Appendix

Problem Set Answers

Session 1. What Is Life?

1. Pick two objects: a living thing and its nonliving model (e.g., a bear and a stuffed teddy bear, a rose and a silk rose). How could you use scientific criteria to convince someone that one object is living and the other isn't?

   Any pair of objects can be observed for a number of the five characteristics of life identified in the video—depending on the tools one has available. In many cases, the easiest way to distinguish between the two examples would be "response to environment"—change something and watch to see which object reacts. If you could observe both over a long period of time, one or more aspects of a lifespan (i.e., growth, reproduction, etc.) could be observed for one but not the other. Probably the best way to distinguish between the two would be to provide food and/or water—energy and matter—and to see which object uses it. If you had a microscope handy, you could check for cells. Probably the only thing that would be difficult to check for without sophisticated equipment is DNA.

2. Of the characteristics of life explored in the video, which do you think are *most* distinctive of living things? Explain your reasoning.

   One could argue for either cells or DNA—since each is so unique to the living world. But of the two, DNA is possibly the most distinctive and, besides, it contains information to *build* cells. In this way, DNA can be said to be behind all of the characteristics of life. It's a molecule that contains coded information that builds the next generation AND passes itself along—this is truly unique. Even something that seems to "make more" of itself (e.g., crystals, fire, clouds) is not propagated in a comparable way.

3. How would you know if something you observed under a microscope were a cell?

   A cell would be observed to have a boundary—a cell membrane, perhaps surrounded by a cell wall—that separates its interior from the exterior environment. A nucleus might also be observed, and maybe other cell parts, depending on the strength of the microscope and the type of cell. It's not uncommon to mistake debris or air bubbles for cells when you're first starting out, so it's important to have clean slides, clean lenses, and reliable specimens.

4. Suppose you took a walk in the woods one day and found a strange object that you couldn't identify. What would you do to try to find out if it was a living thing? Would it make a difference if it was a plant or an animal? Why?

   First, see if it responds to a stimulus—does it move away, shrink or expand, etc. Next, try to offer it food and water, to see if it takes any materials in. Barring any response, one might search for cells. If this weren't conclusive, observation over a long period of time might reveal growth, development, or reproduction. The same approach could be used whether it was an animal or plant—but conclusive results would probably occur more quickly if it were an animal because of its need for food or water

Session 2. Classifying Living Things

1. In Session 2, you were introduced to a system for classifying life into broad groups based on cell features. Describe the details of this system. Which feature(s), if any, seem most useful in classifying living things? Explain your answer.

   The system used in the video applies to the broadest groupings used by life scientists: the domain and kingdom. It involves asking a set of four questions. The four answers, combined, determine how an organism is classified. The questions are:

   - How many cells is it made of?

Problem Set Answers, cont'd.

- Is a nucleus present?
- Is a cell wall present?
- How is energy obtained?

The question that is perhaps the most basic is whether or not a nucleus is present. "No" directs you to a choice of two domains (the Bacteria or Archaea), where it would be necessary to know which type of cell wall was present in order to go further. This is because members of both domains are unicellular, have cell walls, and either make or absorb food. "Yes" directs you to the domain Eukarya, where the next most useful question involves the number of cells. If it's unicellular, it's *probably* a protist (although some protists—the algae—are multicellular and some fungi—the yeasts—are unicellular). If it's multicellular, the next most useful question is about energy. If it makes food, it's a plant. If it ingests food, it's an animal. If it absorbs food, it's a fungus. No single feature is the most useful—with this system, at least two features need to be identified.

2. Most life scientists would agree that a biological classification system that represents evolutionary relationships among life forms is the most useful. In such a scheme, the more characteristics shared by two groups, the more closely related they are and the closer they are to a common ancestor. Develop an argument that supports the claim that fungi are more closely related to plants than they are to animals. Develop the opposite argument. Which argument do you favor?

   Both plants and fungi have similar growth habits—they are stationary with structures that anchor them to their substrate and they project parts above their substrate. They both have cell walls, which gives them rigidity—although their cell walls are made of very different substances. Like animals, however, fungi *cannot* produce their own food and must take it in from living resources. They don't ingest it like animals, however, they absorb it.

   A common argument is that fungi are more closely related to plants than to animals because they share more characteristics and look more alike—the cell wall and growth habits, for example. Recent work in analyzing DNA, however, may prove the opposite to be true.

