6th Grade Plant Biology MCAS Preparation: an Interactive Qualifying Project

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ABSTRACT

According to recent statistics, less than half of Massachusetts students in the fourth and eighth grade are scoring as "proficient" on the science portion of the standardized MCAS (Massachusetts Comprehensive Assessment System) exam. Moreover, those meager scores placed Massachusetts as the second-best state in the country (Chester, 2011). Unfortunately, elementary students' interest in science is decreasing, and, with it, their level of performance. In an effort to renew children's interest in science, our team developed a unit, designated as the Plant Science Unit, and introduced this unit to a sixth grade class.

The general objective was to develop a unit effective in teaching science in a more stimulating and exciting manner that would be inexpensive and easily adoptable. The Plant Science Unit included lesson plans, ample background information to accommodate questions about the material, homework assignments and worksheets, a study guide, and an examination. Also included were a number of hands-on activities to keep the students engaged. Although focused on plant biology, the unit was also designed to tie into a Lunar Base-themed curriculum initially developed by Professor John Wilkes of Worcester Polytechnic Institute in 2010. The Lunar Base project is intended to span fifth to tenth grade in order to teach students information pertinent to the MCAS in an exciting, impactful way.

A number of teaching strategies were incorporated into our lesson plans in an effort to reach each student, and we adapted our unit to accommodate the different skill levels of the groups that we taught. Through analysis of graded exams, worksheets, and questionnaires, we were able to conclude that our unit was successful in teaching the course material. The sixth graders averaged a score of 85.6% ± 12.8, which demonstrated an adequate level of understanding. Excluding the skills-based group, which was composed of lower level students including students with behavioral, developmental, or communication challenges, the students averaged a 90.5%, an impressive achievement indicative of solid comprehension. Beyond effectively teaching the material in a retainable way, students noted a greatly increased interest level in science after having completed the Plant Science Unit. Finally, the teacher's evaluation of the unit indicated that it would be not only easily reproducible, but also worth adopting.

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Chapter 1: Introduction

A Background

According to the 2009 National Assessment of Educational Progress (NAEP) science tests, Massachusetts ranked as the second-best state in the country for science testing in both fourth and eighth grade. In grade four, 45% of students scored above “proficient,” and in grade eight, 42% scored “proficient” or higher. Although second in the country sounds great, less than half of the elementary and middle school students are scoring as “proficient,” indicating a need in the state for a greater interest in science and test preparation (Chester, 2011). Unfortunately, interest in science is steadily decreasing; students see science as a series of facts and do not understand that science is in fact an iterative, explorative process. Without a firm understanding of and passion for science, these children will grow up lacking motivation to study science, or to engage in thoughtful science-based policy decisions. We aim to instill a passion for science in the next generation in order to encourage an appreciation of science and its use in everyday life. This can be accomplished in the early years of schooling; however, with the high stress associated with standardized tests such as the MCAS, students can lose their fascination with science at a very young age (Duschl et al., 2007). In an attempt to minimize this risk, the aim of our project was to show students that science can be interesting and fun through a series of engaging, hands-on projects designed in a manner to prepare students for the biology portion of the MCAS science exam, the MCAS-S.

We chose to work with a group of sixth grade students and their teacher, Ms. Debra Conn, at Flagg Street Elementary School in Worcester, Massachusetts. We spent our time in the classroom instructing the students in a series of interactive projects related to the use of plants in a futuristic lunar base. This lunar base was an engaging, tangible model on which fifth to tenth grade science can be taught. The contrast of lunar conditions to the environment on Earth was intended to help students thoroughly examine factors that influence the survival and proliferation of life, creating realistic examples to which students can relate. Throughout the project, we focused on preparing students for their tenth grade MCAS test. We used various teaching techniques in what we hoped was an exciting manner. To stimulate the students’ appreciation of science, we used multiple teaching methods to appeal to what are reported to be the varied learning preferences of the students (Duschl, et al., 2007).

A.1 The Science MCAS (MCAS-S): A New Testing Requirement

The Massachusetts Comprehensive Assessment System (MCAS) is a standardized test that each Massachusetts student must pass as part of his or her diploma requirement. The purpose of the exam is to improve curriculum and instruction, to evaluate student performance, and to determine student eligibility for graduation. The test is administered in the tenth grade and contains three main elements: English and Language Arts, Mathematics, and Science (Chester, 2011). Found in the science portion of this test is a mixture of multiple choice and open response questions focused on one of four science subjects, or strands: earth and space science, life science (biology), physical sciences (chemistry and physics), and technology/engineering. The core concepts that should be covered for the Biology track and the Earth and Space Science track are listed in Table 1A.1 (Driscoll et al., 2011).

Table 1A.1: Specific Core Concepts for MCAS-S, outlined by Driscoll et al. (2011).

Life Science (Biology)
Structure and Function of Cells
• Understand that all organisms are composed of cells, and many organisms are single-celled (unicellular), e.g., bacteria, yeast. In these single-celled organisms, one cell must carry out all of the basic functions of life. • Compare and contrast plant and animal cells, including major organelles (cell membrane, cell wall, nucleus, cytoplasm, chloroplasts, mitochondria, vacuoles). • Recognize that within cells, many of the basic functions of organisms (e.g., extracting energy from food and getting rid of waste) are carried out. The way in which cells function is similar in all living organisms.
Systems in Living Things
• Compare sexual reproduction (offspring inherit half of their genes from each parent) with asexual reproduction (offspring is an identical copy of the parent's cell).
Evolution and Biodiversity
• Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms. • Relate the extinction of species to a mismatch of adaptation and the environment.
Living Things and Their Environment
• Give examples of ways in which organisms interact and have different functions within an ecosystem that enable the ecosystem to survive.
Energy and Living Things
• Explain the roles and relationships among producers, consumers, and decomposers in the process of energy transfer in a food web. • Explain how dead plants and animals are broken down by other living organisms and how this process contributes to the system as a whole. • Recognize that producers (plants that contain chlorophyll) use the energy from sunlight to make sugars from carbon dioxide and water through a process called photosynthesis. This food can be used immediately, stored for later use, or used by other organisms.
Changes in Ecosystems Over Time
• Identify ways in which ecosystems have changed throughout geologic time in response to physical conditions, interactions among organisms, and the actions of humans. Describe how changes may be catastrophes such as volcanic eruptions or ice storms.
Earth and Space Science
The Earth in the Solar System
• Recognize that gravity is a force that pulls all things on and near the earth toward the center of the earth. Gravity plays a major role in the formation of the planets, stars, and solar system and in determining their motions. • Compare and contrast properties and conditions of objects in the solar system (i.e., sun, planets, and moons) to those on Earth (i.e., gravitational force, distance from the sun, speed, movement, temperature, and atmospheric conditions). • Explain how the tilt of the earth and its revolution around the sun result in an uneven heating of the earth, which in turn causes the seasons.

A.2 Psychology of Teaching and Learning

Middle school children are more capable of sophisticated comprehension and logic than has been traditionally expected (Duschl, 2007). This suggests that they need only proper guidance and teaching methods to fully develop their scientific ability. Elementary learning depends on a variety of factors including child psychology, teaching methods, school and home environments, and the teacher's knowledge of the subject matter. Of these variables, child psychology is by far the largest contributor in a person's future development and can be influenced by both internal and external factors (Duschl, 2007).

Student engagement in science activities, participation in the classroom, and quality of science learning strongly depend upon a student's motivation, beliefs about science, and their identities as learners. When children are convinced that science is within the reach of their intellectual ability, they perform better, try harder, and are motivated to attempt more challenging problems (Duschl, 2007). On the other hand, once science becomes more difficult and loses its excitement, students develop quite contrary feelings towards science (Lartigue et al., 2004). Usually, students will not force themselves to study something if they think that they will not succeed, or if the outcomes of their effort differ from what they expect (Duschl, 2007). These students refrain from class participation and are often quiet during classroom activities. Such students should not be confused with less outgoing students that are quiet by nature. Sometimes, these reticent students may even hesitate to ask questions in order to avoid embarrassment from their lack of understanding. Although being quiet can also be a personality trait of a person that is less outgoing, children that are quiet for whatever reason do not benefit from class participation and peer discussion. In addition, middle school students are not regularly exposed to scientific terms and language, and the practices of scientific interpretation differ largely from those in everyday life. As a result, introductory science may be awkward, challenging, or discouraging as children face new words, concepts, protocols, and argumentation. Moreover, poor teaching habits, a limited teaching methodology, demanding examinations and teachers inadequately trained in science can further discourage students. These reasons may create an aversion toward learning and understanding science (Duschl, 2007). If students do not have some reason for pursuing science, they will not fully engage in learning, even if they believe they can be good at science (Duschl, 2007). Hence, students should possess certain goals, values, and interests in order to succeed in science classes.

Student goals can be either learning or performance oriented. Learning oriented goals are more motivational, rewarding, and effective as the student becomes self-motivated to learn science purely for the sake of interest and growth. In contrast, performance-oriented student goals focus on increasing grades and decreasing errors, while the knowledge gained is of little import (Duschl, 2007). Students also display varying values towards certain topics, disciplines, or subjects. These values are assigned according to what interests students more, and where students see their strengths and weaknesses. As a result, students value subjects in which they perform better or display more interest (Duschl, 2007). To appeal to the varied tastes and values of students, we supplemented our teaching material with a number of interesting facts. By covering a variety of topics and introducing the lunar base theme, we appealed to students that valued different subjects based on their interests.

Some psychologists argue that there is a need for resources and teaching methods that enhance deeper understanding of science in a positive way (Lartigue, 2004). Accordingly, a concrete understanding of child psychology with appropriate teaching methods is essential to an understandable, exciting, and interesting science curriculum. There are many unique methods of teaching, and each brings something different to the learning experience. Different children respond better to different teaching methods; therefore, it is important to incorporate a variety of styles in teaching so every child has an equal opportunity to learn in his or her preferred manner with material easy to retain.

There are two general learning categories: passive and active learning. Passive learning is largely dependent on lecturing and involves teacher-centered discussion in which students are passive recipients of information (Sirinterlikci et al., 2008). They are not given the ability to reinforce or develop the received information by other means such as experimentation, discussion, or participation (Anderson et al., 2000). Students are taught in an instructive manner, and tested through “regurgitation” of information. Due to the vast breadth of material, passive learning encourages the memorization of superficial facts, while conceptual principles and explanations are glossed over (Dunlap, 1997). Passive learning is also founded on an individual learning approach, where students do not interact with their peers or the teacher while they learn the material (Gess-Newsome et al., 2008).

Active learning is based on interactive instruction and experimentation, maximizing student engagement. To learn material through active thought and argument makes the learning process a more memorable one, providing concrete comprehension as well as a sense of accomplishment once a solution has been reached (Worley, 2007). Many active learning methods are team-based and rely on student collaboration to resolve a problem (Gueldenzoph, 2007). While students work in groups, they can confer with their peers, enriching their knowledge and experience (Gladie, 2005). Most active learning strategies follow a pattern of four sequential steps: experiencing, reflecting, generalizing, and applying. The first step, experiencing, allows students to observe the concepts first hand (Walker, 2003). The next, reflecting, is where students contemplate their observations and attempt to explain concepts they have experienced. The third step, generalizing, has students relate such concepts to real-life situations. The final step, application, brings students to use their gained knowledge to solve a problem (Gavalcova, 2008). For example, in discussing what plants need to survive, students could first experience the problem by observing two potted plants. One would be carefully watered while the other would be overwatered. Students might note that the plant with too much water is not thriving compared to the more carefully watered plant. As the students reflect in step two of the pattern, they might try to rationalize why the overwatered plant is not doing as well. Step three, generalization, might lead the students to associate the plants with other well-known living organisms such as air-breathing animals. If an animal is immersed in water for too long it will not survive. Why? The answer to this question lies in the generalization of all air-breathing organisms - animals cannot get enough oxygen in water. Neither can plant roots, so both organisms will "suffocate" and eventually die. In the final step, application, the students might propose that plants should not be overwatered, and develop a potential solution for this problem, such as a pot with a drain or a less frequent watering schedule.

Beyond the broad scope of active versus passive learning, there is a diverse spectrum of teaching methods, defined by Thomson (2009), Barbosa et al. (2004), and Duschl (2007), each of which has distinct advantages. Command, self-check, reciprocal learning, guided discovery, inclusion, convergent and divergent production, concept-oriented reading instruction (CORI), and problem-/project-based learning are all valuable methods; these methods are explained in Table 1A.2. Different children learn in different ways, so an effective teacher needs to use a combination of these methods to reach every student.

Table 1A.2: Teaching Methods

Teaching Method	Description
Command	Command is a method of instruction in which the teacher formally outlines the practice or problem, directing students on exactly what to do. This technique gives a solid format for students to follow, minimizing misinterpretation.
Self-Check	In the self-check teaching method, a student revisits his own work, scrutinizing it for errors. This method is ideal for teaching a student to be self-reliant and thorough in providing answers (Thomson, 2009).
Reciprocal Learning	Reciprocal learning is the process through which a student would get feedback from a peer observer. This allows for the students to both propose ways of correcting errors and also offer positive feedback as an active way of correcting mistakes. The reciprocal process aids in students' understanding and retention of the material because, in order to give a sufficient explanation on why the answer is right or wrong, the student must first solidify his own understanding (Thomson, 2009).
Guided Discovery	Using guided discovery, the teacher directs the discussion through a series of deliberate questions, allowing students to arrive at the solution themselves. This enables a more comprehensive discussion of the problem at hand, ensuring that all important points are reached and fully evaluated (Thomson, 2009).
Inclusion	Inclusion is a method in which students are exposed to multiple levels of task difficulty, and are included in the process of solving a challenging problem. This method shows students that it is possible to solve intimidating problems by breaking them down into smaller tasks of varying difficulty (Thomson, 2009).
Convergent Production	In convergent production, students comprehensively discuss a topic in order to decide on one correct answer. This process introduces an informal debate, allowing for students to argue and defend their rationale while taking into consideration the arguments of others. Convergent production allows for students to evolve their arguments to the point at which everyone is in agreement with the decided solution (Thomson, 2009).
Divergent Production	In contrast to convergent production, divergent production encourages diverse suggestions, as many correct solutions can exist for the same problem. In divergent production, groups of students are able to arrive at concepts themselves while defending their ideas (Thomson, 2009).
Concept-Oriented Reading Instruction (CORI)	Concept-Oriented Reading Instruction (CORI) encourages students to understand the concepts behind the facts they read in textbooks; in conjunction with CORI, journal entries can be assigned to further assess and strengthen students' understanding of material (Barbosa et al., 2004).
Problem Based or Project Based Learning	Problem-based and project-based learning approaches enhance understanding through exposure to real-life problems. Students work together through deep investigation and research in order to overcome these problems (Duschl, 2007).

A.3 The Lunar Base: A Learning Activity

Professor John Wilkes of Worcester Polytechnic Institute began the Lunar Base Project with a group of fifth grade students in 2010. A lunar base, as shown in Figure 1A.3, was designed to be completely self-contained, allowing people to live comfortably on the moon and grow their own crops and livestock. The lunar base theme aims to demonstrate that humans could one day be able to sustain life in places other than earth. The purpose of this lunar base project is to provide an exciting and tangible theme to science learning, which will better engage students in the curriculum at hand. This lunar base theme was introduced in the Worcester school system to reiterate curriculum material as well as to prepare students for the MCAS. This theme creates the opportunity for an intuitive, hands-on approach for students to learn and master the required material, with the desired outcome of retaining it (Wilkes, 2011).

Figure 1A.3: A conceptual illustration of the proposed lunar base (Wilkes, 2011)

By using the lunar base as a major theme, the project spanning fifth through tenth grade aims to teach students information pertinent to the MCAS in an exciting, impactful way. The fifth grade unit concentrates on comparing the Earth and the moon; students will learn earth science in the process. Sixth graders focus on the biosphere aspect of the lunar base, including plant biology and ecosystems. In seventh and eighth grade, students explore robotics and use hands-on methods to demonstrate how robots on the moon could be operated remotely to tend plants, capture water, and perform other everyday tasks. The ninth and tenth grades would concentrate on introductory physics relevant to life on the moon.

Our unit within the continuum focused on teaching 6th grade students plant biology, as plants are one of the most important aspects of the lunar base design. Current lunar base plans also use plants as air scrubbers; they would be responsible for converting carbon dioxide into oxygen for humans and other life forms to breathe. Plants would also be the main source of food for the lunar base inhabitants, so it is very important that anyone living in the lunar base has an intimate knowledge of the science of plants and their cultivation (Finetto et al., 2010).

A.4 Main Objectives

The main objective of this project was to develop a preparation method for the MCAS-S that excited students about science as opposed to stressing the necessity of passing the test. Students should be able to demonstrate a basic knowledge of science, not just to pass the MCAS but also to exhibit a well-rounded understanding necessary for future education and for their eventual participation in society. In an effort to raise test scores, educators often respond by replacing a substantive curriculum with test preparation materials that have little educational value (Gordon and Reese, 1997). This "test preparation" or "teaching to the test" not only adds pressure on students regarding the testing, but also restricts access to an actual comprehensive curriculum. In addition, the potential stress of this "high-stakes" testing itself negatively affects performance (McNeil, 2000).

The focus in the past has been largely on two proficiencies: English and mathematics. Until recently, science was ignored, so students were ill-prepared for both high school science and post-secondary school opportunities. Science also has been stigmatized as uninteresting and tedious. Here we aspired to change a small sector of elementary school science to something fascinating and fun, as it should be, so that a healthy curiosity is inspired in future generations. Similarly, we intended to stimulate the curiosity of the generation that would be of age to actually go to a lunar base circa 2050. If the current curriculum remains unchanged and the interest in science dwindles, a lunar base would fail due to lack of eligible astronauts, auxiliary scientists, and public support.

Besides the general objectives of MCAS-S preparation and reestablishing youth interest in science, we had specific classroom objectives. These were to reinforce the curriculum through demonstrations and hands-on activities and to create a series of learning modules that are easy, effective, and inexpensive enough to be adopted in other schools. Our classroom team aimed to enrich class time with demonstrations involving plant life, simulations of ecosystems, and other relevant material. This would serve as a hands-on approach to reinforce knowledge of 6^{th} grade science through the use of a lunar base theme. In addition, we provided an alternate method of teaching through demonstration and hands-on activity in order to "mix things up" in the classroom, targeting children who might learn better through such styles.

The final objective, to create a learning module that might be universally adopted, began with organization. We constructed detailed and intuitive lesson plans, instructing the teacher on each activity, so that the teacher would be able to continue using the program in subsequent years. Ideally, the unit could be effective and inexpensive enough to eventually be circulated through the Worcester school system. With this unit, schools everywhere might be able to offer more thorough and interesting education in plant science, which would wholly fulfill our general objectives of improving MCAS-S scores and enriching overall science education.

Chapter 2: Methodology

A Teaching Strategies

As traditional education consists of mainly passive education, our team employed active learning during the majority of our class time. We intended to cover every teaching method we investigated to ensure that we had the best opportunity of reaching each student.

B Hands-on Projects

Although we had many ideas for projects that could be used in the classroom, these were narrowed to a few main projects, mostly because of our limited time and resources. The teacher with whom we worked has access to "Investigate" experiment kits. These kits were prepared by the publisher for use along with the textbook, 2009 HSP Science Student Edition (2009 Harcourt School Publishers), and contained very useful pre-assembled science projects.

The team identified and constructed several projects that related to major concepts that should be taught, as shown in Table 2B. The chosen concepts were intended to provide an appropriate understanding of plant biology. Importantly, we need to relate the projects back to the lunar base to maintain the cohesiveness of the overall unit and multi-year curriculum concept thread.

The team opened the unit with a discussion on the lunar base itself. Then we posed questions, including the following:

- If you could only fill your backpack with supplies, what would you bring with you to a lunar base?
- What do humans need to survive?
- Do humans, animals, and plants need the same things to survive?
- What are some possible plants that humans could use to survive in space?

In the beginning of the unit, we covered the basic structure and function of plants, including pollination and plant reproduction. This part of the unit led to a discussion on the intricate process of how plants take in carbon dioxide and release oxygen and then segued into self-sustaining ecosystems.

Table 2B: An Outline of the Major Concepts of the HSP Textbook

1. Seed germination, growth, and development along with the factors that influence these procedures, including sunlight, warmth, nutrients, available water, etc.
2. Material and environmental requirements to keep plants alive and healthy
3. Photosynthesis, its reactants, products, and its importance in an ecosystem
4. Transport and storage systems in plants that include the following:
    a. concentration gradient (mass transfer)
    b. force of gravity
    c. pressure variations
5. Plant cell division and growth
6. Plant response and sensitivity to environmental factors such as: light, gravity, acidity, pollution
7. Seasonal changes and their effects on the plants
    a. Temperature change
    b. Amount of sunlight
    c. Day and night lengths
8. Types of plants and their contributions/purpose
9. Reproduction
    a. sexual and asexual reproduction
    b. pollination
    c. seeds, and fruit

A greenhouse project was designed and used in class to include different soil types and light sources in order to demonstrate the necessity of a sustainable environment for plant growth (Figure 2B-1). Different conditions were established in order to show the conditions in which plants are most successful. This project was also related to different farming methods, including hydroponics and aeroponics. Groups of students were asked to design their own greenhouses or growing areas to be used on a lunar base.

