Investigative Case-Based Learning in Biology
Version 1.4

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Investigative Case-Based Learning in Biology

Overview

This module is about using complex, open-ended problems, presented as narrative cases, as a way to initiate student centered investigation. Cases are descriptions of richly complex, realistic situations and the people, organisms, and systems involved in those situations. Three cases in multiple parts are presented in Kingdoms Entangled: Molecules, Maize, and Malaria, the first of this four part module. User Notes provides much additional specific information on using cases, as well as information and illustration on case-based learning approaches and about writing your own cases. A preliminary set of Resources and References that support teaching and learning with the cases are provided as well as illustrations of how such resources might be used to investigate issues raised by the case. Student Notes is designed to help to prepare the student for case-based learning by providing examples, explanations, and suggested learning approaches.

A Word About Case-Based Learning

Case based learning approaches are based on the ageless techniques of the storyteller who is using a story to teach a lesson. Cases are stories of a sort. They are narratives based on realistic situations with characters acting in a situation or facing a dilemma. Cases have been used longest to teach effective decision making in business, law and other professions. Recently the approaches have been modified for teaching medical science content.

A New Use Of Cases: Contexts For Developing Scientific Investigations

The cases in this module introduce a new element to the case study method. They are springboards for student-designed investigations. The cases do not necessarily point the learner toward solving a specific problem, but rather open a context with many potential problems that students can define. By using the case study approach in this new way, instructors better serve a significant objective of science education: to teach science so that learners have an applicable and flexible knowledge of science content and skill in investigation.

These cases for biology are open-ended. They don't provide all the details; rather, they sketch a situation in a way designed to provide a rich space for generating student questions. The cases draw from a broad range of applications in biology. Students must move beyond an initial searching for “facts” related to the questions they are exploring. They must develop accountable approaches to investigate these biological phenomena and then carry them out. Investigative case-based approaches encourage problem posing, investigation and persuasion.
Instruction with cases can be organized in many ways, from pairs looking at minicases in a large lecture, to small groups studying a case for an extended period, to brief case discussions before and after laboratory experiences. Ideally, cases, lectures, labs and other instructional approaches would be well integrated within a course. One of the most important elements of the case-based approach, however, is that it include collaborative discussion of the case issues. In that way, students can identify what they already know and what they need to find out in order to understand the case and pose a problem to investigate. Their learning becomes problem-motivated and self-directed.

In case-based learning students draw on a wide range of resources. This text module illustrates some of the kinds of resources that might be used with these cases, and provides some examples of ways the resources might be used for teaching and learning biology with cases.
Kingdoms Entangled: Molecules, Malaria and Maize

Introduction
The cases in Kingdoms Entangled: Molecules, Malaria and Maize examine interactions among representatives of biological kingdoms. Originally conceived as a single super case to organize learning in an entire biology course, Kingdoms Entangled is presented in three storylines that include linked, smaller cases. The smaller cases, more easily used in a wider range of biology courses, share a central event that organizes the action, namely a blight of corn and the people investigating it. Its main characters are two graduate biology students studying corn genetics and ecology as they work on the corn epidemic. We follow their circumstances and the science beneath the surface events.

Overall Case Summary
The corn crop in the U.S. and Canada is in danger due to a fungal disease for which corn has little resistance. Teosinte, wild corn found only in Central America, may have genetic and ecological resistance to the fungus. Two graduate students travel to Mexico and Guatemala to conduct research on the evolution, ecology and genetics of teosinte. They become ill part way through the field season. Maria Santini, dehydrated because of the travel, requires hospitalization where she learns she has sickle cell trait and is pregnant. Derrick Hernandez contracts malaria for which he is treated. Back home, Derrick relapses and possibly has drug resistant malaria. Later, Maria’s husband Marcus, Maria and Derrick reflect on corn history and disease.

Overview of “Kingdoms Entangled”

Case Authors: Margaret Waterman and Ethel Stanley
Copyright 1998
Case 1: Maria’s Travels

An epidemic caused by a fungus has begun in the U.S with potentially devastating effects on the corn crop. Derrick Hernandez and Maria Santini are graduate students studying the epidemic and crop improvement. An important resource in their studies is wild corn, teosinte, which may be resistant to the fungus. Teosinte grows in a few isolated locations in Central America. Maria, a geneticist, and Derrick, an ecologist, are headed south for their first field season. Maria went first to Mexico city to do some archival research on Zea at the Tiemplo Major. Derrick went first to Guatemala to another teosinte site. He'll join Maria and other researchers at the main teosinte site in the mountains of western Mexico, near the town of Durango.

Maria's Travels: Part 1

While enroute to Durango from Mexico City, Maria was delayed several days by storms. Worse, she contracted diarrhea, which she began treating right away. After a day's rest in Durango, she made the steep and difficult hike to the research site where she soon collapsed. Her symptoms were abdominal and leg cramping, disorientation, and rapid shallow breathing. Alerted by radio, Dr. Frederico Stegnaro in Durango advised giving her small amounts of saline over the night. The next day she made her way down the mountain on a pack mule and with Derrick’s help (he was feeling poorly himself) to see the doctor.

At the clinic, Dr. Stegnaro took Maria’s blood samples and did a variety of procedures to test out several possibilities. Thin and thick blood slides showed no evidence of malaria, but her blood chemistry was more revealing. Her hematocrit was abnormally high, blood pH lower than normal and K+ very low. He also noted what might be one or two unusual red blood cells. He started rehydration therapy and sent her by ambulance jeep to Mazatlan Hospital.
Maria's Travels: Part 2

Maria's husband of five years, Marcus Woods, met her in Mazatlan where he had flown upon hearing the news of her collapse. At the hospital, additional tests were run to try to determine the cause of Maria's symptoms. Rehydration therapy was continued.

Dr. Margarita Villas-Incle, who specialized in general internal medicine and Dr. Carlos Luna, a hematologist, visited Maria and Marcus to interpret the blood tests and other results. Dr. Villas said, "We are not sure what exactly caused your collapse two days ago. Dr. Stegnaro was able to find evidence of electrolyte imbalance and severe volume depletion. We think the most likely explanation is the combination of fatigue, diarrhea, and unusual exertion. The dehydration is probably the most important factor. Your baby will not be harmed by this episode."

Almost together, Maria and Marcus exclaimed "Baby?"

"You did not know? We ran a pregnancy test on you as part of the blood work. We do it on all female patients of child bearing age," Dr. Villas said. "You are pregnant."

"I have been trying to get pregnant for four years," Maria said happily.

"This is wonderful news," Marcus agreed.

Dr. Villas said, "Congratulations. Now, though you must be careful to make sure all goes well. You must not return to physically demanding work for at least two weeks, but you can travel home in a day or two."
Maria's Travels: Part 3:
Dr. Luna said, "I wanted to talk with you about some of the other findings. The doctor in Durango reported one or two odd erythrocytes. I did not find these. But I did do a special electrophoresis test on a sample of your blood. Senora Santini, are you aware that you have sickle cell trait?"

Maria, stunned, said, "What? What? I have sickle cell disease?"

"No, Senora Santini, you have sickle cell trait, not the disease. You will live normally with no restrictions."

"How could I have this? I'm Italian!"

"Most people think that only individuals with African ancestry can have sickle cell," the doctor replied, "but that is not true."

Maria turned to Marcus and quietly asked "Marcus, doesn't your cousin Leland have sickle cell?"
Case 2: Derrick’s Malaise

An epidemic caused by a fungus begun in the U.S with potentially devastating effects on the corn crop. Derrick Hernandez and Maria Santini are graduate students studying the epidemic and crop improvement. An important resource in their studies is wild corn, teosinte, which may be resistant to the fungus. Teosinte grows in a few isolated locations in Central America. Maria, a geneticist, and Derrick, an ecologist, are headed south for their first field season. Maria went first to Mexico city to do some archival research on *Zea* at the Tiempo Major. Derrick is going first to Guatemala to another teosinte site. He'll join Maria and other researchers at the main teosinte site in the mountains of western Mexico, near the town of Durango.

**Derrick’s Malaise: Part 1**

Derrick waved goodbye to his father and got on the plane for Guatemala. It had been fun visiting the family in Houston, Texas despite the steamy heat so early this summer. His first season of field research was about to start and he was excited. He would have just two weeks to study the ecology of a new teosinte site in the valley of the Rio Huista before going on to Mexico where he would join up with Maria and the rest of the team.

Derrick loved field work. An early riser, Derrick would get up before dawn to be ready to head out at first light. As he had found in Texas, the mosquitoes were worst at dawn and dusk. He was so busy that he just splashed on some repellant, then ignored the mosquitoes as best he could. At night, he faithfully used mosquito netting.

Two days after arriving in Mexico from Guatemala, Derrick felt like he had the flu. He climbed down the mountain (with Maria who was quite ill), to visit the doctor in Durango. After testing his blood, Dr. Stegnaro said, “You have malaria. It’s caused by a protozoan.”

“Oh, isn’t that caused by *Plasmodium*?” Derrick asked. “I took the drugs the CDC recommended as protection against malaria. Wasn’t that enough?”

“Well, there are several different kinds of *Plasmodium*, and sometimes people get malaria even if they’ve done everything right,” Dr. Stegnaro replied. “Seems like we’re seeing more and more of it recently.” He prescribed sulfadoxine, an antimalarial drug, and Derrick left. Shrugging his shoulders, Dr. Stegnaro thought to himself, “Here’s another case of malaria I have to report to the World Health Organization.”

After the malaria drugs took effect, Derrick was able to finish his field work in Mexico.
Derrick's Malaise: Part 2

About a month after returning home, Derrick began to feel sick. His roommate took him to the university clinic. It was the malaria. "How could I have these symptoms again?" Derrick asked the resident, Dr. Welty. "I know I finished my prescription."

"I'm not sure. We'll be needing a blood sample so we can analyze the bug causing you this trouble. In the meantime, let's try a different drug. I'm going to switch you to chloroquine," Dr. Welty suggested. "You know, malaria is the most common infectious disease in the world. I've got some contacts at CDC who may be interested in your case. May I share your records with them?" Derrick nodded.

Derrick's roommate asked, "Dr. Welty? Can I get malaria from Derrick?"

"You have nothing to worry about," the doctor replied, but Derrick's roommate wasn't entirely comfortable.
Derrick's Malaise: Part 3
Susan Welty glanced at the screen and clicked on the Send button.

Hi Steve,

Thanks for the info on my patient D.H. with the recurrent malaria. I will interview him again to learn more about where he might have been exposed to this strain of Plasmodium. I know he was in Houston, Guatemala and western Mexico. No one else in the group he was with in Mexico has come down with malaria (yet). It was reported to the WHO registry by the diagnosing doc in Durango.

Eda -- are you interested in this? A woman was diagnosed with sickle cell trait in the potential exposure group in Mexico.

Emily -- can you tell me more about the interactions? Do they relate to the drug resistance?
Susan

>On 4/27 7:30 a.m. you wrote:
>Susan, Thanks for the blood sample from this case. The bug is _P. falciparum_.
>Depending on where he picked it up, there might be more than one mosquito vector.
>Got any ideas on most likely site of infection? Incidence of this plasmodium is
>increasing. We're looking at effects of new mosquito control for _A. vivax_ on
>other vectors.

>Emily says "falciparum" interacts oddly with RBC membranes. Steve
Case 3: Zea’s Wild Roots

An epidemic caused by a fungus has begun with potentially devastating effects on the corn crop. Derrick Hernandez and Maria Santini are graduate students studying the epidemic and crop improvement. An important resource in their studies is wild corn, teosinte, which may be resistant to the fungus. Teosinte grows in a few isolated locations in Central America, and Maria and Derrick are headed south for their first field season. Maria went first to Mexico City to do some archival research on Zea at the Tiemplo Major. Derrick went first to Guatemala to another teosinte site. He'll join Maria and the others later at the main teosinte site in the mountains of western Mexico, near Durango.

Zea’s Wild Roots: Part 1

Marcus Woods, Maria’s husband, began moving the cardboard boxes from storage to their new home office. It was just the sort of project he liked doing while Maria was away. After unsuccessfully struggling with a file drawer, he reached down and picked up one of her Ag papers that had ended up on the floor. It was entitled Teosinte: Corn’s Missing Link. “ Hmm, what makes teosinte a missing link?” Marcus wondered. He began reading.

