Peas in a Pod

This episode introduces the concepts of genetics and its origin. The idea of code itself and how it relates to the study of genetic structure is touched upon, and a lighthearted view of the history of how gender and heredity have been explained throughout the ages is presented. As the program progresses through history, we meet several luminaries in the world of genetics, including Carolus Linnaeus, lauded as the Father of Classification; Josef Kölreuter, known for his experimentation with hybridization of plants, their fertilization, and development; Charles Darwin, a pioneer in the concepts of evolution who pursued and categorized heredity and inheritance; and the man considered to be the father of modern genetic theory, Gregor Mendel.

Lesson Planner

Day 1: Activity: Decode . . . and Decide
Homework: Decode . . . and Decide

Day 2: View Segments 1 and 2
Journal notes: Early scientists
Activity: Begin Wrinkled/Smooth Peas in a Pod lab

Day 3: View Segment 3
Journal notes: Mendel's Laws
Activity: Continue Peas Lab

Day 4: Activity: Continue Peas Lab
- Wrinkled and smooth peas sugar test
- Starch body observations

Day 5: Activity: Continue Peas Lab
- Enzymatic synthesis of starch

National Science Education Standards

Content Standard C

. . . basis of heredity, biological evolution . . . and behavior of organisms.

SEGMENT ONE: *THE CODE*

The episode opens with a discussion of the four-part genetic code (DNA) of which all living things are comprised and its billions of different permutations that cause variation and diversity.

This first segment presents the impacts genetic engineering will have on all walks of human, and other, life and the changes and dilemmas this knowledge will bring about.

Key Words

biotechnology	exploit
dilemma	progeny
dossier	unique

Learning Objectives

Students will:
- Define and use in context to the material all key words.
- Explain the concept of code.
- Identify Linnaeus, Kölreuter, Darwin, and Mendel and their contributions to the history of genetics.

Pre-Viewing Activity

Devote 20 to 30 minutes at the beginning of the period to the first part of the "Decode . . . and Decide" learning activity at the end of this lesson. Hand out the worksheet provided, and let students proceed. This activity serves as a prelude to the concept of coding overall and variation caused by the different juxtapositions. The follow-up homework assignment involves continuing fun with Morse code.

Viewing Activities

The opening segment is very short and lends itself to perhaps a single PAUSE point. CUE the tape to the very beginning of the segment, including the opening graphic and the series' opening music.

Inform your students that you will be using this videotape to aid in their learning experience as it pertains to genetics and concepts of heredity. Encourage students to actively listen to the lyrics of the series' opening music, *Cracking the Code,* and ask them to take notes on whether or not the lyrics present any new thoughts to them on the subject of heredity. PLAY the tape through the opening musical segment completely. PAUSE at the end of the musical opening, prior to the beginning of the rest of the segment. Copy and distribute the lyrics for the song (found at the end of this lesson).

Discussion Point

Ask students if the music presented any new concepts to them. Had they ever thought of heredity in terms of history as well as passing on genetic traits to their progeny? Had they ever wondered how those traits are passed?

Resume PLAY and continue until you see a full-screen image of a toddler playing with blocks and the narrator says, ". . . and is the subject of this series." PAUSE the tape.

Discussion Point

Students just heard the narrator talk about genetic code and its potential effects on science, medicine, and agriculture. Ask them what they think she meant when she said that genetic engineering brings about dilemmas and difficult choices.

Cross-Curricular Applications

Math: Discuss how code is implicit in mathematics. In turn, discuss how code is found everywhere around you. Some examples might include: sign language, binary code, braille, military code, HTML, Morse code, UPC bar codes, area codes, mailing address codes, library code, etc.

SEGMENT TWO: *FROM ANCIENTS TO EVOLUTION*

This segment of the episode briefly touches on early ideas concerning heredity and inheritance and how these theories were garnered from the beliefs of ancient Greece and persisted into the nineteenth century.

Key Words

cross-breeding	heredity
divining	inheritance

Learning Objective

Students will:

- Articulate some ancient concepts of heredity.

Viewing Activities

CUE tape to the drawing of a woman sitting in an apple tree. The first thing the narrator says is, "How did we arrive at this point?" PLAY.

PAUSE the tape when you hear the narrator say, "There seemed to be no consistent pattern within the visible complexity of life." The visual will be a baby in a yellow sleeper smiling and clapping its hands.

Discussion Point

If you deem it to be appropriate based upon the make-up of your student roster, ask your students to use their own family as their guide. Ask them to describe whether or not they believe they themselves carry more visible genetic links to their parents or to their grandparents? To their siblings? Or cousins? Chart their findings on the board and mathematically profile your classroom, figuring out the percentage(s) of those who feel they resemble their parents or their grandparents, and so on.

Let students know that they're going to be seeing one or two archaic concepts of heredity and inheritance. Ask them to watch for erroneous information and make note of why it may have come about. Resume PLAY ▶. When you see the Greek animation played out on the urn and hear the pregnant Greek woman say, "Give me a break!" STOP ■ the tape.

Discussion Point

Ask students what they felt about the information received in the last segment. What are their initial reactions to the theories presented?

