Project Learning Tree®

Exploring Environmental Issues: Biotechnology Supplement

Introduction to Activity 4

Forest Biotechnology

Background

- In this activity you will consider the ways biotechnology has been used to improve the physical or genetic traits of trees
- You will learn about tree improvement methods, then experiment with some common lab and field procedures used in forestry

What is the current role of forests?

Forests are important because they provide:

- Climate regulation – temperature, moisture, wind, etc.
- Local habitats
- Nutrient recycling – N, P, S, C, O, water...
- Consumable goods for the human culture
- A source of carbon through photosynthesis

What are the modern demands on forests?

- One-half of the earth is covered by forests
- 50% of the wood used globally goes to heating or cooking
- Forests are being cleared rapidly to make land available for farming or livestock

Forest Management in the Past

- Artificial selection was applied to trees more than 6000 years ago to make orchards from trees with the best physical traits
- Reforestation began as early as 2300 years ago in Egypt in an effort to reduce erosion and off-set firewood demands

How have forest management practices changed?

Selective breeding practices where applied to reforestation in the early 1900's using:

- Inbreeding
- Outcrossing
- Hybridization
- Introduced non-natives
- Backcrossing
- Cross pollination
- Vegetative cloning

What is the outcome of these practices?

- Hybridization has been used to make “plus” tress that exhibit genetically superior traits
- “Plus” trees are then used as the parents to provide orchards of highly selected trees from a limited genetic stock using grafting, inbreeding, back crossing or vegetative cloning

What is the outcome of these practices?

- The drawback is less genetic variability leaves trees vulnerable to disease
- Ecosystems become more homogenous, similar to a monoculture with less species diversity on the higher trophic levels
- Single species forests create a problem of nutrient depleted soils

What is the future of biotechnology in forest management?

Trees may be genetically engineered for:

- Herbicide resistance
- Drought resistance
- Fast growth of firewood or erosion control species
- Environmental tolerance to poor soils, a low pH or soils contaminated with toxins (such as salt)

What are the risks and benefits of using biotechnology on forests?

Risks include:

- Lower resistance to pest species and disease
- Depletion of soil nutrients
- Lack of biodiversity
- It may lead to pesticide resistance in insects
- Cross-fertilization may occur between GE species and non-GE species
- Modified species may invasively outcompete native species

Benefits include:

- Resistance to herbicide application
- Land area is freed up for agricultural use or for use as biological preserve
- Trees can be grown on marginal land or degraded land areas
- Faster growing trees can be produced for higher rates of consumption

What role do forests play in your life?

- How do you use the forests of this country and of other countries?
- Why does it matter if the forests have high species diversity or low species diversity?
- What do you want to learn about the processes used by forest scientists?
- How do you think forests should be managed?

Part A: Background

- For most of the last 6000 years tree improvement techniques have been focused on improving the physical traits of trees such as the strength of the wood, the grain, the height of the tree, the fruit produced, etc.
- Trees were bred using artificial selection, cross breeding, inbreeding or outcrossing where botanists hand-selected the parent trees based on desired physical traits

Part A: Background

- With recent advances in the field of genetics scientist have developed procedures to locate, replicate and/or insert specific genes that can produce desired physical traits in trees
- Genetic engineering procedures are becoming more and more sophisticated and specific

Tree improvement techniques – are they all the same?

In Part A you will:

- Research one of the five tree improvement techniques
- Create an informational brochure on your topic
- Peer grade class brochures for your topic
- Read and take notes on brochures from other topics

Reflection questions

- What precautions should biologist take when using each technique so the natural ecosystem surrounding managed forests has the least amount of disturbance?
- Which tree improvement techniques increase the genetic diversity of the forest? Which techniques decrease the genetic diversity of forests?
- What is the relative time frame for each technique?

