Seeds of Change

Principle of Plant Biology #3

Land plants evolved from ocean-dwelling, algae-like ancestors, and plants have played a role in the evolution of life, including the addition of oxygen and ozone to the atmosphere.

If you could travel back in time 10,000 years, most of the plants that you eat would look completely different. Corn, tomatoes, oranges, and many other plants have been dramatically changed by humans through selective breeding. Likewise, if you traveled back 200 million years, almost all of the plants you know would not exist. You would see mosses, ferns, and gymnosperms (plants with seeds but no flowers). However, you would see no fruits or flowers since angiosperms (flowering plants) had not yet evolved.

If you traveled back two billion years, you might think that Earth was another planet. Earth's land was mostly barren. There were no trees, grasses, or shrubs. The air contained almost no oxygen and no ozone to offer protection from the sun. Yet somewhere in the oceans, a few algae-like organisms were making their start. These ancestors of modern plants transformed the planet by making oxygen, which formed ozone.

Although modern plants can look very different from each other, you can still observe their common ancestry by examining their DNA. The common ancestor of plants had DNA containing a long string of adenines, thymines, cytosines, and guanines (A's, T's, C's, and G's). As plants adapted and evolved, their DNA sequences changed, as well. Comparing the DNA sequences of modern plants is like looking back in time. You can trace ancestry and understand how closely related a plant is to other plants. You can also compare plants to organisms in other kingdoms of life.

In the following activity, you will compare the DNA sequences of an aquatic alga, a moss, a fern, a gymnosperm, and an angiosperm to explore their ancestry.

Real-world Connection:
Evolution is the unifying theme of Biology. Evolutionary concepts are useful in every area of biological research, including the development of new drugs, foods, conservation strategies, and biofuels.

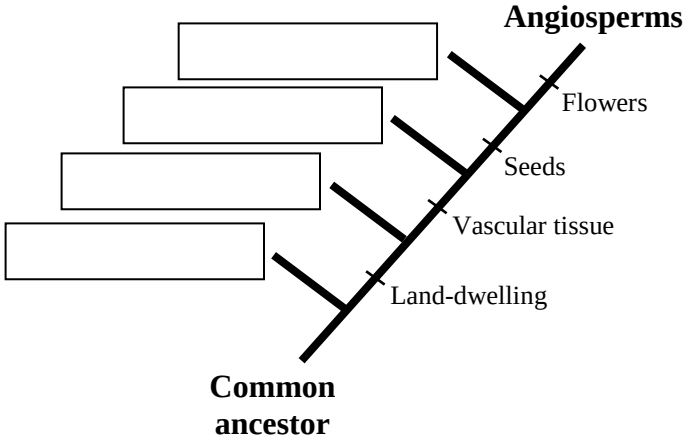
Activity: Constructing an Evolutionary Tree

Procedure:

1. Examine the DNA sequences on the following page.

2. Compare each pair of sequences and calculate what percentage of DNA bases are the same for each pair. Keep your place by holding a sheet of paper over the DNA bases you are not examining. Then enter the percentages into the table on the next page. Ignore the shaded boxes, since they are redundant. [Note: Each sequence is short (50 bases) so that you can easily complete this activity. However, for a scientific study, you would use much more DNA sequence].

3. Use the data in the table to complete the evolutionary tree below. Start by considering which sequences are most similar to angiosperms.



4. The characteristics along the bottom of the tree show some of the major steps in the evolution of plants. Use these to answer the following questions.

What groups of plants have vascular tissue?

What groups of plants have seeds?

What groups of plants have flowers (and fruits)?

Student-Designed Experiments

Go to the following website of the National Center for Biotechnology Information: http://www.ncbi.nlm.nih.gov/blast/Blast.cgi. Under "BLAST Assembled Genomes," click "Human." Type in one of the sequences above into the box at the top of the screen and then click "Begin Search." On the next page, click "View Report." The search engine is comparing the DNA sequence you entered with the DNA of humans. Once the next page finishes loading (which may take a minute), you will see comparisons with the closest matches of human DNA. You can use the DNA sequences you find to construct other evolutionary trees and test all sorts of hypotheses! You can also go back to the initial webpage and search the DNA of other organisms.

Using the methods you learned in the activity above and the "Guide for Student Experimentation" below, design and carry out your own experiment. Question topics you might consider include how closely related the plants above are to other types of plants, animals, humans, etc. If you start clicking around on the NCBI website, you can also find other DNA sequences to analyze.

```
Algae:        TCGACCTGAGCTCAGGCAAGAACACCCGCTGAACTTAAGCATATCAATAA

Moss:         CAGACCTCTGATCAGGGAAGACTACCCGCTGAGTTTAAGCATATCAATAA

Fern:         GCGACCC-AGGTCAGGCGGGACTACCCGTTGAGTTTAAACATATCAATAA

Gymnosperm:   GCGACCCCAGGTCAGGCGAGAGTACCCGCTGAGTTTAAGCATATCAATAA

Angiosperm:   GCGACCCCAGGTCAGGCGGGATTACCCGCTGAGTTTAAGCATATCAATAA
```

* These sequences are from ribosomal RNA genes of a plant species within each group.