Ask students to list what they wrote down as erroneous information as they watched the program. Ask them what they thought about the concept of divining, or reasoning something through? How many times have they done the same thing, tried to reason something out and not test their own theories? What are the pros and cons of this concept? Promote discussion.

Ask students to give their best guess as to when humans started manipulating genes and creating "life to order." Tell your students that, as is often the case, common people discover things all the time. In this case, people discovered how to manipulate genes many thousands of years ago. Tell students to listen for when plants were able to be crossbred, as they view the next clip.

Resume PLAY ▶ until you hear the narrator say, "In the 1700s, the Swedish scientist and physician Carolus Linnaeus undertook the monumental task of cataloguing and classifying every known form of life." The visual will be an eighteenth-century painting of Linnaeus. PAUSE ⏸ the tape.

Discussion Point

Ask students if the classification system developed by Linnaeus is still in existence today. How is it represented? (*ANSWER: The hierarchical structure is kingdom, phylum, class, order, family, genus, and species. *NOTE: This offers an opportunity for the discussion of the emerging classification of domains.)*

Let students know that after Linnaeus, scientists began to wonder about what causes differences in species, and whether or not change occurs over time, or if we are simply discovering new species that were present all along. Ask students to watch for information on this subject in the next segment and listen for the name of the scientist associated with determining that new species are continuously evolving.

Resume PLAY ▶. When you see the woodcut of Carolus Linnaeus and hear the narrator say, "Linneaus was convinced that the crossbreeding of two different plant species would produce a new intermediate one, but he didn't put his theory to the test." PAUSE ⏸ the tape.

Discussion Point

Ask students who actually determined the first evidence of evolution? Is it the original idea or the person who provides experimental support of the idea that deserves the credit for a new discovery?

Let students know that they're going to meet the individual who went one step further than Linnaeus and tested out the theory of crossbreeding. Ask students to watch for the video's definition of what is the real test of whether or not a hybrid is a new species? *(ANSWER: If it can reproduce itself.)*

Resume PLAY ▶. Play through until you hear the narrator say, "Kölreuter didn't recognize its significance. Perhaps he was too distracted by his gardener." The visual is the animated battle between Kölreuter and his gardener, Saul. When the screen goes to black, PAUSE ⏸.

Discussion Point

Ask students to articulate what the video claims to be the test of a new species.

Ask students for the name of the scientist we usually associate with the concept of evolution. Someone should be able to come up with Charles Darwin. Tell students they will be seeing more about Darwin and his theories in the next segment. Ask them to listen for the name of Darwin's theory, which describes survival of the fittest, or the continued survival of species that seem best equipped to successfully reproduce. *(ANSWER: Theory of Natural Selection.)*

PLAY ▶ this segment on Darwin's concept of Natural Selection. When you hear the narrator say, "It caused a sensation and made him a world celebrity." PAUSE ⏸ the tape. The visual cue will be a book open to the flyleaf emblazoned with the title of Darwin's book.

Review for comprehension to be sure all students understand the concept of Natural Selection.

Ask students for the name of the Austrian monk who is most commonly linked with genetics. Let them know this individual will be featured in the final video segments. Resume PLAY ▶.

When you hear the narrator say, "In the process he laid the groundwork for the new science of genetics," and see the screen morph the word "heredity" into the name of Gregor Mendel, STOP ⏹ the tape.

Post-Viewing Activity
Be sure students clearly understand and can articulate the contributions to the history of genetic theory of Linnaeus, Kölreuter, and Darwin.

Journal Notes
Have students jot down each scientist's contribution in their journals before ending the lesson that day.

SEGMENT THREE: *GREGOR MENDEL*

In this information-packed segment, students are introduced to the concepts of Mendelian genetics, from basic phenotype and genotype, through independent assortment. Biographical information on Gregor Mendel himself, indicating some of his reasons for his research, are touched upon. The strength of this segment is the graphical representations of the basic vocabulary of genetics.

Key Words
alleles	humble
"breeding true"	hybrid
control (noun)	imbibement
diploid	meticulous
dominant	obscure
eukaryotic cells	paradox
factors	phenotype
fertilize	random
genotype	recessive
germ cell	recombination
heterozygous	segregation
homozygous	trump

Learning Objectives
Students will:
- Clearly articulate Mendel's 1st and 2nd Laws of Heredity.
- Define the terms *phenotype* and *genotype*.

Pre-Viewing Activity
In order to determine just how much students already know about Gregor Mendel, conduct a Think/Pair/Share activity. Have students face a neighbor, either in front or behind, or to the left or right. This pair is to come up with the most detailed information, or knowledge statements, it can about monk/scientist Gregor Mendel. Give pairs roughly five minutes to put together their notes. At the end of that time, the instructor will serve as scribe and write these knowledge statements on the board.

Inform students they will be viewing the final segment of this episode, which is devoted to a biographical and career sketch of Gregor Mendel. Because it is always wise to involve students with a task when viewing video in the classroom, assign students to watch for validation of their knowledge statements about Mendel and for new information.