In 1978, a student at the University of Guadalajara named Rafael Guzman had discovered a new species of teosinte growing wild in the high plains of Jalisco, Mexico. The teosinte species was named Zea diploperennis. Furthermore, it was considered quite important that this species was completely interfertile with corn. Was this the wild maize Maria had talked about collecting in Mexico? Well, he could always ask her when she phoned on Tuesday.
Zea's Wild Roots: Part 2
Derrick accepted the invitation to dinner shortly after arriving from Texas where he had gone for his sister's birthday. Derrick's recent bouts with malaria were certain to be discussed, but the real reason for the get together was to celebrate Maria's unexpected and long awaited pregnancy. Derrick smiled to himself, quite pleased at the non-traditional gift he brought. Knowing Maria's love of archival work on the ancestry of corn, he had obtained a replica of Indian pottery over 600 years old. The Central American piece featured imprints from cultivated corn of the period. Even though the ears were small, it was easy to see multiple rows of seeds.

Derrick's roommate was intrigued by the small ears of ornamental corn Derrick had used to decorate the package. "How come regular corn doesn't have all these colors?" he wondered.
Zea’s Wild Roots: Part 3
"As long as we’ve known each other, I’ve never asked. How did you two meet?"
Derrick asked Marcus as the dinner got underway.

Between bites, Marcus began, “I met Maria while working with OXFAM, a hunger relief organization...”

“Remember stuffing all those envelopes and making all those calls?” Maria said as she flashed Marcus a smile. “Derrick, you’ll be interested in this. At that time corn crops were being lost in Africa due to maize streak virus...”

“Thousands of people were suffering without those crops,” Marcus interjected.

“... and the teosinte species found in the late 70’s proved to be resistant to the virus and gave some real hope. That’s when I knew I was going into corn genetics,” Maria continued.

“You know, what made me decide to study Zea,” Derrick said, “was hearing about when my uncle lost his entire crop in 1970 due to southern leaf blight. He just couldn’t understand why every field in the county was affected.”

Maria nodded her head knowingly and said simply, “Weather...”
Investigative Case-Based Learning (ICBL) is a variation of case study methods for teaching and learning. Students use a realistically complex situation (the case) to pose questions which serve as springboards for problem solving investigations in biology. Examples of case analysis and case writing as well as suggestions for implementing ICBL are featured in this section.

Figure 1. Learners and the case in a large class setting.

What are case based learning methods?
The use of cases is as old as storytelling itself. It is instruction by the use of narratives - stories - about individuals facing decisions or dilemmas. The learners are encouraged to engage with the characters and circumstances, to investigate them so as to understand the facts, values, contexts and decisions in the story, and to connect the meaning of the story to their own lives.

Models of case learning build on this general approach and formalize it in different ways to suit the subject matter and learning goals (Boehrer and Linsky, 1990). Cases are most commonly used to teach decision making skills to professionals. A well known model for this goal is the Harvard Business School case method (Christensen and Hansen, 1987) in which students receive extensive case histories that they individually analyze before attending a instructor-led, large class discussion. In the business school model, cases are often a culminating activity coming last in the instructional sequence.

A radically different case study model is called problem-based learning or PBL (Barrows and Tamblyn, 1980), which originated for learning basic medical science and is being used at increasing numbers of US medical schools. The medical school use of cases differs from that in other professional schools in that PBL emphasizes learning medical subject matter more so than medical decision-making, makes use of small group collaborative learning, and is student-centered. This model is more fully described below.

The PBL model is spreading quickly in undergraduate education, particularly in engineering and the sciences. The basic elements of the medical model are usually retained, with variation existing in such features as the amount of instructor directedness, the expected amount of collaboration among students, the degree to which the problem is focused or open-ended, when and if instructor goals are revealed, and the timing of the case in the curriculum. PBL as practiced in some of
these settings can encourage inquiry (see, for example, Bergland and Klyczek), although it is usually used to help students master and apply content.

**What is different about BioQUEST cases and the ICBL approach for science learning?**

What sets the ICBL approach featured here apart from previous PBL approaches is the extent to which the ICBL cases deliberately promote research-like environments for learning biology. Students are not only asked to learn new material, but to pose a question, develop accountable approaches to investigate it and present conclusions to the class that provide a reasonable answer to this question. Further, although the problem space is defined by the case, these cases are more open-ended than usual. They describe problems very broadly thus offering multiple avenues for student investigation.

**Lessons from medical PBL useful for ICBL**

The ICBL approach to case study grew out of our experience with medical case-based PBL. Some elements of that approach are extremely useful and are retained in ICBL.

1. **Cases are based on realistic and meaningful problems; they are multidisciplinary**

In the ICBL approach students learn biology in the context of realistic situations. They have practice using biological information to investigate and come to resolution on complex problems. Since learning occurs around a particular realistic problem, there is greater likelihood that the learned material will be better retained and more easily applied to similar situations (Brown et al., 1989, Schmidt, 1983). In their lives they may never face the exact problems they study, however, they will have had experience using scientific knowledge and scientific thinking to work out reasonable solutions.

2. **The case defines a problem space, and the problem comes first in instruction**

In case-based PBL, the problem is used in a different fashion than problems are traditionally used for science learning. In PBL the case defines a problem space that learners will investigate. In case-based PBL, the case comes first in the instructional sequence. This is a reversal of the usual use of problems in science teaching. By putting the case early in the instructional sequence, the learners use the case to brainstorm a set of questions they will try to answer. They thus become more directed in their reading and more motivated in subsequent lectures, labs, and discussions. In fact, they are learning in just the way most of us learn-- because they have a problem or question of their own to work on.

   **An example of a medical case:**

Ben Brown seemed lost as he approached the emergency room at General Hospital with a young boy. “You looking for the hospital's
homeless shelter?” the security guard asked. “No. My dad’s sick” said the boy as Ben coughed violently, spitting out bloody mucus. The guard jumped aside “Hey, watch it! Don’t get that on me! Yeah, alright. Go on in.”

Case Author: Margaret Waterman, 1997

Since the faculty members usually choose the cases to be studied or write their own, they take responsibility for drawing the boundaries on the problem space. The case defines a problem space in much the same way that the lines on a soccer field defines a playing space. As in soccer, the case sets some limits on the area of subject matter to be explored. And as in soccer, once the game has begun, the players move over the playing field moving in general directions, and with goals, but not in a prescribed linear manner. Unlike soccer, it’s ok to go out of bounds for a while with a case, as long as the general direction and goals are attained.

3. Students make decisions about their learning, and
4. Some phases of case study are best done collaboratively

Commonly in the medical case-based PBL approach, students work in groups of 8-10 with a “tutor,” meeting to discuss a case based on a real patient or situation (Fig. 2). Students read part of the case out loud, then discuss the elements presented thus far in the case. They generate hypotheses, list their outstanding questions, and develop a learning agenda -- issues they agree to pursue before their next meeting. This phase of case study is one in which students are actively engaged and working together to brainstorm issues, share what they know, and develop their plans for learning.

Some possible learning issues from the Ben Brown case: Access to health care, causes of coughs, parts of the body involved in breathing and coughing, the blood supply of the lungs, homelessness, universal precautions.

Certainly the logistics of medical case discussions must be modified for purposes of biology learning, and for the larger class sizes found in undergraduate biology programs. This is taken up later in the User Notes.

5. The faculty member becomes more of a guide to methodology than an information source

As you look at Figure 2, think about what the students are doing, who is at the board and what she is doing there. Notice what is in the room and what is written on the board. This image, drawn by a Harvard Medical School student, gives a snapshot of what a case discussion might look like in a small group.

The “tutor” has several roles (though to the student eye it may seem he does little): facilitates discussion, helps students explore their thinking and reasoning without leading them, and helps with group dynamics. During case discussions, students are actively engaged in interpreting the case, proposing problems and possible solutions, brainstorming, and using resources. At Harvard Medical School the faculty
and students agree that the chalkboard belongs to the student during case
discussions. Students take on roles we commonly think of as teacher roles:
deciding what to focus on, developing questions, leading the discussion, using the
board to keep notes, make drawings, or list learning issues. Resources to support
student learning are frequently in the room - books, images, access to the Internet,
computer simulations, models, etc.

Figure 2. Who is the teacher here?
Image by Neal Atebara. Copyright 1987. All rights reserved. Used with permission.
Investigative Case Based Learning Approach for Science Learning

The investigative case-based learning (ICBL) approach is a method of learning and teaching using realistically complex situations (cases) and group problem solving strategies. It is a variant of Problem Based Learning (see, in detail, above). The ICBL approach gives students opportunities to direct their own learning as they explore the science underlying the case.

Students not only identify issues and frame questions of interest to them, but also learn to:

- locate and manage information;
- develop reasonable answers to the questions;
- provide support for their conclusions, and;
- work on decision making abilities.

ICBL is student-centered. Students structure their own learning, using the “story” of the case as a focus. Although the case defines the general area of biology under investigation, students define their own topic of study. The cases provided here are open-ended to serve as springboards to student-designed investigations. Students will pose problems, try to solve them, and present conclusions that represent their own findings to others. The instructor as well as the students are collaborators in this process.

Cases useful for ICBL biology teaching are open-ended and draw from a broad range of situations in which biology can be applied. Open-ended cases are needed to lead students beyond the facts of science and into using the skills of investigating and scientific knowledge to frame questions and answer them. These investigative case-based learning approaches encourage problem posing, investigation and persuasion.

Instruction with cases can be organized in many ways, from pairs looking at minicases in a large lecture, to small groups studying a case for an extended period, to brief case discussions before and after laboratory experiences. Ideally, cases, lectures, labs and other instructional approaches would be well integrated within a course. One of the most important elements of ICBL (retained from the original PBL model), however, is that it include collaborative discussion of the case issues. For additional information on collaborative learning see Bruffee (1993).
What are some ways of proceeding with investigative case based learning in the classroom?

At the 1996 BioQUEST summer workshop a group of biology faculty worked on case based learning, wrote cases and thought about teaching biology with cases. One product of that group was an analysis of how the case study approach fits with the open-ended, investigative 3P’s philosophy of BioQUEST: Problem posing, Problem solving and Peer persuasion. You may wish to use this as a way to think about what you might ask students to do as they work with cases.


Problem-Posing
Recognizing potential issues
Brainstorming connections & to define problem space
Identifying material to be learned
Posing specific questions
Defining and specifying focus
Defining problems further by peer consultation

Problem-Solving
Obtaining additional references/sources
Managing information
Defining problem further (share views/info.)
Designing and conducting investigations
   With simulation software for
   Modeling
   Representing information
With field/laboratory methods
With new resources (further references, interviews, etc.)

Peer Persuasion
Presenting conclusions of investigations
Developing analyses or reports to persuade peers
Conducting debate/opposite views or outcomes
Producing other materials that show understanding of the conclusions.

Working through an example using this framework
In the next box is a short biology case. The first paragraph will be used to work through the framework shown above. In case-based learning, the first thing to do is to
see what the case is about. Read it through to get a sense of the story and issues. One surprisingly productive case-learning method is to have one student read the case out loud while the others in the group read along silently. This sounds silly perhaps, but it gets everyone “on the same page” and students say it helps them get started. Have a good dictionary and reference books available for students to look things up quickly.

Fleaing Louisiana

Case author: Margaret Waterman, 1996. This case may be reproduced and used for educational purposes, with proper reference and copyright notice included.

Moses Anders hung up the phone after talking with Ella Cardinale-Jones about her troubles. She had ticks on the dog, roaches in the house and hungry mosquitoes chewing up her kids. “Now Mr. Anders, I’m used to seeing some bugs around -- this is Louisiana. But it seems no matter what I do there are more and more of them. How can I get rid of them? I don’t feel like my children are safe.” Ms. Cardinale-Jones was the 19th caller about these insects* this month, and it was only January 7th.

Moses Anders is an intern with the Louisiana Cooperative Extension Service while he finishes his BS in biology. Moses dug out the last of the old tick, flea, and roach pamphlets in the files to send a copy to Ms. Cardinale-Jones. It said that these insects shouldn’t be significant problems until late spring, it didn’t mention mosquitoes, and the pamphlet did not really answer Ms. Cardinale-Jones questions.

He talked about this situation with his internship mentor Fran Collins, an agent who has been with the Service for several years. “Yeah,” she said, “it’s been really busy this winter. In fact, it’s been this way all the time for a couple of years now.” She agreed with Moses that the pamphlet needed to be updated and that he could take on the project, once he’d given her a work plan and time line.

Moses and Judy Yee, an intern in the public health office, traded stories over lunch at one of the city’s crowded outdoor cafes. She told him that the first case of Lyme disease in the area had recently been reported, and he told her about his new project. Their talk turned to the weather as they made their way back to work.

