Unit 7: Natural Selection

Topic	Learning Objective(s)
7.1 Introduction to Natural Selection	**EVO-1.C** Describe the causes of natural selection.
	EVO-1.D Explain how natural selection affects populations.
7.2 Natural Selection	**EVO-1.E** Describe the importance of phenotypic variation in a population.
7.3 Artificial Selection	**EVO-1.F** Explain how humans can affect diversity within a population.
	EVO-1.G Explain the relationship between changes in the environment and evolutionary changes in the population.
7.4 Population Genetics	**EVO-1.H** Explain how random occurrences affect the genetic makeup of a population.
	EVO-1.I Describe the role of random processes in the evolution of specific populations.
	EVO-1.J Describe the change in the genetic makeup of a population over time.
7.5 Hardy-Weinberg Equilibrium	**EVO-1.K** Describe the conditions under which allele and genotype frequencies will change in populations.
	EVO-1.L Explain the impacts on the population if any of the conditions of Hardy-Weinberg are not met.
7.6 Evidence of Evolution	**EVO-1.M** Describe the types of data that provide evidence for evolution.
	EVO-1.N Explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time.
	EVO-2.B Describe the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry.
7.7 Common Ancestry	**EVO-2.C** Describe structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes.
7.8 Continuing Evolution	**EVO-3.A** Explain how evolution is an ongoing process in all living organisms.
7.9 Phylogeny	**EVO-3.B** Describe the types of evidence that can be used to infer an evolutionary relationship.
	EVO-3.C Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.
7.10 Speciation	**EVO-3.D** Describe the conditions under which new species may arise.
	EVO-3.E Describe the rate of evolution and speciation under different ecological conditions.
	EVO-3.F Explain the processes and mechanisms that drive speciation.
7.11 Extinction	**EVO-3.G** Describe factors that lead to the extinction of a population.
	EVO-3.H Explain how the risk of extinction is affected by changes in the environment.
	EVO-3.I Explain species diversity in an ecosystem as a function of speciation and extinction rates.
	EVO-3.J Explain how extinction can make new environments available for adaptive radiation.

7.12 **Variations in Populations**	**SYI-3.D** Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.
7.13 **Origin of Life on Earth**	**SYI-3.E** Describe the scientific evidence that provides support for models of the origin of life on Earth.

Topic 7.1: Introduction to Natural Selection

Learning Objective	**EVO-1.C** Describe the causes of natural selection.
I can…	☐ I can describe the causes of natural selection. ☐ I can describe how natural selection leads to evolution. ☐ I can describe Darwin's theory of natural selection. ☐ I can apply differential survival in a situation of competition for limited resources.

1. What is natural selection?
2. How does natural selection lead to evolution?
3. What is Darwin's theory of natural selection?
4. Why do organisms require competition for limited resources to allow for natural selection?

Learning Objective	**EVO-1.D** Explain how natural selection affects populations.
I can…	☐ I can explain how natural selection affects populations. ☐ I can explain how evolutionary fitness is measured. ☐ I can explain reproductive success. ☐ I can explain ways biotic environments can affect the direction of evolution. ☐ I can explain ways biotic environments can affect the rate of evolution. ☐ I can explain ways abiotic environments can affect the direction of evolution. ☐ I can explain ways abiotic environments can affect the rate of evolution.

5. What is evolutionary fitness?
6. How is evolutionary fitness measured?
7. What is reproductive success?
8. How does reproductive success lead to natural selection?
9. What does biotic and abiotic mean?
10. How does a biotic environment affect the direction of evolution?
11. How does an abiotic environment affect the direction of evolution?
12. How does a biotic environment affect the rate of evolution?
13. How does an abiotic environment affect the rate of evolution?

Topic 7.2: Natural Selection

Learning Objective	**EVO-1.E** Describe the importance of phenotypic variation in a population.
I can…	☐ I can describe the importance of phenotypic variation in a population. ☐ I can describe what natural selection acts on. ☐ I can describe ways an environment applies selective pressure to a population. ☐ I can describe ways a phenotypic variation can increase fitness of an organism in a particular environment. ☐ I can describe ways a phenotypic variation can decrease fitness of an organism in a particular environment.

1. What is phenotype?
2. What does natural selection act on … PHENOTYPE or GENOTYPE?
3. What does natural selection modify … PHENOTYPE or GENOTYPE?
4. How does natural selection act on and modify different levels of genes?
5. What are selective pressures?
6. How does an environment apply a selective pressure to a population?
7. Identify one example of a phenotypic variation that increases fitness of an organism in a snowy environment.
8. Identify one example of a phenotypic variation that decreases fitness of an organism dark colored forest.

Topic 7.3: Artificial Selection

Learning Objective	**EVO-1.F** Explain how humans can affect diversity within a population.
I can…	☐ I can explain ways humans affect diversity within a population. ☐ I can describe artificial selection. ☐ I can describe ways artificial selection affects variation in a species.

1. What is artificial selection?
2. How does artificial selection modify the variation in a species?
3. Identify two examples of artificial selection due to humans.
    a. How has this modified the species?

Learning Objective	**EVO-1.G** Explain the relationship between changes in the environment and evolutionary changes in the population.
I can…	☐ I can explain the relationship between changes in the environment and evolutionary changes in the population. ☐ I can explain convergent evolution. ☐ I can explain ways selective pressures result in similar phenotypic adaptations in different populations.

4. What is convergent evolution?
5. Identify two examples of organisms that demonstrate convergent evolution.
6. How do selective pressures result in similar phenotypic adaptations?

Topic 7.4: Population Genetics

Learning Objective	**EVO-1.H** Explain how random occurrences affect the genetic makeup of a population.
I can…	☐ I can explain ways random occurrences affect the genetic makeup of a population. ☐ I can explain the different types of mutations ☐ I can explain ways that mutations affect genetic makeup of a population. ☐ I can explain genetic drift. ☐ I can explain bottleneck. ☐ I can explain ways bottleneck affects genetic makeup of a population. ☐ I can explain founder effect. ☐ I can explain ways founder effect affects genetic makeup of a population. ☐ I can explain gene flow. ☐ I can explain ways gene flow affects genetic makeup of a population.

