ActionBioscience.org lesson

To accompany the article by Lawrence M. Page, Ph.D.:
"Planetary Biodiversity Inventories: A Response to the Taxonomic Crisis" (May 2006)
http://www.actionbioscience.org/biodiversity/page.html

What Is a Species? (December 2006)

Lesson adapted from the activity "Species: An Evolving Concept" Developed by the Biological Sciences Curriculum Study (BSCS) for the Evolution symposium sponsored by AIBS/BSCS/NESCent at the 2006 NABT national conference.

Educator's Section: *pp. 1–3*
Unit 1 instructions: *pp. 4–5*
Unit 2 instructions: *pp. 6–7*
Masters/worksheets*: pp. 8-17*

Grades & Levels:

- **Student Activity Unit 1:** high school (all levels) – undergraduate (year 1)
- **Student Activity Unit 2:** high school (all levels) –undergraduate (year 1)

Time Recommendations:

- 1 class period and/or assignment for article review and discussion questions
- 1-3 class periods for activities or a combination of classroom and assignment work

NSES (USA) Content Standards, 9–12:

- NSES 1.2. Unifying Concepts and Processes: Evidence, models, and explanation
- NSES 2.1. Science as Inquiry: Abilities necessary to do scientific inquiry
- NSES 4.3. Life Science: Biological evolution

Note: View the NSES content standards on this site to choose other curricular applications for additional activities at www.actionbioscience.org/educators/correlationcharts.html

Lesson Objectives: Students will…

- recognize that scientists use different definitions of species
- be able to assess the strengths and limitations of species definitions depending on their context
- use definitions of species to enhance their understanding of speciation
- understand the concept of taxonomy and biodiversity inventories

Key Words Include:
Biodiversity, clade, classification, genus, inventories, invertebrates, monophyletic, species, speciation, taxa, taxonomy, vertebrates

Preparation

Article Discussion: Several approaches are possible the questions on page 2:

1. Have students read the article on their own, or distribute questions to groups.
2. Give students copies of the questions and have them do the reading and complete the content questions on their own, perhaps as a short-answer writing assignment. Have them

discuss their answers and the more complex questions either in a large or small group.
3. The extension questions may be more suitable for HS students as homework.
4. Activity 1 in "Fun with Taxonomy" should be assigned with a long-term deadline since it requires students to search for lichen outdoors. Activity 2 can be done with a few clicks of the mouse.

Student Activity Unit 1 and 2:

1. Each activity unit is preceded by suggestions for teaching and preparation.
2. The units should be used sequentially for a complete lesson based on the 5E model: Engage, Explore, Explain, Elaborate, and Evaluate. The 5E model is based on a constructivist approach to teaching, which encourages students to take an active role in learning. If there are time constraints, unit 1 could be used for general high school biology and unit 2 with honors/AP high school students and undergraduate students.
3. Refer students to “useful links for student research” in the “Educator Resources” section at the end of the Morse article. These links help students with their activities and provide a source for research information.

For Educators: Article Discussion

About the article by Lawrence M. Page, Ph.D.:
"Planetary Biodiversity Inventories: A Response to the Taxonomic Crisis"
http://www.actionbioscience.org/biodiversity/page.html

Article Content Questions

1. What is taxonomy?
2. Why is there a taxonomic crisis?
3. How do biodiversity inventories hope to ease the problem?
4. Why are catfish a good group for a global inventory?
5. What success has the All Catfish Species Inventory had so far?
6. What suggestions does the author make to improve the field of taxonomy?
7. Is a species inventory cost effective?

Article Extension Questions

1. How did the modern system of classification start?
2. What are some of the advantages of having a universal taxonomy?
3. How could a scientist use taxonomy to control invasive species?
4. How could taxonomy help conservation efforts?
5. What skills do you think a taxonomist should have?

