

the
botany Based on the book by Michael Pollan
of desire



far afield
(control)

This lesson prompts thought and discussion on controversial human efforts to alter plants, most recently by means of genetic engineering. As we grow more and more single crop varieties for food, are we jeopardizing the genetic diversity that's so critical to plant survival in the natural world?

far afield (control)



overview

Aldo Leopold, who lived from 1887 to 1948, was one of America's most influential environmental thinkers. A forester, conservationist and author, he once wrote: "To keep every cog and wheel is the first precaution of intelligent tinkering." His point was that all the different plants and animals in an ecosystem, whether we realize it or not, play roles within it.

Biological diversity helps an ecosystem adapt to changes, including threats, from the environment. One species of animal will outrun a predator better than another. If drought or disease kills one kind of plant, a hardier cousin may survive. Even a single species of plant typically consists of many slightly different varieties. Those plant varieties carry genes for a wide assortment of traits – from size to flavor to disease resistance. The greater the genetic diversity of a plant species, the less likely it is that one single threat – such as a virus, bacterium, drought, flood or predator – can destroy the species. That's important not only for the species itself, but for other plants and animals that depend on it for their survival. Leopold believed in preserving genetic diversity and would have likely agreed with Michael Pollan's argument that when it comes to food crops, the genetic diversity we find in nature should be protected and preserved. A diverse gene pool enables those crops to withstand a broad range of environmental threats.

Very simply, a vast field of identical plants will always be exquisitely vulnerable to insects, weeds, and disease—to all the vicissitudes of nature."

– Michael Pollan,
The Botany of Desire



In *The Botany of Desire*, Michael Pollan explores risks inherent in one of the most widespread practices in modern agriculture. It's called monoculture, and it refers to cultivation of single or very similar varieties of a food crop on large acreages. In many cases, the variety is one that dominates the marketplace, like the Russet Burbank potato, whose shape makes it a favorite for cutting French fries, or one of the few apple varieties commonly seen in supermarkets. Monoculture may offer economic advantages, but Pollan argues that it brings serious environmental risks.

Maintaining biodiversity, Pollan argues, is like an insurance policy. By growing multiple varieties of a crop, we increase the chances that if one fails, another will have the genetic traits that enable it to thrive. Maintaining pest resistance through biodiversity can reduce the need to use pesticides.

But others argue for protecting crops by giving them genes from other organisms like bacteria – genes that endow those plants with resistance to pests or diseases. The process of inserting genes from one organism into the cells of another in the laboratory is called genetic engineering. Today, many of the most widely grown crops in America, like corn and soybeans, are genetically engineered. The practice is the focus of an international debate.

The controversies over biodiversity and genetic engineering raise important questions about farming:

- Why do monocultures require large inputs of weed killers and insecticides?
- What are the consequences of growing primarily single varieties of common food and feed crops?
- How well do genetically engineered crops resist disease or insects, and withstand weed killers?
- What are the potential costs and benefits of genetically engineered crops?
- Does our focus on a relatively few varieties of field crops and food plants take us so far afield from wild varieties that it threatens the diversity in that natural gene pool?
- Should we focus on controlling nature to satisfy our food needs or working with it?
- What role does maintaining biodiversity play in protecting food crops?

This lesson encourages students to investigate the human role in developing a cultivar (cultivated variety) of their choice (wheat, soybean, corn, cotton, or canola). Students will explore the relationship between cultivars and wild varieties, discuss the need for cultivars, and discuss risks from modern agricultural practices:

- What are some of the effects on the environment from increasing pesticide use?
- What is the impact on pest control from our increasing use in crops of insecticide-encoding genes from the soil bacterium *Bacillus thuringiensis*?
- Why do crops engineered to tolerate weed killers lead to the emergence of herbicide-resistant weeds?



objectives

Students will:

- Seek out and synthesize information necessary for a debate on this topic: In our quest to control plants, are we relying too much on pesticides and genetically modified plant varieties?
- Discuss the pros and cons of preserving crops either through gene banks (repositories of the genetic material of plants and animals) or Vavilov Centers (places that preserve the habitats of food sources).

grade level: Grades 8-12

subject areas:

Physical Science, Life Science, Biology, and Chemistry

National Science Education Standards

History and Nature of Science

As a result of activities in grades 5-12, all students should develop understanding of:

- Science as a human endeavor
- Nature of science
- History of science

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science

- Structure and properties of matter

Science and Technology

- Understandings about science and technology

materials needed

- Printouts of the Background section of this lesson
- Clips from the film *The Botany of Desire* (available online)
- Internet access (see resources below) and/or other seminal sources of information dealing with conservation of wildlife such as:

E.O. Wilson: *The Diversity of Life*

Michael Soule: *Viable Populations for Conservation*

Eugene Odum: *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments*

Daniel B. Botkin: *Discordant Harmonies: A New Ecology for the Twenty-first Century*

estimated time needed

180+ minutes

background

This lesson prompts thought and discussion on controversial human efforts to alter plants, especially recently by means of genetic engineering. This section provides context for what we mean by "intelligent tinkering" with nature.



