Unit: Evolution

- **Topics**
  - *Natural Selection*
  - *Genetic Drift/Gene Flow*
  - *Evidence of evolution*
  - *Phylogenetic Trees/Cladograms*
  - *Speciation*
  - *Origin of Life/Endosymbiotic theory*
- KEY EXAMPLES: peppered moths, DDT resistance in insects, sickle cell anemia, antibiotic resistance, Finches in the Galapagos
- *KEY CONCEPTS: Natural selection acts of phenotypes and individuals but the allele frequency and population evolves, Evolutionary change is also driven by random processes*
- *KEY MATH SKILLS: Hardy-Weinberg equation, interpret and construct cladogram/phylogenetic tree*
- *KEY LABS: Artificial Selection #1, Hardy-Weinberg #2, Blast #3*

Enduring understanding 1.A: Change in the genetic makeup of a population over time is evolution.

Essential knowledge 1.A.1: Natural selection is a major mechanism of evolution.

a. According to Darwin's theory of natural selection, competition for limited resources results in differential survival. Individuals with more favorable phenotypes are more likely to survive and produce more offspring, thus passing traits to subsequent generations.

b. Evolutionary fitness is measured by reproductive success.

c. Genetic variation and mutation play roles in natural selection. A diverse gene pool is important for the survival of a species in a changing environment.

d. Environments can be more or less stable or fluctuating, and this affects evolutionary rate and direction; different genetic variations can be selected in each generation.

e. An adaptation is a genetic variation that is favored by selection and is manifested as a trait that provides an advantage to an organism in a particular environment.

f. In addition to natural selection, chance and random events can influence the evolutionary process, especially for small populations.

g. Conditions for a population or an allele to be in Hardy-Weinberg equilibrium are: (1) a large population size, (2) absence of migration, (3) no net mutations, (4) random mating and (5) absence of selection. These conditions are seldom met.

h. Mathematical approaches are used to calculate changes in allele frequency, providing evidence for the occurrence of evolution in a population.

Essential knowledge 1.A.2: Natural selection acts on phenotypic variations in populations.

a. Environments change and act as selective mechanism on populations.

b. Phenotypic variations are not directed by the environment but occur through random changes in the DNA and through new gene combinations.

c. Some phenotypic variations significantly increase or decrease fitness of the organism and the population.

d. Humans impact variation in other species.

Essential knowledge 1.A.3: Evolutionary change is also driven by random processes.

a. Genetic drift is a nonselective process occurring in small populations.

b. Reduction of genetic variation within a given population can increase the differences between populations of the same species.

Essential knowledge 1.A.4: Biological evolution is supported by scientific evidence from many disciplines, including mathematics.

a. Scientific evidence of biological evolution uses information from geographical, geological, physical, chemical and mathematical applications.

b. Molecular, morphological and genetic information of existing and extinct organisms add to our understanding of evolution.

1. Fossils can be dated by a variety of methods that provide evidence for evolution. These include the age of the rocks where a fossil is found, the rate of decay of isotopes including carbon-14, the relationships within phylogenetic trees, and the mathematical calculations that take into account information from chemical properties and/or geographical data.
2. Morphological homologies represent features shared by common ancestry. Vestigial structures are remnants of functional structures, which can be compared to fossils and provide evidence for evolution.
3. Biochemical and genetic similarities, in particular DNA nucleotide and protein sequences, provide evidence for evolution and ancestry.
4. Mathematical models and simulations can be used to illustrate and support evolutionary concepts.

Enduring understanding 1.B: Organisms are linked by lines of descent from common ancestry.

Essential knowledge 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.

a. Structural and functional evidence supports the relatedness of all domains.

