If They Can Mate, Did They Speciate?

A Case Study in Evolution and Meaning of Species

Introduction:

How many times have teachers heard students say that an animal evolved when a member of species X mated with a member of species Y? How many times have we been asked questions such as: Is there really such as thing as a liger? Can a dog and a wolf mate? What would happen if a Chihuahua and a Great Dane mated? Did humans mate with chimps and that's how we got AIDS? Haven't we explained that a species is defined by reproductive isolation only to have students point out exceptions such as the dog and the wolf, or the recent hybrid Grizzly/Polar bear?

This unit is designed to address the vexing issue of the species concept by using these common student questions and recent biology news. It is based on a case study approach. It is designed to offer AP Biology students an opportunity to review/relearn evolutionary concepts in a manner different than that in an introductory course. This method is being increasingly used in colleges because it fosters deeper thinking, independent learning and more sophisticated understanding. It can be done in whole or in part and can be used as a webquest.

For further explanation of the design and use of the unit, please see the teacher notes.

If They Can Mate, Did They Speciate?

A Case Study in Evolution and Meaning of Species

Part 1:Ligers and Chumans and Pizzly Bears! Oh, My!

"Hello dear," said Mom while cutting the tomatoes for dinner, "How was school?"

Tammy had just arrived home from her after school volunteer work at the animal shelter. "Kinda cool. We had a huge debate in biology today. Hi Dad."

Dad looked up from his newspaper. "Hi hon."

"So dear, what did you debate about?" Mom said while concentrating on the tomatoes, "Not the value of genetic altered food again, I hope. I don't care what they do to plants as long as we can get tasty tomatoes"

"It's genetically modified organisms, and no it wasn't that. We were discussing evolution and species and stuff. George, will you lower that!"

Tammy's brother George was listening to music in the other room.

"Anyway, Mr. Murray was explaining what a species is and how they can't breed with other species and he was all excited about a news story of how some hunters have found a bear who was a cross between a polar bear and a grizzly and another news story about how human ancestors and chimp ancestors may have interbred not long after they split into two species. Then Mel asked, 'If there was a pizzly, and a chuman, could there really be a Liger?'"

"That's from that movie, Napoleon Dynamite. Someone asked the same question last year when I had bio," said George as he entered the room. "It's a cross between a lion and a tiger. I'll bet Murray was really piz…"

"Don't open that refrigerator, dear. We'll be eating in a little while," said mom. "So, is there such a thing?"

"…off!"

Tammy stared at George, wondering what day George actually stayed awake in bio last year. "Actually, he went on a long lecture about how we shouldn't think of the chimp and human actually being a chimp and human yet. The human ancestor would have seemed very ape like to us. And apparently the tiger and lion are similar enough that they can mate but since they are only together in zoos I guess it doesn't count. And no, they aren't magic."

"That's interesting dear. In the supermarket I saw pluquats. I think they are a cross between plums and kumquats."

"Yeah, well, anyway, then Erica asked if a Chihuahua and a Great Dane could actually, you know, mate. And, if they couldn't, were they different species? She always asks the best questions."
"Now that I'd like to see!" said George. "I bet they couldn't fit together!"

"Hmmrph, I'm going to uhh, polish my golf clubs," said Dad rising suddenly.

Mom giggled, "He always gets so nervous when we discuss s-e-x. So, what did the teacher say?"

"Well, after the boys all stopped laughing, he explained that they might not be able to do it, umm naturally, but their sperm and eggs are compatible. But, if paleontologists in the future found Chihuahua bones and Great Dane bones they would probably consider them different species."

"Sounds like the liger dear"

"That's what I thought. I was going to ask about it at the shelter but Dr. Edwards wasn't in. Anyway, that got us wondering if the Chihuahua and the Great Dane were different species like the tiger and the lion. Then Erica asked if there were any cases of species in the wild that could mate. Mr. Murray said he read that about 25% of plants and 10% of animals do make hybrids with closely related species."

Mom pulled her finger away from the knife suddenly, "Hmm, if scientists could cross a tomato and a navel orange…"

"Yeah, anyway, that's when Susan said that if they can make hybrids then they are the same species. Sophia thought that the hybrids are sterile, like a mule but Mr. Edwards point out that there was one who just gave birth. Then Tara started chanting 'If you can mate than you didn't speciate'. Mr. Edwards made her stop and then said that the whole species concept is kinda murky."