Fun with Taxonomy

1. Can you identify a lichen? Look around your garden, local park, or when you take an outdoor trip. Then go to http://www.nhm.ac.uk/jdsml/nature-online/lichen-id-guide/index.dsml (A Guide to Lichens on Twigs) and follow the step-by-step interactive guide to identification.
2. "Walking with Woodlice" is an interactive activity that will lead you to species identification. Go to http://www.nhm.ac.uk/nature-online/life/other-invertebrates/walking-with-woodlice/identification.html

What Is a Species? Student Activity Units
General Information for Educators

Overview

In his 1859 masterwork *On the Origin of Species by Means of Natural Selection*, Charles Darwin described how natural selection accounts for changes within populations and existing species. He also said that natural selection explains the origin of new species. His phrase, "descent with modification" summarized his conclusion that all new species arise from existing species and are modified in the process, primarily by natural selection.

Perhaps surprisingly, Darwin had only a vague idea of what a species was. Later, in the 20th century, biologist Ernst Mayr used the concept of interbreeding to develop a formal definition called the biological species concept. It defines a species as any population or group of populations whose members have the potential to interbreed with one another in nature to produce viable, fertile offspring. As useful as the biological species concept is, it has limitations. For example, scientists cannot apply it to fossil organisms or those that reproduce asexually. To solve such problems, scientists have proposed other definitions of species. In this activity, students explore the concept of species and assess the strengths and limitations of different definitions of species.

Major Concepts

- Most people have a general understanding of what is meant by a species.
- Scientists use different definitions of species that depend on characteristics such as reproduction, morphology, and ecology.
- There is no single scientific definition of species that works for all situations.
- Scientists continue to encounter situations that test their abilities to define a species.

Preparation

Student Activity Unit 1

Master 1.1, *Darwin Quotation* (Prepare an overhead transparency.)
Master 1.2, *Textbook Definition* (Prepare an overhead transparency.)
Master 1.3a–d, *Case Descriptions* (Make one copy per group of four students.)
Master 1.4, *First Worksheet* (Make one copy per group of four students.)

Student Activity Unit 2

Master 1.3a–d, *Case Descriptions* (Make one copy per group of four students.)
Master 1.5, *Different Species Definitions* (Make one copy per group of four students.)
Master 1.6, *Second Worksheet* (Make one copy per group of four students.)
Master 1.7, *Speciation* (Make one copy per group of four students and prepare an overhead transparency.)

Acknowledgment: The Student Activity Units, originally titled "Species: An Evolving Concept" were developed by the Biological Sciences Curriculum Consortium. The original activities has been structured to conform to ActionBioscience.org lesson guidelines but their content has not been changed.

What Is a Species?
Student Activity Unit 1

The 5E model: Engage

1. **Ask students how they define a biological species.**
   Write the important aspects of their definitions on the board or an overhead transparency. Accept all responses and do not correct their preconceptions.

2. **Ask students how they think their definitions of species might compare to that of Charles Darwin.**

   Some students may think that their definitions are likely not as good as that of Charles Darwin because he was an expert who gave the concept a great deal of thought. Other students may believe that their definitions are better than Darwin's because today we know more about biology than in Darwin's time.

3. **Display a transparency of Master 1.1, *Darwin Quotation* and ask for a volunteer to read it aloud.**

4. **Ask students if they are surprised by Darwin's view of species.**
   Some students may be surprised that Darwin viewed species as a term "arbitrarily given for the sake of convenience." Others may not be surprised because they feel that the science of biology was not very sophisticated in Darwin's time.

5. **Explain that in this activity, they will explore the concept of species and investigate its strengths and limitations.**

The 5E model: Explore

1. **Divide the class into groups of four students.**

2. **Display a transparency of Master 1.2, *Textbook Definition* and ask for a volunteer to read it aloud.**
   Explain that this is a typical definition of species taken from a high school biology textbook.

3. **Pass out to each group one copy of Master 1.3a–d and one copy of Master 1.4, *First Worksheet.***

4. **Instruct the students to read the four case descriptions and use the textbook definition of species to answer the questions on Master 1.4.**
   Give groups about 15 minutes to complete their tasks.

5. **After students have completed their worksheets, ask for a volunteer to read his or her group's responses to the first case description.**

Case 1

Students should conclude that the mule is not a separate species since mules cannot interbreed with each other. Some students may believe that the second part of the definition (individuals possessing similar anatomical characteristics) is consistent with the mule being its own species.