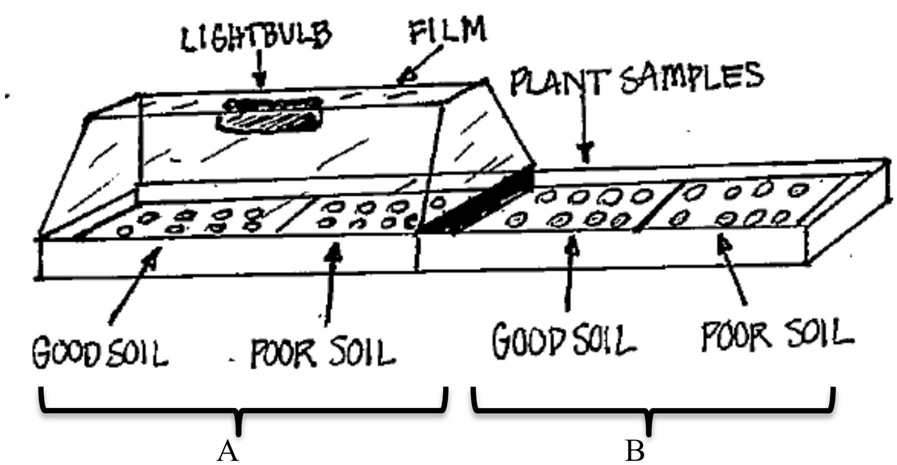


Figure 2B-1: A simple growth system for use in the classroom.

With the greenhouse experiment, children worked in teams to plant their own bean seeds, and hypothesized which conditions would best suit plant growth. This project was ideal because seed germination, Figure 2B-2, was observed rather than just explained. In addition, the children took responsibility for the growth and germination of their seeds, and were motivated to tend to them.

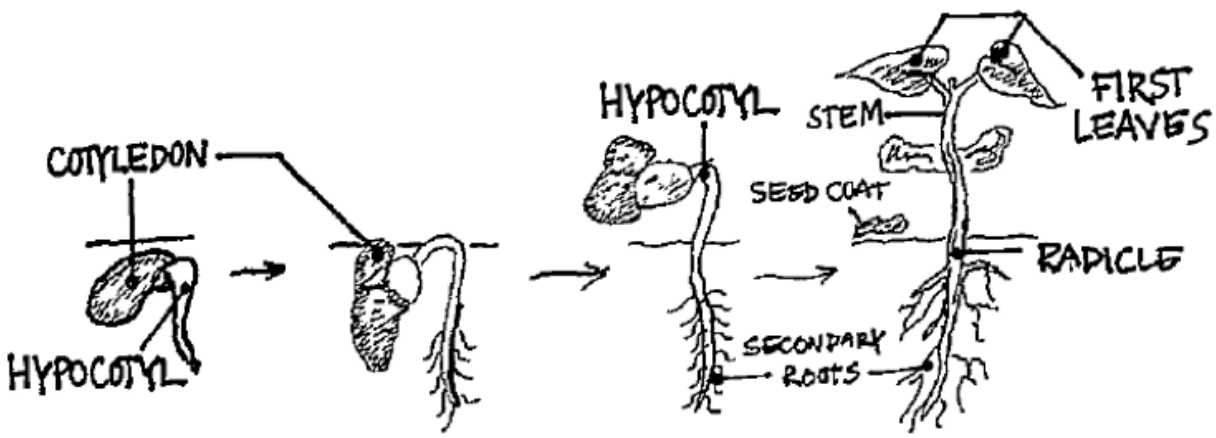


Figure 2B-2: An illustration of bean seed germination

Because space is at a premium on the lunar base and the importation of goods will be expensive, a class period was dedicated to learning about plant versatility and recycling. Students learned about the various ways in which plants can be used for clothing, medicine, and food. Pressed plants (WPI Herbarium specimens) were passed around so students could look at some plants whose products they use daily. These specimens were useful because it is not likely that students would ever see most live plants of these important species. Potatoes, peas, carrots, oats, wheat, coffee, and tea were a few of the plants that were passed around that students may eat or use on a daily basis without knowing what the original plant looks like. A full list of the plants shown in the classroom is detailed below:

Carrots	Peppermint	Wheat	Coffee	Unprocessed cotton
Butterfly Peas	Rhubarb	Oats	Common Tea	Processed cotton
	Tulips	Irish Potatoes	Bamboo	

The class dissected a plant so students could move beyond just a drawing, to view and study the different parts of flowering plants. In this activity, students were given either lilies or daffodils to dissect. The team led the students in the dissection by instructing them on what parts of the plant to remove at what time. The students were also asked to count the number of parts and observe the leaves in order to infer whether the plant was a monocot or a dicot. The team also aided the students in opening the ovaries of the flowers to view the eggs.

C Methods of evaluation of effectiveness

One way in which we evaluated whether or not we achieved our goals in the classroom was to assess student performance on assignments distributed in class. Their graded assignments consisted of worksheets that we created as well as worksheets, provided by Ms. Conn, which accompanied the textbook. In addition to the worksheets, we assessed student performance with an examination we developed that was administered by Ms. Conn. The final exam incorporated multiple choice, fill-in-the-blank, matching, true and false, and short answer questions. We averaged the scores and calculated a standard deviation to account for outliers.

Students were also expected to keep a journal where they could answer provided questions or comment freely on their level of interest and understanding in the material after each class. The journal entries allowed us to assess, in a qualitative manner, how much the students learned as well as how interested they were in each topic and activity. Additionally, the journal entries gave students that were hesitant to ask questions in class the private opportunity to record their questions, concerns, or comments.

To gain feedback on our unit from the class, we distributed a questionnaire allowing students to evaluate the projects, the specific activities within the unit, and our teaching performance. In addition, we gave Ms. Conn a separate questionnaire to evaluate the team and the unit. The responses to those questions were statistically analyzed to help evaluate our effectiveness in achieving our goals.

Chapter 3: PROJECT RESULTS

A Classroom Experience

A.1 Foreword

Information presented in Chapter 3 is based on the order of visits to the classroom and sequence of science topics presented in each class. There is also a self-evaluation of the strengths and weaknesses of each lesson as taught. Finally there is an evaluation of student performance (Table 3A.1).

Table 3A.1: A walkthrough of the general organization applied to each visit.

1	Lesson Plan	A detailed description of the material taught and the activities implemented in each lesson
2	Methods	A summary of the teaching methods used to target varying types of learning styles
3	Lesson Content	A list of the worksheets and handouts provided to the students
4	Homework	An outline of the homework assigned for each lesson
5	Student Reception	An overview of the students' responses to the each lesson, activity, and assignment
6	Strengths and Weaknesses	A concluding segment regarding the strengths and weaknesses of each individual lesson, and evidence for those assertions

Each visit was accompanied by a corresponding lesson plan, found in Appendix A. Handouts and homework assignments (lesson content), as well as in-class whiteboard illustrations, are found in Appendix B. Used as a tool to stimulate learning, Jeopardy games are provided in Appendix B in a printable format adapted from the original PowerPoint file. Quizzes and exam materials can be found in Appendices C and D, respectively. All teaching methods referenced are outlined in Table 1A.2. In addition, each journal entry assigned used the CORI method [Table 1A.2, h] in an attempt to integrate reading comprehension and writing into the science unit.

A.2 Pre-Classroom

A letter to the parents, found in Appendix B, was distributed during the first visit. This letter served to notify parents as to who we are, the general overview of the project, and our intent in introducing this unit into Worcester public schools. We provided our contact information and encouraged parents as well as students to contact us, had they any questions or concerns. We were never contacted, but students frequently came to the class to ask us questions regarding our schedule or the next week's lesson material.

There were 68 sixth grade students in the Flagg St. School; they were organized into three groups that met for science at different times during the day. These three groups will be referred to as Group A, Group B, and Group C. The Flagg St. School did not have a special education program, so lower level students including children with developmental, communicative, or behavioral challenges were placed in the skills-based group, Group A. We were informed by Ms. Conn that our class time would be more effective if we formatted Group A's lessons to be straightforward and highly structured; upon meeting the students, we agreed that this strategy would be best to avoid wandering minds and disruptive chatter. We taught Group A in a more straightforward manner in order to help them achieve as high a level of understanding and personal self-sufficiency as possible. We mainly used the command style of teaching with Group A, which allowed for more class control.

B Visit 1

B.1 Lesson Plan

Visit 1 acted as an introduction to the unit, outlining the planned objectives and activities. After the team members introduced themselves, they briefly discussed topics and asked questions about plants, ecosystems, and the idea of a lunar base. First came the topic of plants, and how plants meet their needs. Afterward, the team members asked questions about ecosystems, discussed species interdependence, and assessed how ecosystems join to create a biosphere. Next, worksheets with diagrams of ecosystems were distributed. These worksheets were intended to aid students in visualizing the concept of species interdependence. Once the basics were taught, plant importance in ecosystems was further discussed. The discussion of a potential lunar base came last, touching on the need for a lunar base along with its technical, physical, and cost related requirements. Afterward, we touched upon biological and nonliving things necessary for survival on a lunar base. This discussion was designed in such a way that students would develop answers to problems by themselves, and instructors would elaborate on student answers. Once the discussion about the specifics of the lunar base was over, the class was asked to suggest the most appropriate plant types for a lunar base. At the end of the class, letters to student parents were distributed in order to introduce the team and the planned unit.

All the topics discussed during the first visit were primarily intended to introduce the overall unit topics, and assess the level of student knowledge relative to the material taught. This would help the team better adjust classes to the varied skill levels of each group.

B.2 Methods

During the first visit, the team used guided discovery [Table 1A.2, d] merged with inclusion [Table 1A.2, e]. The team members directed the class discussion with deliberate questions asked with increasing difficulty. For example, questions were asked regarding the interdependence of different species and ecosystems; afterward, students were asked about plants and their role in a biosphere, and then in a lunar base. Each question was slightly more difficult than the former one, and to answer any one of them, students needed to understand and then build upon the concepts from previous questions. The method of inclusion enabled students to solve a large-scale problem with varying levels of difficulty by piecing through it step by step. In addition to these methods, divergent production [Table 1A.2, g] was also used with questions that could have more than one answer; as a result, students learned new concepts from one another when different solutions were proposed.

While the use of the guided discovery and inclusion methods worked well with Groups B and C, it was not as effective with skills-based Group A. Accordingly, the team relied more heavily upon the command method of teaching [Table 1A.2, a] with Group A in order to help them understand the material. For example, the students in groups B and C readily suggested possible answers to our questions, and easily followed along, using knowledge already established from earlier points in the conversation. The students in Group A rarely raised their hands with anything other than questions, and did not come to the conclusions we had hoped they would achieve to by the end of our discussion.

B.3 Lesson Content [Visit 1, Appendix B]

During this visit, a handout was distributed that was associated with Chapter 3, Lesson 1, “How Do Plants Meet Their Needs?” of the textbook, HSP Science Student Edition (Harcourt School Publishers). This lesson covered how plants meet their own needs, the basic equation of photosynthesis, and the differences between vascular and non vascular plants.

B.4 Homework

The students were assigned their first journal entry in which they were asked to detail what they already knew about plants before this unit, and why they thought plants were important. Chapter 3, Lesson 1 was assigned for reading and vocabulary.

B.5 Student Reception

During Visit 1, the students in Groups B and C asked well-thought-out questions and provided reasonable solutions to posed problems, demonstrating an understanding of the material. The students of the skills-based group, Group A, were less responsive, and provided answers that were irrelevant to the lesson material. Conversely, students in Groups B and C showed a firm command of the material and asked thought-provoking questions that frequently challenged us, pertaining to how plants grow and the physics of the moon. The students were also very interested in the orbit of the moon, its phases, and its affect on the tides. All of the classes were very enthusiastic and readily participated in group discussions, but this excitement may be attributed to the team's first visit to the classroom.

B.6 Strengths and Weaknesses

The first visit provided an outline for our future visits while also giving us a gauge for the standing skill level of each group, so there were no clearly defined strengths and weaknesses.

C Visit 2

C.1 Lesson Plan [Visit 2, Appendix A]

Visit 2 began with photosynthesis and why plants are green, a main topic for the plant biology unit. As photosynthesis is an enormous contributor to life on earth, we made sure to cover it thoroughly in the first substantial lecture. The discussion then shifted to what in plants makes them green and, of course, the pigment chlorophyll. The discussion then shifted to vascular and nonvascular plants, and which type of plant would contribute more to a lunar base.

As a class activity, the students were grouped into teams of four or five, and were instructed to plant bean seeds in different environments. This experiment, the "Greenhouse Project", provided a means for student research to query and then reaffirm what conditions plants require to grow, and how these variables might affect plant growth in different ways. The different variables were the following: light, no light, cold, warmth, soil, and a growth medium lacking minerals. Each team of 4-5 students was given 6 bean seeds so that they could test each variable to ensure that each student could determine how the plants responded to each condition. For example, the plants grown without access to sunlight would germinate and grow tall without growing large photosynthetic organs, then die from lack of sunlight, whereas cold bean seeds might not germinate at all. We assigned a number of students the task of watering and caring for the plants, which were placed in and around a "Germination Station" as shown in Figure 2B-1 part A and Figure 3C.1. The germination station provided warmth for the plants, which were grown in a classroom during the winter, and the plants placed around instead of inside the greenhouse were the "cold" plants.

Figure 3C.1: The actual greenhouse (germination station) as illustrated in Figure 2B-1 part A

C.2 Methods

As in Visit 1, the team relied heavily on guided discovery [Table 1A.2, d] mixed with inclusion [Table 1A.2, e] throughout the initial class discussions. For example, questions were posed requiring students to really think about vascular and nonvascular plants, thus leading students to assess the more difficult question regarding whether the abundance of more vascular or nonvascular plants would be better for a lunar base. The command method [Table 1A.2, a] was used for instructing students through the greenhouse experiment, as they were shown through the proper way to plant the bean seeds, and how they must tend their plants. The Greenhouse Project also served as project-based learning [Table 1A.2, i], allowing students to use their knowledge and predictions in real-life applications.

C.3 Lesson Content [Visit 2, Appendix B]

The materials provided to the students were a team signup sheet, which allowed students to choose their own teams, a tray worksheet, to help each team plant their bean seeds and identify each individual variable throughout the project, and a handout associated with the textbook.

C.4 Homework

Students were assigned the reading and vocabulary from Chapter 3, Lesson 3 in the text, entitled "What Are Some Types of Plants?" which covered the moss family, ferns, angiosperms, and gymnosperms, as well as their similarities and differences. They were also instructed to create a journal entry hypothesizing how each of their six plants would grow in the varying conditions.

C.5 Student Reception

When the topic of why plants are green was discussed, some information regarding wavelengths of light seemed too in depth for the students. It was beyond their comprehension, and decreased the level of interest exhibited in the classroom. The rest of the material was seemingly well understood and interesting, and the students really enjoyed planting the beans.

The students were enthusiastic about watering and tending to their plants. Unfortunately, the enthusiasm led them to overwatering the plants, and the majority of the bean seeds rotted. Afterward, we replanted the bean seeds, explained again the delicate balance required for keeping the plants alive, and revised our directions for care so that this would not happen again. Not only did the students keep the plants alive, but also they grew so tall that the students had to remove the plastic cover capping the germination station.

C.6 Strengths and Weaknesses

The major strength of this lesson was, by far, the bean planting – students were excited and engaged throughout this activity. The students asked questions and made predictions that demonstrated their retention of the material we had covered that day.

One of the bigger weaknesses of this visit was the germination station itself – the plant holder was one uniform tray, and had to be cut into many sections to accommodate all the students and teams. Because of this, the teams had to go up one by one to plant their beans, which took a lot more time than we had initially intended. Had this unit been introduced during the warmer months, we could use separate cups to plant the beans, as a heating station would not be necessary. If the students had separate cups, we could have created stations through which students could rotate, speeding up the process. Also, as mentioned in the Student Reception section of this visit (C.5), certain material was overly in depth, and was at a level that surpassed the grasp of the sixth graders. A potential way to discuss wavelengths of light and the associated colors in a way that is more comprehensible might be to describe the spectrum of light using a prism.

D Visit 3

D.1 Lesson Plan [Visit 3, Appendix A]

When Visit 3 began, the team had established a good rhythm with their teaching in the classroom and student interactions. The team led a discussion on what plants need to survive, covering topics such as sunlight, water and minerals, gas exchange, movement of water and nutrients, and growth media.

A discussion also ensued on plant tropisms, their environmental triggers, and their effect on plant survival. These ranged from thigmotropism (a plant's reaction to touch) to phototropism (a plant's reaction to light). We were able to bring the material to life using engaging videos from "Plants in Motion," provided by Indiana University. The time-lapse and real-time videos helped the students visualize the tropisms, reminding students that plants are actually alive, and that they move and respond to their environments, but on a slower time scale than humans. The students loved the videos, especially the videos on the mimosa plant folding its leaves in response to heat and the time-lapse video of a morning glory twining around two stakes. The final part of the lecture for this meeting focused on circadian rhythms, short-day plants, and long-day plants.

This visit concluded with a game of Jeopardy that the teaching team had created in Microsoft PowerPoint, adapted from a PowerPoint template [Jeopardy Template - 6 Topic, T. Dyson], which was meant to serve as a review of visits 1 through 3. The topics covered by the game included plant survival, photosynthesis, plant structures, the moon, and tropisms. The class was divided into four teams, and students were allowed to collaborate with their teammates and use the notes that they had taken over the course of the lectures. The sixth-graders were surprisingly fierce competitors and had so much fun with Jeopardy that they requested it nearly every visit.

D.2 Methods

By visit three, the team was becoming more confident in their teaching methods. It had learned that the whiteboard was very useful for illustrating important points, and also helped keep students quiet when the students had to write information. The team relied heavily on guided discovery [Table 1A.2, d] during this visit, asking questions to lead the students to the correct answer. For example, students were asked what plants needed to survive, and then were asked why plants needed such resources and how they obtained them. The command teaching method [Table 1A.2, a] was used during the lecture in order to make sure students understood the material. The command method was also useful for encouraging students to write notes and sketch pictures. Jeopardy relied heavily on convergent production [Table 1A.2, f], demanding full attention from each student as they collaborated to find a single answer. The group environment during Jeopardy was conducive to learning because it got every student involved in trying to find every answer as opposed to calling on a single student in the class during a lecture.

D.3 Lesson Content [Visit 3, Appendix B]

This lesson used online videos from Indiana University's "Plants in Motion" (Hangarter, 2000). The class used a Jeopardy game made by the WPI team and adapted from a template on Microsoft PowerPoint [Jeopardy Template - 6 Topic, T. Dyson].

D.4 Homework

The homework assigned after this visit included a journal entry focusing on the progress of the bean plants. The reading and vocabulary of Chapter 3, Lesson 2 from HSP Science, "How

Do Plants Respond to Their Environment", was also assigned, along with questions 2, 3, and 6 in the lesson's concluding review. This lesson discussed the different forms of plant tropisms as well as circadian rhythms.

D.5 Student Reception

Students were thoroughly engaged during the lecture in visit three, and were especially interested in the tropism videos. They diligently copied down every note and picture that the team wrote on the whiteboard in order to improve their chances at jeopardy. The highlight for the students during this visit was undeniably Jeopardy. The students were very excited during the entire game, and the team felt that the game helped the students better learn the material through the discussion of incorrect answers as well as the debates between teammates to settle on an answer.

D.6 Strengths and Weaknesses

Students listened very well during the lecture section of this visit as the material, especially the drastic movement and growth responses of plants, proved to be more interesting than material in previous visits material. Another major strength of this visit was the Jeopardy game; the team found it engaging. Team-based games are very useful as a review tool, motivating students to problem solve and investigate by appealing to their competitive natures. The students, as part of a team, were more motivated to provide answers and help their team; similarly, they discussed within their groups as opposed to providing a correct answer individually, so they were more apt to suggest possible answers and reason through the problem. The knowledge that we might play this fun game again motivated the students to study harder and pay attention so that, the next time the game was played, their team would have a better chance of winning.

The biggest weakness of this visit was the organization of the jeopardy game. Students were loud when trying to debate answers, and the teacher had to step in to get them to quiet down more than once. Another weakness of the jeopardy game was judging who raised their hand to answer a question first. Real jeopardy uses a buzzer system, but we were not able to buy or construct one. This problem with the game frustrated some students because they felt that they were not being given a chance to answer. We had considered using bells, clickers, or other noise-making devices, but decided that these would be more disruptive than beneficial.

E Visit 4

E.1 Lesson Plan [Visit 4, Appendix A]

Visit 4 began with an investigation of the differences between ferns, mosses, flowering plants, and nonflowering plants. The lecture focused on the parts of flowers, mosses, and ferns as well as the differences in reproduction. Students suggested which plants they thought to be flowering and nonflowering, and were surprised by some of the flowering plants, such as grass, that do not have an easily observable, stereotypical flower. Students were surprised that most plants had both male and female parts, and were very interested in the mechanism of reproduction in angiosperms.

Plant anatomy was then discussed, using handouts and worksheets to identify the different parts of plants, as well as by observing illustrations of leaves on a cellular level, as shown in Figure 3E.1.

