

There are 18 questions, each worth a maximum of 6 points. Multiple choice questions are worth 3 points, while explanations are worth 3 points. If you need to, use the back of the page for your answer.



If you have no idea how to answer a question, you can pick “no idea” and get +1 point. HOWEVER, IF you pick “no idea”, we will NOT grade the written part of that question.

**1: (PICK the CORRECT ANSWER) The observation (law) that all known organisms can be placed in a unique position in a hierarchical (Linnaean) classification system is best explained by**

- ...
- A. the idea that all cells come from pre-existing cells
- B. the effects of non-adaptive processes, such as founder effects and genetic drift
- C. the idea that evolutionary processes drive the diversification of populations       no idea

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.

That cells come from other cells (A) does **not** explain why there are various different types of organisms, for that we need to include the ability of populations of organisms to change over time in response to different environmental opportunities, so that they become distinct species, which we summarize as “evolutionary processes”). Non-adaptive processes (B) can explain apparent non-adaptive aspects of various species, that arise in the course of their history, but do not explain why organisms can be placed into a Linnaean system.

**2. (PICK the CORRECT ANSWER) Is the requirement for dietary vitamin C in the subset of primates that display vitamin C dependence ....**

- A. a homologous trait
- B. analogous traits
- C. the result of natural selection       no idea

**Explain** the logic of your choice and what does it tell you about the common ancestor of all primates (both vitamin C dependent and vitamin C independent).

Given that most mammals are vitamin C independent, we can reasonably assume that the group of vitamin C-dependent primate species share a common vitamin C dependent ancestor. This vitamin C-dependent ancestor presumably diverge from the common ancestor of all primate, which (like other mammals) was vitamin C independent.

3. (PICK the CORRECT ANSWER) **When a theory changes what must happen to relevant laws ...**

(PICK the CORRECT answer)

- A. they remain unchanged
- B. they also change to make the theory correct
- C. they will change, providing support new theories  **no idea**

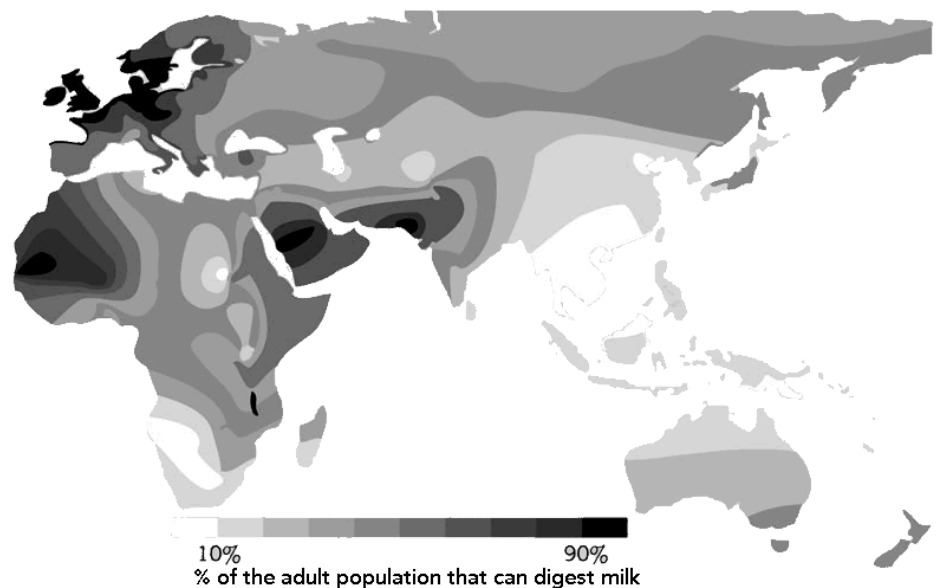
**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.

