M3.G7 Lesson 3: Let There Be Light!

Unit Overview: Oak Woodlands
Grade 7

Key Concepts:
- Growth and development
- Tradeoffs
- Inheritance of traits
- Variation of traits
- Adaptation
- Analyzing data

Time: 40 - 60 minutes

Materials for the Teacher:
- ✓ Student handout and teacher key M3.7.3a
- ✓ M3.7.3R reference sheet (pictures of a tree's life cycle)
- ✓ Examples of seedlings (optional)

Connections:
STEM, botany, agriculture, biomass, genetics, soil science, chemistry, biodiversity, environmental science, forestry, climate change, watersheds, human population, human impact, restoration, conservation, physics, mathematics

Forest Ecology 101 integration:
M1: Integrative Forest Ecology

Learning Objectives: Students will interpret data regarding how oak seedlings respond to different levels of light. In doing so they will learn about life history tradeoffs, competitive advantages, and potential reasons for poor oak regeneration. They will compare results of shoot and root mass and overall biomass of seedlings from three different species after exposure to three different light levels.

Background information: Refer to the appropriate section in Part II: Teacher Companion for Module 3 and the original paper:
Callaway, R.M. 1992. *Morphological and physiological responses of three California oak species to shade*. International Journal of Plant Science 153(3): 434-441.

Suggested procedure: To add enrichment you may want to plant seeds several weeks before starting this lesson. Begin this lesson by reviewing the importance of oak woodlands and the concern over lack of recruitment. One of the biggest threats facing existing populations of several oak species is survival of young trees, otherwise known as recruitment. For some reason several different species of oak don't survive to a sapling stage (see M3.7.3R). Few young to intermediate stands of oaks are observed, which has been a concern to land managers, ecologists, and conservationists. This study looks at the responses of three different oak species and the responses of seedlings grown in three different light levels. There are several competitive forces that may contribute to the lack of recruitment, such as getting eaten by cattle and deer and having to compete with non-native annual grasses that were introduced about 200 years ago. Understanding the requirements of seedlings helps in replanting and restoration efforts. After presenting background information review some of the key concepts by asking some of the preliminary questions below. It is optional to have them grow their own sprouts first to add enrichment. Sprouting bean seeds can be done in less than two weeks inside wet paper towels. Another option is to have students observe cut-open acorns (refer to reference sheet M3.7.3R). You will probably want to review the concept of biomass and a tree's life cycle before you begin, depending on the level of knowledge and experience of your group (refer to M3.7.3R). The three figures used in this lesson do not represent the entire results from the study. It also measured root elongation per day and photosynthetic capacity by measuring leaf area. Mass was selected because it can be easily

	understood, and is something that can be measured relatively simply in a student lead investigation (see student worksheet M3.7.3a). Notice that the figures show error bars and shared letters designating whether there is significance difference or not within and among species. Shared letters represent no significant difference. For simplicity, students can just ignore these or you can use them to denote the importance of using statistical analysis in science and related fields.

Preliminary questions:

- What is the seed of an oak tree called?
- What are the five stages of a tree's life?
- What is one of the main concerns facing oak woodlands today? (*you may want to get two or three main concerns*)
- What sorts of factors might be responsible for the observed lack of regeneration in oaks?
- What are some examples of human impact that may contribute to the lack of oak regeneration?
- Why are land managers and conservationist concerned about the lack of regeneration in oaks?

Critical Thinking: Why could a seedling have a more difficult time surviving compared to a young sapling?

Keywords: allocation, biomass, intolerance, luminance, percent error, regeneration, sapling, seedling, tolerance

NGSS alignment:

MS-LS1: From Molecules to Organisms: Structures and Processes
MS-LS2: Heredity: Inheritance and Variation of Traits
LS1.B Growth and Development of Organisms
LS1.C Organization for Matter and Energy
LS3.A Inheritance of Traits
LS3.B Variation of Traits

Online resources:

Investigation the Oak Community: A curriculum guide for grades 4-8
http://www.californiaoaks.org/ExtAssets/investigating_the_oak_community.pdf
This curriculum guide was published by the California Oak Foundation and is written by Kay Antúnez de Mayolo. It has great ideas that can be integrated into any lesson about oaks.
California Oaks Foundation, reference page
http://www.californiaoaks.org/html/reference.html
There are great links on this page that can be integrated into this lesson or other lessons including a comprehensive list of species dependent on oaks for food and shelter, the role fire in oak woodlands, and an oak slide show.