3. Imagine that you can see life at different levels of organization: macroscopic (organismal level), microscopic (cell level), and molecular (the level of molecules and atoms). At the molecular level inside a plant cell, what might you see? At the microscopic level? At the macroscopic level? How would this compare to an animal?

Level of organization	**Plant**	**Animal**
molecular	CO_2 and H_2O being taken in and sugar being formed with O_2 being released; O_2 being taken in and "burning" food and CO_2 being released; proteins, carbohydrates, lipids, DNA, and H_20	O_2 being taken in and "burning" food and CO_2 being released; proteins, carbohydrates, lipids, DNA, and H_20
microscopic	Many cells, nucleus, cell wall, cell membrane, organelles	Many cells, nucleus, cell membrane, organelles
macroscopic	Stationary organism, green, with leaves, stem, and roots	Moving organism, not green, with structures for moving and sensing*

* It should be noted that not ALL animals move or have well-developed senses and some even have growth habits like plants.

Problem Set Answers, cont'd.

4. In the video, you saw life thriving in some of the deepest parts of the ocean. Which domains do you expect to find represented in this environment? Which kingdoms? Explain your reasoning.

   It is reasonable to expect to find organisms from all domains present: Bacteria, Archaea, and Eukarya. These are the most basic and ancient groupings, and it is sensible to believe that at least some representatives of each group have evolved to live in this environment at some point over the past four billion or so years. This would seem to be particularly true of the Bacteria and Archaea, as these groups are ubiquitous in almost all environments. The Archaea, in particular, are noted for living in extreme environments. Within the Eukarya, one might expect to find representatives from all kingdoms *except* the plant kingdom as well as any plant-like protists. Plants are classified by their ability to photosynthesize—they use the Sun's energy to make food. There is no Sun at the bottom of the ocean!

   Note that the above prediction is supported by evidence from deep-sea research. The Bacteria and Archaea are currently found to be the most abundant and diverse.

Session 3. Animal Life Cycles

1. "Offspring resemble their parents." This is a simple way of summarizing the outcome of reproduction in the living world. Yet this is profoundly significant. Life has evolved a way of ensuring that like begets like. Discuss why this is significant. Then, discuss what you think is most important in ensuring the continuity of life and the millions of life forms on Earth today.

   If there were not a way for a parent generation to produce offspring that were like themselves, offspring would face the likelihood of not being adapted to their environment, which might threaten survival to reproductive age. Put another way, the parent generation must be made of "the right stuff" if they made it far enough to reproduce, so keeping the same features in the offspring is a "safer bet" than producing offspring with untested features. Continuity of life *without* continuity of life forms would mean that each generation would be a new experiment, which would probably fail.

   The ability of DNA to both carry information and reproduce it reliably could be argued to be the most important factor in ensuring the continuity of life *and* life forms.

2. Part of a life cycle involves growth and development—processes that involve reproduction at the level of cells. In animals (and other multicellular organisms), this is very different from reproduction at the level of populations. In each case, a distinct cell process is involved. For more information about these cell processes, visit our Web site (A Closer Look: Body Cell Reproduction, Sex Cell Production). Compare and contrast these two processes.

   - What is the role of each process in a life cycle?
   - Where does each process occur?
   - How many cell divisions are involved?
   - What happens to the chromosomes?
   - How many cells result?
   - How many chromosomes are in each cell that results?
   - What is the significance of this?

Problem Set Answers, cont'd.

	Body cell reproduction	Sex cell reproduction
Role in life cycle	Growth and maintenance	Reproduction
Where process occurs	Cells in all parts of body	Sex organs or tissues
Number of cell divisions	One	Two
What happens to chromosomes	All chromosomes line up singly, each chromosome replicates, the two copies separate, and one copy of each chromosome is distributed to each daughter cell	First division: chromosomes duplicate and copies remain attached, chromosome pairs line up alongside each other, the members of each pair separate, one member of each pair goes to each daughter cell. Second division: all chromosomes line up singly, the two copies separate, one copy of each chromosome is distributed to each daughter cell.
Number of cells that result	Two	Four
Number of chromosomes in resulting cells	Same number as in parent cell	Half the number as in parent cell
Significance	Genome is maintained; all information is passed along	Genome is halved; will be restored at fertilization

3. "Egg" is a word that has several meanings—both familiar and scientific. How do you define what an egg is? Visit our Web site and read about eggs (A Closer Look: The Incredible Egg). How are these different meanings for "egg" connected to an animal life cycle? How do the eggs of different groups of animals reflect adaptation to their environment?