Aldo Leopold And Intelligent Tinkering

Aldo Leopold prompted a great deal of thought and debate about the idea of intelligent tinkering. The following excerpt from his book *Round River* provides some insight into his views:

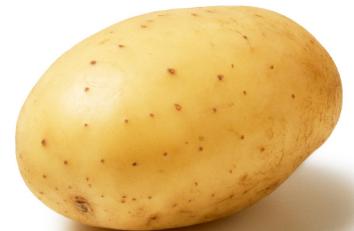
“Conservation is a state of harmony between men and land. By land is meant all of the things on, over, or in the earth. Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left. That is to say, you cannot love game and hate predators; you cannot conserve the waters and waste the ranges; you cannot build the forest and mine the farm. The land is one organism. Its parts, like our own parts, compete with each other and co-operate with each other. The competitions are as much a part of the inner workings as the co-operations. You can regulate them—cautiously—but not abolish them. The outstanding scientific discovery of the twentieth century is not television, or radio, but rather the complexity of the land organism. Only those who know the most about it can appreciate how little we know about it. The last word in ignorance is the man who says of an animal or plant: ‘What good is it?’ If the land mechanism as a whole is good, then every part is good, whether we understand it or not. If the biota, in the course of [eons], has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.”

Leopold, Aldo: *Round River*, Oxford University Press, New York, 1993, pp. 145-146.

SOME QUESTIONS AT THE HEART OF THE DEBATE

Although we might agree that understanding the “complexity of the land organism” is important, there is no consensus on the degree of “tinkering” we should be doing with domesticated crops. Some questions can help frame a discussion on this topic:

- Do genes that are inserted into genetically engineered crops like Round Up® Ready Corn threaten the wild relatives of these crops? Can engineered genes drift from genetically modified plants and become incorporated into growing populations of nearby related crops or wild relatives?
- How effective and reliable are seed banks? Should we invest in seed banks, sperm banks, and cryogenically frozen tissues to conserve wild species of plants and animals?
- How can we prevent environmental disasters like the one that was created when kudzu was introduced to the Southeastern United States? *
- Do botanical gardens and zoos effectively help to preserve plant and animal species? Is there a better way to do that than preserving native habitats?
- Does an individual seed contain all of the genetic variability necessary to assure that a species can survive extinction?



**In 1876, countries around the world were invited to build exhibits to celebrate the one-hundredth birthday of the United States. The Japanese government constructed a beautiful garden filled with the sweet-smelling blooms of kudzu. American gardeners were captivated by the plant and used it for a variety of ornamental purposes. By the 1920s, the plant was used to feed animals and then, a decade later, to control erosion. In the 1940s, farmers were paid to grow the plant. However, because the kudzu vine grows so fast and is so prolific, enveloping trees and denying them sunlight, it was recognized as a weed by the USDA in the 1970s and listed by the U.S. Congress as a Federal Noxious Weed in 1997. With the propensity to replace existing vegetation, kudzu causes much economic and ecological damage. Some government publications estimate that kudzu causes more than \$100 million of damage per year in the U.S. According to another source, which factors in \$336 million of lost productivity in forests, losses from kudzu are “greater than \$500 million per year” (Blaustein, Richard J. 2001).*



Note to Teachers: To view the movie clips referenced in these steps, please go to this lesson plan's page on *The Botany of Desire* website at <http://www.pbs.org/thebotanyofdesire/lesson-plan-control.php> and choose the clip from the video player.

