Session 1: Theory Behind Evolution I

Overview:
In this first session, we introduce the topic of evolution with three videos. Dr. Hale introduces Darwinian evolution and the concepts of heritable traits, genetic variation, and natural selection. She explains speciation and describes how phylogenetic trees can be constructed from fossil and DNA evidence and used to compare the relatedness of species. Dr. Hoekstra elaborates on how changes in genes can produce phenotypic variation which can be acted upon by natural selection. And finally, Dr. Gordon discusses how interaction networks evolve in different ecological settings.

First video:
Title: Introduction to Evolution
Speaker: Melina Hale

Questions for Part 1:

1. What is likely to happen when there is an increase in the population of a prey species?
    a. Higher incidence of interactions between prey and predators.
    b. A subsequent increase in the predator population size.
    c. More chances for the prey species members to be killed.
    d. A and C.
    e. None of the above.

2. Which of the following are tenets of Darwin's theory of evolution by natural selection?
    a. There is heritable variation between individuals in a population.
    b. Individuals that are better able to compete for limited resources are more likely to survive and reproduce.
    c. Natural selection drives changes from the ancestral form.
    d. An organism can modify its phenotype during its lifetime and pass these changes onto their offspring.
    e. All of the above.
    f. a, b, and c only.

3. Which statement(s) listed below is/are consistent with Darwin's theory? Choose all of the answers that apply.
    a. Non-heritable traits enhance species survival in the local environment.
    b. Non-heritable traits enhance species survival and reproductive success in the local environment.
    c. Heritable traits enhance reproductive success of a species in the local environment.
    d. Heritable traits have no effect on species survival and reproductive success in the local environment.
    e. Heritable traits enhance species survival in the local environment.

4. Select which of the following is/are an example(s) of an heritable trait. Choose all of the answers that apply.
    a. Building more muscles at the gym.
    b. Somatic cells mutations.
    c. Genetic predisposition to breast cancer.
    d. HIV.

5. In a phylogenetic tree, a node or branching point represents:
    a. the common ancestor from which the descendent species diverged.
    b. the species in the fossil record from which the descendent species diverged.
    c. one of the descendent species in the phylogeny.
    d. the ancestral species from which all species in the phylogeny arose.
    e. A node could be any of the above, depending on the nature of the phylogenetic tree.

6. Sarah is studying protein X. She discovered a significant difference in the amino acid sequence of protein X between species A and species B. However, the sequence of protein X between species B and C is very similar. Using this information, draw a phylogenetic tree that connects these species.

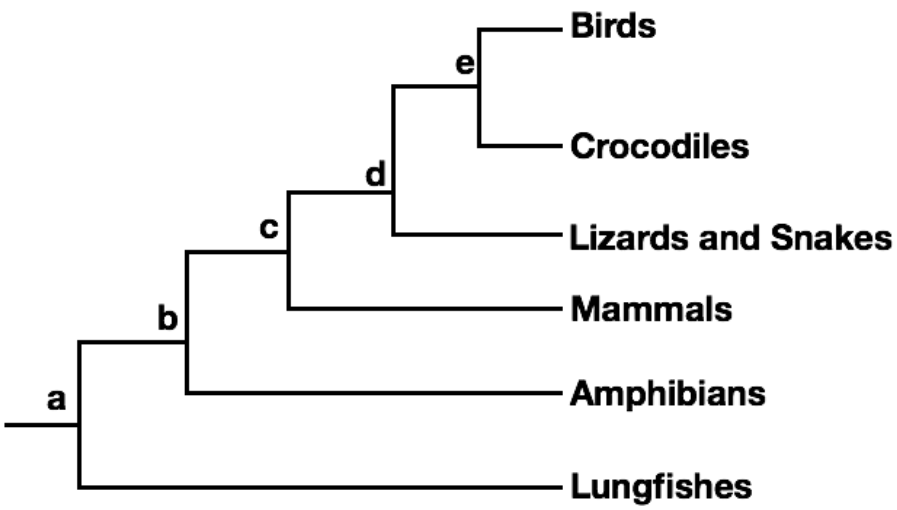
7. Scientists have argued for many years that skin cancer was an evolutionary driver that enforced the predominance of dark-skin individuals in areas with high levels of sun exposure. Dark skin does reduce the chance of getting skin cancer, but studies have shown that skin cancer often occurs after individuals are 45 years old.
    a. Given the information provided above, could skin cancer explain the high selective pressure for dark skin in areas with high doses of sun exposure? Briefly explain.

