AP Bio FRQ Fridays

2015 #2

Cellular Respiration

NOTES

Hi!

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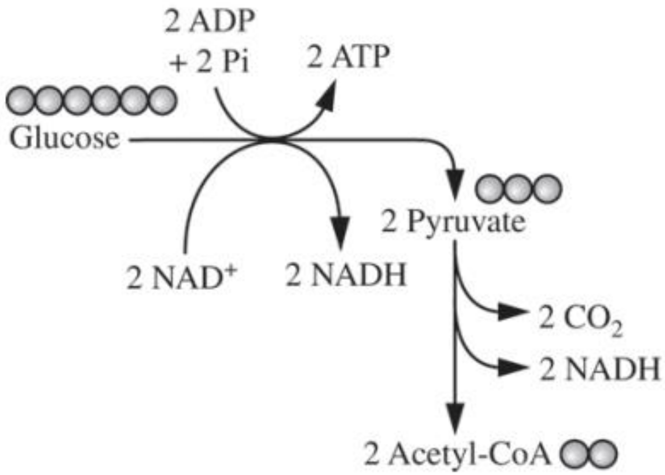

Figure 1. Glycolysis and pyruvate oxidation

SGs

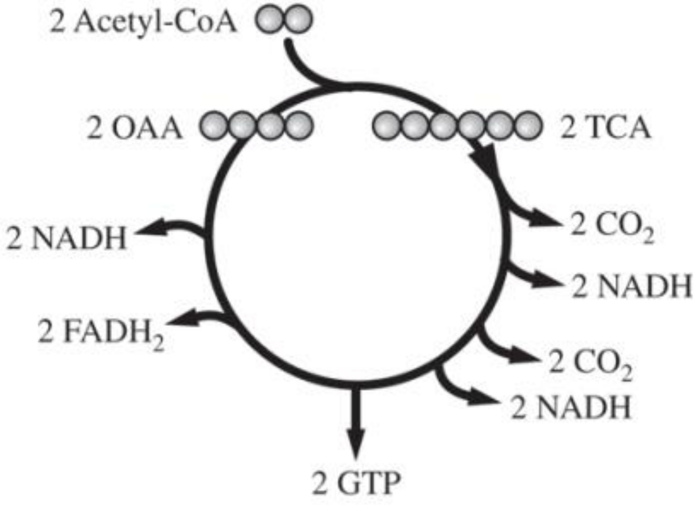

Figure 2. Krebs cycle

SGs

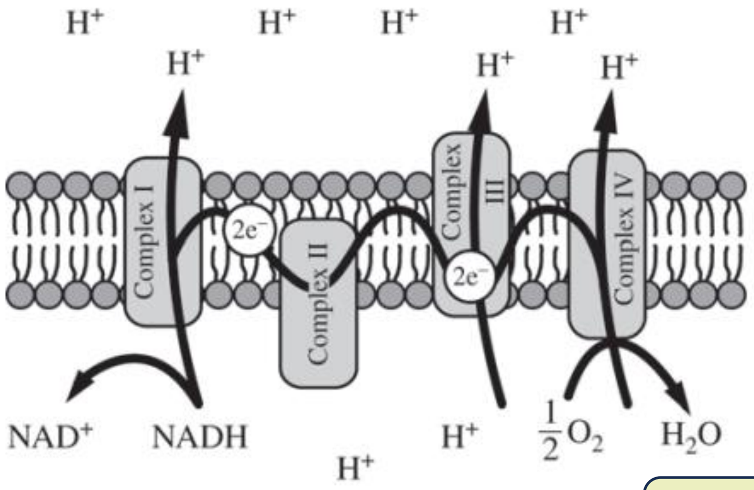

Figure 3. Electron transport chain

SGs

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Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

(a) Using the information above, **describe** ONE contribution of each of the following in ATP synthesis.