Laws describe the observable, theories provide explanations for why these behaviors are observed. The situation is complicated by the fact that a new theory (such as general relativity) may lead to new observations under previously not examined situations, such as the behavior of light near a massive object. If the predictions of a theory are confirmed, the law will be “extended” as predicted by the theory, but previous observations remain valid.

4: (PICK the CORRECT ANSWER) **In contrast to vitamin C dependence, which is universal in humans, adult lactose tolerance is restricted to a number of distinct human populations. Which is the most likely evolutionary mechanism that explains the appearance of adult lactose tolerance in humans?**

- A. natural selection
- B. genetic drift
- C. founder effects  **no idea**

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.



Adult lactose intolerance is the common, presumably ancestral behavior of mammals, and so primates. We assume that the common ancestor of human had adult lactose intolerance. That the adult tolerance trait has arisen multiple times in populations in which animals, such as sheep, goats, and cows, had been domesticated suggests that it was actively selected based on its effects (such as added nutrition). We would argue against drift (B), because it would not be expected to be found associated with the domestications of animals. Founder effect (C) would imply that the lactose tolerance phenotype was present in the original population.

**(no 5). 6. (PICK the CORRECT ANSWER) In an addiction module, such as the one associated with programmed cell death, you would expect that ...**

- A. both toxin and anti-toxin have a long half life
- B. both toxin and anti-toxin have a short half life
- C. the anti-toxin will have a shorter half-life than the toxin  **no idea**

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.

The addiction phenotype arises because the toxin is always present, but fails to kill the cell because of the presence of the anti-toxin. If both had similar half-lives (A and B), they would disappear together (and no death would occur). Only if the anti-toxin disappears faster, can the toxin work to kill the cell. ...

**7. (PICK the INCORRECT ANSWER) To be meaningful scientifically, which is not relevant...**

- A. an idea must have been proposed by an established scientist
- B. an idea must lead to verifiable or refutable predictions
- C. experimental observations must be reproducible by others  **no idea**

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.

Unless an idea makes verifiable predictions, it has no necessary connection to reality (which is what science is about). Similarly, reproducibility is essential, since it controls for un-recognized variables. Personal authority is irrelevant in science - because someone did something clever once, it does not mean they have a special ability to discern how the world works (or appears to work).

**8. (PICK the CORRECT ANSWER) In the slime mold *Dictyostelium*, the social behaviors of forming a multicellular slug, a fruiting body, and then spores is valuable because**

- A. these are complex behaviors that single cells cannot perform
- B. it allows individuals to move out of a hostile environment
- C. it depends upon social cooperation  **no idea**

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.

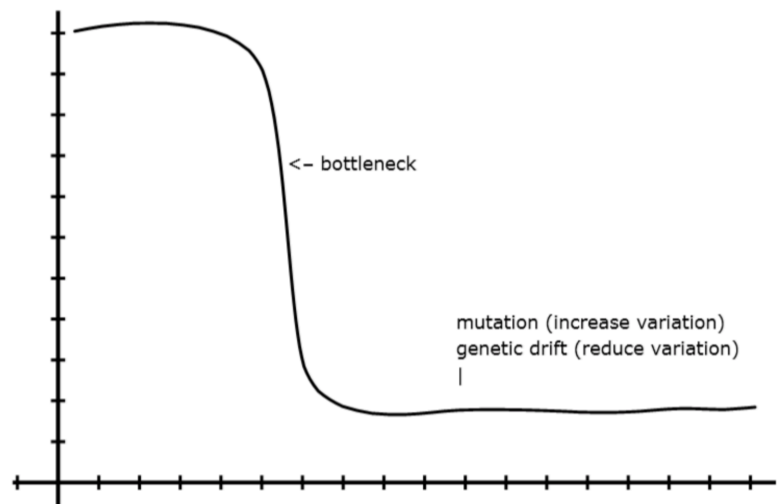
While these behaviors are certainly dependent upon social cooperations (C) and reflect behaviors that cannot be carried out by a single cell (A), they are valuable (and evolved) because they impact reproductive success (B) by enabling individuals to escape from a potentially hostile environment.