6. Ask for additional volunteers to share responses to the other cases.

Case 2

Students should conclude that the liger is not a separate species because they cannot breed with each other. Some students may note that the female ligers are fertile and use this as evidence for ligers being a species. If not mentioned by a student, point out that female ligers cannot breed with male ligers as required by the species definition.

Case 3

Students should recognize that Poodles and Pekingese are both dogs and members of the same species. This means that the "Peakapoo" is also a member of the same species.

Case 4

Bacteria reproduce asexually. Students may respond that the species definition doesn't work for bacteria since it requires interbreeding.

The 5E model: Explain

1. Ask students to suggest changes to the textbook species definition that would enable it to account for all of the cases just described. Write their suggestions on the board or on an overhead transparency.

Do not expect students to come up with a definition that works for all cases.

2. Acknowledge the difficulty with writing a definition that works in all cases.

- **Ask students what factors are important in writing a definition of species.**
- **Write their answers on the board or on an overhead transparency.**

Answers will vary. Students may suggest the ability to interbreed, to produce fertile offspring, having similar physical traits, having similar genomes, and occupying the same ecological niche.

3. Explain that in unit 2 they will examine other definitions of species (if you intend to cover both units.

What Is a Species?
Student Activity Unit 2

The 5E model: Elaborate

1. **Pass out to each group one copy of Master 1.5, *Different Species Definitions* and one copy of Master 1.6, *Second Worksheet*, and Master 1.3a–d. *Note:* If you completed Student Activity Unit 1 with your class, the students will already have a copy of Master 1.3a-d.**

2. **Explain to the students that they will**
   - **read four different definitions of species on Master 1.5;**
   - **relate them to the four case descriptions from Master 1.3; and**
   - **decide which definition works best for each case description.**

   For each definition chosen by the students, they should identify on their worksheets the aspects of each definition that helped and did not help them make decisions about a species. Give groups about ten minutes to complete their tasks.

3. **After students have completed their worksheets, ask for a volunteer to read his or her group's responses to the first case description.**

   Ask if other groups agree with the definition selected by the first group. If there are disagreements, have the students explain why they selected a different definition.

4. **Ask for additional volunteers to share responses to the other cases.**

   As before, when groups disagree about which definition works best for a case description, have them explain their reasoning.

5. **Ask students, "Why is it important to agree upon and use a precise definition of a biological species?"**

   Write their responses on the board or an overhead transparency. Students' responses will vary. Guide the discussion to bring out the following:
   - a precise definition is needed to allow scientists to share information;
   - to obtain accurate population data;
   - to assess biodiversity; and
   - to investigate the process of speciation.

The 5E model: Evaluate

1. **Display an overhead transparency of Master 1.7, *Speciation* and pass out one copy of the master to each group.**

2. **Ask for a volunteer to read aloud the description of the indigobirds.**

   Before proceeding, make sure that the students understand the description. Answer any questions that they may have.

3. **Instruct students to answer the discussion questions on Master 1.7.**

   Give students about ten minutes to complete their tasks.

4. **Ask for volunteers to read the answers to the discussion questions.**

   1. Are the two populations of indigo birds separate species? Why or why not?

   Students should respond that the two populations are not separate species because they can still interbreed.

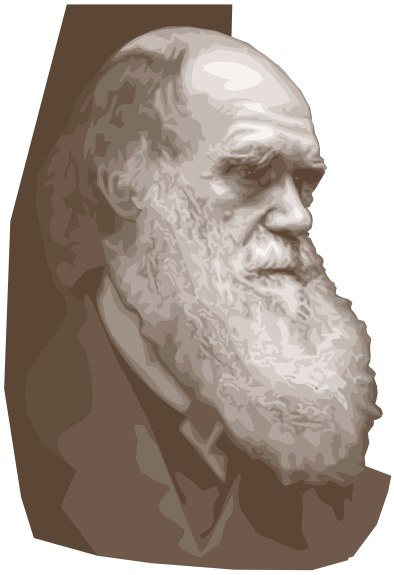
   2. Which of the species definitions on Master 1.5 is most helpful in deciding if the two populations of indigobirds are separate species?