   Life scientists define an egg as being the sex cell produced by a female—called the female gamete. It is a living cell that carries half of the genome of the female parent. With a few exceptions, it can't survive long under natural conditions without the other half. Once united with the other half—provided by sperm—it becomes a fertilized egg—called a zygote. Given the appropriate environment, this one cell, containing the whole genome, can develop into an adult. But there is no sensible alternative for the term "egg" when referring to a supermarket egg, so unless you use the scientific terms "gamete" and zygote" in your daily language, the distinction can remain unclear. Nonetheless, both supermarket and other eggs are the structures that house and support a developing embryo, which is formed as the fertilized egg begins to divide.

   The different features of eggs reflect "solutions" to "problems" caused by the environment in which an embryo develops. The main differences have to do with whether they are produced by aquatic or terrestrial organisms. On land, eggs provide a structure that protects the embryo from drying out, while still allowing gas exchange. Examples include reptiles, birds, and many insects. In water, this type of egg isn't necessary. Fish and amphibians have jelly-like eggs, which are adapted to a watery environment. Mammals have eggs unlike either—their young develop internally.

Problem Set Answers, cont'd.

4. In the video, Dr. Sigal Klipstein describes the process of cloning—a process that has been described as "bypassing the normal life cycle". What *is* a clone? How is cloning accomplished? Compare and contrast cloning to sexual reproduction. What parts of a "normal life cycle" are bypassed? Visit our Web site to learn more about cloning (A Closer Look: Cloning).

   A clone is an organism that is an identical copy of a single parent. In order to clone an organism, one of its body cells, containing a full set of chromosomes, is placed into an egg that has had its chromosomes removed. The egg and cell are induced to fuse together, usually by applying an electric current, and cell division commences. This cell develops as an embryo would, eventually becoming one offspring. In cloning, there is thus only one parent, and only one source of hereditary information.

   In sexual reproduction, there are two parents, each forming sex cells that provide exactly half of the information needed to form an offspring. The hereditary information provided by each parent will differ for many traits, so variability is possible in the resulting offspring. Cloning bypasses this aspect of sexual reproduction—the formation of sex cells from two different parents and the joining of sex cells to produce variable offspring.

Session 4. Plant Life Cycles

1. In Session 3, the role of DNA in an animal life cycle was introduced. The idea that the genome must be maintained between parent and offspring generation during sexual reproduction was also introduced. Animals and plants are no different in this regard. Apply your understandings of DNA and sexual reproduction to the flowering plant life cycle. What is the role of DNA? How is the genome maintained?

   In flowering plants, part of the female reproductive structure—the ovary—generates female spores, which produce eggs that contain half of the genome (one member of each chromosome pair). The male structure—the stamen—generates pollen, which produces sperm that also contains half of the genome. The genome is maintained when sperm fertilize eggs, bringing the members of each chromosome pair back together. The role of DNA, half of which is contributed by each parent, is to provide the information that results in the offspring. This is exactly the same as what occurs with animals.

2. Distinguish between pollination and fertilization. Identify the specific structures that are involved in each and describe the details of each process in a flowering plant.

   Pollination occurs when pollen produced by the male reproductive structure of one plant lands on the female reproductive structure of another. A "pollen tube," carrying sperm, begins to grow toward the ovary. Once it reaches the ovary, it penetrates it and delivers the sperm. Fertilization occurs when sperm join with eggs inside the ovary. Each fertilized egg has the potential of developing into a seed.

3. Dr. Judith Sumner noted that plants have a challenge in completing a life cycle that animals don't. What is this challenge? How have plants evolved to "get around" this challenge? Give specific examples.

   The two big hurdles in plant life cycles both result from plants' immobile nature. They can't move around to find mates, and their offspring can't move away from their parents to find a suitable environment for living on their own. In the first case, plants have evolved ways to use insects (like bees) and other animals (like hummingbirds) to help move their pollen from one plant to another. They've also evolved to use wind to aid in pollination. Animals, wind, and even water are used to help disperse fruit and seeds. Pollination and dispersal of offspring are both "weak points" in plant life cycles, and plants have evolved a variety of strategies that enhance their reproductive efficiency.

Problem Set Answers, cont'd.

4. Flowering plants are only one group within the plant kingdom. How are all plant life cycles alike? How are they different?

