

Questionnaire for comprehending the concepts of natural selection

What «Darwin's finches» can teach us about evolution

PROJECT 01956/Evo.Res.Con.Edu

**Unraveling the educational potential of the research and
concepts of evolution**

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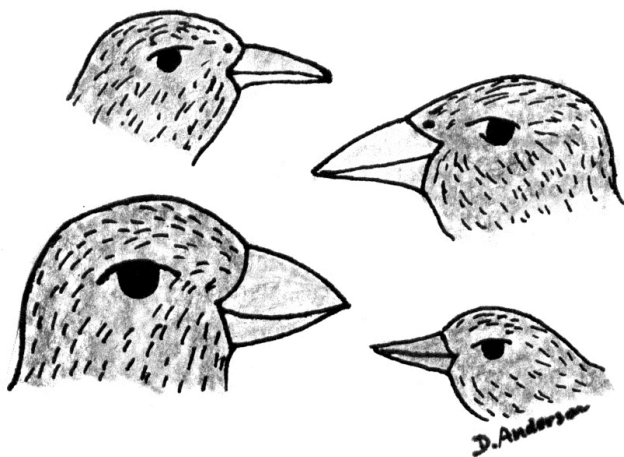
The questionnaire is based on the article: Andersen, D. L., Fisher, K. M., and Norman, G. J. (2002), Development and Evaluation of the Conceptual Inventory of Natural Selection (CINS), *J. Res. Sci. Teaching* **39**, 952-978. <https://doi.org/10.1002/tea.10053> (pages CINS1 and CNS2) (supplemented and slightly modified on the basis of more recent evidence).

Galapagos finches (Darwin's finches)

Galapagos finches (also known with the name «Darwin's finches») were first introduced by C. Darwin as specimens that he had collected during the second voyage of *HMS Beagle* at the Zoological Society of London in January 1837. Ornithologist James Gould, who undertook the taxonomic identification of those specimens, soon realized that they constitute an entirely unprecedented group of finches consisting of several different species (12 according to the first account by J. Gould, or 14 as it was later proposed when more analytical systematics and phylogenetic tools became available) (Suloway, 1982). Scientists have long believed that the 14 species of finches of the Galapagos islands evolved from a single finch species that migrated to the islands one to five million years ago (Lack, 1940).

Indeed, recent DNA analysis, phylogenetic analyses and long-term ecological studies suggest that all of the Galapagos finches derive from a single ancestral species, of which they have evolved since 2 to 3 million years ago and established different biotopes in the islands of the Galapagos archipelagos (which includes more than 100 individual islands) due to different natural selection conditions that had occurred as a consequence of drastic changes in the environment, an evolutionary scenario that fulfills Darwin's predictions (Sato *et al.*, 2001; Grant and Grant, 2003; Burns *et al.*, 2014).

Different species live on different islands or different biotopes in the same island. For example, the medium ground finch (*Geospiza fortis*) and the cactus finch (*Geospiza scandens*) live on the same island, whereas the large cactus finch (*Geospiza conirostris*) occupies a different island. The most prominent differences between the different species of Galapagos finches are in their beak shapes and sizes.



Drawing of characteristic differences in the beaks of Galapagos finches by D. Anderson (based on the initial drawings by C. Darwin himself (Darwin, 1890)), from the article Anderson *et al.*, 2002 (CINS1).

In the following questions, select the one answer that best reflects how an evolutionary biologist would answer:

Question 1

What would happen if a breeding pair of finches was placed on an island under ideal conditions with no predators and with unlimited food so that all individuals could potentially survive?

Given enough time, the finch population:

- [1] would stay small because birds only have enough babies to replace themselves.
- [2] would double and then stay relatively stable.
- [3] would increase dramatically.
- [4] would initially grow rapidly but then level off.

Correct answer: 4. This answer accounts for the fact that the available food would progressively decrease over evolutionary time due to its consumption by the finches, causing changes in the environment conditions and sources. Therefore, conditions cannot remain «ideal» forever, but food availability will decrease after some generations of finches. In other words, the environment can «withstand» only up to an **upper limit** of finches (an upper limit in the size of finch population).