1. What are mutations?
2. Identify two examples of mutations that potentially could affect phenotype.
3. What is genetic drift?
4. What is the bottleneck effect?
5. How does the bottleneck effect modify genetic makeup of a population?
6. Identify one example of a population that has undergone the bottleneck effect.
7. What is the founder's effect?
8. How does the founder's effect modify genetic makeup of a population?
9. Identify one example of a population that has undergone the founder's effect.
10. What is gene flow?
11. How does gene flow modify genetic makeup of a population?
12. Identify one example of a population that has undergone gene flow.

Learning Objective	**EVO-1.I** Describe the role of random processes in the evolution of specific populations.
I can…	☐ I can describe the role of random processes in the evolution of specific populations. ☐ I can describe the effect of decrease in genetic variation in a population on the differences between other populations of the same species.

13. What is genetic variation?
14. Why is genetic variation important for a population's survivability?
15. How does a decrease in genetic variation affect a population?

Learning Objective	**EVO-1.J** Describe the change in the genetic makeup of a population over time.
I can…	☐ I can describe the change in genetic makeup of a population over time. ☐ I can describe ways that mutations cause genetic variation. ☐ I can describe ways that genetic variation provides different phenotypes. ☐ I can describe ways natural selection acts on phenotypes. ☐ I can describe directional selection. ☐ I can describe stabilizing selection. ☐ I can describe disruptive selection.

16. What is the effect of mutations on genetic variation?
17. Describe directional, disruptive and stabilizing selection.

Topic 7.5: Hardy-Weinberg Equilibrium

Learning Objective	**EVO-1.K** Describe the conditions under which allele and genotype frequencies will change in populations.
I can…	☐ I can describe the conditions under which allele frequencies will change in populations. ☐ I can describe the conditions under which genotypes frequencies will change in populations. ☐ I can describe a population demonstrating Hardy-Weinberg. ☐ I can calculate allele frequencies from genotype frequencies. ☐ I can identify the variables in Hardy-Weinberg equation.
Formula Sheet	**RELEVANT EQUATION** Hardy-Weinberg Equation— $p^2 + 2pq + q^2 = 1$ $p + q = 1$ where: p = frequency of allele 1 in the population q = frequency of allele 2 in the population

1. What are the five conditions that must be TRUE for Hardy-Weinberg equilibrium?
2. What is allele frequency?
3. What is genotypic frequency?
4. What does the p represent and what does the q represent in the Hardy-Weinberg equilibrium?
5. There are two ways to solve for the variables in the equation.
   a. In a population of 1234 humans, 199 have blue eyes, which are recessive, find all of the values below.

p	q	p^2	2pq	q^2

   b. Flowers can either be purple (dominant) or white (recessive). Solve for all the values if 75% of the flowers are purple.

p	q	p^2	2pq	q^2

Learning Objective	**EVO-1.L** Explain the impacts on the population if any of the conditions of Hardy-Weinberg are not met.
I can…	☐ I can explain the impacts on the population if any of the conditions of Hardy Weinberg are not met. ☐ I can explain ways that small populations are more susceptible to changes in allele frequency.

6. What does it mean if the genotype frequency stays the same from one generation to the next?
7. Why are small populations more susceptible to changes in allele frequency?

Topic 7.6: Evidence of Evolution

Learning Objective	**EVO-1.M** Describe the types of data that provide evidence for evolution.
I can…	☐ I can describe the types of data that provide evidence for evolution. ☐ I can use geographical data to support evolution. ☐ I can use geological data to support evolution. ☐ I can use physical data to support evolution. ☐ I can use biochemical data to support evolution. ☐ I can use mathematical data to support evolution.

1. What is biogeography?

Learning Objective	**EVO-1.N** Explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time.
I can…	☐ I can explain ways morphological data provide evidence that organisms have changed over time. ☐ I can explain ways biochemical data provide evidence that organisms have changed over time. ☐ I can explain ways geological data provide evidence that organisms have changed over time. ☐ I can date fossils using information about the age of rocks layers where it is found. ☐ I can date fossils using carbon-14 decay. ☐ I can date fossils using geographical data. ☐ I can compare DNA nucleotide sequences to provide evidence for evolution and common ancestry. ☐ I can compare protein amino acid sequences to provide evidence for evolution and common ancestry.

2. What are fossils?
3. How can fossils be used as evidence of evolution?
4. How do the rock layers allow for dating of fossils?
5. DNA and proteins can be used as evidence of evolution. Which is more accurate to determine most recent common ancestor? DNA or PROTEINS
6. How do the number of differences of nucleotides or amino acids demonstrate ancestry of organisms?

Learning Objective	**EVO-2.B** Describe the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry.
I can…	☐ I can describe the fundamental features shared across all domains of life, which provide evidence of common ancestry. ☐ I can describe the molecular features shared across all domains of life, which provide evidence of common ancestry. ☐ I can describe the cellular features shared across all domains of life, which provide evidence of common ancestry. ☐ I can use structural evidence to support relatedness of organisms in all domains. ☐ I can use functional evidence to support relatedness of organisms in all domains.

7. Identify two molecular features shared across organisms.
8. Identify two cellular features shared across organisms.
9. What are homologous structures?
10. What are analogous structures?
11. What is embryology?

Topic 7.7: Common Ancestry

Learning Objective	**EVO-2.C** Describe structural and functional evidence on cellular and molecular levels that provides evidence for the common ancestry of all eukaryotes.
I can…	☐ I can describe structural evidence on the cellular level that provides evidence for the common ancestry of all eukaryotes. ☐ I can describe functional evidence on the cellular level that provides evidence for the common ancestry of all eukaryotes. ☐ I can describe structural evidence on the molecular level that provides evidence for the common ancestry of all eukaryotes. ☐ I can describe functional evidence on the molecular level that provides evidence for the common ancestry of all eukaryotes. ☐ I can describe ways that membrane-bound organelles indicate common ancestry of all eukaryotes. ☐ I can describe ways that linear chromosomes indicate common ancestry of all eukaryotes. ☐ I can describe ways that genes containing introns indicate common ancestry of all eukaryotes.

1. What are membrane-bound organelles?
2. What type of cells have membrane-bound organelles? EUKARYOTIC or PROKARYOTIC
3. How did membrane-bound organelles originate?
4. How do membrane-bound organelles indicate common ancestry for all eukaryotes?
5. Describe a linear chromosome.
6. How are prokaryotic chromosomes organized?
7. How are eukaryotic chromosomes organized?
8. How do linear chromosomes indicate common ancestry for all eukaryotes? What is an intron?
9. When are introns removed?
10. What type of cells have introns? EUKARYOTIC or PROKARYOTIC
11. How do genes containing introns indicate common ancestry for all eukaryotes?