Viewing Activities
CUE the tape to where you see the text art "Heredity" morph into the name Gregor

Mendel. The tape begins with some pertinent biographical information about the Austrian monk. PLAY ▶ through the segment until you hear the narrator say, "Once admitted into the order, Mendel was given the new Christian name of Gregor." PAUSE ⏸ the tape.

Discussion Point

The tape clearly implies that Johann Gregor Mendel's impetus for entering the monastery was related far more to his educational goals than those of a religious nature. Do the students consider this arrangement to be a fair deal? Why or why not? How does Mendel's decision and reasoning compare with that of someone today who enters the military to earn financial aid for college?

Resume PLAY ▶. When you hear the narrator say, ". . . and he wondered if a new species could arise from the cross-breeding of two existing species," PAUSE ⏸ the tape.

Discussion Point

Ask your students to put into their own words what made the contribution of Mendel even more important than, perhaps, that of Darwin and Kölreuter. (*ANSWER: With the marriage of scientific theorization and quantitative data, no more is a theory merely speculative.*)

Resume PLAY ▶ until you see the animated page of Mendel's journal that shows "Dominant" and "Recessive" at the top, "P, F1, and F2" generations on the page, and hear the narrator say, "He was well aware that traits sometimes skipped generations, so this was no surprise." PAUSE ⏸.

Discussion Point

To ensure comprehension, have several students put into their own words what the terms *P, F1, F2, dominant* and *recessive* mean. Garner several students' viewpoints in order to get a cross-section of understanding. When you are sure your students understand, resume PLAY ▶.

Mendel will make his big, earthshaking discovery in this next section of the episode. Have students listen closely to determine that discovery. *(ANSWER: Pattern of Inheritance, the cornerstone of genetics.)*

PAUSE ⏸ after the graphic illustration of the concept of factors (genes) contributing to phenotype, when you hear the narrator say, ". . . three possible genotypes: two dominant genes, in which case the phenotype is purple, two recessive genes in which case the phenotype is white, and . . . one of each, in which case the single dominant gene causes the phenotype to be purple."

Discussion Point

Once again, use this time to assess student understanding. Make sure the distinction between genotype and phenotype is clearly understood, by asking students to give additional examples of each.

Journal Notes

Ask students to record an example of genotype and phenotype (other than what Mendel observed in pea plants) in their journals. Ask them to write a sentence or two explaining why they chose this example.

Viewing Activities

Resume PLAY ▶ until the computer animation of birds carrying a banner saying, "The Law of Random Segregation" flits across the screen. PAUSE ⏸ to ensure student comprehension of this law.

Resume PLAY ▶ until you hear the narrator say, "His experimental results were now explained," and see the battered animated image of Mendel kick up his bandaged heels. PAUSE ⏸ once again to check for comprehension. Use probing questions or invite students to raise their own questions about these laws. (*NOTE: This is a good opportunity to utilize the strategy of rewinding and replaying a segment if you determine review is needed.*)

Explain to students that the next section of the episode will deal with Mendel's efforts to determine the statistical elements of the "Law of Independent Assortment," in which two or more traits are measured.

This section concludes with the Mendel Song. Copies may be made for the lyrics of the song and distributed prior to viewing this section or at the conclusion of it.

Resume PLAY ▶ until the end of the program and then STOP ■.

> ***Discussion Point***
> Why do you think Darwin achieved the recognition he did, while Mendel's discoveries remained in relative obscurity for nearly another generation?

Journal Notes

Invite students to review their notes and to record all of Mendel's Laws in their journals, along with their own notes explaining each law, and giving additional examples.

Post-Viewing Activities

Wrinkled/Smooth Peas in a Pod/ Peas Probability

Genetics in the 2000s is a blend of classical studies of inheritance and molecular genetic procedures that permit one to decode the causal basis for particular traits. Often, students are given instruction in genetics without understanding the relationship between classical and molecular genetics. Bridging this gap is the focus of the primary laboratory investigation for this episode, "Wrinkled/Smooth Peas in a Pod."

Wrinkled peas were cultivated years before Mendel's time, probably because they tasted sweeter than smooth peas (Bhattacharyya et al., 1990). Reviewing Mendel's work shows that seed shape is determined by a single gene, with the allele for smooth peas dominant over the allele for wrinkled peas. When Mendel's work was re-discovered, research determined the biochemical differences between smooth and wrinkled peas. Differences were found in the content of various macromolecules (Bhattacharyya et al., 1990). Particular attention was paid to the content of sucrose and starch.

The differences in starch and sugar content are considered to determine the phenotypic differences between smooth and wrinkled peas. The wrinkled pea, having higher levels of sucrose, is recognized to have higher water content in the developing embryo and consequently a larger cell size in the maturing embryo. When the wrinkled pea seeds mature and dry, a larger proportion of seed volume is lost as compared to the smooth pea seeds. Wrinkling results because the outer seed layer does not shrink proportionately as much as the embryonic plant parts (Bhattacharyya et al., 1990).

The sugar and starch differences between smooth and wrinkled seeds gave clues to the molecular mechanism behind the phenotypic differences—namely, difference in starch metabolism. It is at this level that we consider genotypic expression. Enter the enzyme. It was loss of a functional enzyme named starch-branching enzyme 1, SBE1, which catalyzes conversion of amylase to amylopectin, that caused a higher concentration of sugar in the wrinkled pea (Guilfoile P., 1997).