*Note: We are aware that ticks are not insects but arachnids, yet choose to lump them together with insects in the case for students to sort out as they discuss and research the facts of the case.

How to begin? (Problem Posing)

Individuals approach learning with cases in very different ways. You may wish to consider having students do one or more of the following after reading a case:

• **Recognize potential issues.** Go back and read the case again, this time noting words or phrases that seem to be important to understanding what the case is about. If students have a hard copy, they may underline these phrases. They are looking for
learning issues that they might explore further. They might jot down ideas and questions about these phrases. If students are working in a group, this approach might be done as a group discussion, with one person keeping a list of issues (maybe on the chalkboard) as they are raised.

Here is an example of some of the kinds of potential issues loaded into one paragraph of Fleaing Louisiana (items that are underlined):

Moses Anders hung up the phone after talking with Ella Cardinale-Jones about her troubles. She had ticks on the dog, roaches in the house and hungry mosquitoes chewing up her kids. “Now Mr. Anders, I’m used to seeing some bugs around -- this is Louisiana. But it seems no matter what I do there are more and more of them. How can I get rid of them? I don’t feel like my children are safe.” Ms. Cardinale-Jones was the 19th caller about these insects this month, and it was only January 7th.

• Brainstorm for connections. By connections we mean connections between the specifics of the case and potential learning issues or potential biology problems to investigate. There are several ways to do this. One way is to think about the case as a whole and see if there are underlying themes. Ask the question: “What is this case about, in general?” Global warming, insect borne diseases and careers in biology are some themes many people identify for “Fleaing Louisiana.” Posing specific questions as well as generalizing from those questions to larger learning issues are two other ways to find connections between the case and biology, as illustrated next.

“One of the greatest challenges in biology is to frame appropriate and productive questions that can be pursued by the technology at hand. You have probably had a great deal of experience in solving pre-posed problems, such as those found at the end of textbook chapters. However, if you were asked to go into a lab or out in a field and pose a research question, you will find that this is often difficult to do without some practice....

(The BioQUEST Library IV: A Note to the Student 1996)

• Pose specific questions. Another way to generate ideas and connections is to be clear about what is known so far, and then to see what questions arise.

What we know now: It’s January in Louisiana. There are lots of insects, perhaps more than usual, and people with safety concerns are calling Moses Anders about this.

Using the first paragraph again as an example, here are some questions raised by learners who have worked with this case:

Why are there lots of insects in January? What affects the number of insects at any given time of year? Are there really more than usual? What is the usual pattern?
Why is Ms. Cardinale-Jones concerned for the safety of her children? What diseases do ticks, roaches and mosquitoes carry? Are there other reasons besides disease to be concerned about these insects?

What can Ms. Cardinale-Jones do to control the insects? What advice should Moses give her? What is the biology of ticks? Roaches? Mosquitoes?

Why are people calling Moses Anders about this? What do they think he knows or can do for them? What sorts of jobs deal with these issues?

By generalizing on the questions raised, students can identify potential learning issues. For any one of these issues, they may generate further questions to structure their learning.

Potential learning issues: Insect populations and the factors that affect them. Problems posed to humans by insects. Insect control measures. Unusual insect occurrences in winter. The job held by Moses that would lead people to call him.

Brainstorming can lead to a long list of questions, and there is not time to pursue them all. Have groups spend time identifying a few key questions of interest. Students are usually careful to use the contextual clues provided by the course title, syllabus topics, etc., as ways to help them narrow the list of potential topics. But you never know, a student may become very interested in a good question that is only tangential to the case. If the goal is to learn to pose questions, solve problems, and argue convincingly, some instructors might decide any topic related to the case is fair game.

The questions raised by the brainstorming can lead to different sorts of learning activities. Remember that the goal with investigative case-based learning is to develop problems of interest to students, that can be investigated using the tools of science. Below is an analysis of some of the different types of learning that might follow from some of the questions on the brainstorming list.

<table>
<thead>
<tr>
<th>Learning Activity</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Further brainstorming</td>
<td>“Why is Ms. Cardinale-Jones concerned for the safety of her children?” or</td>
</tr>
<tr>
<td></td>
<td>“What affects the number of insects at any given time of year?” or “What</td>
</tr>
<tr>
<td></td>
<td>sorts of jobs deal with these issues?”</td>
</tr>
<tr>
<td>Searching out basic facts.</td>
<td>“What diseases do the insects carry?” or “What is the biology of ticks?”</td>
</tr>
<tr>
<td></td>
<td>or “What advice should Moses give her?” These questions in and of</td>
</tr>
<tr>
<td></td>
<td>themselves do not pose a scientific research problem, but learning</td>
</tr>
<tr>
<td></td>
<td>more about these may lead to other questions that are scientific.</td>
</tr>
</tbody>
</table>
### Decision making

“What advice should Moses give her?” Students will need to understand the issues, and evaluate the consequences of the options before they can answer this question. Group discussion and negotiation of diverse viewpoints will also be involved.

### Finding information, analyzing it and finding patterns

“What is the usual pattern of insects in Louisiana?” and “Is it different this year?” These questions might lead students to the Internet or elsewhere to get insect sampling data for analysis.

### Scientific investigations

“What affects the number of insects at any given time of year?” could be refined to focus on climatic variables. These could then be investigated by modeling (with Biota or EDM), by actually collecting weather and insect population data, by using data sets collected by others, or by finding published information on the topic.

- **Define problems further by sharing views and concerns** As learners define problems and frame specific questions to investigate, it will be important for them to consult with others, most likely members of the group or other classmates. Talking about ideas and plans with others is an important step in refining problems, and can lead to different perspectives that might help shape good research problems. You might want to save some class time for this kind of activity, or students could do it online, or out of class. Encourage learners to continue this practice of sharing their ideas, plans and concerns with others as they gather evidence in answer to the problem and as they prepare to present conclusions. Such conversation and collaboration is a hallmark of the work of scientists.

Why are some research questions considered better than others? What are the cultural, personal, and political biases that influence what questions are posed and how they are posed?

(From *The BioQUEST Library IV: A Note to the Student 1996*)

**We’ve got a question, now what? (Problem Solving)**

- **Obtain additional references/resources.** No matter what type of question learners pose, it is likely they will seek and use additional resources to help them support and research a reasonable answer. Resources may include textbooks; other library materials; results of computer simulations; results of lab or field research; articles from professional journals or popular press, data sets, maps, emails, websites or other electronically based resources; pamphlets from organizations; interviews with experts; information from museum exhibits, etc. Encourage students to be creative in seeking information.
Suppose, for example, the students chose to study the question: What affects the number of ticks or mosquitoes in Louisiana at any given time of year? They could consult entomology books to learn the basic biology of the chosen organism, or they could locate tick or mosquito sites on the world wide web. Such sites might include annual data on mosquito prevalence collected by the CDC, or it might include a scientist describing their research on global warming and insect populations. They could search the professional literature for likely articles. They might contact a Lyme disease support group to see how to find information on tick prevalence. They could see if the cooperative extension service had contacts with scientists who regularly sample insect populations or who work on insect control. A different sort of resource students could seek might be computer simulation software that could potentially be used for modeling studies.

See Resources and References, below, for specific examples of materials supporting the nine cases in Kingdoms Entangled. In the same section are scenarios for you to consider of students learning with a variety of resources.

• **Design and conduct scientific investigations.** These might use appropriate laboratory or field methods or perhaps computers with relevant software modules, spreadsheets, graphics, etc. One important mode in which scientists operate is the synthesis of pieces of existing information into a new theoretical framework (work which may be accompanied by modeling, as was done by Watson and Crick). Students might locate datasets, conduct interviews, gather ideas from their reading and library research. What makes this kind of work scientific is the use of these bits of information to form a new, justifiable and testable point of view.

For our example, the students might decide to use insect trapping methods to assess insect population size and dynamics over a several month period. (They might even propose it as a multi-year project, to be carried on by future students.) Or they might decide to use software like Ecobeaker or Environmental Decision Making to investigate and model the effect on insect populations of changing climatic variables. Their instructor might have laboratory experiences coordinated with this case, so that, for example, students learn concepts of population dynamics using models and simulations. Then the students could tailor these general modeling skills to their specific question.
How to end? (Peer Persuasion)

“Research is not complete, no matter how many experiments have been conducted, no matter how many puzzles have been solved, until peers outside of a research team are persuaded of the utility of the answers. Persuasion is a social process and an essential one for you to experience in order to understand the nature of scientific theories and paradigm shifts. Communication in the science community is an active process full of controversy and debate. The productive side of science involves open criticism of the methods and conclusions made by a research group. This controversy and debate is important to the creation and acceptance of new scientific knowledge.”

(The BioQUEST Library IV: A Note to the Student 1996)

When learners are ready to present their own conclusions, consider asking them to do one or more of the following, and build in ways for students to view and review each other’s work:

- **Develop scientific analyses and reports to persuade others of the soundness of your ideas.** Any of the formats that scientists use to describe their work might be appropriate here. These might include: a report written in the format of an appropriate journal, a poster such as might be presented at a professional meeting, an article about the work for the popular press, or a report such as scientists in an organization might write to administrators. Such reports or posters would provide an evidence-backed position on the question.

  For our example, students studying insect patterns might include data tables, photographs of insect-laden traps at various times of the year, or relevant printouts from the simulation programs in their reports.

- **Produce materials that support understanding of the conclusions.** Traditionally we ask for term papers or lab reports, but the possibilities for other supporting materials are vast: posters, poetry, plays, videos, booklets, pamphlets, consulting reports, artwork, designs for new technology, scientific publications, newspaper stories, editorials, or new case studies for example. When students review each others products, then they can engage in the kind of discussion and possible controversy about differing methods and results that is common in scientific discourse.

  For Fleaing Louisiana, learners might produce a new pamphlet that includes the information about yearly fluctuation in tick, flea and roach populations, a scientifically based public talk of the kind extension agents offer, or a set of insect control guidelines. Any of these could be used to incorporate findings from student scientific investigations of the questions.
• **Initiate debate on views or outcomes.** This could take on many forms. It could be that a poster session is set up, with a discussion (led by a commentator?) on the views and outcomes presented. Or, it could be an actual debate. For “Fleaing Louisiana,” a debate on global warming might be something teams of students might choose to prepare. Or it could be a format that brings in perspectives in addition to the scientific. For example, in the case of global warming it could be a heated exchange of letters to the editor in a newspaper, a fictional email exchange between opponents and proponents of global warming, or mock congressional hearings at which various stakeholders present their views.

### Fitting Investigative Case Study Approaches into Courses

Instructors may want to consider the following four areas when planning for case learning.

1. **The learning goals and objectives of the course**

Which goals could be met by having students use the case study approach? Often a case will allow students to address more than one goal at a time. This kind of analysis can be a starting place for case writing by preparing cases to address one or more specific goals.

A second way to use the goals of the course is when you evaluate a case for use in your class. Ask yourself these questions:

- What is the case about?
- Will there be issues my students will care about?
- What are some of the potential learning issues?
- Are these central enough to the case for me to use this case? Can I modify the case?
- How difficult or obscure are the issues in the case?
- Is the case open-ended enough for students to go beyond fact finding and into investigation?
- What do I see as possible areas for investigation?
- What product might I ask students to produce?
- Is the case too short or too long for the time I have available?
- What sorts of learning resources might be needed for this case? Are they accessible?
- If I use this case, what lectures/labs/discussions might I want to change, add or eliminate?
2. The course structure - a not entirely logistical consideration

As you can see from the above list of questions, sometimes using cases can lead to changing a course syllabus to delete, rearrange, change or add other components like lectures or labs. Another consideration is the temporal structure of the course, and the space available for teaching. When does the course meet? How often? How long? For what purposes? When would you fit in cases? Here, in figure 3, are some suggested “prototypical weeks”- temporal structures showing when cases might be used.

Figure 3. Several “Prototypical Weeks” to illustrate ways to incorporate case time.

### Traditional 3 hours of lecture, 2-3 hours in lab

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<tbody>
<tr>
<td>AM</td>
<td>Lecture</td>
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<td>Lecture</td>
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<td>Lecture</td>
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<tr>
<td>PM</td>
<td>Lab(2-3 hrs)</td>
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### Option A Two blocks per week “workshop” style with some time for case work

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<tbody>
<tr>
<td>AM</td>
<td>Bio time 2-3 hours case 45 min</td>
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<td>Bio time 2-3 hrs case 45 min</td>
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<td>PM</td>
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### Option B Combine lecture and case work, sandwiching lab

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<tbody>
<tr>
<td>AM</td>
<td>Lecture</td>
<td>Lecture and Case</td>
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<td>Lecture and case</td>
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<tr>
<td>PM</td>
<td></td>
<td></td>
<td>Lab</td>
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### Option C Start case on Fri., work on in lab, finish next Fri..