1. DNA and RNA are carriers of genetic information through transcription, translation and replication. [See also **3.A.1**]
2. Major features of the genetic code are shared by all modern living systems. [See also **3.A.1**].
3. Metabolic pathways are conserved across all currently recognized domains. [See also **3.D.1**].

b. Structural evidence supports the relatedness of all eukaryotes. [See also **2.B.3, 4.A.2**]

Essential knowledge 1.B.2: Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.

a. Phylogenetic trees and cladograms can represent traits that are either derived or lost due to evolution.

b. Phylogenetic trees and cladograms illustrate speciation that has occurred, in that relatedness of any two groups on the tree is shown by how recently two groups had a common ancestor.

c. Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species, and from DNA and protein sequence similarities, by employing computer programs that have sophisticated ways of measuring and representing relatedness among organisms.

d. Phylogenetic trees and cladograms are dynamic (i.e., phylogenetic trees and cladograms are constantly being revised), based on the biological data used, new mathematical and computational ideas, and current and emerging knowledge.

Enduring understanding 1.C: Life continues to evolve within a changing environment.

Essential knowledge 1.C.1: Speciation and extinction have occurred throughout the Earth's history.

a. Speciation rates can vary, especially when adaptive radiation occurs when new habitats become available.
b. Species extinction rates are rapid at times of ecological stress. [See also **4.C.3**]

Essential knowledge 1.C.2: Speciation may occur when two populations become reproductively isolated from each other.

a. Speciation results in diversity of life forms. Species can be physically separated by a geographic barrier such as an ocean or a mountain range, or various pre-and post-zygotic mechanisms can maintain reproductive isolation and prevent gene flow.
b. New species arise from reproductive isolation over time, which can involve scales of hundreds of thousands or even millions of years, or speciation can occur rapidly through mechanisms such as polyploidy in plants.

Essential knowledge 1.C.3: Populations of organisms continue to evolve.

a. Scientific evidence supports the idea that evolution has occurred in all species.
b. Scientific evidence supports the idea that evolution continues to occur.

<u>Enduring understanding 1.D: The origin of living systems is explained by natural processes.</u>

Essential knowledge 1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence.

a. Scientific evidence supports the various models.

1. Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized due to the presence of available free energy and the absence of a significant quantity of oxygen.
2. In turn, these molecules served as monomers or building blocks for the formation of more complex molecules, including amino acids and nucleotides. [See also **4.A.1**]
3. The joining of these monomers produced polymers with the ability to replicate, store and transfer information.
4. These complex reaction sets could have occurred in solution (organic soup model) or as reactions on solid reactive surfaces. [See also **2.B.1**]
5. The RNA World hypothesis proposes that RNA could have been the earliest genetic material.

Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

a. Geological evidence provides support for models of the origin of life on Earth.

1. The Earth formed approximately 4.6 billion years ago (bya), and the environment was too hostile for life until 3.9 bya, while the earliest fossil evidence for life dates to 3.5 bya. Taken together, this evidence provides a plausible range of dates when the origin of life could have occurred.
2. Chemical experiments have shown that it is possible to form complex organic molecules from inorganic molecules in the absence of life.

b. Molecular and genetic evidence from extant and extinct organisms indicates that all organisms on Earth share a common ancestral origin of life. Scientific evidence includes molecular building blocks that are common to all life forms. Scientific evidence includes a common genetic code.

Can You Questions:

1. Identify the mechanisms of how variation occurs in a given population?
2. Explain how the effects of genetic drift vary based on population size?

3. Discuss the different types of selection, and how each drives evolution?
4. Determine the frequency of the alleles and genotypes in a population?
5. Interpret a graph showing how evolution favors different phenotypes?
6. Determine relative relatedness between organisms as represented by a cladogram?
7. Draw a cladogram, if given names of organisms and specific characteristics?
8. Use data provided to determine what organisms shared a more common ancestor?
9. Discuss specific cellular similarities between related eukaryotes?
10. Explain the difference between allopatric and sympatric speciation?
11. Differentiate between prezygotic and postzygotic mechanisms of reproductive isolation?
12. Explain the theory of endosymbiosis?
13. Identify and justify characteristics of the first living cell?
14. Discuss similarities and differences between the three Domains in order to justify relatedness between organisms?

Base your answers to questions 1 through 4 on the reproductive isolation mechanisms listed below.

(A) Gametic Isolation
(B) Reduced Hybrid Fertility
(C) Reduced Hybrid Viability
(D) Behavioral Isolation
(E) Temporal Isolation
(F) Mechanical Isolation

1. Eastern and Western Meadowlarks are physically identical and have identical habitats. However, they remain separate species due to differences in song.