(Online resources continued)
UC ANR publication 21538: *Living Among the Oaks: A Management Guide for Landowners and Managers.*
http://anrcatalog.ucdavis.edu/items/21538.aspx
At this site you can download a free pdf about living among oak trees written by Douglas McCreary. It reviews the importance of oaks and how to enhance wildlife in oak habitats. In addition, it gives a short overview of 10 oak species living in California.
UC ANR publication 21601: *Regenerating Rangeland Oaks of California*
http://ucanr.edu/sites/oak_range/files/59453.pdf
This is a great guide to use if you want to plant acorns or oak seedlings. It explains how to best collect, store, and plant acorns and reviews some of the problems with poor regeneration in some oak species.

EEI Connection:

B.6.a. Biodiversity: The keystone of Life on Earth
B.6.b. Ecosystem Change in California
B.8.b Biological Diversity: The World's Riches

Answers to preliminary questions:
- What is the seed of an oak tree called? (the seed is called an acorn)
- What are the five stages of a tree's life? (acorn - sprout or seedling- sapling - tree - snag. You can add a 6th stage - a log)
- What is one of the main concerns facing oak woodlands today? (1 - there is poor regeneration in young oaks, often referred to as lack of recruitment 2 - oaks live where there are a lot of people and more areas are at risk of development 3 - S.O.D. is killing tanoaks, live oaks, and black oaks. This is a relatively new disease and is spreading.)
- What sorts of factors might be responsible for the observed lack of regeneration in oaks? (possible causes for lack of recruitment include competition with annual grasses and forbs, browsing by livestock, deer, and rodents, absence of surface fires, and soil compaction)
- What are some examples of human impact that may contribute to the lack of oak regeneration? (with the introduction of livestock came non-native grasses that compete with seedlings. Also livestock eat young saplings in winter when food is scarce. The biggest threat today is continued human expansion and development. California remains the fastest growing state in the union)
- Why are land managers and conservationist concerned about the lack of regeneration in oaks? (oaks have a disproportionate amount of species that utilize them and are considered keystone species. They provide food, shelter, and shade for plants and animals. They protect watersheds and prevent soil erosion. Oaks provide fuel and food for people as well as recreational opportunities. They are also beautiful and increase property values)

M3.G7.L3 Unit Overview (continued)

Suggested extensions:

- Have students perform a similar investigation by growing seedlings and then separating them into up roots, stems, and leaves and taking the dry weight of each.
- Learn about plant reproduction by having students cut open large seeds, such as acorns or lima beans, and identify the different features such as the cotyledons, epicotyl, radicle, and the seed coat.
- Plant seeds in different soils and measure their growth rate.
- Compare transpiration rates between plants in the shade and plants in the sun by collecting moisture inside plastic bags and measuring it.
- Show a video about the growth of trees and/or of a deciduous forest ecosystem.
- Get a classroom pet and have students record changes in its growth and development throughout the year.
- Collect, leach, and prepare acorns for eating during the fall.
- Visit a local farm to observe the assortment of plants grown there.

M3.7.3a Student worksheet
M3.7.3T Teacher key
M3.7.3R Reference sheet

Student worksheet M3.7.3a Name _____
Date _____ Period _____

Let There Be Light!

Background:

Many studies have attempted to understand the limiting factors responsible for why several different oak species are not regenerating well. Most agree that it is not just one factor responsible for this problem, but is probably a combination of factors that are involved. The inability for young trees to survive can be due to competition with grasses and other plants, being eaten by cattle and other animals, and not enough water, light, and nutrients. Human impacts and the *lack* of fire can also be part of the problem.

Oak trees sprouts from an acorn that grows into a seedling and then into a sapling before becoming a tree. Oaks grow slowly and many can live to be over 300 years old. When they are young they are the most vulnerable. Understanding the seedling stage of an oak tree's lifecycle, can help us understand why some aren't surviving very well and can potentially help us find solutions to the problem. Certain species of oaks live along the coast while others live inland where it is much drier. Which ones have more tolerance for shade? Are any able to tap into more water because of a longer root? Oak trees are considered keystone species, and without them, the survival of many species could be in jeopardy.

