial) membrane. xvi. NADH and FADH<sub>2</sub>, products of Glycolysis and Krebs are oxidized by Q (molecule embedded in the membrane). Electrons are passed to cytochrome and protons are pumped into the proton pumps. xvii. The protons diffuse back through ATP synthase in a process called chemiosmosis.

The energy harnessed allows an oxidative phosphorylation of ATP. (3 for each NADH, 2 for each FADH<sub>2</sub>) xviii. Free protons in the matrix and the electrons accepted by E. T. C are passed to O<sub>2</sub>, which is reduced to water.

Stomata Allows gas exchange; since a lot of water can be lost, plants only open stomata for photosynthesis in daylight; at night they close to reduce loss of water. \*\*\*CAM plants keep their stomates closed during day and open at night\*\*\*

Mesophyll C-3 Plants: Calvin Cycle during day C-4 Plants: CO<sub>2</sub> combines with 3 carbon molecule PEP to form C-4 acid CAM Plants: stores CO<sub>2</sub> in organic compounds that are synthesized at night

Bundle sheath C-4 Plants: Calvin Cycle during day CAM Plants: Calvin Cycle during day

Thylakoid lumen Light dependent reactions Stroma Calvin Cycle/Light independent reactions Inner membrane E. T. C. Cytoplasm Glycolysis & Fermentation Matrix

Kreb's Cycle Diagrams (know following structures and what takes place there)