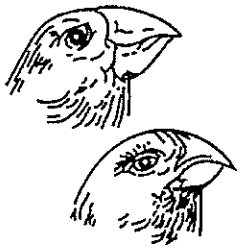
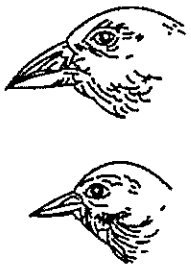
EVOLUTION





Overview:

Evolution is an ongoing process of change in species over time. These changes have their origin in genetics. When changes in genes occur, the result is variation, which is the basis for evolution. Evolution within a species can include changes in structure, function, or even behavior over a period of time. A widely held mechanism for evolution involves a process known as *natural selection*. Natural selection is a process where certain organisms are selected based on their favorable genetic makeup. These organisms pass those successful genes on to future generations, ultimately changing the species. Evidence from fossils, anatomy, and biochemistry supports the concept of evolutionary change.

Essential Information:

Evolution Evidence – According to the basic evolutionary theory, species that exist on present day Earth evolved from earlier species that may have been distinctly different. Various types of evidence support this theory of change. The *fossil record* provides support that earlier species changed structurally into modern day species. Scientists have been able to piece together the history of a species by examining fossil evidence in successive layers of undisturbed *sedimentary rock*. By examining *vertebrate anatomy*, such as bone structures and embryo features, scientists have been able to conclude that certain species have a common ancestry based on shared characteristics. Scientists have used *biochemical similarities* in proteins and DNA to link species together and understand their evolutionary relationships and ancestry. Using biotechnology methods, such as *gel electrophoresis* and *DNA sequencing*, scientists can examine different species' DNA for common sequences. The more shared DNA sequences, the more closely related the species. Through various types of evidence, evolutionists have a more complete picture of the changes that occurred to species over time and the relationships that those species share.

Natural Selection – The most widely held mechanism for evolution is the process of natural selection. The concept of natural selection was developed by Charles Darwin through his visits to the Galapagos Islands and his study of variation among finch beaks, as well as other variations in animal species. The process is based on the concept that environments on Earth change. When changes occur, there may be fewer or different resources available for species to use. Because of this, species will either adapt or possibly become extinct. When resources are available, species' population numbers will increase until a point where *competition* occurs for those resources. Certain individuals with more desirable traits, will be more successful and their frequency will increase in population.

Within a population, there exists *genetic variation*. These variations may occur through several sources. *Mutations* occur when a gene sequence is suddenly changed. These changes may occur as a result of agents such as harmful chemicals or *radiation*. During sexual reproduction, *recombination* or *crossing over* can also lead to new variations of genetic information. These variations may be slight modifications of a structure, process, or behavior that allow for those individuals to be better competitors for *available*

resources or be able to avoid predation successfully. This is sometimes called *survival of the fittest.* Variation is an important factor that ensures that at least some of the individuals within a species may survive when conditions are not favorable. Those that survive will continue to reproduce, passing that successful genetic variation on to their offspring. Over time, the genetic makeup of the population may change to reflect those successful variations. The percentage of individuals with the desirable variation will increase. Individuals with a genetic makeup that prevents them from competing will diminish in numbers and they may eventually become *extinct.* Most species that have lived on Earth are now extinct. As one can see, natural selection allows for a changing environment where individual members of populations that have successful genetic variations are selected for survival.

Modern Applications of Natural Selection – Antibiotic resistance in bacteria or insecticide resistance in insects occurs when a variation within the genetic makeup of an organism allows that organism to survive exposure to those chemicals. That organism passes that gene on to future generations and eventually a population becomes resistant to that chemical. The term "superbug" is a microbe that is resistant to the effects of medication previously used to treat that microbe.

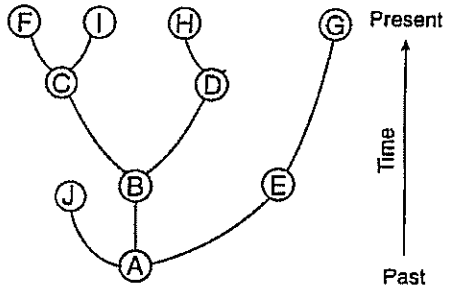
Evolutionary Model – Scientists believe that life on Earth began with simple *unicellular* organisms. Billions of years later, today's complex multi-cellular organisms have evolved. To help explain what evolution looks like, scientists have suggested a *evolutionary model* that somewhat resembles the look of a tree. At the base of the tree are the simpler, less complex organisms from which modern day life evolved. As variation occurred and new, more complex life forms developed, branching began to occur, leading to new and different species. Some branches extend to the present, and species at the end of those branches exist today. Some branches do not reach present day, and those species have died out becoming extinct. Species that have had relatively minor changes throughout their existence will be represented by a single branch that extends to the present time. Species that are found on the same branches are more closely related than those on separate branches, as evidenced by their related DNA base sequences. The rate of reproduction may also influence how rapidly species can change and the number of branches that exist. Organisms with a short *reproductive cycle*, such as bacteria, have the capacity to develop many more evolutionary changes than those organisms with longer reproductive cycles. Thus, those rapidly reproducing species will have more branches in their part of the evolutionary model.

Additional Information:

- Variations in color can be a distinct advantage when avoiding predation. For example, changes in fur color in the pocket mouse has allowed the mouse to successfully adapt to geologic changes in its habitat and avoid predation by hawks in the southwest United States.
- Anole lizards have successfully adapted to specific niches in Puerto Rico based on the type and length of their legs allowing them to successfully navigate vegetative levels within their tropical habitat.
- As biotechnology continues to develop, more evidence is provided to create a clearer and more accurate picture of evolutionary relationships.
- The evolution theory is still a theory, and there exist other views/theories that conflict with evolution and deserve credence.

Diagrams:

1. **Evolutionary Model** – This model shows that evolution involves changes that give rise to a variety of organisms, some of which continue to change through time, while others die out. In this evolutionary model, all organisms have a common ancestral linkage to *A*. Organisms *F*, *I*, *H*, and *G* are still alive. Of these, *F* and *I* are most closely related and would have the most similar DNA base sequences. Organism *J* had insufficient adaptive characteristics for survival in a changing environment, thus became extinct.



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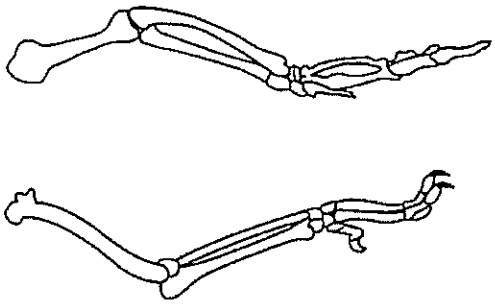
2. **Vertebrate Anatomy** – Vertebrate anatomy is often used to conclude common evolutionary linkage of organisms. In this diagram, bones of forearms of two animals that are alive today are so similar they most likely evolved from a common ancestor. Members of the original ancestral population may have been separated by natural events. Over time, changes to the forearms contribute to the survival of the organism in its new environment.



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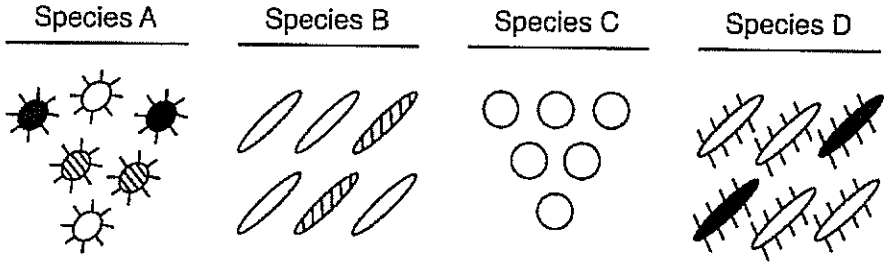
3. **Variation** – Variation within a species is important to the survival of that species, especially when conditions are not favorable. Species *A* has the best chance of survival because it has the most genetic diversity. Species C has the least chance of survival, as it lacks genetic diversity. Genetic diversity provides for the chance that a trait might help an organism adapt and survive a change in its environment.



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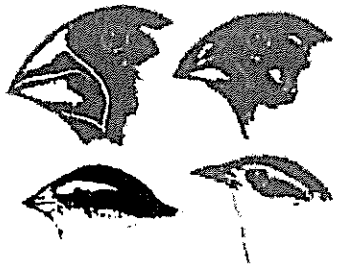
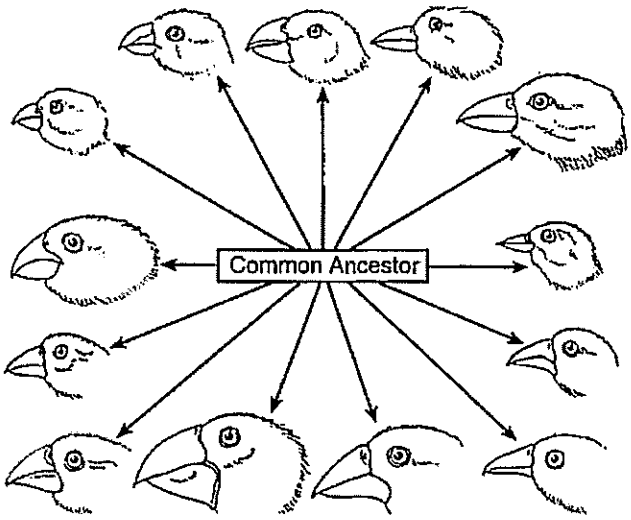
4. **Variation of Finch's Beaks** – Darwin, through his visits to the Galapagos Islands, studied the variation in organisms on these islands, especially the variation in the beaks of finches. From his observations and research, he proposed the theory of natural selection.



