Instructions

Question 1

The evolution of eukaryotes is interesting to study for a variety of reasons. What can single-celled eukaryotes do that prokaryotes can't?

- A. Eukaryotes are top predators and can engulf prokaryotic cells
- B. Eukaryotes can be symbiotic hosts (i.e. take in endosymbionts)
- C. Eukaryotes can enclose their cytoplasm in a cellular membrane
- D. Eukaryotes can perform photosynthesis
- E. A and B

Question 2

There are two main theories describing the formation of the nucleus. Which of the following would be the most helpful for determining which theory is correct?

- A. Constructing a phylogenetic tree with LECA as the outgroup
- B. Using in vitro evolution to re-create the origin of multicellularity
- C. The discovery of an intermediate between prokaryotes and eukaryotes (e.g. a transitional form in the fossil record)
- D. Using cellular automata to examine how global patterns emerge
- E. The discovery of a law for mammals that relates body size to to metabolic rate

Question 3

Eukaryotes can take in free-living cells and form a close relationship with them. Why is this ability important?

- A. Prokaryotes would otherwise not be able to survive on their own
- B. All eukaryotes rely on the consumption of prokaryotes to survive
- C. Cyanobacteria cannot perform photosynthesis unless enclosed in a host cell
- D. This led to the formation of mitochondria and chloroplasts
- E. All of the above

Question 4

Which of the following is used to construct phylogenetic trees?

- A. The age of each individual organism included in the tree
- B. Categorizing the type of environment in which each organism lives
- C. Putting all of the organisms in a test tube and seeing how they evolve
- D. A group of genes shared by each organism that encode for the same functions in their cells
- E. Genes whose sequences cannot be aligned

Question 5

What do the nodes and branching patterns on a phylogenetic tree tell us?

- A. How long ago each branching event occurred

- B. How to find an outgroup for the origin of life
- C. How the nucleus formed in eukaryotic cells
- D. How organisms evolved from common ancestors
- E. When the Great Oxidation Event occurred

Question 6

The branches on a phylogenetic tree are measured in units of substitution, not time. What would be the most helpful for inferring the exact time common ancestors lived?

- A. Fossils of common ancestors that can be dated
- B. The maximum likelihood inference
- C. Bayesian inference using algorithms
- D. Measuring the length of the branches
- E. Estimating the number of mutations that occurred between common ancestors

Question 7

What do we know about the metabolic and physiological limitations of organisms?

- A. A cell cannot consume more than its uptake of nutrients
- B. There appears to be a three-quarter law between metabolic rate and body size for mammals
- C. Any metabolic rate process must scale with cell size
- D. A and B
- E. A, B, and C

Question 8

Why might we expect there to be a law of biology?

- A. As organisms evolve, they can optimize their physiology with respect to one or more physical constraints
- B. All organisms must obey the laws of physics and chemistry
- C. Mammals can grow in size regardless of physical constraints like gravity
- D. A and B
- E. A, B, and C

Question 9

Some researchers have determined a set of interconnected laws based on particular optimization and physiological tradeoffs seen in life today. In origins of life research, why might it be helpful to create an abstracted physiological space that allows us to imagine all physiological possibilities?

- A. It would help us understand how life today would compete against life in the past
- B. It would help us determine if early life was capable of different methods of metabolism
- C. Different physiologies might have been possible in early life contexts, prior to the co-constrained physiology seen today
- D. It would help us compare the physiologies of different organisms
- E. None of the above

Question 10

What are the three parts that make up the evolutionary process?

- A. Phenotype, competition, drift
- B. Variation, competition, drift
- C. Mutations, competition, survival
- D. Uniformity, inheritance, selection
- E. Variation, inheritance, selection

Question 11

Which of the following is an example of evolution?

- A. In a forest, there are only white rabbits without variation in color. In the winter, the trees are covered in snow, and only white rabbits survive
- B. As more prey becomes available, a lion eats more and gains weight over the course of its lifetime
- C. When a chameleon sits on a green leaf, its skin is green; when it moves to the brown bark of a tree, its skin is brown
- D. During years of extreme drought where only small seeds survive on an island, the average beak size (a heritable trait) changes in a population of finches who eat seeds
- E. A woman with red hair (a heritable trait) gives birth to a baby who has red hair too

Question 12

In addition to instructions that can be copied and read out, what is required to build Von Neumann's self-reproducing machine that is capable of evolving?

- A. There has to be no changes in the machine's environment
- B. It has to be able to build any machine – not just itself
- C. It has to be able to delete its instructions and make a different set
- D. A and B
- E. A, B, and C

Question 13

What aspect of biological systems causes there to be more state-dependent laws than in physics?

- A. In biology, there is more than one "initial state"
- B. In biology, genetic information changes over time
- C. Biology has to follow chemical laws, in addition to physical ones
- D. There are no real patterns that emerge in biological populations
- E. All of the above

Question 14

In living systems, what is an example of Von Neumann's self-reproducing machine, almost like a "universal constructor"?

- A. The set of genes shared by all organisms on Earth

- B. The ribosome and assisting biomolecules, with DNA as the "instruction tape"
- C. Proton pumps embedded in the phospholipid bilayer
- D. The Calvin Cycle
- E. The symbiotic relationship between fungi and algae to form lichen

Question 15

One area of origins of life research explores which aspects of extant life are general and which are arbitrary. Which of the following aspects are likely general?

- A. Biological systems have emergent properties and global patterns
- B. Living systems are capable of undergoing evolution
- C. After life evolves for over 3 billion years on a planet, mammals will emerge
- D. A and B
- E. A, B, and C

Question 16

What is one reason to believe that there may have been an extensive pre-LUCA history of emergence and evolutionary innovation?

- A. We have fossil evidence of intermediate life-like entities prior to LUCA
- B. LUCA was a very sophisticated organism unlikely to arise spontaneously
- C. There are separate roots in the phylogenetic tree for the three domains of life
- D. By using an outgroup prior to LUCA, we can see that evolution was necessary early on
- E. None of the above

Question 17

Evolution is a complicated process connected to the origins of life. What is one way that researchers constrain evolution in a simple and mathematical way?

- A. Using reaction diffusion equations to calculate the relative fitness of an animal species
- B. Using nonequilbrium physics to calculate the speed of a fracture as it propagates through a population
- C. Only looking at one individual as it evolves over its lifetime
- D. Using the Pythagorean Theorem to model two chemical species
- E. Using a binary genome (two nucleotides: 0 and 1), where a species is a string of 0s and 1s, and fitness is the relative growth rate of different genomes

Question 18

What happens when a species is below the extinction threshold?

- A. It will grow exponentially
- B. It will eventually disappear
- C. It will stabilize over time
- D. It will slowly grow over time
- E. It will spontaneously clone itself

Question 19

The Error Threshold means that there's a maximum mutation rate that allows for adaptation in a complicated fitness space. What does this maximum mutation rate depend on?

- A. The length of the sequence
- B. The fitness of the master sequence relative to all the other sequences
- C. The maximum mutation rate of neighboring sequences
- D. A and B
- E. A, B, and C