

Instructions

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 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

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

Question 7

There are many different modifications that would allow for alternatives to the DNA we see in biological systems today. What is one reason life 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 all living 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 with this 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

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

Question 14

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

- 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

Question 15

Given the diffusion equation for the total flux into a cell ($4\pi r D C_{\infty}$), 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

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