   Students should respond that species definition 1 best addresses the species question of the indigobirds.

   3. What do you predict will happen to these two populations in the future?

   Student responses will vary. Some students may predict that the two populations will continue to grow more different with time. Eventually, they may lose the ability to interbreed and will become distinct species.

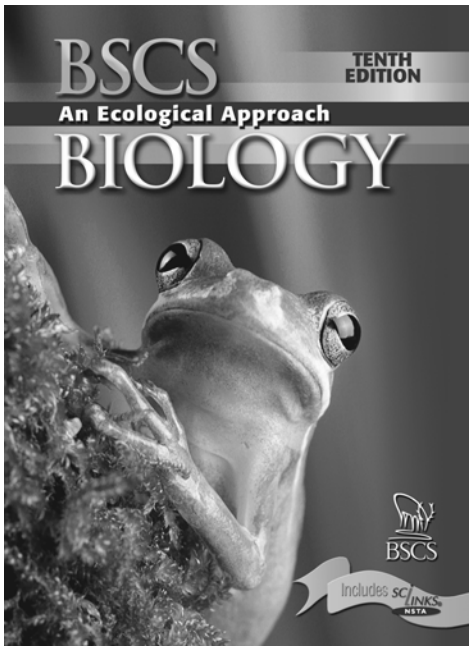
Master 1.1 - *Darwin Quotation*



“I look at the term species, as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other.”

Charles Darwin

Master 1.2 - *Textbook Definition*



"Species: A group of organisms that can interbreed with others of the same type; individuals within a species possess similar anatomical characteristics."

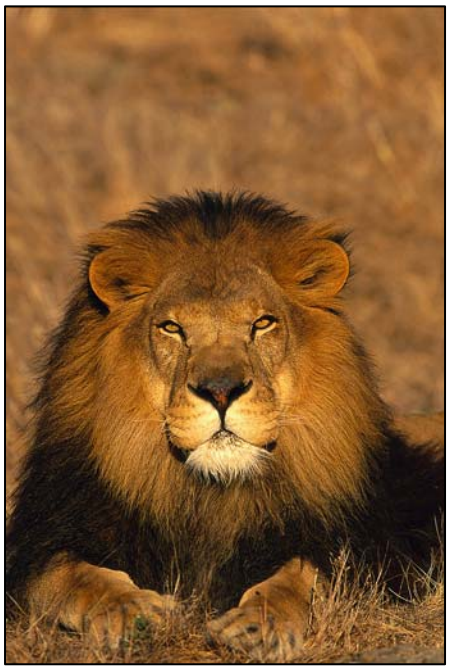
BSCS Biology: An Ecological Approach, 10th edition

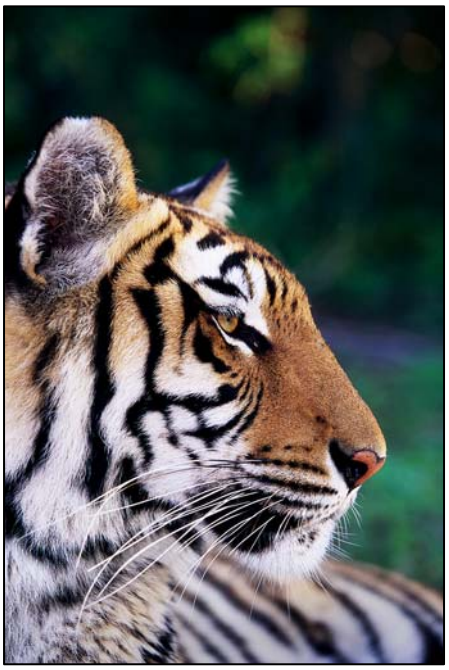
Master 1.3a - *Case Description 1*

Case 1

A mule is the offspring of a male donkey and a female horse. In contrast, the hinny is the offspring of a male horse and a female donkey. The mule is easier to breed and larger in size than the hinny. For these reasons, the mule became an important domesticated animal. Horses have 64 chromosomes while donkeys have 62. Mules have 63 chromosomes, which cannot evenly divide. This accounts for the fact that mules are sterile.