Topic 7.8: Continuing Evolution

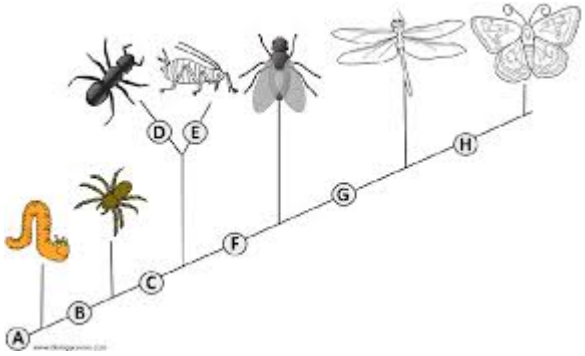
Learning Objective	**EVO-3.A** Explain how evolution is an ongoing process in all living organisms.
I can…	☐ I can explain ways to show that evolution is an ongoing process in all living organisms. ☐ I can explain ways to show that population of organisms continue to evolve. ☐ I can use genomic changes over time to support the claim that all species have evolved and continue to evolve. ☐ I can use continuous change in the fossil record to support the claim that all species have evolved and continue to evolve. ☐ I can use evolution of resistance to antibiotics, pesticides, herbicides, or chemotherapy drugs to support the claim that all species have evolved and continue to evolve. ☐ I can use pathogen evolution and causation of emergent disease to support the claim that all species have evolved and continue to evolve.

1. What evolves? INDIVIDUALS or POPULATIONS
2. True or False: Once a population of organisms are perfect, they will cease evolving.
3. How can scientists use genomes to prove that all species continue to evolve?
4. How can scientists use fossil record to prove that all species continue to evolve?
5. What does it mean if a population of bacteria is antibiotic resistant?
6. How does a population of bacteria become antibiotic resistant?
7. How does this resistance to antibiotics support the claim that all species have evolved and continue to evolve?
   - Note this should be applicable to pesticides, herbicides, or chemotherapy drugs.
8. Why do you need to get the influenza vaccine every year?

Topic 7.9: Phylogeny

Learning Objective	**EVO-3.B** Describe the types of evidence that can be used to infer an evolutionary relationship.
I can…	☐ I can describe the types of evidence that can be used to infer an evolutionary relationship. ☐ I can use phylogenetic trees and cladograms to show evolutionary relationships among lineages. ☐ I can compare the data provided by a phylogenetic tree and cladogram. ☐ I can contrast the data provided by a phylogenetic tree and cladogram. ☐ I can use trait gained or lost during evolution to construct a phylogenetic tree or cladogram. ☐ I can describe shared characters. ☐ I can describe shared, derived characters. ☐ I can describe the outgroup. ☐ I can identify the outgroup in a phylogenetic tree or cladogram. ☐ I can describe the most accurate and reliable data for the construction of phylogenetic tree or cladogram.

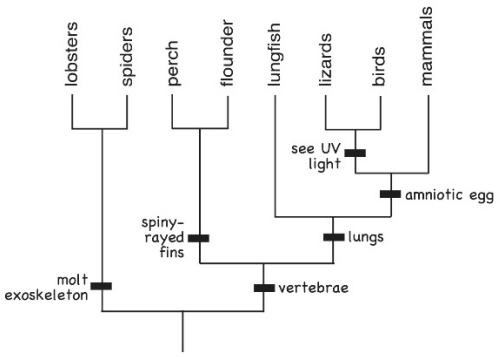
1. What is a phylogenetic tree?
2. What is a cladogram?
3. Identify one similarity about the data presented in a phylogenetic tree and cladogram.
4. Identify one difference about the data presented in a phylogenetic tree and cladogram.
5. Where would you see a gained or lost trait on a cladogram or phylogenetic tree?
    a. For example: Using the following cladogram, identify at what point wings were gained?



6. What are shared characters?
7. What are derived characters?
8. What is an outgroup?
    a. How do you identify the outgroup on a cladogram?
9. Which if the most accurate and reliable data for construction of phylogenetic tree or cladogram? MOLECULAR DATA or MORPHOLOGICAL TRAITS
    a. Justify why this type of data is the most accurate and reliable.

Learning Objective	**EVO-3.C** Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.
I can…	☐ I can explain ways a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness. ☐ I can determine when speciation occurred using a phylogenetic tree and/or cladogram. ☐ I can determine the most recent common ancestor of any two groups or lineages on a phylogenetic tree and/or cladogram. ☐ I can describe evidence used to construct a phylogenetic tree and/or cladogram. ☐ I can use DNA/protein sequences to develop a phylogenetic tree and/or cladogram. ☐ I can use fossil evidence to develop a phylogenetic tree and/or cladogram. ☐ I can use evidence to revise a phylogenetic tree and/or cladogram.

10. What does a branch point in a cladogram or phylogenetic tree represent?
11. How do you determine the most recent common ancestor on a cladogram or phylogenetic tree?
    a. For example: Identify the most recent common ancestor of lizards and mammals.



12. In the above example, what organism is most closely related to:
    a. Spiders?
    b. Perch?
    c. Birds?
13. What evidence is used to develop a cladogram or phylogenetic tree?
14. When using molecular evidence, how do you determine if two organisms are closely related?
15. When using fossil evidence, how do you determine if two organisms are closely related?

Topic 7.10: Speciation

Learning Objective	**EVO-3.D** Describe the conditions under which new species may arise.
I can…	☐ I can describe the conditions under which new species may arise. ☐ I can describe speciation. ☐ I can describe the types of reproductive isolation. ☐ I can describe the biological species concept. ☐ I can determine whether two organisms are from the same species.

1. What is speciation?
2. What is reproductive isolation?
3. How can you determine if two organisms are from the same species?

Learning Objective	**EVO-3.E** Describe the rate of evolution and speciation under different ecological conditions.
I can…	☐ I can describe the rate of evolution and speciation under different ecological conditions. ☐ I can describe punctuated equilibrium. ☐ I can describe gradualism. ☐ I can describe divergent evolution. ☐ I can describe the effect of adaptive radiation on speciation rates.

4. What is punctuated equilibrium?
    a. Identify an example of an organism that underwent punctuated equilibrium.
5. What is gradualism?
    a. Identify an example of an organism that underwent gradualism.
6. What is divergent evolution?
    a. What term do we use when two organisms have similar characteristics due to divergent evolution?
7. What is adaptive radiation?
8. What is the effect of adaptive radiation on speciation rates?