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<tbody>
<tr>
<td>AM</td>
<td>Lecture</td>
<td></td>
<td>lecture</td>
<td></td>
<td>Wrap up this week’s case, begin next week’s</td>
</tr>
<tr>
<td>PM</td>
<td>Case and Lab</td>
<td></td>
<td>Lab</td>
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3. Class size and the need for student collaboration

Sure, it would be great if there were only 15 students in the class, but very few of us have that luxury, especially in beginning biology courses. In very large classes, it may work best to do case learning in lab or recitation time, when groups are smaller. This is especially important when students are learning how to work together on cases. Additional teaching staff can be faculty working in teams, graduate students (if available) and advanced undergraduate teaching assistants (who may volunteer or may get internship credit). It is possible to break up large classes into smaller groups, but you do need a high tolerance for noise while a couple of hundred students, working in near-neighbor groups, discuss the case.

Some biology faculty have established electronic communications such as bulletin boards and real time “chat” so that student case groups can work together on-line. There are many solutions to having students in larger classes do meaningful work in smaller groups. There are several workshop biology/studio science courses whose materials and advice are available on line (see, for example, the University of Oregon materials referenced in the bibliography).

4. Preparing students to use case study approaches

Most college students are ill-prepared for collaborative group work, although this may change in the future as collaborative methods are being more widely used in secondary science education. Nonetheless, at present, college faculty need to recognize that they will have to teach students how to work together. They will also have to teach them how to use case study approaches. For example, at Harvard Medical School incoming classes of medical students are introduced to case-based learning in three ways. First, in orientation, they do a case about plumbing (which few know about and it isn’t medical, so the pressure is off). Second, also during orientation, they sit as a group of 160 in a lecture hall and watch a small group tutorial take place live in front of them (run by second year students). Third, in their first real course, time is allotted for discussing group dynamics and case processes.

Students also need guidelines for how to act during discussions. Having printed guidelines can help, such as “Don’t interrupt one another” “Don’t attack people personally, focus on ideas” “Each person must contribute to the group. There are many ways to do this.” General advice books on college teaching like Barbara G. Davis, Tools for Teaching, (San Francisco: Jossey-Bass, 1993) will be useful for developing such guidelines, as will faculty colleagues in disciplines that use regularly use discussion (e.g., psychology, english, history, education, philosophy).
You will likely want to create a low-pressure situation for your students the first time they do a case. Make the case short, fun and easy, so they can learn how to brainstorm the issues and questions of the case. You might, for example, make up a little case about a library book that’s neither on the shelves nor checked out. Students would have to brainstorm possibilities, then plan the order and ways in which they might investigate each of these possibilities. Don’t be afraid to give explicit directions, such as

“We begin by having one person read the case out loud. Who would like to do this?”

“Are there any words you don’t know?” Or “what do you think this case is about?”

“It will help you later if one of you acts as scribe and writes down the ideas (on the chalkboard). You might want to keep track of facts, questions, issues, and proposed answers to the problem.”

“We have 10 minutes left and you need to plan for the next meeting. What do you see as key issues you’d like to work on?

An example of a structured first use of science cases, with specific directions and worksheets is available at http://cstl.semo.edu/waterman/LifeLines/zeaimplement.htm

This example uses Part 3 of Zea’s Wild Roots from this text module to introduce ecology in a nonmajors, one-semester biology class.

**Evaluation and assessment of case-based student learning**

There are many opportunities to evaluate students’ performances when they are using case-based learning approaches. Here are some assessable activities students might engage in as they work on their investigations:

- their participation and contribution to work in groups,
- the kinds of issues they identify,
- the questions they develop,
- the investigations they propose,
- where and how they locate resources,
- how they conduct investigations, and
- the presentations they make.

You may wish to ask if learners are:

- actively acquiring information about a biological topic within this problem space?
• re-organizing this information?
• using strategies to select resources beyond text materials?
• using a problem-oriented approach? (Is there a question for investigation?)
• collaborating with other individuals in problem posing or problem solving?
• choosing among alternative approaches to solve problems?
• negotiating, arguing, or attempting to convince others?
• generating graphs, tables, charts, or other graphics?
• presenting conclusions?
• presenting evidence to support their conclusions?
• generating further questions as a result of this activity

There are many ways to evaluate the quality of student work on these kinds of activities, including

1. observations of students at work,
2. evaluations of the products they create,
3. case-based exams (in which students individually analyze a case and generate questions),
4. peer evaluations of presentations,
5. group self-evaluations.

A very good resource for assessment tools and rubrics is The Handbook of Engaged Learning, a compilation of projects that use technology for teaching science. While these are designed for K-12 science, many of the high school projects are sophisticated and suitable for undergraduates. This web-based resource has excellent teacher-produced projects that include assessment plans, rubrics and resources. Assessment information is in each project's summary page. The project on inheritance of diseases suggests alternative assessment tools, like concept maps and projects logs (Peretz, 1998) The prairie project has three very useful rubrics for scoring performance on technology use, research, and presentation (Fraccaro, et al., 1998). The project index address is http://www-ed.fnal.gov/help/index.html

At this index, choose individual projects to explore.

**Assessing the effectiveness of a specific use of a case:**
Questions to ask once the case has been used for teaching and learning:

1. How well does the case work as a learning tool with students (as assessed by their performance)?
2. What were stumbling blocks for the students?
3. Were the students led “down the wrong path” by anything in the case?
4. Was the time allotted for case study adequate?
5. Were the students able to generate questions that they could investigate?
6. Was there a problem with the case in this regard (too vague, difficult, long)
7. Did student discussion generally address the objectives of the case? Were there any other important objectives that should be included?
8. Were the students able to locate useful additional resources? Were the resource materials and readings useful?
9. How well did the case study fit with other elements of the course (lectures, labs, discussions, recitations)?
10. What worked especially well?

Suggestions for developing your own cases

These suggestions are drawn from the work done by the case development group at the 1996 BioQUEST Faculty Development Workshop (Waterman, et al., 1996) and follow a framework commonly used in English writing classes, and for developing cases at Harvard Medical School (1991).

To develop the initial cases we used the following format that alternates between individual work and work with a partner.

1. To begin, the authors are asked to write down a topic they would like to teach, and one big “take home” message on this topic.
2. Next, individuals are asked to think of two or three settings or scenarios useful for leading students to explore that topic.
3. Working in pairs, each member explains their topic and possible scenarios, with the intent of convincing the partner of the utility of at least one of the scenarios.
4. Next, each individual drafts a brief paragraph or two describing the scenario/situation as though writing to a nonscientist friend.
5. In the last step, new partnerships form, and each author reads his or her case aloud with the partner responding by telling what he or she thinks the case is about.

We used the following case review process for further case development:

1. The case author reads their case out loud to the group.
2. The other members of the group offer suggestions (preferably in the form of questions that the case stimulates for them) as to what the case is about.
3. The author then shares what he or she intended the case to be about. Sometimes there is great congruence between what the listeners think and what the author intended, often there is some incongruity.
4. When there is much incongruity, it's time to think about recasting the case, perhaps in a new scenario.

Once the story clearly leads to the intended objectives, it is time to start structuring the case for teaching. This means analyzing each paragraph to see what it might stimulate for the students – the sort of analysis done for the first paragraph of “Fleaining Louisiana,” above. It also means deciding where the story should be split up into parts for the students to work on a bit at a time. Keep the parts short. They will contain much more learning material than you anticipate.

In addition to the story (the narrative) the case might also have as components:

- A list of resources - you may wish to supply a starting list of readings, web sites, etc. You can make this longer or shorter, depending on your goals for student learning. If you want students to learn to find resources, the list will be shorter, of course.

- List of learning goals (these may or may not be given to the students). It is helpful in some circumstances to provide students with a list of the learning objectives you had for the case. It is important, however, to delay giving this to them until after they have worked on the case for some time. Otherwise, the learning becomes too teacher-directed and the power of student-centered learning is lost.

- Instructor’s guide - this is important if you are teaching a course with multiple instructors or if you are planning on publishing the case. The instructor’s guide lists the objectives and the main anticipated learning issues. It may also have information about resources, related learning activities, possible student projects, suggested products students could create related to this case, and the like.

- Visuals, simulations, web sites - these are all possible components of cases that can be an integral part of the case or resources to support learning with the case.

Some starting references on cases and problem-based learning


**Connecting via Internet to others using cases and PBL:**

The University of Delaware is using cases and other forms of problems for an institution-wide reform of science learning and teaching.

[http://www.udel.edu/pbl/](http://www.udel.edu/pbl/)

Clyde Herreid has been working with faculty at the University of Buffalo on case-based science learning for more than ten years. This is a well-organized web site, with links to many other projects and faculty working with cases in several disciplines.

[http://ublib.buffalo.edu/libraries/projects/cases/case.html](http://ublib.buffalo.edu/libraries/projects/cases/case.html)

At the University of Oregon a group has been developing “workshop” biology for the past few years and uses some case material, especially for the “issues” activities.

[http://biology.uoregon.edu/Biology_WWW/Workshop_Biol/Activities/format.html](http://biology.uoregon.edu/Biology_WWW/Workshop_Biol/Activities/format.html)

At Niagara University, a project on cases for human anatomy and physiology is underway. They have a few cases on line, and some questions that accompany them.

[http://www.niagara.edu/~bcliff/](http://www.niagara.edu/~bcliff/)

The BioQUEST Curriculum Consortium has been working on the problem of connecting cases to open-ended student investigations. A multipart case is under development, and is designed to help students and faculty raise researchable questions. The case is supported by the BioQUEST library of investigative software.

[http://bioquest.org](http://bioquest.org)
Harvard Medical School has a catalog of cases used in their basic biology courses. These cases can be purchased.

Contact the Director of Medical Education, Office of Educational Development, Harvard Medical School, Boston MA 02115.

**Literature Cited**


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- Edith Beard-Brady, Saunders College Publishing
- Mary Polacco, Curator for Maize DB
- ACUBE (Association of College and University Biology Educators-formerly the AMCBT)
- NABT (National Association of Biology Teachers)
- CELS (Coalition for Education in the Life Sciences)
- BQCC (BioQUEST Curriculum Consortium)
- Beloit College
- Southeast Missouri State University
- Harvard Medical School
- Howard Hughes Medical Institute
What kinds of resources support case-based student investigations?

The obvious answer is the resources we are currently using in teaching and learning in biology. However, case-based learning has different means, if not ends, than the lecture-driven portions of a course. The lifeblood of case-based teaching is encouraging students to pose their own questions, to employ methods of investigation including collaborative exploration and resolution of these questions, and to develop closure with some aspect of the case.

What counts as a resource for posing a question may be very different than what counts for supporting a conclusion.

Students come to the classroom with a rich experiential knowledge that may be the resource most commonly overlooked by instructors and students alike. They come with a variety of interests, skills, dislikes, and models of how they think things work. They also come with questions generated by their experience.

The textbook for the course is perhaps the most frequently used resource in the classroom. Texts can be extremely useful. Interestingly though, when students leave the classroom behind, they also leave the textbook behind. Solving problems is a lifelong endeavor and one could argue that education should include experiences in which the resources used in learning include those the students will use long after the course is completed.
A preliminary list of resources that would be helpful for students who are investigating various aspects of the case follows:

### Potential Support for Case-Based Learning

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<td>Interviews</td>
<td>Questioning a caregiver about sickle cell</td>
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<td>Textbook/lab manual</td>
<td>Life cycle of Plasmodium</td>
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<td>Video</td>
<td>Emerging diseases</td>
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<tr>
<td>Web articles</td>
<td>Engineering sickle cell mouse</td>
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</table>
Cases on Cases

The scenarios that follow are intended as a sampler of activities students could engage in while working with cases. These scenarios are not intended as “model” examples, but offer different pedagogical and learner approaches for your consideration. Some scenarios are brief, while others are quite complex. We urge you to think about these resource scenarios - “cases on cases” - with respect to your students and your classes.