"Just like you!" muttered George as he left with a tomato slice shoved in his mouth.

"Loser," said Tammy. "Anyway, Elliot was saying that on his farm his family had a smallish Jack Russell terrier that mated with a medium size Brittany. One of the puppies grew up and mated with the neighbor's German Shepard. His family was worried because they had always suspected that the Shepard was actually part coyote since it was so vicious and there are coyote in the area. In fact, the terrier's mom was eaten by a coyote. That's why they put up that big fence."

"Hmm, do they grow tomatoes on that farm?"

Case analysis:

1. In your Case Study Journal, create a chart with the headings:

I Know…	*I Think I Know…*	*I Want to Know…*

Think about this case and reflect back on your homework and prior learning. Make as many entries as possible in each column of the chart.

2. Discuss your list with your group. Add notes to your lists.

3. Using your textbook make sure you understand the following concepts. Record definitions and connections to the case in your journal.

The stages of Natural Selection (as already discussed)
Reproductive isolating mechanisms (as listed in the book)

Species	Sympatric speciation
Biological species concept	Hybrid
Morphological species concept	Gene Flow
Phylogenetic species concept	Gene Pool
Ecological species concept	Taxonomy
Allopatric speciation	Phylogeny

4. Read these brief articles at these websites:

Grizzly-Polar Bear Hybrid Found—But What Does It Mean?
http://news.nationalgeographic.com/news/2006/05/polar-bears.html

Did Humans and Chimps Once Interbreed?
http://www.newscientist.com/article.ns?id=mg19025525.000

Morocco's Miracle Mule
http://news.bbc.co.uk/2/hi/science/nature/2290491.stm

Ligers and Tigons (including pictures)
http://www.pbs.org/wgbh/evolution/library/05/2/l_052_02.html

5. Discussion questions (answer these questions in your case journal in preparation for the follow-up class discussion):

A. Consider the examples of "murky species" mentioned in the case (polar bear/grizzly, dog/coyote, Great Dane/Chihuahua). Apply each of the species concepts to these examples. Do the concepts differ in their ability to help make sense of the examples?

B. Does the ability of two species to hybridize indicate anything about how recently they speciated?

C. Should biologists decide on set number of genetic differences or morphological differences be used to decide if a two populations are different species (or subspecies)?

D. Are populations that speciate sympatrically more likely to be able hybridize than ones that speciate allopatrically?

E. Does the presence of hybrids (especially fertile) mean that there is no species barrier?

F. Can new species be created by hybridization?

G. Be sure to review reproductive isolating mechanisms very carefully.

H. Do you think this is an important issue?

I. Relate your research to the "want to know" column. What questions can you now answer?

6. For more information, check out the following websites:

Speciation (from the Understanding Evolution Website)
http://evolution.berkeley.edu/evosite/evo101/VSpeciation.shtml

What Is A Species And What Is Not by Ernst Mayr
http://darwiniana.org/mayrspecies.htm#Mayr

A species definition for the modern synthesis by James Mallet
http://www.ucl.ac.uk/taxome/jim/pap/mallet95tree.pdf

Genetics and the origin of species: An introduction by Francisco Ayala and Walter Finch
http://www.pnas.org/cgi/content/full/94/15/7691

*Hybridization As An Invasion Of The Genome b*y James Mallet
http://www.ucl.ac.uk/taxome/jim/pap/mallethyb05.pdf

How To Define A Species. (posts examining the dog question)
http://www.madsci.org/posts/archives/1999-09/936393054.Ev.q.html
http://www.madsci.org/posts/archives/1999-09/936393054.Ev.r.html
http://www.madsci.org/posts/archives/2002-05/1021060022.Ge.r.html
http://www.madsci.org/posts/archives/2001-09/999932294.Zo.r.html

Evolution Caught In The Act (Galapogos finches)
http://www.nature.com/news/2006/060710/pf/060710-11_pf.html

Ligers and Tigons
http://www.messybeast.com/genetics/new-species.htm
http://www.sierrasafarizoo.com/animals/liger.htm

What is a species? (a good primer on speciation, includes red wolf)
http://courses.bio.indiana.edu/S318-brodie/S318%20PPT/S318%20L%2029%20species.pdf

Part 2: The Sisterhood of the Rings

The next morning, Tammy did her usual Saturday volunteer work at the Animal shelter. She found the vet working on repairing the wing of a Sea Gull.

