

## Teacher Notes for “What is a species?”<sup>1</sup>

In this analysis and discussion activity, students evaluate different approaches to defining a species. The goal is to define a group of organisms that is evolving separately from other groups of organisms and thus can evolve their own suite of adaptive characteristics. Students analyze data from various examples to appreciate that the difficulties of defining a species arise from real properties of the process of evolution.

As background for this activity, you may want to have your students complete either of the following general introductions to natural selection.

- “What is natural selection?”  
(<https://serendipstudio.org/exchange/bioactivities/NaturalSelectionIntro>) or
- "Evolution by Natural Selection" ([http://serendipstudio.org/sci\\_edu/waldron/#evolution](http://serendipstudio.org/sci_edu/waldron/#evolution)).

### Learning Goals

In accord with the Next Generation Science Standards<sup>2</sup>:

- This activity, together with the recommended follow-up activities,<sup>3</sup> will help students to understand the Disciplinary Core Idea, LS4.C, “Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, ...”
- This activity, together with the recommended follow-up activities, will help to prepare students for the Performance Expectation, HS-LS4-5, "Evaluate the evidence supporting claims that changes in environmental conditions may result in: ... the emergence of new species over time...."
- Students will engage in the Scientific Practice, Analyzing and Interpreting Data, “Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.”
- This activity provides the opportunity to discuss the Crosscutting Concept, Stability and change, “Students understand much of science deals with constructing explanations of how things change and how they remain stable.”

### Suggestions for Implementation and Background Biology

To maximize student participation and learning, I suggest that you have your students work in pairs to complete each group of related questions and then have a class discussion after each group of questions. In each discussion, you can probe student thinking and help them develop a sound understanding of the concepts and information covered before moving on to the next group of related questions.

If your students are learning online, I recommend that they use the Google Doc version of the Student Handout available at <https://serendipstudio.org/exchange/bioactivities/species>. For the included “Same or Different Species?” activity

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<sup>1</sup> By Ingrid Waldron, Department of Biology, University of Pennsylvania, © 2024. These Teacher Notes and the Student Handout are available at <https://serendipstudio.org/exchange/bioactivities/species>. This activity provides scaffolding to help students understand the activities in "Speciation" (<https://teach.genetics.utah.edu/content/evolution/speciation/>); some of the activities in "Speciation" are included in this activity.

<sup>2</sup> Next Generation Science Standards quotations from <https://www.nextgenscience.org/> and <https://www.nextgenscience.org/sites/default/files/HS%20LS%20topics%20combined%206.13.13.pdf>

<sup>3</sup> See page 4 of these Teacher Notes.

(<https://teach.genetics.utah.edu/content/evolution/speciation/same-or-different-species.pdf>), students learning online won't be able to arrange the cards, but you can instruct your students to group the species into five categories:

- A. Definitely the same species
- B. Ambiguous, but closer to the same species
- C. Ambiguous
- D. Ambiguous, but closer to different species
- E. Definitely different species.

You may want to revise the Word document or Google Doc to prepare a version of the Student Handout that will be more suitable for your students. If you use the Word document, please check the format by viewing the PDF.

A key is available upon request to Ingrid Waldron ([iwaldron@upenn.edu](mailto:iwaldron@upenn.edu)). The following paragraphs provide additional instructional suggestions and background information – some for inclusion in your class discussions and some to provide you with relevant background that may be useful for your understanding and/or for responding to student questions.

The driving question for this activity is “What is a species?” Student answers to question 1 will help you understand what your students already know and be aware of any misconceptions they may have.

The Student Handout offers two definitions of a species (near the top of page 1 and at the top of page 2), and the included video (<https://learn.genetics.utah.edu/content/evolution/species/>) provides a more extended discussion of the species concept. The definition offered on page 1 of the Student Handout introduces the biological species concept, which defines a species as a group of organisms which interbreed with each other and which don't successfully interbreed with organisms from other species in nature. The goal of the biological species concept is to identify a genetically isolated group that is evolving separately from other groups, so a species can evolve a distinctive suite of characteristics that are adapted for its environment and niche. (In ecology, a niche is the way an organism interacts with its biotic and abiotic environment to satisfy its needs.)

Question 2 provides the opportunity to reinforce student understanding that reproductive isolation allows different species to evolve different characteristics. As discussed in question 3, a limitation of the biological species concept is that it can't be used for fossils or for organisms that do not reproduce sexually (e.g. prokaryotes).<sup>4</sup>

The coyote-wolf-domestic dog example<sup>5</sup> illustrates the generalization that some pairs of closely related species have interbred in nature and produced viable hybrids. The eastern coyote has most of its DNA from ancestral coyotes, but 8-25% has come from wolves and 8-11% from domestic dogs. Wolves also have some coyote genes.<sup>6</sup> Nevertheless, coyotes and wolves have evolved separately enough so they have different suites of adaptations, including differences in the size and shape of their heads and the relative size of their ears. (For more differences between

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<sup>4</sup> Prokaryotes often transfer some DNA to other prokaryotes, even from one type of prokaryote to a very different type of prokaryote (often referred to as horizontal transfer).