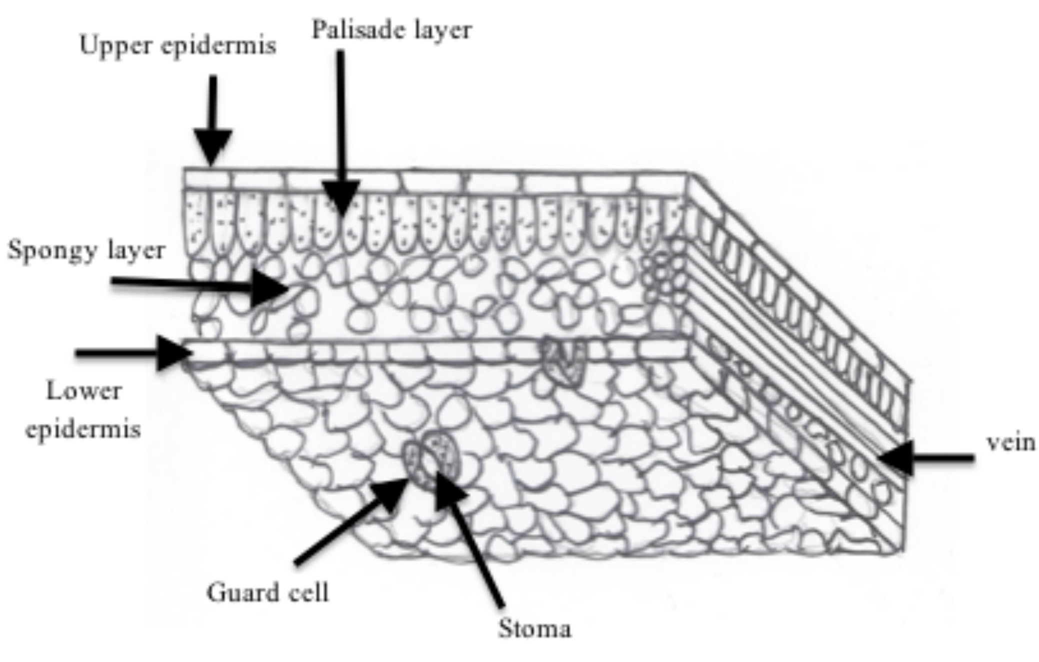


Figure 3E.1: Cross section of a leaf on the cellular level.

The team concluded this lesson by passing around pressed plants from the WPI

Herbarium. Although they may never actually see the live plant, students were able to see plants from which they might encounter products on a daily basis. Examples of pressed plants the team presented were carrots, tea, and coffee. Students were also able to see and feel, first-hand, the differences between unprocessed and processed cotton. They were able to identify just how hard it is to remove a seed from the unprocessed cotton.

At the end of this visit, the team took home the bean plants the students began growing in Visit 2. Overenthusiastic students had enjoyed watering the plants a bit too much, and the drowned and rotting seedlings required replanting.

E.2 Methods

The main teaching methods used in Visit 4 were divergent and convergent production. Divergent production [Table 1A.2, g] was used when students were encouraged to suggest various benefits for a plant having fruits and enclosed seeds, nectar, and bright, colorful flower petals. Convergent production [Table 1A.2, f] was key in having students determine whether a plant was an angiosperm or a gymnosperm based on a number of characteristics including the number of flower parts and the veining on the leaves.

This visit focused mostly on plant anatomy and processes, which was a lot of factual information for the students to take in at once. The team made drawings on the board in order to ensure that the students grasped the concepts, and used pictures to visually demonstrate them.

E.3 Lesson Content [Visit 4, Appendix B]

The students were provided with two illustrations clearly labeling the different anatomical parts of a flower, one of which shown in Figure 3E.3, as well as an illustration and a photograph of a leaf on a cellular level. Also provided were pressed plants and cotton for the students to examine.

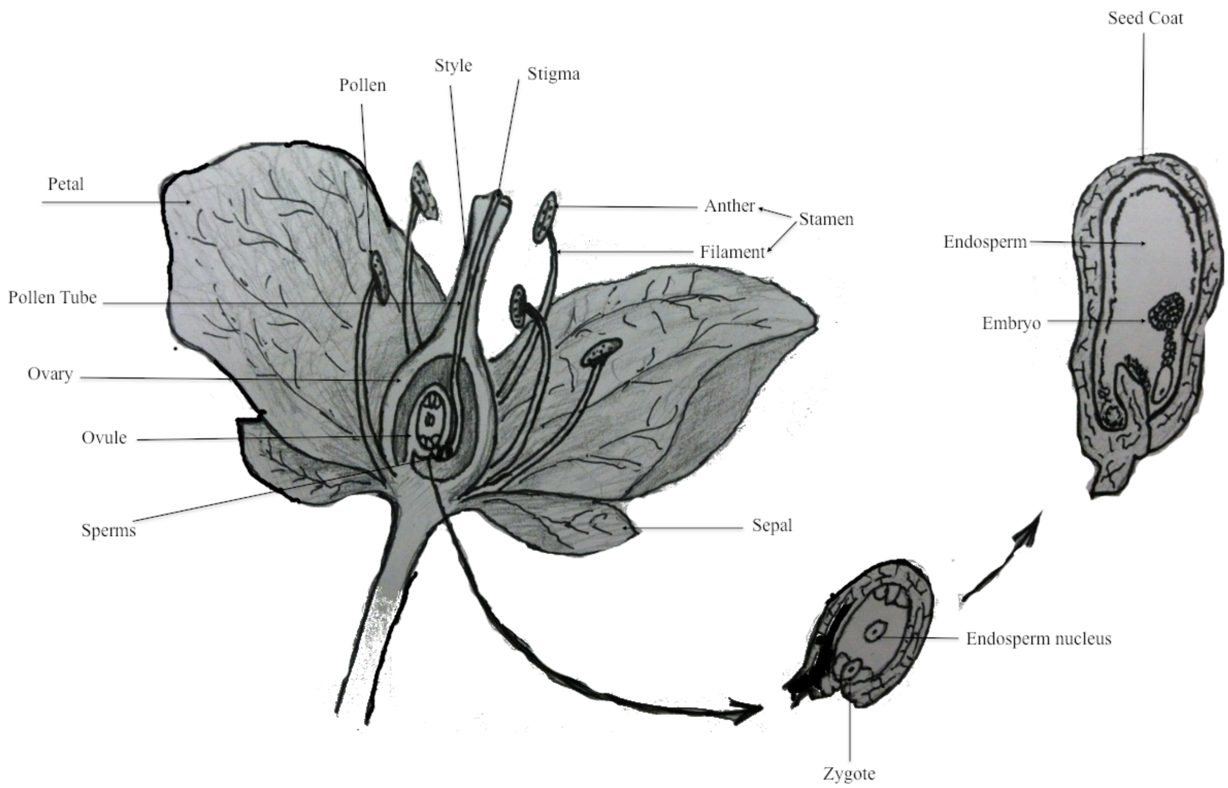


Figure 3E.3: A flower's labeled anatomical parts.

E.4 Homework

Students were given a fill-in-the-blank worksheet on angiosperms. They were also assigned to read Chapter 3, Lesson 4 of HSP Science ("How Do Angiosperms Reproduce"), write down the vocabulary, and answer questions 3 through 5 at the end of the chapter. They were also instructed to make a journal entry focusing on why the bean plants had died.

E.5 Student Reception

The lecture was not as interesting as previous lectures in that it was strictly classification and labeling. There were no real concepts to discuss, so the students were confined to taking notes on categorizations and parts of plants. They seemed to enjoy passing around plants, and especially in viewing the differences between processed and unprocessed cotton.

E.6 Strengths and Weaknesses

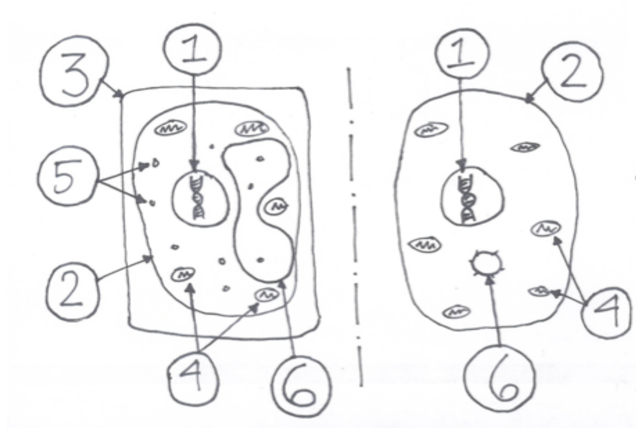
Students enjoyed handling the Herbarium specimens, and diligently took notes during the lectures. There were no problems with getting the students to stay quiet during this visit, which made teaching less stressful.

This may have been the team's least engaging visit to the classroom. There were not many hands-on activities and students seemed bored with the material presented, as it was strictly terminology instead of concepts. A future improvement of this visit could be to introduce more hands-on activities, breaking up long periods of note taking between them. Another modification could be to run a plant dissection during this visit while the students are simultaneously introduced to plant anatomy.

F Visit 5

F.1 Lesson Plan [Visit 5, Appendix A]

Visit 5 began with a collocation of diagrams of a plant cell and an animal cell. As shown in Figure 3F.1-1 the cells were diagrammed and the parts numbered as students suggested parts that were similar and parts that were different, identifying them by their physical appearances. We then went through the list, identifying each part by name and function. Students were encouraged to suggest why they thought, for example, that animal cells contained more mitochondria than plant cells, or why the cell wall was stiff and rigid on plant cells while animal cells required no cell wall.



1. Nucleus
2. Selectively permeable cell membrane
3. Cell wall
4. Mitochondria
5. Chloroplasts
6. Vacuole

Figure 3F.1-1: Plant and Animal Cell Illustration

The difference in number of mitochondria segued into the flow of energy**,** which was outlined on the board. Using a graphic, shown in Figure 3F.1-2, the flow of energy was tracked from the sun to energy usable by organisms.

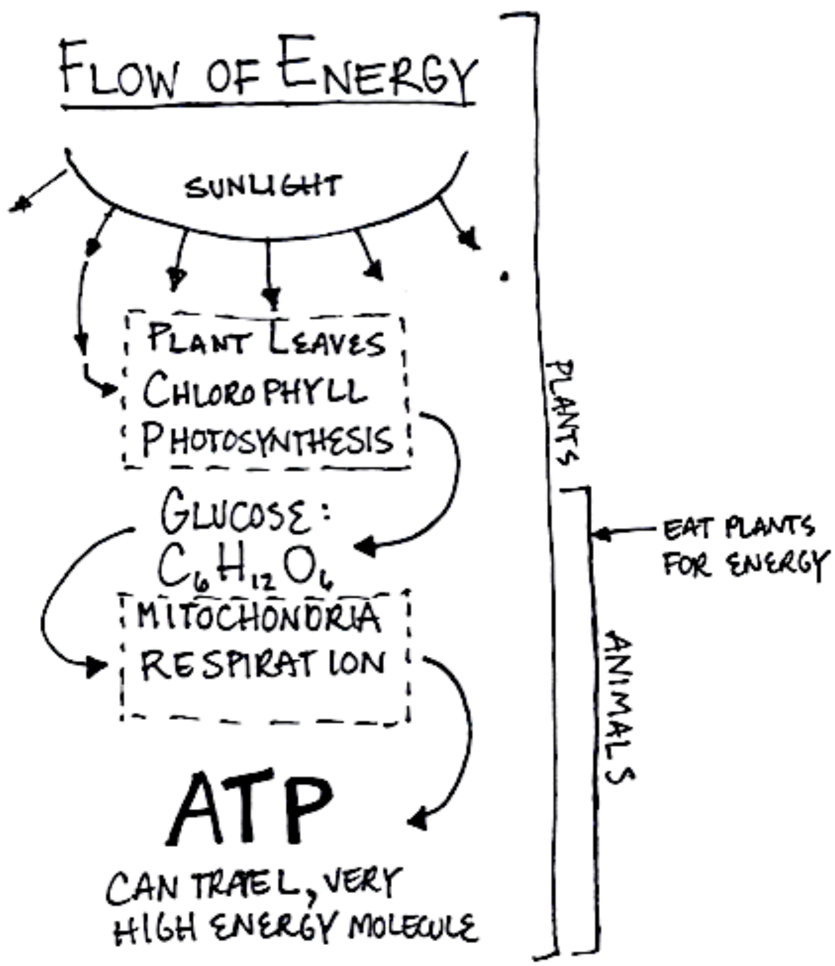


Figure 3F.1-2: Flow of Energy Illustration

We then highlighted the differences between monocots and dicots, and reiterated the section on plant anatomy through a flower dissection activity. The class was given an illustrated handout outlining the differences between monocots and dicots to which they could refer throughout the lesson. A number of differences were discussed and examples were provided, allowing students to relate personal experiences and observations with the material. For example, palm trees were discussed, and the students concluded that they were monocots because they had leaves with veins that run parallel along their lengths, and their trunks were not made of wood.

Lilies and daffodils were then distributed to the students, with one flower per one to five students, and we led them through a structured dissection that noted each part of the plant, its characteristics, and its functions. This hands-on dissection gave the students an opportunity to experience the material first-hand. For example, the students had the chance to actually feel the "sticky stigma" of the flower, note where it is located, and understand why and how the pollen adheres to it.

F.2 Methods

The main teaching methods used in Visit 5 were command, self-check, convergent production and, in closing, guided discussion. In the plant dissection, command [Table 1A.2, a] was used to instruct the students through the dissection, while guided discovery [Table 1A.2, d] and convergent production [Table 1A.2, f] were used to lead the students to a conclusion of whether each plant was a monocot or dicot. The self-check method [Table 1A.2, b] had students refer to their monocot and dicot handouts [Visit 5, Appendix B] in order to confirm their assertions.

F.3 Lesson Content [Visit 5, Appendix B]

The students were given handouts to help them distinguish between monocots and dicots, as well as a worksheet to complete during the dissection.

F.4 Homework

The homework assigned for Visit 5 was simply to begin studying all material covered throughout the Plant Science Unit, outlined on their provided study guides, in order to prepare for the final Jeopardy game.

F.5 Student Reception

The entire lecture was well received, as the material was easy to relate to and easily visualized. The plant dissection was thoroughly enjoyed, with every student engaged and enthusiastic. The activity helped the students identify each plant part and relate it to function, e.g. pollination attractant, photosynthetic part, reproductive part, etc.

F.6 Strengths and Weaknesses

A main strength of Visit 5 was the plant dissection; students were able to see tangible evidence of the functions and organization of the plants' anatomical parts. The students loved seeing the egg cells, and the dissection helped reinforce the material from Visit 4. The whiteboard drawings and handouts allowed students to pay attention and contribute to class discussion without needing to take notes. The board comparison between plant and animal cells proved to be a strong point as well. The method of asking students, visually, to identify similarities and differences between plant and animal cells forced students to scrutinize the two configurations, and their own observations were used to underline differences between the cells. Finally, the trace of the flow of energy from the sun to ATP reinforced the entirety of the chapter in a very understandable way.

This visit was, in all, a very strong visit; however, there were a few minor weaknesses. The acquisition of both monocots and dicots would have been preferred for the plant dissection so that students could note the differences first-hand as opposed to just identifying all the plants as either monocots or dicots. Also, while two of the groups had dissected lilies, which had large, well-defined parts, one class was given daffodils, which had much smaller parts.

G Visit 6

G.1 Lesson Plan [Visit 6, Appendix A]

Visit 6 served to recap the entire unit through the distribution of a study guide and a final game of Jeopardy. No new content was taught, but material with which students had struggled was reviewed.

G.2 Methods

As in Visit 3, the teaching method of convergent production [Table 1A.2, f], as well as a method of review, was used in Jeopardy in order for each team to settle on an answer.

G.3 Lesson Content [Visit 6, Appendix B and C]

A comprehensive study guide was distributed to the students and reviewed to facilitate studying for the final exam. A second Jeopardy game was also played.

G.4 Homework

The students were instructed to study for the final exam using their study guides, notes taken in their Plant Science journals, and their books.

G.5 Student Reception

Students were grateful for the review of the Chapter 3 material in order to prepare for the final Jeopardy game and their exam. As expected from their positive response to the first Jeopardy game, they had fun during this activity.

G.6 Strengths and Weaknesses

This lesson was strong in that it helped students prepare for the final exam, as their performance on previous assignments indicated that open discussion and review greatly improved their understanding of the material.

H Evaluation of Student Performance

H.1 Exam

Table 3H.1: Exam Results and Statistics

Exam statistics	Group A	Group B	Group C	Groups B and C	All Students
Average Score	69.65%	83.12%	88.55%	85.66%	81.41%
Standard Deviation	±11.23	±9.85	±9.04	±9.77	±12.35
Minimum Score	41%	58%	62%	58%	41%
Maximum Score	83%	100%	100%	100%	100%
Median	72%	84%	88.5%	87%	83%

After grading the final exams and analyzing the data, the average of the exam grades from Group A was 69.7% ± a standard deviation of 11.2, 83.1% ± 9.9 for Group B, and 88.6% ± 9.0 for Group C [Table 3H.1]. The average and the standard deviation of the total exams combined in all three groups were 81.4% ± 12.4. For just groups B and C, the average was an

85.6 ± 9.8.

H.2 Student Evaluations

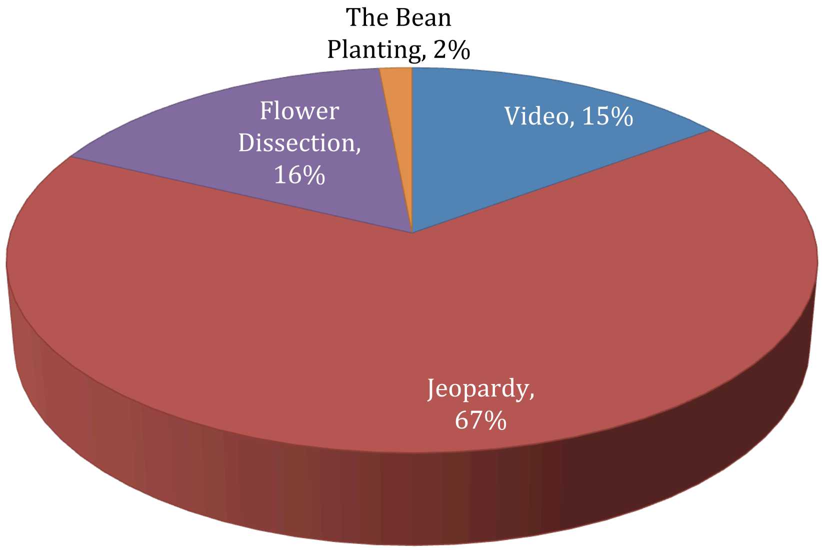
Table 3H.2: Student Suggestions for Improvement

Suggestions for Improvements	Number of Suggestions
Everything was fine – no necessary improvements	17
Explain better	15
Improve content of lessons, make it more interesting	8
More hands-on activities	7
Come more often, one visit a week is not enough	6
More fluid lecture without interruptions	4
Talk clearly, slowly, and in more simple language	4
Go over previously covered material in class	4
Too much note taking during class	3
Material taught was too much in depth	2
Do not pick favorites	2
Too much material being taught	2
Talk more about the moon	2

The students were asked questions rating their experience with the unit at the end of their final exam. In these questions, they were asked to rate their answers between one and five – five being "strongly agree" and one being "strongly disagree." On average, the students scored the statement, "I found plant science fun and interesting before this unit" with 2.97 ± 1.19 the next statement "I found plant science fun and interesting after this unit" 4.10 ±1. The statement, "I feel like I learned a lot from this unit," was scored with a 4.61 ± 0.657. The statement "I think this unit would help other sixth graders learn about plant science in a fun and interesting way" received a score of 4.52 ± 0.875. Finally, "I feel like the WPI students did their best to make sure I understood material" received a score of 4.49 ± 0.894.

Regarding in-class activities: 67% of the students said that their favorite activity was Jeopardy, 16% chose the flower dissection, 15% enjoyed the tropism videos, and 2% favored the bean planting experience, as shown in a pie chart in Figure 3H.2.

Figure 3H.2: Favored Student Activities



H.3 Journals

While there are no quantitative data from the journals, the assigned student journal entries indicated an impressive understanding of the material taught. For example, a number of vocabulary words taught throughout the unit, such as xylem, phloem, photosynthesis, respiration, transpiration, etc., were used fluently in later explanations, implying a familiarity with the language of plant science. In addition, the responses to questions demonstrated full understanding of at least those queries. The student journal entries showed that they had a firm grasp on the main mechanisms of plant growth and development. Students also showed that they understood the different types of tropisms, and that they knew that plants react and adapt to their environments. They also realized that plants need oxygen as well as carbon dioxide to survive.

Chapter 4: OVERALL CONCLUSIONS

A Teaching

The effectiveness of the Plant Science Unit may have been lessened by the team's inexperience with teaching. That being said, the team's research into developmental psychology and teaching methods strengthened our teaching, allowing us to provide lessons that were more than adequate.

While our classroom lectures were bolstered by learning about teaching, student learning, and developmental psychology, it is likely that an experienced teacher could more effectively deliver this material. Our inexperience may have affected the students, but the unit is intended for a teacher to adopt into his or her classroom. Because of this, we feel that our unit provides some new insight into both the scientific language and core concepts essential to a knowledge of plant biology, which will help to prepare students for the MCAS-S.

The teacher that the team worked with, Ms. Debra Conn, evaluated the effectiveness of the unit once it was completed. According to her evaluation, the team's biggest weaknesses all revolved around a lack of time in the classroom. Because the could only meet with the students once a week, she stated that the "notes" sections of the lecture seemed rushed in order to make time for the hands-on activities sections of the lessons. She also mentioned that the hands-on activities were as effective as they could be given the time limitations.

Ms. Conn praised the team for being able to schedule around the Flagg St. School's departmentalized schedule, and also stated that the unit enhanced the current curriculum. She also believed that the team was very thorough in covering the material required of the plant unit.

B Lunar Base Theme

The lunar base theme was intended to provide an exciting, fun, awe-inspiring topic that would keep students engaged throughout the unit. We agree that this theme is a fantastic idea on which to base a project; it is interesting and thought-provoking to imagine what life would be like on an alien landscape, and this theme alone is an engaging science-linked topic that is very much tied to biology and earth science.

When this topic was introduced into the classroom; however, it caused more confusion than excitement. It seemed that the students' knowledge about life on Earth was not sufficient for comparison between life on Earth to a biosphere on the moon. The students had no prior introduction to the moon and its environment, which required an understanding of either the basics of biotic life or lunar conditions to even consider the challenges of a lunar base. Because of this obstacle, we decided that it would be more practical to focus our time on teaching the actual material of plant science rather than possibly wasting time or confusing the students in trying to integrate the lunar base into our lessons.