Molecular studies include several concepts that illustrate control of protein and enzyme synthesis by DNA. The nature of the gene is frequently discussed to interrelate the two subunits. However, the physical appearances of smooth and wrinkled peas are rarely looked at on a molecular level in the classroom. "Wrinkled/Smooth Peas in a Pod" is designed to explore this relationship.

References

Cell 60, 115–22
by M.K. Bhattacharyya, A.M. Smith, T.H.N. Ellis, C. Hedley, C. Martin (1990)

The wrinkled-seed character of peas described by Mendel is caused by a transposon-like insertion in a gene encoding starch branching enzyme.

The American Biology Teacher 59, 92–94.
by Guilfoile, P. (1997)

Wrinkled peas and white-eyed fruit flies, the molecular basis of two classical genetic traits.

National Science Education Standards

http://nap.edu/readingroom/books/nses/html

Content Standard C
As a result of their activities in grades 9–12, all students should develop understanding of the cell, molecular basis of heredity, biological evolution, interdependence of organisms, matter, energy, and organization in living systems and behavior of organisms.

The Molecular Basis of Heredity
In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from sub-units of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (through a template mechanism). Each DNA molecule in a cell forms a single chromosome.

Links

Experiments in Plant Hybridization (1865) by Gregor Mendel
www.MendelWeb.org/Mendel.html

MendelWeb
www.MendelWeb.org/MWtoc.html
www.MendelWeb.org/MWorel.intro.html

"Heredity Before Mendel," an essay by Vítezslav Orel, Emeritus Head, The Mendelianum (Brno, Czech Republic) Translated by Stephen Finn Copyright © 1996 by Oxford University Press

Cross-Curricular Activities

Language Arts
Have students take on the role of Mendel's protégés. The scenario? They have been encouraged and nurtured by Gregor Mendel and are now in the world of 21st-century genetics. They write to Gregor, letting him know how far genetics has come from white and purple pea plants.

Mathematics
Conduct a school-wide (or at least grade-wide) survey of "Can you roll your tongue?" The ability (or lack thereof) to perform this is genetic in nature. Rolling one's tongue is a dominant trait; therefore, according to Mendelian genetics, phenotypically the population of the school that *can* roll its tongue compared to that which *cannot* should be three to one. Have students compile their data, put together their information in a graphic form (e.g., table, graph, figure, etc.), and determine if the Mendelian expectation is supported by their data. (*NOTE: The larger the population the better the chance that the ratio will match expectation. If you have a small school population, and your students are stymied by the results, consider it another teachable moment in the area of statistical sampling.*)

CRACKING THE CODE THEME SONG

The script that's written in our genes
Directs us from behind the scenes;
The words within it shape life's destiny.

Hidden in your DNA
Is your genetic dossier;
It tells your future and your history.

How traits get passed from parents to a child,
Is something that has kept us so beguiled.

Cracking the Code,
Genetic mysteries to unfold!

Cracking the Code,
Genetic secrets will be told!

Now we're reading from life's page,
How did we get to this new stage,
To solving what was once life's mystery?

Would you like to know from whence you've sprung?
Would you like to stay forever young?
Would you like to shape your own heredity?

We're learning how to pull upon the strings
To rewrite the script from which life itself springs.

Cracking the Code,
Genetic futures will be foretold!

Cracking the Code,
Genetic power about to explode!

Cracking the Code,
Genetic mysteries to unfold!

Cracking the Code,
Genetic secrets will be told!

Cracking the Code!

MENDEL SONG

Oh why dear God did you make it so complex,
To understand the offspring
That result when there is sex?

But there is one monk among us who can tell
How it all works, we feel like jerks
Next to Gregor Mendel.

The answer's in my garden
Where I've planted different peas,
And sprinkled pollen as I please,
Then counted out the progenies.

What did you discover
In your garden with your peas
About those factors we can't see, but
Which explain our family trees?

Here's the news. They come in twos,
They segregate, it's up to fate,
If an egg or a sperm
Has a trait that will dominate.

Here's the news. They come in twos,
They segregate, it's up to fate,
If an egg or a sperm
Has a trait that will dominate.

And when they join together
My forecasting's most impressive.
Betcha three times out of four I'm right,
Unless they're both recessive.

To what do you owe your success?
To counting and my green thumb.
But where these unseen factors are
Well that I cannot fathom.

Here's the news. They come in twos,
They segregate, it's up to fate,
If an egg or a sperm
Has a trait that will dominate.

Later on the world was awed, at
What he learned from those pods.
But back then no one hurrahed
Gregor Mendel but his God.
Back then no one hurrahed
Gregor Mendel but his God.

WORKSHEET

Student Name: ___________________________________

Peas in a Pod

DECODE . . . AND DECIDE

What is a code? Cells of living organisms use chemical code to transmit information, intracellularly, intercellularly, and from one generation to another generation. By itself, a coded message is nothing. The importance of the code is in its ability to tell cells what to do, how to do it, and when it should be done.

