Joel E. Greengiant Learns About Peas: From Nucleotides to Selection

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Introduction (~30 minutes)

Joel E. Greengiant and his wife, Jolene, were discussing their favorite food in the whole world, green peas. Joel E. said, "When they come in from the field, they are so sweet! You don't have to do anything at all—just scoop them up and eat them."

Jolene said, "I know—they are wonderful! Have you ever seen pea seeds when they're all dried out? They're hard, of course, but also very wrinkled; they look quite unlike the fresh peas we eat. However, because of my particular passion for peas, I did some research and found out that the ancestral dried pea was round in shape, not wrinkled."

Joel E. replied, "Is that so? I wonder why modern peas get all wrinkled when they dry out."

"I'm pretty sure that it as to do with water content of the fresh peas, and that in turn has to do with how much sugar they have," replied Jolene. "Ancient peas were starchier then the ones we produce and prepare for our customers."

"Yuk, who wants to eat starchy peas—it's sweet we want!" said Joel E. "I imagine that ancient farmers wanted sweet peas too, and figured out how to do that. How do you suppose peas became sweet in the first place?"

Jolene said, "That's the task ahead of us: to determine all the basic biology involved when starchy peas evolved into the sweet peas we eat today. It's worth the effort, don't you think?"

Joel E. said, "Of course I do! I love peas!"

Instructions

1. Make a list of everything you know about sweet and starchy peas. Some items on your list may be derived from the information above while other information may come from prior knowledge about peas that you may have. We will discuss your lists as a class.
2. After the class discussion, based on your lists and also the handout of "expert facts" that your instructor will provide you, in your small groups generate a list of questions articulating any gaps remaining in your understanding of how starchy peas evolved into sweet peas.
3. In your small groups, propose answers to these questions (generate hypotheses).

Back to the story …

Jolene said, "It seems we have a lot to learn about sweet peas and starchy peas. I'm sure we're going to have to learn about what goes on in a pea cell in terms of both genetics and biochemistry in order to understand how ancestral starchy peas became sweet. It seems as though ancient farmers caused pea populations to change pretty fast once they had a few sweet peas in hand. Where do you want to start? It really doesn't matter, since this is all one big story."

Module: Natural History of Round and Wrinkled Peas (~40 minutes)

Joel E. said, "Being a purveyor of peas, I really would like to know something about ancestral peas and where they originated."

"Me too," said Jolene. "Let's get started!"

Instructions

Sort through your findings from the case study introduction and identify information that applies to the natural history of domesticated peas. This information (facts, questions, or hypotheses) will be the basis for your small group investigations. You may have further hypotheses about the domestication of peas, which you will have an opportunity to investigate in this module of the case study.

Investigation Phase

1. Download the *Pea Taste Evolution* Powerpoint® presentation from:
   http://evo-ed.com/PowerPoint Teaching Resources/Pea Taste Evolution.pptx
   These slides will be used in this module and throughout the case study.

   Slide Notes:

   - Slides 5–8 provide a summary of the domestication of *Pisum sativum*. More detailed information can be found in: Abbo, et al. 2009. Reconsidering domestication of legumes versus cereals in the ancient Near East. *The Quarterly Review of Biology* 84(1): 29–50.

2. After viewing the slides, complete the questions below for homework.

Homework Questions

1. Abbo et al. state that "domestication [of plants] was influenced by both biological and cultural determinants." Explain this statement.
2. What particular features were selected for by humans in *P. sativum* and why?
3. Why do we think that ancestral peas were round, and that these ancestors gave rise to wrinkled descendants? Why are there still round peas today?
4. *Synthesis question:* Variation in populations is important for domestication of a species. Explain this statement in terms of pea domestication.

Module: The Cell Biology of Round and Wrinkled Peas (~40 minutes)

"What makes a pea seed sweet? We know that sweet peas have more sugar than the starchier ones. The trick is to figure out how that happens," said Joel E.

"I think you're on the right track," said Jolene. "I remember from basic biology that the products of photosynthesis can be stored as sugar or starch. However, I don't have a clue how that happens or why a pea plant would make more sugar."

"Hmmm—photosynthesis. This is a blast from a lesson past! You're probably talking about cellular events, perhaps some biochemical processes? I think it's time for a little research," said Joel E.

Instructions

Sort through your findings from the case study introduction and identify information that applies to the cell biology of peas. This information and the statements made by Joel E. and Jolene will be the basis for your small group investigations. You may have further hypotheses about sugar and starch synthesis in peas, which you will have an opportunity to investigate in this module of the case study.

Investigation Phase

1. Download the *Pea Taste Evolution* Powerpoint® slides slide set from:
   http://evo-ed.com/PowerPoint Teaching Resources/Pea Taste Evolution.pptx
   These slides will be used in this module and throughout the case study.

