Evolution & Classification

Darwin & Evidence for Evolution

Classwork

1. In your own words, restate Darwin’s 5 observations made on the Galapagos Islands.
2. What was unique about the Galapagos Islands that made it an ideal area for collecting specimens to be used as evidence for Darwin’s theories?
3. Discuss what is meant by the phrase “survival of the fittest”.
4. Humans have been breeding dogs to get specific characteristics for hundreds of years, does this fall under Darwin’s idea of Natural Selection?
5. Briefly describe “adaptive radiation” and provide an example.
6. Which type of homology is most accurate, least accurate? Why?
7. Discuss an example of a vestigial structure in a species. Explain how this structure can provide evidence of the evolution of the species.
8. There are three families of the plant group cycads, the Cycadaceas, Strangeriaceae and Zamiaceae. These families contain 185 species in 11 genera. They grow in tropical and temperate environments worldwide. Explain how it is possible that these related species can be found in the Americas, Asia, Africa, and Europe.
9. A recently uncovered skeleton was found to be 17,000 years old. Using carbon-14 dating, what percentage of carbon-14 was remaining in the bones?
10. How have ecologists affected our understanding of evolution?

Homework

11. Describe why Darwin believed that adaptation was the driving force behind all evolution.
12. Describe an example of evolution occurring now.
13. Explain how the development of new breeds of domestic animals and plants relates to Darwin’s idea of selection.
14. Describe the observations that convinced Darwin that evolution had occurred.
15. Describe how adaptations come about in evolution.
16. Describe natural selection. Create a fictional organism and story that portrays this theory.
17. How are anatomical comparisons used as evidence for evolution? Why do you think insects have six legs rather than four like dogs?
18. Based on the idea of biogeography, species in the Phillipines would be most closely related to species on which major continent?
19. Describe at least two different dating techniques used on fossils.
20. On an archeological dig, a graduate student has determined that the percentage of carbon-14 remaining in the artifacts is approximately 2%. What is the approximate age of the find?
21. How has genetics contributed to the modern theory of evolution?

Natural Selection

Classwork

22. In terms of evolution, describe the term fitness. Provide an example.
23. Describe the evolutionary mechanism that is responsible for antibiotic resistance in bacteria.
24. Describe a population from an evolutionary standpoint.
25. Describe directional, divergent, and stabilizing selection. Provide an example of each.
26. In a population of corn plants, the taller, larger plants produced more yield (more corn for consumption). However, these taller plants were more likely to topple over in a storm causing the corn ears to be lost. Devise a strategy the farmer could utilize to maintain a high yield in his corn crop.
27. In a population of mice, 832 were white, 25 were grey, and 677 were black when the scientist originally surveyed the area in which they lived. The scientists returned 15 years later to resurvey the area. This time they identified 34 white mice, 781 grey mice, and 1242 black mice. Is this population evolving? If
so, name the type of selection it is undergoing and hypothesize a possible selective pressure causing the evolution.

**Homework**

28. The story of the peppered moths shifting from speckled to black is a classic case of evolutionary change. What evolutionary mechanism is being described by this example?
29. Human birth weight is an example of stabilizing selection. Discuss why.
30. How does the definition of a population account for organisms that reproduce by asexual decedents?

Read through the illustration found at the web site below. Then answer the questions that follow. [http://www.flmnh.ufl.edu/fhc/relatives1.htm](http://www.flmnh.ufl.edu/fhc/relatives1.htm)

31. Explain how the development of the single toe could have been caused by natural selection.
32. Describe the difference between artiodactyls and perissodactyls.