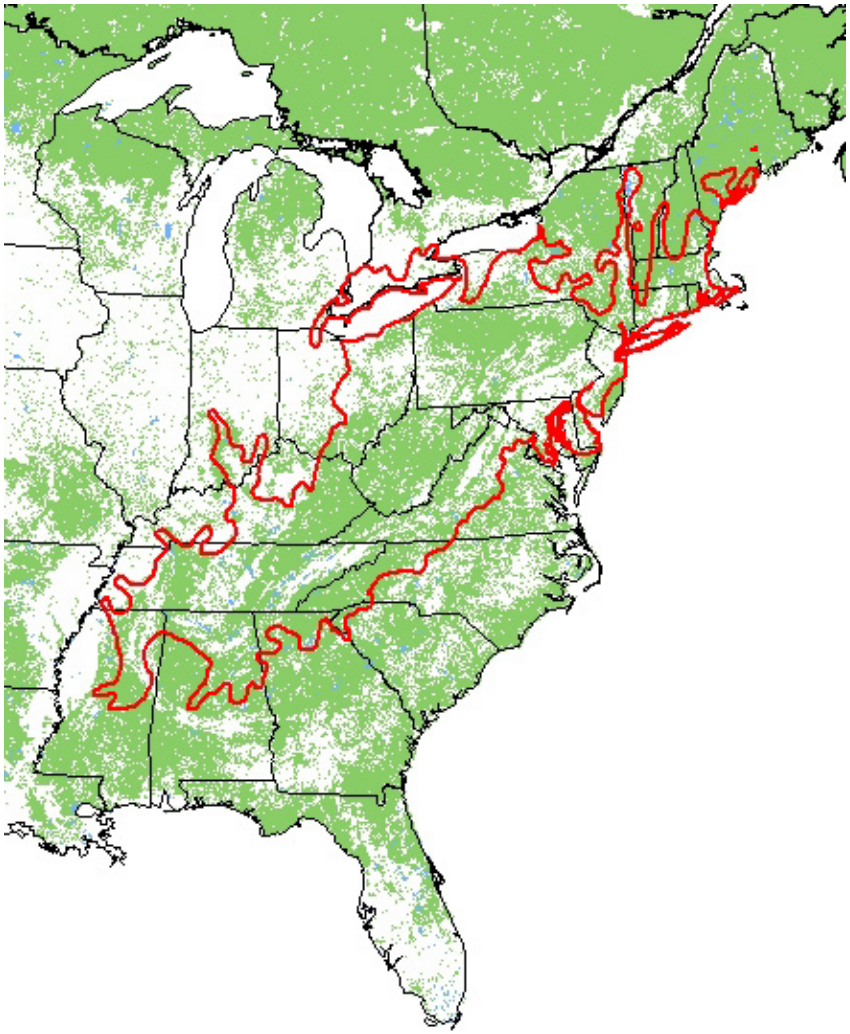
Part B: Background

- Up until the early 1900s the American chestnut tree was the most common naturally occurring tree in eastern forests
- The strong, fine-grained, rot-resistant wood was used for nearly all building purposes, the nuts were gathered for food by humans and animal alike and shade provided by these 100 foot beauties was a nurturing addition to the ecosystem
- Today there are no mature American chestnuts trees between Maine and Georgia
- What has happened to this species?

Where are the American chestnuts?

In Part B you will:

- Map the historic range of the American chestnut at various time intervals to see how the species' distribution has changed over time
- Perform a webquest to learn how what caused the demise of the Amer. chestnut and how the loss of this species has impacted humans and the environment