    b. A different type of skin cancer is more prevalent in adolescents and can appear in areas with low or no sun exposure (e.g. armpits). This type of skin cancer is as frequent in light- skinned as in dark-skinned individuals. Could evolution through natural selection decrease the number of individuals that develop this type of skin cancer? Briefly explain.

8. There is a cave in Mexico where an eyeless fish lives. Explain the selective pressures which could have been involved in this evolutionary outcome.

9. Where do scientists get the information to build a phylogenetic tree? Provide two examples and briefly explain how they're measured/used.

Use the following phylogenetic tree to answer questions 10-12. The letters at each branch point represent the common ancestor for groups beyond that point.

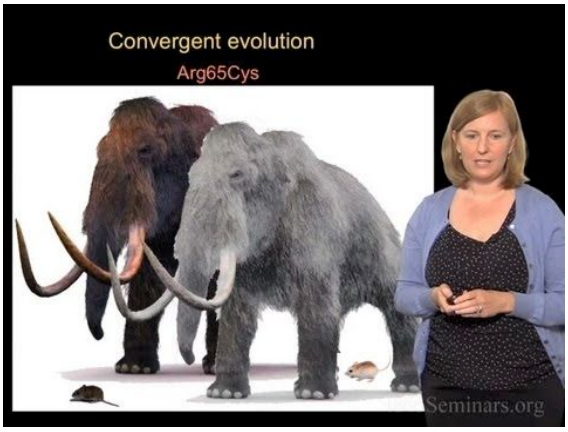


10. Which was the last common ancestor of crocodiles and the lineage of lizard and snakes?
    a. a
    b. b
    c. d
    d. d
    e. e

11. Which of the following can be concluded from this evolutionary tree?
    a. Mammals are more closely related to amphibians than to birds.
    b. Mammals are more closely related to lizards and snakes than to birds.
    c. Birds are more closely related to lizards and snakes than to mammals.
    d. Birds and mammals are more closely related than are birds to lizards and snakes.
    e. Lungfishes are not related to any of these groups.

12. Which of the following groups could be described as being monophyletic (all descendants of a common ancestor)?
    a. Lungfishes and mammals.
    b. Amphibians and birds.
    c. Birds, crocodiles, lizards, and snakes.
    d. Lungfishes and amphibians.
    e. Mammals, lizards, and snakes.

Second video:
Title: Introduction to The genetic Basis of Evolutionary Change in Morphology and Behavior
Speaker: Hopi Hoekstra



Questions for Part 2:

1. Protein A is expressed in the brain and is known to be involved in synaptic transmission. Which of the following is/are an example(s) of adaptive mutation(s)? Choose all of the answers that apply.
    a. A mutation in the non-coding region of protein A that enhances its expression in the brain.
    b. A mutation in protein A that generates the same protein.
    c. A mutation in protein A that decreases its expression in the brain.
    d. A mutation in protein A that produces a truncated version of the protein.

2. Which of the following is an example of evolution?
    a. The ability of human adults to digest lactose.
    b. A tall giraffe that can eat plants that other members of its species cannot reach.
    c. A bacterium that survives antibiotic treatment.
    d. All of the above are correct.
    e. None of the above.

3. You are working in the field and discover a species of butterfly that looks very similar to the horse spider. Provide a possible reason why this butterfly may have evolved to resemble the horse spider.