**Population Genetics**

**Classwork**

33. Describe a gene mutation, a point mutation and a chromosome mutation.
34. Explain why most gene mutations tend to be deleterious.
35. Describe how sexual reproduction adds to the variability of a species.
36. There are times when conditions become adverse and harsh, describe how variation can be an advantage in this instance.
37. Describe the Hardy-Weinberg principle and the conditions that must be met for it to be valid.
38. In a population of 1000 sheep, 300 are black. Black is recessive phenotype. How many are homozygous dominant? How many are heterozygous?
39. In a population of 1754 students, 800 have attached earlobes, a recessive trait. Determine the frequency of AA, Aa, aa.
40. In a population of 250 dogs, 175 have floppy ears. If floppy ears are dominant, what is frequency of q?

**Homework**

41. Proteins tend to be the go-to spot for mutations to occur. Explain why this statement is true.
42. Although we often think of sexual reproduction as an advantage, describe some ways that that it can be a disadvantage.
43. Some organisms reproduce by cloning themselves. Describe a clone and explain how they resemble their parent.
44. Sickle cell disease can be deadly due to the cells inability to carry oxygen. However, individuals who are carriers, heterozygous, have been shown to ward off malaria better than those that have normal blood cell. In a population of 10,981 males, 1141 have sickle cell. Of those remaining, how many could be carriers (heterozygous)'
45. Having dimple is a dominant trait. You decide to use the Hardy Weinberg formula to determine how many students are carries in your school. For the next week, you and your friends stake out the cafeteria and systematically survey the entire school. Out of 987 students, 386 have dimples. Calculate the number of heterozygotes.
46. In a population of drosophila, the t allele has a frequency of 0.75. Calculate the frequency for TT, Tt, tt.
47. According to the Hardy-Weinberg Theorem, are humans evolving? Why or why not?

**Macroevolution & Reproductive Isolation**

**Classwork**

48. Students often confuse the terms microevolution and macroevolution. Provide a brief synopsis of each.
49. Describe how genetic drift is important in evolution.
50. Contrast the founder effect and the bottleneck effect.
51. Evolution of new species can occur by splitting or by one species changing into another. Briefly describe the difference between the two.
52. Describe the role of an ecological niche in the development of a new species.
53. Explain how geographic speciation occurs.
54. Prezygotic and postzygotic barriers have a definite effect on reproduction capability. Which is more efficient to the emergence of a new species as far as environmental resources are concerned?

Homework
55. Predators and prey are often said to coevolve. Explain this term and how selection plays a role in the changes in the predator population and prey population.
56. Describe how the founder effect is involved in the formation of a new species.
57. If a group of living beings were found on another planet, would they be exactly like the ones found on Earth? Explain.
58. Describe the significance of reproductive isolation in the formation of a new species.
59. Environmental changes can lead to geographic separation of species. List some of these environmental changes, and provide a recent example that occurred in our area.
60. Describe the processes that lead to the genetic divergence of populations and reasons why change occurs once they become separated.
61. Describe sympatric speciation, and relate it to quantum speciation.
62. Why do natural extinctions occur, and how have they been an important factor in the evolution of new species?

Phylogenetics
Classwork
63. Discuss at least 3 pieces of evidence used to generate phylogenetic trees. Of those you discussed which type is the most accurate?
64. Define maximum parsimony.
65. Bats and birds have undergone convergent evolution, meaning they have both evolved wings to fit their ecological niches but they are not closely related species. Explain how convergent evolution can make it difficult to create cladograms.
66. Based on physical features, draw a cladogram for the following species: domestic cat, domestic dog, chicken, cow, rat, parrot, and goldfish. Identify the evolutionary event for each node.