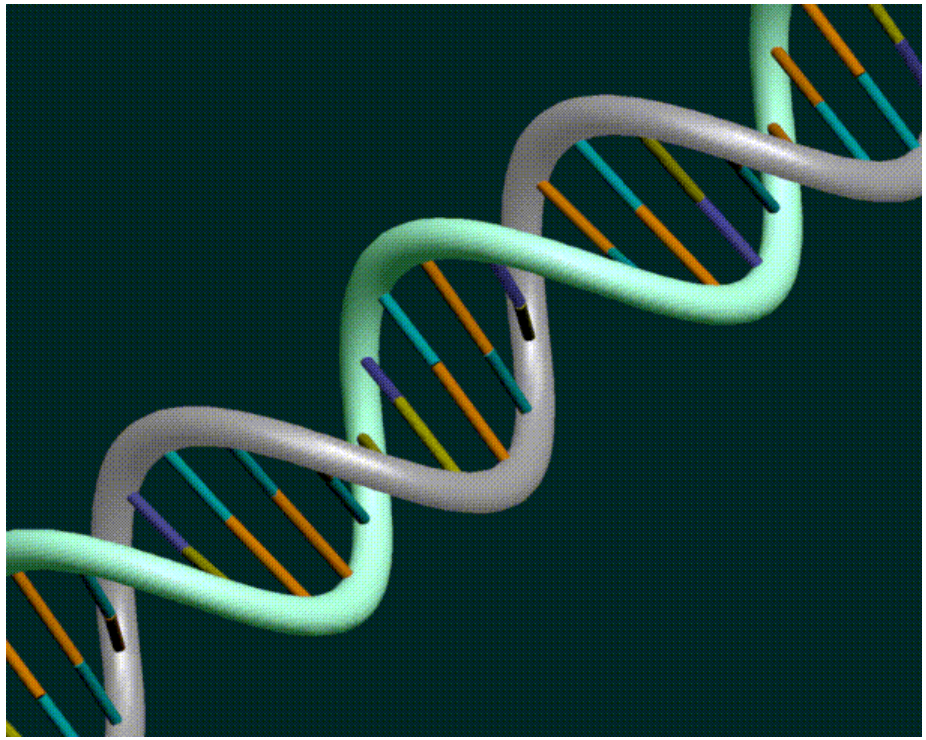


Reflection questions

- Why does the history of the American chestnut matter to people today?
- Can you think of an organism in your region that has undergone a change in range or distribution?
- If so, what were the contributing factors for the changes in range or distribution of these species?

Part C: Background

- Modern methods of tree improvement include the manipulation of DNA to analyze the genes of a species or incorporate new genes that are desired in a lineage of trees
- In this part of the activity you will first extract DNA from a plant and then cut plant DNA into fragments to analyze the genetic relationships between closely related individuals



DNA Lab Experiment

During the first experiment of Part C you will:

- Mash the strawberry in plastic bag with extraction buffer
- Pour the mixture through mesh to collect liquid in a tube
- Use small amount of resulting liquid and alcohol to collect DNA

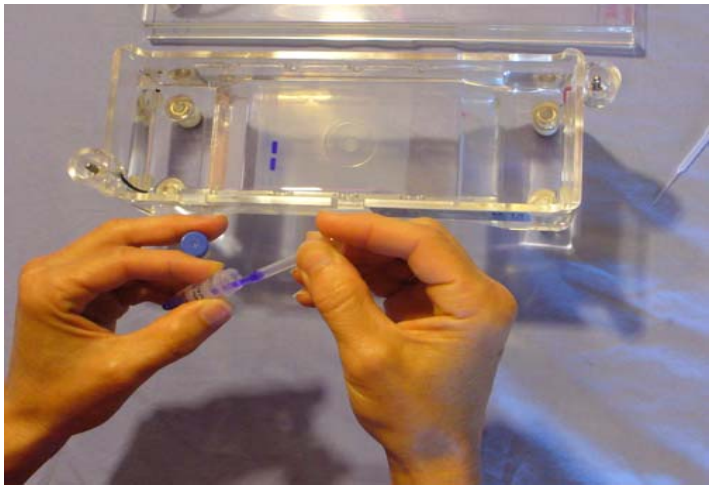
Activity: DNA Analysis Lab using Electrophoresis