"Someone found this bird in the mall parking lot, got hit by a car," Dr. Edwards explained. She had a thriving practice tending to people's dogs and cats, but liked to help out at the shelter evenings and weekends. The other volunteers loved her energy and knowledge. "It has a broken humerus in this left wing. Even though its humerus is just like that of a dog or cat or us, I doubt I can fix it, bird's bones are so fragile, but I'll try. You know how I love birds. He probably won't fly again. Perhaps we can send it to the zoo. How's school?"

While handing Dr. Edwards tape and gauze, Tammy told Dr. Edwards about her bio class and thinking about species. "So, if animal A can mate with B and B can mate with C, but A and C can't mate, who and what is a species? It's so confusing!"

"You know, Tammy, this gull might be able to help."

"Dr. Edwards, the gull seems to have too much on its mind to want to discuss the species concept. It'd be like discussing it with my brother. Yuk, and just as messy."

"Okay, let me explain," said Dr. Edwards as she readjusted the gull on the table. "Perhaps he'll stay still long enough to learn something too. This is an American Herring gull. It exists in the northern part of North America, all across the continent. In England and Northern Europe, there is the Herring gull. It's considered to be a different species or subspecies, but it does sometimes hybridize with the American Herring Gull in Iceland and Greenland. The English version is a lighter grey. In Alaska, the American Herring gull sometimes mates with a gull from far eastern Siberia. It's called the Vega herring gull. It's darker than the American version. In Siberia, as you head west, the Vega gull is replaced by the darker Birula's gull…"

"Let me guess," interrupted Tammy, "They can sometimes hybridize."

"Yup, and the Birula's range borders on the Heuglin's range which borders on the Siberian lesser black backed gull's range. Each one can hybridize and each species is a bit darker than the more eastern one. In Northern Europe and England we find the Lesser black backed gull, which is really dark."

"Wait, "Tammy yelled, while wiping bird droppings off her smock. The gull was now safely in a large cage. "You said the plain ole herring gull was there."

"Right, but so is the lesser black backed gull, and, these two won't mate. Seem's the color or something keeps them from mating."

"So, A won't mate with G"

"Exactly! Biologists call this a ring species. They see it as speciation in process. Perhaps the Lesser Black Backed Gull started it, spread east and lightened up as it did. Now some say this isn't a good example because there is some question about whether all the species are evolving from a common ancestor—the American herring gull may have evolved from a different set of gulls and has converged on the herring gull. Some birds can hybridize you know. But you get the idea. Genetically, all these birds are pretty similar. Actually, when I did my Master's degree I studied bird evolution. Another good example is some warblers in Asia. Oh, and there's the famous salamanders in California. Seems that species can interbreed for a while after their speciation. Did you hear about how ancestors of the chimps and ancestors of humans interbred for a while after they split up?"

"Yeah, but that was when the human and chimp ancestors were barely different. Could they have been ring species?"

"Well, I think the definition of ring species requires a bit more than that, but maybe that's how they start. Yup, evolution is interesting! And important. I just read a paper about how evolution in heart worm is interfering with medicines. But that's a discussion for another day. Hope the explanation of the gull ring species cleared some things up. Thanks for the help." Dr Edwards left to help a bulldog that had slipped on some ice.

'Yeah, it helped,' thought Tammy. 'But are those gulls A species or G species? And is species singular or plural, anyway?'

Case analysis:

1. In your Case Study Journal, create a chart with the headings:

I Know…	*I Think I Know…*	*I Want to Know…*

Think about this case and reflect back on your homework and prior learning. Make as many entries as possible in each column of the chart.

2. Discuss your list with your group. Add notes to your lists.

3. Using your textbook make sure you understand the following concepts. Record definitions and connections to the case in your journal.