Master 1.3b - *Case Description 2*





Case 2

A *liger* is the offspring of a female tiger and a male lion. In contrast, the *tigon* is the offspring of a male tiger and a female lion. These two species do not breed in nature because their habitats are mostly different. Lions live in open grasslands while tigers live in forests. In captivity, it is possible to produce ligers and tigons. Male ligers are sterile but female ligers are fertile and can be bred to either tigers or lions.

Master 1.3c - *Case Description 3*

Case 3

There are a wide variety of domesticated dog breeds. Most of these are capable of breeding with each other to produce mixed offspring that feature a combination of the traits of the parents. For example, Poodles and Pekingese can be bred to produce what some have referred to as *Peakapoos*. These mixed breeds are healthy and can reproduce with other dogs.

Master 1.3d - *Case Description 4*

Case 4

***Escherichia coli* (*E. coli*) is a bacterium normally found in the human gut. It is harmless and may actually be beneficial to the human digestive system. There is a pathogenic strain of *E. coli* that produces a toxin that can kill its human host. The two strains look very similar under the microscope. Comparison of their genomes reveals that the pathogenic strain lacks 528 genes found in the normal strain and has 1,387 genes not found in the normal strain.**

Master 1.4 - *First Worksheet*

Species definition
"A group of organisms that can interbreed with others of the same type; individuals within a species possess similar anatomical characteristics."

BSCS Biology: An Ecological Approach, 10th edition

Directions

1. Read the four case descriptions on Master 1.3.
2. For each case, refer to the textbook species definition above and use it to answer the questions below.
3. For each of your answers, write down
   - how the species definition helped you to answer the question.
   - how the species definition did not help you answer the question.

Question	Answer	How the definition helped	How the definition did not help
Case 1 Is the mule a separate species from the horse and donkey?	Yes No		
Case 2 Is the liger a separate species from the lion and tiger?	Yes No		
Case 3 Is the "Peakapoo" a separate species from the Poodle and Pekingese?	Yes No		
Case 4 Are the normal and pathogenic strains of *E. coli* separate species?	Yes No		

Master 1.5 - *Different Species Definitions*

1. A species is any population or group of populations whose members have the potential to interbreed with one another in nature to produce viable, fertile, offspring.

2. A species is any population or group of populations whose members occupy the same ecological niche. Members of the same species occupy the same habitats, use the same environmental resources, and exhibit the same behaviors.

3. A species is any population or group of populations whose members share an ancestor. The species members maintain their lineage through space and time.

4. A species is any population or group of populations whose members differ morphologically from other populations.

Master 1.6 - *Second Worksheet*

Directions

1. Read the four species definitions on Master 1.5.
2. Review the four case descriptions on Master 1.3 and decide which of the four definitions best helps you decide if the organisms in question are different species. (You may use a given definition more than once.)
3. For each of your answers, write down
    - how the species definition helped you to answer the question.
    - how the species definition did not help you answer the question.

Case description number	Definition number	How the definition helped	How the definition did not help
1			
2			
3			
4			

Master 1.7 - *Speciation*

African indigobirds lay their eggs in the nests of different species of finches. The newborn indigobirds act as though they belong there and as adults they incorporate the songs of the finches into their own mating calls. The blue indigobird species lays eggs in the nests of both the African firefinch and the Black-bellied firefinch. The newborn indigobirds learn the songs of their foster parents and seem to have evolved into two different "populations."

The two populations can still interbreed. However, female indigobirds prefer suitors who know the same songs that they do. For example, female indigobirds that grow up in an African firefinch nest tend to lay eggs in the same type of nest rather than a nest belonging to a Black-bellied firefinch.

Discussion questions

1. Are the two populations of indigo birds separate species? Why or why not?

2. Which of the species definitions on Master 1.5 is most helpful in deciding if the two populations of indigobirds are separate species?

3. What do you predict will happen to these two populations in the future?