Learning Objective	**EVO-3.F** Explain the processes and mechanisms that drive speciation.
I can…	☐ I can explain the processes that drive speciation. ☐ I can explain the mechanisms that drive speciation. ☐ I can describe the results of speciation. ☐ I can describe sympatric speciation. ☐ I can describe allopatric speciation. ☐ I can identify prezygotic barriers. ☐ I can describe habitat/ecological isolation. ☐ I can describe temporal isolation. ☐ I can describe behavioral isolation. ☐ I can describe gametic isolation. ☐ I can describe geographical isolation. ☐ I can identify postzygotic barriers. ☐ I can describe hybrid breakdown. ☐ I can describe reduced hybrid viability. ☐ I can describe reduced hybrid fertility. ☐ I can describe ways that reproductive barriers cause speciation.

9. What are the results of speciation?
10. What is sympatric speciation?
11. What mechanisms lead to speciation in sympatric speciation?
12. What is allopatric speciation?
13. What mechanisms lead to speciation in allopatric speciation?
14. What is the difference between pre- and post- zygotic reproductive barriers?
15. Using the following chart, describe the types of pre- and post- zygotic reproductive barriers with examples.

Prezygotic Reproductive Barriers		
Reproductive Isolation Type	Description	Example
Habitat/Ecological Isolation		
Temporal Isolation		
Behavioral Isolation		
Gametic Isolation		
Geographical Isolation		
Postzygotic Reproductive Barriers		
Reproductive Isolation Type	Description	Example
Hybrid Breakdown		
Reduced Hybrid Viability		
Reduced Hybrid Fertility		

16. How does reproductive isolation lead to speciation?
17. What three potential results occur when two species come in contact in the hybrid zone?

Topic 7.11: Extinction

Learning Objective	**EVO-3.G** Describe factors that lead to the extinction of a population.
I can…	☐ I can describe factors that lead to the extinction of a population. ☐ I can describe extinctions that have occurred throughout Earth's history. ☐ I can describe the effect on extinction rates of ecological stress.

1. Identify two extinctions that have occurred in Earth's history?
2. What lead to the extinctions that you identified?
3. How does extinction rates effect ecological stress?

Learning Objective	**EVO-3.H** Explain how the risk of extinction is affected by changes in the environment.
I can…	☐ I can explain ways the risk of extinction is affected by changes in the environment. ☐ I can explain ways that human activity is driving changes in ecosystems. ☐ I can explain ways that changes in the ecosystems is causing extinctions.

4. Identify two ways that human activities are driving changes in ecosystems leading to extinctions.
5. What changes in environments lead to extinction of organisms?

Learning Objective	**EVO-3.I** Explain species diversity in an ecosystem as a function of speciation and extinction rates.
I can…	☐ I can explain species diversity in an ecosystem as a function of speciation and extinction rates. ☐ I can predict the effect on species diversity based on rate of speciation and rate of extinction changes.

6. What is species diversity?
7. How does species diversity impact the rate of speciation?
8. How does species diversity impact the rate of extinction?

Learning Objective	**EVO-3.J** Explain how extinction can make new environments available for adaptive radiation.
I can…	☐ I can explain ways extinctions can make new environments available for adaptive radiation. ☐ I can describe the effect of newly available niches on speciation.

9. How do extinctions affect available niches in an ecosystem?
10. How do changes in available niches affect organisms in an ecosystem?

Topic 7.12: Variation in Populations

Learning Objective	**SYI-3.D** Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.
I can…	☐ I can explain ways the genetic diversity of a species affects its ability to withstand environmental pressures. ☐ I can explain ways the genetic diversity of a population affects its ability to withstand environmental pressures. ☐ I can explain why a species/population with little genetic diversity are at risk of decline or extinction. ☐ I can predict a population's ability to respond to changes in the environment based on population diversity. ☐ I can describe the advantage of generic diversity in times of environmental perturbation. ☐ I can explain ways alleles can affect individuals differently in different environments.

1. What is genetic diversity?
2. Why are populations with little genetic diversity at risk of decline or extinction?
3. If a population is more genetically diverse, how do they respond to environmental changes?
4. What is the advantage of a population being genetically diverse?
5. True or False: Alleles that are helpful in one environment will be helpful in another environment.
6. Why do allele affect individuals differently in different environments?