Ring species
Cline
Sexual selection
Disruptive selection
Stabilizing selection
Directional selection
Divergent evolution
Convergent evolution

4. Read the brief articles at the following websites:

The Larus Gulls Circumpolar Species Ring
http://darwiniana.org/zimmergulls.htm

Ring Species (from the PBS Evolution Website)
http://www.pbs.org/wgbh/evolution/library/05/2/l_052_05.html

Evolving Before our eyes
http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2001/03/26/MN172778.DTL

Ring Species: Unusual Demonstrations of Speciation
http://www.actionbioscience.org/evolution/irwin.html

Ring Species and Clinal variation
http://darwiniana.org/rings.htm#Rings

5. Discussion questions (answer these questions in your case journal in preparation for the follow-up class discussion):

A. Why do biologists like to study ring species?

B. What would happen if a highway or shopping mall prevented the interbreeding of parts of the ring species?

C. Should members of a ring species be considered separate species, separate subspecies or just one species?

D. The expanding desert in China has broken the ring of the greenish warblers. Should the species that has lost connection to the rest now be thought of as a different species?

E. What selections are driving the evolution of the salamanders and warblers? Are these cases of sympatric or allopatric speciation?

F. The two northern (incompatible) species of warblers live in similar environments and have evolved similar traits to each other (diverging from the common southern ancestor). Doesn't speciation only occur when a species adapts to a different environment?

G. Relate your research to the "want to know" column. What questions can you now answer?

6. For more information, check out the following websites:

The Greenish Warbler Ring Species
http://www.zoology.ubc.ca/~irwin/GreenishWarblers.html

Ensatina eschscholtzi: Speciation In Progress
http://www.santarosa.edu/lifesciences2/ensatina2.htm#gradualism

Ring Species
http://www.answers.com/topic/ring-species

Levels Of Selection And Speciation Mechanisms
(scroll to section on ring species in gulls and ring species in salamanders)
http://bio.research.ucsc.edu/~barrylab/classes/animal_behavior/SPECIATE.HTM

The Auk: Overview: Circular Overlaps: Rare demonstrations of speciation.
http://www.findarticles.com/p/articles/mi_qa3793/is_200207/ai_n9133429/print

Ring Species As Bridges Between Microevolution And Speciation.
http://www.zoology.ubc.ca/~irwin/PDFs/IrwinIrwin%26Price2001.pdf

Part 3: **The Mouse That Caused the Roar**

On Sunday, Tammy and her family were having their usual Sunday breakfast at Bauer's Diner. The TV over the counter was tuned to a news channel. As usual, Sandy was working the counter; pouring coffee while loudly commenting on the news stories to the men hunched over their coffees. The news anchor was talking to a person seen in a small monitor in the upper right corner of the screen. Another person could be seen in a monitor in the lower right. Tammy heard a word that caught her attention.

"…species! I mean if they can't prove it is a different species I don't see why it should be on the list," said the person in the upper monitor.

As Tammy listened to the story she teased out some of the details. The Secretary of the Interior wanted to remove the Preble's meadow jumping mouse from the endangered species list. It is found in areas of Colorado and was interfering with construction of housing and retail developments. A biologist hired by the Interior Department had determined Preble's mouse was not that genetically different from another, more plentiful species of jumping mouse. Now, another study was contradicting that finding.

"The department and its scientists are just promoting the President's pro-development agenda! This is not how science should be done," said the person in the lower monitor.

"I don't think that any reasonable person wants to see the whales go extinct, but we are talking about a mouse that may not actually be a species. The Endangered Species Act does not protect hybrids" said the upper speaker.

"This mouse is not a hybrid. The Act protects endangered species and all subspecies of an endangered species. This mouse is either its own species or a subspecies of another…"

"…Mouse species that is not endangered and therefore should not be protected. Look at what has gone on with the Red Wolf!" the man in the upper screen interrupted.

The man in the lower corner looked frustrated, "But, it is different and part of the biodiversity! It may be an endangered species or we may be seeing speciation. It may be evolving…"

Sandy changed the channel with a stab of the clicker. "Who cares!" she said, "It's just a mouse and don't give me any of that evolving stuff!" She seemed to be yelling at a guy with a trucker hat who was stirring his coffee and looking at another waitress. "Anyway, it could only be a different species if it was created that way. One species does not become another one! And if you ask me one mouse is the same kind as another! If they can mate then they havta be the same species just the way they we created. Mice don't change over time."