***Quercus lobata* or Valley Oak** - this species loses its leaves in winter and is in leaf between late March and November. Acorns germinate in the fall and seedlings usually keep their leaves for at least the first year. Seedlings tend to be shade intolerant and seedlings rarely survive under shrubs. This species is the largest of all oak trees in North America.

***Quercus douglasii* or Blue Oak** - Similar to Valley Oak, this species is also deciduous and is in leaf from March until November. Seedlings are relatively shade tolerant, however the adult trees don't like shade. Seedlings are frequently found growing in shrubs, which act as a sort of nursery. This species is drought tolerant and is known to grow in very hot and dry places.

***Quercus agrifolia* or Coast Live Oak** - this species lives along the coast of California and is evergreen. It can grow in chaparral, which receives a lot of sun and in mixed forest, which are relatively shady. When young it is probably shade tolerant because it is found living in shrubby areas. Adult trees grow wide instead of tall and branches can reach over 15 m (50 ft).

Directions: Answer the preliminary questions and then analyze the three different graphs by answering the questions in each box. These results were taken from a scientific paper trying to find how different oak seedlings respond to different levels of light. The seeds were grown outside for 140 days before being pulled and dried.

Questions:

1. What does irradiance mean?

_____

_____

2. List the three different light levels the seedlings were exposed to in this experiment.

_____

_____

_____

3. Predict what part of the plant will be the heaviest once dried - roots or shoots (shoots include the leaves and stem)? _____

Graph #1

1. What unit is used for measuring mass?

_____

2. What part of the seedlings were measured?

_____

3. Briefly describe how the three different species responded based on the given data.

4. Make a comparison using mathematical terms (a difference in quantity). For example: The root mass for *Q. lobata* was 3 times the mass as *Q. macro.*

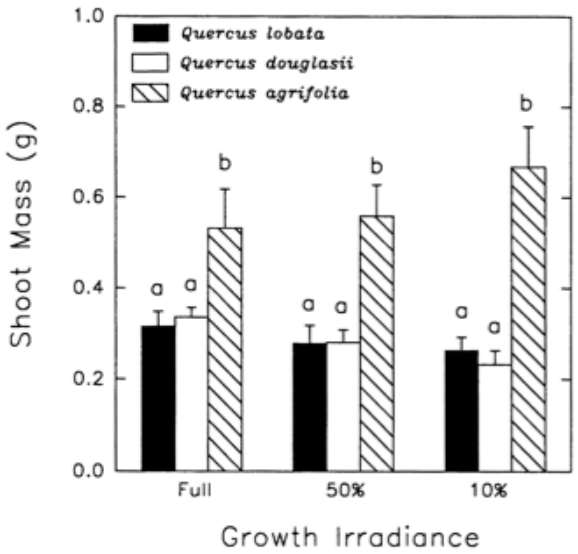


Fig 1. Average shoot mass of 3 oak species' seedlings grown in different light levels.

Graph #2

1. What part of the plants were measured?

_____

2. Rank the results from highest to lowest for each species and each light level.

3. Why might one species have a much larger root than another?

4. Make a comparison using mathematical terms (a difference in quantity).

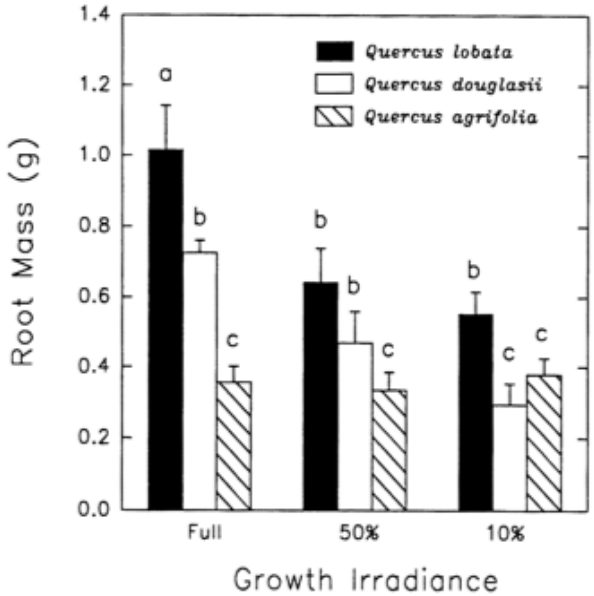


Fig 2. Average root mass of 3 oak species' seedlings grown in different light levels.