Prior to considering the chemical code of cells, we will examine another, perhaps more familiar code. In the nineteenth century, Samuel F. B. Morse invented a code system which was used to send messages across telegraph wires by use of electric current. Presently the same code is sent using radio waves and occasionally military ships use flashing lights (quick for dots, slow for dashes) to communicate silently and secretly. Each set of dashes and dots equals a letter or item of punctuation.

Morse Code Key

A	.-	H	....	O	---	V	...-
B	-...	I	..	P	.--.	W	.--
C	-.-.	J	.---	Q	--.-	X	-..-
D	-..	K	-.-	R	.-.	Y	-.--
E	.	L	.-..	S	...	Z	--..
F	..-.	M	--	T	-	.	.-.-.-
G	--.	N	-.	U	..-	?	..--..

Classroom Activity

Below is a sentence to be translated, or decoded, in class. Before you discuss the translation aloud, please check with a partner for verification.

... - .. -.-. -.-   --- ..- -   -.-- --- ..- .-.   - --- -. --. ..- .

Homework Activity

As a homework assignment, answer the following questions:

1. Translate (decode) the message on the next page using the Morse Code key above. Check with a partner to verify translation.

2. How many different symbols does Morse Code use?

3. Provide a brief explanation of how this system can code 26 letters and two items of punctuation using so few symbols.

Student Name: ______________________________

Decode . . . and Decide

.-.. .. ...- .. -. --.   - .... .. -. --. ...   ..- ... .

.-   -.-. --- -.. .   - ---   -.-. .- .-. .-. -.--   .- .-..

- .... -. ... - .-. ..- -.-. - .. --- -. ...   -. . . -.. . -..

..-. --- .-.   ... ..- .-. ...- .. ...- .- .-..   .-.-.-

- .... -. ..-. --- .-. -- .- - .. --- -.   .. ...

.. -.   - ....-. --- .-. --   --- ..-.   .-

-.-. .... . -- .. -.-. .- .-..   -.-. --- -.. .

-.-. .- .-.. .-.. . -..   -.. -. .-   .-.-.-

-.. ---   -.-- --- ..-   - .... .. -. -.-   .-- .   -.- -. --- .--   . -. --- ..- --. ....

- ---   . - .... .. -.-. .- .-.. .-.. -.--   -.-. .-. .- -.-. -.-   - .... .   -.-. --- -.. . ..--..

Note:
The second line *does* contain an error. The last word in the line is incorrect but deliberately so. It should code for the word "all," but is missing a letter. How do you think an error in genetic code could impact an organism?

Cracking the Code
The Continuing Saga of Genetics

Peas in a Pod

Answers to Decode . . . and Decide Homework Activity

1. Verification—The decoded message says: *Living things use a code to carry all the instructions needed for survival. This information is in the form of a chemical code called DNA. Do you think we know enough to ethically crack the code?*

2. Two symbols, a dot and a dash.

3. The type and the number of symbols are used in sets that are arranged in a different manner for each letter or item of punctuation.

Peas in a Pod

WRINKLED/SMOOTH PEAS IN A POD

Introduction

As you saw in the video, *Cracking the Code*: "Peas in a Pod," Brother Gregor Mendel chose pea plants as his model partially for their flower shape, which helps prevent cross-pollination. One of the characteristics he focused on was the shape of the pea seed. Some pea seeds are wrinkled, and some pea seeds are smooth in their appearance. When Mendel crossed plants grown from round (or smooth) pea seeds with plants grown from wrinkled pea seeds, the first generation pea seeds were all round and smooth. He called it the F1 generation. When he crossed two offspring from the first generation, the second generation (F2) produced an almost perfect 3:1 phenotypic ratio. Three-fourths of the second generation produced round seeds, and one-fourth produced wrinkled seeds. Combined with his studies of six other traits, Mendel concluded that pea plant traits were governed by two determiners (we now call these genes). One of the determiners was contributed by the pollen, the other by the pea-plant ovule. His further conclusion, important to this learning experience, was that smooth pea seed factors are dominant to factors for wrinkled pea seeds.

Mendel's findings were made before knowledge of cell structure. He knew nothing about chromosomes and genes. He was not aware of the diploid state found in most eukaryotic cells. But he was a mathematician, and he did deduce the probability that two determiners control hereditary traits in pea plants.

This lab experience is separated into four investigative segments:

1. Analyzing dry and imbibed weights of wrinkled and smooth pea seeds
2. Wrinkled and smooth peas sugar test
3. Starch body observations
4. Enzymatic synthesis of starch

1) Analyzing dry and imbibed weights of wrinkled and smooth pea seeds

Materials per lab station

- 11 smooth and 11 wrinkled pea seeds
- 2 small beakers (or waxed cups)
- triple beam or digital balance
- paper towels
- wax pencil or permanent marker
- water

Begin the experience by selecting ten smooth and ten wrinkled pea seeds. Examine a representative from each of the seed types. Good observation requires using as many of the senses as possible. Obviously, tasting and hearing will not be used in your observations, but the other three senses may certainly be employed as you investigate.