Answers 1 and 2 are wrong, because they do not account for the exponential growth that the population would follow for several generations due to the plenitude of food sources. Answer 3 would only be correct regarding the initial stages of exponential growth of the population, but it does not account for the change in food availability that would occur over evolutionary time.

Question 2

Finches on the Galapagos Islands require food to eat and water to drink.

- [1] When food and water are scarce, some birds may be unable to obtain what they need to survive.
- [2] When food and water are limited, the finches will find other food sources, so there is always enough.
- [3] When food and water are scarce, the finches will start to eat and drink less so that all birds survive.
- [4] There is always plenty of food and water on the Galapagos Islands to meet the finches' needs.

Correct answer: 1. This answer is consistent with the concept of natural selection, because it directly refers to the degree of the finch survival (and, hence, reproduction) success at a given condition and underscores that the survival success of the finches is **relative** («some of the birds **may be unable** to survive»).

Answers 2 and 4 are wrong, because they assume that the available food and water sources will always be enough for the finches to survive. Answer 3 is wrong, because it assumes that finches could drastically modify their nutritional needs (which basically depend on their genetic background) in the course of their lifetime. This statement is not valid; for example, finches with beaks that are suitable («specialized») for a particular type of seeds would not be able to use a different type of food if such seeds were no longer available in their environment.

Question 3

Once a population of finches has lived on a particular island with an unvarying environment for many years,

- [1] the population continues to grow rapidly.
- [2] the population remains relatively stable, with some fluctuations.
- [3] the population dramatically increases and decreases each year.
- [4] the population will decrease steadily.

Correct answer: 2. Due to the stable environmental conditions (hence, stable conditions of natural selection), the population would have been established in the environment after many generations and would not experience major increases and/or decreases across generations. Some fluctuations in the population size from generation to generation are expectable, due to minor differences in reproduction rates and numbers of offspring survivors that might be due to random changes at the genetic or the ecosystemic level.

Answers 1, 3, and 4 are wrong, because an intense increase and/or decrease of the population would imply that the population has been exposed to a serious environmental change, which is not the case in the current example.

Question 4

In the finch population, what are the primary changes that occur gradually over time?

- [1] The traits of each finch within a population gradually change.
- [2] The proportions of finches having different traits within a population change.
- [3] Successful behaviors learned by finches are passed on to offspring.
- [4] Mutations occur to meet the needs of the finches as the environment changes.

Correct answer: 2. Evolution of a population is based on the change of the frequencies of the various forms of the genes (alleles) present in the population and, therefore, in the proportion of the various characteristics of finches in the population.

Answers 1, 3, and 4 are wrong. Answer 1 is wrong, because evolution does not apply to each one of the finches separately, but to changes occurring at the population level as the frequencies of different forms of finches in the population change across generations. Answer 3 is wrong, because it implies that characteristics that are shaped in the course of a lifetime can be inherited to the offspring, which contradicts a basic principle of genetics and evolutionary Theory (that «acquired» characteristics are not inherited). Answer 4 implies a cause-and-effect relationship between mutations occurring in the genetic material and changes occurring in the environment, which contradicts a basic principle of gene and genome evolution (that mutations happen continually in the context of physiological processes in living organisms, independent of changes in the environment).

Question 5

Depending on their beak size and shape, some finches get nectar from flowers, some eat grubs from bark, some eat small seeds, and some eat large nuts.

Which statement best describes the interactions among the finches and the food supply?

- [1] Most of the finches on an island cooperate to find food and share what they find.
- [2] Many of the finches on an island fight with one another and the physically strongest ones win.
- [3] There is more than enough food to meet all the finches' needs so they don't need to compete for food.
- [4] Finches compete primarily with closely related finches that eat the same kinds of food, and some may die from lack of food.