   Slide Notes:

   - Slides 9–12 provide an introduction to the wrinkled/sweet traits of peas.
   - Slides 13–25 explore the biosynthetic pathway for sugar and starch production, with emphasis on the starch branching enzyme (SBE1) that catalyzes the formation of the branched amylopectin starch from the linear amylose starch. A non-functional SBE1 protein results in the accumulation of sucrose.
   - Slide 26 poses a question about the water content of round and wrinkled peas.
2. After viewing the slides, complete the questions below for homework.

Homework Questions

1. What molecule is the initial output of photosynthesis?
2. What are the three primary storage products of photosynthesis?
3. What is the role of ADP-glucose in the synthesis of storage molecules?
4. What are the roles of the starch *synthase enzyme* and the *starch branching enzyme* in plant cells?
5. What happens in terms of starch production when there is a defective starch branching enzyme? How does this defect lead to a sweeter tasting pea seed?
6. How does less starch and more sucrose production in pea seeds result in a wrinkled seed (i.e., when dried)?
7. *Synthesis question:* From the point of view of a pea plant, is it advantageous to be a sweet or starchy pea? Explain your answer.

Module: From Mendel to Molecules (~40 minutes)

"Do you remember that in introductory biology we learned about Mendel the Monk and that peas were the plant he used when investigating patterns of heredity? What a smart guy to focus on peas!" said Jolene.

"Pea plants are powerful," agreed Joel E. "However, I do have some questions about what we learned. Didn't Mendel determine important rules of heredity? And wasn't pea seed shape one of the characteristics he studied?"

"Yes it was," said Jolene. "I guess we should review what Mendel had to say about peas."

Instructions

Sort through your findings from the case study introduction and identify information that applies to the inheritance of pea seed traits. This information and the questions posed by Joel E. will be the basis for your small group investigations. You may have further hypotheses about the genetic basis of pea seed traits, which you will have an opportunity to investigate in this module of the case study.

Investigation Phase

1. Download the *Pea Taste Evolution* Powerpoint® slides slide set from:
   http://evo-ed.com/PowerPoint Teaching Resources/Pea Taste Evolution.pptx
   These slides will be used in this module and throughout the case study.

   Slide Notes:

   - Slides 27–31 introduce and summarize Mendel's work.
   - Slides 32–37 tie Mendel's rules to meiotic events.

2. After viewing these slides, complete the questions below for homework.

Homework Questions

1. What are Mendel's two fundamental rules of inheritance?
2. Explain these rules in term of meiotic events.
3. What is an allele? How do the two alleles that determine pea seed shape/taste function?
4. Which of Mendel's laws is applicable to pea taste and how?
5. *Synthesis question:* Mendel and Darwin were contemporaries, although they did not know one another. How might the principles of Mendel's laws of inheritance overlap with Darwin's theory of evolution?

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Module: Molecular Genetics of Round and Wrinkled Peas (~40 minutes)

"Of course, we know a lot more about how traits are determined than Mendel did. For example, we know that the information for the proteins that determine traits resides in DNA," said Jolene.

"Hmmm—I'm not sure I remember how that works—what's the nature of DNA and how does it determine pea seed taste?" asked Joel E.

"To answer this question, we should investigate DNA, the information that is the molecular basis for what Mendel found," said Jolene.

"And the next logical question is: what is the nature of the information that makes some pea seeds round… and how does it compare to the information that makes other pea seeds wrinkled," said Joel E.

"Correct—let's get cracking!" said Jolene.

Instructions

Sort through your findings from the case study introduction and identify information that applies to the molecular biology of pea seed taste and shape. This information and the questions posed by Joel E. will be the basis for your small group investigations. You may have further hypotheses about molecular biology of pea seed taste and shape, which you will have an opportunity to investigate in this module of the case study.

Investigation Phase

1. Download the *Pea Taste Evolution* Powerpoint® slides slide set from:
   http://evo-ed.com/PowerPoint Teaching Resources/Pea Taste Evolution.pptx
   These slides will be used in this module and throughout the case study.

   Slide Notes:

   - Slides 38–43 provide a review of basic genetics and the relationship between the sbe1 gene and the SBE1 protein.
   - Slides 45–51 present the molecular differences of the R and r alleles.
2. After viewing these slides, complete the questions below for homework.

Homework Questions

1. How does the coding sequence (DNA) for the SBEI protein differ between the round (R) allele and the wrinkled (r) allele?
2. Why do *both* the RR and Rr genotypes produce round peas?
3. We call some traits *dominant* and others *recessive*, and we relate this to their respective alleles. Explain, in terms of protein function, why some traits are expressed when alleles are heterozygous.
4. *Synthesis question:* Does the rr genotype result in a gain or loss of function? How could either a loss or gain of function be evolutionarily important?