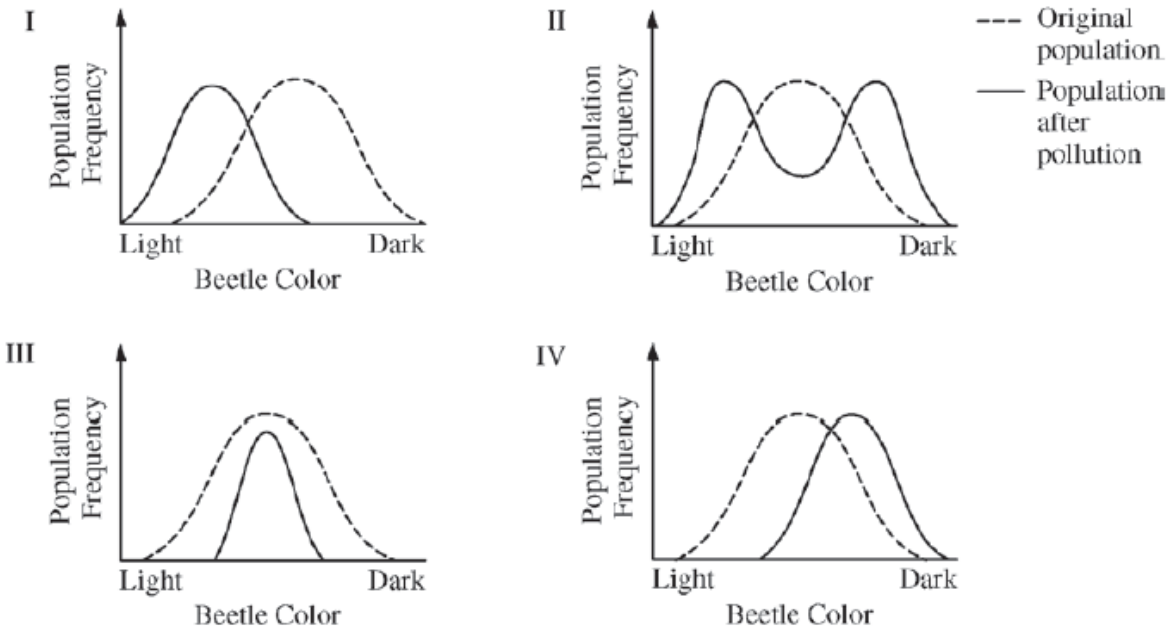
Topic 7.13: Origin of Life on Earth

Learning Objective	**SYI-3.E** Describe the scientific evidence that provides support for models of the origin of life on Earth.
I can…	☐ I can describe the scientific evidence that provides support for models of the origin of life on Earth. ☐ I can use geological evidence to support the model of the origin of life on Earth. ☐ I can identify approximately when Earth was formed. ☐ I can identify approximately when the environment on Earth was no longer considered hostile for life. ☐ I can identify approximately when the earliest fossil evidence for life was dated to. ☐ I can describe primitive earth. ☐ I can describe where organic molecules originated. ☐ I can describe chemical experiment that have shown it is possible for form complex organic from inorganic molecules in the absence of life. ☐ I can describe ways polymers formed from monomers. ☐ I can describe the RNA World Hypothesis.

1. What geological evidence provide support for the origin of Earth?
2. Approximately when did the Earth form?
3. Approximately when was Earth no longer hostile for life?
4. What were the characteristics of primitive Earth?
5. Where did organic molecules originate?
6. What occurred in Stanley Miller's experiment regarding primitive Earth?
    a. What was concluded?
7. How could this process take place on primitive Earth?
8. What is the RNA World Hypothesis?

Multiple Choice Practice

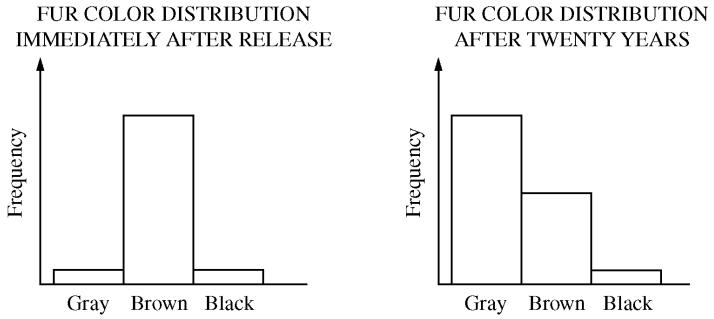
1. In a hypothetical population of beetles, there is a wide variety of color, matching the range of coloration of the tree trunks on which the beetles hide from predators. The graphs below illustrate four possible changes to the beetle population as a result of a change in the environment due to pollution that darkened the tree trunks.



Which of the following includes the most likely change in the coloration of the beetle population after pollution and a correct rationale for the change?

a. The coloration range shifted toward more light-colored beetles, as in diagram I. The pollution helped the predators find the darkened tree trunks.
b. The coloration in the population split into two extremes, as in diagram II. Both the lighter-colored and the darker-colored beetles were able to hide on the darker tree trunks.
c. The coloration range became narrower, as in diagram III. The predators selected beetles at the color extremes.
d. The coloration in the population shifted toward more darker-colored beetles, as in diagram IV. The lighter- colored beetles were found more easily by the predators than were the darker-colored beetles.

2. A group of mice was released into a large field to which no other mice had access. Immediately after the release, a representative sample of the mice was captured, and the fur color of each individual in the sample was observed and recorded. The mice were then returned to the field. After twenty years, another representative sample of the mice was captured, and the fur color of each individual in the sample was again recorded. Which of the following best explains the change in the frequency distribution of fur color phenotypes in the mouse population, as shown in the figures above?



   a. The allele for gray fur color is unstable, and over twenty years most of those alleles mutated to become alleles for black fur.
   b. The field was composed primarily of light-colored soil and little vegetation, affording gray mice protection from predators.
   c. Sexual selection led to increased mating frequency of black and brown versus gray and brown.
   d. The gray mice were hardest to capture and so were underrepresented in the twenty-year sample.

Use the following information to answer question 3:

The following figures display data collected while studying a family, some members of which have sickle-cell disease—a rare genetic disorder caused by a mutation in the hemoglobin beta gene (HBB). There are at least two alleles of the HBB gene: the HbA allele encodes wild-type hemoglobin and the HbS allele encodes the sickle-cell form of hemoglobin. Genetic testing provided insight into the inheritance pattern for sickle-cell disease.

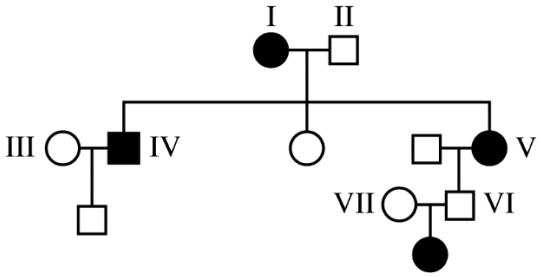


Figure 1. Pedigree of a family with affected individuals. Squares represent males, circles represent females, shaded symbols represent individuals with sickle-cell disease.

5' CTG ACT CCT GAG GAG AAG TCT 3' Non-template Strand
3' GAC TGA GGA CTC CTC TTC AGA 5' Template Strand

Figure 2. A portion of the DNA sequence from the wild-type hemoglobin allele (HbA) that codes for normal hemoglobin.

Second Base in Codon

First Base in Codon	U	C	A	G	Third Base in Codon
U	UUU, UUC: Phe; UUA, UUG: Leu	UCU, UCC, UCA, UCG: Ser	UAU, UAC: Tyr; UAA: Stop; UAG: Stop	UGU, UGC: Cys; UGA: Stop; UGG: Trp	U C A G
C	CUU, CUC, CUA, CUG: Leu	CCU, CCC, CCA, CCG: Pro	CAU, CAC: His; CAA, CAG: Gln	CGU, CGC, CGA, CGG: Arg	U C A G
A	AUU, AUC, AUA: Ile; AUG: Met or Start	ACU, ACC, ACA, ACG: Thr	AAU, AAC: Asn; AAA, AAG: Lys	AGU, AGC: Ser; AGA, AGG: Arg	U C A G
G	GUU, GUC, GUA, GUG: Val	GCU, GCC, GCA, GCG: Ala	GAU, GAC: Asp; GAA, GAG: Glu	GGU, GGC, GGA, GGG: Gly	U C A G

Figure 3. Codon table showing nucleotide sequences for each amino acid.