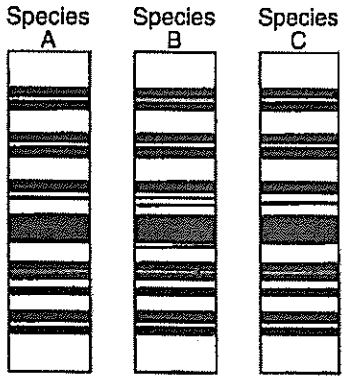
5. **Links to a Common Ancestor** – Although variation exists within the many species of finches, each type of finch shares a common ancestor with the others. Different environments and food sources lead to natural selection and the development of many new species.



6. **Amino Acids and Biochemical Similarities** – Biochemical similarities in proteins and amino acids are used to link species together to understand their evolutionary relationships and ancestry. In this chart, amino acids sequences are being compared. The more shared amino acids sequences, the more closely related the species are to each other.

Species	Sequence of Four Amino Acids Found in the Same Part of the Hemoglobin Molecule of Species
human	Lys–Glu–His–Phe
horse	Arg–Lys–His–Lys
gorilla	Lys–Glu–His–Lys
chimpanzee	Lys–Glu–His–Phe
zebra	Arg–Lys–His–Arg

7. **Banding Pattern in Gel Electrophoresis** – This diagram represents the results of gel electrophoresis, where DNA fragments are moved through a gel creating a banding pattern. In this case, evolutionary relationships can be determined by comparing the banding pattern for species *A*, *B* and *C*. Species *A* and *C* are more closely related because they share more common bands with each other compared to species *B*.



Vocabulary Refresher

Group A *Directions* - Match the correct definition for the following terms:

1. _____Natural selection
2. _____Vertebrate anatomy
3. _____Common ancestry
4. _____DNA sequencing
5. _____Genetic variation
6. _____Available resources
7. _____Gel electrophoresis
8. _____Fossil record
9. _____Biochemical similarities
10. _____Crossing over
11. _____Survival of the fittest

A. Different sets of genes that are expressed as different forms of a trait within a population.

B. A process where molecular base sequences of an individual's genetic code is determined.

C. Organisms having similar genetic traits that can be traced back to a shared ancestor.

D. A natural process where organisms that are best adapted to their environment survive and pass those favorable traits to the next generation.

E. Evidence found in sedimentary rocks that shows the existence and changes that have occurred within populations of organisms.

F. Having common sequences of DNA, amino acids, or common proteins or even sharing chemical processes.

G. Obtainable nutrients and materials that are essential for organisms to survive.

H. The term given when variations occur that allow for individuals to be better competitors for available resources and survive as of a result of this.

I. A biotechnology process that uses the movement of fragments of DNA to determine evolutionary or genetic relationships.

J. Physical features, such as bone structure, used to compare animals with backbones for evolutionary relationships.

K. The trading of sections of two homologous chromosomes during meiosis which leads to variation.

Vocabulary Refresher

Group B *Directions* - Match the correct definition for the following terms:

1. _____Radiation
2. _____Extinct
3. _____Unicellular organisms
4. _____Evolution model
5. _____Reproductive cycles
6. _____Species
7. _____Evolution
8. _____Mutations
9. _____Recombination
10. _____Competition

A. A model containing branches coming from common ancestors that show the relationship between ancestral and modern day species.

B. The amount of time between reproduction in one generation and reproduction in the next generation.

C. Sudden changes within the genetic code or DNA that may contribute to evolutionary differences.

D. This occurs when individuals or populations go after the same food, space or mates.

E. These single cell organisms that have rapid reproductive cycles are more likely to exhibit genetic diversity among the offspring in a short period of time.

F. High energy waves or particles that can damage DNA molecules, which may lead to mutations.

G. A group of individuals that are able to interbreed and produce viable offspring.

H. A slow process of change in species, populations, or individuals across successive generations.

I. A species that could not successfully adapt to a changing environment or lacked needed variations for survival and died out.

J. The joining of genetic information from each gamete (sperm and egg), resulting in genetic variation.

1. Natural selection and its evolutionary consequences provide a scientific explanation for each of the following except

(1) the fossil record
(2) protein and DNA similarities between different organisms
(3) similar structures among different organisms
(4) a stable physical environment 1 _____

2. Which statement represents the major concept of the biological theory of evolution?

(1) A new species moves into a habitat when another species becomes extinct.
(2) Every period of time in Earth's history has its own group of organisms.
(3) Present-day organisms on Earth developed from earlier, distinctly different organisms.
(4) Every location on Earth's surface has its own unique group of organisms.
2 _____

3. Which situation would most likely result in the highest rate of natural selection?

(1) reproduction of organisms by an asexual method in an unchanging environment
(2) reproduction of a species having a very low mutation rate in a changing environment
(3) reproduction of organisms in an unchanging environment with little competition and few predators
(4) reproduction of organisms exhibiting genetic differences due to mutations and genetic recombinations in a changing environment 3 _____

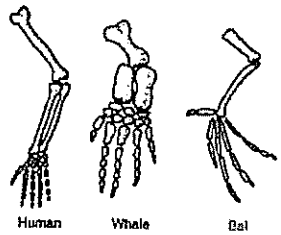
4. Some behaviors such as mating and caring for young are genetically determined in certain species of birds. The presence of these behaviors is most likely due to the fact that

(1) birds do not have the ability to learn
(2) individual birds need to learn to survive and reproduce
(3) these behaviors helped birds to survive in the past
(4) within their lifetimes, birds developed these behaviors 4 _____

5. Which statement is not part of the concept of natural selection?

(1) Individuals that possess the most favorable variations will have the best chance of reproducing.
(2) Variation occurs among individuals in a population.
(3) More individuals are produced than will survive.
(4) Genes of an individual adapt to a changing environment. 5 _____

6. The diagrams how the bones in the forelimbs of three different organisms.



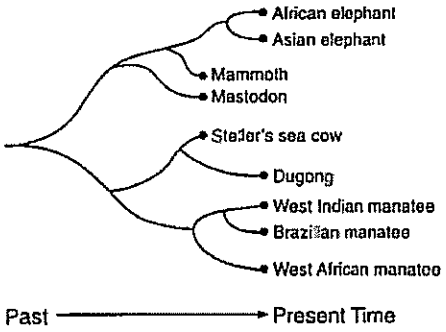
Differences in the bone arrangements support the hypothesis that these organisms

(1) are members of the same species
(2) may have descended from the same ancestor
(3) have adaptations to survive in different environments
(4) all contain the same genetic information 6 _____

7. Which population of organisms would be in greatest danger of becoming extinct?

(1) A population of organisms having few variations living in a stable environment.
(2) A population of organisms having few variations living in an unstable environment.
(3) A population of organisms having many variations living in a stable environment.
(4) A population of organisms having many variations living in an unstable environment. 7_____

8. The relationship of some mammals is indicated in the diagram below.



Which statement about the African elephant is correct?

(1) It is more closely related to the mammoth than it is to the West African manatee.
(2) It is more closely related to the West Indian manatee than it is to the mastodon.
(3) It is not related to the Brazilian manatee or the mammoth.
(4) It is the ancestor of Steller's sea cow. 8_____

9. Which factor contributed most to the extinction of many species?

(1) changes in the environment
(2) lethal mutations
(3) inability to evolve into simple organisms
(4) changes in migration patterns 9_____

10. A characteristic that an organism exhibits during its lifetime will only affect the evolution of its species if the characteristic

(1) results from isolation of the organism from the rest of the population
(2) is due to a genetic code that is present in the gametes of the organism
(3) decreases the number of genes in the body cells of the organism
(4) causes a change in the environment surrounding the organism 10_____

11. Which statement best explains the significance of meiosis in the process of evolution within a species?

(1) The gametes produced by meiosis ensure the continuation of any particular species by asexual reproduction.
(2) Equal numbers of eggs and sperm are produced by meiosis.
(3) Meiosis produces eggs and sperm that are alike.
(4) Meiosis provides for variation in the gametes produced by an organism.
11_____

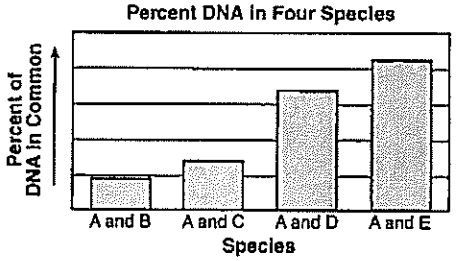
12. Over time, data that support the successful evolution of a species would include observations that describe

(1) an increase in the genetic changes occurring in body cells
(2) a decrease in the genetic variety carried in sex cells
(3) an increase in the proportion of offspring that have favorable characteristics
(4) a decrease in the proportion of the population that has beneficial traits
12_____

13. Which two processes result in variations that commonly influence the evolution of sexually reproducing species?

(1) mutation and genetic recombination
(2) mitosis and natural selection
(3) extinction and gene replacement
(4) environmental selection and selective breeding 13_____

14. The percent of DNA that species *A* has in common with species *B*, *C*, *D*, and *E* are shown in the graph below.



Which statement is a valid conclusion that can be drawn from this graph?