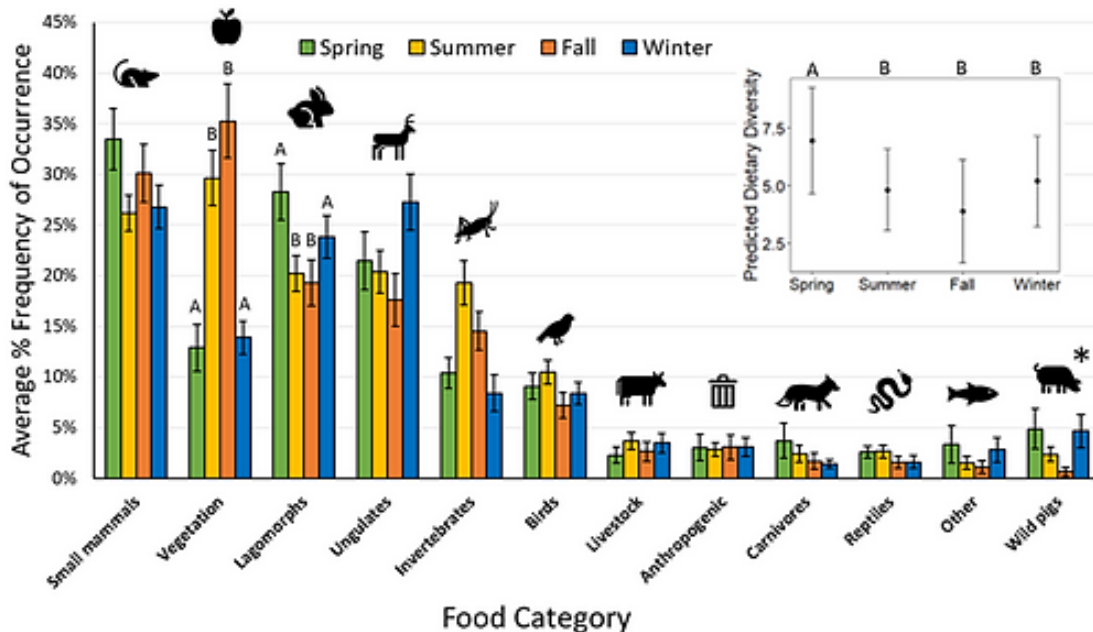
<sup>5</sup> The scientific name for coyotes is *Canis latrans*. The scientific name for the gray wolves discussed in the Student Handout is *Canis lupus*. The scientific name for domestic dogs is *Canis familiaris*.

<sup>6</sup> This has contributed to the currently unresolved debate about the number of wolf species in North America.

coyotes and wolves, see the second paragraph below and the second paragraph on page 2 of the Student Handout.)

Page 2 of the Student Handout begins with another species concept, which is based on differences in genes, anatomy, physiology, behavior, and ecological roles. This species concept is more broadly applicable than the biological species concept, but it still has problems. Because the formation of new species is generally a gradual process, the decision when two populations have become different enough to call them separate species is often arbitrary.<sup>7</sup> Similarly, when populations change over time so that the early and late populations are recognized as different species, the time when the earlier species became the later species is generally arbitrary.

The second paragraph on page 2 of the Student Handout briefly summarizes additional differences between wolves and coyotes (<https://wolfwatcher.org/wp-content/uploads/2016/11/Wolf-Coyote-Dog-Comparison.pdf>). Wolves usually hunt in packs, whereas coyotes usually hunt alone or in mated pairs. Wolves tend to hunt ungulates (large hooved plant-eating mammals), whereas coyotes have a varied diet (see figure below). Limited evidence suggests that much of the ungulate meat in coyote diets comes from scavenging wolf kills, road kills or other dead ungulates. However, coyotes have been observed to kill adult white-tailed deer and their fawns. It has been hypothesized that coyotes that have more wolf genes and traits may be better able to kill deer; this hypothesis suggests that hybridization may sometimes introduce valuable traits into a population.



The Y axis gives percent of coyote scats that contain each item. The importance of vegetation (e.g. fruits) in coyote diets may be overestimated by this measure, since vegetation generally has fewer calories per volume. (<https://onlinelibrary.wiley.com/doi/full/10.1111/mam.12299#:~:text=Coyotes%20were%20generally%20more%20carnivorous,where%20human%20footprint%20was%20greater.>)

<sup>7</sup> Although this learning activity emphasizes that the process of speciation is often gradual, speciation can occur abruptly, particularly in plants where interspecific hybridization followed by polyploidy can abruptly produce a new species. It should also be mentioned that, in some cases, the fossil record suggests periods of stasis, followed by relatively rapid evolutionary change and the formation of new species (called punctuated equilibrium).