9. Draw a graph of the genetic variation within a population as a function of time; assume that the population undergoes a genetic bottleneck at time  $X = M$ , with the size of the population reduced by 95%. After the event, the population stays small thereafter.

no idea how to answer

Explain (below) the shape of the curve you drew.

The genetic variation will dramatically decrease with the bottleneck (at time M). After that new variation will arise by mutation and will be lost by drift, so we might expect it to stay more or less constant for some period after that.



10. (PICK the CORRECT ANSWER) The egg of the Cuckoo (a bird) is similar to that of another species of bird, the Reed Warbler. Cuckoos have the trait of laying their eggs in the nests of Reed Warblers. Reed Warbler mothers can recognize and destroy Cuckoo eggs that are significantly different in size compared to Reed Warbler eggs. What type of selection does this impose on Cuckoo egg size.

A. disruptive

B. directed

C. conservative

no idea

Explain what would be expected to happen to Cuckoos if Reed Warblers disappeared in a particular region.

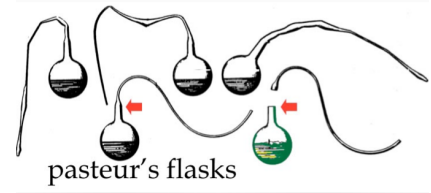
Selection is conservative, since it is expected to act to maintain Cuckoo egg size as similar to Reed Warbler egg size. It may have been directed originally, when the Cuckoo developed the trait of parasitizing Reed Warbler nests first evolved.

Assuming that Cuckoos cannot raise their own young, we would expect them to disappear. If they can, Cuckoo egg size might change (become bigger or smaller) as different selective pressures come into play.

11. (PICK the CORRECT ANSWER) **An important (positive) control in Pasteur's sterile broth experiment was to break the necks of the sterilized flasks, the result was that ...**

- A. spontaneous generation did not occur  
 B. bacteria now grew in the broth  
 C. the broth remained bacteria free  **no idea**

**Explain** what the positive control experiments established, that is, how would the interpretation of the experiment change if the positive control experiment had turned out differently.

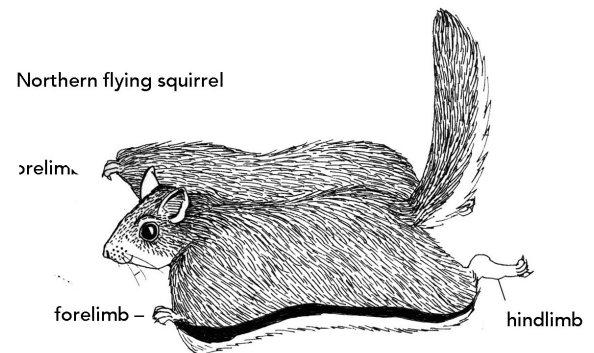


If bacteria could not grow after the flask neck was broken, we could conclude very little from the experiment - It could be that boiling the broth destroyed a key component needed for spontaneous generation, or generated a poison that blocked the process. If growth occurs, at the very least we know that the broth has not become toxic.

12. (PICK the CORRECT ANSWER) **You are asked to consider the evolutionary relationship between bats and flying squirrels. Based on your analysis of traits, you would argue that their common ancestor did not have ...**

- A. four limbs  
 B. hair  
 C. wing-like structures  **no idea**

**Explain** the logic of your choice and why the two wrong responses are wrong, incomplete or irrelevant.



There are many different types of mammals (including bats and flying squirrels). All have four limbs (although some are vestigial, such as is found in whales). Only a few mammals have wing like structures, and given the dramatic differences between these structures (the wing of a bat based on changes in the forelimb while the "wing" like structure of a flying squirrel as an extension of the skin between fore- and hind limbs) these are clearly derived independently - that is, not present in the common ancestor.