"George, will you lower that!" yelled Mom.

George put down the pitcher of maple syrup he was holding high over extending tongue.

"I don't think it should matter if it is its own species," said Tammy, not sure if anyone in her family was listening. "Species boundaries are kinda real and kinda man made, but it is important that we preserve the gene pool."

"No, dear, you can't wear your jeans in the pool." said Dad as he looked up over the newspaper.

"No, I'm talking about why it shouldn't matter what species it is."

"Actually, Sis," said George, with one eye on the blonde girl wearing a shirt that said 'HERBIVORE" at the next table. "It would appear that classification and species designation is important if it can be used justify habitat destruction and promote the intelligent design agenda." George glanced over at the blonde with an arch to his right eyebrow.

Tammy opened her mouth. Dad looked up over the newspaper, and Mom cried ouch as she dropped her knife.

"Check please!" Dad called out.

That night Tammy did an internet search on Preble's meadow jumping mouse.

Case analysis:

1. In your Case Study Journal, create a chart with the headings:

I Know…	I think I know…	I want to know…..

Think about this case and reflect back on your homework and prior learning. Make as many entries as possible in each column of the chart.

2. Discuss your list with your group. Add notes to your lists.

3. Read the brief articles at the following websites:

Status Of Threatened Mouse On Trial
http://www.denverpost.com/news/ci_4021577

*Western Business Roundtable: FWS Long Past Due In Delisting Mo*use
http://www.eastvalleytribune.com/index.php?sty=68367

FAQ Preble's Meadow Jumping Mouse
http://www.voiceforthewild.org/wildspecies/news/n17dec03.html

Government Postpones Decision On Jumping Mouse Status
http://www.foxnews.com/story/0,2933,185418,00.html

Subspecies Fight For Space On Protected List (listen to news story)
http://www.npr.org/templates/story/story.php?storyId=5028780

5. Discussion questions (answer these questions in your case journal in preparation for the class discussion):

A. Why should we protect endangered species?

B. Is it more important to preserve the organisms or the genes?

C. Why is protecting subspecies and hybrids more controversial than protecting species?

D. If one member of a ring species was endangered, but other members were plentiful, should the endangered member be protected?

E. Why would those who do not believe in the evolution of species (macroevolution) have difficulty with idea of preserving of subspecies or members of a ring species?

F. Relate your research to the "want to know" column. What questions can you now answer?

6. **Written Assignment:**

Write a 5 paragraph essay in which you argue for the importance of government funding of research into evolution (especially research into phylogenetic relationships and speciation). Include three well supported arguments based in evolutionary science.

7. For more information, check out the following websites:

The Red Wolf: Is It A True Species?
http://canidae.ca/MTDNA.HTM

Arizona Agave [a hybrid] *Taken Off The Endangered Species List*
http://www.eastvalleytribune.com/index.php?sty=68367

Hybridization: The Double Edged Threat?
http://www.canids.org/PUBLICAT/CNDNEWS3/hybridiz.htm

Speciation and Biodiversity (an interview with E.O. Wilson)
http://www.actionbioscience.org/biodiversity/wilson.html

Systematics And Endangered Species Conservation

http://darwin.eeb.uconn.edu/eeb310/lecture-notes/systematics/systematics.html

Teacher notes (a.k.a., The Importance of Being Ernst):

Introduction

AP course challenges:
Teaching AP Biology is especially challenging. The students have already taken biology. Some of the students will have an excellent background while others may have a poor background. The teacher can not repeat the introductory course but has to review the basic ideas. We have to balance a review/reteaching of the basic material with processing of the big ideas, development of thinking skills and the increased detail contained in a college text. Of course there is also time pressure and the AP test. It isn't easy to teach a course that is college like to students that are still in high school even if the students are brighter and more independent than average.

Using a case study approach:
Given the challenges, different approaches should be tried. The case study approach is increasingly used in college. A case study increases independence, activates and expands thinking and discussion skills, and provides a mechanism to learn important concepts. The idea here is that the students can review, relearn, and apply concepts without having to repeat intro biology activities.