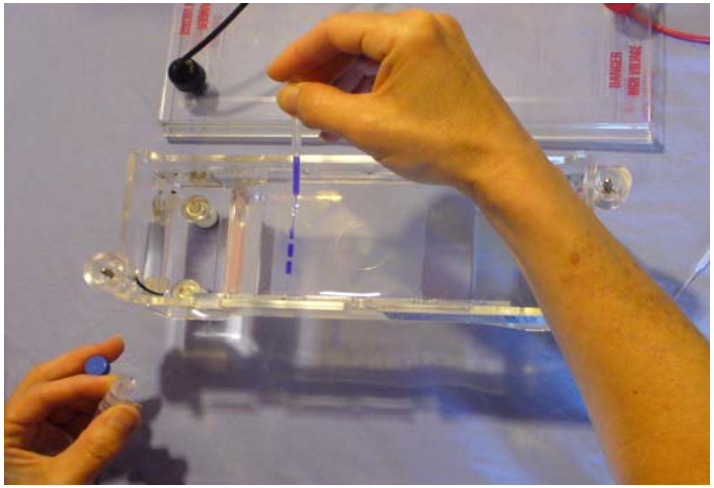
During the second experiment of Part C you will:

- Load gel with DNA samples
- Run electricity through gel to separate DNA fragments by size
- Compare DNA banding patterns of parents and offspring to determine the genetic relationships

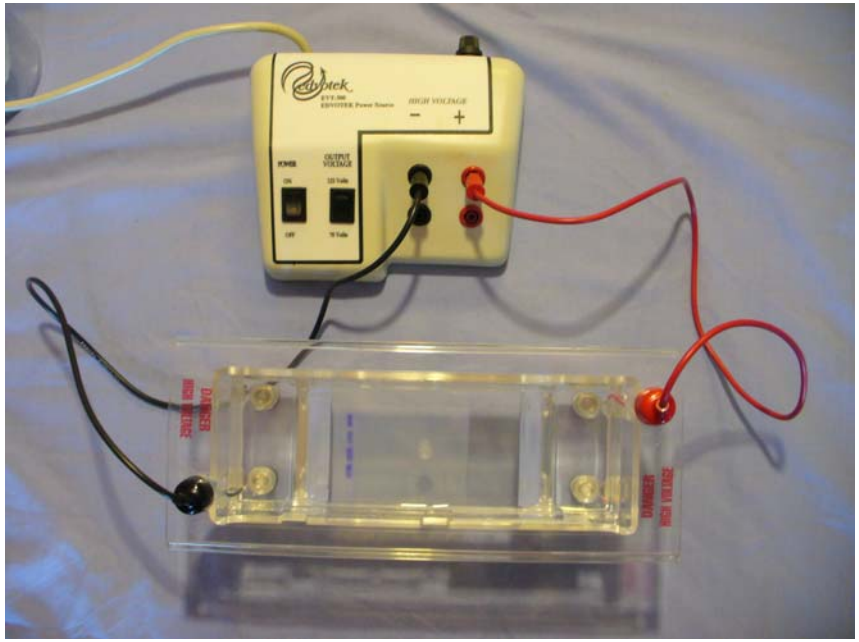
DNA Analysis Lab Procedure

- Load gel with DNA samples
- Keep your hand steady by resting it against the frame of the gel rig
- You may want to practice the technique first on a dry gel that is not submerged in the buffer