- Catabolism of glucose in glycolysis and pyruvate oxidation
- Oxidation of intermediates in the Krebs cycle
- Formation of a proton gradient by the electron transport chain

Step 1

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Step 2

Process	**Description (1 point each box; 3 points maximum)**
Catabolism of glucose in glycolysis and pyruvate oxidation	• Produces NADH for use in ETC • Produces acetyl-CoA for entry into Krebs cycle • Provides energy for (substrate level) phosphorylation of ADP

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Oxidation of intermediates in the Krebs cycle	• Produces NADH or FADH2 for use in ETC • Releases high energy electrons for use in ETC • Provides energy to pump protons against their concentration gradient • Produces GTP for (substrate level) phosphorylation of ADP

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Formation of a proton gradient by the electron transport chain	• The flow of protons through membrane-bound ATP synthase generates ATP • Provides energy for (oxidative) phosphorylation of ADP

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a) The catabolism of glucose provides the raw materials for the further stages of cellular respiration. First, NADH is produced for use as a proton donor in the electron transport chain. Second, oxidized pyruvate is provided for the Kreb's Cycle. The Kreb's Cycle produces NADH and $FADH_2$ which are necessary proton donors in the electron transport chain. The formation of a proton gradient in the electron transport chain uses energy from the previous processes to pump protons across the inner membrane. This is neccessary because the cell then harnesses the energy of this concentration gradient by using the H^+ ions to pass through the ATP Synthase molecules which creates ATP by pressing ADP and P_i together.

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(b) Use each of the following observations to **justify** the claim that glycolysis first occurred in a common ancestor of all living organisms.

- Nearly all existing organisms perform glycolysis.
- Glycolysis occurs under anaerobic conditions.
- Glycolysis occurs only in the cytosol.

Observation	**Justification (1 point each box; 3 points maximum)**
Nearly all existing organisms perform glycolysis	• Trait/gene/process originated early and was inherited/passed down/highly conserved • Glycolysis provided a selective advantage that was passed on to descendants
Glycolysis occurs under anaerobic conditions	Origin of glycolysis pre-dates free atmospheric oxygen/photosynthesis
Glycolysis occurs only in the cytosol	Origin of glycolysis pre-dates cell types with membrane-bound organelles/eukaryotes/endosymbiosis

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b) The fact that all organisms perform glycolysis is an example of a homologous cellular process and suggests all life are descended from one common ancestor capable of performing the reaction. Glycolysis occuring in anaerobic conditions is further evidence since the early Earth atmosphere had low concentrations of O_2 so the process had to be anaerobic. Finally, occuring in the cytoplasm is neccesary because the process had to be performed by a very simple organism lacking internal membrane structures.

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(c) A researcher estimates that, in a certain organism, the complete metabolism of glucose produces 30 molecules of ATP for each molecule of glucose. The energy released from the total oxidation of glucose under standard conditions is 686 kcal/mol. The energy released from the hydrolysis of ATP to ADP and inorganic phosphate under standard conditions is 7.3 kcal/mol. **Calculate** the amount of energy available from the hydrolysis of 30 moles of ATP. **Calculate** the efficiency of total ATP production from 1 mole of glucose in the organism. **Describe** what happens to the excess energy that is released from the metabolism of glucose.

	Calculation/description (1 point each box; 3 points maximum)
Calculate available energy in ATP	219 kcal
Calculate efficiency	0.31 - 0.32 or 31 - 32%
Describe fate of excess energy	Released as heat/increases entropy

c) Energy from hydrolysis of 30 mol ATP = 30 mol · 7.3 $\frac{kcal}{mol}$ = 219 kcal

1 mol glucose · 30 mol ATP/mol glucose = 30 mol ATP ⇒ 219 kcal

% Efficiency = 219 kcal / 686 kcal · 100% = 31.9%

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Calculate available energy in ATP	219 kcal
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Describe fate of excess energy	Released as heat/increases entropy

Excess energy is lost to the environment as heat.

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(d) The enzymes of the Krebs cycle function in the cytosol of bacteria, but among eukaryotes the enzymes function mostly in the mitochondria. **Pose** a scientific question that connects the subcellular location of the enzymes in the Krebs cycle to the evolution of eukaryotes.

Question (1 point)

- A valid scientific question related to evolution of eukaryotes (e.g., Since the Krebs cycle occurs in the "cytoplasm" of the mitochondria (matrix), does it suggest that mitochondria were once prokaryotes?)

d) Do mitochondria in modern eukaryotes descend from endocytosed prokaryotes that could perform the Kreb's Cycle?

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