Homework
67. Why is it said the phylogenies are “trees not ladders”?
68. Research the genetic similarities between in the primate family and draw a phylogenetic tree for the following species: chimpanzees, orangutans, humans, bonobos, gorillas, howler monkeys, and lemurs.
69. Explain the role of an ultrametric tree in evolutionary biology.
70. Organisms in a clade share many similar traits. Newly evolved traits are used to place organisms on new branches in the cladogram. How does the absence of a trait affect the placement of an organism in a cladogram? Provide an example.
Free Response

1. A haplotype is a combination of alleles at adjacent locations on a chromosome that are inherited together. A long haplotype surrounding the lactase persistence allele is observed in Europeans. The lactase persistence allele is prevalent (~77%) in European populations but lies on a long haplotype, suggesting that it is of recent origin. The dark bands represent similar alleles in different individuals within the human population. Lactase is the enzyme that breaks down the sugar lactose in milk to glucose and galactose.

   a) If the lactase persistence allele were in Hardy-Weinberg equilibrium in the human population, would we be able to see a 77% frequency in the European and a <10% frequency in the African population? Describe your rationale behind your answer.

   b) Why does the length of the lactase haplotype suggest that the lactase allele is of recent origin?

   c) Predict the conditions that might have caused the 70% frequency of the lactase persistence allele in Europeans?
2. Evidence for evolution.

A. Right lateral views of the head and cervical region of selected embryos (except Fig. d, which is a dorso lateral view), mostly drawn after a Sea lamprey (*Petromyzon marinus*). b Electric ray (*Torpedo ocellata*). c Sterlet (*Acipenser ruthenus*). d Puerto Rican treefrog (*Eleutherodactylus coqui*). e European pond terrapin (*Emys orbicularis*), 40 somite embryo. f Chicken (*Gallus gallus*). g Brush-tailed possum* (*Trichosurus vulpecula*), 25 somite embryo. h Domestic cat (*Felis catus*).

There is no highly conserved embryonic stage in the vertebrates: implications for current theories of evolution and development


C. Protein Family (pFam) Seed sequence alignment for PF07388 [http://pfam.sanger.ac.uk/family/PF07388/alignment/seed/html](http://pfam.sanger.ac.uk/family/PF07388/alignment/seed/html)

a) How do the above data support biological evolution?

b) Figure A shows accurate drawings of embryos that are not totally consistent with Haeckel’s famous drawings of comparative embryology shown below that scientists have used to support the idea of evolution for many years. This inconsistency has been used by anti-Darwin supporters to detract from the theory of biological evolution. Describe how the drawings, both Haeckel’s and Richard’s, can be reconciled with biological evolution.

c) The platypus is a mammal with similarities to birds. To study the evolution of mammals using information from morphology, biochemistry and geology, devise a plan to investigate if mammals evolved from birds or had a common ancestor.

3. Trypanosomes are protists that are usually found in associations that range from symbiotic (benefit to both cells) to parasitic (benefit to one, damage to the host) with host cells (pictured on left, trypanosomes in blood). Some trypanosomes form intracellular associations with proteobacteria (symbiont-harboring trypanosomatid). The symbiont-harboring trypanosomatid (SHTs) have less nutritional requirements than the trypanosomes that do not have intracellular bacteria (RTs).

The above figure shows the diaminopimelate (DAP) pathway for the amino acid lysine biosynthesis in trypanosomes and the endosymbiotic bacteria that some species harbor. Enzymes surrounded by a thick gray box were shown to be horizontally transferred from bacteria to trypanosomes.

**Metabolites** – I: L-aspartate; II: 4-aspartyl-phosphate; III: aspartate 4-semialdehyde; IV: 2,3-dihydrodipicolinate; V: 2,3,4,5-tetrahydrodipicolinate; VI: N-succinyl-L-2-amino-6-oxopimelate; VII: N-succinyl-LL-2,6-diaminopimelate; VIII: LL-2,6-diaminopimelate; IX: meso-2,6-diaminopimelate; X: lysine. **Enzymes** – 2.7.2.4: aspartate kinase; 1.2.1.11: aspartate-semialdehyde dehydrogenase; 4.2.1.52: dihydrodipicolinate
synthase; 1.3.1.26: dihydrodipicolinate reductase; 2.3.1.117: tetrahydrodipicolinate succinyltransferase; 2.6.1.17: succinyl-diaminopimelate transaminase; 3.5.1.18: succinyl-diaminopimelate desuccinylase; 5.1.1.7: diaminopimelate epimerase; 4.1.1.20: diaminopimelate decarboxylase.  