(1) Species *A* is closely related to species *B*, but is not related to species *E*.
(2) Fewer mutations have occurred in species *B* and *C* than in species *A*.
(3) Species *A* and *E* have the greatest similarity in protein structure.
(4) Environment influences the rate of evolution. 14_____

15. Woolly mammoths became extinct thousands of years ago, while other species of mammals that existed at that time still exist today. These other species of mammals most likely exist today because, unlike the mammoths, they

(1) produced offspring that all had identical inheritable characteristics
(2) did not face a struggle for survival
(3) learned to migrate to new environments
(4) had certain inheritable traits that enabled them to survive 15_____

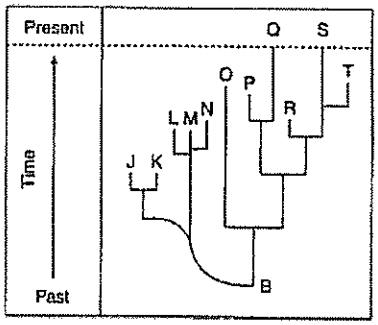
16. Natural selection is best described as

(1) a change in an organism in response to a need of that organism
(2) a process of nearly constant improvement that leads to an organism that is nearly perfect
(3) differences in survival rates as a result of different inherited characteristics
(4) inheritance of characteristics acquired during the life of an organism 16_____

17. What will most likely occur as a result of changes in the frequency of a gene in a particular population?

(1) ecological succession
(2) biological evolution
(3) global warming
(4) resource depletion 17_____

18. Some evolutionary pathways are represented in the diagram below.



An inference that can be made from information in the diagram is that

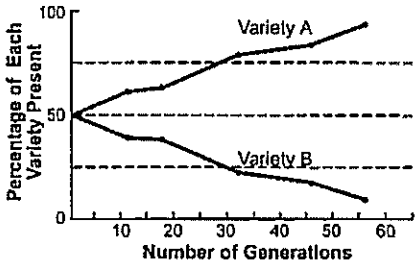
(1) many of the descendants of organism *B* became extinct
(2) organism *B* was probably much larger than any of the other organisms represented
(3) most of the descendants of organism *B* successfully adapted to their environment and have survived to the present time
(4) the letters above organism *B* represent members of a single large population with much biodiversity 18_____

19. Which species in the chart below is most likely to have the fastest rate of evolution?

Species	Reproductive Rate	Environment
A	slow	stable
B	slow	changing
C	fast	stable
D	fast	changing

(1) *A* (3) *C*
(2) *B* (4) *D* 19_____

20. What is the most probable reason for the increase in the percentage of variety *A* in the population of the species shown in the graph below?



(1) There is no chance for variety *A* to mate with variety *B*.
(2) There is no genetic difference between variety *A* and variety *B*.
(3) Variety *A* is less fit to survive than variety *B* is.
(4) Variety *A* has some adaptive advantage that variety *B* does not have.

20_____

21. Which statement provides evidence that evolution is still occurring at the present time?

(1) The extinction rate of species has decreased in the last 50 years.
(2) Many bird species and some butterfly species make annual migrations.
(3) New varieties of plant species appear more frequently in regions undergoing climatic change.
(4) Through cloning, the genetic makeup of organisms can be predicted.

21_____

22. Which process is correctly matched with its explanation?

	Process	Explanation
(1)	extinction	adaptive characteristics of a species are not adequate
(2)	natural selection	the most complex organisms survive
(3)	gene recombination	genes are copied as a part of mitosis
(4)	mutation	overproduction of offspring takes place within a certain population

22_____

23. The table below shows adaptations in two organisms.

Environmental Adaptations

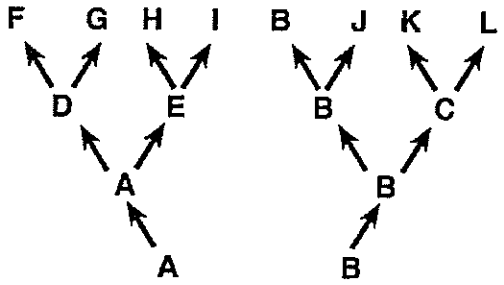
Organism	Environment	Adaptation
desert rat	hot and dry	comes out of burrow only at night
Arctic poppy plant	cold and windy	grows low to ground next to rocks

The presence of these adaptations is most likely the result of

(1) reproductive technology (3) asexual reproduction
(2) natural selection (4) human interference

23_____

Base your answers to question 24 on the diagram. Letters *A* through *L* represent different species of organisms. The arrows represent long periods of geologic time.



24. *a*) Which two species are the most closely related?

(1) *J* and *L* (3) *F* and *H*
(2) *G* and *L* (4) *F* and *G* a _____

b) Which species was best adapted to changes that occurred in its environment over the longest period of time?

(1) *A* (2) *B* (3) *C* (4) *J* b_____

c) Which two species would most likely show the greatest similarity of DNA and proteins?

(1) *B* and *J* (2) *G* and *I* (3) *J* and *K* (4) *F* and *L* c_____

d) The pattern of these evolutionary pathways is most likely the result of alterations within which structure?

(1) vacuole (2) cell membrane (3) nucleus (4) ribosome d_____

Base your answers to question 25 on the information below.

Evolutionary changes have been observed in beak size in a population of medium ground finches in the Galapagos Islands. Given a choice of small and large seeds, the medium ground finch eats mostly small seeds, which are easier to crush. However, during dry years, all seeds are in short supply. Small seeds are quickly consumed, so the birds are left with a diet of large seeds. Studies have shown that this change in diet may be related to an increase in the average size of the beak of the medium ground finch.

25. *a*) The most likely explanation for the increase in average beak size of the medium ground finch is that the

(1) trait is inherited and birds with larger beaks have greater reproductive success
(2) birds acquired larger beaks due to the added exercise of feeding on large seeds
(3) birds interbred with a larger-beaked species and passed on the trait
(4) lack of small seeds caused a mutation which resulted in a larger beak a _____

b) In exceptionally dry years, what most likely happens in a population of medium ground finches?

(1) There is increased cooperation between the birds.
(2) Birds with large beaks prey on birds with small beaks.
(3) The finches develop parasitic relationships with mammals.
(4) There is increased competition for a limited number of small seeds. b _____

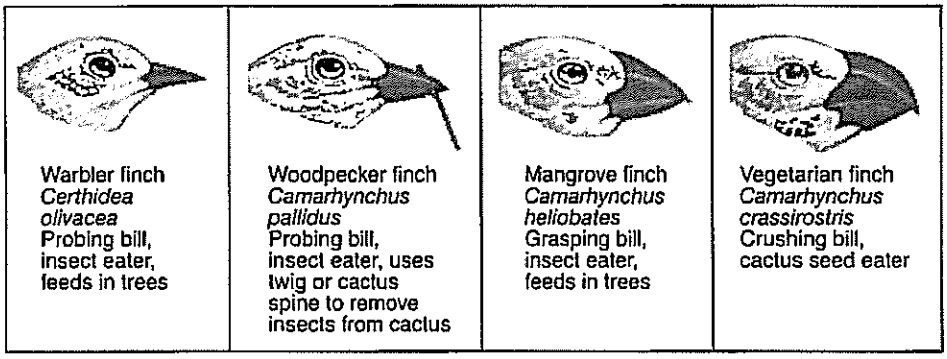
26. When Charles Darwin traveled to the Galapagos Islands, he observed 14 distinct varieties of finches on the islands. Darwin also observed that each finch variety ate a different type of food and lived in a slightly different habitat from the other finches. Darwin concluded that the finches all shared a common ancestor but had developed different beak structures.

The 14 varieties of finches are most likely the result of

(1) absence of biodiversity
(2) biological evolution
(3) asexual reproduction
(4) lack of competition

26_____

Base your answers to question 27 on the information below and on your knowledge of biology.