   Other major groups of plants include mosses, ferns and their relatives, and conifers. All of these groups are similar to flowering plants in that they reproduce sexually—that is, they produce sperm and egg that unite to form offspring. All of these groups also have life cycles that are characterized by alternation of generations. That is, there are two generations of "adults" in the life cycle. One generation (we'll call this A) produces the other (usually much smaller) and this generation (we'll call this B) produces the sex cells. When the sex cells unite, the first generation (generation A) is formed again—thus the alternation of generations.

   In addition to having appearances that distinguish each group, the different plant groups vary in other ways. Flowering plants and conifers produce seeds—an adaptation to life on land. Mosses and ferns don't produce seeds—their life cycles depend on nearby water for fertilization and early development.

   These plant groups also differ with regard to alternation of generations. Ferns, for example, produce spores that grow into generation B. Generation B is independent of generation A (it is released and grows on its own) and produces both types of sex cells. Flowering plants produce two types of spores in generation B: male spores (also called pollen) and female spores. The male spores—which are released from generation A—produce sperm. The female spores—which grow within generation A—produce eggs.

   It's at first quite complicated, but rather fascinating, and truly a way that plants and animals differ.

Session 5. Variation, Adaptation, and Natural Selection

1. The human population is remarkably variable. Pick a characteristic that varies among humans. Describe how individuals vary. How might genes play a role in this variation? If you observed an individual that varied in a way you had never seen before, what might be true about this individual?

   Many human traits vary among individuals—hair, eye, and skin color are a just few. Traits may vary in "continuous" ways—like height—or "discrete" ways—like the ability to taste PTC or not. While the environment may affect the extent to which a trait is expressed, genes code for traits. If traits are seen to vary, the information in each individual's genes probably varies. If an individual varied in a way never seen before—say, purple eyes—it would be reasonable to suppose that one or more genes responsible for eye color had mutated.

2. Distinguish between adaptation, natural selection, and evolution.

   Evolution is the process by which populations change over time. Evolution is accounted for by natural selection. Natural selection occurs as individuals with traits that are best suited for a particular environment survive to produce more offspring than those without those traits. Nature thus "selects" the traits that survive, and over many generations, these traits become more common in the population. Given a change in the environment, a population becomes better suited to its environment—this is what is meant by adaptation. Traits themselves are often called adaptations, but they are what *result* from the process.

Problem Set Answers, cont'd.

3. Mutations in genes are one source of new variation in a population. Mutations are actually rather common—some are harmful, some are neutral, and some are helpful. While a mutation may affect the individual in which it occurs, it may NOT affect that individual's offspring. Why? In order for a mutation to play a role in the evolution of a population, what must be true?

   In order for a mutation to play a role in the evolution of a population, it must occur in genes that are passed from parent to offspring. In sexually reproducing organisms, the mutated gene must therefore be present in one of the sex cells since these are the only cells that link parent to offspring.

4. The inheritance of acquired characteristics (Lamarck) and natural selection (Darwin) both account for change in a population over time. Compare these two theories, and explain why the former was eventually discarded.

   The inheritance of acquired characteristics proposes that traits acquired during an individual's life span can be passed to offspring. The acquired traits involve the use or disuse of body structures or functions, and variation in a population is the result of this use or disuse. Natural selection assumes that variation in traits *already exists* in a population—that is, individuals inherit these traits from their parents rather than develop them during their life span. Individuals pass the variations they have to their offspring regardless of use or disuse. Natural selection eventually prevailed as the theory to account for evolution because of the wealth of evidence that acquired traits could not be passed on to offspring. **Note:** Lamarck and Darwin developed their theories before the scientific community had discovered the nature and role of genes.

Session 6. Evolution and the Tree of Life

1. In the video, P.J. and Michael remark that they think it's possible for a tiger and a lion to produce offspring, but not a frog and a human. What do you think their reasoning is? Think of two forms of evidence that might convince them that their ideas are inaccurate.

   P.J. and Michael may think that it would be possible for a tiger and lion to mate (and thus produce offspring) because they are similar physically, whereas a frog and human are much less so. They may also think that the likelihood of being able to produce offspring together is possible between closely related life forms, but not between those that are distantly related.

   Evidence that this is inaccurate might be the fact that this never happens in the wild—there are NO "crossbreeds" that we know of—even though populations mix freely. Lab evidence from attempts to crossbreed could also be shown as being unsuccessful.

   Note: Although there are some species that can crossbreed in this way (a horse and a donkey produce a mule; a whale and a dolphin produce a wholphin), the majority of sexually reproducing species have "built-in" barriers that prevent this from happening. These barriers may be physical (e.g., they physically can't mate), chemical (e.g., invading sperm are killed), or behavioral (e.g., they attack members of other species). And, even organisms that can crossbreed generally produce offspring that are sterile.