For a great deal of information on the design and use of case studies in science education, as well as many examples (designed for college students but adaptable for advanced high school students) go to the **National Center for Case Study Teaching in Science** Website:

http://ublib.buffalo.edu/libraries/projects/cases/case.html

I have tried to follow the guidelines discussed at this site, but have deviated from them in adapting to the high school student. For instance, I have used more High School humor and have more discussion questions listed than may be recommended. Teachers using this case study may prefer to remove some questions from the student handouts and use them as in class discussion questions.

This unit is highly adaptable. A teacher can choose to:

- do all of it or only parts
- remove the reading lists and have the students do their own research or treat it more like a webquest
- do a series of discussion or just a large group one
- expand on the writing assignment and have it be a longer research type paper
- See also Time Management (below)

Context for this case study within the evolution unit:
This case should follow coverage of Natural Selection and evidences for evolution (homologous structures, fossils, etc.). Topics such as Genetic drift and limits to Natural selection can precede or follow the case study. This case can be followed up with look at classification schemes and techniques (Morphological comparisons, DNA hybridization, genomics, MT-DNA). In fact, you

can select organisms mentioned in the case and compare phylogenetic trees created by molecular and morphological means.

Goals & Objectives

Overall goals:

1. Students should gain insight into the importance of classification and evolution research.
2. Students should analyze current controversies involving classification.
3. Students should evaluate the various concepts of species.
4. Students should review and apply evolutionary concepts (see key concepts list) to the problem of defining species.
5. Students should examine evolutionary concepts (see key concepts list) in light of the problem of defining species.
6. Students should further develop reasoning, discussion, analysis, writing and reading skills within a science context.
7. Students should evaluate arguments concerning the relationship among species and the importance of evolutionary research.

Key Concepts:

Species
Biological species concept
Morphological species concept
Phylogenetic species concept
Ecological species concept
Allopatric speciation
Sympatric speciation
Hybrid
Gene Flow
Gene Pool
Taxonomy
Phylogeny
Ring species
Cline
Sexual selection
Disruptive selection
Stabilizing selection
Directional selection
Divergent evolution
Convergent evolution
The stages of Natural Selection
Reproductive isolating mechanisms

National Science Standards:

BIOLOGICAL EVOLUTION

- Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring. The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.
- Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.
- The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.
- Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

Massachusetts State Frameworks:

5. Evolution and Biodiversity

Broad Concept: Evolution is the result of genetic changes that occur in constantly changing environments. Over many generations, changes in the genetic make-up of populations may affect biodiversity through speciation and extinction.

5.1 Explain how evolution is demonstrated by evidence from the fossil record, comparative anatomy, genetics, molecular biology, and examples of natural selection.

5.2 Describe species as reproductively distinct groups of organisms. Recognize that species are further classified into a hierarchical taxonomic system (kingdom, phylum, class, order, family, genus, species) based on morphological, behavioral, and molecular similarities. Describe the role that geographic isolation can play in speciation.

5.3 Explain how evolution through natural selection can result in changes in biodiversity through the increase or decrease of genetic diversity from a population.

6. Ecology

Broad Concept: Ecology is the interaction among organisms and between organisms and their environment.

6.1 Explain how birth, death, immigration, and emigration influence population size.

6.2 Analyze changes in population size and biodiversity (speciation and extinction) that result from the following: natural causes, changes in climate, human activity, and the introduction of invasive, non-native species.

Time management:
There are a number of approaches that can be taken with this case study depending on the size of the class, ability/skill level, available time, and curriculum sequence.

Only hand out one part of the case study at a time. The case should be spread out over parts of three days (or more). Of course, it is possible to do fewer than three parts.

A typical sequence for each part would be:

Students read case
Students complete the Know/Think/Want (KTL) list (analysis part 1)
Comparison of lists (small discussion (analysis parts 1, 2))
In-class or at home read articles, answer discussion questions (if in class can be done alone or in small group)
Large group discussion

If reading and discussion questions are to be done at home, the rest of class can be used for learning of related topics.

It may also be desirable to let the students find the websites on their own and only provide these lists if needed or after students have done that research.