Investigative case-based learning is just one strategic approach to the classroom. ICBL users value participatory activities that frequently requires an expanded multi-stage assessment focus. A check list of questions that may help define potential ICBL classroom issues is provided:

- Are learners provided with an opportunity for choice within the problem space?
- Are learners actively acquiring information about a biological topic within this problem space?
- Are learners re-organizing this information?
- Are learners utilizing more than one resource?
- Are learners utilizing resources beyond text materials?
- Are learners using strategies to select these resources?
- Are learners using a problem-oriented approach? (Is there a question for investigation?)
- Is this problem provided by the learner?
- Are learners collaborating with other individuals in problem posing or problem solving?
- Are learner choosing among alternative approaches to solving problems?
- Is there evidence of errors being identified and acted upon?
- Do learners appear to be negotiating, arguing, or attempting to convince others?
- Are students generating graphs, tables, charts, or other graphics?
- Are learners presenting conclusions?
- Are learners presenting evidence to support their conclusions?
- Are further questions generated as a result of this activity?
- Is the instructor providing an open problem space for student inquiry?
- Is the instructor comfortable considering biological topics beyond those originally conceived of?
- Does the environment allow for multiple resource utilization?
- Is the instructor providing space/time/support for student collaborations?
- Is the instructor acting as a collaborator?
- Is the instructor valuing student work products? (For example, incorporating prior student work as resources for the current students.)
- Is the instructor prepared to assess problem posing and problem solving approaches in addition to the "conclusions" presented at the end of the investigations?
- Is the instructor willing to accept an argument for asking different questions as a form of closure?
Using Text Illustrations as Resources

Angela, a new student who was undecided about her major, sighed as she held a copy of Derrick’s Malaise. “I’m supposed to come up with my own problems for study in this bio course?” she asked no one in particular. She re-read the short exchange in Part 1 of Derrick’s Malaise between Dr. Stegnaro and Derrick:

Two days after arriving in Mexico from Guatemala, Derrick felt like he had the flu. He climbed down the mountain (with Maria who was quite ill), to visit the doctor in Durango. After testing his blood, Dr. Stegnaro said, “You have malaria. It’s caused by a protozoan.”

“Oh, isn’t that caused by Plasmodium?” Derrick asked. “I took the drugs the CDC recommended as protection against malaria. Wasn’t that enough?”

If Derrick’s malaria was caused by Plasmodium, how did he get the Plasmodium? The only thing she knew about malaria was that people got it when they went to other countries.

She noticed other students leaving the table to go to the computers or leaf through a shelf of books near the window. She decided to get a book or two herself and came back to the table with a large modern text entitled Microbiology by Perry and Staley. After finding Plasmodium in the index, she turned to page 597.

Figure 23.25: The life cycle of Plasmodium vivax, one of the species that cause malaria in man. (Used with permission from Perry, and Staley, 1996. Microbiology. Philadelphia, Pa:  Saunders College Publishing.)
Using the Web as a Resource

In Part 1 of Zea’s Wild Roots, the term *Zea diploperennis* caught Shiro’s eye. The relationship between cultivated corn which he knew was *Zea mays* and this teosinte seemed to be a worthwhile pursuit:

“Hmm, what makes teosinte a missing link?” Marcus wondered. He continued reading. In 1978, a student at the University of Guadalajara named Rafael Guzman had discovered a new species of teosinte growing wild in the high plains of Jalisco, Mexico. This species was named *Zea diploperennis*. Furthermore, it was considered quite important that this species was completely interfertile with corn.

Shiro then accessed the URL, http://www.agron.missouri.edu, one of several websites his general search had turned up. This site provided links to the latest references on *Zea diploperennis* as well extensive genetic resources. He had limited access to geneticists and database experts responsible for the site.

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**MaizeDB Working Group**

At Columbia, Missouri site:
Ed Coe: Project Leader; maps and recombination data; literature
Mary Polacco: Curator; links to external databases; gene products; literature
Denis Hancock: System Administrator
Pat Byrne: QTL and traits; literature
Georgia Davis: maps, probes; literature.
Mike McMullen: maps, probes.

Off-site and on-line:
Mary Berlyn: database design advisor.
Christiane Fauron mitochondrial genome data.
Stan Letovsky: database design and software.
Marty Sachs: Maize Genetics Cooperation Stock Center Director; genetic stocks (germplasm)
Carolyn Wetzel: chloroplast genome through summer 1995

E-mail: maizedb@teosinte.agron.missouri.edu
Using the Simulation LateBlight as a Resource

A group of students working with Part 3 of Zea’s Wild Roots centered their investigations on the following exchange between Derrick and Maria:

“You know, what made me decide to study Zea,” Derrick said, “was hearing about when my uncle lost his entire crop in 1970 due to southern leaf blight. He just couldn’t understand why every field in the county was affected.”

Maria nodded her head knowingly and said simply, “Weather...”

The students were unfamiliar with blight, but thought that Maria’s cryptic “Weather...” comment deserved to be investigated. Everyone in the group had chosen this unexplained comment as a question they might like to explore.

One of the resources that was available to the group was Late Blight, the computer simulation program shown below involving crop management of potatoes featuring late blight. The program was developed to model multiple variables affecting potato crop yields. Although the host was potatoes instead of corn, the students wished to model the impact of the weather on a crop plant exposed to blight. Afterall, no one in the urban group knew very much about agriculture.

LateBlight is a Windows only program that is widely available. It is also included in First Review Modules in the BioQUEST Library.

The program was simple to use, but it was not easy to get started. In fact it required considerable negotiation since many different kinds of models could be investigated. The group finally agreed that the simpler the model was when they started, the easier it would be to interpret the initial results.

The students decided to use one of the default models (in this case, late season potatoes with low resistance to blight) to investigate the effects of weather on the success of the potato crop. They also chose not to interfere with the progress of the infection by spraying fungicides in this simulation. Their intent was to look at the
progress of an uncontrolled blight infection and then focus on weather variables that might have contributed to the spread of the disease.

By choosing `coolwet.lwx`, the students are creating a set of weather conditions for the model that they can compare to other weather conditions. There are many other variables they could manipulate as well, including characteristics of the potato and the blight.

This first simulation showed rather dramatic effects of a blight infection in late summer. A simple graph showing the percent of leaves affected by the blight was produced. Then the group decided to produce more graphs displaying weather variables that may have affected the crop production.

Two weather variables, temperature and rainfall, were selected to create new plots. The students used the plots to determine if either seemed to be linked with an increase in the percent of leaf blight.
The temperature seesawed between 45 and 80 degrees over the summer.

Rainfall, on the other hand, was sporadic, but increased significantly during the late summer when the blight also seemed to increase.

Connections between new infections and rainfall were then explored.
An analysis of the data generated in graphic form resulted in the observation that rain preceded the large increase in infections. There may be other variables at work here, but rainfall seems likely to be contributing to the rise in leaf blight.

By comparing the late summer rainfall shown by the black area under the curve and the escalation in new infections highlighted in gray above the rainfall, an argument could be made to link the two. An increase in new infections seems to be triggered by recent rain.

The students generated several more graphs by running the simulation under hot, dry conditions and decided to present a poster on the role of “weather” on crops affected by blight. Two seasons, hot and dry versus cool and wet, would be the included.

One member of the group discovered that an economic report could be generated at the end of the season by simply clicking on the menu. In order to create a dramatic image for the poster, the students decided to also include the economic reports for the two seasons being modeled. These were overlaid on each of the plots showing percent leaf blight and rainfall.
Percent Leaves with Blight versus Rainfall
Low Resistance Late Season Potatoes During Cool, Wet Season

Percent Leaves with Blight versus Rainfall
Low Resistance Late Season Potatoes During Hot, Dry Season
Using Late Blight (the same resource), another student extended the investigation using a different part of the Zea’s Wild Roots case as her cue. She wished to look more closely at Maria’s remark:

“... and the teosinte species found in the late 70’s proved to be resistant to the virus and gave some real hope. That’s when I knew I was going into corn genetics.”

She chose another line of potatoes with high resistance to late blight.

This model using highly resistant potatoes subjected to a cool wet season shows a remarkable decrease in percent of leaves infected.

<table>
<thead>
<tr>
<th>Percent Leaves with Blight</th>
<th>High Resistance Late Season Potatoes During Cool, Wet Season</th>
</tr>
</thead>
</table>

This economic report further indicated an excellent yield of tubers despite the weather:

<table>
<thead>
<tr>
<th>Economic Report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Season ended on Sept. 28 with 18.57% blighted foliage.</strong></td>
</tr>
<tr>
<td><strong>Your crop is 295.20 cwt./acre.</strong></td>
</tr>
<tr>
<td><strong>At the current market price of 5.00 this would bring 1475.98/acre 8.0% of your tubers are blighted.</strong></td>
</tr>
</tbody>
</table>

**YIELD REPORT**

<table>
<thead>
<tr>
<th>Price</th>
<th>Yield</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>/cwt.</td>
<td>cwt.</td>
<td></td>
</tr>
<tr>
<td>Total Potential Yield:</td>
<td>5.00</td>
<td>300.0</td>
</tr>
<tr>
<td>Yield Losses due to Plant Blight:</td>
<td>5.00</td>
<td>4.8</td>
</tr>
<tr>
<td>Yield Losses due to Tuber Blight:</td>
<td>5.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Total Losses due to All Blight:</td>
<td>5.00</td>
<td>4.8</td>
</tr>
<tr>
<td>Net Yield:</td>
<td>5.00</td>
<td>295.2</td>
</tr>
</tbody>
</table>

**SPRAY REPORT**

- **Pesticide Sprays**
  - 0 0.00 0.00
- **Protectant**
  - 0 0.00
- **Systemic**
  - 0 0.00

**COST REPORT**

- **Fixed Costs**: 1100.00
- **Spray Costs**: 0.00
- **Application Costs**: 0.00
- **Blitecast Costs**: 25.00
- **Net Profit**: 350.98
Using Work from Prior Students as a Resource

Computer Generated Pedigrees from the Inherit Program
A group of students was intrigued by two passages from Part 3 of Maria’s Travels.

Maria, stunned, said, "What? What? I have sickle cell disease?"

"No, Senora Santini, you have sickle cell trait, not the disease. You will live normally with no restrictions."

"How could I have this? I'm Italian!"

"Most people think that only individuals with African ancestry can have sickle cell," the doctor replied, “but that is not true."

Maria turned to Marcus and quietly asked "Marcus, doesn’t your cousin Leland have sickle cell?"

“Look,” one member of the group exclaimed. “They might both have sickle cell. Maria has it for sure and Marcus might have it since his cousin has it.”

“So what does that mean?” asked another.

“It’s genetic,” said a third student looking up from her text book where she was reading about sickle cell disease. “People with sickle cell trait have only one copy of it, people with the disease have two copies.”

Just then the teacher announced that when students had settled on a question to explore, they could come and get an extended resource that might help them.

“OK, so how can we figure out if Marcus will get the disease?”

“Yeah, and what about if the baby will get it?”

“Wait a second,” said the third student. “Let’s not get confused. You don’t get sickle cell. You’re born with it or not. It’s genetic.”

When the group discussed their questions with the teacher, he said, “I have copies of some family pedigrees for Marcus and Maria that the students did last semester based on a part of the case you haven’t seen yet. These pedigrees were created in Inherit, a computer program that we used for organizing family histories. We’ll be using it later in the semester.”
“Boy, these are confusing,” said one of the students while looking at the pedigree.

“I think the circles are girls and the squares are guys,” he added, “... and see Maria here? Her circle is half black and half white. I guess it means she has the trait.”

The teacher nodded and handed the group a second pedigree. He explained, “Look at the pedigree for Marcus. The people in black, like Leland, most likely have sickle cell disease. Those in gray, like Lil and Tom, might have it, but we’re not sure.”

The group took the pedigrees back and began to work on their questions.
Using the Simulation Evolve as a Resource

GROUP 1

Group 1 decided to focus on the evolutionary relationship between sickle cell trait and the geographical source of a population and sickle cell hinted at by the conversation between the doctor and Maria in Part 3 of Maria’s Travels:

"No, Senora Santini, you have sickle cell trait, not the disease. You will live normally with no restrictions."

"How could I have this? I'm Italian!"

"Most people think that only individuals with African ancestry can have sickle cell," the doctor replied, "but that is not true."

One member of the group commented, “I’m sure we learned something about a connection between sickle cell and malaria in my intro bio course. Don’t people, like Maria, who have sickle cell trait have some kind of protection against malaria?”

“I seem to remember that, too,” began the student next to her, “...and aren’t people in areas of both Italy and Africa at risk for malaria?”

Using a simulation program called Evolve, the group began to explore the question of how long would it take for an allele that is no longer favored by selection to be reduced in a population.