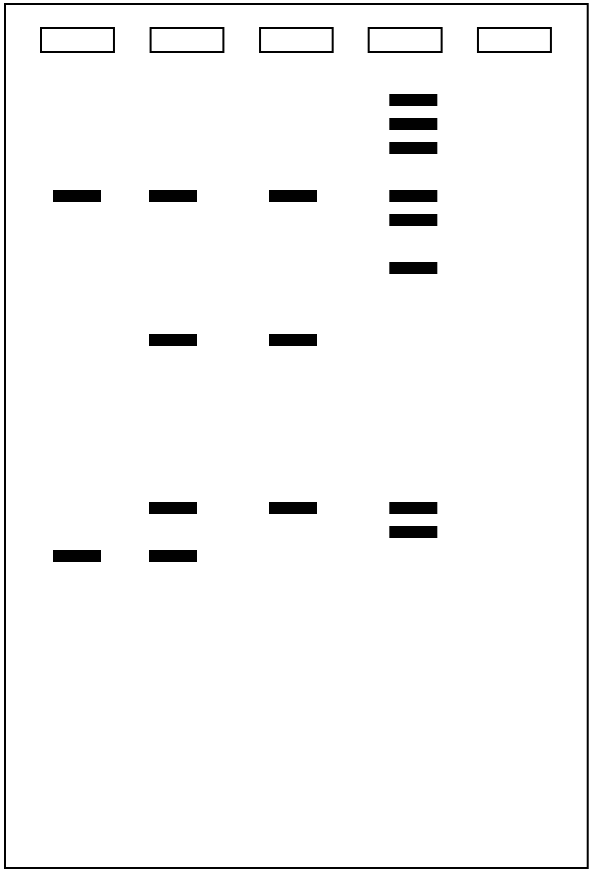
DNA Analysis Lab Procedure



- Run electricity through the gel to separate DNA fragments by size
- The current on the + cathode will attract the negative ends of the DNA strands and force them through the matrix of the gel

DNA Analysis Lab Procedure

- Compare DNA banding patterns of parents and offspring to determine the genetic relationships
- The hybrid offspring should have some fragments of DNA similar to each parent



Reflection questions

- The DNA fragments are generated by allowing restriction endonucleases to cut the DNA at certain patterned parts of the DNA – explain how the hybrid offspring has some fragments the same length as each parent
- Draw a diagram of what the fragment pattern might look like if your DNA was run next to a lanes of DNA from each of your parents
- Draw a diagram of what the fragment pattern might look like if the hybrid offspring was backcrossed with one particular parent for several generations

Parts D and E: Debating controversial issues

- Advances in science are often accompanied by controversy both within the scientific community and in the general public
- In some cases there is a lack of understanding or lack of information on the topic, in other cases informed parties have opposing opinions based on ethics or religion
- Part D and E will present three separate case studies where you will have the opportunity to research and develop an opinion on a controversial biotechnology topic

What's your point of view?

During Parts D or E you will:

- Pick a position or stance on a controversial topic
- Research your group's position to develop your best arguments and refute criticism
- Hold a debate against other teams during class

Reflection questions

- What types of information did you find to be the most persuasive?
- How did the delivery of debate information (tone of voice, volume of voice, etc.) effect the persuasiveness of the argument?
- Regardless of which side you researched and presented, what is your current position on this topic now that you have more information?

Part F: Mapping trees in your community

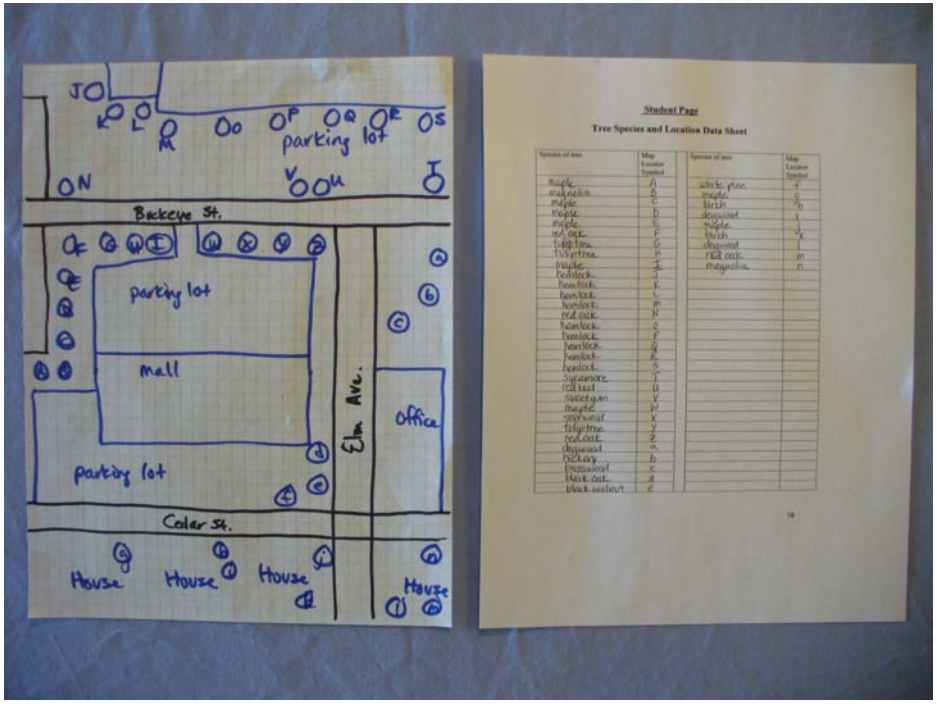
During Part F you will:

- During this activity your class will generate a composite map of all the trees in a particular region near your school
- Individual portions of the region will be mapped by your group
- Each group will be responsible for identifying the location and the species of all trees on their portion of the map
- When all the group maps are reassembled into a composite map the area can be analyzed to predict what would happen if a particular tree species contracted a disease

Mapping trees in your community

- During this activity your class will generate a composite map of all the trees in a particular region near your school
- The map will start out as a simple street map with major landmarks

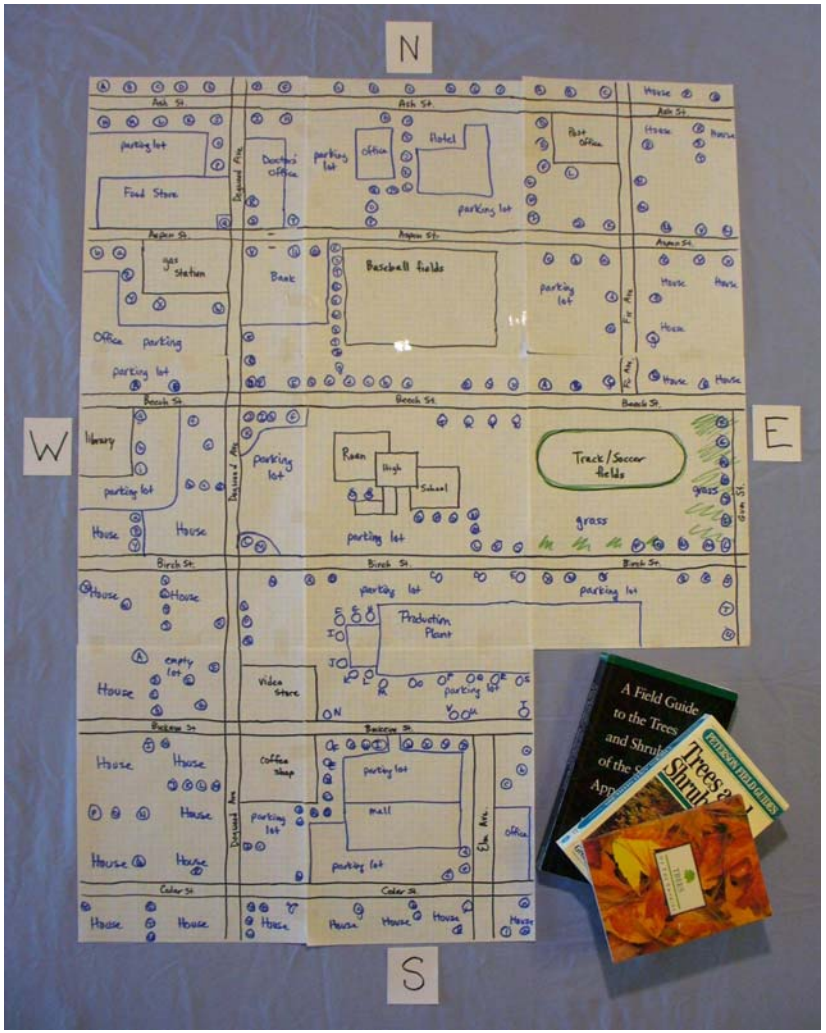
Mapping trees in your community



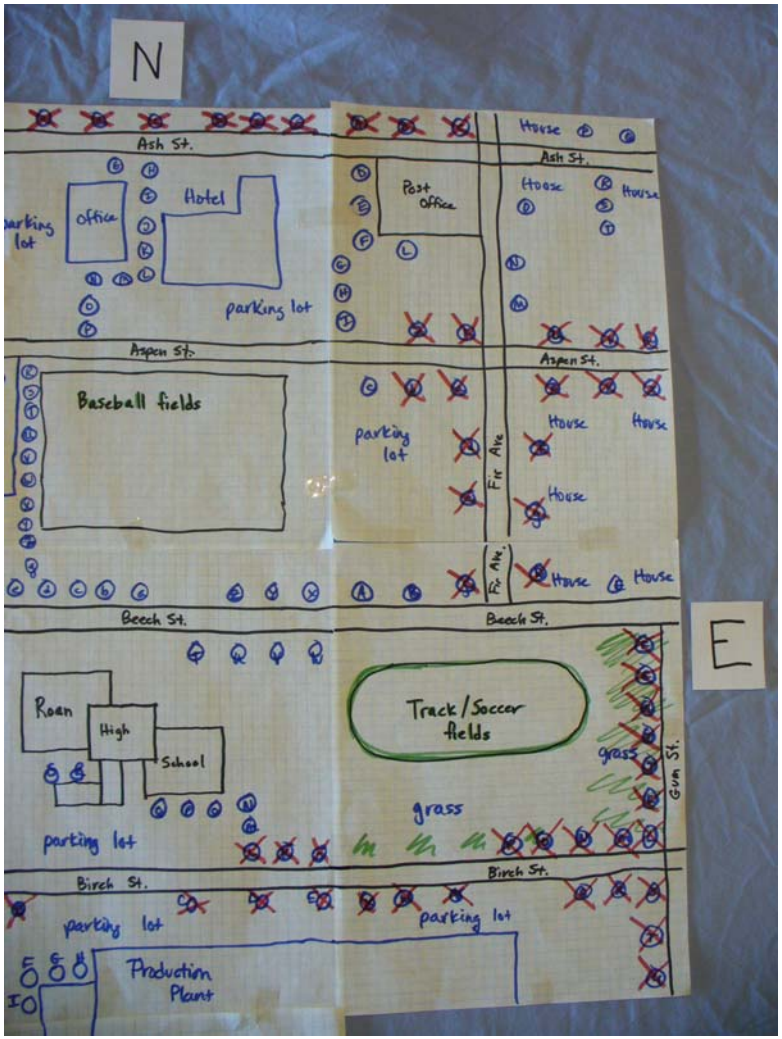
- Individual portions of the region will be mapped by your group using tree identification books and a map of one part of the neighborhood
- Trees will be added to a list that is coded with a letter for each tree on the map

Mapping trees in your community

- Each group will be responsible for identifying the location and the species of all trees on their portion of the map
- These will be used to make a composite map of the area



Mapping trees in your community



- When all the group maps are reassembled into a composite map the area can be analyzed to predict what would happen if a particular tree species contracted a disease

Reflection questions

- What did you enjoy most about this activity?
- Do you feel that you know your community any better now that you have mapped the trees in your immediate area?
- If there was one species of tree that was destroyed by a disease, which species would have the greatest overall change in the ecosystem that you mapped?
- How do you think the other trees, insects, birds and other animals in the area would respond to the loss of this species?
- How do you think the people would respond?

What do you know?

- Historically, which tree improvement techniques have been the most powerful in changing the usefulness of trees grown as a commodity?
- Traditional methods of tree improvement focused on the phenotype, or physical characteristics of trees. With advances in genetics, scientists have begun to focus on the genotype, or genetic characteristics of trees. Describe which focus is more important, defending your position with facts and examples.
- How do the available procedures or techniques determine the direction of scientific practices?