To our delight and surprise, the students seemed to find the material thoroughly engaging and entertaining without the incorporation of the lunar base theme. It appeared that the plants themselves were exciting enough, which was great news to us!

The lunar base theme may have also failed in our particular unit because it was designed to span fifth through tenth grade classes in a comprehensive and successive program. The lunar base curriculum theme is in its developmental stages, so the children we worked with had not been introduced to it in their previous year of earth science, a topic that has a much more tangible link to a lunar base. We assert that, had this unit been part of a successive program, the students would have had enough of an understanding of the moon to be able to apply our unit's material to an ongoing comparison with Earth.

C Measure of Effectiveness

C.1 Grades

Group A was a skills-based, low-level group, hence, the lower scores on the exams. However, the standard deviation was quite high at ±11.2. Group B had a higher average of 83.1 on the exams, with a standard deviation of ±9.9. Most grades in this group were in the high eighties or mid-nineties. The students in this group were very talented and we expected them to have the highest grades, but the Group C students showed better results on the exam. Group C had the best performance of the three groups. The average of the Group C exam grades was 88.6 ± 9.0. In this group, only one student received a grade below 70, while three students received the maximum points possible and one student received 98 points. Such grades indicate a high level of understanding, affirming that we adequately delivered the material and that the students were engaged.

The team did not have access to any prior exams for these students on plant biology. Therefore, the results of the unit could only be deduced from student responses and Ms. Conn's evaluation and comments. To assess whether the group was successful in improving the student interest in plant biology, a statistical analysis was performed. The test statistic method was used to compare questions 1 ("I found plant science fun and interesting before this unit") and 2 ("I found plant science fun and interesting after this unit") on the exam. From this statistical analysis, it was determined at $p \leq .0\ 01$ for $n = 63$ that the appreciation of plant biology before this unit was much lower than after the unit was taught. In accordance with this analysis, it can be concluded that this unit increased student interest in plant biology.

C.2 Interest Level

According to the student responses, on average students did not display much interest in plant science before this unit. However, it is worth noting that standard deviation on this response was quite high, 1.19 on the scale of 5. On average, the students agreed that after this unit was introduced they became more interested in plant biology. For this response, the standard deviation was $\pm$ 0.995 points

Most students strongly agreed that they thought that they learned a lot from this unit. There were only four students that gave a score below 4 to this question. The standard deviation was very low for this question as well. This suggested that our efforts to teach students were not in vain, and that the team instilled some knowledge of plant science in children, which they are going to use later in life and their academic careers. Most of the students also strongly agreed that this unit would help other 6th graders in learning plant science in a fun and interesting way.

When evaluating the unit itself on a scale of 1 (lowest) to 5 (highest), only 6 students of the 68 gave scores lower than 4 points. According to the majority of the students, this unit will be a useful tool to educate sixth-graders in plant science. The students also agreed that the team taught the unit to the best of their ability and helped the students learn in the best way possible.

From the four main hands-on activities, about 67% percent of students preferred the Jeopardy games. Many students said that they enjoyed learning in such a fun, competitive way. Several other students suggested that they liked Jeopardy because they had never done anything like it in class before; others said that they liked the lollipop prizes that they received, and others just liked to review material in this fashion. Jeopardy was the most successful activity of this unit and appears to be an effective tool that other instructors could use in the future.

Flower dissection ranked second with 16% of students liking it the best. Most students that liked the flower dissection commented that they loved to observe the hidden parts of the plant. Other students said that they liked to witness, first-hand, the concepts learned in class while they dissected the flower. Many students commented that they also liked the teamwork involved in the flower dissection.

About 15% of students ranked the tropism videos as their favorite activity. They noted that they enjoyed the videos the most because they had never seen a plant respond to its environment in a physical, kinetic way. Some students also said that, while watching the films, they loved to see everything that they learned in class come to life.

Only 2% of students said that they liked the bean planting activity. This was possibly due to the fact that bean planting was our first activity and we were somewhat limited in time and disorganized. Another problem was that the germination station was not designed for a large number of students to plant at once, which resulted in long waiting periods for the students. Another factor that influenced the low popularity of this project was the death of most of the initial germinated seed due to excessive moisture.

D Measure of Reproducibility

D.1 Qualitative

As each lesson was thoroughly outlined and supplemented by the "Background Information" packets, any instructor should easily be able to teach this unit smoothly in his or her classroom. The lesson plans are organized in a dialogue-like manner so that the teacher can consult the lesson plan step-by-step throughout the class, if necessary, to stay on track. The background information is comprehensive enough that almost any question a student might ask could be answered with a quick look into the packet. Each hands-on activity includes materials that are both easy to acquire and inexpensive; they were compiled on a college student's budget, so the cost is negligible when compared to the value of the unit.

D.2 Cost Analysis

The cost analysis of the project pertains to the cost of this unit per school, as the materials would be divided throughout the sixth grade science classes. Table 2D.2 reflects the cost for the Flagg St. School, and pertains to a sixth grade comprised of 68 students. The number of flowers is adjustable by preference, as a flower per student is ideal, but only a flower per team of four or five students is necessary in adequately viewing the distinct plant parts. Also, conducting some of these experiments either early or late in the academic year, e.g. September or May, could reduce costs because plants are still growing and are not in winter dormancy.

Table 2D.2: Cost Analysis

Item	Number Required	Cost Per Unit	Total Cost
Germination Station	1 Kit	$37.99	$37.99
Germination Station With Heat Mat			
SKU: 93-1230 (Home Depot)			
Soil	1 Bag	$3.79	$3.79
Scotts 1 cu. ft. Premium Garden Soil			
Model # 72251750 (Home Depot)			
Sand	1 Bag	$3.98	$3.98
Pavestone 50 lb. All Purpose Sand			
Model # 55141 (Home Depot)			
Bean Seeds	2 Packets	$1.19	$2.38
Burpee Lima Bean			
Model # 65359 (Home Depot)			
Flowers (Shaw's Supermarket)	Daffodils	$0.29	$19.38
○ 68 (1 per student)	3.99 per bunch (~14 flowers)		
	Total		$67. 52
or			
	Lilies	$1	$13.98
○ 14 (1 per team)	7.99 per bunch (~8 flowers)		
	Total		$62.12

It is important to note that, with the book used, numerous "Investigate Kits" were included in the school's purchase. The school had dirt, sand, and bean seeds, reducing the total cost down to $57.37.

Additionally, different seeds and plants could be used interchangeably with the bean seeds, daffodils, and lilies, specifically with the flowers. Monocots as well as dicots would be preferred in the plant dissection activity; however, it is difficult to obtain a large dicot flower for dissection. They are sufficient for superficial viewing, but difficult for 6^{th} graders to dissect because their parts are not as easily discernable.

Chapter 5: Conclusion

A Overall Project Strengths

One of the strengths of this project was the incorporation of a unit that strayed from the normal course of the textbook. Every time we walked into the classroom or spoke with Ms. Deb Conn we were overwhelmed by the excitement the students voiced in having completed their assignments, in looking forward to the next jeopardy game, or in what they would learn next. The students eagerly anticipated the one day a week that we would break up their day-to-day routine and show them, first-hand, something fascinating about the plants that they had previously overlooked. All information, research, and planning aside, the simple interruption of their classroom routine with hands-on activities and engaging, new material seemed to instill fresh motivation in the students.

Another strength of this project was that this unit is likely reproducible. Not only were the lesson plans, background information packets, and hands-on activities effective and easy to adopt, the entire unit is so inexpensive at around $60 per school that it is cost effective to implement. Additionally, the supplies would not be exhausted after one year – the germination station, soil, sand, and potentially bean seeds (depending on the availability of the kits associated with the HSP textbook) would not need to be purchased annually. The only things that would need to be obtained for the next year are flowers and, potentially, bean seeds, so the price for successive years would only be between $13 and $20. Had the plants been purchased during a normal growing season as opposed to on Valentines Day, the only day a good selection of plants was available to use during the cold months, they would be much less expensive, so the unit could cost less than $10 each year, after the initial cost.

A third strength of the Plant Science Unit, and probably the most important, is that the unit is effective in teaching the students about plants. The average grade earned by the students was an 81.4 ± 12.4, including Group A. Omitting the skills-based group, the class average was an 85.7 ± 9.8, indicating that the lessons and hands-on activities were prepared in a manner that had an impact on the students.

B Project Weaknesses

This unit would be best taught in the early fall or late spring when it is still warm. Doing the unit during the winter was a challenge for the team, not only because of the temperature but also because of the limited availability of seeds and plants. A warmer season would not only be conducive to growing plants, but it would also allow the students to go outside and see different examples of plants in the woods near their school.

Another major weakness in the project was that the team was only able to go into the school to teach each section once a week. This disrupted the student's schedules because the team needed to leave their regular length periods early in order to get to their next class on time. The length of the unit itself could also be improved. The team needed to fit the entirety of the unit into only seven visits, which averaged less than seven hours spent per class section. If the team had more time with each section, they would have been able to better accommodate different student learning styles.

The budget for this project was expected to come from the WPI team, and was not provided by either institution. This restriction encouraged the team to be creative and to use available resources to minimize out-of-pocket expenses.

Finally, the lunar base theme was not much help for us in exciting the students about science because it was not formerly introduced to them. An obvious improvement to this project, as it was intended to be part of a continuum, is to teach this unit successive to the fifth grade lunar base unit. Then, students would be exposed previously to the material regarding a lunar base and would have a better understanding of the basic knowledge needed to compare and contrast a lunar environment with the material presented to them.

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Chapter 7: APPENDICES

Appendix A LESSON PLANS AND BACKGROUND INFORMATION

Lesson Plan: Visit 1

Plant Biology

Grade 6

Group 7,8,9

Materials

Journals

Letters to parents

Handout

Overview

Visit 1 will serve as an introduction of the group and the lunar base in general. We will hand out letters for the parents that introduce ourselves, as well as journals. This visit will be more thought-provoking than informational, introducing the topics we will cover and the importance of that information.

Objectives

- Introduce group
- How do plants meet their own needs? (absorb water, create food, reproduce, etc.)
- What is an ecosystem? Relate to biosphere
- Hand out worksheet on levels of organization
- How are plants important to the ecosystem? (they liberate oxygen for us, provide food, etc.)
- What is a lunar base?
- What we need to survive on a lunar base (guided discussion) – brainstorm with class about different factors
- What type of plants would we bring with us (…)
- Give kids letters for parents

Activities

Hand out journals and worksheets; use guided discussion through lesson plan.

Homework

Journal entry 1:

- Tell us what you know about plants, and why you think they are important
- Read Chapter 3, Lesson 1: Pages 144 to 153, and write down vocabulary

Lesson Plan 1

Make introductions

- Names, ages, school, major
- Why are we here
    - Project from school to enrich science

Ecosystems

- What is an ecosystem?
    - A community and all its non-living surroundings. The living parts are called biotic, and the nonliving are called abiotic
    - Different species interact with each other and their environment to survive
- How do different species rely on each other?
    - For food?
        - Animals eat plants and other animals, plants make their own food with sunlight and water and carbon dioxide.
    - For air?
        - Humans need oxygen to breathe, and we breathe out carbon dioxide. Plants need carbon dioxide to live, and output oxygen.
    - For shelter?
        - Humans build things out of plants, such as using wood to build houses or cotton plants to make cotton for clothing
        - Humans also use animals for usable materials such as leather, furs, and wool.
        - Animals need plants for shelter, as some animals live in trees and others use plants to build their nests.

Plants

- What do you know about plants?
    - Where do most plants grow best?
        - In places where it is warm, moist, with soil
            - Do they grow well in deserts?
            - How about on the north and south poles? Do you think there are as many plants there as there are in warmer climates?
    - So, what do they need to survive?
        - Water
        - Carbon dioxide
        - Sunlight
        - Minerals
        - Warmth
- How do plants get what they need?
    - Think about it:
        - How do the leaves at the very tops of trees get the things they need, such as water and nutrients?
        - If you have a flower, do you put water on the flower or in the soil? Why?
        - How do trees in forests produce nutrients through photosynthesis if only the top parts get sunlight?
            - Plants can grow taller, branch out more, and grow in ways that allow them to get more sunlight because the VASCULAR SYSTEM allows them to get the nutrients they need without being in direct contact with them.
            - You can water the roots because the water will travel through the plant and reach every single part of it.

            - A tree can grow in a thick forest, where the bottom of the tree only gets limited sunlight, because you know the nutrients from photosynthesis in the leaves will travel through the entire tree.
    - Nutrient distribution
        - Nutrients and water from the soil, plus the organic compounds produced in leaves (such as the sucrose, or sugar, from photosynthesis) are either absorbed and stored directly into the cells or distributed through the xylem and phloem
        - What are the xylem and phloem?
            - Think about your body. Your body has an internal system called the circulatory system, which is made up of things like veins that pass blood through your entire body. Plants have a system like this too. Their system is made up of xylem and phloem.
            - Xylem
                - *The xylem of a plant is the system of tubes and transport cells that circulates water and dissolved minerals through the plant.*
                - *As a plant, you use roots to absorb water. These roots branch out into the soil and grab up enough water to feed the plant.*
                - *They also have a secondary function of support.*
                - If you cut down an old tree, you can see a set of rings. Those rings are the remains of old xylem tissue, one ring for every year the tree was alive!
            - Phloem
                - *Most plants have green leaves, where the photosynthesis happens. When those sugars are made, they need to be given to every cell in the plant for energy (some cells are very far away!)*
                - *The phloem cells are laid out end-to-end through the entire plant, transporting sugars and other molecules that the plant creates. The phloem is always alive. Xylem tissue dies after one year and then develops again (think of the rings on the tree trunk)*
            - What is the best way to think about phloem? Think about sap coming out of a tree. The sap usually comes from the phloem
- Do you think plants can grow on the moon? Why or why not?
    - Does the moon have all the necessary requirements for plants to live?
        - Temperature
            - +/- 250 degrees Fahrenheit!
            - Plants need around 75 degrees Fahrenheit
            - Normal plants can live at just above freezing temperature (32 F) to about 100°F (a hot summer day)
            - Arctic plants can live from 14°F to 100°F, and desert plants from 32° to 122°
                - *Page 144 (life processes of plants, galston)*
        - Atmosphere
            - The moon has basically no atmosphere which means no carbon dioxide!
        - Water
            - If the moon reaches such extreme temperatures, any water there would either freeze or evaporate. There would not be liquid water on the moon and plants cannot use water if it is frozen

What is a Lunar Base?

- Does anyone know?
    - It is a place on the moon in which astronauts can live, along with plants and animals if you design it correctly
    - It is closed off so you can fill it with things necessary for humans to breathe, such as oxygen
- Why would we want a lunar base?
    - To learn about conditions on the moon
    - To learn about the effect the lunar environment would have on life and reproduction
    - To colonize another planet for exploratory as well as precautionary reasons

- What challenges would it pose?
    - How is the moon different than the Earth/what challenges does this pose?
        - Gravity
            - Transportation, body systems
            - The moon has 1/6th the earth's gravity (9.81m/s^2)
        - Air/atmosphere
            - Breathing (people, animals)
            - CO_2 for plants
            - Atmosphere to block radiation, maintain temperature
        - Days/nights – sunlight
            - The moon has varying day and night lengths – sometimes it goes for long periods without light and sometimes it goes for long periods with it. The change between light and no light is very different than that on the earth.
            - Because the moon is rotating around the earth, instead of the sun, and revolving around its own axis in the meantime, exposure to the sun varies a lot.
            - Plants need sunlight at regular intervals for photosynthesis, so light must be utilized
        - Ground – soil or not?
            - Plants need soil and minerals from soil to grow. The moon is not made up of the same elements as earth is.
            - Soil is defined as having organic content, and lunar regolith has none
            - The lunar surface is made of what is called lunar regolith, made of silicon, iron, calcium, aluminum, magnesium, oxygen, and other minerals.
        - Are there already plants and animals there?
            - No, we would need to bring plants and animals
- What types of plants would we bring with us?
    - Plants for us to eat
    - Plants for animals to eat
    - Plants to produce a lot of oxygen

Lesson Plan: Visit 2

Plant Biology

Grade 6

Group 7,8,9

Overview

Visit 2 will discuss photosynthesis, reactants, and products, as well as why plants are green. We will give an overview of vascular vs. nonvascular plants. Students will begin the germination experiment.

Objectives

- Photosynthesis, reactants, products
- Why are plants green
- Vascular vs. nonvascular plants, which is best for moon
- Plant beans for future experiments
- Show students how to water and tend plants

Activities

Guided discussion, students will plant beans:

Each class will have 3 teams (red, orange, yellow), and each team will be responsible for seven beans (light, no light, lack of minerals, normal soil, excess of minerals, heat, and no heat).

Homework

Journal entry 2:

- Create chart of varying growth factors (light, no light, lack of minerals, normal soil, excess of minerals, heat, no heat) and write your predictions for how well each plant will grow in that particular condition.
- Read Chapter 3, Lesson 3: Pages 162 to 173, and write down vocabulary

Choose group "scientist" to water and tend plant

Details

Each team will have 3 bean seeds to germinate in 3 cups of soil.

Materials

Bean Seeds

Germination Station

Cups

Extra Cups for Outside the Germination Station

Tape for labeling

Soil

Journals

Homework

Students will rotate through the group watering the plants, measuring growth (when applicable), and drawing progress.

Photosynthesis

$6CO_2 + 6H_2O$ –light→ $C_6H_{12}O6 + 6O_2$
carbon dioxide + water –light→ sugars + oxygen

Why are plants green

The parts of the plants that are green contain chloroplasts, which are responsible for carrying out photosynthesis.
Chloroplasts contain chlorophyll, a pigment that absorbs all the "different colors" for photosynthesis, but reflects a green color. There are about 30 to 40 chloroplasts in each plant cell, while each chloroplast contains millions of chlorophyll pigments.

Two main types of chlorophyll
Chlorophyll A absorbs red and violet light well, while chlorophyll B absorbs blue and red light well. Since green light is not absorbed, it is reflected back, causing plants to appear green.

Carotenoids

Leaves also contain carotenoids, a type of pigment that has yellow-orange color. Carotenoids partly account for the different colors of trees during the fall because, when daylight is shortened, chloroplasts stop chlorophyll production, while carotenoid production continues a bit longer.
Other variations in color are due to genetics and environmental factors such as geography, elevation, climate, and moisture.

But why is chlorophyll green?

To get into the specifics, visible light is composed of different colors. Some light is absorbed, while other light is reflected. Chloroplasts reflect green light, so we see them as green.

Light Dependent Reactions

Reactants: water
Products: Oxygen
This part of photosynthesis is what accounts for most of the Oxygen that we and other animals need to breathe.

The Calvin Cycle (light-independent reactions)

The Calvin cycle takes place in the stroma of chloroplasts, and is also known as the dark reaction
It converts CO_2 and H_2O into organic compounds.
Named after Melvin Calvin
Reactants: $6CO_2$
Products: one 6-carbon molecule (glucose)

What affects the rate of Photosynthesis?

Water availability

Water is essential to photosynthesis; oxygen that plants release comes from H_2O

Plants have stomata, which close to decrease water loss as well as a waxy coating, which prevents evaporation from cells.

Temperature

High / low temperatures can dry out / freeze plants.
Certain proteins require a specific temperature range to operate optimally.
Plants in different environments have developed different enzymes and proteins in order to survive in their surrounding environment
(A survivable temperature for normal plants ranges from right above freezing to 40°C; arctic plants extend this range down 10°C; desert plants extend this range upward 10°C)

Light intensity

Varies greatly between from plant to plant, but all plants need sunlight to carry out photosynthesis.

Photosynthesis occurs in chloroplasts, which animal cells do not have.

Vascular vs. nonvascular plants, xylem and phloem

What are nonvascular plants?

Mosses, liverworts, and types of algae

They do not have a specific internal system for distributing nutrients. Instead, the entire plant absorbs and stores nutrients directly into the cells

What are vascular plants?

Vascular plants absorb nutrients through an internal system that conducts water, minerals, sugar, and other nutrients. This system includes roots, stems, and leaves

Most existing plants are vascular, and there are approximately 235,000 different species of vascular plants!
This includes all flowering plants and conifers, such as pines, spruces, and firs.

- Xylem
    - *The xylem of a plant is the system of tubes and transport cells that circulates water and dissolved minerals through the plant.*
    - *As a plant, you would use roots to absorb water. These roots branch out into the soil and grab up enough water to feed the plant.*
    - *The xylem also has a secondary function of structural support.*
        - If you cut down an old tree, you can see a set of rings. Those rings are the remains of old xylem tissues; one ring for every year the tree was alive!
- Phloem
    - *Most plants have green leaves, where the photosynthesis takes place. When those sugars are made, they need to be delivered to every cell in the plant for energy.*

        - *The phloem cells are laid out end-to-end through the entire plant, transporting sugars and other molecules that the plant creates. The phloem is always alive. Xylem tissue dies after one year and then develops again (think of the rings on the tree trunk)*

    - What is the best way to think about phloem? Think about sap coming out of a tree. The sap usually comes from the phloem

Which is better?

Vascular plants have more opportunity to get sunlight, water, and all the factors they need to grow because they can grow larger and branch out more.

Plant beans for future experiments

Show kids how to plant, water, and tend plants

Background Notes: Visit 2
Vascular vs. nonvascular plants: which is best for the moon?