If the class has access to the internet or class packets of the reading are handed out, and individual time on the KTL lists and discussion questions is reduced, it is possible to do each part in a class period.

If time is a problem, everything prior to the large group discussion can be done at home.

Discussion questions and class preparation

Class Discussion Format
If your class size and layout allows, arrange the students in a circle and sit as member of the circle. This allows the students to talk to each other and not just the teacher.
Begin by asking questions that get out the facts of the case and some of the key concepts. This will enable the students to discuss concrete concepts and begin in a "comfort zone". It will also provide opportunities to explain some of the key concepts (or clarify misconceptions). For example, watch for students sounding Lamarckian as they explain the evolution in the ring species. Make sure they understand the human and chimp ancestors that interbred had only recently speciated. Check for understanding of the various species concepts and reproductive mechanisms.

Using the additional readings:
I have included additional readings within the student handouts. The assigned readings come from current news and educational sources. Most of the additional readings are more technical while others are not. These readings will provide the teachers with additional background material that can be used to generate in class discussion questions. They will also provide better answers, ideas for questions, and examples than my key. However, it is not necessary to read all of them. Should a teacher wish to broaden the written assignment, these readings may be of great help to the student.

Selected discussion question answers and possible questions to use during the discussion:
My answer key really only hints at the answers. Familiarizing yourself with the additional readings will help a lot. Leading the large group discussion requires a lot of "thinking on your feet". You can anticipate some student comments and questions and you can plan some follow-up, in class questions (I offer some below). However, be prepared to ad-lib.

Part 1:
A. Consider the examples of "murky species" mentioned in the case (polar bear/grizzly, dog/coyote, Great Dane/Chihuahua). Apply each of the species concepts to these examples. Do the concepts differ in their ability to help make sense of the examples?

Review the various concepts through questions to the students.
Relate them to the various hybrid situations.
Is "species" a meaningful term in the real world or is it simply a human construct to make sense of the biodiversity?

B. Does the ability of two species to hybridize indicate anything about how recently they speciated?

Most biologists think that there is a direct connection between the time since speciation and the ability to hybridize. See *Hybridization As An Invasion Of The Genome*.
Will reproductive isolating mechanisms change over time?
Will hybrid fertility decrease over time?
Is this related to molecular clocks?

C. Should biologists decide on set number of genetic differences or morphological differences be used to decide if a two populations are different species (or subspecies)?

This is highly debated. Certainly it seems like genetics are becoming more important.
Many biologists look for evidence for shared monophyly (both mitochondrial and nuclear DNA evolving shared between species.
Which method requires more judgements?
Which method reveals information with more real world connections?
Use the Great Dane and Chihuahua case to challenge the students.

D. Are populations that speciate sympatrically more likely to be able hybridize than ones that speciate allopatrically?

Mayr emphasizes allopatric speciation while Wilson emphasizes sympatric. However, Mayr assumes hybridization is not significant (if present at all). Besides, how can species hybridize if they are in different places?

E. Does the presence of hybrids (especially fertile) mean that there is no species barrier?

It indicates an incomplete, not fully established barrier.

F. Can new species be created by hybridization?

Not in animals, but a plant hybrid that then reproduces asexually can.

Why is this more possible in plants than in animals?

H. Do you think this is an important issue?

It would not surprise me if most students think that deciding what is (or isn't a species) is not terribly important.

Isn't important to know if human and chimp ancestors mated?

You can do some foreshadowing of part 3.

Part 2:

A. Why do biologists like to study ring species?

They see ring species as speciation in action, the formation of incipient species.

Relate ring species to cline. In a cline we have a single species that exhibits variation based on shifting environmental conditions. Isn't that happening in a ring species?

B. What would happen if a highway or shopping mall prevented the interbreeding of parts of the ring species?

Given time we might expect the barrier to create an allopatric speciation condition.

Can you explain how allopatric speciation takes place?

Examples?

C. Should members of a ring species be considered separate species, separate subspecies or just one species?

It seems some are considered different species, others are subspecies.

Review the classification systems given in the example ring species.

Discuss Lumpers vs. Splitters in classification

D. The expanding desert in China has broken the ring of the greenish warblers. Should the species that has lost connection to the rest now be thought of as a different species?

