Study Guide Cellular Respiration

1. Cellular Respiration: Liberation of Energy by Oxidation of Food

2. Respiration and Photosynthesis: Photosynthesis uses CO₂ and H₂O molecules to form C₆H₁₂O₆ (glucose) and O₂. Respiration is just the opposite, it uses O₂ to breakdown glucose into CO₂ and H₂O. It results in chemical cycling in biosphere.

3. Respiration and Breathing: Respiration takes place in cells and need O₂ to breakdown food and release the waste matter CO₂. Breathing exchanges these gases between lungs and air.

4. Overall equation for cellular respiration is:
   \[ C₆H₁₂O₆ + O₂ \rightarrow 6CO₂ + 6H₂O + ATP \]

5. Glucose  Oxygen   Carbon Dioxide   Water   Energy

6. Redox reactions: reduction-oxidation reactions. The gain of electrons during a chemical reaction is called Reduction. The loss of electrons during a chemical reaction is called Oxidation. Glucose is oxidized to 6CO₂ and O₂ is reduced to 6H₂O during cellular respiration. Glucose loses electrons and H during cellular respiration and O₂ gains them.

Energy and Food

7. All living things need energy.

8. Some living things can make their food from CO₂ and H₂O – Producers (plants, algae)

9. Animals feeding on plants – herbivores (chipmunk)

10. Animals feeding on animals – Carnivores (lion)

11. Producers change solar energy to chemical energy of organic molecules – glucose, amino acids

12. Animals and also plants break chemical bonds of sugar molecules and make ATP. Use ATP for all cellular functions

4 Main Step of Cellular Respiration

13. Glycolysis: Glucose \( \rightarrow \) 2 Pyruvate + 2NADH + 2 ATP

14. Preparatory Step: Pyruvate \( \rightarrow \) Acetyl-CoA + CO₂ + NADH (no ATP)

15. Kreb’s Cycle: Acetyl-CoA \( \rightarrow \) CO₂ + NADH + FADH₂

16. Electron Transport Chain or Oxidative Phosphorylation: electrons of NADH + O₂ \( \rightarrow \) ATP + H₂O

17. Aerobic Harvest of energy: is the main source of energy for most organisms. It consists of more than 20 reactions (pathway). Each reaction (step) is controlled by a specific enzyme. It has 3 main parts, Glycolysis, Citric Acid Cycle and Electron Transport Chain.

   \[ \text{Glucose} + 6 \text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy} \]

18. Glycolysis: It takes place in cytosol. Glucose (6C) is broken down to 2 molecules of Pyruvate (3C).

19. Energy Investment

20. Glucose + 2 ATP \( \rightarrow \) P – 6C – P + 2 ADP

21. Energy Harvest

22. P – 6C – P \( \rightarrow \) 2X P – 3C

23. 2X P – 3C + 2 NAD + 2P \( \rightarrow \) 2X P – 3C – P + 2 NADH
24. \(2 \times P - 3C - P + 4 \text{ADP} \rightarrow 2 \times 3C \text{(Pyruvate)} + 4 \text{ATP}\)

25. **Overall Reaction** of Glycolysis:

26. \(\text{Glucose} + 2\text{NAD} + 2\text{ADP} \rightarrow 2 \text{Pyruvate} + 2\text{NADH} + 2 \text{ATP} + 2\text{H}_2\text{O}\)

27. During Glycolysis neither \(O_2\) used nor \(CO_2\) produced.

Fermentation: Anaerobic Harvest of Food Energy

28. **Fermentation**: is breakdown of Glucose in absence of \(O_2\). Glucose breaks down to 2 molecules of Pyruvic Acid. But Pyruvic Acid either changes into Lactic Acid (human muscles) or into Ethyl Alcohol (yeasts or bacteria). It yields much less energy because still many C – H bonds are present in products and Electron Transport Chain is not working.