They would model a population of humans that moved from an area where malaria was a constant threat to an area where malaria rarely occurred.
This program had a “canned problem” called “Selection for Heterozygotes” that made a great starting point for the group. They quickly generated a graph showing the number of heterozygous individuals in the population. (Note: These individuals would have the sickle cell trait that protected them somewhat from malaria, but did not give them the sickle cell disease.)

![Selection for Heterozygotes]

The group observed a rise in heterozygotes. This made sense. Selection for the sickle cell trait was the result when, before reproducing, more individuals without the trait died from malaria than those with the trait.
The simulation permitted the group to directly manipulate selection in terms of rates of survival and reproduction. The initial population of 8000 contained 20 individuals with sickle cell disease and 760 with sickle cell trait like Maria. The default values for this population are shown below:

After some debate, the group decided that their question would be:

“How long would it take for the sickle cell allele to be reduced by 50% in a population no longer at risk for malaria?”

In order to simulate a malaria free environment with this same population, selection for individuals without a sickle cell allele and those with just one sickle cell allele were set to the same values. With no malaria risk, heterozygotes were no longer favored by selection over those without a sickle cell allele. Selection for individuals with two sickle cell alleles (sickle cell disease) was not changed. Survival rates and mortality rates were the only variables changed from those in the initial population.
A new graph was generated:

![Graph Image]

### Title: Malaria Free Environment

**Random Num.**  **Generations**

**Initial Population**

- **Hardy-Weinberg Equilibrium**
- Allele Frequencies: 0.950 0.050

- Genotype Numbers: 7220 760 20
- Total Pop: 8000

**Evolutionary Forces**

- **Natural Selection**
  - Survival Rates: 25.0 25.0 22.0
  - Reproduction Rates: 6.0 6.0 5.0
- **Gene Flow**
- **Genetic Drift**

Update  Revert  Done
Looking at this new graph, the group could see that the number of individuals with sickle cell trait in this population didn't change much over time. (Their question had an answer that surprised all of them!)

“But wait,” exclaimed a student, “didn’t we set up the initial population with a really low % with the sickle cell allele. I wonder what % sickle cell allele most populations have in malaria risk areas? Maybe we just didn’t define the question we started with very well, so our results are misleading...”

Group 2
Meanwhile, Group 2 decided to investigate a similar question with a different approach.

“How long would it take for the number of individuals with sickle cell disease to disappear from a population that moved to a malaria free environment?”

This graph showed the number of individuals that have sickle cell disease rather than the number of heterozygous individuals that have sickle cell trait.

The simulation was interrupted after 24 generations.
In order to simulate a “move” to a malaria free environment, the selection for individuals without sickle cell allele and those with a sickle cell allele were changed to the same value. (Selection for individuals with sickle cell disease was not changed.) The simulation with survival and mortality rates for a population without malarial risk, was restarted to produce more generations.

The graph of the "malaria free" population was continued for 26 generations showing an obvious decrease in sickle cell cases:

Two members of the group thought this graph clearly answered their question. Further investigation was unnecessary.

The third member pointed out that the population above showed a decrease in sickle cell cases after it was moved to the new environment, but there still were sickle cell disease cases even after 25 generations. “Why ... and what about the impact of another population that might already occupy the malaria free area?” he inquired further, “Would that speed the process up or slow it down?”
The scenarios on resources use given above were intended to provide you with a sense of the breadth of activities students could engage in while working with cases. While not authentic experiences, they can still serve as a basis for discussion. Scenarios on how instructors use case-based teaching are helpful for the same reason, but we would also like to draw on the experiences of practicing teachers using case-based investigations.

Implementing Case-Based Investigative Teaching in the Classroom

Investigation 1. How Do We Inherit Sickle Cell?
Shelly Peretz, who teaches at Thornridge High School and chairs the science department, developed a website that uses an early version of the Kingdoms Entangled case as part of a biology unit on inheritance using cases of inherited disorders as a way to facilitate student learning. You can access the site directly at:


There are many characteristics of this implementation of case-based teaching that we find useful. First, she required a product - a genetics consulting report - from her students. Although the learning experience was highly structured, the students had enormous flexibility since they could pose their own questions, design how they would answer them, and make their own presentation within the guidelines provided. This well-developed site supports her students by providing several useful links to other sites. She anticipated questions such as how to search the internet, how to cite internet addresses in bibliographies, etc. and provided optional resources that students could use to complete their project.

A facsimile of portions of her site is included on the next page.
Two graduate students travel to Central America to conduct research on the evolution, ecology and genetics of wild corn, teosinte. While in Guatemala, one student, Maria Staiti, 4 months pregnant, becomes dehydrated because of the travel and requires hospitalization. Another student, Derrick Hernandez contracts malaria for which he is treated. In hospital, Maria learns she is a sickle cell carrier. Derrick will be able to continue his field research on ecology and evolution of teosinte and Zea. He collects seeds for Maria's plant breeding work as well.

Back home, Maria consults with sickle cell specialists and learns more about sickle cell trait. Maria's husband learns that he, too is a carrier of sickle cell, and they seek genetic counseling for themselves and their baby. Family histories, pedigree development, and reflection on the counseling session are included. They must decide whether to do prenatal testing and about the options for that testing. They have many questions about sickle cell trait and disease, and what the possibilities are for their child.

Classroom Scenario written by Margaret Waterman, Ph.D.

Your assignment for the next three weeks will be to investigate this disease and prepare a "story book" about the disease. The genetics counseling community ascribes to a belief in non-directive counseling. That is, they feel that it is their duty to provide all of the information that is available and desired by a family so that they can make the decisions that are appropriate to them based on their own cultural, moral, religious, etc. beliefs.

Your investigation should include medical information important for people with this disease so that they can live a healthy and prolonged life. This might include:

- a pedigree for the family described
- family members who appear to possibly have the disease
- a prediction of the chances of their offspring having this disease
- the ethical and social issues involved in this case for the child and the parents

Each image must have a caption. The presentation will be given using ClarisWorks® or Microsoft PowerPoint® presentation software. It should be written such that someone else could view the presentation and understand the key points without an accompanying verbal explanation.

You may not violate copyright laws. Any images or other resources retrieved from the internet and used in your presentation must be accompanied by a reference telling where it was obtained.
Investigation 2. Caught in the Act: Agents of Evolutionary Change

Peter Woodruff of Champlain College has developed an investigative case that presents a “natural experiment” in evolution based on a recently published article:


“Caught in the Act” asks students to examine field data on an Old World fruit fly that was introduced to the New World. Using datasets of wing images from populations collected in the yellow highlighted areas shown in the figure below, students calculate wing size and correlate latitudinal information for these populations.


The case is deliberately open-ended and therefore highly adaptable. In the materials Woodruff has provided for the BioQUEST Library, a number of teaching strategies are evident. For example, students could use their findings to discuss the relative contribution in the evolution of wing size in Drosophila subobscura of factors such as:

• Mutation
• Migration
• Nonrandom Mating
Genetic Drift (Founder effect and Bottleneck effect)
Selection (Artificial and Natural)

What is the “Natural Experiment?”
1. Studies reveal that Old World Drosophila subobscura form a latitudinal cline in body size.
2. D. subobscura was introduced into the western Americas about 20 years ago & is now widespread.
3. Sampling after ten years showed no American cline.
4. Samples taken after twenty years are now available.
5. What hypotheses could be tested using these data?

The materials for “Caught in the Act” are included in the Investigative Case-based Learning module.
The Introduction to Kingdoms Entangled frames each of the three cases and is recommended as an introduction when using any of the individual cases. Here it is an example of how one could dissect a case in order to identify questions as well as to determine potential learning issues.

An epidemic caused by a fungus has begun in the US with potentially devastating effects on the corn crop. Derrick Hernandez and Maria Santini are graduate students studying the epidemic and crop improvement. An important resource in their studies is wild corn, teosinte, which may be resistant to the fungus. Teosinte grows in a few isolated locations in Central America. Maria, a geneticist, and Derrick, an ecologist, are headed south for their first field season. Maria went first to Mexico City to do some archival research on Zea at the Tiemplo Major. Derrick went first to Guatemala to another teosinte site. He'll join Maria and other researchers at the main teosinte site in the mountains of western Mexico, near the town of Durango.

Synopsis of the Introduction:

A blight fungus is causing serious disease in corn in the US. Wild corn found in Guatemala and Mexico, teosinte, may be resistant. Crop improvement scientists in genetics and ecology work together in teams to study this plant in the field. Zea can be studied in the archives of a place called "Tiemplo Major." Three kingdoms are represented so far: animalia, plantae and fungi. Already many interactions are suggested within and among these kingdoms.

Potential learning opportunities:

Students are introduced to some of the central event around which these cases are constructed, namely the corn blight epidemic being worked on by Maria and Derrick. It provides an opportunity for students to learn relevant terms and to think about the problem of diseases (especially agriculturally important ones) and how people fight them using genetics, ecology, and clues from ancient corn. Students will need to learn about teosinte - why isn't it used agriculturally? Why hasn't it become modern corn? Why does it live only in Central America?
Some terms students are likely to work on:

epidemic, zea, teosinte, resistance, crop improvement, fungus, genetics.

Other issues that might pertain to this introduction:

how to prepare for foreign travel,
design of field studies (very generally),
ancient agriculture,
evolution of corn,
what graduate school is,
why ecology is important in crop improvement,
the geography of Central America.

A key issue is the teosinte and its importance as a source of resistance. Students could look at resistance in general, and question the importance of biodiversity. Students may become interested in how the genes of one species can be used to improve the genes of another -- which leads to genetic engineering.

Notes on the Introduction

The exact fungus causing the organism is not specified and there are several different species of organisms that cause blight diseases in corn and other major crops. One of the most famous is the 1970 epidemic called southern corn leaf blight caused by Helminthosporium (Bipolaris) maydis, race T which attacked the widely grown Texas male sterile cytoplasm corn cultivars. Such cultivars require no hand detasseling and were seen as a major improvement in agricultural practice. (Potato late blight of Irish potato famine fame is caused by Phytophthora infestans which acts like a fungus, but is actually a protist.)

The Tiemplo Major is an important archaeological site with excellent archives on ancient corn species (up to 3000 years old). As a plant geneticist, Maria wants to understand the history of Zea mays, corn. This line of the case is developed more in Zea's Wild Roots.

Teosinte is a wild relative of modern corn. Humans have been breeding corn and improving its qualities for millennia. Teosinte has a few large kernels on each small cob. Over the centuries cob size, kernel size and kernel number have been improved. There are several species, one of which is interfertile with modern corn. As a source of gene plasm it is invaluable. (For other crops, like potatoes, tomatoes and wheat there are wild relatives that can play the same roles as well.) Teosinte grows in isolated regions at different altitudes in Mexico and Guatemala. Ecological factors in genetic isolation are likely to be important in understanding the continued existence of wild corn.

One of the listed case resources gives data from field-based resistance/infectivity studies for two diseases on corn and teosinte.
Synopsis of Maria’s Travels:

Maria's Travels is the sickle cell storyline. In part 1: While in Mexico Maria collapses and requires medical attention and hospitalization. Some of her clinical symptoms and lab results are included. In part 2, at the hospital, she and her husband Marcus learn that she is pregnant, and that she was most likely dehydrated. Part 3 continues in the hospital where Maria learns she is a sickle cell carrier. It may also be on Marcus's side of the family.

Case 1: Maria’s Travels -

Part 1:

While enroute to Durango from Mexico City, Maria was delayed several days by storms. Worse, she contracted diarrhea, which she began treating right away. After a day's rest in Durango, she made the steep and difficult hike to the research site where she soon collapsed. Her symptoms were abdominal and leg cramping, disorientation, and rapid shallow breathing. Alerted by radio, Dr. Frederico Stegnaro in Durango advised giving her small amounts of saline over the night. The next day she made her way down the mountain on a pack mule and with Derrick’s help (he was feeling poorly himself) to see the doctor.

At the clinic, Dr. Stegnaro took Maria’s blood samples and did a variety of procedures to test out several possibilities. Thin and thick blood slides showed no evidence of malaria, but her blood chemistry was more revealing. Her hematocrit was abnormally high, blood pH lower than normal and K+ very low. He also noted what might be one or two unusual red blood cells. He started rehydration therapy and sent her by ambulance jeep to Mazatlan Hospital.

Possible learning opportunities for Part 1 of Maria’s Travels:

Physiological effects of dehydration, how neurons work and their dependence on electrolytes.