13. (PICK the CORRECT ANSWER) **The assumption that organisms obey physicochemical laws is necessary to justify ...**

- A. their evolution  
 B. detailed aspects of their behavior  
 C. their scientific study  **no idea**

**Explain** the logic of your choice (and why the other two choices are incorrect or irrelevant).

We will accept either B or C, depending on your justification. Their evolution (A) is not acceptable since physiochemical laws constrain but do not dictate evolutionary processes and outcome. Obeying physicochemical laws (B) implies that biological system can be studied scientifically (C), since there are no mysterious, supernatural processes to contend with.

**14. (PICK the CORRECT ANSWER) Sexual selection was originally proposed to explain ....**

- A. sexual dimorphism
- B. the presence of seemingly disadvantageous traits
- C. monogamous mating systems  **no idea**

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant..

From an evolutionary perspective, certain traits seem actively disadvantageous - a brightly colored bird (or a peacock's tail) may make it easier for predators to find and kill the animal. But if such traits advertise the "fitness" of the animal that displays them, and so increase their reproductive (mating) success, they can be selected for. Sexual dimorphism (A) can be seen as resulting from, and responding to sexual (and natural) selection. The presence of sexual selection does not necessarily lead to monogamy.

**15. (PICK the CORRECT ANSWER) Sexual dimorphism is based on the fact that ....**

- A. males and females behave differently
- B. the mechanisms involved in sex determination led to unexpected differences in morphology
- C. males and females differ in reproductive costs  **no idea**

Sexual dimorphism could be seen as due to a type of disruptive selection between males and females; why doesn't it lead to speciation.

The differences in male and female behavior (A) would appear to be due to, not based on differences in reproductive costs and strategies (C). Sex determination (B) does not necessarily lead to differences in morphology.

Sex is an example of a cooperative behavior, involved in generating greater genetic variation in a population. Males and females cannot reproduce without each other. That said, there are organisms that are hermaphroditic, that is contain both male and female tissues in the same body, they can (in theory at least) exist without co-operation with other organisms.

**16. If we ignore distracting details such as the sex chromosomes, which of the following statements apply to individuals of a particular species?**

- A. Individuals have different sets of alleles
- B. Individuals have different genes
- C. Individuals of different species have completely different sets of genes.  **no idea**

**Explain** your logic and why the two wrong responses are wrong, incomplete or irrelevant.

Because of mutation and other processes, different individuals will have different version of the same genes (A), but they contain the same genes (B), based on the fact that the members of a species arose from a common ancestral population. C is wrong, because the genes present are those present in that ancestor. In fact, no two species contain "a completely different set of genes" from any other, due to evolutionary (ancestral) relationships between all living species (shared last common ancestor).

17. Draw out a simple diagram of the arrangement of five hypothetical genes along a particular region of a chromosome.

no idea how to answer

Five genes along a length of a chromosome (a single DNA molecule).

**Explain** how strong positive selection for one of these genes will influence the selection of its neighbors. .

Because they are linked together, strong selection for one will increase the frequency of the linked neighbors, unless the alleles present have stronger negative effects, that is, stronger than the positive effect of the allele we have been considering.

18. Consider a generalized social interaction network (for example between slime mold or bacterial cells): Draw out the major necessary components and their interactions.

Drawing should contain 1) a signal whose production can be regulated depending upon environmental conditions, 2) a receptor for that signal, with a threshold that responds depends upon density, 3) a response - the production of a valuable (but expensive) behavior.

**THEN** describe one way that an individual can cheat the system, include how their cheat strategy benefits them in the short term and damages the community in the long term (if it does).

no idea how to answer

They can cheat by avoiding costly aspects of the social network (making the signal or the expensive behavior) while maintaining the benefit (exploiting the fact that others are producing the expensive behavior).

This can continue as long the valuable behavior continues to be produced by the group. If the number of cheaters becomes too high, this behavior will suffer or fail, and so its benefits will be lost. Other groups that retain it will have an advantage.