4. For many generations, humans have been selecting animals with specific features (e.g. a fast running horse). How could this procedure affect evolution through natural selection? Provide an example of beneficial or detrimental consequences that this procedure could have in a particular species.

5. The MC1R is a gene that is linked with coat color in mice. If a species of mice is homogenous at the MC1R locus, could natural selection act on this gene? Briefly explain.

6. *Peromyscus polionotus* is a species of oldfield mice that recently (6,000-10,000 ybp) invaded the islands off of the coast of northwestern Florida. Mice that live on the mainland are dark brown, matching the dark, loamy soil, while the subspecies of mice that live on the white sandy beaches have much paler coloration. Briefly explain how the lighter coloration in the mice evolved.

Third video:
Title: The Evolution of Collective Behavior
Speaker: Deborah M. Gordon (Start video at T = 10:02)

Questions for Part 3:

1. Ecology is the study of the interactions within a system. Which of the following examples show how ecological factors can drive natural selection? Choose all of the answers that apply.
    a. Plants that require high volumes of water have low reproductive success during a drought.
    b. Two species of beetles compete for food.
    c. A plant that releases metabolites attracts pollinators.
    d. None of the above.

2. Could two species of ants that do not interact with each other, but live in the same ecosystem have an impact on each others evolutionary history? Briefly explain.

3. Scientists can use the principles of evolution to understand certain features of cancer cells. Provide an example of how the evolution of cancer cells could resemble the evolution of species.

4. Eric is studying a population of wolves in Yellowstone National Park. He observes that the prevalence of wolves correlates with an increased survival rate of young trees.
    a. Propose a hypothesis that could help explain this observation.

    b. By studying the metabolites of the tree, Eric discovers that the tree releases a compound that attracts wolves. Using the concepts of natural selection and evolution, propose a hypothesis that explains this observation.

Answers for Session 1:

Questions for Part 1:

1. What is likely to happen when there is an increase in the population of a prey species?
    a. Higher incidence of interactions between prey and predators.
    b. **A subsequent increase in the predator population size.**
    c. More chances for the prey species members to be killed.
    d. A and C.
    e. None of the above.

2. Which of the following are tenets of Darwin's theory of evolution by natural selection?
    a. There is heritable variation between individuals in a population.
    b. Individuals that are better able to compete for limited resources are more likely to survive and reproduce.
    c. Natural selection drives changes from the ancestral form.
    d. An organism can modify its phenotype during its lifetime and pass these changes onto their offspring.
    e. All of the above.
    f. a, b, and c only.

3. Which statement(s) listed below is/are consistent with Darwin's theory? Choose all of the answers that apply.
    a. Non-heritable traits enhance species survival in the local environment.
    b. Non-heritable traits enhance species survival and reproductive success in the local environment.
    c. **Heritable traits enhance reproductive success of a species in the local environment.**
    d. Heritable traits have no effect on species survival and reproductive success in the local environment.
    e. **Heritable traits enhance species survival in the local environment.**

4. Select which of the following is/are an example(s) of an heritable trait. Choose all of the answers that apply.
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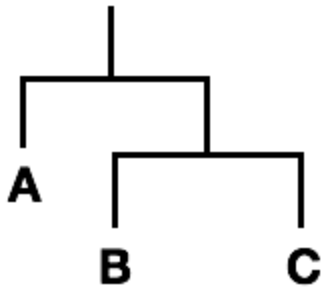
6. Sarah is studying protein X. She discovered a significant difference in the amino acid sequence of protein X between species A and species B. However, the sequence of protein X between species B and C is very similar. Using this information, draw a phylogenetic tree that connects these species.



7. Scientists have argued for many years that skin cancer was an evolutionary driver that enforced the predominance of dark-skin individuals in areas with high levels of sun exposure. Dark skin does reduce the chance of getting skin cancer, but studies have shown that skin cancer often occurs after individuals are 45 years old.
    a. Given the information provided above, could skin cancer explain the high selective pressure for dark skin in areas with high doses of sun exposure? Briefly explain.

