

# Origins of Life (Summer 2022)

## 3.10 Exam - Unit 3 » Unit 3 Exam

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### Question 1

Which of the following are ways that life extracts energy from its environment?

- A. Using light to drive the transport of protons and electrons
  - B. Using a build-up of charge outside the cell to help couple chemical reactions
  - C. Preventing nutrients from entering the cell
  - D. A and B
  - E. A, B, and C
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### Question 2

When examining the binding energy of base pairs, the biggest difference between right and wrong pairs is 60-fold. Which piece of evidence indicates that the binding energies of base pairs alone is not sufficient to explain DNA's ability to replicate with such high fidelity?

- A. The flux of nutrients into a cell is limited by the background concentration
  - B. There are no other correction mechanisms in the cell
  - C. The mutation rate in DNA is  $10^{-10}$  errors/(rep\*base)
  - D. The structure of DNA is kinetically stable
  - E. Sugar molecules preferentially form D-sugars when interacting with L-amino acids
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### Question 3

Which of the following does NOT contribute to DNA's ability to replicate with such high fidelity?

- A. DNA polymerase controls pairing
  - B. There are a large number of specific and general repair enzymes
  - C. dNTP concentration is controlled
  - D. There are only four bases in DNA
  - E. The hydrogen bonds between base pairs (two between A and T; three between G and C)
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### Question 4

Why are other solvents, such as ammonia, not as favorable for life?

- A. Water is the only solvent that can form hydrogen bonds
- B. Water is the only solvent that can dissolve polar molecules
- C. Water is the only abundant solvent found on Earth
- D. Water is the only solvent with such a high entropy; the N-H hydrogen bonds in ammonia aren't as strong as the O-H hydrogen bonds in water
- E. Water is the only solvent with such low entropy; the N-H hydrogen bonds in ammonia are stronger than the O-H hydrogen bonds in water

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**Question 5**

How does water act as an organizing force in living systems?

- A. Water's hydrophobic effect causes the aggregation of lipid membranes
  - B. Water aggregates proteins into folded, catalytic structures
  - C. Hydrogen bonding allows water to interact strongly with nucleobases
  - D. A and B
  - E. A, B, and C
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**Question 6**

When looking for environments where life could emerge, what thermodynamic and kinetic conditions do researchers look for?

- A. All processes (e.g. production of biological building blocks, polymerization, folding) must be kinetically favorable and thermodynamically unfavorable
  - B. All processes (e.g. production of biological building blocks, polymerization, folding) must be thermodynamically favorable and kinetically unfavorable
  - C. Production of biological building blocks: thermodynamically favored  
Exploration of their sequence space: kinetically favored (i.e. polymerization)
  - D. Production of biological building blocks: kinetically favored  
Exploration of their sequence space: thermodynamically favored (i.e. polymerization)
  - E. All processes that led to life's emergence were thermodynamically and kinetically unfavorable
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**Question 7**

There are many different modifications that would allow for alternatives to the DNA we see in biological systems today. What is one chose the structure that it did?

- A. Other sugars are unable to support double helices and form base pairs
  - B. A-T and G-C base pairs are the only chemically viable pairs in our genetic code
  - C. There is only one configuration of phosphates that allows DNA to function
  - D. Prebiotic selection alone led to the formation of DNA we see today
  - E. None of the above
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**Question 8**

When exploring a new environment, which of the following would be the most compelling evidence that life is present?

- A. The presence of L-amino acids
- B. The presence of D-sugars
- C. An entity identical to LUCA
- D. Polymerized nucleic acids
- E. A lipid membrane

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**Question 9**

All of the building blocks of life – energy molecules, biopolymers (e.g. proteins, nucleic acids), and lipids – require what process in all systems?

- A. Horizontal gene transfer
  - B. Photosynthesis
  - C. Carbon fixation
  - D. Chemoautotrophy
  - E. Folding
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**Question 10**

Which of the following is an example of an electron transfer mechanism that may have been seen in prebiotic conditions?

- A. An iron sulfide layer in a hydrothermal vent through which electrons are transferred from a basic alkaline system to the acidic ocean
  - B. The transport of electrons driven by light, where water is the electron donor, and NADP accepts electrons
  - C. Aerobic respiration, where oxygen accepts electrons
  - D. Reduction of oxygen to water
  - E. None of the above
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**Question 11**

The metabolism of LUCA (Last Universal Common Ancestor) must have been able to do which of the following?

- A. Replicate DNA
  - B. Produce ATP
  - C. Function without proteins
  - D. A and B
  - E. A, B, and C
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**Question 12**

Consider a chemical reaction, where A is converted into B ( $A \rightarrow B$ ) and  $\Delta G$  is positive (+). Which reaction below could be coupled with reaction to make the overall process favorable, and what would be the summed reaction?

- A. Coupled with:  $X \rightarrow Y$ ;  $\Delta G = (-)$   
Summed reaction:  $A + X \leftrightarrow B + Y$
- B. Coupled with:  $X \rightarrow Y$ ;  $\Delta G = (-)$   
Summed reaction:  $A + B \leftrightarrow X + Y$
- C. Coupled with:  $X \rightarrow Y$ ;  $\Delta G = (+)$   
Summed reaction:  $A + X \leftrightarrow B + Y$
- D. Coupled with:  $X \rightarrow Y$ ;  $\Delta G = (+)$   
Summed reaction:  $A + B \leftrightarrow X + Y$
- E. It is not possible to make the process favorable

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**Question 13**

By creating charge separation across the membrane, cells are able to harvest energy to use for otherwise unfavorable processes. Which of the following is a way that living systems can create a charge difference between the exterior and interior of the cell?

- A. Pumping protons out of the cell
  - B. A redox loop moving electrons in and protons out of the cell
  - C. Consumption of protons inside the cell
  - D. A and B
  - E. A, B, and C
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**Question 14**

Many origins of life researchers investigate the process of encapsulation in a membrane. What do we know about encapsulation in cells?

- A. All known life today is encapsulated in a cell membrane
  - B. We know life cannot adaptively evolve or self-propagate without encapsulation
  - C. The first life to perform oxygenic photosynthesis was likely not encapsulated
  - D. The cell membrane is not important for harvesting energy in a cell
  - E. LUCA likely had a cell membrane without synthesizing lipids
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**Question 15**

Given the diffusion equation for the total flux into a cell ( $4\pi rD\Delta C$ ), what can we predict about the metabolic rate of cells of varying sizes?

- A. We would predict the same maximum rate of consumption regardless of cell size
  - B. Smaller cells have a higher maximum rate of nutrient consumption
  - C. Larger cells have a higher maximum rate of nutrient consumption
  - D. We can predict the minimum rate of nutrient consumption for all cell sizes
  - E. The flux of nutrients into a cell does not imply anything about the metabolic rate inside the cell
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**Question 16**

Which of the following can drive organization in living systems?

- A. The entropy of water
- B. Coupling of chemical reactions
- C. The kinetic stability of most proteins
- D. A and B
- E. A, B, and C

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**Question 17**

Which of the following may have emerged prebiotically?

- A. Carbon fixation on mineral surfaces
- B. The chirality of amino acids
- C. Chemoheterotrophy
- D. Aerobic respiration
- E. A and B