Source: http://taggart.glg.msu.edu/isb200/beagle.htm

27. *a*) The differences seen in the beaks of the four species of finches are most likely the result of

(1) gene expression and asexual reproduction
(2) variation and natural selection
(3) migration and the need to adapt
(4) heredity and a diet of seeds

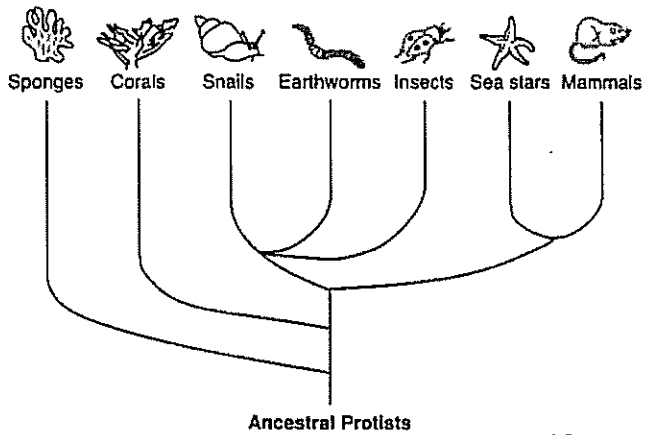
a_____

b) A person expressed concern that the vegetarian finch may face greater competition when other finch populations increase. State whether the vegetarian finch will face competition if the populations of warbler finches, woodpecker finches, and mangrove finches increase. Support your answer.

Answer:_____

Supporting Statement:_____

28. The diagram represents possible evolutionary relationships between groups of organisms.



Which statement is a valid conclusion that can be drawn from the diagram?

(1) Snails appeared on Earth before corals.
(2) Sponges were the last new species to appear on Earth.
(3) Earthworms and sea stars have a common ancestor.
(4) Insects are more complex than mammals.

28_____

Base your answers to question 29 on the information below.

A plant known as caltrop is found on one of the Galapagos Islands. The caltrop plant produces seeds with tough, spiny coats. There is a bird species, *Geospiza fortis*, that can crack the tough seed coat and eat the contents inside. On one part of the island where there are many of these birds, the caltrop plants produce fewer seeds and the coats of the seeds have longer and more numerous spines. On another part of the island where there are few of these birds, the plants produce more seeds and the seed coats have fewer, shorter spines.

29. *a*) Identify one variation the caltrop seeds have for survival. _____

b) Identify one process that can result in adaptations. _____

c) Identify *one* adaptation, other than beak size and shape, a finch species might possess and state how that would aid in its survival.

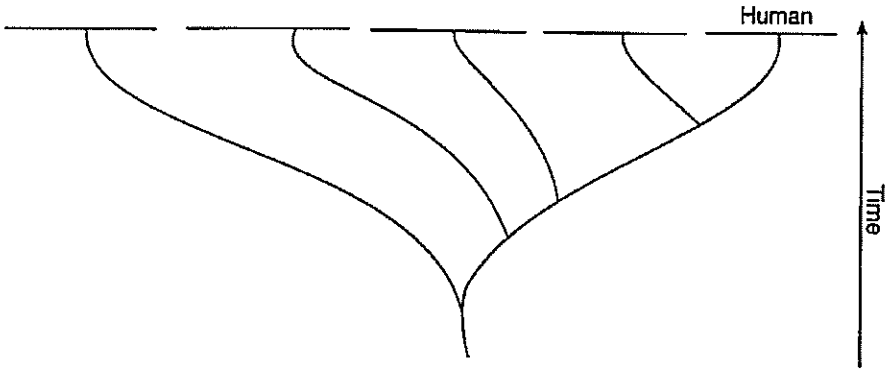
Adaptation: _____ Aid in survival: _____

30. The data table shows the number of amino acid differences in the hemoglobin molecules of several species compared with amino acids in the hemoglobin of humans.

Based on the information in the data table, write the names of the organisms from the table in their correct positions on the evolutionary tree below.

Amino Acid Differences

Species	Number of Amino Acid Differences
human	0
frog	67
pig	10
gorilla	1
horse	26



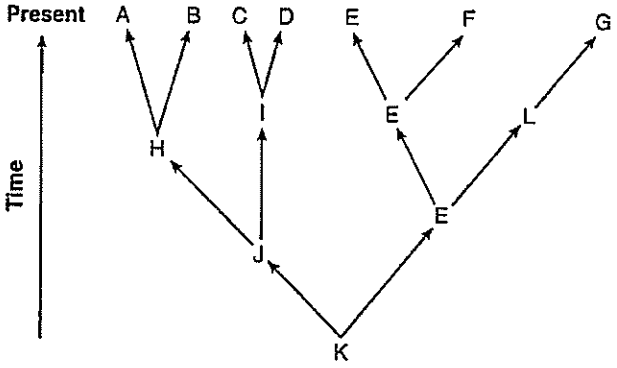
31. The evolutionary pathways of several species are represented in the accompanying diagram.

Which species was best adapted for survival in changing environmental conditions? Give a supporting statement for your answer.

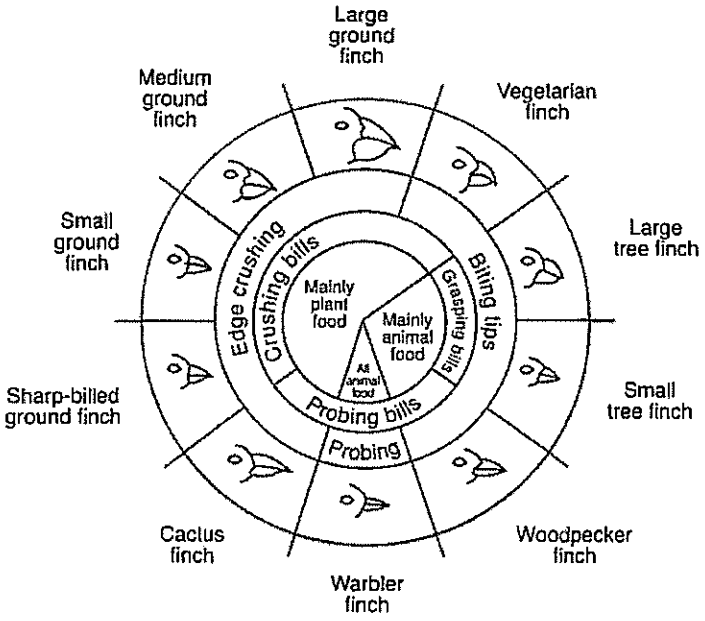
Species: _____

Supporting statement:

_____



Base your answers to question 32 on the diagram that shows variations in the beaks of finches in the Galapagos Islands.



From: *Galapagos: A Natural History Guide*

32. *a*) The diversity of species seen on the Galapagos Islands is mostly due to

(1) gene manipulation by scientists
(2) gene changes resulting from mitotic cell division
(3) natural selection
(4) selective breeding a ____

b) Warbler finches are classified as

(1) producers
(2) herbivores
(3) carnivores
(4) decomposers b ____

c) Finches that eat mainly plant food are given what classification?_____

d) State one reason why large ground finches and large tree finches can coexist on the same island.

_____

_____

e) The cactus finch, warbler finch, and woodpecker finch all live on one island. Based on the information in the diagram, which one of these finches is least likely to compete with the other two for food?

Answer: _____

Support your answer with an explanation.

_____

_____

f) How would the introduction of another species of seed-eating ground finch to the Galapagos Islands most likely influence the medium ground finch?

_____

_____

g) Identify the term that describes the ecological role each finch performs within the Galapagos Islands.

_____

Base your answers to question 33 on the information below.

Scientists attempted to determine the evolutionary relationships between three different plant species, *A*, *B*, and *C*. In order to do this, they examined the stems and DNA of these species. Diagram 1 represents a microscopic view of the cross sections of the stems of these three species. DNA was extracted from all three species and analyzed using gel electrophoresis. The results are shown in diagram 2. Based on the data they collected, they drew diagram 3 to represent the possible evolutionary relationships.

Diagram 1

Diagram 2

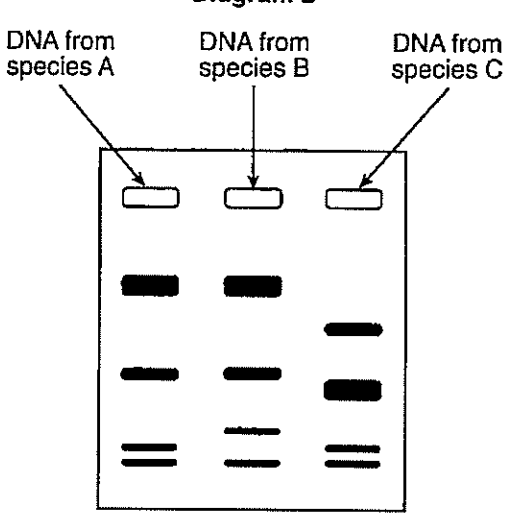
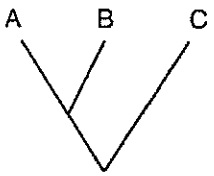


Diagram 3

Possible Evolutionary Relationships Between Species A, B, and C



33. *a*) State why the evolutionary relationships shown in diagram 3 are not supported by the data provided by the stem cross sections in diagram 1.