Vascular plants

- **Definition**
  - Also known as Tracheophyta or Tracheobionta or higher plants
  - Plants that have lignified tissues for conducting water, minerals, and photosynthetic products through the plant
- **Examples**
  - Clubmosses, equisetum, ferns, gymnosperms[1] (including conifers[2]) and angiosperms[3] (flowering plants)
- **Basics**
  - Have vascular tissues which circulate resources through the plant
    - This allows the plant to evolve to a larger size than nonvascular plants, which lack the specialized conducting tissues and are restricted to small sizes
  - The principal generation phase is the sporophyte, which is usually diploid with two sets of chromosomes per cell
    - The more complex diploid structure allows for more photosynthetic area for the spore-bearing structure, the ability to grow independent roots, woody structure for support, and more branching
- **Nutrient distribution**
    - Nutrients and water from the soil and the organic compounds produced in leaves are distributed through the xylem and phloem
      - The xylem draws water and nutrients up from the roots to the upper sections of the plant's body
        - → The xylem consists of tracheids[4]. A tracheid cell wall usually contains the polymer lignin
      - The phloem conducts other materials, such as sucrose produced during photosynthesis, which gives the plant energy to keep growing and seeding
        - → The phloem consists of living cells called sieve-tube members. Between the sieve-tube members are sieve plates, which have pores to allow molecules to pass through
          - Sieve-tube members lack such organs as nuclei or ribosomes, but the cells next to them (companion cells) function to keep the sieve-tube members alive
  - Movement of nutrients, water, and sugars is affected by transpiration, conduction, and absorption of water
  - Transpiration

---

[1] Seed-bearing plants with "naked seeds". Seeds develop either on the surface of scale- or leaf-llike appendages of cones, or at the end of short stalks

[2] Cone-bearing seed plants (trees and shrubs)

[3] Flowering plants, keeping their seeds or ovules enclosed during pollintion

[4] Dead hard-walled hollow cells arranged to form tiny tubes to function in water transport

        - Definition: the main process a plant calls upon to move compounds within its tissues
        - Water is transpired from the leaves via stomata, carried there via leaf veins and vascular bundles within the plants cambium layer.
        - The movement of water out of the leaf stomata creates a transpiration pull (when the leaves are considered collectively)
            - The pull is created through water surface tension within the plant cells
        - The draw of water upward is assisted by the movement of the water into the roots via osmosis
        - This process also assists the plants in absorbing nutrients from the soil as soluble salts, a process known as absorption. The movement of water upward requires very little to no energy from the plant
            - Hydrogen bonds exist between water molecules, causing them to line up. As molecules at the top of the plant evaporate, each pulls the next one up to replace it, and so on.
    - Absorption
        - Xylem vessels allow for the movement of water and nutrients upward toward the shots and leaves through the roots and fine root hairs from the soil
        - Living root cells passively absorb water in the absence of transpiration pull via osmosis creating root pressure
        - It is possible for there to be no evapotranspiration and therefore no pull of water toward the shoots and leaves. This is usually due to high temperatures, high humidity, darkness or drought
    - Conduction
        - Xylem and phloem tissues are involved in the conduction processes within plants
        - Sugars are conducted throughout the plant in the phloem and other nutrients through the xylem
        - Conduction occurs from a source to a sink for each separate nutrient
        - E.g. sugars are produced in the leaves (source) by photosynthesis and transported to the roots (a sink) for use in cellular respiration or storage
        - Minerals are absorbed in the roots (a source) and transported to the shoots to allow cell division and growth
    -

Nonvascular plants

- **Definition**
- A general term for plants without a vascular system (xylem and phloem). Although these plants lack the xylem and phloem, a number of non-vascular plants possess tissues specialized for internal transport of water.
    - The term is no longer used in scientific nomenclature. They are categorized into two distantly related groups:
    - Bryophytes

        - Bryophyta (mosses), Marchantiophyta (liverworts), and Anthocerotophyta (hornworts)
            - In these groups, the primary plants are the haploid gametophytes, with the only diploid portion being the attached sporophyte, consisting of a stalk and sporangium
    - Algae
        - The most common is green algae.
        - The only algae still considered plant is the Archaeplastida
            - Comprise of red and green algae, and land plants, together with a small group called Glaucophytes
- **Basics**
    - Non-vascular plants are termed the "lower plants" because they are the earliest plants to evolve.
        - Side note – lower plants is also used to describe vascular plants such as ferns and fern allies

Xylem

- **Basic**
    - One of the two types of transport tissue in vascular plants
    - Its basic function is to transport water, but it also transports some nutrients through the plant
- **Structure**
    - The most recognizable xylem cells are the long tracheary elements that transport water
        - Tracheids and vessel elements are distinguished by the multitude of spots that occur on the vessel elements – in these spots, both the inner and outer walls are missing. The vessel elements are connected together into long tubes that are called vessels
    - Xylem can also contain other cell types, e.g. parenchyma
        - Parenchyma are thin-walled cells of the ground tissue that make up the bulk of most nonwoody structures
    - Primary xylem
        - The xylem that is formed during primary growth from procambium
    - Secondary xylem
        - The xylem formed during secondary growth from vascular cambium.
        - Although it can be found in a few gymnosperms and cycadophyta, the two main groups that contain secondary xylem are conifers and angiosperms
- **Main function**
    - Upward water transport – water and soluble mineral nutrients from the roots through the plant, as well as replacing water lost during transpiration and photosynthesis

      - Little energy is necessary for upward water transport – occurs from transpirational pull (hydrogen bonds, capillary pull, and evaporation) as well as from root pressure (osmosis)
- **Development**
  - Centrarch
    - Common in early land plants, such as rhyniophytes (extinct); found with one strand of primary xylem
      - Primary xylem forms a single cylinder in the center of the stem and develops outward. The protoxylem is found in the central core and the metaxylem in a cylinder around it
  - Exarch
    - The roots of vascular plants are found to have exarch development
      - Xylem develops from the outside inward toward the center; the metaxylem is closest to the center of the stem or root and the protoxylem closest to the outside
  - Endarch
    - The stems of seed plants typically have endarch development
      - Xylem develops from the center outward. The protoxylem is closest to the center of the stem or root and the metaxylem is closest to the outside
  - Mesarch
    - The leaves and stems of many ferns have mesarch development
      - Xylem develops from the middle of a strand in both directions. The metaxylem is on the outer and central sides of the strand, with the protoxylem between the metaxylem (possibly surrounded by it)

Phloem

- **Basic**
  - Living tissue that carries organic nutrients, in particular, sucrose, to all parts of the plant where needed
  - In trees, the phloem is the innermost layer of the bark
  - The phloem is mainly concerned with the transport of soluble organic material made during photosynthesis (translocation)
- **Structure**
  - Phloem tissue consists of: conducting cells (sieve elements), parenchyma cells (specialized companion cells or albuminous cells), and supportive cells (fibers and sclerids)
- **Main function**
  - Unlike xylem, which is composed primarily of dead cells, the phloem is composed of still-living cells that transport sap
    - Sap is a water-based solution rich in sugars made by the photosynthetic areas. These sugars are transported to non-photosynthetic parts of the plant, such as the roots, or into storage structures, such as tubers or bulbs
  - Also unlike xylem, the movement through the phloem is multidirectional
  - During growth period (usually during spring)

        - Storage organs such as roots are sugar sources, while the plants growing areas are sugar sinks
    - After the growth period (when the meristems are dormant)
        - The leaves are sources, and storage organs are sinks
        - Developing seed-bearing organs (such as fruit) are always sinks
    - Movement through the phloem, translocation, is driven by positive hydrostatic pressures. This is accomplished by phloem loading and unloading
        - Cells in a sugar source "load" a sieve-tube element by actively transporting solute molecules into it. This causes water to move into the sieve-tube element by osmosis, creating pressure that pushes the sap down the tube.
        - In sugar sinks, cells "unload", or actively transport solutes out of the sieve-tube elements, producing the opposite effect.
            - Some plants appear to not load the phloem by active transport. Small sugars such as sucrose move into intermediary cells through narrow plasmodesmata, where they are polymerized to larger oligosaccharides. They are now unable to move back, but can proceed through wider plasmodesmata into the sieve tube element
            - → This effect is confined mostly to plants in tropical rainforests, and is seen as more primitive
- **Sidenote – Girdling**
    - Because phloem tubes sit outside the xylem in most plants, a tree or plant can be effectively killed by stripping away the bark in a ring on the trunk or stem; with the phloem destroyed, nutrients cannot reach the roots, and the tree/plant will die
    - Trees located in areas with animals such as beavers are vulnerable because they chew off the bark at a fairly precise height; this process is known as girdling
    - Girdling can be used in agriculture → enormous fruits and vegetables can be made by placing a girdle at the base of a large branch, then by removing all but one fruit/vegetable from that branch; all the sugars manufactured by the leaves on that branch would have no sinks to go to but that one fruit/vegetable, and it would expand to an abnormal size
- **Development**
    - The phloem originates and grows outward from meristematic cells in the vascular cambium; phloem is produced in phases
        - Primary phloem is laid down by the apical meristem and develops in the procambium
        - Secondary phloem is laid down by the vascular cambium to the inside of the established layer(s) of phloem

Summary

- **Xylem**
    - Transport tissue in vascular plants, which transports water and nutrients
        - Uses upward water transport which requires little to no energy – occurs from transpirational pull (hydrogen bonds, capillary pull, and evaporation) as well as from root pressure (osmosis)

- **Phloem**
    - Living transport tissue that carries organic nutrients, e.g. sucrose, to all parts of the plant
- **Vascular plants absorb nutrients necessary for survival through an internal system that conducts water, minerals, sugars, and other nutrients. This system includes roots, stems, and leaves.**
    - Most of the world's plants are vascular. This includes all flowering plants and conifers, such as pines, spruces, and firs. There are approximately 235,000 species of vascular plants
- **Nonvascular plants do not have specific internal conducting systems for receiving nutrients. Instead, the entire plant absorbs and stores nutrients directly into the cells**
    - Nonvascular plants include mosses and liverworts. Liverwort is generally found in a permanently wet habitat, while mosses can be found throughout forested areas

Lesson Plan: Visit 3

Plant Biology

Grade 6

Group 7,8,9

Overview

Visit 3 will focus on explaining plant response when faced with environmental changes, as well as the needs plants must meet in any environment.

Objectives

- Illuminate following concepts
  - What plants need to survive
  - How their environments affect growth
    - Tropisms
  - Circadian Rhythms

Activities

Take notes on tropisms and responses

Play jeopardy, check on plants

Homework

Journal entry 3:

- Continue tracking progress of plants
- Read Chapter 3, Lesson 2: pg. 154 - 161
  - Write down vocabulary
  - Answer questions 2, 3, and 6 on pg. 161

Materials

Jeopardy game plan

Science notebooks – tracking plant growth

Lesson Plan: Visit 3

What do plants need to survive

- Sunlight
  - Photosynthesis
  - Leaf is the "organ" of photosynthesis
  - When there is no sunlight, electrons do not become excited and phosphorylation cannot occur
- Water and Minerals
  - Constant supply of water
  - http://www.ncagr.gov/cyber/kidswrld/plant/nutrient.htm
    - Macronutrients: Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulfur
    - Micronutrients: Boron, Copper, Iron, Chloride, Manganese, Molybdenum, Zinc
- Gas Exchange
  - Plants need CO2 for photosynthesis, but also need oxygen for cellular respiration
  - Stomata keep plant from losing too much water vapor to transpiration
  - Plants also need to get rid of excess oxygen (through stomata)
- Movement of water and nutrients
  - Simple plants move water and nutrients using diffusion (multicellular green algae, bryophytes)
  - If plants cannot move water to all parts of the plant (especially leaves for photosynthesis) then the plant will die
  - Phloem carries created sugars down to roots to be stored in plants with vascular systems
- Growth Medium
  - Different plants need varying soils and mediums to grow in
  - Best soil for soil-less greenhouse growing is a combination of: (depends on plant being cultred)
    - Peat
    - Bark
    - Perlite
    - Sand
    - Vermiculite
  - Media must:
    - Be aerated
    - Be able to hold water
    - Be rich in Nitrogen (perlite used)
- Bacteria
  - Plants carry bacteria and can suffer from bacterial diseases similar to humans and higher animals
  - Bacteria can be beneficial or detrimental to plants
  - Useful in nitrogen-fixation in legumes
    - Peanuts
    - Clovers
    - Soybeans
  - *Rhizoba* is a bacteria that dwells in plant nodules in the root systems
    - Produce compounds such as NH3 that help plants prosper

How environmental factors affect plant growth

- Tropism (book)
    - A biological phenomenon indicating growth or a turning movement of an organism (plant) in response to an environmental stimulus
  - Geotropism/gravitropism (book)
      - Plants exhibit phenomenon called gravitropism – a growth movement (called turning by biologists)

        - Positive Gravitropism
            - Roots show positive gravitropism (growing in the direction of gravity)
        - Negative Gravitropism
            - Stems show negative gravitropism (growing against gravity)
    - Heliotropism
        - Plant movement or growth in response to sunlight
        - Floral heliotropism is not necessarily exhibited by the same plants that exhibit leaf heliotropism
        - Heliotropism is a response to blue light
    - Hydroptropism
        - Movement or growth in response to water
            - Roots are prone to grow in a direction in which the humidity content is higher
            - This effect only spans over distances in the range of millimeters
    - Phototropism (book)
        - Movement or growth in response to lights or colors of light (e.g. sunflower)
        - Positive phototropism
            - Most shoots of plants exhibit positive phototropism, growing in the direction of the light source
        - Negative phototropism
            - Most roots exhibit negative phototropism, growing away from light
        - Phototropism is controlled by red and blue light
            - Red light sensors – phytochromes
            - Blue light sensors - cryptochromes
    - Thermotropism
        - Movement or growth in response to temperature
    - Thigmotropism <- can be used for heat, or to help plants find a structure to grow around for support
        - Movement or growth in response to touch or contact
            - Can be influenced by being touched, shaken, heated, or rapidly cooled
    - Photoperiodism
        - Response to the seasons
            - Related to circadian rhythm, plants sense the seasonal changes in night length, which they take as a signal to flower
            - Other than flowering, photoperiodic movement includes the growth of stems or roots during certain seasons, or the loss of leaves

- Gravity beyond Gravitropism
    - Increased gravity
        - Acceleration of gravity affects water flow and delivery of nutrients, oxygen, and minerals to plant soil and microorganisms.
    - Decreased gravity
        - Plants can function in low gravity
            - Low gravity causes decreased water and solute nutrient leaching from plants
            - This accounts for increased plant growth rate
            - Low gravity plants require lower qualities of nutrients and water
- Other Plants in the vicinity
    - Plants grow in communities
    - In those communities, they compete for sunlight, nutrients, and water
        - Sunlight
            - Plants grow taller or branch out more in order to gain more sunlight; one plant may exhibit overgrowth, covering another and stealing it's sunlight
            - The plant that captures first light will grow and suppress plants beneath it
        - Nutrients
            - Compete for nutrients in soil unless there are enough for both
        - Water
            - Compete for water in soil unless there is enough for both
        - Other

- Other
    - Allelopathy – plants produce compounds in their leaves, roots, or both, that inhibit the growth of other plants
    - E.g. black walnut roots can suppress many vegetable plants, and their leaves. If mulched over the winter, black walnut roots can affect annual crops like a herbicide (kills plants) the following spring
    - Some weeds show allelopathic traits and prevent desired species from growing

Circadian Rhythms

- What is photoperiodism?
    - The photoperiodism is ability of a plant to measure length of light and darkness within 24 hours.
    - Influences tuber development, leaf fall, and dormancy of the plant
    - Plants actually measure the length of dark period
    - Each plant requires different day/night lengths to flower. Sometimes, plants need certain amounts of repeated short/long, days/nights to flower.
    - Sometimes plants change their photoperiods due to temperature.
- What is Phytochrome?
    - Plants use a protein phytochrome as a sensor. Phytochrome provides a plant with information about the length of light and darkness.
    - Phytochrome receives signals about diminishing or increasing daylights by sensing decrease or increase in light energy (red light)
- Where the signal of night lengths is received by plants?
    - Photoperiodic signal is perceived by the leaves of the plant. Leaves then produce a hormone (florigen) and send it to the shoot apex which starts to flower. Sometimes phytochromes are located near the apex of trees where the flowering bead is located
- How do seeds germinate?
    - Some seeds can germinate in total darkness (the most important seeds)
    - Other seeds need little light for germination. That light penetrates through the soil.
- When do plants flower?
    - Plants are genetically programmed to flower at certain times of the year.
- What are short day plants?
    - Plants that flower during the short day lengths and longer night lengths.
- What are long day plants?
    - Plants that flower when the nights are shorter than days
- What are day-neutral plants?
    - Plants that do not depend on light and dark lengths

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Visit 3: Background Notes

What do plants need to survive

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    - Leaf is the "organ" of photosynthesis
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    - Plants need CO2 for photosynthesis, but also need oxygen for cellular respiration
    - Stomata keep plant from losing too much water vapor to transpiration
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        - Be rich in Nitrogen (perlite used)
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    - Plants carry bacteria and can suffer from bacterial diseases similar to humans and higher animals
    - Bacteria can be beneficial or detrimental to plants
    - Useful in nitrogen-fixation in legumes
        - Peanuts
        - Clovers
        - Soybeans
    - *Rhizoba* used in plant nodules in root systems
        - Produce compounds such as NH3 that help plants prosper

How environmental factors affect plant growth

- Tropism (links to Indiana University Plants in Motion videos hyperlinked, click to view)
        - A biological phenomenon indicating growth or a turning movement of an organism (plant) in response to an environmental stimulus
    - Geotropism/gravitropism
            - Plants exhibit phenomenon called gravitropism – a growth movement (called turning by biologists)
        - Positive Gravitropism and another link here
            - Roots show positive gravitropism (growing in the direction of gravity)
            - Root growth occurs by the division of stem cells in the root meristem located at the tip of the root
            - Roots bend in response to gravity due to polar auxin transport, the regulated movement of the plant hormone auxin
                - *An increase in the concentration of auxin, as when it accumulates toward the gravity vector on the lower side of tissues, inhibits cell expansion and results in root curvature*
        - Negative Gravitropism
            - Stems show negative gravitropism (growing against gravity)
                - *Auxin accumulates on the lower side of tissues in the stem, but, in contrast to roots, it promotes growth, causing an increase in cell expansion in the lower side, causing the shoot to curve up (statolithic gravitropism)*
    - Heliotropism
        - Plant movement or growth in response to sunlight
            - Heliotropic flowers track the sun's motion across the sky from east to west
            - Some heliotropic leaves orient themselves perpendicularly to the sun's rays in the morning, while others orient themselves parallel to the rays at midday
        - Floral heliotropism is not necessarily exhibited by the same plants that exhibit leaf heliotropism
            - Motion is performed by motor cells in a flexible segment below the flower called the pulvinus – the motor cells are specialized in pumping potassium ions into nearby tissues, changing their turgor pressure. The segment flexes because the motor cells at the shadow side elongate due to a turgor rise.
        - Heliotropism is a response to blue light
    - Hydroptropism
        - Movement or growth in response to water
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Lesson Plan: Visit 4

Plant Biology

Grade 6

Group 7,8,9

Overview

Visit 4 will highlight the differences between classes of plants, specifically flowering vs. nonflowering plants. We will outline the basic structures of plants, and discuss the processes and challenges of plant reproduction.

Objectives

- Flowering vs. nonflowering plants
  - Angiosperms, gymnosperms, sporophytes
- Plant reproduction
- Plant structure and anatomy
- Pass around samples of various pressed plants, and discuss their similarities and differences.
- Hand out plant anatomy worksheet

Activities

Pass around pressed plants

View images of plant anatomy, label plant anatomy worksheet

Homework

Journal entry 4:

- Tell us why you think the majority of the bean plants did not survive?
- Read Chapter 3, Lesson 4, write down vocabulary and answer questions 3, 4, and 5.

Materials

Pressed plants

Plant anatomy worksheet

Lesson Plan: Dialogue

Flowering plants (spermatophytes)

- Angiosperms
  - Background
    - The most diverse group of land plants
    - Seed-producing plants, like gymnosperms, and can be distinguished by characteristics such as:
      - Flowers
      - Endosperm within the seeds
      - Production of fruits that contain seeds
        - *Gymnosperms – seed-bearing plants that include conifers, cycads, Ginkgo, and Gnetales*
        - Difference lies in naked seeds (angiosperms enclose seeds during pollination)
        - Gymnosperm seeds develop on the surface of scale- or leaf-like appendages of cones, or at the end of short stalks (Ginkgo)
        - *Gymnosperms and angiosperms comprise the spermatophytes (seed plants)*
    - Ancestors of flowering plants diverged from gymnosperms 202-245 million years ago, and the first flowering plants known to exist arrived 140 million years ago
  - Characteristics
    - Flowers
      - Flowers are reproductive organs of flowering plants
      - Enable a wider range of adaptability, allowing flowering plants to dominate terrestrial ecosystems
    - Closed carpel enclosing ovules
      - *Carpel (or carpels) and accessory parts may become a fruit*
      - Closed carpel allows adaptations to specialized pollination syndromes and controls
      - Helps prevent self-fertilization, maintaining increased diversity
      - Once the ovary is fertilized, the carpel and surrounding tissues develop into a fruit
      - This serves as an attractant to seed-dispersing animals

Nonflowering plants (crytogams => sporophytes)

- (Sporophytes except for conifers)
  - Liverworts
  - Mosses
  - Hornworts
  - Whisk ferns
  - Club mosses
  - Horsetails
  - Ferns
  - Algae
  - Gymnosperms
    - Conifers
    - Cycads
    - Ginkgo
    - Gnetophytes

Plant Structure

- Roots
  - What do roots do?
    - Roots tap water and minerals from the soil, anchor the plant firmly to ground, provide place for storage of carbohydrates and other organic molecules.

How do roots grow?

Roots grow downwards according to the force of gravity, just like the shoots which grow upwards against gravity.

Root growth is due to a small region of cells at the tip of the stem called meristems. Meristems are embryonic cells of the plant; they divide without limit. Meristems divide repeatedly and expand. As a result, growth of the root takes place.

What is the root hair?