SHT: symbiont-harboring trypanosomatid; RT: regular trypanosomatid; TPE: trypanosomatid proteobacterial endosymbiont.

Endosymbiosis in trypanosomatids: the genomic cooperation between bacterium and host in the synthesis of essential amino acids is heavily influenced by multiple horizontal gene transfers. Alves et al. BMC Evolutionary Biology 2013, 13:190


a) Propose at least two questions that may be answered by looking at the biosynthetic pathways between a host and an endosymbiont.  
b) Describe how this endosymbiosis between these two cells and others such as mitochondria and chloroplast support the idea of a common ancestry of all life on Earth.  
c) Describe the environment that would select for either symbiont-harboring or non-harboring trypanosomes.
Disjunct distributions of freshwater snails testify to a central role of the Congo system in shaping biogeographical patterns in Africa
Schultheiß et. al. BMC Evolutionary Biology 2014, 14:42 (6 March 2014)

4. The formation of the East African Rift System played a decisive role in the evolution of Africa’s tropical fauna and flora. The diagram above illustrates the speciation of freshwater snails that rely on the movement of water for their habitats and dispersal. The model comprises four progressive stages covering roughly (1) Middle Miocene (~12 mya), (2) Late Miocene (~5 mya), (3) Pliocene (5-3 mya) and (4) Pliocene/Early Pleistocene timeframes. The map shows the current borders and courses of the drainage systems and rivers as well as the current sizes of the lakes. Inset phylogenies track the diversification of Clade I: colors correspond to geographic ranges and the phylogenetic groups. The borders of the suggested ranges are approximations. Question marks within the dashed areas in stages 3 and 4 indicate potential remnant populations of the clusters from stage 2.

a) Why would the cytochrome oxidase subunit I, the mitochondrial large subunit (LSU) of ribosomal RNA, a fragment of the nuclear LSU rRNA [60], and the nuclear histone 3 DNA data used to differentiate between and establish similarities in the species in this study be an accurate measure of speciation? 

b) Why does Clade 1 separate into 2 distinct groups in scenario 2?

c) If the migration borders would disappear, how would the populations be affected evolutionarily?
5. Positive selection (the increase frequency of alleles in a population) in the human genome can be detected in a number of ways. Two examples of positive selection are shown in figures A and B. Figure A shows low diversity (same DNA sequence) and many rare alleles (red dots) at the Kell blood antigen cluster. On the basis of three different statistical tests, the 115-kb region (containing four genes) shows evidence of a selective sweep (positive selection) in Europeans. Figure B shows an excess of high-frequency derived alleles at the Duffy red cell antigen (FY) gene. The 10-kb region near the gene has far greater prevalence of derived alleles (represented by red dots) than of ancestral alleles (represented by gray dots). Derived alleles come from ancestral alleles.

Positive Natural Selection in the Human Lineage

a) Why would a region that is being positively selected for in population have low diversity and many rare alleles or mutations?

b) Compare the evidence for positive selection shown in figures A and B.

c) How can changes in the environment affect the selection seen in the above examples?
Evolution-Answer Key