_____

_____

b) Explain how the DNA banding pattern in diagram 2 supports the evolutionary relationships between the species shown in diagram 3.

_____

c) This technique used to analyze DNA involves the

(1) synthesis of new DNA strands from subunits
(2) separation of DNA fragments on the basis of size
(3) production of genetically engineered DNA molecules
(4) removal of defective genes from DNA

c ____

1. A certain plant species, found only in one particular stream valley in the world, has a very shallow root system. An earthquake causes the stream to change its course so that the valley in which the plant species lives becomes very dry. As a result, the species dies out completely. The effect of this change on this plant species is known as

(1) evolution (3) mutation
(2) extinction (4) succession 1 _____

2. Scientists in the United States, Europe, and Africa have now suggested that the hippopotamus is a relative of the whale. Earlier studies placed the hippo as a close relative of wild pigs, but recent studies have discovered stronger evidence for the connection to whales. This information suggests that

(1) genetic engineering was involved in the earlier theories
(2) structural evidence is the best evolutionary factor to consider
(3) natural selection does not occur in hippopotamuses
(4) scientific explanations are tentative and subject to change 2 _____

3. Exposure to cosmic rays, x rays, ultraviolet rays, and radiation from radioactive substances may promote

(1) the production of similar organisms
(2) diversity among organisms
(3) an increase in population size
(4) a change from sexual to asexual reproduction 3 _____

4. A species in a changing environment would have the best chance of survival as a result of a mutation that has a

(1) high adaptive value and occurs in its skin cells
(2) low adaptive value and occurs in its skin cells
(3) high adaptive value and occurs in its gametes
(4) low adaptive value and occurs in its gametes 4 _____

5. Certain antibacterial soaps kill 99% of the bacteria present on hands. Constant use of these soaps could be harmful over time because

(1) more pathogens may be resistant to the soap
(2) microbes prevent viral diseases
(3) large populations of pathogens are beneficial to the hands
(4) the soap stimulates skin cell division 5 _____

6. In 2007, scientists broke open a fossil of a dinosaur bone and found some preserved tissues. Analysis showed that some proteins in these tissues are very similar to proteins found in modern chickens. The conclusion that these dinosaurs are related to modern chickens is based on

(1) molecular similarities
(2) natural selection
(3) similarities in behavior
(4) the occurrence of mutations 6 _____

7. Thousands of years ago, giraffes with short necks were common within giraffe populations. Nearly all giraffe populations today have long necks. This difference could be due to

(1) giraffes stretching their necks to keep their heads out of reach of predators
(2) giraffes stretching their necks so they could reach food higher in the trees
(3) a mutation in genetic material controlling neck size occurring in some skin cells of a giraffe
(4) a mutation in genetic material controlling neck size occurring in the reproductive cells of a giraffe 7_____

8. Which statement is most closely related to the modern theory of evolution?

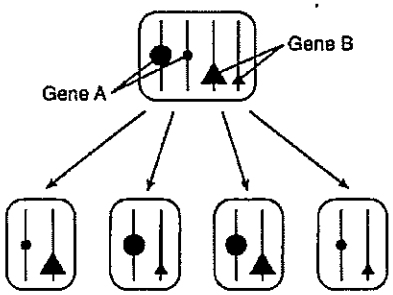
(1) Characteristics that are acquired during life are passed to offspring by sexual reproduction.
(2) Evolution is the result of mutations and recombination, only.
(3) Organisms best adapted to a changed environment are more likely to reproduce and pass their genes to offspring.
(4) Asexual reproduction increases the survival of species. 8_____

9. To determine evolutionary relationships between organisms, a comparison would most likely be made between all of the characteristics below except

(1) methods of reproduction
(2) number of their ATP molecules
(3) sequences in their DNA molecules
(4) structure of protein molecules present

9_____

10. The diagram below represents a process involved in reproduction in some organisms.



This process is considered a mechanism of evolution because
(1) mitosis produces new combinations of inheritable traits
(2) it increases the chances of DNA alterations in the parent
(3) it is a source of variation in the offspring produced
(4) meiosis prevents recombination of lethal mutations 10_____

11. The first life-forms to appear on Earth were most likely

(1) complex single-celled organisms
(2) complex multicellular organisms
(3) simple single-celled organisms
(4) simple multicellular organisms

11_____

12. The teeth of carnivores are pointed and are good for puncturing and ripping flesh. The teeth of herbivores are flat and are good for grinding and chewing. Which statement best explains these observations?

(1) Herbivores have evolved from carnivores.
(2) Carnivores have evolved from herbivores.
(3) The two types of teeth most likely evolved as a result of natural selection.
(4) The two types of teeth most likely evolved as a result of the needs of an organism. 12_____

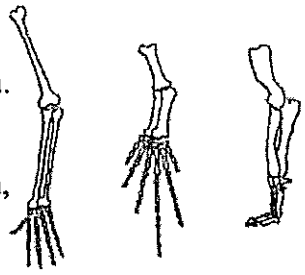
13. Which statement best describes a current understanding of natural selection?

(1) Natural selection influences the frequency of an adaptation in a population.
(2) Natural selection has been discarded as an important concept in evolution.
(3) Changes in gene frequencies due to natural selection have little effect on the evolution of species.
(4) New mutations of genetic material are due to natural selection. 13_____

14. Which statement describing a cause of extinction includes the other three?

(1) Members of the extinct species were unable to compete for food.
(2) Members of the extinct species were unable to conceal their presence by camouflage.
(3) Members of the extinct species lacked adaptations essential for survival.
(4) Members of the extinct species were too slow to escape from predators. 14_____

15. The bones in the forelimbs of three mammals are shown.



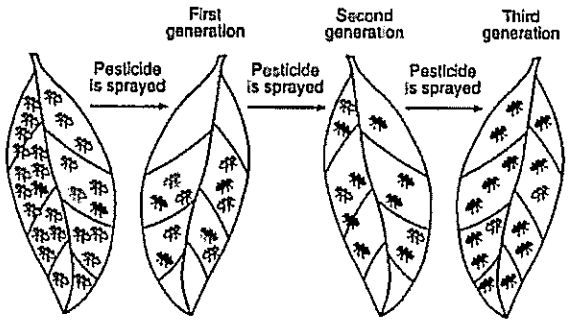
For these mammals, the number, position, and shape of the bones most likely indicates that they may have

(1) developed in a common environment
(2) developed from the same earlier species
(3) identical genetic makeup
(4) identical methods of obtaining food 15_____

16. In an area of Indonesia where the ocean floor is littered with empty coconut shells, a species of octopus has been filmed "walking" on two of its eight tentacles. The remaining six tentacles are wrapped around its body. Scientists suspect that, with its tentacles arranged this way, the octopus resembles a rolling coconut. Local predators, including sharks, seem not to notice the octopus as often when it behaves in this manner. This unique method of locomotion has lasted over many generations due to

(1) competition between octopuses and their predators
(2) ecological succession in marine habitats
(3) the process of natural selection
(4) selective breeding of this octopus species 16_____

17. The diagram below shows the effect of spraying a pesticide on a population of insects over three generations.



Which concept is represented in the diagram?

(1) survival of the fittest
(2) succession
(3) dynamic equilibrium
(4) extinction 17_____

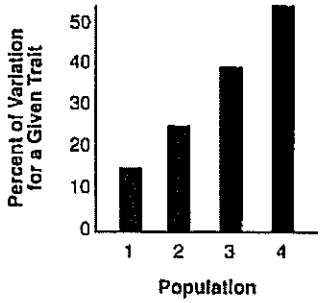
18. Which statement is best supported by the theory of evolution?

(1) Genetic alterations occur every time cell reproduction occurs.
(2) The fossil record provides samples of every organism that ever lived.
(3) Populations that have advantageous characteristics will increase in number.
(4) Few organisms survive when the environment remains the same. 18____

19. A species that lacks the variation necessary to adapt to a changing environment is more likely to

(1) develop many mutated cells
(2) become extinct over time
(3) begin to reproduce sexually
(4) develop resistance to diseases 19_____

20. The graph below shows the percent of variation for a given trait in four different populations of the same species. The populations inhabit similar environments.



In which population will the greatest number of individuals most likely survive if a significant environmental change related to this trait occurs?

(1) 1 (3) 3
(2) 2 (4) 4 20_____

21. A researcher recently discovered a new species of bacteria in the body of a tubeworm living near a hydrothermal vent. He compared the DNA of this new bacterial species to the DNA of four other species of bacteria. The DNA sequences came from the same part of the bacterial chromosome of all four species.

Species	DNA Sequence
unknown species	ACT GCA CCC
species I	ACA GCA CCG
species II	ACT GCT GGA
species III	ACA GCA GGG
species IV	ACT GCA CCG

According to these data, the unknown bacterial species is most closely related to

(1) species I (3) species III
(2) species II (4) species IV 21_____

22. A population of animals is permanently split by a natural barrier into two separate populations in different environments. What will likely result after a long period of time?