2. Reproductive isolation—resulting in the inability of two species to interbreed—is considered to be a condition for the evolution of new species.

   - What caused reproductive isolation in the case of Darwin's finches?

   The distance between different Galapagos Islands contributed to reproductive isolation because the different populations that colonized them no longer interbred.

Problem Set Answers, cont'd.

- What are some other ways that a population might become reproductively isolated from an originating population?

The most common cause of reproductive isolation is geographic isolation—a physical barrier separates one part of a population from another. Isolation can also happen if different parts of a population begin to use different resources within the same habitat.

- Why does the concept of reproductive isolation break down in species that reproduce asexually?

In asexually reproducing species, individuals do not reproduce together, so the criteria of reproductive isolation for distinguishing between species cannot apply.

Note: This doesn't mean that a population of asexually reproducing species cannot evolve into two different species if subsets of the population become isolated from one another. They *can* become different enough genetically to be considered different species.

- What other forms of evidence might be useful to distinguish among asexually reproducing species?

One of the best forms of evidence for distinguishing between asexually reproducing species—especially microbes that cannot be distinguished by physical features—is comparison of DNA. Two populations are designated as different species if their DNA is significantly different.

3. Using DNA, human beings have been estimated to be "98% gorilla" and "97% chimpanzee."

- What does this mean in terms of relatedness?

This means that human beings are more closely related to gorillas than they are to chimpanzees. 98% of our DNA is essentially the same as that of a gorilla.

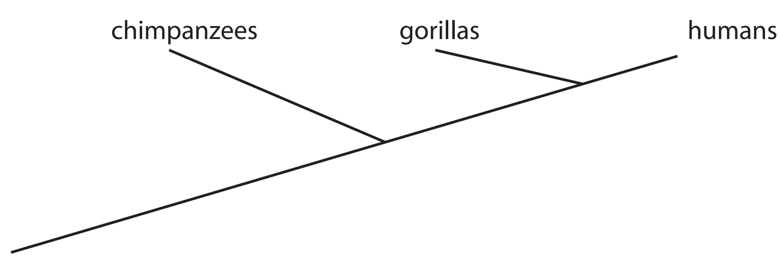
- What does this mean in terms of common ancestors?

Human beings and gorillas share a more recent common ancestor than humans and gorillas do with chimpanzees.

- How could the evolution of these three life forms be described?

A common ancestor gave rise to two lineages: one that includes chimpanzees, and another that includes a common ancestor that gave rise to a lineage of gorillas and a lineage of human beings.

- How would you draw the branches on a tree of life to depict evolution of humans, gorillas, and chimpanzees?



Problem Set Answers, cont'd.

4. Near the end of the video, Dr. Zook remarks that evolution occurs in a tree-like manner and that this contrasts with a ladder-like view, where one group of organisms replaces another. Dr. Grisham comments that there is no one species or lineage at the "top" of the tree of life and that life forms that arose earlier weren't replaced by those arising more recently. How does a tree of life demonstrate these ideas?

   In a tree of life, different lineages branch from points that represent a common ancestor. The lineages continue to the top of the tree, with the tips of the branches representing modern species. This shows that species that emerged earlier in time continued to evolve and weren't replaced by those that arose later. Both ancient and very recent lineages can be seen to have representatives at the top of the tree.

   Note: Evidence supports the claim that 99.9 % of all species that ever lived have gone extinct. If a tree of life depicted this, only .01 % of its branches would end at the top of the tree. 99.9 % of the branches would end "inside" the tree.

Session 7. Energy Flow in Communities

1. Photosynthesis and cell respiration are often considered "complementary" processes with regard to energy flow. Write the chemical equations for these two processes and discuss whether or not this is an appropriate description.

   Photosynthesis: $CO_2 + H_2O \rightarrow CH_2O + O_2$

   Cell respiration: $CH_2O + O_2 \rightarrow CO_2 + H_2O$

   These two equations are essentially the "reverse" of one another in terms of their chemical inputs and outputs. In particular, sugar, which is the fundamental energy ingredient for life, is the output of the first, and the input of the second. In terms of energy, however, these equations are not exact opposites. Light energy is an input in photosynthesis, but it is not an output of cell respiration. In the same sense, energy released from sugar and heat energy is an output of cell respiration but not an input in photosynthesis. In this sense, it is important to note that the energy itself is not reusable—it changes form and is eventually "lost" as heat.