Irwin seems to think not. Sibley's classification system does designate a separate species.

E. What selections are driving the evolution of the salamanders and warblers? Are these cases of sympatric or allopatric speciation?

Sympatric.

What is the selection pressure at work in the warbler case?

What is the selection pressure at work in the salamander case?

What is sexual selection?

Does resource partitioning and competitive exclusion apply here?

G. The two northern (incompatible) species of warblers live in similar environments and have evolved similar traits to each other (diverging from the common southern ancestor). Doesn't speciation only occur when a species adapts to a different environment?

This is similar to the salamanders. The same selection pressures are selecting for similar traits but since the two populations are evolving in a parallel fashion. The environment is somewhat different than the original range. They are diverging from that original population.

What is parallel evolution (contrast with divergent, convergent)?

Are we seeing disruptive, directional or stabilizing selection?

Part 3:

A. Why should we protect endangered species?

Stability of ecosystem. Preservation of genes that may be useful later (proteins for medicine or resistance to disease in domestic species). Ethics.

Expect some students to only care about furry species or those that are beneficial to us.

This question can take much time so move on after opinions are given.

B. Is it more important to preserve the organisms or the genes?

See above.

C. Why is protecting subspecies and hybrids more controversial than protecting species?

Many are against the Endangered Species Act because it prevents development. The ESA does not protect hybrids as they are not considered species. The ESA does protect all subspecies of a protected species, however, it does not necessarily protect subspecies of unprotected species even if that subspecies is rare. A species has to have had separate "creation" (not kidding!) to be recognized as a species. The debate over the Preble's mouse is whether it is a rare species or a variant of a plentiful species.

Should this influence species designation? If you wanted to preserve the mouse, would you designate it as a species even if the science indicated otherwise?

Does the lack of agreement about the definition of species make this more possible?

D. If one member of a ring species was endangered, but other members were plentiful, should the endangered member be protected?

See above and below. Ring species offer biologists a chance to observe speciation happening. Those against the ESA or the plausibility of evolution disagree.

E. Why would those who do not believe in the evolution of species (macroevolution) have difficulty with idea of preserving of subspecies or members of a ring species?

Those who believe in creation or intelligent design see subspecies as an impossibility. They are just variants of the species that was created. They see subspecies as a population on the way to becoming a separate species (as do biologists) and therefore impossible. Biologists see them as an important way to observe speciation.

How does the ID/creationist concept of biologist differ from that of biologists?

Should biologists try to reach a consensus on the meaning of species?

Should biologists be comfortable with some ambiguity and disagreement?

Is it possible that species will mean something different for various taxa (mammals, birds, insects, plant, protists, prokaryotes)?

Assessment:

The teacher may choose to assess each part of the case study process or just one or two aspects. I have divided assessment into three areas and offer standards for each. Since many teachers and schools have established rubrics for discussions and essay writing, I'll leave rubric writing and weighting of each section to the user:

Research and case journal:

Look for evidence of making connections to the concepts and prior learning. It is the definitions of the terms and their connections to the case that will help the students on the AP exam. The questions that the students ask should show evidence of higher thinking skills. Answers to the discussion questions may be fully developed or written as notes at the teacher's preference; however concept vocabulary should be used and applied correctly. Students should not leave assigned discussion questions blank.

Large group discussion:

Students should contribute expository answers, questions about basic concepts, as well as higher thinking/opinion answers and questions. Look for risk taking and attempts to make connections between the case and concepts. Students should talk to each other and not just to the teacher. Students should treat each other respectfully and not interrupt or make others feel bad.

Written Assessment:

Alternate writing topics could be:

A letter making the case (or not) for a meeting devoted to deciding on a definition of species.

An essay on what the students thinks should be a definition of species. This could involve reading of some of the additional readings.

An essay defending the endangered status for the Preble's mouse or some other species.

Look for a clear thesis statement, supporting arguments and supporting details based in the science concepts. All vocabulary should be defined. Examples from the case should be used. Extra credit (or consideration) could be given for evidence of reading the addition resources. Soft writing in which the student gives opinions based on feelings, lacking scientific support, lacking connection to the case, or merely restating points made during the discussion should be discounted.