

Last name: ..... First name: .....

**Exam / Microbiology Bachelor's Degree**

**Module: Biochemistry of microorganisms**

**Question 1. Answer with true or false and correct the false sentences (3.75pts)**

1. The Entner-Doudoroff (ED) pathway produces: 2 ATP and 1 NADPH. **False**

**The Entner-Doudoroff (ED) pathway produces: 1 ATP, 1 NADH, and 1 NADPH**

2. Fermentation produces ATP only via substrate-level phosphorylation. **True**

3. Chemolithotrophic bacteria obtain energy by oxidizing organic compound. **False**  
**Chemolithotrophs use inorganic compounds (like NH<sub>3</sub>, H<sub>2</sub>S, Fe<sup>2+</sup>) as energy sources, not organic molecules.**

4. During Glycolysis, the enzyme aldolase produces two identical molecules of Glyceraldehyde. **False**  
**During glycolysis, aldolase splits fructose-1,6-bisphosphate into: glyceraldehyde-3-phosphate (G3P) and dihydroxyacetone phosphate (DHAP),**

5. Amino acid degradation in bacteria involves deamination as the main pathway. **False**

**Amino acid degradation in bacteria involves deamination and decarboxylation as the main pathways.**

**Question 2**

1. Cite and explain briefly the Characteristics of microbial metabolism? **(1.5 pts)**

1. Microbial metabolism includes all chemical reactions occurring inside microorganisms.
2. Microbes use different energy sources such as light or chemical compounds.
3. They may use CO<sub>2</sub> or organic matter as carbon sources.
4. Catabolism breaks down molecules to release energy and Anabolism uses energy to synthesize cellular components.
5. Metabolic reactions are controlled by specific enzymes. Microorganisms can grow in aerobic or anaerobic conditions.
6. Microbial metabolism is highly adaptable and produces various by-products like acids, gases, and alcohols.

1. Why does aerobic respiration produce more ATP than anaerobic respiration? **(1.5pts)**

Oxygen (O<sub>2</sub>) is the best electron acceptor because it has a **very high electron affinity**, meaning it strongly attracts electrons at the end of the electron transport chain. This strong attraction allows **efficient electron flow** through the electron transport chain, As electrons move, **protons (H<sup>+</sup>)** are pumped across the membrane, This creates a **large proton gradient**, The gradient drives **ATP synthase**, producing a high amount of ATP.

2. Why is ATP production in fermentation low? **(0.75pts)**

Because fermentation does not use the electron transport chain or oxidative phosphorylation.

3. Explain the relationship between NADH, proton gradient, and ATP synthesis ? **(2.5pts)**

This process is called **oxidative phosphorylation**: works in **three linked steps**: 1.NADH carries **high-energy electrons** from metabolic pathways (glycolysis, Krebs cycle) to the electron transport chain. 2.NADH donates electrons to the electron transport chain, As electrons move through protein complexes, energy is released, This energy is used to **pump H<sup>+</sup> ions across the membrane**, which creates a **proton gradient (electrochemical gradient)**. 3. **ATP synthesis**: Protons flow back through **ATP synthase**, this movement provides energy to convert: ADP + Pi → ATP.

4. A fatty acid with 16 carbons (palmitic acid type): how many acetyl-CoA molecules are produced during β-oxidation, **(0.75 pts)** and how many cycles occur? **(0.75pts)** Calculate the energy yield considering the acetyl-CoA produced ? **(3.5pts)**

**Number of acetyl-CoA ; palmitic acid:  $16 C = 2n$  means  $n = 16 / 2 = 8$  acetyl-CoA 0.75pts**

**Number of  $\beta$ -oxidation cycles (n-1) :  $8-1 = 7$  cycles. 0.75pts**

**3. Energy calculation :** We include BOTH:  $\beta$ -oxidation energy, Krebs cycle energy from acetyl-CoA

**A.  $\beta$ -oxidation energy :** Each cycle produces: (n-1) NADH =7, (n-1) FADH<sub>2</sub>=7 **0.5pts**

1 NADH = 3 ATP, 1 FADH<sub>2</sub> = 2 ATP **0.25pts**

**So : 7 NADH=  $7 \times 3 = 21$ ATP and 7 FADH<sub>2</sub>=  $2 \times 7 = 14$  ATP 0.5pts**

For 7 cycles:  $21+14=35$  ATP **0.25pts**

**B. Energy from acetyl-CoA (Krebs cycle)**

Each acetyl-CoA produces: 3 NADH = 9 ATP, 1 FADH<sub>2</sub> = 2 ATP, 1 GTP = 1 ATP **0.5pts**

Total: 12ATP per acetyl-CoA **0.25pts**

For 8 acetyl-CoA:  $8 \times 12 = 96$ ATP **0.25pts**

**C. Total ATP produced :  $35+96=131$  ATP 0.25pts**

**Activation cost :** Fatty acid activation consumes: 2 ATP **0.25pts**

**Total energy produced:  $131-1=130$  ATP (net) 0.5pts**

**4. a. Which fermentation pathway produces: Lactic acid , 2,3-butanediol, Mixed acids ? (0.75pts)**

**Lactic acid  $\rightarrow$  Lactic acid fermentation , 2,3-butanediol  $\rightarrow$  Butanediol (2,3-butanediol) fermentation , Mixed acids  $\rightarrow$  Mixed acid fermentation**

**b. Cite the main products and Give one example of bacteria for each fermentation type? (2.75pts)**

**1. Lactic acid fermentation : Main product:** Lactic acid (lactate), **Example bacteria:** *Lactobacillus acidophilus*

**2. 2,3-Butanediol fermentation : Main products:** 2,3-butanediol + CO<sub>2</sub> (and small amounts of ethanol/acetoin intermediates), **Example bacteria:** *Enterobacter cloacae*

**3. Mixed acid fermentation : Main products:** mixture of organic acids (lactate, acetate, succinate) + gases (H<sub>2</sub>, CO<sub>2</sub>) , **Example bacteria:** *Escherichia coli*

**c. Which pathway of glucose catabolism is utilized in bacteria that perform heterolactic fermentation? (0.5pts)**

**Pentose Phosphate Pathway (PPP).**