A) D B) B C) A D) E E) C

2. A donkey and a horse form a mule that cannot reproduce

A) A B) B C) F D) H E) C

3. Frogs belonging to the genus *Rana* occasionally hybridize. However, the hybrids do not develop completely, and those that do are very weak.

A) D B) A C) F D) C E) E

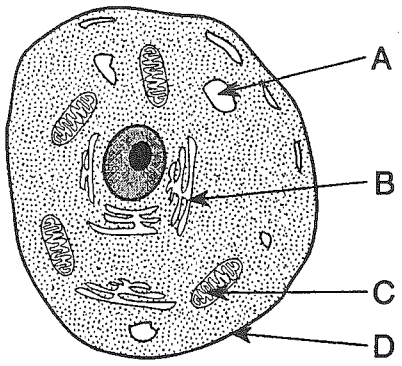
4. Though they live in the same region, *Spilogale gracilis* (western spotted skunk) and *Spilogale putorius* (eastern spotted skunk) remain separate species because *S. gracilis* mate in the summer and *S. putorius* mate in the winter.

A) B B) F C) E D) A E) D

5. Which of the following was LEAST likely to have been present on the primitive Earth during the evolution of self-replicating molecules?

A) Amino acids
B) Water
C) Sugars
D) Oxygen rich atmosphere
E) Nitrogen

6. Base your answer to the following question on Base your answer to the following question on the picture below.



Indicate the structure(s) thought to be descendant of endosymbiotic bacterial cells.

A) B and C B) C only
C) A only D) A and B
E) A and C

7. Allopatric speciation is the process by which

A) evolution selects organisms for survival
B) members of two distinct species interbreed
C) the gene pool is stabilized
D) the background rate of extinction is doubled
E) a population that inhabits a particular area is divided into two or more geographically separated groups

8. Which is not a condition necessary to maintain Hardy-Weinberg equilibrium?

A) Random mating among members
B) Sexual reproduction
C) Lack of emigration or immigration
D) Small population size
E) Absence of new mutations

9. Which of the following statements accurately describes genetic drift?

A) Natural selection causes genetic drift.
B) It refers to random changes in gene frequencies due to drop in population size
C) Mutation often causes genetic drift.
D) It occurs when individuals drift into a population, via immigration.
E) It occurs when individuals drift out of a population via emigration.

Base your answers to questions 10 and 11 on the following information. In a certain population of birds, 16 percent of the population have grey feathers and 84 percent have red feathers. Assume the population is in Hardy-Weinberg equilibrium.

10. If grey feathers is a recessive trait, what percentage of the population is heterozygous for this trait?

A) 48% B) 64% C) 20% D) 80% E) 32%

11. What percentage of the population is homozygous for red feathers?

A) 64% B) 36 % C) 28% D) 20 % E) 4 %

12. The tonsils and appendix are examples of

A) analogous structures
B) balance polymorphism
C) divergent evolution
D) vestigial structures
E) homologous structures

13. Which of the following statements best expresses the concept of disruptive selection?

A) Extreme types of organisms are selected against common traits.
B) Organisms in a population with extreme traits are eliminated.
C) Evolutionary change consists of bursts of speciation alternating with long periods of unmodification.
D) Under competition for identical resources, one of the two competing species will be eliminated or excluded.
E) One of the phenotypes is favored at one of the extremes of the normal distribution.

14. Mitochondria are thought to be descendants of endosymbiotic bacterial cells. Which of the following statements best supports this statement?

A) Both mitochondria and bacteria have cristae.
B) Mitochondria and bacteria possess different ribosomes and DNA.
C) Mitochondria and bacteria possess similar ribosomes, DNA, and cell membranes.
D) Neither mitochondria nor bacteria possess chloroplasts.
E) Glycolysis occurs in both mitochondria and bacteria.

15. According to Oparin's hypothesis, which of the following is the correct order in which organisms were thought to have developed on Earth?