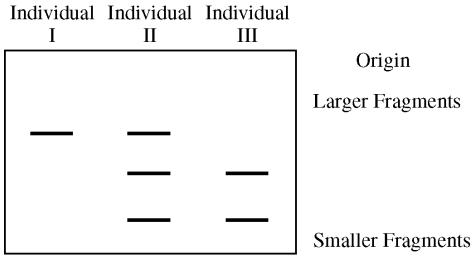
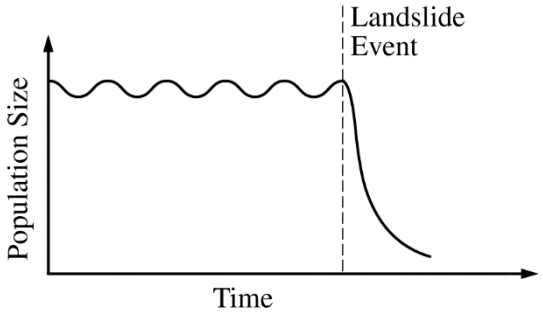


Figure 4. Image of a gel following electrophoretic separation of DNA fragments of the HBB gene from three individuals in the pedigree in Figure 1.

3. Possessing a single copy of the HbS allele has been shown to provide some resistance to infection by Plasmodium falciparum, the parasite that causes malaria. Which of the following individuals represented in the pedigree would have the greatest selective advantage in an area where malaria is common?
   a. I
   b. II
   c. III
   d. V

4. Undersea landslides can disrupt marine habitats by burying organisms that live on the ocean floor. The graph above shows the size of a population of a certain organism that lives on the ocean floor. The population was affected by a recent landslide at the time indicated on the graph. Which of the following best predicts how the population will be affected by the landslide?



   a. The surviving organisms will evolve into a new species.
   b. The reduced population will likely have allelic frequencies that are different from the initial population.
   c. The population will adapt to deeper waters to avoid future landslides.
   d. The reduced population will have a greater number of different genes than the initial population.

5. The data below demonstrate the frequency of tasters and non-tasters of a certain compound in four isolated populations that are in Hardy-Weinberg equilibrium. The allele for non-tasters is recessive. In which population is the frequency of the recessive allele highest?

Letter Choice	Populations	Tasters	Non-tasters	Size of Population
A	1	110	32	142
B	2	8,235	4,328	12,563
C	3	215	500	715
D	4	11,489	2,596	14,085

6. Ellis-van Creveld syndrome is a recessive genetic disorder that includes the characteristics of short stature and extra fingers or toes. In the general population, this syndrome occurs in approximately 1 in 150,000 live births. In a particular isolated population, however, the incidence of this syndrome among live births is 1 in 500.

   Assume that both the isolated population and the general population are in Hardy-Weinberg equilibrium with respect to this syndrome. Which of the following best describes the difference between the frequency of the allele that causes the syndrome in the general population and the frequency of the allele in the isolated population?

   a. The frequency of the Ellis-van Creveld allele is 0.002 in the isolated population and 0.0000066 in the general population, which suggests that selection for this trait is occurring in both populations.
   b. The frequency of the Ellis-van Creveld allele is 0.0447 in the isolated population and 0.0026 in the general population, showing that the rate of genetic mutation is highest among individuals in the isolated population.
   c. The frequency of the Ellis-van Creveld allele is 0.002 in the isolated population and 0.0000066 in the general population, which demonstrates gametic incompatibility between the populations.
   d. The frequency of the Ellis-van Creveld allele is 0.0447 in the isolated population and 0.0026 in the general population, which suggests that genetic drift has occurred in the isolated population.

Use the following information for question 7:

Different photosynthetic organisms have different types of chlorophyll molecules. The distribution of chlorophylls in several different groups of organisms is shown in Table 1. A plus sign (+) in the table indicates the presence of a chlorophyll, while a minus sign (-) indicates its absence.

Table 1. The distribution of chlorophylls in several groups of organisms

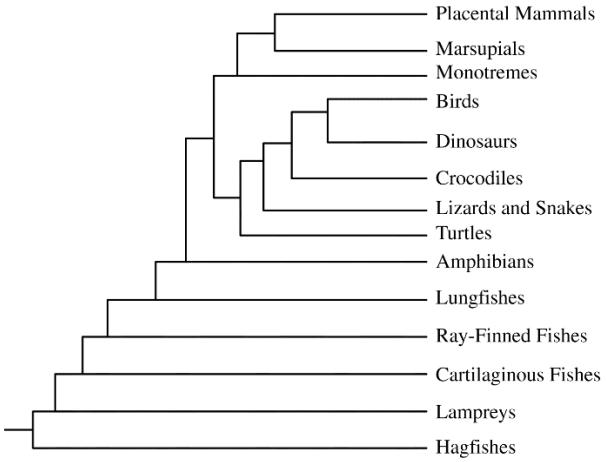
	Chlorophyll *a*	Chlorophyll *b*	Chlorophyll *c*	Chlorophyll *d*
Flowering plants	+	+	–	–
Green algae	+	+	–	–
Brown algae	+	–	+	–
Red algae	+	–	–	+
Cyanobacteria	+	–	–	–

7. Based on the data, which of the following most likely describes the evolutionary relationship among the organisms?
    a. Because brown algae, red algae, and cyanobacteria lack chlorophyll b, they evolved before green algae and flowering plants did.
    b. Because green algae and flowering plants contain chloroplasts, they evolved more recently than brown algae, red algae, and cyanobacteria did.
    c. Because increasingly complex forms of chlorophyll are found in red algae, brown algae, green algae, and flowering plants, respectively, this reflects the order of their appearance.
    d. Because all of the organisms contain chlorophyll a, the organisms share a common ancestor.

8. Experimental evidence shows that the process of glycolysis is present and virtually identical in organisms from all three domains, Archaea, Bacteria, and Eukarya. Which of the following hypotheses could be best supported by this evidence?
    a. All organisms carry out glycolysis in mitochondria.
    b. Glycolysis is a universal energy-releasing process and therefore suggests a common ancestor for all forms of life.
    c. Across the three domains, all organisms depend solely on the process of anaerobic respiration for ATP production.
    d. The presence of glycolysis as an energy- releasing process in all organisms suggests that convergent evolution occurred.