Correct answer: 4. Finches that are closely related to each other normally have similar beak shapes and sizes and, therefore, they can feed on the same or similar kinds of food. Competition between these finches for the same kind of food would limit the survival chances of the finches, especially when availability of the particular kind of food would be limited. Consequently, deaths might occur because some finches would be unable to obtain the food necessary for survival.

Answers 1, 2, and 3 are wrong. Answer 3 assumes that all food sources are amply available in the environment, which is not true, because food availability is limited by both, consumption by animals that feed on that source and changes in the conditions of the environment (e.g., after a prolonged period of draught). Answer 1 assumes collaboration between different finches for finding and sharing food, which is not the case. Answer 2 assumes direct antagonism (fight) between finches for prevalence and exploitation of the food sources in a biotope, which is also not the case.

Question 6

How did the different beak types **first** arise in the Galapagos finches?

- [1] The changes in the finches' beak size and shape occurred because of their need to be able to eat different kinds of food to survive.
- [2] Changes in the finches' beaks occurred by chance, and when there was a good match between beak structure and available food, those birds had more offspring.
- [3] The changes in the finches' beaks occurred because the environment induced the desired genetic changes.
- [4] The finches' beaks changed a little bit in size and shape with each successive generation, some getting larger and some getting smaller.

Correct answer: 2. This answer includes a correct interpretation of the concepts of mutations in genetic material (which occur «by chance») and adaptation and natural selection which are linked with the **reproductive success** of the organisms in an environment (finches with beak structure «that matched the available food» «had more offspring»).

Answers 1 and 3 are wrong, because they imply a direct cause-and-effect relationship between changes in the environment and changes in the finches («because of their need to be able to eat different kinds of food to survive» or «because the environment induced the desired genetic changes»), which contradicts the concept of natural selection. Answer 4 is wrong, because it refers only to changes of the finches, without any relevance to the concepts of adaptation to different environments and of natural selection.

Question 7

What type of variation in finches is passed to the offspring?

- [1] Any behaviors that were learned during a finch's lifetime.
- [2] Only characteristics that were beneficial during a finch's lifetime.
- [3] All characteristics that were genetically determined.
- [4] Any characteristics that were positively influenced by the environment during a finch's lifetime.

Correct answer: 3. This answer clearly defines that all genetically determined characteristics **are inherited** to the offspring (independent of conditions of the environment, which act subsequently, affecting survival and, eventually, reproductive success of the offspring).

Answer 1 is wrong, because it refers to characteristics that are shaped in the course of a lifetime and are not inherited to the offspring. Answers 2 and 4 are wrong, because they imply a cause-and-effect relationship between inherited characteristics and favorable environmental conditions. This is not valid, because even characteristics that are not favored in a given environment will be transferred to the offspring through genetic and sexual reproduction, albeit the offspring with such characteristics will have lower chances for survival and reproduction (thus, a lower percentage of such offspring will survive and reproduce relative to the offspring with more favored characteristics).

Question 8

What caused populations of birds having different beak shapes and sizes to become distinct species distributed on the various islands?

- [1] The finches were quite variable, and those whose features were best suited to the available food supply on each island reproduced most successfully.
- [2] All finches are essentially alike and there are **not** really fourteen different species.
- [3] Different foods are available on different islands and for that reason, individual finches on each island gradually developed the beaks they needed.
- [4] Different lines of finches developed different beak types because they needed them in order to obtain the available food.

Correct answer: 1. This answer is consistent with the basic concept of natural selection (that natural selection acts on a **background of genetic diversity** of a population and reproductive success of each individual in a population depends on the degree of its adaptation to given conditions of the environment (like «the available food supply» in this case)).

Answer 2 is wrong, because it does not account for the factor of genetic diversity which is decisive for the interpretation of the natural selection concept. Answers 3 and 4 are wrong, because they imply a direct cause-and-effect relationship between changes in the finches and changes in the environment («**for that reason**, individual finches developed **the beaks they needed**» or «finches developed different beak types **because they needed them** in order to obtain the available food»), which contradicts the basic concept of natural selection.

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