Notes:
Her blood results suggest dehydration (low blood volume leads to higher hematocrit(% of solids), lower pH and low electrolytes). Dehydration and exertion without adequate water could lead to this. The abnormal cells could artifacts. They could also be sickled red blood cells, an extremely rare condition in heterozygotes (see references) that occurs only under conditions of extreme dehydration, low oxygen pressure and exertion. These people DO NOT HAVE sickle cell disease!! Instead , it is a temporary sickling of some cells. Students are not likely to pick up these clues at
this time, but may come back to this part of the case after reading Part 3. It is extremely important to avoid the misconception that people heterozygous for sickle cell have symptoms. They do not except these few reported under extreme conditions. It is highly unlikely that Maria's cells were actually sickled.

Part 2:

Maria's husband of five years, Marcus Woods, met her in Mazatlan where he had flown upon hearing the news of her collapse. At the hospital, additional tests were run to try to determine the cause of Maria's symptoms. Rehydration therapy was continued.

Dr. Margarita Villas-Incle, general internal medicine and Dr. Carlos Luna, a hematologist, visited Maria and Marcus to interpret the blood tests and other results. Dr. Villas said, "We are not sure what exactly caused your collapse two days ago. Dr. Stegnaro was able to find evidence of electrolyte imbalance and severe volume depletion. We think the most likely explanation is the combination of fatigue, diarrhea, and unusual exertion. The dehydration is probably the most important factor. Your baby will not be harmed by this episode."

Almost together, Maria and Marcus exclaimed "Baby?"

"You did not know? We ran a pregnancy test on you as part of the blood work. We do it on all female patients of child bearing age," Dr. Villas said. "You are pregnant."

"I have been trying to get pregnant for four years," Maria said happily.

"This is wonderful news," Marcus agreed.

Dr. Villas said, "Congratulations. Now, though you must be careful to make sure all goes well. You must not return to physically demanding work for at least two weeks, but you can travel home in a day or two."

Possible learning opportunities:
Fertilization and the human life cycle, problems getting pregnant, more on dehydration and how to rebalance the body's fluid and electrolyte levels.
Part 3:

Dr. Luna said, "I wanted to talk with you about some of the other findings. The doctor in Durango reported one or two odd erythrocytes. I did not find these. But I did do a special electrophoresis test on a sample of your blood. Senora Santini, are you aware that you have sickle cell trait?"

Maria, stunned, said, "What? What? I have sickle cell disease?"

"No, Senora Santini, you have sickle cell trait, not the disease. You will live normally with no restrictions."

"How could I have this? I'm Italian!"

"Most people think that only individuals with African ancestry can have sickle cell," the doctor replied, "but that is not true."

Maria turned to Marcus and quietly asked "Marcus, doesn’t your cousin Leland have sickle cell?"

**Possible learning opportunities:** Sickle cell disease (homozygosity for the S allele) vs. sickle cell trait, prevalence of sickle cell worldwide and by ethnicity, genetics of sickle cell, a pedigree for Maria and Marcus, genetic counseling, raising children with sickle cell, testing for sickle cell. As mentioned in part 1, the issue of sickling in heterozygotes can be explored.

**Notes:** A pedigree and notes on family history are included in the resources.

**Synopsis of Derrick’s Malaise:**

Derrick's Malaise is the malaria storyline. In part 1, Derrick travels to Texas, Guatemala and Mexico, becoming ill in Mexico. He has been somewhat lax in mosquito avoidance, although he did take drugs in preparation for his Central American travel. He is diagnosed with malaria and given drugs. His case is reported to the malaria registry at WHO. In Part 2, he relapses and new drugs are given. In part 3, samples of his blood have been analyzed by researchers and are the subject of email as is research on mosquito control and its effects on disease spread, and relations between sickle cell and malaria.
Case 2: Derrick’s Malaise

Part 1:

Derrick waved good-bye to his father and got on the plane for Guatemala. It had been fun visiting the family in Houston, Texas despite the steamy heat so early this summer. His first season of field research was about to start and he was excited. He would have just two weeks to study the ecology of a new teosinte site in the valley of the Rio Huista before going on to Mexico where he would join up with Maria and the rest of the team.

Derrick loves field work. An early riser, Derrick would get up before dawn to be ready to head out at first light. As he had found in Texas, the mosquitoes were worst at dawn and dusk. He was so busy that he just splashed on some repellant, then ignored the mosquitoes as best he could. At night, he faithfully used mosquito netting.

Two days after arriving in Mexico from Guatemala, Derrick felt like he had the flu. He climbed down the mountain (with Maria who was quite ill), to visit the doctor in Durango. After testing his blood, Dr. Stegnaro said, “You have malaria. It’s caused by a protozoan.”

“Oh, isn’t that caused by Plasmodium?” Derrick asked. “I took the drugs the CDC recommended as protection against malaria. Wasn’t that enough?”

“Well, there are several different kinds of Plasmodium, and sometimes people get malaria even if they’ve done everything right,” Dr. Stegnaro replied. “Seems like we’re seeing more and more of it recently.” He prescribed sulfadoxine, an antimalarial drug, and Derrick left. Shrugging his shoulders, Dr. Stegnaro thought to himself, “Here’s another case of malaria I have to report to the World Health Organization.”

After the malaria drugs took effect, Derrick was able to finish his field work in Mexico.

Possible learning opportunities:

Malaria incidence world wide, types of plasmodium, mosquito control, prophylaxis for travelers, the epidemiology of the disease, Plasmodium life cycle, how one tests for malaria, the drugs for malaria treatment and their effectiveness, disease registries.
Part 2:

About a month after returning home, Derrick began to feel sick. His roommate took him to the university clinic. It was the malaria. "How could I have these symptoms again?" Derrick asked the resident, Dr. Welty. "I finished my prescription."

"I'm not sure. We'll be needing a blood sample so we can analyze the bug causing you this trouble. In the meantime, let's try a different drug. I'm going to switch you to chloroquine," Dr. Welty suggested. "You know, malaria is the most common infectious disease in the world. I've got some contacts at CDC who may be interested in your case. May I share your records with them?" Derrick nodded.

Derrick's roommate asked, "Dr. Welty? Can I get malaria from Derrick?"

"You have nothing to worry about," the doctor replied, but Derrick's roommate wasn't entirely comfortable.

Possible learning opportunities: How malaria is spread (it's not just mosquitoes), resistance, more on drugs for malaria.
Part 3:

Dr. Susan Welty glanced at the screen and clicked the Send button.

Possible learning opportunities: This section of the case is packed with issues, many of which are only hinted at. Students might look at the kinds of Plasmodium if they haven't already, the incidence of the different kinds of malaria around the world, the doctor's choice of drugs given we know it's P. falciparum. The issue of controlling one vector population and its effects on populations of other types of vectors is mentioned. There is also a hint in the note to Eda about the relations between malaria and sickle cell disease, and to Emily about relations between the parasite and the host blood.

Notes: With these questions there are many opportunities for using simulations and modeling interspecies relationships, evolutionary mechanisms in sickle cell, control of insets (Curcaco).
Synopsis: Zea's Wild Roots:

Part 1: While Maria is away, Marcus reads about a teosinte species that might be the one Maria is studying since it is interfertile with corn. Part 2: Derrick brings a gift of a replica of ancient pottery with corn imprints to dinner. Multicolored ornamental corn embellishes the gift. Part 3: The dinner conversation turns to the reasons Maria and Derrick chose to work on corn improvement, and the weather factors in the 1970 corn blight.

Case 3: Zea’s Wild Roots

Part 1:

Marcus Woods, Maria’s husband, began moving the cardboard boxes from storage to their new home office. It was just the sort of project he liked doing while Maria was away. After unsuccessfully struggling with a file drawer, he sat down and picked up one of her Ag papers entitled Corn’s Missing Link. “Was this the wild maize Maria had talked about collecting in Mexico?” Well, he could always ask her when she phoned on Tuesday.

In 1978, he read, a student at the University of Guadalajara named Rafael Guzman had discovered a new species of teosinte growing wild in the high plains of Jalisco, Mexico. “Hmm, what makes teosinte a missing link?” Marcus wondered. He continued reading. The teosinte species was named Zea diploperennis. Furthermore, it was considered quite important that this species was completely interfertile with corn.

Possible learning issues:

the roles of students in research, the importance of Zea diploperennis to corn improvement research (its resistance genes and interfertility with corn), what are evolutionary missing links?

Part 2:

Derrick accepted the invitation to dinner shortly after arriving from Texas where he had gone for his sister’s birthday. Derrick's recent bouts with malaria were certain to be discussed, but the real reason for the get together was to celebrate Maria’s unexpected and long awaited pregnancy. Derrick smiled to himself, quite pleased at the non-traditional gift he brought. Knowing Maria’s love of archival work on the ancestry of corn, he had obtained a replica of Indian pottery over 600 years old. The Central American piece featured imprints from cultivated corn of the period. Even though the ears were small, it was easy to see multiple rows of seeds.
Derrick’s roommate was intrigued by the small ears of ornamental corn Derrick had used to decorate the package. "How come regular corn doesn't have all these colors?" he wondered.

**Potential learning issues:** the history of corn, selection for multi-seeded cobs, corn kernel color genetics.

**Part 3:**

Between bites, Marcus began, “I met Maria while working with OXFAM, a hunger relief organization...”

“Remember stuffing all those envelopes and making all those calls?” Maria said as she flashed Marcus a smile. "Derrick, you’ll be interested in this. At that time corn crops were being lost in Africa due to maize streak virus...”

“Thousands of people were suffering without those crops,” Marcus interjected.

“... and the teosinte species found in the late 70’s proved to be resistant to the virus and gave some real hope. That’s when I knew I was going into corn genetics,” Maria continued.

“You know, what made me decide to study Zea,” Derrick said, “was hearing about when my uncle lost his entire crop in 1970 due to southern leaf blight. He just couldn't understand why every field in the county was affected.”

Maria nodded her head knowingly and said simply, “Weather...”

**Potential learning issues:** the world hunger problem and organizations working for hunger relief, the role of maize streak virus in hunger problems in Africa, resistance to disease and how that gave real hope, how disease spreads leading to crop devastation.
Selected Resources and References

Books


Pamphlets and Brochures


Simulations


Web sites (accessed October 1999)

http://bioquest.org/case.html
   Molecules, Malaria and Maize: Case-Based Learning with the BioQUEST Library

http://www.ag.iastate.edu/departments/plantpath/extension/leaf1.html
   Pictures of many corn leaf diseases

http://www.gene.com/ae/AB/WYW/fink/fink_2.html
   The First Genetically Engineered Plant

http://www.dukcnws.duke.edu/Research/CORN.html
   NEW EVIDENCE FOR CORN'S ANCESTRY

http://www.agron.missouri.edu/
   MaizeDB: A Maize Genome Database

http://www.rics.bwh.harvard.edu/sickle/menu_sickle.html
   Sickle Cell Anemia

http://www.kfshrc.edu.sa/annals/143/rev9239.html
   THE GEOGRAPHY OF SICKLE CELL DISEASE

http://uhs.bsd.uchicago.edu/uhs/topics/sickle.cell.html
   Sickle cell disease - Kristy Woods

http://www.ils.nwu.edu/~e_for_e/nodes/NODE-298-pg.html
   Testing Sickle Cell

   Tables on prevalence and testing methods--Clinical Guide 6: Sickle Cell Disease

   Sickle Cell Disease in Newborns and Infants -- A Guide for Parents

   Building a Better Mouse Model for Sickle-Cell Disease

   How Do We Inherit Sickle Cell?

http://www.who.int/ith/english/country.htm
   malaria situation by country, with vaccination requirements

http://www.who.int/ctd/index.html
   malaria info from WHO
http://wonder.cdc.gov/wonder/prevguid/tp_00557.htm
CDC prevention guidelines malaria

http://www.lbl.gov/Science-Articles/Archive/malaria-microscopy.html
Malaria researchers take closer look at pathogen inside red blood cell

http://wonder.cdc.gov/wonder/prevguid/m0046488/m0046488.htm
Click on number of malaria cases by state for map. Number of malaria cases, by Plasmodium species and area of acquisition -- U S, 1993  Note: only works if you copy this address

http://wonder.cdc.gov/wonder/prevguid/m0046488/m0046488.htm#Figure_2
Figure 2. Number of US malaria cases by state 1992. Note, copy this address

http://www.cdc.gov/ncidod/EID/vol2no1/zuckerei.htm#figure2
Areas of the United States where malaria was thought to be endemic in 1882 and 1912.

http://www.who.ch/programmes/ctd/ctd_home.htm
Division of Control of Tropical Diseases

Genetic research on malaria. An incredible database of information

http://www.med.nyu.edu/Research/J.Vanderberg-res.html
Research tying molecular approaches to life history in malarial organism

http://pharminfo.com/pubs/msb/malaria_TX.html
Medical Sciences Bulletin Reports possible re-emergence of malaria in US.

http://konops.immb.forth.gr/AnoDB/Species/malariaspeciesR.html
Malaria vector species: Anopheline vector-species of malaria in the epidemiological zones

http://www.who.int/ctd/html/malariaepidat.html
Three part article on most recent world-wide malaria epidemiology. Use Acrobat reader

http://www.niaid.nih.gov/factsheets/Malaria1.htm
MALARIA

http://www.malaria.org/WHAT.HTM
THE MALARIA FOUNDATION basic information on mosquitoes and malaria

http://www.med.nyu.edu/Research/J.Vanderberg-res.html
Parasite-Host Cell Interactions in Invasion and Immunity
Articles
Maps

Educational approaches are constantly revised. These "new" methods of teaching and learning enable us to deal with the objectives each generation feels are essential for their learners. The case study approach is a method of providing students with an opportunity to use stories of people dealing with science-based issues (i.e., the cases) as a way to structure their own learning. The cases provided here are specially designed to serve as springboards to student-designed investigations. Case-based learning is student-centered. Working with a teacher-provided case, students determine issues they wish to pursue, and then use a wide variety of approaches and resources for learning.