9. To determine the evolutionary history and relationships among organisms, scientists gather evidence from a wide variety of sources including paleontology, embryology, morphology, behavior, and molecular biology. A phylogenetic tree of vertebrates is shown.

    Which of the following statements is most consistent with the phylogenetic tree shown?

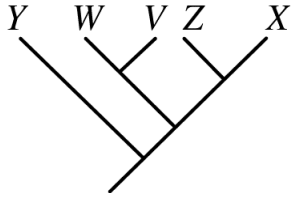


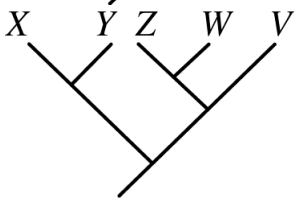
    a. Birds and turtles evolved their own means of gas exchange independently of the other vertebrates.
    b. Mammals are most closely related to birds because they share a direct common ancestor.
    c. The common ancestor of reptiles, birds, and mammals produced amniotic eggs.
    d. Crocodiles are direct descendants of ray-finned fishes since they live in the same environment.

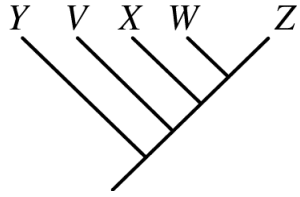
10. Data regarding the presence (+) or absence (-) of five derived traits in several different species are shown in the table below.

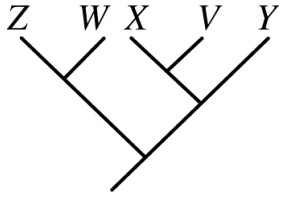
	Trait				
Species	1	2	3	4	5
V	+	+	+	-	-
W	+	+	-	-	-
X	+	-	-	-	-
Y	-	-	-	-	-
Z	+	-	-	-	+

Which of the following cladograms provides the simplest and most accurate representation of the data in the table?

a. 

b. 

c. 

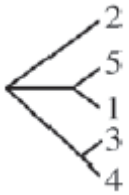
d. 

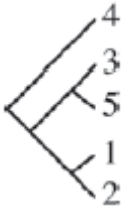
11. Five new species of bacteria were discovered in Antarctic ice core samples. The nucleotide (base) sequences of rRNA subunits were determined for the new species. The table below shows the number of nucleotide differences between the species.

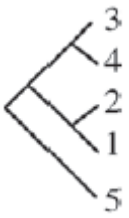
NUCLEOTIDE DIFFERENCES

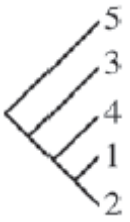
Species	1	2	3	4	5
1	–	3	19	18	27
2		–	19	18	26
3			–	1	27
4				–	27
5					–

Which of the following phylogenetic trees is most consistent with the data?

a. 

b. 

c. 

d. 

12. The apple maggot fly, *Rhagoletis pomonella*, is native to North America and originally fed on fruit of the wild hawthorn. Since the mid-1800s, a population of flies has emerged that instead feed on domesticated apples. Apple maggot flies typically mate on or near the fruit of their host plants. Many varieties of apples ripen three to four weeks before the hawthorn fruits do.

    The different fruit preferences of the two fly populations will most likely have which of the following effects?
    a. The flies that eat hawthorn fruit will increase in number, while the flies that eat apples will decrease in number because of the use of insecticides on apple trees.
    b. The single fly species will evolve into two distinct species because of the lack of gene flow between the two populations.
    c. The ability to survive on a diet of two different fruits will help the flies learn to eat many more types of fruit.
    d. The flies that eat hawthorn fruit will lay some of their eggs on the earlier ripening apples to minimize competition among the larvae.

    Use the following information to answer questions 13 – 15:

    Rhagoletis pomonella is a parasitic fly native to North America that infests fruit trees. The female fly lays her eggs in the fruit. The larvae hatch and burrow through the developing fruit. The next year, the adult flies emerge.

    Prior to the European colonization of North America, the major host of *Rhagoletis* was a native species of hawthorn, *Crataegus marshallii.* The domestic apple tree, *Malus domestica*, is not native to North America, but was imported by European settlers in the late 1700s and early 1800s.

    When apple trees were first imported into North America, there was no evidence that Rhagoletis could use them as hosts. Apples set fruit earlier in the season and develop faster, where hawthorns set later and develop more slowly.

    Recent analysis of *Rhagoletis* populations has shown that two distinct populations of flies have evolved from the original ancestral population of flies that were parasitic on hawthorns. One population infests only apple trees, and the other infests only hawthorns. The life cycles of both fly populations are coordinated with those of their host trees. The flies of each population apparently can distinguish and select mates with similar host preferences and reject mates from the population specific to the other host tree. There is very little hybridization (only about 5 percent) between the two groups.

13. The divergence between the two populations of Rhagoletis must have occurred very rapidly because
    a. the apple tree was imported into North America with European settlement approximately 200 years ago
    b. flies were imported into North America with European settlement approximately 200 years ago
    c. long-distance rail transport of fruit increased only after the American Civil War (1861–1865)
    d. heavy use of gunpowder during the American Civil War (1861–1865) led to increased mutation rates in many natural populations of plants and animals

14. Initially, which of the following isolating mechanisms is likely to have been the most important in preventing gene flow between the two populations of *Rhagoletis*?
    a. Gamete incompatibility
    b. Temporal isolation
    c. Mechanical isolation
    d. Reduced hybrid viability

15. Matings between individuals from the two populations of *Rhagoletis* produce hybrid flies that appear to be healthy and have normal life spans. The eggs laid by these hybrid flies, however, hatch less often than those of flies from either of the two populations. What isolating mechanism seems to be important in this hybrid population?
    a. Prezygotic isolation
    b. Mechanical isolation
    c. Reduced hybrid fertility
    d. Habitat isolation

16. A group of students summarized information on five great extinction events.

Mass Extinction	Time of Extinction	Organisms Greatly Reduced or Made Extinct
End of the Ordovician period	443 million years ago	Trilobites, brachiopods, echinoderms, and corals
End of the Devonian period	354 million years ago	Marine families on tropical reefs, corals, brachiopods, and bivalves
End of the Permian period	248 million years ago	Trilobites, mollusks, brachiopods, and many vertebrates
End of the Triassic period	206 million years ago	Mollusks, sponges, marine vertebrates, and large amphibians
End of the Cretaceous period	65 million years ago	Ammonites, dinosaurs, brachiopods, bivalves, and echinoderms