(1) The evolution of the two populations will be identical.
(2) The production of variations will stop in the two populations.
(3) The two populations will evolve into separate species.
(4) Autotrophic nutrition will replace heterotrophic nutrition in the two populations. 22_____

23. Which characteristics of a population would most likely indicate the lowest potential for evolutionary change in that population?

(1) sexual reproduction and few mutations
(2) sexual reproduction and many mutations
(3) asexual reproduction and few mutations
(4) asexual reproduction and many mutations

23_____

24. In a certain species of insect, some individuals have flattened white disks on their bodies that protrude and interlock, resembling an orchid flower. This adaptation provides the insect with a better opportunity to capture its prey. If environmental conditions remain unchanged, it is most likely that, in future generations, the proportion of the population with this adaptation will

(1) increase, only
(2) decrease, only
(3) increase, then decrease
(4) decrease, then increase 24_____

25. Which statement is best supported by fossil records?

(1) Many organisms that lived in the past are now extinct.
(2) Species occupying the same habitat have identical environmental needs.
(3) The struggle for existence between organisms results in changes in populations.
(4) Structures such as leg bones and wing bones can originate from the same type of tissue found in embryos.

25_____

Researchers discovered four different species of finches on one of the Galapagos Islands. DNA analysis show ed that these four species, shown in the accompanying illustration, are closely related even though they vary in beak shape and size. It is thought that they share a common ancestor.

26. *a*) Which factor most likely influenced these differences in beak size and shape?

(1) Birds with poorly adapted beaks changed their beaks to get food.
(2) Birds with yellow beaks were able to hide from predators.
(3) Birds with successful beak adaptations obtained food and survived to have offspring.
(4) Birds with large, sharp beaks become dominant. a_____

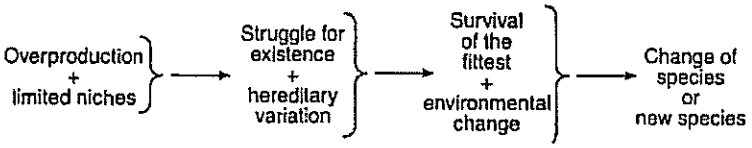
b) Which factors most likely had a role in the development of beak characteristics in these finches?

(1) mutation and cloning
(2) genetic engineering and selective breeding
(3) unchanging environment and the need to reproduce
(4) variation and recombination b_____

c) Relationships between animal species may most accurately be determined by comparing the

(1) habitats in which they live
(2) structure of guard cells
(3) base sequences of DNA
(4) shape of these cells c_____

27. Which concept is best illustrated in the flowchart?

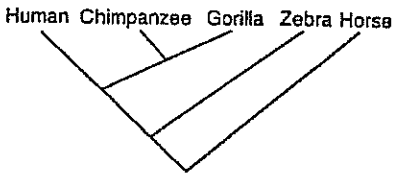


(1) natural selection
(2) genetic manipulation
(3) dynamic equilibrium
(4) material cycles

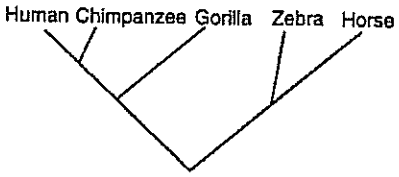
27_____

28. Which evolutionary tree best represents the information in the chart?

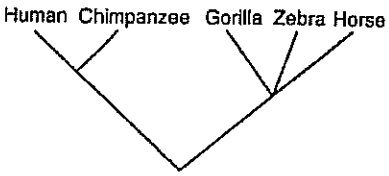
Species	Sequence of Four Amino Acids Found in the Same Part of the Hemoglobin Molecule of Species
human	Lys–Glu–His–Phe
horse	Arg–Lys–His–Lys
gorilla	Lys–Glu–His–Lys
chimpanzee	Lys–Glu–His–Phe
zebra	Arg–Lys–His–Arg



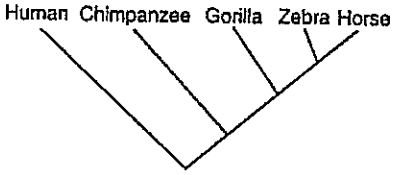
(1)



(3)



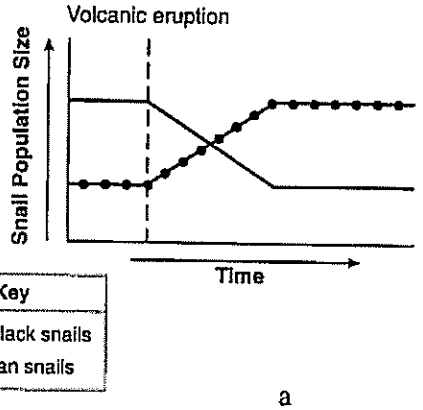
(2)



(4)

28_____

29. A population composed of tan snails and black snails inhabits the same sandy beach. A nearby volcano erupted, and black lava particles washed down to the beach. The once tan beach was now black. The graph shows the population of tan snails and black snails before and after the volcanic eruption.



a) Which statement concerning the snails is correct?

(1) The lava particles turned the tan snails black.
(2) The tan snails will become extinct.
(3) The black snails had an adaptive advantage.
(4) The tan snails preyed on the black snails.

a_____

b) The increase in the number of black snails can best be explained by

(1) natural selection after an environmental change
(2) climatic change followed by ecological succession
(3) increased stability due to a decrease in variation
(4) an increase in mutation rate

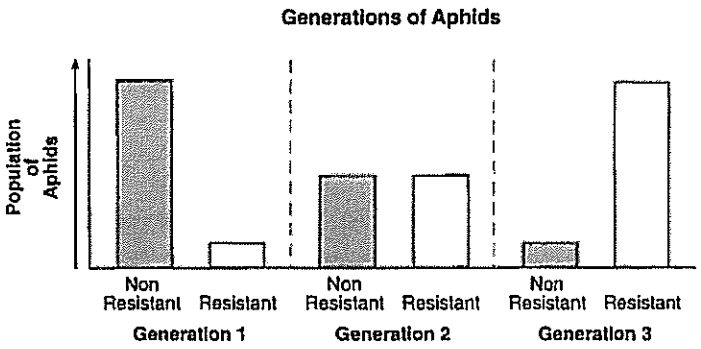
b_____

c) Variation in snail color is an example of

(1) environmental stability
(2) a natural limitation
(3) equilibrium
(4) diversity

c_____

30. A farmer growing potatoes notices aphids, a type of insect, feeding on the plants. An insecticide was sprayed on the plants several times over a two-year period. The graph represents samples of three different generations of insecticide-resistant and nonresistant aphids over this time period.



a) The resistance gene was present in the aphid population as a result of

(1) the need of the potatoes to become resistant to the insecticide
(2) changes in the aphids' local habitat by the insecticide
(3) a recombination of the proteins in the potato cells
(4) a random change in the aphids' DNA sequence a_____

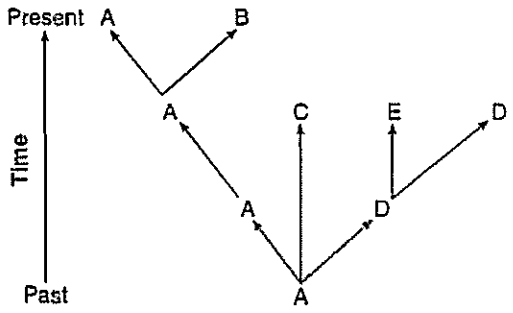
b) In year three, the farmer discontinued the use of the insecticide. Which statement would best predict the population in generation 4?

(1) The nonresistant aphid would become extinct.
(2) The nonresistant aphid population would likely increase.
(3) The resistant aphid would mutate to a nonresistant aphid.
(4) The plants would be free of insect populations. b_____

c) One negative consequence of using an insecticide is that it

(1) selects for insecticide-resistant organisms
(2) keeps a balance of organic compounds
(3) encourages biodiversity in plants
(4) gives the nonresistant aphids a survival advantage c_____

Base your answers to question 31 on the diagram.
Letters *A* through *E* represent different species of organisms.
The arrows represent long periods of geologic time.



31. *a*) Which species would most likely show the greatest similarities in their amino acid sequences?

(1) *A* and *E* (3) *B* and *D*
(2) *A* and *B* (4) *C* and *E* a _____

b) Which species is the common ancestor to all of the other species? _____

c) Identify one species that was not able to adapt to its environment. _____

Support your answer: _____

_____

32. When Charles Darwin was developing his theory of evolution, he considered variations in a population important. However, he could not explain how the variations occurred. Name two processes that can result in variation in a population. Explain how these processes actually cause variation.