1. Populations have the potential to increase exponentially. (2) Populations maintain a constant size. (3) There is a limited amount of resources. (4) Variation exists among individuals. (5) The variations that exist in population are passed on from parents that were able to mate.
2. The islands were close together, sharing similar climate, but far enough apart to isolate populations from one another.
3. If an individual is able to survive long enough in its environment to mate than its genes or traits will be passed on to future generations.
4. No because humans are selecting desired characteristics this is known as artificial selection.
5. A common ancestor gives rise to new species with modified characteristics that allow it to survive in its new habitat.
6. Most accurate is molecular homology. Least accurate would be vestigial organs, since we have no definitive way of knowing their true purpose.
7. Answers will vary.
8. At one time the continents we part of one supercontinent, Pangaea. These plants adaptively radiated before the continental separation.
9. 12.5%
10. Ecologists study interactions between organisms and their environment. They have provided insight into how organisms adapt to a particular niche.
11. Organisms that are best adapted to their environment are able to survive and reproduce. This allows them to pass these beneficial traits to their offspring.
12. Answers will vary.
13. Humans develop new breeds of domestic animals by selecting the individuals in the population best suited for human use and only allowing those individuals to breed and reproduce. This results in the majority of offspring possessing the trait required by humans. It is similar to Darwin’s idea of natural selection but humans are providing the selective pressure so it is termed “artificial selection”.
14. Animals that were found on separate islands had distinct features that allowed them to survive in their environment and pass these traits to future generations.
15. Variation exists in every population. When a particular variation is beneficial to the organism(s) that possess it, they thrive under the selective pressure. The adaptation becomes prevalent in the population.
16. Natural selection occurs when some organisms in a population possess a trait that increases the likelihood of their survival and ability to reproduce. Because these individuals produce more offspring, the beneficial traits are passed down through heredity and become more common in the population. Answers will vary.
17. These comparisons reveal relations of structure and function that can come from common ancestors. Insects and dogs do not share a recent common ancestor.
18. Species in the Phillipines would be most closely related to similar species in Asia.
19. (1) Radioactive dating in which isotopes of elements are tested and compared to a baseline amount. Time is determined based on known half life of the element. (2) Dating by position in the sediment in which artifacts can be compared based on how far down they are found. Older items tend to be lower in the strata, as rock/earth builds up over time.
20. 34000 years old
21. Genetics has shown how traits are passed from parent to offspring, increasing our understanding of how beneficial traits become common in a population. It has also been used to compare species DNA to discover how related species are.
22. Fitness is a measure of the reproductive potential of a genetic type that is able to overcome the selective pressure on the population.
23. Due to the selection pressure of the antibiotic, resistant bacteria are able to survive and reproduce without being affected by the antibiotic.
24. A group of interbreeding individuals sharing the same gene pool.
25. Directional selection is when an extreme phenotype is favored and the median shifts. Divergent selection occurs when both extreme phenotypes in a population are favored. Stabilizing selection is when the median phenotype is favored, variation decreases for the trait. Examples will vary.
26. Answers may vary. Farmer could selectively breed the short plants with the highest yield.
27. Directional selection occurred. Selective pressures will vary, likely a change in color of environment, which lead to darker color providing better camouflage.
28. This illustrates directional selection.
29. Stabilizing selection occurs when the median value is favored. In the case of human birth weight, small in unfavorable because it increases risk of disease and early death; large size in unfavorable because it decreases the ability of the mother to give birth, increasing the likelihood of death to both the child and mother.
30. Even a clone can vary genetically through mutations, they will also react differently to selective forces.
31. The toes were only used during jumping, horses that may have been born without them would have had a better advantage of running from predators, finding food and a mate.
32. Artiodactyls are hoofed animals with an even number of toes, while perissodactyls have an odd number of toes.
33. Gene mutations affect a single gene. Point mutations involve single nucleotide changes and may or may not affect gene expression in the organism. Chromosome mutations occur when sections of a chromosome are missing or translocate (move to another chromosome).
34. Most gene mutations tend to show up in structural and enzymatic proteins upsetting the biochemical balance of the organism.
35. With sexual reproduction, organisms obtain a mate, mixing recombining chromosomes to make new organisms that have a different genome than their parents. Each time they choose a new mate, new genomic combinations are formed.
36. Organism that have a favorable genetic makeup for a particular selection pressure are able to survive and reproduce.
37. The Hardy – Weinberg principle provides a baseline to see if evolution has occurred. There are 5 principles that must be met for no evolution to occur in a population. The conditions are random mating, no mutation, non-immigration and emigration, a large population, no natural selection.
38. 205; 495
39. aa = 0.46, AA = 0.10, Aa = 0.43
40. 0.55
41. Mutations by definition affect the nucleotide sequence in a gene. Many genes code for proteins.
42. The constant mixing and breaking up favorable combinations does not allow the organism to become specialized in a stable environment.
43. Clones are genetically identical copies of their parent. They are duplicates of their parent unless a mutation occurred during the cloning process.
44. About 4779 are carriers.
45. 338 are carriers
46. TT = 0.625; Tt = 0.375; tt = 0.56
47. Yes. Because we do not randomly mate and mutations occur in the population
48. Macroevolution deals with broad scale changes and transcends more than one population. Microevolution is evolution that occurs within a single population.
49. Genetic drift are changes in the allele frequencies of small populations due to chance. These chance events usually favor individuals with a genetic makeup that is unaffected by the selection pressure.
50. The founder effect and bottleneck effect are both random events. The founder effect when a segment of a population moves into a new habitat. The bottleneck effect occurs when a segment of the population remains in its (possibly altered) habitat after a disturbance.
51. Species can be reproductively isolated by physical boundaries, this splitting of populations' leads to new species being formed. When one species evolves into a new species this occurs over time. This is a response to selection pressure, which manifests new characteristics to the present population.