    No. Although dark skin does protects against skin cancer, the prevalence of the disease increases after most species have already reproduced and passed their genetic material onto their progeny. Since there is no evidence that individuals who develop skin cancer are less reproductively successful than individuals who have dark skin, skin cancer does not represent an example of evolutionary selection.

b. A different type of skin cancer is more prevalent in adolescents and can appear in areas with low or no sun exposure (e.g. armpits). This type of skin cancer is as frequent in light- skinned as in dark-skinned individuals. Could evolution through natural selection decrease the number of individuals that develop this type of skin cancer? Briefly explain.
Yes, as long as there is a selective pressure. If the individuals get sick and die before reproductive age, they will not pass their genes on to future generations and the number of individuals with this disease will decrease over time.

8. There is a cave in Mexico where an eyeless fish lives. Explain the selective pressures which could have been involved in this evolutionary outcome.
It is likely that this fish lives in an environment where it is dark and vision is not useful. Therefore it is not beneficial to the fish to expend the developmental energy and brainpower that is needed to sustain vision.

9. Where do scientists get the information to build a phylogenetic tree? Provide two examples and briefly explain how they're measured/used.
    a. **Fossils - Fossils are compared in size, connection between bones, age, etc.**
    b. **DNA - Differences and similarities between genes from different organisms can be compared.**
    c. **Anatomical features/Morphology - Compare eye morphology, presence or absence of feathers, heart function, brain function, etc.**
    d. **Behaviour - Analyze complex behaviours (burrowing, parenting, social interactions, nesting, etc).**

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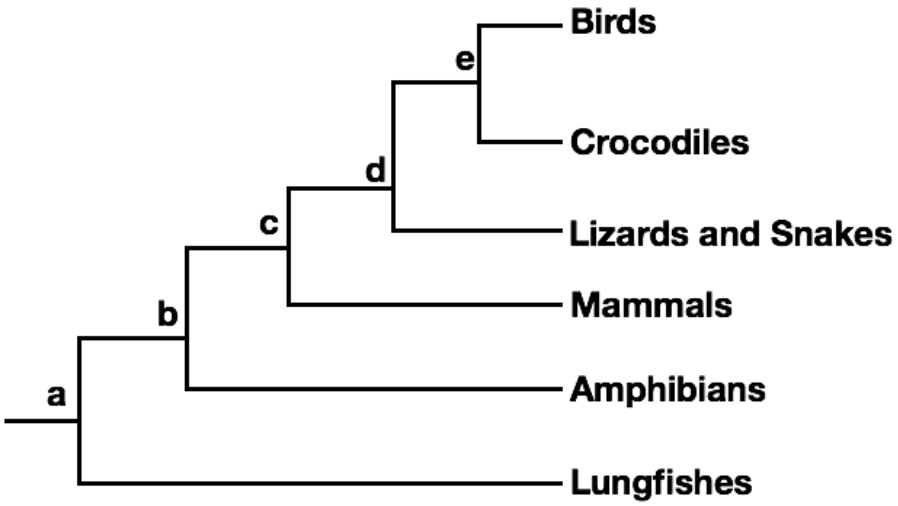

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Questions for Part 2:

1. Protein A is expressed in the brain and is known to be involved in synaptic transmission. Which of the following is/are an example(s) of adaptive mutation(s)? Choose all of the answers that apply.
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2. Which of the following is an example of evolution?
    a. The ability of human adults to digest lactose.
    b. A tall giraffe that can eat plants that other members of its species cannot reach.
    c. A bacterium that survives antibiotic treatment.
    d. All of the above are correct.
    e. None of the above.