2. In the video, Dr. Ellison demonstrates how energy flow applies to plants. In doing so, he describes a two-stage process. How does each stage work? When does each stage occur?

   Dr. Ellison describes the first stage, photosynthesis, as being the capture of light energy from the Sun and its conversion to chemical energy in the form of sugar. The second stage involves cell respiration, where sugar is "burned" as food, which makes its energy available to fuel life processes. Photosynthesis occurs in the presence of light; cell reproduction occurs continuously.

3. In creating your community poster, you included a food chain composed of four links. Dr. Les Kaufman talked about food chains that can be six links long. What would have to be true about a community where food chains are this long?

   At each link in a food chain, most of the energy transferred in is "lost" as heat. At some point, there is not enough energy to support another link. In order for there to be food chains with six (vs. four) links, there may be more energy entering and being stored by the producers.

   Note: Food chains can also be longer if the links are made of organisms that are more "energy efficient" (e.g., they produce less heat). Cold-blooded animals, for example, produce less heat than warm-blooded animals.

Problem Set Answers, cont'd.

4. In Melissa Minnick's classroom, the students discuss a dead anole and claim that the microbes that decompose it will return raw materials to the soil. Do these raw materials represent a source of energy that can continue to sustain the community? Why or why not?

   The raw materials that enter the soil do not represent an energy source that can be used to sustain the community. Beginning with the producers, the type of energy that life requires is stored in organic molecules—most notably, sugar. The raw materials that result from microbial decomposition are inorganic in nature and aren't food.

Session 8. Material Cycles in Ecosystems

1. As with energy, photosynthesis and cell respiration are often considered "complementary" processes with regard to material cycling. Write the chemical equations for these two processes and discuss whether or not this is an appropriate description.

   Photosynthesis: $CO_2 + H_2O \rightarrow CH_2O + O_2$

   Cell respiration: $CH_2O + O_2 \rightarrow CO_2 + H_2O$

   These two equations are essentially the "reverse" of one another in terms of their chemical inputs and outputs. In this way, they demonstrate the principle of the conservation of matter—the same number of carbon atoms are input and output in photosynthesis, as they are in cell respiration. Unlike energy flow, these two processes are "exact opposites" in terms of material cycling. The output of one becomes the input of the other, which results in an ongoing cycle.

2. Producers are sometimes said to be the key players in energy flow—in fact, without them, there would be no energy flow. Which populations are the key players in material cycling? Explain your answer.

   Producers do play a key role in material cycling, because they convert nonliving (inorganic) matter into living (organic) matter. But it is the decomposers that are arguably the key players in material cycling. Without them, the organic matter in wastes and dead bodies would "pile up." Decomposers convert living matter back into nonliving matter, which can be used again.

3. In Session 8, we focused upon two elements that are part of the SPONCH CaFe. What about the other elements? What do all cycles have in common? How do they differ? Support your answer by giving an example.

   All material cycles involve the exchange of matter between the living and nonliving environment. The elements involved shift from being in organic and inorganic molecules. Different elements take different pathways as they cycle. Some (like Carbon and Nitrogen) are part of atmospheric cycles. Others (like Phosphorous and Sulfer) are part of sedimentary cycles. Phosphorus, for example, dissolves from rocks and is taken in by producers, where it's then passed along food chains. The decomposers return the phosphorus in wastes or dead bodies to soil and water in an inorganic form.

4. At the beginning of the video, Dr. Grisham points out that studies of ecosystems involve the study of life at the "extremes" of its levels of organization. How does material cycling illustrate this?

   Material cycles are processes that occur in ecosystems—both the nonliving and living environments are involved. Yet, the materials being cycled are atoms that shift from being in inorganic to organic molecules and back. The processes that are responsible take place inside cells. But organisms in different populations are involved in the food chains through which matter is transferred. So it is entirely accurate to say that material cycles involve life at both "extremes" of its levels of organization.

Action Research Guide

The Action Research Process

Identify your starting point for research

↓

Refine your thinking

↓

Formulate a research question

↓ ↑

Develop and implement strategies for action

↓ ↑

Collect and analyze data

↓ ↑

Reflect on action

↓

Generate practical knowledge

One of the primary reasons for doing action research is to generate knowledge that can inform classroom practice. Your research for the *Life Science* course should focus on some aspect of science teaching and learning in your classroom. Issues involving content, pedagogy, assessment, management, or using children's ideas are all possibilities for productive research. The following is an outline of stages of action research tailored for a 15-week graduate-level course. Refer to the list of readings related to action research that follows for more information.