Create a data table including pea variety, dry and wet weight columns, and a section for percent of increase. Make detailed written notes. Weigh ten smooth pea seeds and place them in a beaker or waxed paper cup labeled “S” for “smooth.” Repeat procedures, using ten wrinkled peas placed in a beaker or waxed paper cup labeled “W” for “wrinkled.” Add identical volumes of water to both samples to cover peas completely. Allow one to two days for peas to absorb water. Reserve remaining dry peas, one of each variety.

A. As you examine the smooth and wrinkled pea seeds, consider the following. Could the phenotypic differences between the two varieties be caused by the drying process, or some other factor? What procedure might you employ to show that the drying of the seeds is *not* responsible for their different appearances?

B. Pour off the water remaining after imbibement (absorption of water). Place the peas on separate paper towels and blot them. Reweigh each sample and record the weight data under “weight wet” in your table. Calculate the percent of weight increase for each pea variety and record the data.

$$\frac{\text{weight difference}}{\text{dry weight}} \times 100 = \%\ \text{increase}$$

C. Take two peas from each sample and allow them to dry out. Make sure you indicate which are from the smooth group and which are from the wrinkled group. Allow one to two days for the peas to dry.

D. Pulverize the remaining smooth peas into a paste, cover and reserve in a clean, labeled jar. Create a separate paste from the remaining wrinkled peas, reserve in a clean, labeled jar.

2) Wrinkled and smooth peas sugar test

Materials per lab station

- 2 peas (one each wrinkled and smooth) reserved from the first day
- test tubes (labeled "S" for "smooth," "W" for "wrinkled," and "C" for "control")
- boiling water bath
- triple beam or digital balance
- ground paste prepared from soaked smooth and wrinkled pea seeds
- distilled water, dH_2O (tap water may be used)
- Benedict's solution
- Pasteur pipettes or medicine droppers
- permanent marker or multicolored tape

Weigh out one gram of smooth pea seed paste and one gram of wrinkled. Fill two test tubes with dH_2O. Add a dropper of Benedict's solution to each tube. Add the gram of smooth pea paste and mark the top of the tube with an "S," using a permanent marker (or use different colored tape). Place your thumb over the tube top and shake vigorously to mix. Repeat for the wrinkled pea paste sample. Prepare a control tube containing all reagents except the paste. Boil samples for five minutes. Record the color of each tube in chart format.

Study Questions

A. Which seeds absorbed the greatest amount of water? Explain. How do the surface areas of the seed coats compare between the two seed varieties?

B. Did each variety return to the original shape after drying?

C. What do the colors produced in the boiled tubes indicate? Was there a difference between the pea varieties?

3) Starch body observations

Materials needed

- compound microscope
- dilute Lugol's solution
- 2 slides and 2 cover slips
- stirring rod
- paper toweling
- 2 Pasteur pipettes or medicine droppers
- 2 beakers labeled "S" and "W" containing the ground pea paste and dH_2O
- lab book and pencil

Prepare two glass slides, one labeled "S" and one labeled "W." Each beaker contains a variety of ground pea seed to which dH_2O has been added. Stir each sample, being careful to wipe the stirring rod clean after doing each one. This will re-suspend samples and maintain integrity for each one. Place a small drop of each sample on the appropriate slide and add a small drop of Lugol's to each. Put the cover slips on and observe for changes in color. If a sample contains starch bodies, it will be stained gray-blue to black. With a pencil, sketch three to four starch bodies of each variety in your lab book or on plain white paper. Label the drawings and note the magnification used.

Study Questions

A. Below you will find some word combinations which could be useful in describing the starch bodies you observe. Which terms would you choose to describe wrinkled pea seed starch bodies? Which terms would you choose to describe smooth pea seed starch bodies?

❑ compound or ❑ simple

❑ whole or ❑ divided

❑ round/oval or ❑ irregular

B. How do starch bodies differ in round (or smooth) and wrinkled pea seeds?

C. Are the differences in the starch bodies more likely caused by genetic or environmental differences? Justify your answer.

4) Enzymatic synthesis of starch

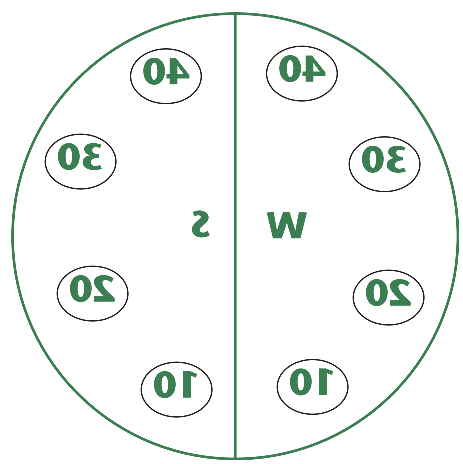
Materials needed

- 1 glucose-6 phosphate Petri plate
- paper towels
- permanent marker
- Pasteur pipette or medicine dropper
- 2 small beakers labeled “S” and “W” containing a crude enzyme extract

The starch bodies that you previously observed contained many starch molecules. These are synthesized from simple sugar molecules by dehydration synthesis or condensation reactions. The question we will address in this learning experience is this: Is there a difference between round—or smooth—and wrinkled pea seeds in their ability to synthesize starch?