Module: Population Genetics and Artificial Selection of Round and Wrinkled Peas (~40 minutes)

Joel E. said, "I wonder how long it took for ancient farmers to figure out how to get the sweet peas that occurred accidentally to be the primary peas in their fields. First, they had to figure out that some were sweeter than others and then start doing some careful planting."

"The 'careful planting' is the same as selective breeding," said Jolene.

"What does that mean? You make it sound like ancient farmers had to manipulate the sex lives of pea plants!" asked Joel E.

"Perhaps… in a way. Maybe we should find out more about manipulating pea plants and getting a field of sweet peas," said Jolene.

"Great! Let's get started," replied Joel E.

Instructions

Sort through your findings from the case study introduction and identify information that applies to the breeding and population genetics of peas. This information and the questions posed by Joel E. and Jolene will be the basis for your small group investigations. You may have further hypotheses about the breeding and population genetics of peas, which you will have an opportunity to investigate in this module of the case study.

Investigation Phase

1. Download the *Pea Taste Evolution* Powerpoint® slides slide set from:
   http://evo-ed.com/PowerPoint Teaching Resources/Pea Taste Evolution.pptx
   These slides will be used in this module and throughout the case study.

   Slide Notes:

   - Slides 52–54 discuss population genetics and artificial selection and include an online simulation called the *Selective Farmer* (see slide 54 or http://www.evo-ed.com/Pages/Peas/Farming/Farming.html), which models selection over many generations for either round or wrinkled peas.
   - Slides 55–61 follow the game with scenarios/questions that connect population genetics with artificial selection.

2. After viewing the slides, complete the questions below for homework.

Homework Questions

1. Why does selecting for wrinkled peas eliminate the information for round peas so quickly in a population?
2. When selecting for round peas in the *Selective Farmer* simulation, can you ever eliminate the information for wrinkled peas from the population?
3. Explain what happens when you choose the "no selection" option in the *Selective Farmer* simulation.
4. Let's say that you are a farmer with a crop of wrinkled peas. Then, for some reason, having starchy peas becomes more desirable. Do you think you could produce a monoculture of starchy peas with your crop population? Explain your answer.
5. *Synthesis question:* Compare and contrast artificial and natural selection.

Guide to the Selective Farmer *Simulation*

Objective: To show changes in frequencies in phenotypes, genotypes, and alleles based on artificial selection.

In this game, you will be given a choice of whether you want to select for round peas, wrinkled peas, or neither. After making your choice, you will harvest the field of peas shown and then automatically replant based on your choice. For example, if you had decided to select for round peas, the simulator will only replant the round pea phenotype.

The basic questions that can be answered using this simulation are:

- For each of the three scenarios, how many generations does it take for one allele to become fixed in the population?
- Does this happen more quickly when selecting for the round phenotype or for the wrinkled phenotype?
- How difficult do you think it was for ancient farmers to remove the R allele from their cultivated pea population?

The Game: The opening screen has three choices: Select for round, No Selection, and Select for wrinkled. Make your initial choice.

At the right, you will see three icons:

1. Provides basic instructions.
2. Grows a crop of peas.
3. Takes you back to the introduction to *The Selective Farmer*

Below the icons is a set of graphs. These record, for each generation, the frequencies of the: two phenotypes (wrinkled, round), genotypes (RR, Rr, rr) and alleles (R, r).

On the left side of the screen are two buttons: *Harvest* and *Show Plants;* there is also a "field" of peas. Clicking on the harvest button clears the "field" and allows you to *plant* the next generation. After each *harvest*, the frequencies of that generation are added to the graph. Alternatively, rather than show the "field" as pea plants, you can click on *Show Peas* to get a visual representation of the number of round and wrinkled phenotypes for that generation. You then *harvest* and *plant* the desired number of generations.

Use data you generate with the *Selective Farmer* simulation to answer the set of homework questions for this module, which are repeated below.

Homework Questions (again)

1. Why does selecting for wrinkled peas eliminate the information for round peas so quickly in a population?
2. When selecting for round peas in the *Selective Farmer* simulation, can you ever eliminate the information for wrinkled peas from the population?
3. Explain what happened when you chose the "no selection" option in the *Selective Farmer* simulation.
4. Let's say that you are a farmer with a crop of wrinkled peas. Then, for some reason, having starchy peas becomes more desirable. Do you think you could produce a monoculture of starchy peas with your crop population? Explain your answer.
5. *Synthesis question:* Compare and contrast artificial and natural selection.