Root hair is a thin walled outgrowth of epidermal cells that increase the absorptive surface area of the root and promote uptake of larger volumes of water and minerals from the soil.

The smaller size of the root hair allows it to easily penetrate the capillary spaces between soil particles, extend contact to soil, and uptake maximal amounts of water and nutrients.

Once the water and minerals enter the plant system they travel via xylem up to the plant trunk and leaves.

- Leaves and buds

What do leaves do?

Leaves account for the most of the photosynthesis in plants

Leaves absorb CO_2 from the atmosphere and release O_2

Leaves also account for transpiration (evaporation of water for cooling, water transport, etc.)

What is transpiration?

Process by which plants evaporate water to cool down during the excessive heat or to transport water to leaves located on higher levels.

How is plant leaf structured?

Leaves contain pores called stomata (Gr. "little mouth") on the upper and lower surfaces, these leaf surfaces are covered with epidermal layer for protection.

What are stomata and what do they do?

Stomata are little gated openings on the surfaces of Leaves

Stomata control CO_2 intake, O_2 release, and transpiration of the plant.

To prevent water loss via transpiration, stomata gates close during heat, and drought to prevent excessive water loss.

What type of cells do Leaves contain?

Mostly Leaves contain flattened photosynthetic cells, which contain chloroplasts and are called **mesophyll cells**. These cells are located towards the surface of Leaves for better light exposure. These cells are also tightly packed to form **Palisade Layer.**

Towards the depths of Leaves, mesophyll cells are irregularly arranged, and fit loosely together to create **spongy layer** with open air space. Open air spaces connect to stomata and are passageways for gases entering and exiting Leaves.

Leaf is connected to the trunk of the plant via a stalk called **petiole**. Petiole contains a large vein that connects with vascular system of the plant root and stem. Towards the leaf side, this vein subdivides into smaller veins so that all the cells in the leaf have access to it.

- Flower and Plant reproductive system

What do flowers contain?

Flowers contain: petals, ovary, pollen tubes, anthers, pollen, and sepals.

- Cool facts:

How do plants respond to injury?

Plant releases ethylene when an injury is present, ethylene travels to the site of injury, meets with the wounded cell, and activates cell division that leads to the wound repair.

Auxin triggers ethylene production in the tree.

Ethylene along with the enzyme cellulose causes leaf abscission during fall.

Ethylene also signals a green fruit to ripen. After exposure to ethylene, fruits ripen and sweeten within 48 hours. Sweetening is due to break down of reserved starch in green fruit to form sugars. Softening of cell wall is due to the fruit cell wall digestion. The increase in tastiness is due to the formation of aromatic substances which give plant its distinctive flavor.

Some fungi produce ethylene in real life that causes fruit ripening. Sometimes they are the cause of fruit rotting.

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Plant Reproduction (Visit 4)

- Mosses (Bryophytes)
  - Need water to reproduce
  - Make sperm which swims to egg
  - Creates “protonema” which stays underground and can survive the winter
  - Spores release into wind
- Ferns (Seedless Vascular Plants)
  - Similar to mosses
  - Also need water to reproduce
  - Create spores, on bottoms of Fronds, which are released
  - Can create “rhizome” – creeping underground stem
  - Heart-shaped structure grows and can live underground through winter
- Seed and Cone Plants (Gymnosperms)
  - Have evolved to not need water to reproduce
  - Pollen cones – male
  - Seed cones – female
  - Male cones are smaller than female cones
  - Females have ovules, which are fertilized by pollen
  - Seeds are released from seed cone once fertilized
- Flowering Plants (Angiosperms)
  - Animals and insects are responsible for most of pollination
  - Shape of flowers aid plants in pollination by other organisms
  - Sticky stigma attracts pollen from anthers; stigma has pollen tubes that lead to ovary containing ovules
  - When ovules are fertilized, fruit can develop

Flowering plants (spermatophytes)

Angiosperms

Background

- The most diverse group of land plants
- Seed-producing plants, like gymnosperms, and can be distinguished by characteristics such as:
  - Flowers
  - Endosperm within the seeds
  - Production of fruits that contain seeds
    - Gymnosperms – seed-bearing plants that include conifers, cycads, Ginkgo, and Gnetales
      - Difference lies in naked seeds (angiosperms enclose seeds during pollination)
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- Ancestors of flowering plants diverged from gymnosperms 202-245 million years ago, and the first flowering plants known to exist arrived 140 million years ago

Characteristics

- Flowers
  - Flowers are reproductive organs of flowering plants
  - Enable a wider range of adaptability, allowing flowering plants to dominate terrestrial ecosystems
- Stamens with two pairs of pollen sacs
  - Stamens are lighter than corresponding organs of gymnosperms
  - Adapt to specialized pollination syndromes, such as particular pollinators
  - Have been modified to prevent self-fertilization, which permits further diversification
- Reduced male parts, three cells
  - The male gametophyte is smaller than that of gymnosperm seed plants
    - The smaller pollen decreases time from pollination (the grain reaching the female plant) to fertilization of the ovary
    - In gymnosperms, fertilization can take up to a year after pollination, whereas angiosperm fertilization occurs very soon after pollination
- Closed carpel enclosing ovules
    - Carpel (or carpels) and accessory parts may become a fruit
  - Closed carpel allows adaptations to specialized pollination syndromes and controls
  - Helps prevent self-fertilization, maintaining increased diversity

Lesson Plan: Visit 5

Plant Biology

Grade 6

Group 7,8,9

Overview

Visit 5 will outline the anatomy of plants on a cellular level, contrasting the structures and functions of plant and animal cells. The differences between monocots and dicots will be explained and then observed through a dissection of plants, with a worksheet guiding the students in classifying their plant as a monocot or dicot.

Objectives

- Cell anatomy
- Plant and animal cell differences
- Monocot and dicot differences
- Plant dissection

Activities

Dissect plants

Homework

- Study for jeopardy/final exam

Materials

Plants (preferably 1 plant to every 2 students)

Plant dissection worksheet

Monocot/dicot worksheet

Lesson Plan: Visit 5

Cells

- What is a plasma membrane?

Plasma membrane is a film of phospholipid bilayer that encloses both the animal and plant cells.

Plasma membrane selectively regulates what goes in and comes out of a cell.

Plasma membrane contains many protein channels that close and open to release, block, or transport molecules across the membrane

- What is a cell wall?

The cell wall is the outermost layer of the plant cell. Cell wall consists of cellulose, a tough and rigid polysaccharide made of glucose monomers that surrounds the plasma membrane

Cell wall is present only in plant cells

Cell wall protects plant cell, maintains cell shape, and prevents excessive water uptake, and consequent bursting of the cell.

Plant cell walls are far thicker than plasma membranes

- What is cytoplasm?

Cytoplasm is the gel like substance of the cell, enclosed by plasma membrane. Cytoplasm holds all the organelles of the cell and molecules that are freely floating within the cell. Nucleus is not part of the cytoplasm

- What are vacuoles?

Vacuoles are membrane enclosed sacs present both in animal and plant cells

In animal cell: vacuoles are mostly used for the food uptake, molecular transport and delivery to the different parts of the cell and to different cells; vacuoles are also involved in digestion of certain molecules which they take up during phagocytosis. Animal cell vacuoles are small in size and numerous.

Plant cell vacuole: Has many functions some of which are: plant uses vacuole to store certain organic molecules (glucose, protein). Vacuole also stores water and is responsible for generating the turgor pressure- vacuole swells when water enters in, and collapses when water leaves the vacuole. Vacuole swelling and deswelling causes plant movement and shrinking or swelling of the plant during humid and arid periods.

- What are mitochondria?

Mitochondria are the energy producing organelles of the cell

Mitochondria generate energy in process called cellular respiration.

Both the plant and the animal cells contain mitochondria, but animal cells contain a lot more mitochondria than do plant cells

- What is cellular respiration?

Cellular respiration is a series of metabolic reactions that retrieve stored energy and carbon molecules from stored sugars.

Process of respiration: $C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+12H_2O$

Respiration provides energy and carbon for maintenance and growth of the cells

Sometimes, when the stomata are closed, a plant will carry out respiration to refill carbon supplies

- What are chloroplasts?

Chloroplasts are plant cell organelles, which are responsible for carrying out photosynthesis.

Chloroplasts contain chlorophyll, a pigment that absorbs all the "different colors" for photosynthesis, but reflects a green color. There are about 30 to 40 chloroplasts in each plant cell.

Chloroplasts contain little sacks called thylakoids. Thylakoids are the place where photosynthesis occurs.

Chloroplasts are present only in plant cells

- What is a nucleus?

Nucleus is an organelle that stores the genetic material and information of the cell. Nucleus contains chromosomes which contain genes. Chromosome is a one big DNA molecule and encloses protein molecules associated with it.

molecules associated with it.

Nucleus is enclosed with double layered perforated membrane that is continuous with endoplasmic reticulum. Endoplasmic reticulum is a network of membranous sacks and tubes, it is producing proteins, cell parts, and stores some produced material.

Where are the chromosomes stored?

Chromosomes are stored within the nucleus in the peripheral part of nucleus called the chromatin

- What is a nucleolus?

Nucleolus is the structure located towards the center of the nucleus. 1 nucleus may have more than one nucleoli

Ribosomes are produced within the nucleolus. Ribosomes are complexes that make proteins, they are found on the walls of endoplasmic reticulum (bound to it), or they are floating free in the cytosol, a liquid inside the cell.

Monocots and Dicots

- Distinctions ONLY within the realm of FLOWERING PLANTS

Monocots

- Monocots diverged from dicots about 100 million years ago
- There are about 65000 species of monocots almost all of which are herbs including, lilies, irises, orchids, and grasses. Palms trees are also monocots
- Embryo usually develops above ground
- Leaves of monocots contain stomata on both sides, and stomata are arranged between the veins of leaves

Dicots

  - In dicots there are smaller amounts of stomata on upper sides of leaves
  - Embryo develops usually below the ground
  - Dicots were the first flowering plants, most primitive of which are peppers, water lilies, and magnolias
  - About 165000 species of dicots exist which include, trees, shrubs, and many broad-leaved herbs
    - Books/authors (Ronald ennos and Elizabeth Sheffield –plant life; Collin tudge- the tree; wendy B. zomlefer; flowering plant families; Hopkins and huner- and introduction to plant physiology)

Monocots	**Dicots**
Embryo with single cotyledon	Embryo with two cotyledons
Pollen with single furrow or pore	Pollen with three furrows or pores
Flower parts in multiples of three	Flower parts in multiples of four or five
Major leaf veins parallel	Major leaf veins reticulated
Stem vascular bundles scattered	Stem vascular bundles in a ring
Roots are adventitious	Roots develop from radicle
Secondary growth absent	Secondary growth often present

- Number of cotyledons

The actual basis for distinguishing the two classes, and the source of the names (monocotyledonae "one cotyledon" and dicotyledonae "two cotyledons"

Cotyledons – "seed leaves" produced by the embryo – they absorb nutrients packaged in the seed until the seedling is able to produce real leaves and begin photosynthesis

- Pollen structure

Single pore – monosulcate

Three pores – triporate

- Number of flower parts

If you count the number of petals, stamens, or other flower parts:

Monocots have a number of parts divisible by three (usually 3 or 6)

Dicots have multiples of four or five (4, 5, 8, 10)

This method is not reliable – some plants have reduced or excessive parts

- Leaf veins

Monocots have leaves with veins that run parallel the length of the leaf

Unreliable method – many monocots (e.g. aroids and Dioscoreales) have reticulate venation

Dicots have numerous auxiliary veins that reticulate between the major ones

- Stem vascular arrangement

Vascular tissue occurs in long strands (vascular bundles)

In dicots, they are arranged within the stem to form a cylinder, appearing as a ring of spots when you cut the stem

In monocots, the bundles appear scattered through the stem, with more bundles located toward the stem periphery than the center

- Root development

In most dicots (and most seed plants) the root develops from the lower end of the embryo, from the region known as the radicle. The radicle gives rise to an apical meristem that produces root tissue for much of the plant's life

In monocots, the radicle aborts and new roots arise adventitiously from nodes in the stem (called prop roots when clustered near the stem)

- Secondary growth

Most seed plants increase diameter through secondary growth, producing wood and bark

Monocots (and some dicots) have lost this ability, and do not produce wood

Some monocots can produce a substitute however, as in the palms and agaves

Dissection

- Sepal

Green part attached to stem

What is this used for?

Structure, foundation, protection

- Petals

Colorful part of plant

Why do flowers need petals?

To attract pollinators

How many petals are there?

3 or multiples of 3 – monocot

4/5 or multiples of 4/5 – dicot

- Stamen

Anther, filament

Is this the male or female part of the plant? How do you know/ what does it do?

Male

Makes pollen

- Pistil

Style, ovary

Is this the male or female part of the plant? Is the tip of the pistil sticky? Why?

Female

Helps to collect pollen

How can you remember that this is the female part of the plant? (open ovary to check for seeds)

Contains seeds, where seed is fertilized (like in humans)

- Leaves

  Do the veins on the leaves run parallel along the length of the leaf? Or do they branch (reticulate)

  Parallel leaf veins – monocots, Branched/reticulated leaf veins – dicots

Visit 1

Name ______________________

Date ______________________

Lesson Quick Study

Lesson 1 - How Do Plants Meet Their Needs?

1. **Inquiry Skills Practice–Draw Conclusions**

The owner of a flower shop wanted red, white, and blue flowers for Independence Day, but she had only red and white. She added blue food coloring to a bucket of water and placed white carnations in the bucket. The next morning, the carnations were blue. Draw a conclusion about how the color got into the flowers. ______________________

____

2. **Use Vocabulary**

Complete each sentence with the correct term from the box.

phloem
nonvascular plant
xylem
vascular plant

Nutrients move from the roots to the leaves of a tree through ______________ tissue.

A ______________ has tissues to transport water, nutrients, and food.

______________ tissue carries sugar from a plant's leaves to its cells.

A ______________ lacks tissues to transport water, nutrients, and food.

3. Focus Skill **Reading Skill Practice–Main Idea and Details**

Read the selection. Underline the main idea. List at least three details about the main idea.

The haircap moss is a nonvascular plant. When it is dry, the fronds of the moss are compressed tightly against its stalks. When it rains, they spread out. This allows this moss to conserve moisture when it is dry and expose as much of the plant's surface as possible when it rains.

____

____

____

4. **Main Idea and Details**

Use this space to complete the graphic organizer.

- **Structures**
  - **Vascular Plants**
    - General Structures
      - Roots
      - Ⓐ ________
      - Ⓑ ________
    - Transport Structures
      - Ⓒ ________
      - Ⓓ ________
  - **Nonvascular Plants**
    - General Structures
      - Ⓔ ________
      - Ⓕ ________
    - Method of Transport
      - Ⓖ ________
      - ________

5. **Critical Thinking and Problem Solving**

Tom observed a water lily and drew a picture of it. He drew large, flat leaves that floated on top of the pond. Then he drew deep, strong roots anchored into the bottom of the pond. How does the water lily get the materials it needs from its environment?

____

____

____

____

____

Name ______________________

Date ______________________

Lesson Quick Study

Lesson 3 - What Are Some Types of Plants?

1. Inquiry Skill Practice–Compare

Pine trees are conifers. Conifers flourish in cold, dry climates. What can you infer about how conifers survive in this climate by comparing the pine needle with the broad leaf?

____

____

____

2. Use Vocabulary

Match the clue on the left to the term on the right.

____ Primitive vascular plant

____ Structures containing cells for asexual reproduction

____ A plant with bare seeds

____ A cone-producing plant

A. Spores

B. Conifer

C. Gymnosperm

D. Fern

3. Focus Skill — Reading Skill Practice–Compare and Contrast

Read the selection. Compare and contrast gymnosperms with angiosperms.

Gymnosperms and angiosperms are plants that make seeds. Gymnosperms do not produce flowers or fruits. Conifers, a type of gymnosperm, bear seeds in cones. Angiosperms flower and produce fruits. Seeds are contained within the fruit.

____

____

____

Name ______________________

4. Focus Skill **Compare and Contrast**

Use this space to complete the graphic organizer.

Patterns of Reproduction			
Mosses	**Ferns**	**Gymnosperms**	**Angiosperms**
Two generations; sexual and asexual	A ______ ______ ______	B ______ ______ ______	C ______ ______ ______

5. **Critical Thinking and Problem Solving**

Derek discovered a juniper tree growing far from other conifers. How might the juniper seed have traveled such a long distance?

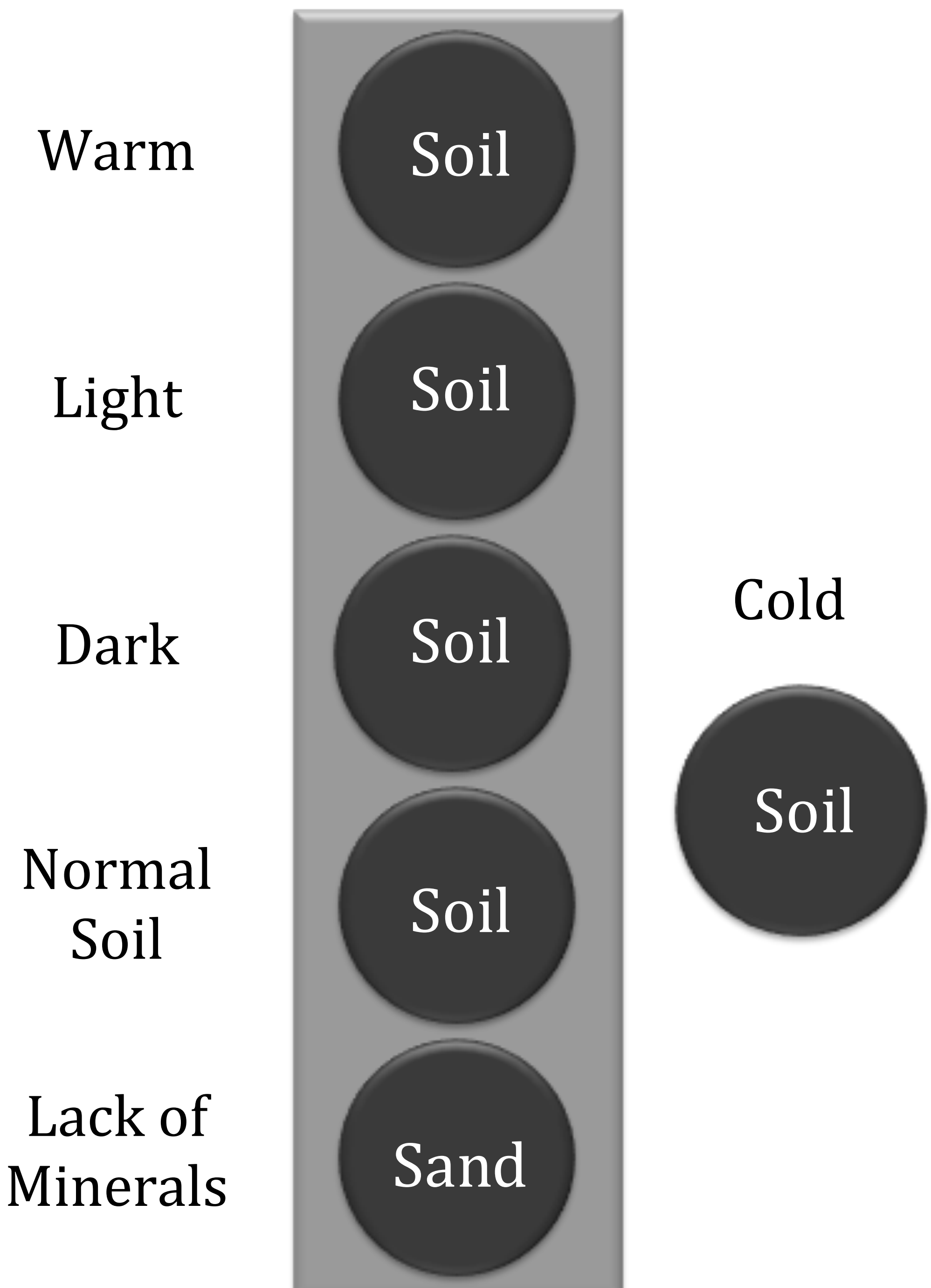
____

____

____

Group ____________ Team ____________

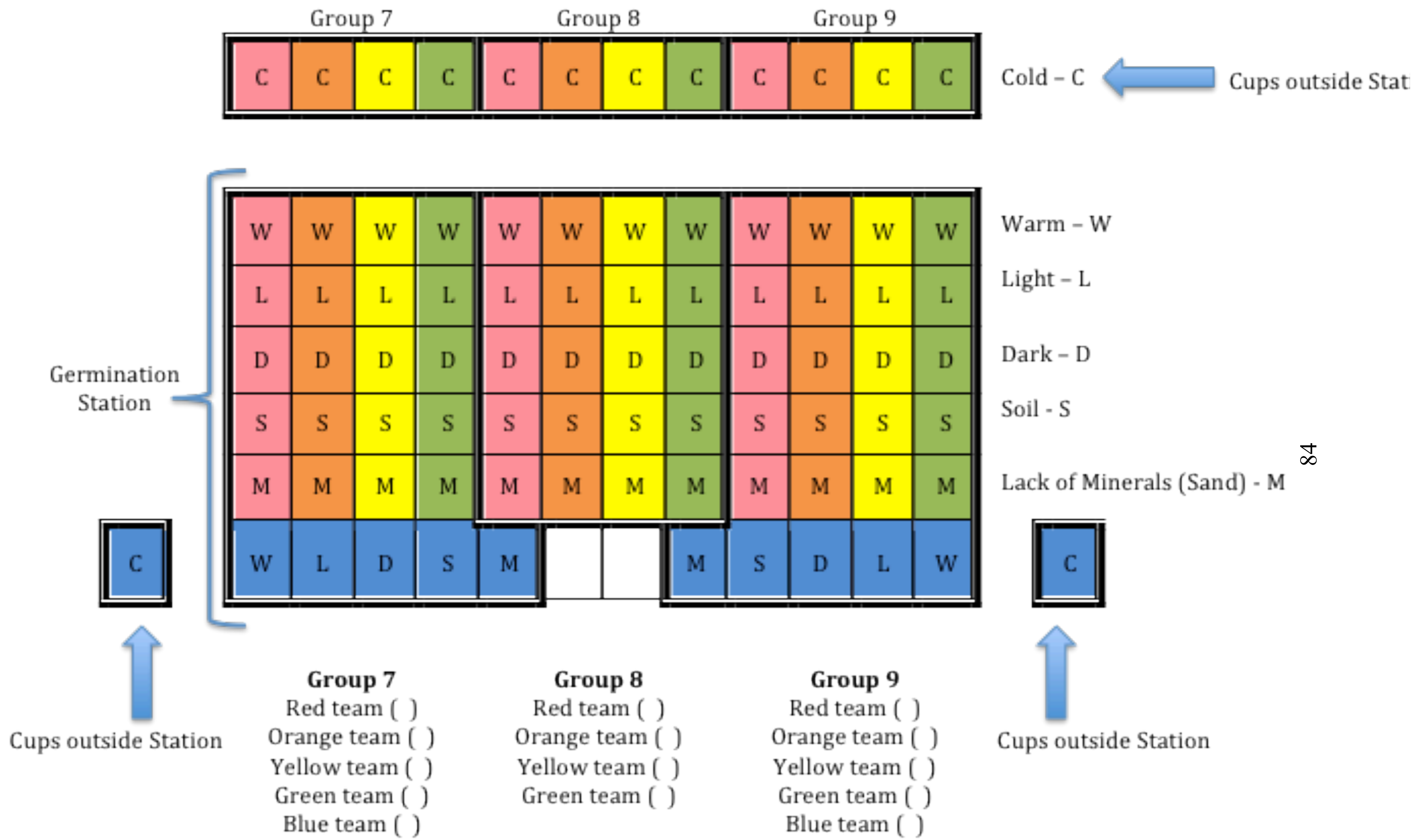
Each team will have a tray, like the one shown below. Each team will also have an individual cup that will go outside the germination station, as shown in the master diagram by the windowsill. **Follow this plan to fill your tray:**