Graph #3

1. List the three parts that were measured to find biomass allocation.

2. What two species allocated similar amounts in all three parts measured?

3. What species allocated more energy to larger leaves?

4. Estimate the percent allocated to roots in full sun for each species?

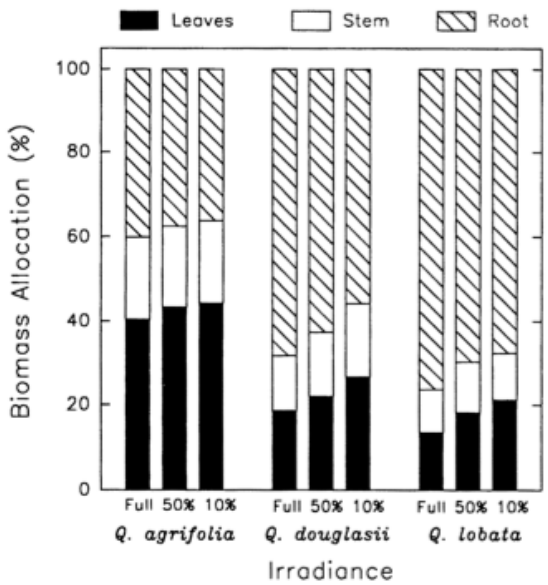


Fig 3. Average percent biomass allocated (leaves, stems, and roots) in 3 oak species' seedlings grown in different light levels.

Conclusion:

1. Write a conclusion for each species. Include quantitative data regarding roots and shoots.

2. What advantage does a species have that allocates a high amount of energy to a well-developed taproot?

3. What advantage does a species have that allocates a high amount of energy to large leaves?

4. Besides environmental factors, what governs how a plant will grow within a particular habitat?

Teacher key M3.7.3T: **Let There Be Light**

1. What does irradiance mean?
Irradiance is a measurement of solar power and is measured in units/area.

2. List the three different light levels the seedlings were exposed to in this experiment.
Light levels are 10%, 50%, and 100%

3. Predict what part of the plant will be the heaviest once dried - roots or shoots (shoots include the leaves and stem)? Answers will vary.

Graph #1

1. What unit is used for measuring mass?
_____grams_____

2. What part of the seedlings were measured?
_____shoot_____

3. Briefly describe how the three different species responded based on the given data.
Q. lobata and Q. douglasii responded similarly. They had a slightly larger shoot in full light compared to less light.
Q. agrifolia had a much larger shoot compared to the other two species. In low light over twice as much.

4. Make a comparison using mathematical terms (a difference in quantity).
Answers will vary.

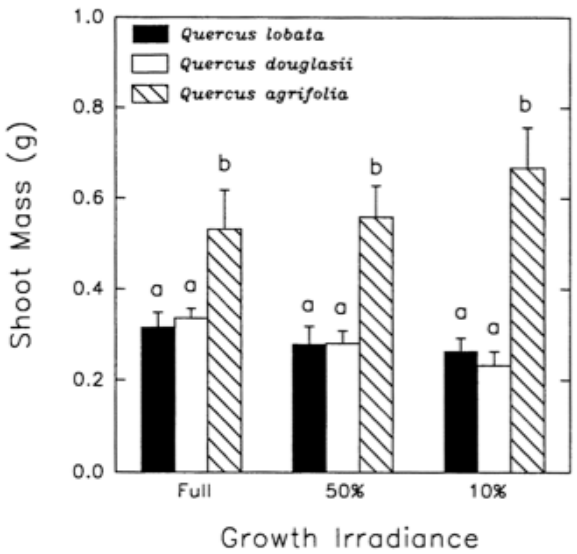


Fig 1. Average shoot mass of 3 oak species' seedlings grown in different light levels.