Domestication Manipulation

1. Put the following quotation on the board or projector:

The last word in ignorance is the man who says of an animal or plant: 'What good is it?' If the land mechanism as a whole is good, then every part is good, whether we understand it or not. — Aldo Leopold

2. Ask students to interpret that statement, rewriting it in a way that might make it easier for people to understand. Students don't need to explain it — they simply need to capture its ideas in their own words.
3. Have students share what they have written.
4. View the following movie clips: *Clip 1* and *Clip 2*. Ask students for how long and in what ways we have been manipulating plants. Have them explain why humans manipulate plants and the effects of some of those manipulations.
5. Would human civilization exist without human manipulation of plants and animals?
6. View the following clips: *Clip 3*, *Clip 4*, and *Clip 5*. Discuss the following:
 - Where did apples come from originally? Is it important to preserve this place? If so, why?
 - Is the collection and storage of seeds a good idea? Why or why not?
 - Is transfer of genes from one apple to another apple a good idea? Why or why not?
 - Do we need to preserve all varieties of apples or not?
7. View *Clip 6* and discuss the following:
 - Why did the number of apple varieties on the market diminish?
 - How does monoculture make crops more susceptible to pests and diseases?
 - How can monoculture lead to wider usage of pesticides?
8. View *Clip 7* and discuss the following:
 - How have the potato growers of the Andes Mountains addressed the question of monoculture?
 - What is the importance of preserving many potato varieties?
 - Tabulate examples of the dangers that can result from monoculture.
9. Have students revisit their restatements of the Aldo Leopold quotation. At minimum, students should edit their rephrasing, and they should add a sentence or two that connects the quotation to the dangers of monoculture. Ask them to write more substantively about the potential dangers of monoculture.





Extending To Other Varieties And Genetic Manipulation

10. Initial research: Using the Additional Resources section below, have your students (individually or in groups) investigate a plant variety and its wild relatives and answer the following questions:
 - What is the human role in domesticating the crop and creating the new variety?
 - How closely does the crop variety being grown today resemble earlier versions?
 - Are there multiple varieties of the crop now being cultivated commercially?
 - Is the variety genetically engineered? If so, in what ways?
 - What advantages, problems, and controversies are associated with the plant variety?
11. Oral presentation: Have your students share the benefits and challenges associated with the domestication/ manipulation of the species or variety that they selected.
12. View Clip 8. Ask students to share their reactions to the use of genes from *Bacillus thuringiensis* (Bt) bacteria to engineer crops to resist insect pests.
13. View Clip 9. Are there alternatives to the way we practice crop agriculture in the U.S.?
14. For homework, have students write their answers to all or some of the following questions.
 - Do the novel genes in genetically engineered, pest-resistant crops (e.g., Bt YieldGard® Corn) pose a threat to the non-engineered varieties of these crops, or to the animals that consume them or humans who consume products that derive from those crops?
 - Can the novel genes that have been inserted into genetically engineered crops travel to and reside in neighboring crops of the same species or in other types of plants, such as weeds?
 - How can we prevent environmental disasters like the one created when kudzu was introduced to the Southeastern United States?
 - Do botanical gardens really help to preserve plant species? Is there a better way to preserve species without preserving their native habitats?
 - Should we invest in seed banks, sperm banks, and cryogenically frozen tissues to conserve wildlife?
 - Does an individual seed or plant contain all of the genetic variability necessary to insure the survival of a species?
15. Have students summarize their answers to homework assignment in two-minute oral presentations. Allow an additional minute for “devil’s advocate” questions (with responses) from other students.

Extension & Adaptation

- Create a community forum for students to present different points of view on genetically modified organisms (GMOs). The forum can be based on a scenario centered on exporting a genetically modified crop (e.g., NewLeaf potato or Golden rice) to a famine-plagued area. Some U.S. consumers may not be willing to accept GMOs, even those with the potential to increase yields per acre. Is it ethically acceptable to export a crop that we are reluctant to consume?

Assessment

As a short writing assignment, have students respond to the following:

- Provide a “State of the Crop” statement about the cultivar that you studied. Can human beings depend upon this particular crop in the future, based on current practices? In other words, are our current practices sustainable?
- Discuss the advantages and disadvantages of one aspect of current agricultural practices surrounding one of the cultivars that you learned about from this study.
- What is one way in which you changed your perception of farming?

Additional Resources

Books and Journals

Damania, A.,J., Valkoun, G. Willcox, and C. Qualset, eds. (1998). *The Origins of Agriculture and Crop Domestication*, 1st ed. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

de Candolle, A. (1992). *Origin of Cultivated Plants*, 1st ed. Cambridge, U.K.

Diamond J (1997) *Guns, Germs and Steel, A short history of everybody for the last 13,000 years*. Viking UK Random House ISBN 0-09-930278-0

Frankel, O. H., A. H. D. Brown, and J.J. Burdon. (1995). *The Conservation of Plant Biodiversity*, 1st ed. Cambridge University Press, Cambridge, U.K.