The answer may be determined by adding equal amounts of crude enzyme extract to glucose-6 phosphate plates. If starch synthesizing enzymes are present, the glucose-6 phosphate will be converted to starch.

Turn over your Petri plate and mark the bottom as shown in the diagram below. With a pipette, apply a small drop of extract at the 40-minute position. Continue this process at ten-minute intervals until all positions on the plate contain extract. Allow the plate to stand an additional ten minutes. Carefully blot up any remaining extract with paper toweling. Apply dilute Lugol’s solution to the entire plate surface. Record your observations after three to five minutes. Record your data in a table format.



Data Legend: - = no starch, + = trace of starch, ++ = moderate starch, +++ = maximum starch

Study Questions

A. Why were glucose-6 phosphate plates used in the last procedure rather than plain glucose plates?

B. Which seed variety contains more starch? Which contains the most sugar? What evidence supports your conclusions? Are your results consistent with other groups in your class?

C. How might the physical differences between round (or smooth) and wrinkled pea seeds be explained by both genetic and environmental differences?

Summary Writing Assignment (Homework)

Summarize how round (or smooth) and wrinkled pea seed conditions are related to your observations. How might one pair of alleles be responsible for the characteristics you observed? Support your hypothesis with data you collected during the laboratory experiences.

Links

Pea Starch Mutants

www.jic.bbsrc.ac.uk/STAFF/trevor-wang/appgen/starch/mutants.html

From this Web site's introductory paragraph:

> "In 1987 a chemical mutagenesis programme was initiated to isolate mutants affected in the development of their seed. The initial screen was designed to isolate wrinkled-seeded mutants, but later screens identified a number of mutants with defective embryos and a number of round-seeded, starch mutants."

Mendel's Peas

www.jic.bbsrc.ac.uk/GERMPLAS/PISUM/ZGS4F.HTM

This Web site is ideal for references on Mendel's work with peas. From this Web site's introductory material:

> "Mendel made notes on a range of plant characters. He discussed the selection of the specific pairs of characters for his studies as being arrived at as those that showed clear and sharp separation when segregating. This removed the uncertainty of characters which were less distinct or *'more or less'* in character. While lacking the exact lines that Mendel used, much material contemporary with that of the day has found its way into germplasm collections from commercial sources and from geneticists who followed up on Mendel's work."

Cracking the Code
The Continuing Saga of Genetics

Peas in a Pod

WRINKLED/SMOOTH PEAS IN A POD

Laboratory Preparation

This laboratory experience is separated into four investigative segments:

1. Analyzing dry and imbibed weights of wrinkled and smooth pea seeds
2. Wrinkled and smooth peas sugar test
3. Starch body observation
4. Enzymatic synthesis of starch

Both round—or smooth—and wrinkled pea seeds can be purchased in one-pound weights from most biological supply houses. For both safety and chemical reasons, avoid purchasing seeds that have been treated with fungicides. We recommend you use a coffee grinder rather than attempt to grind peas with mortar and pestle. Glucose-6 phosphate is available through most biological supply catalogues. It keeps well when refrigerated.

The glucose-6 phosphate Petri plates are prepared by adding 5 grams of glucose-6 phosphate and 12 grams of agar to a liter of cold water. Bring to a boil and pour into 200 disposable 5 mL plates. NOTE: *Adjustments to these amounts can be made according to the number of plates needed.* After pouring the plates, swirl to evenly distribute the agar.

Dilute Lugol's solution can be prepared by diluting the standard Lugol's solution with 9 parts water to 1 part Lugol's.

Time Management

All four segments may be completed in two and a half hours. There is, however, a preliminary task that must also be accomplished. Students will need to weigh out smooth and wrinkled pea seeds and allow them to be imbibed (to absorb water) 24 to 48 hours before doing the investigations. As most high school time periods are confined to 45 minutes, the segments can be completed in three 45-minute periods, excluding the preliminary task.

Day 1 Preliminary Task: This requires students to weigh ten smooth and ten wrinkled pea seeds and place them in small beakers to imbibe (absorb water). This requires parts of classes designated as pre-lab activities. One sample pea of each type should be reserved dry.

Day 2 (45 minutes): This segment requires completion of the first and second procedures. Activities include reweighing imbibed peas, doing calculations, and determining sugar content in the pea types.

Day 3 (45 minutes): Students will stain and examine starch bodies with microscopes under 100x magnification.

Day 4 (45 minutes): Students will expose the glucose-6 phosphate plates to enzymes derived from the smooth and wrinkled pea seeds.

Preparation for Individual Lab Segments

Preliminary Task: (First procedure) Have smooth and wrinkled pea seeds available, as well as beakers, apparatus for weighing mass, and a water source. Students can use a simple table or a computer spreadsheet to record findings.

24–48 Hours Later: (Second procedure) Have magnification opportunities available; these may include hand lenses and/or dissection microscopes. A waste container and apparatus for weighing mass will be required for this procedure.

Day 1: Prepare laboratory stations as prescribed in student portion of laboratory experience. Grind the pea seed samples to a fine paste for laboratory groups. Provide boiling water bath(s) for student use.