A) anaerobic autotroph — aerobic autotroph — anaerobic heterotroph — aerobic heterotroph
B) anaerobic heterotroph — anaerobic autotroph — aerobic autotroph — aerobic heterotroph
C) anaerobic heterotroph — aerobic heterotroph — anaerobic autotroph — aerobic autotroph
D) aerobic heterotroph — aerobic autotroph — anaerobic autotroph — anaerobic heterotroph
E) anaerobic autotroph — anaerobic heterotroph — aerobic autotroph — aerobic heterotroph

16. Which of the following best describes the theory of serial endosymbiosis?

A) A prokaryotic cell takes up genes from the surrounding environment.
B) Cyanobacteria synthesize food and restore oxygen to the atmosphere.
C) Prokaryotes mediate the return of elements from the nonliving components of the environment.
D) An organism will benefit from the symbiotic relationship, while neither is harmed.
E) Some organelles were once small prokaryotes.

17. The recessive allele for a specific hereditary trait has a frequency of 0.30. What percentage of the individuals in the subsequent generation are expected to show the dominant trait, assuming that the population is in Hardy-Weinberg equilibrium?

A) 24% B) 70% C) 91% D) 30% E) 62%

18. A species is considered unique when it is unable to reproduce with other species and produce fertile offspring. In a unified response, **discuss** speciation, **including** models of speciation and types of reproductive isolation.

19. Allele frequencies often are analyzed in order to monitor evolution.
    1 **Discuss** the conditions that must be met in order for allele frequencies to remain constant.
    2 Calculate the frequencies of alleles and the frequencies of genotypes in the following population, where brown is recessive and yellow is dominant: 5,000 brown dogs and 15,000 yellow dogs. Include **formulas** and **work** for full credit.
    3 Suppose brown dogs have a lethal condition due to their alleles for coat color. What general effect would this have on the allelic and genotypic frequencies after four generations?

Answer Key
Evolution

18. Speciation is the origin of a new species. A species is defined as a group of organisms able to successfully breed with one another. A new species has developed when it is no longer able to breed with another species. Anagenesis is when a species develops into a new species without splitting or branching from another. Cladogenesis is when a new species branches off from a pre-existing species. There are three models for speciation: allopatric, sympatric and parapatric speciation. Allopatric speciation occurs due to geographical isolation. A geographical barrier, such as the development of a body of water, rift in the land or the formation of an island could lead to such speciation. A second mode of speciation is sympatric speciation. This occurs from an existing population, and results due to a change in the genome of a subset of the population. An example of such speciation is the development of a polyploidy species from a diploid species. Finally, parapatric speciation occurs from the development of reproductive barriers in a group of the population.
Examples of reproductive barriers include prezygotic and postzygotic barriers. Prezygotic barriers include habitat isolation, temporal isolation, mechanical isolation, and gametic isolation. Habitat isolation occurs when species live in different locations, rarely encountering each other. Species that breed at different times of year encounter temporal isolation. Mechanical isolation occurs when species fail to consummate mating because of incompatible reproductive organs. When gametes are not compatible, gametic isolation occurs. Postzygotic barriers are reduced hybrid viability, reduced hybrid fertility, and hybrid breakdown. In these cases, zygotes form, but the resulting offspring do not survive or are sterile.

19. a.) A population is considered to be in Hardy-Weinberg Equilibrium when the population size is large, there is random mating, no mutation, no migration, and no natural selection.
b.) $p_2 + 2pq + q_2 = 1$
WW and Ww = yellow
ww = brown
W = p
w = q
5,000/20,000 = 0.25 = q_2
allele frequencies $q = \sqrt{.25} = 0.5$
$p = 1 - q = 0.5$
genotype frequencies WW = 0.25
Ww = 0.5
Ww = 0.25
c.) The frequency of the q allele decreases, but remains in the population due to the presence of heterozygotes. The genotype frequencies of WW, Ww, and ww increase, decrease, and decrease respectively.

Answer Key
Evolution

1. A
2. B
3. D
4. C
5. D
6. B
7. E
8. D
9. B
10. A
11. B
12. D
13. A
14. C
15. B
16. E
17. C
18. (essay)
19. (essay)