The case study approach to learning biology may feel awkward at first since it is different from other more structured ways to learn. Although the general area of biology under investigation is defined by the case, you generate the questions which will define your own topic of study. You will find yourself posing problems, trying to solve them, and presenting conclusions that represent your own findings to others. Your instructor as well as your classmates are collaborators in this process.

You may find yourself working in a group. This is an excellent way to begin exploring biology since scientific investigations necessarily involve similar group dynamics. If you are not planning on becoming a scientist yourself, it is nevertheless essential for you to develop a familiarity with the way scientists work. This will help you better understand biological issues that affect you as a global citizen.
What does a case look like?

Cases come in many formats, including videos, computer-based cases, and written forms. Text-based cases are the most common and they can be one paragraph or many pages long. Here is an example of a short biology case. The first thing to do is to see what the case is about. Read it through to get a sense of the story and issues. One good case-learning method when you’re working in groups is to have one student read the case out loud while the others read along silently. This sounds corny, but it gets everyone “on the same page” and students say it helps them get started. Have a good dictionary and reference books available to be able to quickly look things up.

**Fleaing Louisiana**

**Case author: Margaret Waterman, 1996.**

Moses Anders hung up the phone after talking with Ella Cardinale-Jones about her troubles. She had ticks on the dog, roaches in the house and hungry mosquitoes chewing up her kids. “Now Mr. Anders, I’m used to seeing some bugs around -- this is Louisiana. But it seems no matter what I do there are more and more of them. How can I get rid of them? I don’t feel like my children are safe.” Ms. Cardinale-Jones was the 19th caller about these insects this month, and it was only January 7th.

Moses Anders is an intern with the Louisiana Cooperative Extension Service while he finishes his BS in biology. Moses dug out the last of the old tick, flea, and roach pamphlets in the files to send a copy to Ms. Cardinale-Jones. It said that these insects shouldn’t be significant problems until late spring, the pamphlet did not really answer Ms. Cardinale-Jones questions, and it didn’t mention mosquitoes.

He talked about this situation with Fran Collins, his internship mentor, an agent who has been with the Service for several years. “Yeah,” she said, “it’s been really busy this winter. In fact, it’s been this way all the time for a couple of years now.” She agreed with Moses that the pamphlet needed to be updated and that he could take on the project, once he’d given her a work plan and time line.

Moses and Judy Yee, an intern in the public health office traded stories over lunch at one of the city’s crowded outdoor cafes. She told him that the first case of Lyme disease in the area had recently been reported, and he told her about his new project. Their talk turned to the weather as they made their way back to work.
How to begin?

Individuals approach learning with cases in very different ways. You may wish to consider doing one or more of the following after reading a case:

- **Recognize potential issues**
  Go back and read the case again, this time noting words or phrases that seem to be important to you in understanding what the case is about. If you have a hard copy, underline these phrases. You are looking for “learning issues” that you might explore further. Jot down your ideas and questions about these phrases. If you are working in a group, this approach might be done as a group discussion, with one person keeping a list of issues (maybe on the chalkboard) as they are raised.

Here’s an example of some of the kinds of issues raised in one paragraph of *Fleaing Louisiana*:

Moses Anders hung up the phone after talking with Ella Cardinale-Jones about her troubles with ticks on the dog, roaches in the house and hungry mosquitoes chewing up her kids. “Now Mr. Anders, I’m used to seeing some bugs around -- this is Louisiana. But it seems no matter what I do there are more and more of them. How can I get rid of them? I don’t feel like my children are safe.” Ms. Cardinale-Jones was the 19th caller about these insects this month, and it was only January 7th.

What we know now: It’s January in Louisiana. There are lots of insects, perhaps more than usual, and people with safety concerns are calling Moses Anders about this.

Potential learning issues: Insect populations and the factors that affect them. Problems posed to humans by insects. Insect control measures. Unusual insect occurrences in winter. The job held by Moses that would lead people to call him.

- **Brainstorm for connections**
  There are several ways to do this. One way is to think about the case as a whole and see if there are underlying themes. Global warming, insect-borne diseases, and careers in biology are some themes many people identify for “Fleaing Louisiana.”

Another way to brainstorm is to list questions you have as a result of reading the case. Using the first paragraph again as an example, here are some questions raised by learners who have worked with this case:

Why are there lots of insects in January? What affects the number of insects at any given time of year? Are there really more than usual? What is the usual pattern?
Why is Ms. Cardinale-Jones concerned for the safety of her children? What diseases do ticks, roaches and mosquitoes carry? Are there other reasons besides disease to be concerned about these insects?

What can Ms. Cardinale-Jones do to control the insects? What advice should Moses give her? What is the biology of ticks? Roaches? Mosquitoes?

Why are people calling Moses Anders about this? What do they think he knows or can do for them? What sorts of jobs deal with these issues?

• Pose specific questions

“One of the greatest challenges in biology is to frame appropriate and productive questions that can be pursued by the technology at hand. You have probably had a great deal of experience in solving pre-posed problems, such as those found at the end of textbook chapters. However, if you were asked to go into a lab or out in a field and pose a research question, you will find that this is often difficult to do without some practice....

(The BioQUEST Library IV: A Note to the Student 1996)

Brainstorming can lead to a long list of questions, not all of which you or your group (or your teacher) may choose to pursue. Spend time as a group identifying key issues of interest. For our example, there are several types of questions on this list that lead to different types of learning. Here are some examples.

<table>
<thead>
<tr>
<th>Learning</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Further brainstorming</td>
<td>“Why is Ms. Cardinale-Jones concerned for the safety of her children?” or “What affects the number of insects at any given time of year?” or “What sorts of jobs deal with these issues?”</td>
</tr>
<tr>
<td>Searching out basic facts.</td>
<td>“What diseases do the insects carry?” or “What is the biology of ticks?” These questions in and of themselves do not pose a scientific research problem, but learning more about these may lead to other questions that are scientific.</td>
</tr>
<tr>
<td>Finding information, analyzing it and finding patterns.</td>
<td>“What is the usual pattern of insects in Louisiana?” and “Is it different this year?” These questions might lead you to the Internet or elsewhere to get insect sampling data for analysis.</td>
</tr>
<tr>
<td>Decision making.</td>
<td>“What advice should Moses give her?” You will need to understand the issues, and evaluate the consequences of the options before you can answer this question.</td>
</tr>
<tr>
<td>Scientific investigations</td>
<td>“What affects the number of insects at any given time of year?” could be refined to focus on climatic variables. These could then be investigated by modeling (with Biota or EDM), by actually collecting weather and insect population data, by using data sets collected by others, or by finding published information on the topic.</td>
</tr>
</tbody>
</table>
• **Obtain additional references/resources**

No matter what type of question you pose, it is likely you will seek and use other resources to help you develop a persuasive answer. Resources may include your textbooks; other library materials; results of computer simulations; results of lab or field research; articles, data sets, maps, emails, or other electronically based resources; pamphlets from organizations; interviews with experts; museum exhibits, etc., etc.

• **Define problem further by sharing your views and concerns**

<table>
<thead>
<tr>
<th>Why are some research questions considered better than others? What are the cultural, personal, and political biases that influence what questions are posed and how they are posed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>(The BioQUEST Library IV: A Note to the Student 1996)</td>
</tr>
</tbody>
</table>

As you develop problem and questions you want to investigate, it will be important to consult with others: most likely members of your group or other classmates. Talking about your ideas and plans with others is an important step in refining problems, and can lead you to different perspectives that might be good research problems. Continue this practice of sharing with others as you gather evidence in answer to your problem, and as you prepare to present your conclusions.

**What am I expected to do with my question(s)?**

Once you have a problem you want to investigate, you might consider the following:

• **Design and conduct investigations utilizing:**

  - laboratory /field methods
  - computers (software modules, spreadsheets, graphics, etc.)
  - new sources (further references, interviews, etc.)

• **Initiate debate on views or outcomes**

**How to end?**

When you are ready to present your own conclusions, consider the following:

“... you must confront the issue of closure in research. How do you know when you have a "right" answer? When is research done? Scientists do not arrive at a final answer; usually research is abandoned for a variety of reasons, including time, resources, and most importantly when the scientific research team is “satisfied” with their conclusions, that is when the solution is “useful” for some purpose.”

(The BioQUEST Library IV: A Note to the Student 1996)
• Develop analyses/reports to persuade others of your ideas

“Research is not complete, no matter how many experiments have been conducted, no matter how many puzzles have been solved, until peers outside of a research team are persuaded of the utility of the answers. Persuasion is a social process and an essential one for you to experience in order to understand the nature of scientific theories and paradigm shifts. Communication in the science community is an active process full of controversy and debate. The productive side of science involves open criticism of the methods and conclusions made by a research group. This controversy and debate is important to the creation and acceptance of new scientific knowledge.”

(The BioQUEST Library IV: A Note to the Student 1996)

• Produce materials that support understanding of the conclusions you are making

The possibilities are vast: posters, poetry, plays, videos, booklets, pamphlets, consulting reports (if you are role playing), artwork, designs for new technology, scientific reports, a new case study, etc.

How are collaborative efforts assessed and evaluated?

Like most undergraduates, you may have concerns about the assessment and evaluation methods used in group work.

Peer review is a key feature of how scientists judge each other’s work. You are likely to peer review one another’s proposal, investigations, and persuasive materials. Recently, self-assessment has become a more frequent component of assessment in science, especially as more group work is done.

The bottom line is that there are many ways to assess group products and group process. Some teachers give a group grade and an individual grade when both group and individual products are developed. Some include the peer evaluations and group self-evaluations. If he or she has not already explained, you will want to discuss with your teacher how she or he plans to assess students work.

Why does my instructor want me to use the case study approach?

One clearly defined criticism of biology education for undergraduates lies in the inability of most students to link the biology they learn in college with the biological issues they face day to day.
If we believe that biology learning should result in applicable, flexible knowledge of the living world and how to investigate it, then case-based learning may help. When used to generate open-ended investigations, however, case-based learning offers promise of meeting the needs of biology learners. Cases, coupled with powerful tools for investigation, are about meaningful, real-world problems and how to approach them collaboratively using science knowledge and processes. Learning with cases puts the learners more in control of the problems to be studied and the resources used than most other types of learning.

Some kinds of teaching in biology may actually limit the interactions students have with the discipline. Curiously, even the labs which were often described as giving the student an opportunity to explore methods and questions with greater autonomy than in lectures have been recognized as problematic. In fact, they have been criticized for years.

Reform in biology education has been called for so that all biology students may become familiar with the process of science, not just its products. For students to value a scientific approach to problem-solving in their own lives, they should experienced using scientific reasoning in the classroom, laboratory or field.

"...study in botany has often become too mechanical, too stereotyped, too restrictive, too dependent upon a laboratory manual which lays it all out on the line and which thus gives the student little opportunity for independent work, for display of initiative for the exercise of imagination, for the satisfaction of personal curiosity." p. 495


"... an effective way of presenting first-year biology involves an emphasis on the conceptual framework of the discipline, a ruthless de-emphasis of the incredible terminology that plagues many introductory courses and texts, an explicit concern with important human problems for which the biological sciences may suggest solutions, and an emphasis on the strengths and limitations of scientific procedures."