Gepts, P. (2001) Origins of plant agriculture and major crop plants In M. K. Tolba, Ed., *Our Fragile World: Challenges and Opportunities for Sustainable Development*, EOLSS Publishers, UK, pages 629-637.

Gepts, Paul, PLB143: *Evolution of Crop Plants The origins of agriculture and the domestication of plants Spring Quarter*, Department of Agronomy and Range Science, University of California, Davis

Gepts, Paul. Chapter 13. *Ten thousand years of crop evolution*. In Chrispeels, Maarten J.; Sadava, David E. (editors) (2003). *Plants, Genes and Crop Biotechnology*, 2nd ed. Jones and Bartlett. ISBN 0-7637-1586-7.



- Hancock, J.F. (2004). *Plant Evolution and the Origin of Crop Species*, 2nd ed. CAB International, Wallingford, UK. ISBN 0-85199-685-X.
- Harlan J. R. (1992). *Crops and Man*, 2nd ed. American Society of Agronomy, Madison, WI.
- Heun MR et al (1997) Site of Einkorn Wheat Domestication Identified by DNA Fingerprinting *Science* 278:1312-4 DOI: 10.1126/science.278.5341.1312
- Lev-Yadun, Simcha , Gopher, Avi, Abbo, Shahal (2000) The Cradle of Agriculture. *Science* 2 June 2000: Vol. 288. no. 5471, pp. 1602 - 1603 DOI: 10.1126/science.288.5471.
- Lev-Yadun S *et al.* (2000) The cradle of agriculture *Science* 288471:1602-3
- Özkan H et al. (2002) AFLP analysis of a collection of tetraploid wheats indicates the origin of emmer and hard wheat domestication in southeast *Turkey Molecular Biology and Evolution*19:1797-1801 (2002) PMID 12270906
- Smith, Bruce D. (2001) Documenting plant domestication: The consilience of biological and archaeological approaches PNAS | February 13, 2001 | vol. 98 | no. 4 | 1324-1326
- Sun, C. *et al.* (1998) From indica and japonica splitting in common wild rice DNA to the origin and evolution of Asian cultivated rice. *Agricultural Archaeology* 1998:21-29
- Tanno, K Willcox, G (2006) How fast was wild wheat domesticated? *Science* 311 1886 DOI 10.1126/science.1124635 PMID 16574859
- Vavilov, N. I. (1997). *Five Continents*. Rome: International Plant Genetic Resources Institute; St. Petersburg: N. I.Vavilov All-Russian Institute of Plant Industry.

Websites

Biodiversity International (formerly IPGRI)

The world's largest international research organization dedicated solely to promoting agricultural biodiversity.

<http://www.biodiversityinternational.org/>

http://www.biodiversityinternational.org/publications/Web_version/47/ch06.htm

Food and Agriculture Organization of the United Nations (FAO)

The largest specialized agency in the United Nations system working to provide "food security" for the world.

<http://www.fao.org>

Consultative Group on International Agricultural Research (CGIAR)

CGIAR is an association of public and private members supporting a system of 16 Future Harvest Centers that work



in more than 100 countries to mobilize cutting-edge science to reduce hunger and poverty, improve human nutrition and health, and protect the environment.

<http://www.cgiar.org>

The Global Diversity Trust

An activist site with information about the importance of plant gene banks.

<http://www.croptrust.org/main/>

Gene Conserve

"An electronic journal devoted to conservation of crop genetic resources with emphasis on cassava."

<http://www.geneconserve.pro.br/>

Local Harvest

An organization that helps Americans to build a relationship with a farm and receive a weekly basket of produce.

<http://www.localharvest.org/csa/>

Botanical Gardens

Botanique is a portal to over 2400 botanical gardens in Canada and the United States. <http://www.botanique.com/>

References

Blaustein, Richard J. 2001. Kudzu's invasion into Southern United states life and culture. In: McNeeley, J. A. ed. *The Great Reshuffling: Human Dimensions of Invasive Species*. IUCN, Gland, Switzerland and Cambridge, UK. The World Conservation Union: 55-62.

Corbin, R.A. (2006) *Living Science: Human, Student-Inquiry Science Projects for Middle and High School*. A guidebook written for the American Society for the Prevention of Cruelty to Animals.

Corley, R. N., A. Woldeghebriel, and M. R. Murphy. 1997. Evaluation of the nutritive value of kudzu (*Pueraria lobata*) as a feed for ruminants. *Animal Feed Science and Technology* 68: 183-188.

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