	Algae	**Moss**	**Fern**	**Gymnosperm**	**Angiosperm**
Algae	100%				
Moss		100%			
Fern			100%		
Gymnosperm				100%	
Angiosperm					100%

Guide for Student Experimentation

Guidelines for Achieving Great Experiments

1. Ask a very specific, testable question.
2. Test a control for comparison (a group that does not receive the experimental treatment).
3. Use a sample size large enough to allow firm conclusions.
4. To understand a whole population, obtain a random sample of that population to avoid bias.
5. Replicate each part of the experiment (at least 3 times).
6. Hold all variables constant between trials except the variable being tested.
7. Collect quantitative data whenever possible.
8. Measure using metric units.
9. Gather data carefully and accurately.
10. Be objective and honest.

Introduction

Question:

Hypothesis:

Materials and Methods

Independent variable:

Dependent variable:

Experimental constants:

Control:

Protocol:

Results

Data collected:

Other observations:

Graph(s):

Discussion

Interpretation of data:

Conclusions:

Teacher's Guide to "Seeds of Change"

Links to National Science Education Standards

Grades 5-8:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Diversity and adaptations of organisms
- Science and technology in society

Grades 9-12:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Molecular basis of heredity
- Biological evolution
- Science and technology in local, national, and global challenges

Materials

Photocopies are the only materials needed for the activity. For the student-designed experiments, students need access to computers. One computer for every two students would be manageable.

Preparation

No preparation is needed for the activity. For the student-designed experiments, check the NCBI website beforehand to familiarize yourself with it. On occasion, the title and placement of buttons on the pages may change.

Teaching hints

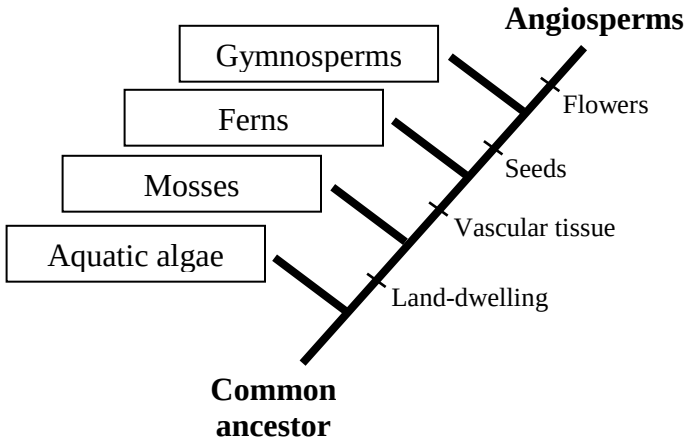
1. **Using plants to teach evolution**: Plants are outstanding subjects for classroom studies of evolution, especially at the beginning of a unit on evolution. Some students will have fewer ideological issues with plant evolution, allowing them to evaluate and internalize evolutionary concepts more objectively.
2. **Interpreting evolutionary trees**: A common tendency is to read evolutionary trees by looking at branch tips. However, this leads to incorrect conclusions. For example, reading from the tips would lead one to conclude that algae are more closely related to ferns than to angiosperms, whereas examining the branching points shows that algae diverged from ferns and angiosperms at the same time (the latter is correct).
3. **Forming groups**: This activity works well when students form pairs.
4. **Successful student-designed experiments**:
   - Emphasize the "Guidelines for Achieving Great Experiments."
   - Before students design experiments, tell them how much time they will have.
   - Allow students to present their experiments and lead a short discussion about each one. Encourage other students to ask questions.

Acknowledgements

DNA sequences were taken from the following GenBank entries: X52320, AF531241.1, AY165473.1, Y17136.1, and AY731085.1. Credits for figures are as follows: Wheat, ©iStockphoto.com/Holly Kuchera; Plant DNA, ©iStockphoto.com/dra_schwartz. This work was funded by the Education Foundation of the American Society of Plant Biologists.

Answer Key

	Algae	Moss	Fern	Gymnosperm	Angiosperm
Algae	100%				
Moss	80%	100%			
Fern	76%	78%	100%		
Gymnosperm	82%	84%	90%	100%	
Angiosperm	80%	82%	92%	96%	100%



What groups of plants have vascular tissue?

Ferns, gymnosperms, and angiosperms

What groups of plants have seeds?

Gymnosperms and angiosperms

What groups of plants have flowers (and fruits)?

Angiosperms