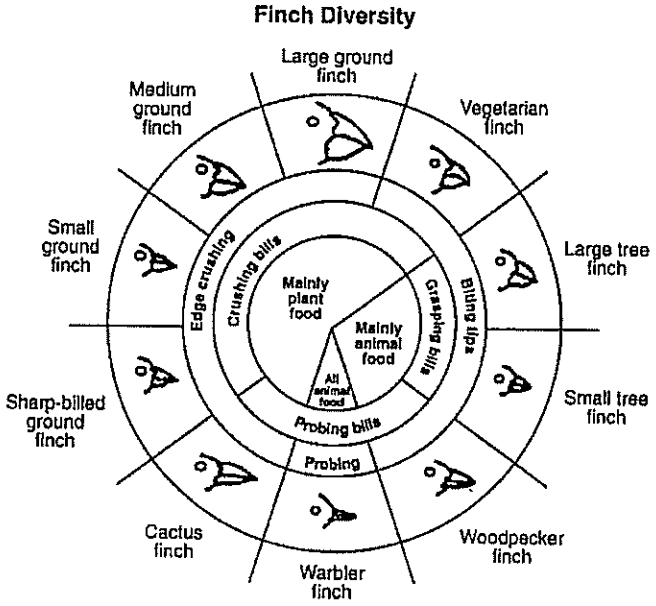
First process: _____

Explanation: _____

Second process: _____

Explanation: _____

Base your answers to question 33 on the finch diversity chart, which contains information concerning the finches found on the Galapagos Islands.



33. *a*) Identify one bird that would most likely compete for food with the large tree finch. Support your answer.

Bird: _____

Supporting statement: _____

_____

_____

b) Identify one trait, other than beak characteristics, that would contribute to the survival of a finch species and state one way this trait contributes to the success of this species.

Trait: _____ Statement: _____

_____

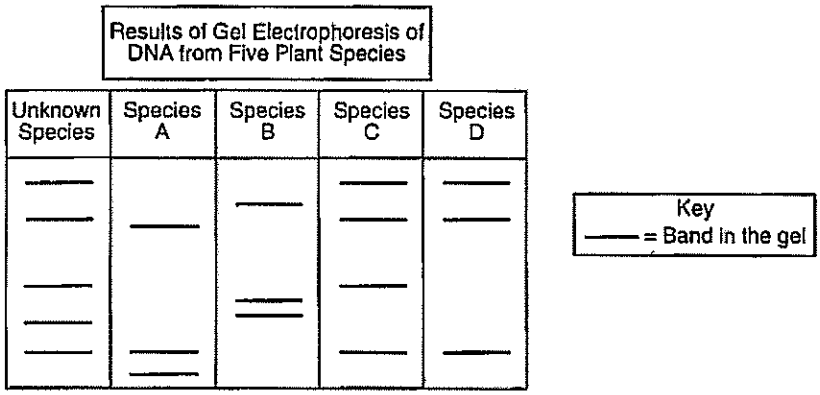
c) Three different species of finch inhabit one particular Galapagos Island. All three species of finch prefer plant food and have edge-crushing bills. Explain how all three species of finch can live successfully on the same island.

_____

34. For many years, health officials had encouraged using antibacterial hand soap. Today, many scientists recommend using hand soap with no added antibacterial substances. State one reason why using antibacterial hand soap may no longer be recommended.

_____

35. Scientists found members of a plant species they did not recognize. They wanted to determine if the unknown species was related to one or more of four known species, *A*, *B*, *C*, and *D*.
The relationship between species can be determined most accurately by comparing the results of gel electrophoresis of the DNA from different species.
The chart below represents the results of gel electrophoresis of the DNA from the unknown plant species and the four known species.



a) The unknown species is most closely related to which of the four known species? _____

Support your answer: _____

b) Identify one physical characteristic of plants that can be readily observed and compared to help determine the relationship between two different species of plants.

_____

c) Explain why comparing the DNA of the unknown and known plant species is probably a more accurate method of determining relationships than comparing only the physical characteristic you identified in question *b*.

_____

d) Of the 4 known species (*A*, *B*, *C* and *D*), which two are most closely related? _____ and _____

e) Identify one additional way to determine the evolutionary relationship of these plants.

_____

36. *R*, *S*, and *T* are three species of birds. Species *S* and *T* show similar coloration. The enzymes found in species *R* and *T* show similarities. Species *R* and *T* also exhibit many of the same behavioral patterns.

Show the relationship between species *R*, *S*, and *T* by placing the letter representing each species at the top of the appropriate branch on the diagram.

Base your answers to question 37 on the information below.

In the Beaks of Finches laboratory activity, students were each assigned a tool to use to pick up seeds. In round one, students acting as birds used their assigned tools to pick up small seeds from their own large dishes (the environment) and place them in smaller dishes (their stomachs). The seeds collected by each student were counted. Some students were able to collect many seeds, while others collected just a few.
In round two, students again used their assigned tools to collect seeds. This time several students were picking up seeds from the same dish of seeds.

37. *a*) Explain how this laboratory activity illustrates the process of natural selection.

_____

_____

b) One factor that influences the evolution of a species that was not part of this laboratory activity is
(1) struggle for survival (3) competition
(2) variation (4) overproduction ___ b_____

c) Identify one trait, other than beak characteristics, that could contribute to the ability of a finch to feed successfully. _____

Base your answer to question 38 on the information and data table.

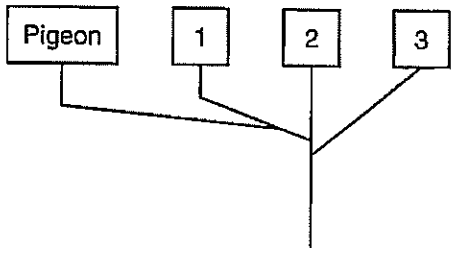
Body Structures and Reproductive Characteristics of Four Organisms

Organism	Body Structures	Reproductive Characteristics
pigeon	feathers, scales 2 wings, 2 legs	lays eggs
A	scales 4 legs	lays eggs
B	fur 2 leathery wings, 2 legs	gives birth to live young provides milk for offspring
C	fur 4 legs	lays eggs provides milk for offspring

38. *a*) Explain why it would be difficult to determine which one of the other three organisms from the table should be placed in box 1.

_____

_____



Evolutionary Tree

b) Identify and describe a technique that could help determine which organism belongs in box 1.

_____

Set 1 – Answers

1. 4 A stable physical environment is not explained or defined by evolution or natural selection. Natural selection and evolutionary consequences result in changes in organisms over the course of time. This is evident in the fossil record.

2. 3 The biological theory of evolution is based on the concept that modern organisms developed through a series of adaptations from early species.

3. 4 Natural selection is the process where new species develop over time based on favorable adaptations. These adaptations may be a result of mutation, genetic variation, or genetic recombination; therefore, the higher the number of mutations or genetic variations, the higher the rate of natural selection.

4. 3 Favorable behavioral adaptations that allowed birds to survive within an environment can be genetically programmed into a bird's genetic code due to the fact that the surviving birds with favorable traits will pass these traits on to their offspring.

5. 4 Genes themselves do not adapt. Genes provide the means, through variation, for the organism to adapt to environmental change. Statements 1, 2, and 3 are all important concepts within the process of natural selection.

6. 3 Each of these organisms inhabits different environments and uses its forelimbs for a different function. In order to survive within their environment, these organisms accumulated adaptations within their bone structure. Even though there are similarities in bone structure suggesting common ancestry, each organism's bones reflect changes due to adaptation to its environment.

7. 2 In an unstable environment, an organism is much more likely to experience stress on its population that could lead to extinction. By having few variations, the population would be less likely to adapt to any changes or diseases within their environment, thus leading to possible extinction.

8. 1 The diagram shows the evolutionary relationships between different mammals. A single origin position to the left represents a common ancestor in the past for all these organisms. The African elephant is more closely related to mammals that follow its evolutionary pathway. Therefore, the African and Asian elephants would be more closely related to the mammoth and mastodon than to any of the other named mammals.

9. 1 Changing environments place pressure on a species. If species adapt to the changing environment through natural selection, they will survive. Species that do not adapt are destined to become extinct. Many factors can influence the environment, such as climate, weather, natural occurrences, and even man.

10. 2 Genes provide the means through variation for an organism to adapt and evolve. In order for a trait to be passed on to the next generation, it must be present in the gametes of that organism. Those successful genes that are passed on will allow that organism to adapt to environmental change.

11. 4 During the process of meiosis, genes are shuffled and crossing over may occur, leading to variation in the resulting gametes. Each sex cell or gamete contains one half the amount of genetic material as the parent cell and will recombine during sexual reproduction, resulting in variation.

12. 3 Natural selection is a process where individuals with favorable traits or characteristics survive and pass those characteristics on to future generations. The proportion (frequency) of that favorable trait within the population will increase over time.

13. 1 Variations are the result of a change in the genetic code brought on by a mutation or by recombination of genes produced when sex cells or gametes come together. Remember that sexually reproducing species produce sex cells by means of meiosis, and each cell contains only half of the genetic material. At fertilization, new combinations of genes may occur.

14. 3 Based on the graph, species *A* and *E* have the most DNA in common. Since DNA provides the code for amino acids and the building of proteins, species *A* and *E* would also have the greatest similarity in protein structure.