52. The ecological niche is the habitat, the food, the way the species obtains the food, and which species are interacted with by the new species. The niche can only be occupied by one species at a time, therefore it must be available to occupy by a new species.

53. A natural event separates a single population into two or more sections. This separation reduces the likelihood of interbreeding between the separated populations. If the populations remain separated long enough changes in their gene pool produce changes in behavior, and physiology reducing the chance of interbreeding between the separated populations.

54. Prezygotic barriers are more efficient, these barriers keep species apart due to different seasons of mating, mechanical prevention this ensures there is no competition for resources.

55. Coevolution occurs when one species evolves in response to another species. In a predator-prey relationship, if the prey adapted to become better at hiding or faster, the predator population would adapt by becoming better at seeking or chasing. If the predator failed to evolve in response, it would have to adapt to a lack of that particular prey species.

56. Small colonizing populations carry a portion of the allele from their former population. They establish a foothold in a new area, with this new limited gene pool.

57. Answers will vary.

58. With reproductive isolation the changes in gene frequencies have accumulated over many generations. This can be attributed to mutations, recombination, genetic drift, and natural selection, which eventually produces a new form of the organism. This does not increase the total number of species.

59. Earthquake, volcano eruption, hurricane, flood.

60. Not only are they separated by geographical boundaries, they are also occupying different ecological niches giving rise to new selection pressures. These new pressure highlight new gene pools, giving rise to new traits within each population.

61. Sympatric speciation is a form of quantum speciation, the rapid evolution of a new species from an existing species that became isolated.

62. The ability of an organism to overcome selection pressures, and still be able to find a mate and produce a viable offspring is crucial to its survival. If it is not able to do this, it will become extinct. When they do become extinct they leave resources available for new species to take advantage of and thrive.

63. Structural homologies, embryonic homologies, molecular homologies, DNA similarities. Molecular homologies and DNA would provide the most accurate data.

64. The simplest explanation is most likely the correct one.

65. If a cladogram is based on structural homologies, bats and birds might be placed in the same clade when they are not in fact closely related.

66. Answers will vary based on physical characteristics chosen.

67. Phylogenies show share ancestry, that two species arose from a single ancestral species. Both modern species have diverge from that ancestral species; one did not arise from the other.

68. See http://en.wikipedia.org/wiki/Primate

69. Ultrametric dating gives a time frame for the emergence (and sometimes extinction) of a species.

70. Traits that have disappeared during evolution can also be used to place species on a cladogram. Such as absence of hair in humans, or lack of tail.

