Origins of Life (Summer 2022)

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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

Question 2

When examining the binding energy of base pairs, the biggest difference between right and wrong pairs is 60-fold. Which piece of ev 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)

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 bonds 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

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

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

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

Question 9

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

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

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

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

Question 12

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

- A. Coupled with: $X \rightarrow Y$; ΔG=(-)

  Summed reaction: $A+X \leftrightarrow B+Y$
- B. Coupled with: $X \rightarrow Y$; ΔG=(-)

  Summed reaction: $A+B \leftrightarrow X+Y$
- C. Coupled with: $X \rightarrow Y$; ΔG=(+)

  Summed reaction: $A+X \leftrightarrow B+Y$
- D. Coupled with: $X \rightarrow Y$; ΔG=(+)

  Summed reaction: $A+B \leftrightarrow X+Y$
- E. It is not possible to make the process favorable

Question 13

By creating charge separation across the membrane, cells are able to harvest energy to use for otherwise unfavorable processes. W
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

Question 14

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

- 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 ($4\pi DaC\infty$), what can we predict about the metabolic rate of cells of varying si

- 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

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