15. 4 Present existing mammals species are successful today because they inherited traits that allowed them to adapt to and evolve in a changing environment. The woolly mammoth did not inherit successful traits and was unable to survive, leading to its extinction. Environmental changes such as climate, weather changes, natural occurrences, and even humans may have contributed towards the extinction of this mammal.

16. 3 Natural selection is a process where individuals with favorable traits or characteristics survive and pass those characteristics on to future generations. The proportion (frequency) of that favorable trait within the population will increase over time.

17. 2 Changes in gene frequency lead to variation within a population. Variation can lead to biological evolution if environmental conditions change. Genetic variation can be brought about by a change within the gene sequence, many times resulting in a mutation.

18. 1 All of the shown evolutionary pathways originated from the ancestral organism *B*. Only organism *Q* and *S* successfully adapted to changing environments and have reached the Present time. The other organisms did not successfully adapt and are now extinct.

19. 4 Organisms that have fast reproductive rates and live in changing environments would show fast evolutionary rates. Evolution reflects an organism's ability to adapt to changes in an environment. Certain genetic traits that allow organisms to survive and therefore adapt are passed reproductively from one generation to the next. If an organism has a rapid or fast reproductive rate, those adaptive genes will be passed faster, thus allowing for a faster evolution rate.

20. 4 Variety *A* is increasing while *B* is decreasing. This shows that variety *A* has successfully adapted to its environment and has some favorable variations that have been passed along many generations. Variety *B* does not have these favorable variations and is heading to extinction, as shown by the graph.

21. 3 Evolution is a change in a population over time as a result of a change in the environment. Climate change in a region may allow for changes in the plant populations. Those with favorable characteristics would survive, perhaps leading to new varieties of plants. This region undergoing climate changes would show more evidence of evolution based on more plant varieties.

22. 1 In unfavorable conditions, if the adaptive characteristics of a species are not adequate, the species faces extinction.

23. 2 Through natural selection, the desert rat and the Arctic poppy plant have adapted differently to their environments. These adaptations have allowed them to survive in their harsh environment, reproduce, and pass those favorable traits on to the next generation, ensuring continual survival of the species.

24. *a*) 4 Species *F* and *G* would be most closely related because they both share the most recent common ancestor *D*.

b) 2 Species *B* was best adapted to environmental change. Species *B* started as an ancestral species and survived through each period of geologic time to the most recent time period.

c) 1 Both *B* and *J* share a common ancestor – species *B*. Because they share this common ancestor, they both will have some DNA related to ancestral species *B*. Remember, DNA serves as a template in protein synthesis.

d) 3 Within the nucleus is found DNA. If a mutation occurs and alters the DNA within a gamete, it may be expressed as new characteristics within the offspring of that species and possibly lead to genetic variation.

25. *a*) 1 Due to a decrease in the numbers of small seeds during the dry years, those finches with the larger beak trait were able to survive and reproduce. The large beak trait was then passed on to future generations. This is an example of natural selection.

b) 4 Due to a diminished amount of seeds, there will be competition for whatever food is available. Those finches that have a better adapted trait, such as a larger beak, can outcompete other finches, survive, and reproduce, passing that trait on.

26. 2 Biological evolution is defined as a slow change over time. As the finches moved to different islands, they adapted to different habitats and foods, evolving beak variations. Over time, the finches with the best adapted beaks for that island survived and formed a particular variety of finch. Eventually 14 different varieties of finches evolved. This is the process described by Charles Darwin as natural selection.

27. *a*) 2 Based on the information provided in the diagram, the differences in beaks of the four finches are most likely a result of variation and natural selection. Each finch beak type has a different structure based on genetic variation which allowed that finch to be successful in a specific niche. The process of natural selection occurs when individuals with successful variations survive in changing environments.

b) No
Supporting statement: The vegetarian finches eat seeds and would not face competition from the insect finches. *or* No, the other finches eat insects and the vegetarian finches eats seeds. *or* they eat different foods.

Yes
Supporting statement: As the finches population increases there will be competition for nesting sites.

28. 3 Based on the diagram, earthworms and sea stars have a common ancestor. This common ancestor is found directly up from the ancestral protists where the straight line branches left and right. The left branch leads to the earthworm and the right branch leads to the sea star. By sharing a common ancestor, the earthworm and sea star are evolutionarily related.

29. *a*) Answer: tough seed coats *or* spiny seed coats

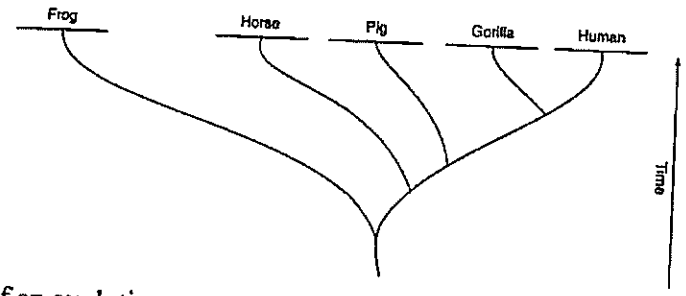
Explanation: The caltrop plants are producing seeds that contain tough spiny coats. These adaptations on the seeds have evolved as a means of protection against being eaten by the bird species – *Geospiza fortis*.

b) Answer: natural selection *or* mutation *or* sexual reproduction

Explanation: All of the above processes will create variations within species. These variations, if favorable to the species, will be passed on to future generations making the species better adapted to the environment in which they live.

c) Adaptation: fast flight speed — to escape predators *or* camouflage — to hide from predators *or* eyesight— to locate food *or* mating behavior (songs)— to attract mates

30.



Explanation: One method of determining evolutionary position is to compare proteins or amino acid sequences of various organisms. Those organisms with a greater number of common amino acids are more closely related. Evolutionary relationships can be expressed in the form of an evolutionary tree, which shows how organisms evolved and when new species appeared. For example, the gorilla has only one amino acid different from humans and would be placed on the branch closest the human. The frog which has the greatest number of differences would be placed on a branch farthest from the human – to the far left.

31. Answer: Species *E*

Supporting statement: Species *E* is best adapted for changing environments because it has survived as species *E* through a long period of time and not changed, whereas other species have changed or become extinct. In the evolutionary tree, species *E* continues through time to present day indicating that it has favorable characteristics that enable it to survive.

32. *a*) 3 Natural selection is a process where organisms adapt to changes in their environment. Genetic variability due to mutations led to particular individuals being more successful on different islands. Those organisms survived while others did not. The Galapagos Islands provide varying habitats with varying food sources for many organisms, leading to diversity through natural selection.

b) 3 Carnivores are organisms that feed exclusively on other animals.

c) Answer: herbivores

Explanation: Herbivores are organisms that feed exclusively on producers.

d) Acceptable responses include but are not limited to:
Large ground finches eat mainly plant food, and large tree finches eat mainly animal food.
or They do not compete for the same resources.
or They occupy different niches.

Explanation: Using the diagram, locate the large ground finch and large tree finch and move directly in towards the center, noting the type of food they eat. Since these birds feed on different food types (plant vs. animal), they will not be competing for the same resources, allowing each bird to be successful. Remember that two organisms cannot successfully occupy the same niche at the same time; one will outcompete the other.

e) Answer: Cactus finch Supporting statement: Because it eats mainly plant food whereas the other two finches eat mostly animal food.

Explanation: A niche is a role that an organism plays in an ecosystem. The diagram shows that the cactus finch feed mainly on plant food, while the warbler and woodpecker finch feed on animal food. Since the cactus finch has a different food source, it occupies a different niche and would not compete with the other two types of finch.

f) Answer: The medium ground finch would face increase competition for seeds.
or The food resources for these birds would be in limited supply.
or One of these bird species might be outcompeted for food and become extinct.

Explanation: Since both of these finches have a diet of seeds, competition will take place. The above given answers are resulting consequences for animals that compete for the same food.

g) Answer: Niche

Explanation: A niche is the role that an organism plays within an ecosystem. Most niches on the Galapagos are based on the nutritional habits of the finches.

33. *a*) Acceptable responses include but are not limited to:
or According to diagram 3, *C* should look different from *A* and *B*, but it does not.
or Stem cross sections in diagram 1 show that *A*, *B* and *C* have similar stem structures, indicating that they are most likely related.
or Diagram 3 shows only *A* and *B* as being closely related.

Explanation: All the stems in diagram 1 are very similar. It is not possible from this diagram to tell the evolutionary relationship that might exist among them.

b) Answer: Species *A* and *B* have the most bands in common.

Explanation: Species that are closely related will share similar DNA sequences. When the DNA is subjected to gel electrophoresis, species with close evolutionary links will have more bands in common. In diagram 2, species *A* and *B* share three bands in common, while *C* shares one band in common with *B* and two with *A*.

c) 2 Gel electrophoresis is a process that separates DNA fragments that have been cut up by restriction enzymes. The DNA is placed in a gel, and an electric current is applied. The DNA migrates through the gel as a result of the electric current, with the smallest fragments moving the farthest. It can then be analyzed for similarities.