Weeks 1–3: Identify Your Starting Point

Begin your action research by reflecting on your current practice and identifying an area of special interest to you. Ask yourself these questions to organize your thinking:

- What science content presents problems for my students?
- Which pedagogical approaches help or hinder me in addressing children's science ideas?
- How do I use assessment to guide my science teaching?
- Which educational situations make teaching science content difficult for me?
- What strengths related to addressing children's ideas would I like to develop?

Gather preliminary data through classroom observations and note taking. Your notes should include detailed descriptions and interpretations, explanatory comments, summaries of conversations, hunches, and insights. Reflect on your role within your area of interest to help you think about alternative courses of action.

Think about your current situation and one that would represent improvement. This can help you understand the sources of problems that your action research will address.

Action Research Guide, cont'd.

Weeks 4–5: Refine Your Thinking

Phrase a preliminary research question that has emerged from a review of your notes. Think about what possible action you could take to better understand this question as well as aspects of your classroom practice you could change to better address issues raised by your question. Collect additional information and reflect on how this knowledge will impact your research question. Revisit and adjust the research question you phrased earlier to reflect any changes in thinking.

Week 6: Formulate a Research Question

Reconstruct your research question into a question with two variables in mind—a strategy and an outcome—to help you be more specific about your research and to make it more focused and manageable. Formulating and refining your research question, developing and implementing your chosen strategy, and collecting and analyzing data during the research process are all ongoing and simultaneous processes. After formulating a question and developing an action strategy, you will implement your chosen strategy. However, as you collect and analyze your data, your analysis may imply that a change in question or action strategy is necessary. This cycle may occur several times as your research progresses through the next seven weeks. Reflection on action should be ongoing throughout the entire process.

Week 7: Develop Strategies for Action

Identify several possible strategies for action ranging from radical changes in pedagogy to slight behavior modifications. Determine what kinds of data to collect that are appropriate to your question.

Week 8: Implement Strategies for Action and Begin Collecting Data

Begin to implement your chosen strategy and collect the appropriate data.

Weeks 9–12: Refine Action, Continue Data Collection, and Begin Data Analysis

Begin to interpret and draw conclusions from your data about the success of your strategy for action. Writing data summaries after reviewing sections of your data is an effective method for organizing and informing your analysis. Check the validity of your perceptions of your progress by establishing a consensus view of the results. You might interview students, ask a neutral party to observe your class, or choose a colleague to be a "critical friend." Consider the reliability of the data you are collecting. If you come across data that substantiates an important finding for your research, search the rest of the data for conflicting evidence that could refute the finding. It is important that you are open to data that both questions and supports your hypothesis.

Begin a theoretical analysis to take your data analysis to another level. After reviewing a section of your data, try writing a summary in which you identify and interpret themes, contradictions, relationships, and different perspectives that are represented in the data. Developing these ideas can lead to establishing practical theories about teaching.

Week 13: Conclude Strategy Implementation and Continue Data Analysis

Draw the implementation of your chosen strategy to a close. Begin to organize information about your methods of data collection and analysis and bring your interpretations of the meaning of your data to some kind of conclusion.

Week 14: Generate Practical Knowledge

Draw conclusions from the activity of your research. Begin to work on organizing a research report that should minimally include an introduction that explains the context of the research and the research question, a description of methods of data collection and data analysis, results of the data analysis, conclusions you have drawn from the study, and the implications of your findings for your teaching.

Week 15: Generate Practical Knowledge

Complete the research report.

Action Research Guide, cont'd.

Readings on Action Research

The following resources will provide you with additional guidance to conduct your action research project:

Altrichter, H., Posh, P., and Somekh, B. (1993). *Teachers Investigate Their Work: An Introduction to Methods of Action Research*. NY: Routledge.

Hubbard, R. and Power, B. (1993). *The Art of Classroom Inquiry*. Portsmouth, NH: Heinemann.

If neither of those resources is available, choose any of the following readings:

Bogdan, R. and Biklen, S. (1998). *Qualitative Research in Education. An Introduction to Theory and Methods.* Third Edition. Needham Heights, MA: Allyn & Bacon.

Burgess, R.G. (1981). "Keeping a Research Diary." *Cambridge Journal of Education,* 11, 1, 75-83.

Denzin, N. and Lincoln, Y. (Eds.). *Handbook of Qualitative Research*. Thousand Oaks, CA: Sage Publications.