3. You are working in the field and discover a species of butterfly that looks very similar to the horse spider. Provide a possible reason why this butterfly may have evolved to resemble the horse spider.
    a. **The butterfly is trying to avoid predation by the spider or any other predator.**
    b. **Butterflies that look like the horse spider are better at attracting a mate.**

4. For many generations, humans have been selecting animals with specific features (e.g. a fast running horse). How could this procedure affect evolution through natural selection? Provide an example of beneficial or detrimental consequences that this procedure could have in a particular species.
   Artificial selection disrupts natural evolution and may have beneficial as well as detrimental consequences. For example, dogs have been selected for many different traits. This may result in a dog that is a good hunter but is also prone to disease (e.g. increased risk of orthopedic disease in Labrador Retrievers). Another example- farm animals which are bred for productivity and would likely not survive in the wild.

5. The MC1R is a gene that is linked with coat color in mice. If a species of mice is homogenous at the MC1R locus, could natural selection act on this gene? Briefly explain.
   No. In order for natural selection to work, there needs to be more than one allele to select from. Given that this population is homogeneous at this locus, evolution will positively select any beneficial mutation, and negatively select any detrimental mutation. It would not have any strong pressure upon seemingly neutral mutations.

6. *Peromyscus polionotus* is a species of oldfield mice that recently (6,000-10,000 ybp) invaded the islands off of the coast of northwestern Florida. Mice that live on the mainland are dark brown, matching the dark, loamy soil, while the subspecies of mice that live on the white sandy beaches have much paler coloration. Briefly explain how the lighter coloration in the mice evolved.
    a. **In the ancestral populations of mice, there would have been some genetic variation in the genes responsible for coat color.**
    b. **The lighter mice that invaded the islands would have had an advantage over darker mice in avoiding predation by being a closer color match to the lighter sand.**
    c. **This slight advantage in survival would give lighter mice an advantage in reproduction because they could survive long enough to reproduce.**
    d. **Because slightly lighter mice would leave more offspring, more of the alleles associated with lighter coat colors would be present in the next generation.**
    e. **The resulting population would be lighter overall than the mainland invaders.**
    f. **Repeating this process over many generations would produce the much paler mice that we see on the islands today.**

Questions for Part 3:

1. Ecology is the study of the interactions within a system. Which of the following examples show how ecological factors can drive natural selection? Choose all of the answers that apply.
    a. Plants that require high volumes of water have low reproductive success during a drought.
    b. Two species of beetles compete for food.
    c. A plant that releases metabolites attracts pollinators.
    d. None of the above.

2. Could two species of ants that do not interact with each other, but live in the same ecosystem have an impact on each others evolutionary history? Briefly explain.
    Yes. A species of ant could perturb the ecosystem in a way that, even without direct interaction, it can affect other species reproductive success. For example, let's say that ant species A is the bullet ant, which is known to have a painful bite. Since animals will avoid eating the bullet ant, species B could evolve to resemble or mimic the bullet ant to avoid predation.

3. Scientists can use the principles of evolution to understand certain features of cancer cells. Provide an example of how the evolution of cancer cells could resemble the evolution of species.
    a. **Random mutations could allow cancer cells to escape chemotherapy treatment.**
    b. **Cancer cells interact with their environment and are subject to selective pressures (e.g. the ability to evade immune cells or undergo metastasis and migration).**

4. Eric is studying a population of wolves in Yellowstone National Park. He observes that the prevalence of wolves correlates with an increased survival rate of young trees.
    a. Propose a hypothesis that could help explain this observation.
    Wolves are predators of an animal that feeds on young trees.

    b. By studying the metabolites of the tree, Eric discovers that the tree releases a compound that attracts wolves. Using the concepts of natural selection and evolution, propose a hypothesis that explains this observation.
    At some point, the ancestor of the tree acquired a mutation which resulted in the production of a metabolite that attracts wolves. The wolves ate the animals, for instance deer, that ate the trees. This increased the survival of the young trees and, over time, more trees reached maturity and had greater reproductive success.