29. **Fermentation in Human Muscle Cells**:

30. \(\text{Glucose} + 2 \text{NAD} \rightarrow 2 \text{Pyruvate} + 2 \text{ATP} + 2 \text{NADH} \rightarrow 2 \text{Lactic Acid} + 2 \text{NAD} \quad \text{OR}\)

31. \(\text{Glucose} \rightarrow 2 \text{Lactic Acids} + 2 \text{ATP}\)

32. **Fermentation in Microorganisms**:

33. \(\text{Glucose} + 2\text{NAD} \rightarrow 2 \text{Pyruvate} + 2\text{ATP} + 2 \text{NADH} \rightarrow 2 \text{Ethyl Alcohol} + 2 \text{CO}_2 \quad \text{OR}\)

34. \(\text{Glucose} + 2 \text{ADP} \rightarrow 2 \text{Ethyl Alcohol} + 2 \text{ATP}\)

Citric Acid Cycle or Kreb’s Cycle

35. **The Link Reaction**: Each of 2 Pyruvic Acid molecule must change to Acetic Acid (2C) which join CoA to form Acetyl CoA

36. \(\text{Pyruvic Acid (3C)} + \text{CoA} + \text{NAD} \rightarrow \text{Acetyl CoA (2C)} + \text{NADH} + \text{CO}_2\)

37. **Krebs Cycle or Citric Acid Cycle**: All the enzymes for Citric Acid Cycle are present in inner chamber of Mitochondria. It is a cyclic event that starts with a 4C acid. 2C Acetyl CoA joins 4C acid and forms 6C acid (Citric). Citric Acid in a series of steps loses 2C in 2 steps and changes back to same 4C acid. First formed acid is Citric Acid and at the end 4C acid is regenerated – so the name Citric Acid Cycle. It was discovered by Hans Kreb.

38. **Overall Reaction** of Krebs Cycle or Citric Acid Cycle:

39. \(\text{Acetyl CoA (2C)} + 3\text{NAD} + \text{FAD} + \text{ADP} \rightarrow 2 \text{CO}_2 + 3 \text{NADH} + \text{FADH}_2 + \text{ATP}\)

Electron Transport Chain: ATP Synthesis by Oxidative Phosphorylation

40. **Electron Transport Chain**: is a series of H-acceptors and electron-acceptors associated with the inner membrane of Mitochondria.

41. \(\text{NADH}\) passes its 2 electrons to first H-acceptor and 2 H+ are pumped out to outer chamber (in between 2 membranes) of mitochondria.

42. The remaining acceptors pump out two more H+ pairs to outer chamber by using energy of downhill moving electron pair. So 3 proton pairs are pumped by using the energy of 1 NADH. 3 H+ pairs or 1 NADH produce 3 ATP molecules.

43. \(\text{O}_2\) is the **ultimate acceptor** for electrons and H+. ETC and CAC cycle can continue to function only if oxygen is available.

44. \(\text{FADH}_2\) passes its electrons to 2nd acceptor and only two H+ pairs are pumped out. Hence only 2 ATP molecules are formed per \(\text{FADH}_2\).
ATP Synthesis: A 2-component system F0-F1 particle acts as ATP Synthase. H+ have higher concentration in outer chamber and return to inner chamber through F0-F1 particles which uses the energy of each pair of H+ to change ADP + P_i → ATP.

ATP’S Produced

46. Glycolysis: produces 2 ATP
47. Glucose → 2 Pyruvic Acids + 2ATP (direct synthesis) + 2 NADH
48. Link Reaction:
49. 2 Pyruvic Acids → 2 Acetyl Co A + 2 CO_2 + 2 NADH
50. Citric Acid Cycle: produces 2 ATP
51. 2 Acetyl Co A → 2 CO_2 + 2ATP (direct synthesis) + 6 NADH + 2 FADH2
52. Electron Transport Chain: produces about 34 ATP molecules indirectly by using the energy of electrons of H generated during glycolysis, link reaction, and citric acid cycle.
53. 10 NADH → 10 NAD + 30 ATP
54. 2 FADH_2 → 2 FAD + 4 ATP
55. Complete breakdown of 1 Glucose yields 38 ATP molecules.

Recap 1 Respiration

1. Pyruvate → Acetyl Co-A + CO_2 is ---------------
2. Glucose → 2Pyruvate + ATP + NADH is ------------
3. NADH + O_2 + ADP → ATP + H_2O is -------------
4. Acetyl CoA → CO_2 + ATP + NADH is ------------
5. CO_2 is produced in ---- and ------ (cellular respiration)
6. No ATP produced in ------ ------ (cellular respiration)
7. Total ATP gained by complete breakdown of 1 glucose --
8. Glycolysis operates in --------------- (part of cell)
9. ------, ------, and------- phases (cellular respiration) occur in mitochondria
10. ---- ------ is glucose (no O_2) → ethanol + CO_2 + ATP
11. In ---- ----- is glucose (no O_2) → Lactate + ATP