Group 7					
	Red Team	Orange Team	Yellow Team	Green Team	Blue Team
1					
2					
3					
4					
5					
6					

Group 8				
	Red Team	Orange Team	Yellow Team	Green Team
1				
2				
3				
4				
5				
6				

Group 9					
	Red Team	Orange Team	Yellow Team	Green Team	Blue Team
1					
2					
3					
4					
5					
6					


Group 7
Group 8
Group 9
C C C C C C C C C C C C
Cold – C
Cups outside Stat
W W W W W W W W W W W W
L L L L L L L L L L L L
D D D D D D D D D D D D
S S S S S S S S S S S S
M M M M M M M M M M M M
W L D S M
M S D L W
Warm – W
Light – L
Dark – D
Soil - S
Lack of Minerals (Sand) - M
Germination Station
C
C
Cups outside Station
Group 7
Red team ( )
Orange team ( )
Yellow team ( )
Green team ( )
Blue team ( )
Group 8
Red team ( )
Orange team ( )
Yellow team ( )
Green team ( )
Group 9
Red team ( )
Orange team ( )
Yellow team ( )
Green team ( )
Blue team ( )
Cups outside Station

Name ______________________________

Date ______________________________

Lesson Quick Study

Lesson 2 - How Do Plants Respond to Their Environment?

1. **Inquiry Skills Practice–Observe**

Scientists germinated wheat seeds in an orbiting space shuttle. The roots and shoots grew in every direction. What kind of tropism did the scientists observe? What can you conclude about the effect of gravity in outer space?

____

____

2. **Use Vocabulary**

Write a complete sentence for each of the following terms:

tropism: ______________________________

____

gravitropism: ______________________________

____

phototropism: ______________________________

____

3. Focus Skill **Reading Skill Practice–Cause and Effect**

Read the selection. Describe the cause and effect of a tropism.

Twining vines respond to touch. This is called *thigmotropism.* Twining vines, such as wisteria, grow toward the side of the plant that is touched. They wind their stems around solid objects for support.

____

____

Name ______________________________

4. Focus Skill **Cause and Effect**

Use this space to complete the graphic organizer.

Cause	Effect
Light shines on a plant.	The plant grows **A** ______ the sunlight.
Gravity pulls on a seedling's root.	The seedling's root grows **B** ______.
A plant is touched.	The plant's tendrils **C** ______ ______ ______.
A plant needs a certain number of hours of daylight in order to flower.	It is either a **D** ______ -day or a ______ -day plant.

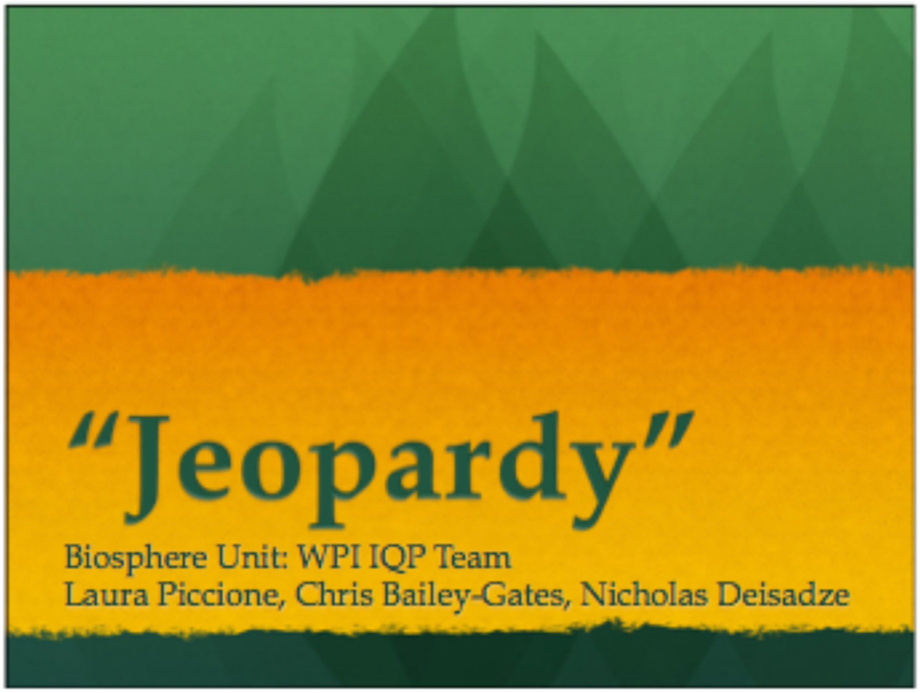
5. **Critical Thinking and Problem Solving**

Karly has a Christmas cactus in her house. The cactus blooms around the winter holidays. It is a short-day plant, needing long periods of darkness before it can bloom. How might Karly make her Christmas cactus flower earlier?

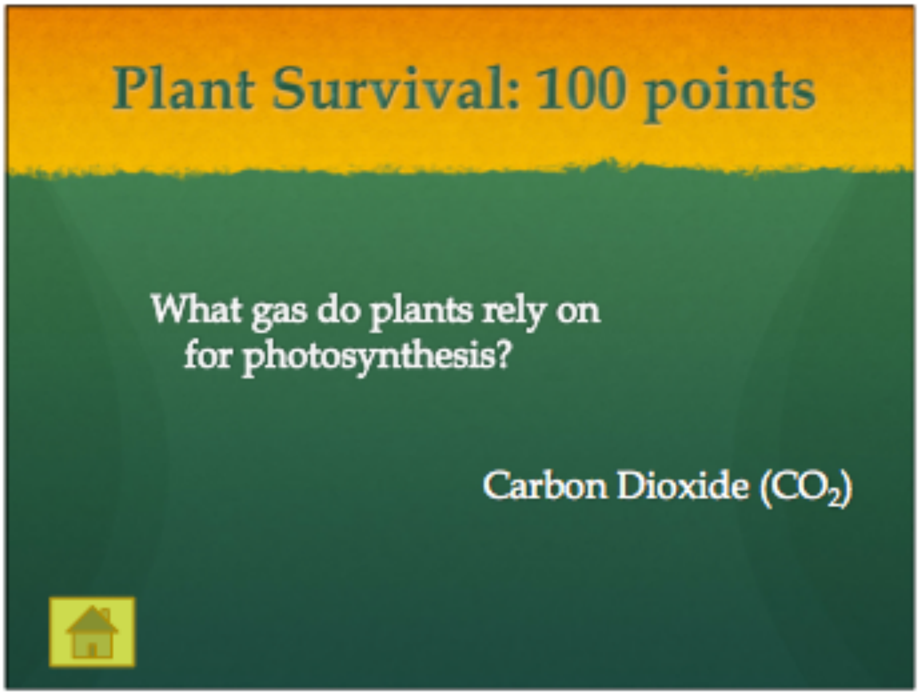
____

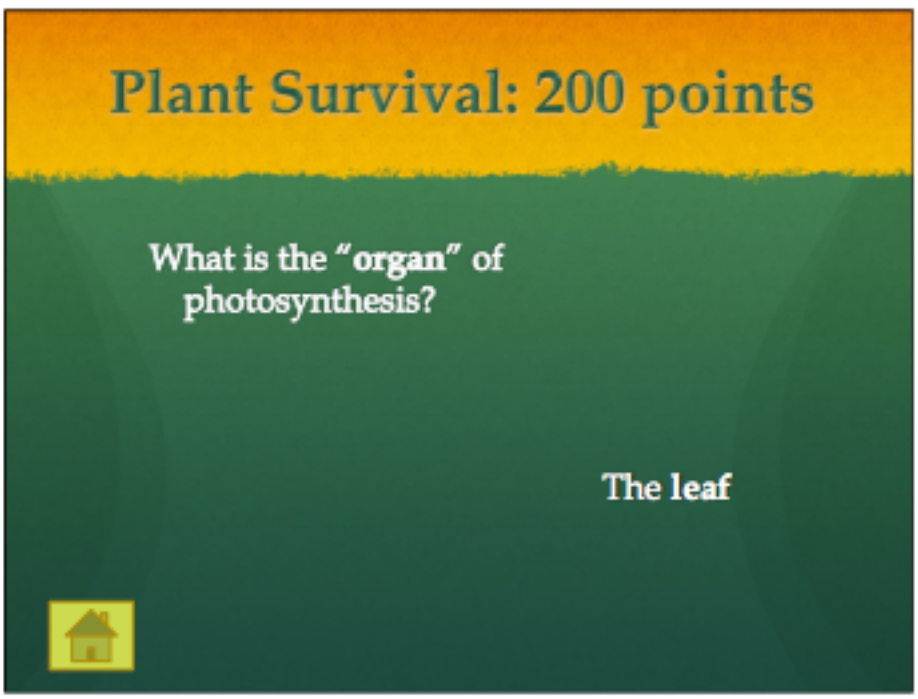
____

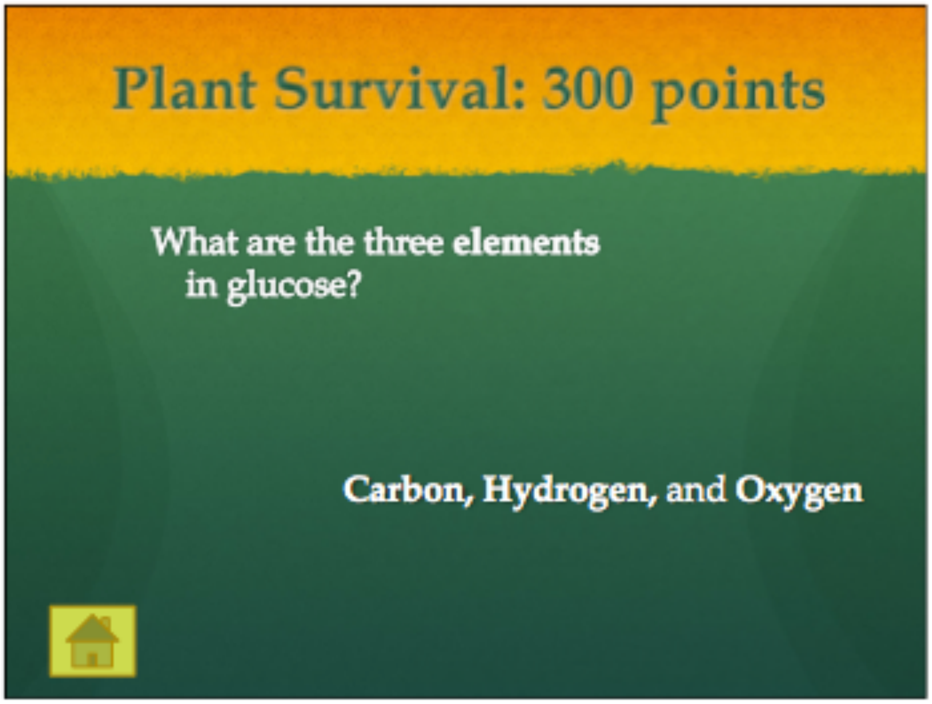
____

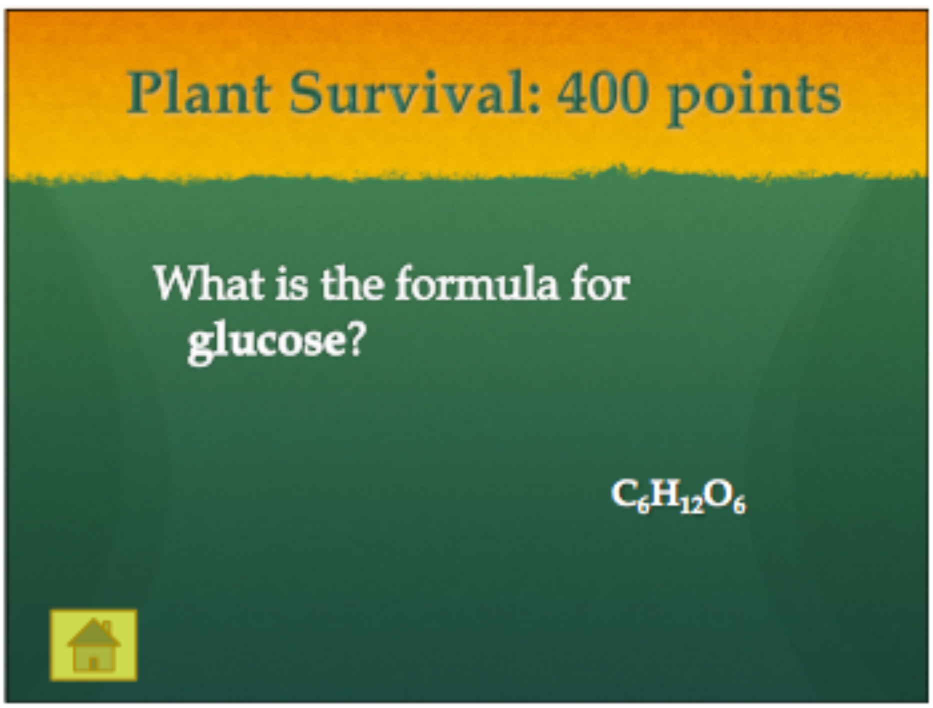

"Jeopardy"
Biosphere Unit: WPI IQP Team
Laura Piccione, Chris Bailey-Gates, Nicholas Deisadze

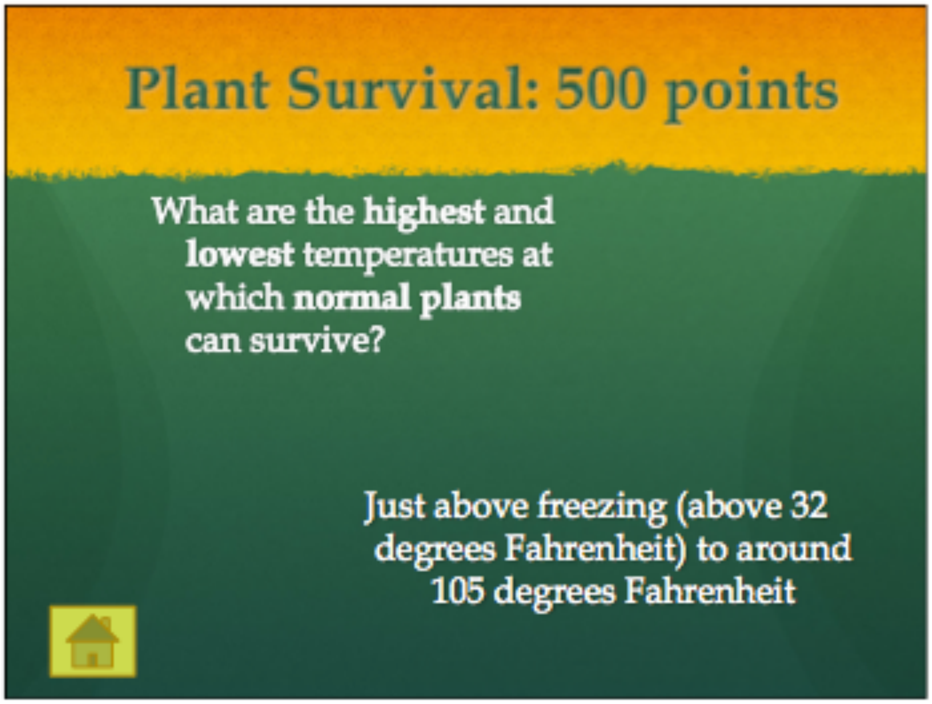

Plant Survival
Photo-synthesis
Plant Structures
The Moon
Tropisms
100 100 100 100 100
200 200 200 200 200
300 300 300 300 300
400 400 400 400 400
500 500 500 500 500

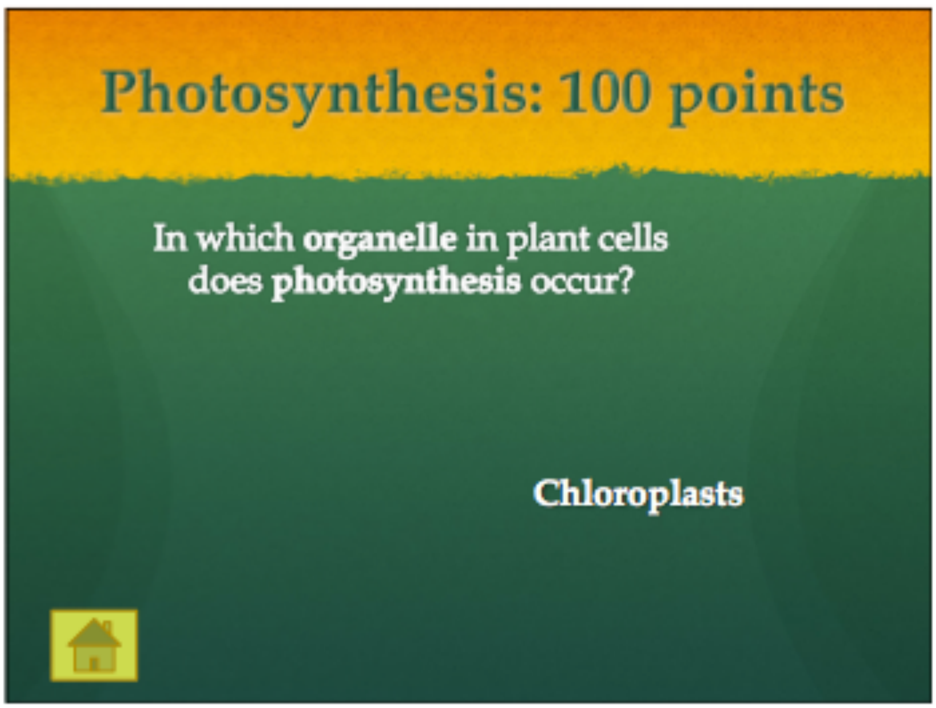

Plant Survival: 100 points
What gas do plants rely on for photosynthesis?
Carbon Dioxide (CO_2)

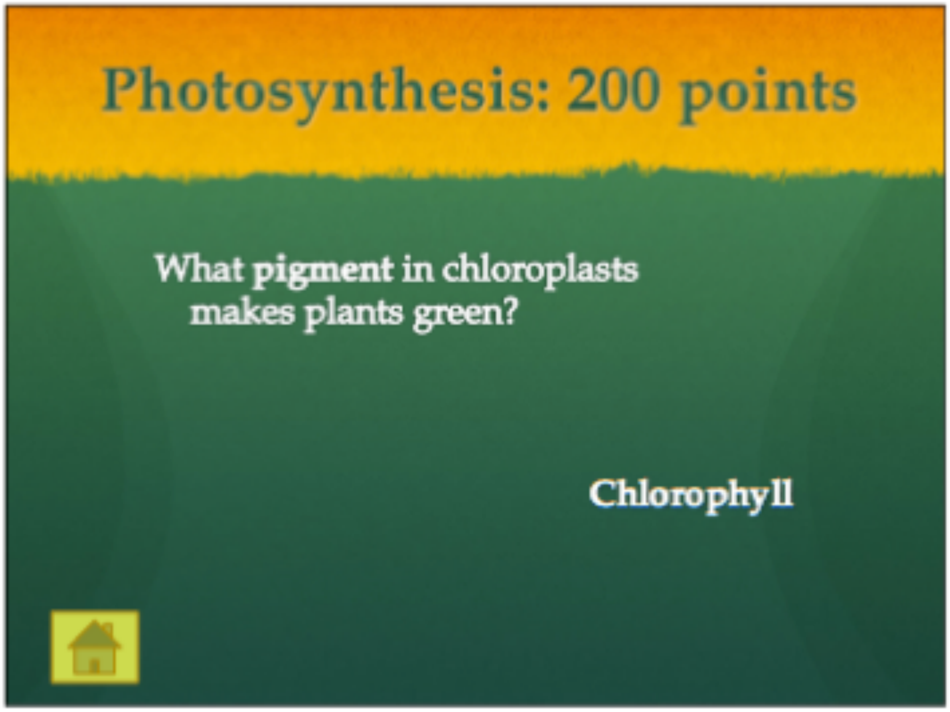

Plant Survival: 200 points
What is the "**organ**" of photosynthesis?
The **leaf**