After you discuss student answers to question 6, you will probably want to point out that this example illustrates the importance of reproductive barriers between species, so each species can evolve a separate suite of adaptations that are suited to its niche.

The Student Handout directs students to watch the ~6-minute video, “What is a species?” (<https://learn.genetics.utah.edu/content/evolution/species/>). This video does a good job of concisely explaining why a species is hard to define and concludes that the best definition varies, depending on the context. In addition, this video recommends focusing on the process of speciation and recognizing that most species emerge gradually so the distinctions between species can be fuzzy. Student answers to questions 7-8 should be based on the video.

Polar bears are specialized for life in the Arctic, where they hunt marine mammals and their white coats blend with the snow and ice of their environment. Grizzly bears are a subspecies of brown bears, which are widespread in Europe, Asia and North America. They live on land and eat a wide variety of foods, including plants, fish and large ungulates. The figure below summarizes the evolutionary history of brown bears and polar bears, and suggests an explanation of why about 10% of the DNA in brown bears comes from polar bears.



After questions 7-8, students are instructed to complete the activity, “Same or Different Species?” (<https://teach.genetics.utah.edu/content/evolution/speciation/same-or-different-species.pdf>). This activity asks the students to sort cards (with pictures and descriptions of two or more types of organisms) along a continuum from the same species to different species.<sup>8</sup> Please read the brief Teacher Guide for this card sort activity, available at

<sup>8</sup> The descriptions on the cards are generally relatively easy to understand, but it may be helpful to have more information about fly agaric mushrooms. Despite their generally similar morphology, genetic analyses have revealed that there are at least six distinct species of fly agaric mushrooms, each of which have been evolving separately for millions or thousands of years. One of these six species is widely distributed in western and northeastern North America; three species have more limited distributions in the southeastern US and Santa Cruz island. Two additional species are found in Eurasia and Alaska – one is widely distributed in temperate, boreal and coastal forests and the other is found in subalpine and alpine tundra. It has been proposed that “Most of the major clades” (species) within the *Amanita muscaria* species complex (fly agaric mushrooms) “may have diverged as a result of multiple fragmentations and geographic isolation of the ancestral populations due to climatic changes in the late Tertiary and Quaternary.” (Molecular Phylogenetics and Evolution 48:694-701, 2008)

[https://teach.genetics.utah.edu/content/evolution/speciation/same-or-different-species\\_TG.pdf](https://teach.genetics.utah.edu/content/evolution/speciation/same-or-different-species_TG.pdf).

Two of the most important points from this Teacher Guide are quoted below.

- “Students may come to different conclusions about some of the in-between examples, and that’s ok. We have intentionally chosen examples that are muddy and challenging. What’s more important is that the examples on the extremes (fish, bears, and rock pocket mice) are arranged correctly, and that students can have productive discussions and can justify their choices.”
- “Because we can observe a range of examples that fit more or less well into the same versus different species categories, we can reason that speciation is a process where species become more defined over time. Differences accumulate over time (often very long periods of time), yet some similarities remain. What we see today is a snapshot of this process unfolding.”

### **Recommended Follow-Up Activities**

“Reproductive Barriers” (<https://learn.genetics.utah.edu/content/evolution/barriers>; <https://teach.genetics.utah.edu/content/evolution/speciation/>) is a slide presentation with narration about different types of reproductive barriers. The learning activity, “Hawthorns to Apples – New Host, New Species?” (<https://teach.genetics.utah.edu/content/evolution/speciation/>), will guide students to understand the processes that lead to the formation of new species.<sup>9</sup>

### **Sources of Figures in Student Handout**

- Wolf and coyote heads on page 1 – adapted from <https://www.fieldandstream.com/hunting/wolf-vs-coyote/>
- Coyote pouncing on a small prey animal – [https://images.squarespace-cdn.com/content/v1/5e11e82c0efb8f0d16a5dbc8/7fccf70f-f1d4-4c8f-ba9e-1940b6840963/Coyote+Canis+ltrans+hunting+pounce+CDODDS\\_CID9438.jpg](https://images.squarespace-cdn.com/content/v1/5e11e82c0efb8f0d16a5dbc8/7fccf70f-f1d4-4c8f-ba9e-1940b6840963/Coyote+Canis+ltrans+hunting+pounce+CDODDS_CID9438.jpg)
- Wolves hunting as a pack – [https://www.pbs.org/wnet/nature/files/2008/08/610\\_ag\\_graywolf1.jpg](https://www.pbs.org/wnet/nature/files/2008/08/610_ag_graywolf1.jpg)

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<sup>9</sup> See also “Resources for Teaching and Learning about Evolution” (<https://serendipstudio.org/exchange/bioactivities/evolrec>). These Teacher Notes provide (1) suggestions for teaching evolution to students with religious concerns, (2) a review of major concepts and common misconceptions concerning natural selection, with recommended learning activities, (3) a review of major concepts and common misconceptions about species, descent with modification, and the evidence for evolution, with recommended learning activities, and (4) recommended general resources for teaching about evolution.