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Kemmis, S. and McTaggart, R. (Eds.). (1988). *The Action Research Planner*. B.C. Canada: Deakin University Press.

LeCompte, D. (2000). "Analyzing Qualitative Data." *Theory Into Practice;* 39(3), 146 - 154.

McNiff, J. (2003). "Action Research in the Classroom: Notes for a Seminar." Available at http://www.leeds.ac.uk.educol/documents/00002397.htm.

Oberg, A. (1990). "Methods and Meanings in Action Research: The Action Research Journal." *Theory Into Practice,* 29(3), 214 - 221.

Schon, D. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.

Scott, P. and Driver, R. (1998). "Learning About Science Teaching: Perspectives From an Action Research Project." In Fraser, B.J. and Tobin, K.G. (Eds.) *International Handbook of Science Education*. London: Kluwer Academic.

Simpson, M. and Tuson, J. (1995). "Using Observations in Small-Scale Research: A Beginner's Guide." Eric Clearinghouse Document ED394991.

Spiegel, S., Collins, A., and Lappert, J. (Eds.). (1995). "Action Research: Perspectives From Teachers' Classrooms." Tallahassee, FL: SERVE Eisenhower Consortium for Mathematics and Science Education.

Related Readings List

Aram, R. and Bradshaw, B. (2001). "How Do Children Know What They Know?" *Science and Children,* 39(2), 29-33.

Barker, M. and Carr, M. (1989). "Teaching and Learning About Photosynthesis." *International Journal of Science Education,* 11(1), 48-56.

Barman, C., et al. (2000). "Students' Ideas About Animals: Results for a National Study." *Science and Children,* 38(1), 42-47.

Bishop, B. and Anderson, C. (1990). "Student Conceptions of Natural Selection and Its Role in Evolution." *Journal of Research in Science Teaching,* 27(5), 415-427.

Braund, M. (1991). "Children's Ideas in Classifying Animals." *Journal of Biological Education,* 25(2), 103-110.

Brumby, M. (1979). "Problems in Learning the Concept of Natural Selection." *Journal of Biological Education,* 13(2), 119-122.

Brumby, M. (1982). "Students' Conceptions of the Life Concept." *Science Education,* 66: 613-622.

Carey, S. (1985). *Conceptual Change in Childhood.* Cambridge, MA: The MIT Press.

Deadman, J. and Kelly, P. (1978). "What Do Secondary School Boys Understand About Evolution and Heredity Before They Are Taught the Topics?" *Journal of Biological Education,* 12(1), 7-15.

Driver, R. et al. (1992). *Life and Living Processes.* Leeds National Curriculum Support Project, Part 2. Leeds City Council and the University of Leeds, UK.

Eisen, Y. and Stavy, R. (1988) "Students' Understanding of Photosynthesis." *American Biology Teacher,* 50, 208-212.

Engel Clough, E. and Wood-Robinson, C. (1985). "Children's Understanding of Inheritance." *Journal of Biological Education,* 19(4), 304-310.

Kargbo, D. et al. (1980) "Student Beliefs About Inherited Characteristics." *Journal of Biological Education,* 14(2): 137-146.

Leach, J. et al. (1996) "Children's Ideas About Ecology: Ideas Found in Children Aged 5–16 About the Interdependency of Organisms." *International Journal of Science Education,* 18, 19-34.

Settlage, J. (1994). "Conceptions of Natural Selection: A Snapshot of the Sense-Making Process." *Journal of Research in Science Teaching,* 31(5), 449-457.

Stavy, R. and Wax, N. (1989). "Children's Conceptions of Plants as Living Things." *Human Development,* 32, 88-94.

Stepans, J. (1985). "Biology in Elementary Schools: Children's Conceptions of Life." *American Biology Teacher,* 47: 222-225.

Tamir, P., Gal-Choppin, R., and Nussinowitz, R. (1981). "How Do Intermediate and Junior High School Students Conceptualize Living and Non-Living?" *Journal of Research in Science Teaching,* 18: 241-248.

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Curriculum Resources
Investigating Life Cycles
BSCS Science T.R.A.C.S.
Kendall/Hunt Publishing Company

Causal Patterns in Ecosystems
The Understandings of Consequence Project, available through Project Zero
http://pzweb.harvard.edu/ucp/
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Bones and Skeletons
Insights
Kendall/Hunt Publishing Company

Exploring With Wisconsin Fast Plants
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Organisms
Science and Technology for Children
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