1. Lactose Tolerance
   a. Hardy–Weinberg equilibrium is maintained if the following conditions are met: organisms are diploid, only sexual reproduction occurs, generations are non overlapping, mating is random, population size is infinitely large, allele frequencies are equal in the sexes, there is no migration, mutation or selection. These conditions are hardly ever met, and thus populations are forever evolving. A large difference in allele frequencies seen in lactase persistence between human
population shows that certain populations have undergone a drastic selection for lactase persistence, while in other populations that selection pressure is not widely felt.

b. Since the genes or alleles around the lactase persistence alleles are linked or on the same chromosome, the whole chromosome is the unit of selection and not just the lactase allele. Since the haplotypes are similar or the same among different individuals a population, unlike the African population, the allele must have been inherited or appeared relatively recent. Recombination during meiosis overtime lowers the length of the haplotypes that are shared in a population, and therefore a measure of time in genetic terms.

c. During harsh winters or times of scarcity, individuals with the lactase persistence alleles that were able to maintain domesticated animals that produce milk and dealt with the winters better than humans. Over a few generations the people with lactase persistence would survive and reproduce better than the ones without lactase persistence, leading to the selective sweep seen in Europeans.

Learning Objectives:

LO 1.6 The student is able to use data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and effects of selection in the evolution of specific populations. [See SP 1.4, 2.1]

LO 1.7 The student is able to justify data from mathematical models based on the Hardy-Weinberg equilibrium to analyze genetic drift and the effects of selection in the evolution of specific populations. [See SP 2.1]

LO 1.8 The student is able to make predictions about the effects of genetic drift, migration and artificial selection on the genetic makeup of a population. (See SP 6.4)

2. Evidence for Evolution

a. Comparative embryology and cell biology show that all of life has cells as the basic units of structure and function, and multicellular organisms undergo similar patterns of development from zygote to embryo to fetus. The embryos have similar requirements for growth and show similar processes to accomplish a specific function. Sedimentary rock contains fossils that connect ancient life with a continuous line of organisms that lead to present day species. The fossils provide concrete evidence of diversity and similarities of past organisms with present day organisms. The comparison of molecular sequences, such as DNA and protein, give a concrete measure of the level of relationship between all present day organisms and some recently extinct species. DNA connects all of life on Earth.

b. To show common ancestry, the embryos do not need to be exactly like each other or undergo the development growth and cell divisions exactly at the same time. The fact the embryos start as one cell, grow by mitosis or mitosis with minor differences, and have similar structures appear and remain in some species while disappear for other species shows that small variations in embryonic development lead to the differences we see in adult organisms.

c. To study the relationship between mammals and birds, we can compare the bone structure of the organisms. Birds have many distinct species; therefore, multiple bone structure measuring the diversity with birds to compare to mammalian bone structure. Comparative embryology and fossils could add circumstantial evidence as well, but it would boil down to the DNA sequence similarity of birds and mammals.

Learning Objectives:

LO 1.9 The student is able to evaluate evidence provided by data from many scientific disciplines that support biological evolution. [See SP 5.3]

LO 1.10 The student is able to refine evidence based on data from many scientific disciplines that support biological evolution. [See SP 5.2]

LO 1.11 The student is able to design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry and geology. [See SP 4.2]

LO 1.12 The student is able to connect scientific evidence from many scientific disciplines to support the modern concept of evolution. [See SP 7.1]
LO 1.13 The student is able to construct and/or justify mathematical models, diagrams or simulations that represent processes of biological evolution. [See SP 1.1, 2.1]