Day 2: Prepare laboratory stations. Add a pinch of paste to a 20 mL beaker and fill with water. Students will stir contents before taking a drop of solution with a medicine dropper. Make sure students use separate droppers for the smooth and wrinkled pea seed samples. Prepare the glucose-6 phosphate plates to be used in the Day 3 learning experience. Prepare a *crude* extract of enzyme by adding 10 grams of smooth pea seed paste to 100 mL of water. Repeat for wrinkled pea seed. Stir the solutions and place under refrigeration for use in Day 3 activities.

Day 3: Prepare laboratory stations. Remove refrigerated pea seed extractions. Strain the suspensions through four layers of cheese cloth, squeezing the cloth to extract the maximum amount of enzyme. Dispense crude sample amounts to each laboratory station.

Note

Once imbibed, both smooth and wrinkled pea seeds will appear to be similar. This strongly suggests that the size, structure, and composition of pea-seed coats are similar in both varieties.

- Wrinkled seeds contain more sugar than do smooth seeds, and smooth pea seeds contain more starch than wrinkled seeds contain.
- Smooth pea seed starch bodies are simple, whole, and round to oval. Wrinkled pea seed starch bodies are compound, divided, and irregularly shaped.
- Starch production by smooth pea seed extract consistently produces more starch on glucose-6 phosphate plates than does wrinkled pea seed extract.
- The wrinkled pea seed condition is a result of a defective allele and becomes apparent only when the seeds are dried.

Summary

The time frame for these learning experiences may appear to be extensive, but the concepts and skills acquired by your students are also extensive. Inquiry is a priceless portion of good science teaching and learning, and these activities were designed with that thought in mind. A very special thank you goes out to **Ken House**, an award-winning retired New York State biology teacher, for his input into these learning experiences.

WORKSHEET

Student Name: ______________________________

Peas Probability

No. of flips	H	T
1		
2		
Totals		
Percent		
3		
4		
5		
6		
7		
8		
9		
10		
Totals		
Percent		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
Totals		
Percent		

No. of flips	H	T
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
Totals		
Percent		

No. of flips	H	T
51		
52		
53		
54		
55		
56		
57		
58		
59		
60		
61		
62		
63		
64		
65		
66		
67		
68		
69		
70		
71		
72		
73		
74		
75		
Totals		
Percent		

No. of flips	H	T
76		
77		
78		
79		
80		
81		
82		
83		
84		
85		
86		
87		
88		
89		
90		
91		
92		
93		
94		
95		
96		
97		
98		
99		
100		
Totals		
Percent		

Questions (answer on a separate sheet)

1. What happened to the percentages as the number of coin tosses was increased?

2. Why is it important to have a large number of offspring in a genetic study to have reliable results?

Peas in a Pod

PEAS PROBABILITY

Mathematics

It was made clear in the video that Gregor Mendel married the concepts of science and mathematics by applying the study of statistics to his work with peas and their recurring traits. In this day and time of education requiring real-life application and relevance, this aspect of the story of Mendel provides an opportunity for educators to make links from the curriculum to students' daily lives.

Probability is the name given to the branch of mathematics that deals with chance and how to predict whether a result is likely or unlikely. Saying something has a chance of happening is akin to asking, "What is the probability of this event occurring?" Some ways to express probability include:

- A coin has a *50/50* chance of showing a head when tossed.
- A die has a *1/6* chance of showing a 6 when thrown.

It is important to remember that in order for issues of probability to be accurate, all things must basically be equal.

The following activities serve to get students thinking. The homework assignment is to list five real-life applications of probability in their day-to-day lives. Some areas they may come up with include life insurance (rates are based upon projections, which are probabilities involving life expectancy); the lottery; medical prognoses; political polls; weather forecasting; and surveys.

Activity #1

Distribute the "Peas Probability Lab" worksheet found at the end of this lesson. Separate students into pairs, providing each pair with a coin to toss and making sure students have pencils or pens. Instruct students to follow the patterns presented on the worksheet, as follows:

1. Toss the coin twice.

2. Record the numbers of heads and tails.

3. Calculate the percentage of heads and tails.

Next, toss the coin for trials three through ten, and again total the heads and tails and calculate the percentage. Follow through on the activity as directed through trial number 100.

Finally, have the students, as a team, determine the answers to these two questions:

- What happened to the percentages as the number of coin tosses was increased?
- Why is it important to have a large number of offspring in a genetic study to have reliable results?

Activity #2

Copy the contest flyer and distribute to student groups. Inform students that 200 couples (or 400 people, depending on whether the tickets are sold individually or as couples) are attending the prom. Ask students to calculate the odds of their winning a free tux or formal-dress rental if they purchase a ticket to the prom. Explain that probability plays the main role in this exercise. If the tickets are sold individually, and there are 200 couples attending, it means 400 people have entered, thereby offering each person a 1/400 chance of winning the prize.

Contest

sponsored by

Jack & Jill's Formal Wear

Jack & Jill's Formal Wear is pleased to offer the following chance for the lucky school prom attendee!

Buy a ticket to the prom and be entered into a drawing to win a free tux or formal-dress rental!