Graph #2

1. What part of the plants were measured?
_____roots_____

2. Rank the results from highest to lowest for each species and each light level.

100%	50%	10%
1st Q. Lobata	Q. Lobata	Q. Lobata
2nd Q. douglasii	Q. douglasii	Q. agrifolia
3rd Q. agrifolia	Q. agrifolia	Q. doug.

3. Why might one species have a much larger root than another? Allows it to tap into deeper water

4. Make a comparison using mathematical terms (a difference in quantity).
Answers will vary

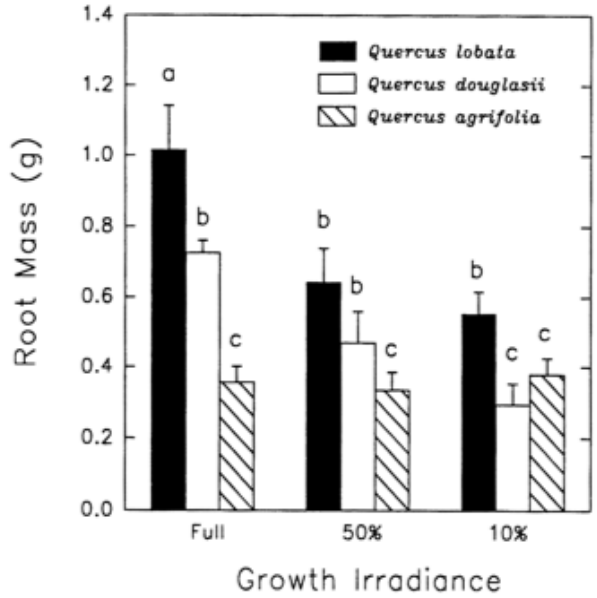


Fig 2. Average root mass of 3 oak species' seedlings grown in different light levels.

Graph #3

1. List the three parts that were measured to find biomass allocation.
Leaves, stems, and roots

2. What two species allocated similar amounts in all three parts measured?
Q. douglasii and Q. lobata

3. What species allocated more energy to larger leaves?
Q. agrifolia

4. Estimate the percent allocated to roots in full sun for each species?
Q. agrifolia - 40%
Q. douglasii - 16-20%
Q. lobata - 12-16%

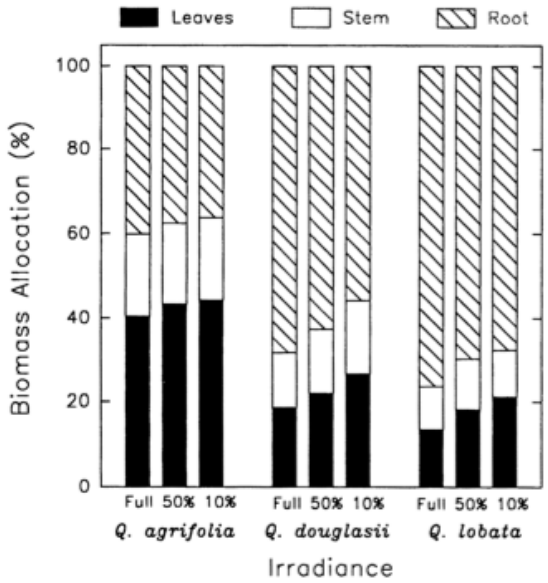


Fig 3. Average percent biomass allocated (leaves, stems, and roots) in 3 oak species' seedlings grown in different light levels.

Conclusion:

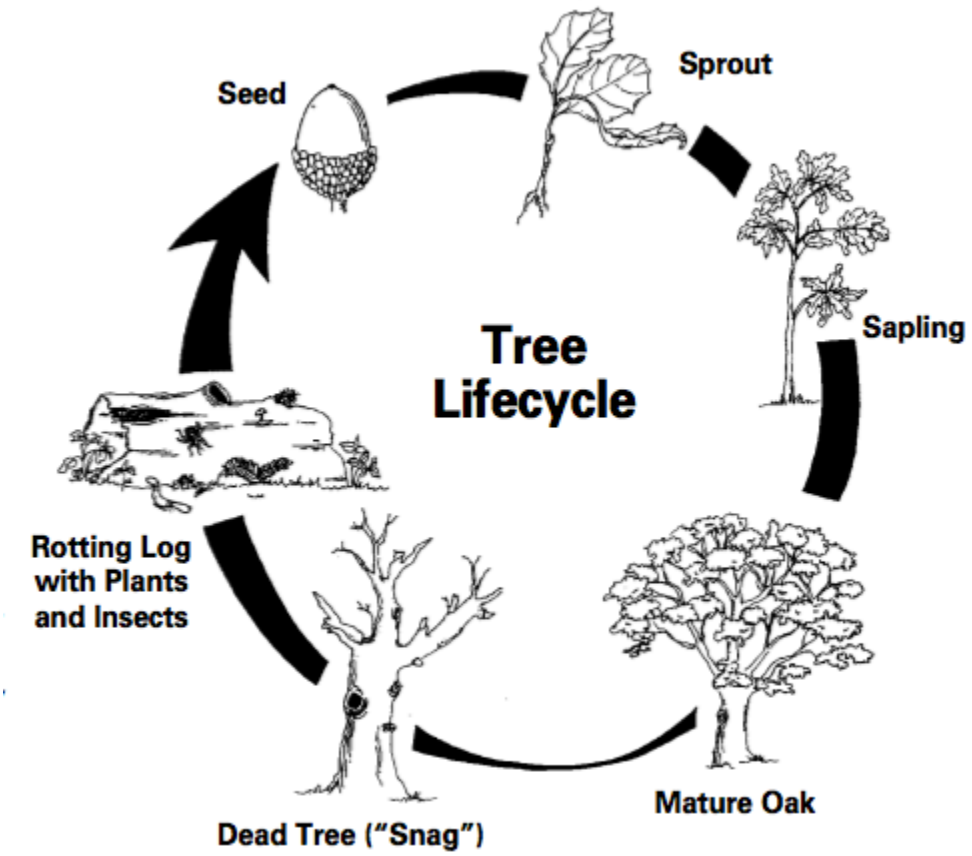
1. Write a conclusion for each species. Include quantitative data regarding roots and shoots.
Answer will vary. Expect some of the basic trends to be described.
Q. agrifolia (coast live oak) allocated 50 - 60% less root biomass compared to the other two species, however it had the highest shoot mass. In low light the shoot mass was more than twice as much higher and overall about 1.6 x more than the other two species.
Q. douglasii (blue oak) allocated 50 - 60% lower biomass to its roots compared to the other two species. It has the lowest root biomass in full and 50% light. It had a similar shoot mass to Q. lobata.
Q. lobata (valley oak) had a similar shoot mass to blue oak. It had the highest root mass compared to the other two species (1.4 and 2.9 x higher). Over 70% of its overall biomass was allocated to its roots in both high and low levels of light.

2. What advantage does a species have that allocates a high amount of energy to a well-developed taproot? Answers will vary. A larger taproot and hold the tree in place and can probe deeper for water. It may need to live in moist places.

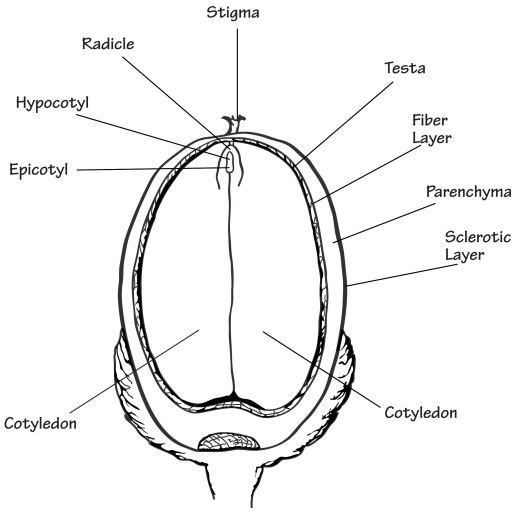
3. What advantage does a species have that allocates a high amount of energy to large leaves?
Answers will vary. Larger leaves capture more sunlight. This may mean that it can perform better in low light conditions or in shady places.

4. Besides environmental factors, what governs how a plant will grow within a particular habitat?
Plants are governed by their genes or the blueprint of life - their DNA.

Reference sheet M3.7.3R



source*:* student page from PLT *Forests are More Than Trees*



Artwork by Melody Hjerpe