3. Symbiosis
   a. Some questions that may be answered by looking at the biosynthetic pathways between a host and an endosymbiont are (1) Do the organisms complement each other in completing biosynthetic pathways? (2) Does the endosymbiont have genes from the host that it requires? Other questions might be: Where in the cell are the endosymbionts located?, Can you endosymbiosis be abrogated or prevent from being established?, Do the host with the endosymbionts have a selection advantage over other species when the nutritional requirements are met? etc…
   b. These examples of symbiosis among others like the legume association with nitrogen-fixing bacteria all provide evidence to the evolution of the cell as we speak, not only as an event in the far and distant past or on some other side of the Universe. The study of the inner working of symbiotic relationship between cells and organisms show a mechanism for the evolution of life from a LUCA right here on Earth, and an extraterrestrial origin of life is not required.
   c. An environment that would have a scarcity of hosts or limiting resources such as amino acids would favor the symbiont-harboring trypanosomes and would select for their proliferation. Other the hand, an environment with abundant hosts would favor the parasitic non-harboring trypanosomes because the endosymbionts would not be providing a service and would be taking energy (ATP) away from the host cell.

Learning Objectives:
LO 1.14 The student is able to pose scientific questions that correctly identify essential properties of shared, core life processes that provide insights into the history of life on Earth. [See SP 3.1]
LO 1.15 The student is able to describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms. [See SP 7.2]
LO 1.16 The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today. [See SP 6.1]

4. African Snail Speciation
   a. Some genetic markers must be established to characterize a population as species or subspecies of an ancestral species. Using mitochondrial and nuclear genes such as the cytochrome oxidase subunit I, the mitochondrial large subunit (LSU) of ribosomal RNA, a fragment of the nuclear LSU rRNA [60], and the nuclear histone 3 establishes maternal (mitochondrial genes) and a combination of paternal and maternal (nuclear genes) markers to help differentiate one population from another population.
   b. A migration border was established between the interbreeding populations. Given time, the two populations became distinct species. The inability to interbreed allow for mutations and/or chromosomal arrangements to arise independently, leading to varying chromosome number and structure and thus speciation. Each population would be under different selection pressures in the different environments.
   c. Depending on time, the species may or may not be able to interbreed. Their adaptations may require them to remain in their micro-environments. The species may acquire different behaviors of breeding or collecting food that may keep the species apart. But, most likely, given the scenario of millions of years, these fishes have become different species and will not be able to sexually reproduced, because the chromosomes cannot lined up properly during meiosis or mitosis.

Learning Objectives:
LO 1.22 The student is able to use data from a real or simulated population(s), based on graphs or models of types of selection, to predict what will happen to the population in the future. [See SP 6.4]

LO 1.23 The student is able to justify the selection of data that address questions related to reproductive isolation and speciation. [See SP 4.1]

LO 1.24 The student is able to describe speciation in an isolated population and connect it to change in gene frequency, change in environment, natural selection and/or genetic drift. [See SP 7.2]

5. Positive selection
   a. Since individuals with the positively selected regions are increasing in number because of their added fitness, more and more individuals with the region have descended from one or few individuals where the alleles or mutations arose; therefore, the diverse, negatively selected regions decrease in number or disappear.
   b. Both regions show positive selection. Figure A shows that many rare alleles or mutations can elicit the positive selection and the mutations are not limited to specific region with the four genes. Figure B shows selection with much less variability in the locations of the mutations; Specific regions in the protein must be mutated to elicit the positive selection. Mutations in other areas of the protein may be negatively selected.
   c. If the selection pressures are constant, you will see an increase of mutations in both regions consistent with the distribution seen thus far. But if the selection pressures vary, you will see other mutations creep in to the distribution seen in the regions. In region A, you might see derived alleles and more sporadic mutations. In region B, you might see more ancestral mutations and fewer derived mutations.

Learning Objectives:
LO 1.25 The student is able to describe a model that represents evolution within a population. [See SP 1.2]
LO 1.26 The student is able to evaluate given data sets that illustrate evolution as an ongoing process. [See SP 5.3]
LO 1.4 The student is able to evaluate data-based evidence that describes evolutionary changes in the genetic makeup of a population over time. [See SP 5.3]
LO 1.5 The student is able to connect evolutionary changes in a population over time to a change in the environment. [See SP 7.1]