The students are sampling a site in search of fossils from the Devonian period. Based on the chart, which of the following would be the most reasonable plan for the students to follow?
    a. Searching horizontal rock layers in any class of rock and try to find those that contain the greatest number of fossils
    b. Collecting fossils from rock layers deposited prior to the Permian period that contain some early vertebrate bones
    c. Looking in sedimentary layers next to bodies of water in order to find marine fossils of bivalves and trilobites
    d. Using relative dating techniques to determine the geological ages of the fossils found so they can calculate the rate of speciation of early organisms

17. By discharging electric sparks into a laboratory chamber atmosphere that consisted of water vapor, hydrogen gas, methane, and ammonia, Stanley Miller obtained data that showed that a number of organic molecules, including many amino acids, could be synthesized. Miller was attempting to model early Earth conditions as understood in the 1950s. The results of Miller's experiments best support which of the following hypotheses?
    a. The molecules essential to life today did not exist at the time Earth was first formed.
    b. The molecules essential to life today could not have been carried to the primordial Earth by a comet or meteorite.
    c. The molecules essential to life today could have formed under early Earth conditions.
    d. The molecules essential to life today were initially self-replicating proteins that were synthesized approximately four billion years ago.

18. Which of the following best explains the process of natural selection?
    a. individuals with less favorable phenotypes are more likely to survive and produce less offspring, thus modifying traits for subsequent generations
    b. individuals with more favorable phenotypes are more likely to survive and produce less offspring, thus modifying traits for subsequent generations
    c. individuals with more favorable phenotypes are more likely to survive and produce more offspring, thus passing traits to subsequent generations
    d. individuals with less favorable phenotypes are more likely to survive and produce more offspring, thus passing traits to subsequent generations

19. Natural selection acts on
    a. phenotype
    b. genotype
    c. gene expression
    d. reproduction

20. Which of the following best explains convergent evolution?
    a. different selective pressures result in similar phenotypic adaptations in different populations or species
    b. similar selective pressures result in similar phenotypic adaptations in different populations or species
    c. similar selective pressures result in different phenotypic adaptations in a population or species
    d. different selective pressures result in similar phenotypic adaptations in a populations or species

21. Which of the following is the cause of genetic variation?
    a. crossing over
    b. independent assortment
    c. random fertilization
    d. mutations

22. Which of the following describes why bottleneck effect is harmful to genetic diversity?
    a. the reduction in population size could lead to fixation of an allele
    b. the reduction in population size could result in a change in allele frequency
    c. the reduction in population size could cause a change in genotype frequency
    d. the reduction in population size could inhibit reproductive events

23. Which of the following describes why the founder's effect results in an increase of differences between populations of the same species?
    a. presence of genetic drift
    b. absence of gene flow
    c. addition of harmful alleles
    d. removal of reproductive barriers

24. Which of the following is a condition that must be met for a population to be in Hardy-Weinberg equilibrium?
    a. small population size
    b. nonrandom mating
    c. absence of selection
    d. presence of migration

25. If the recessive allele frequency is 0.4, what is the genotypic frequency of the heterozygous individual?
    a. 0.16
    b. 0.24
    c. 0.36
    d. 0.48

26. Which of the following describes a population most susceptible to random environmental impact?
    a. small populations
    b. large populations

27. Which of the following is NOT a method to date fossils?
    a. DNA sequencing
    b. age of rocks where a fossil is found
    c. rate of decay of isotopes including carbon-14
    d. geographical data

28. Which of the following does provides evidence for evolution and common ancestry?
    a. analogous structures
    b. homologous structures

29. Which of the following does NOT indicate common ancestry of all eukaryotes?
    a. membrane-bound organelles
    b. linear chromosomes
    c. genes that contain introns
    d. presence of chloroplasts

30. Which of the following describes why single HIV drugs are ineffective over time?
    a. Reverse transcriptase binds to HIV drugs inhibiting drug effectiveness
    b. Mutations in the HIV genome leads to reproductive success
    c. HIV engulfs drugs through phagocytosis and digests them in the lysosome
    d. Drugs decompose prior to inhibit HIV genome from replication

31. Which of the following best represents the outgroup in a cladogram?
    a. least closely related to the remainder of the organisms in the cladogram
    b. most closely related to the remainder of the organisms in the cladogram
    c. organism found on the farthest branch point from the common ancestor
    d. organism found on the closest branch point to the organism of interest

32. Which type of data provides the most accurate and reliable evidence to construct phylogenetic trees or cladograms?
    a. morphological
    b. molecular
    c. biogeographical
    d. temporal

33. Which of the following describes the biological species concept?
    a. group capable of interbreeding and exchanging genetic information to produce feeble, fertile offspring
    b. group capable of interbreeding and exchanging genetic information to produce feeble, sterile offspring
    c. group capable of interbreeding and exchanging genetic information to produce viable, fertile offspring
    d. group capable of interbreeding and exchanging genetic information to produce viable, sterile offspring

34. Which of the following contrasts punctuated equilibrium and gradualism?
    a. punctuated equilibrium occurs slowly over hundreds of thousands of years while gradualism results in rapid evolution after long period of stasis
    b. punctuated equilibrium results from allopatric speciation while gradualism results from sympatric speciation
    c. punctuated equilibrium results from sympatric speciation while gradualism results from allopatric speciation
    d. punctuated equilibrium results in rapid evolution after long period of stasis while gradualism occurs slowly over hundreds of thousands of years

35. Which of the following types of reproductive barriers involves inhibiting reproduction due to a different mating season?
    a. behavioral
    b. temporal
    c. gametic
    d. ecological

36. Which of the following types of reproductive barriers involves inhibiting reproduction due to a difference in mating rituals?
    a. behavioral
    b. temporal
    c. gametic
    d. ecological

37. Which of the following describes ways that the amount of diversity in an ecosystem can be determined?
    a. rate of speciation and rate of extinction
    b. rate of reproductive and rate of speciation
    c. rate of extinction and rate of immigration
    d. rate of reproduction and rate of immigration

38. Which of the following provides a viable option as to the origin of organic molecules?
    a. biotic synthesis
    b. transported to Earth by meteorite
    c. hydrolysis of inorganic molecules
    d. Earth colliding with other planets

39. Which of the following was the earliest genetic material?
    a. DNA
    b. RNA
    c. Proteins
    d. Carbohydrate