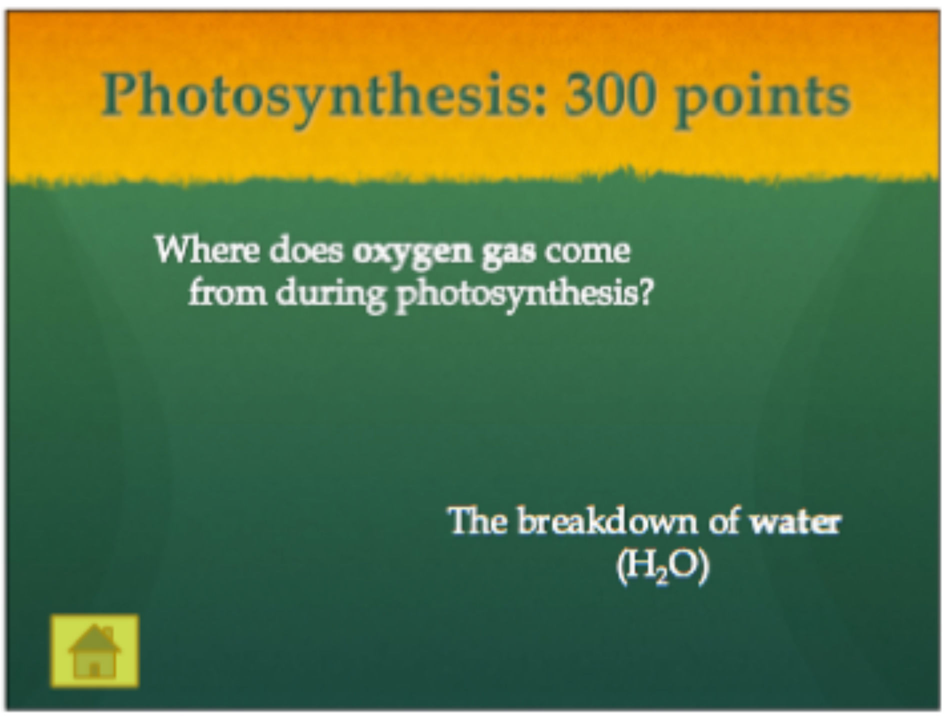

Plant Survival: 300 points
What are the three elements in glucose?
Carbon, Hydrogen, and Oxygen

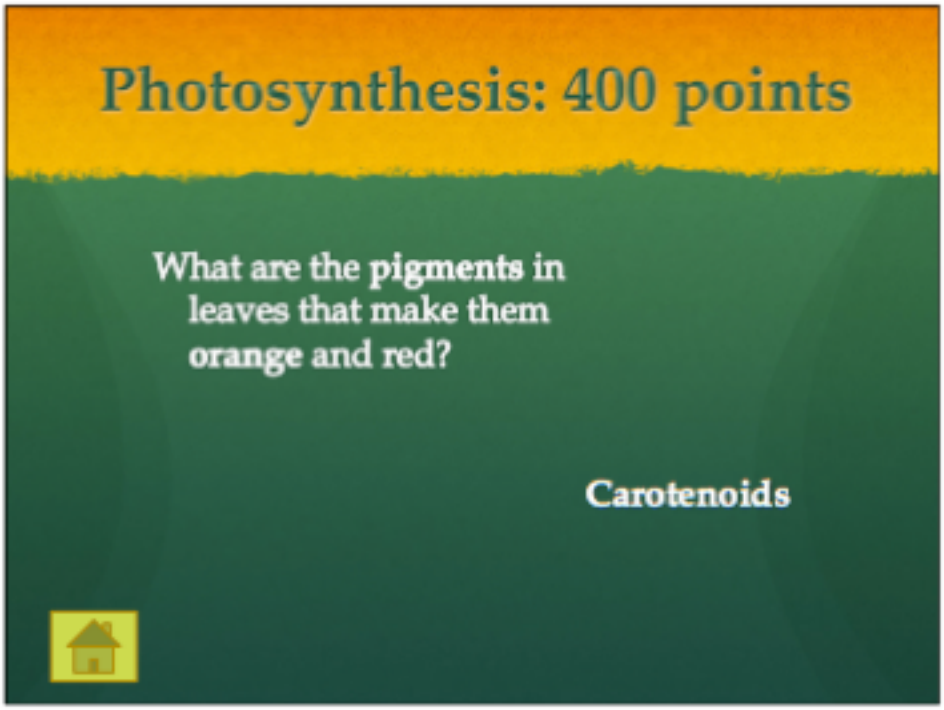

Plant Survival: 400 points
What is the formula for glucose?
$C_6H_{12}O_6$

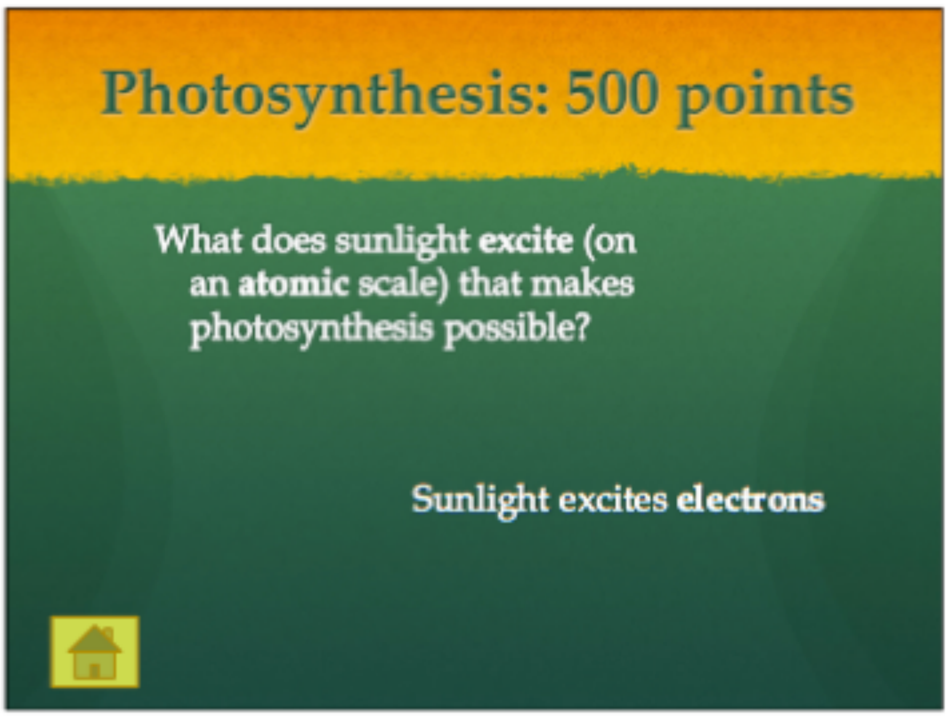

Plant Survival: 500 points
What are the highest and lowest temperatures at which normal plants can survive?
Just above freezing (above 32 degrees Fahrenheit) to around 105 degrees Fahrenheit

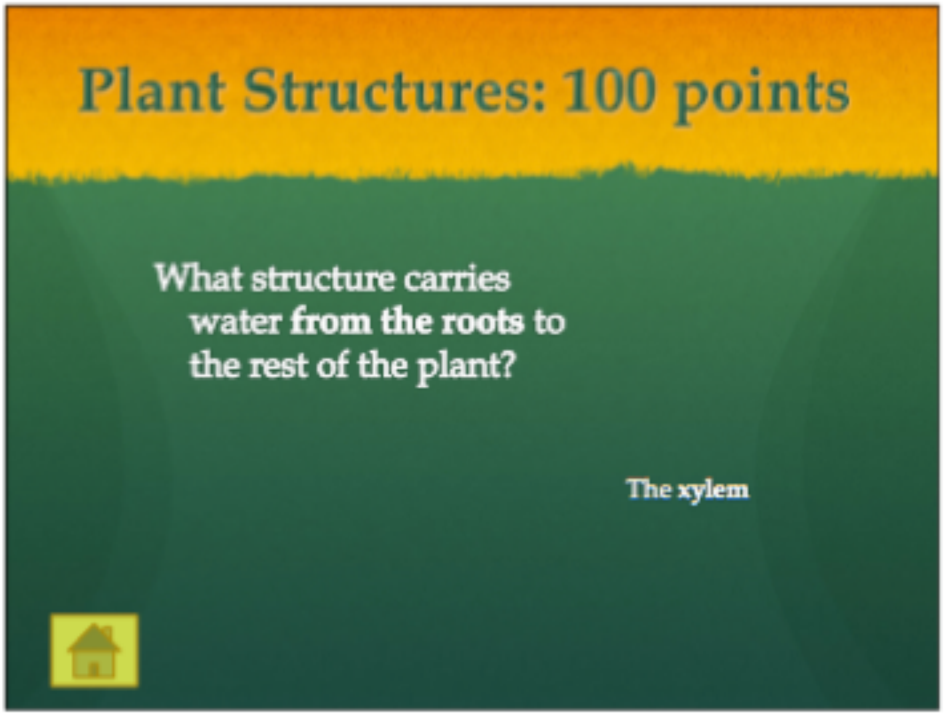

Photosynthesis: 100 points
In which organelle in plant cells does photosynthesis occur?
Chloroplasts

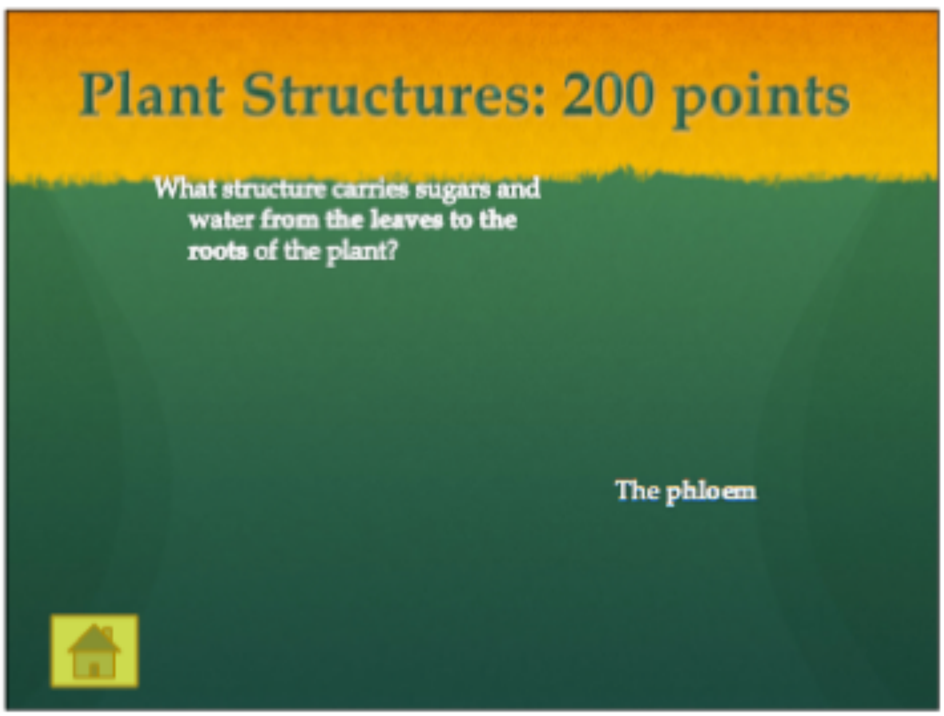

Photosynthesis: 200 points
What **pigment** in chloroplasts makes plants green?
Chlorophyll

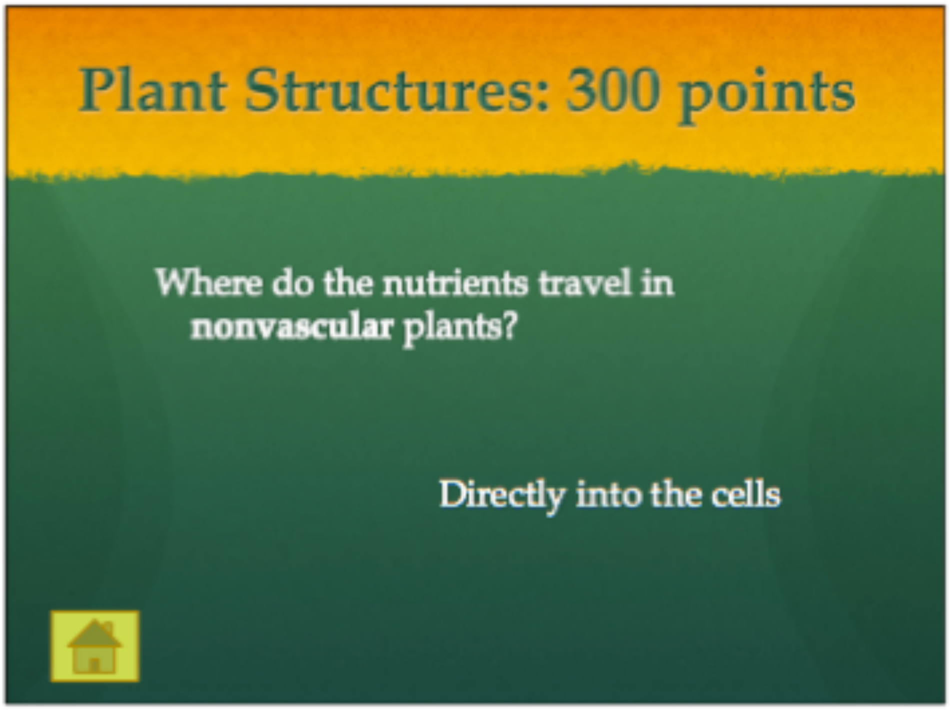

Photosynthesis: 300 points
Where does **oxygen gas** come from during photosynthesis?
The breakdown of **water** (H_2O)

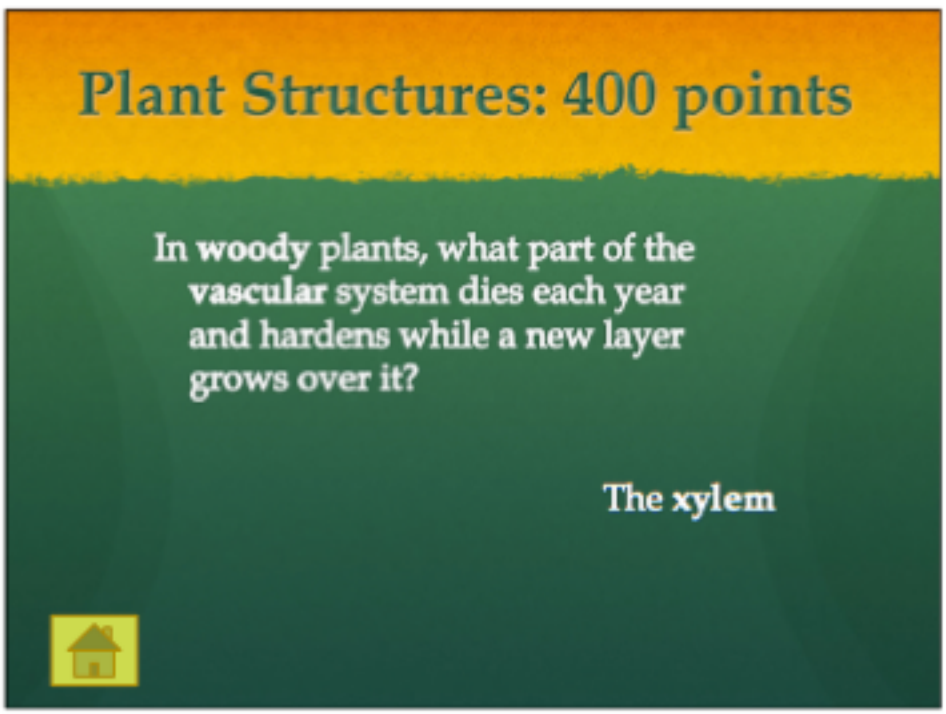

Photosynthesis: 400 points
What are the **pigments** in leaves that make them **orange** and red?
Carotenoids

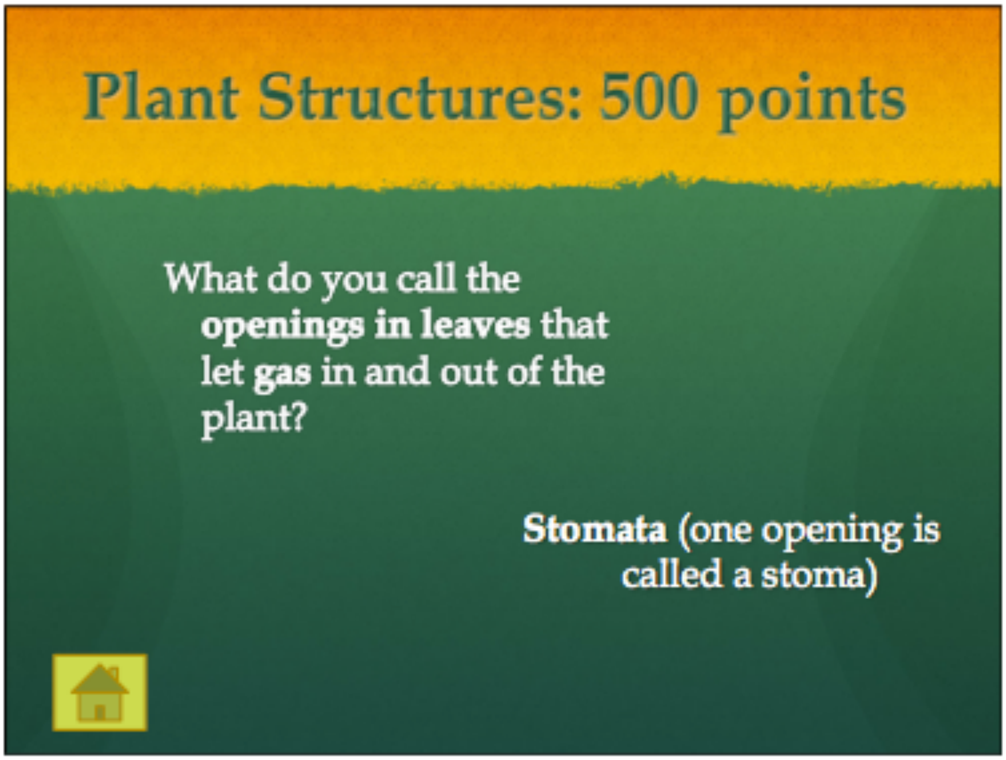

Photosynthesis: 500 points
What does sunlight **excite** (on an **atomic** scale) that makes photosynthesis possible?
Sunlight excites **electrons**

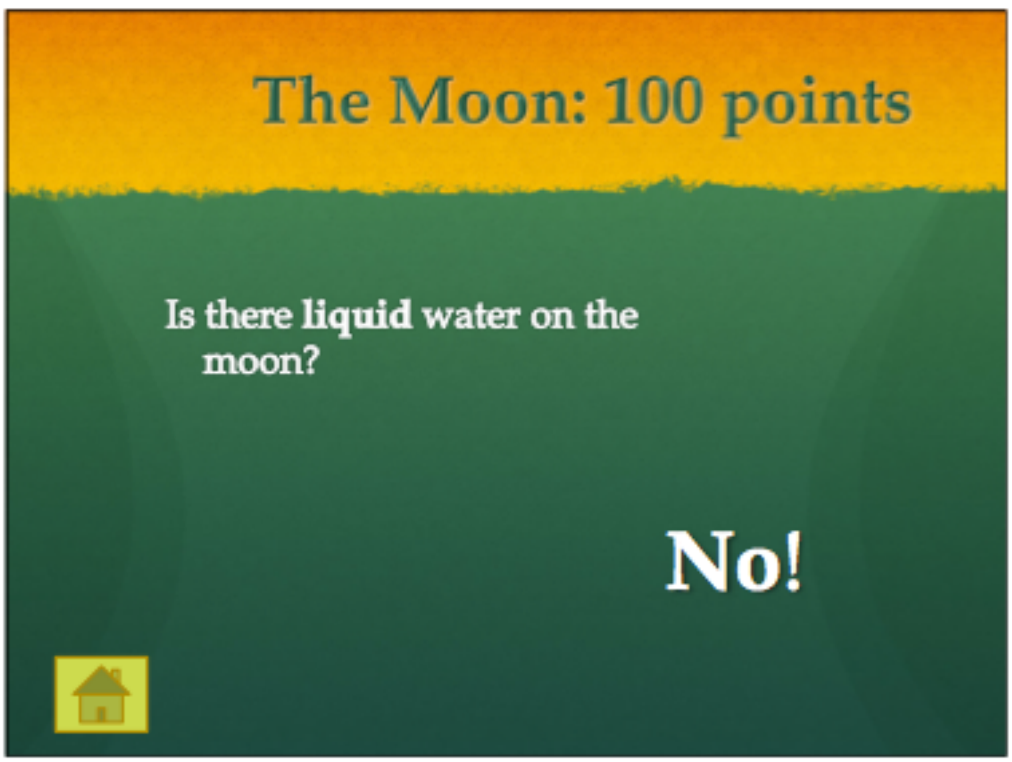

Plant Structures: 100 points
What structure carries water from the roots to the rest of the plant?
The xylem

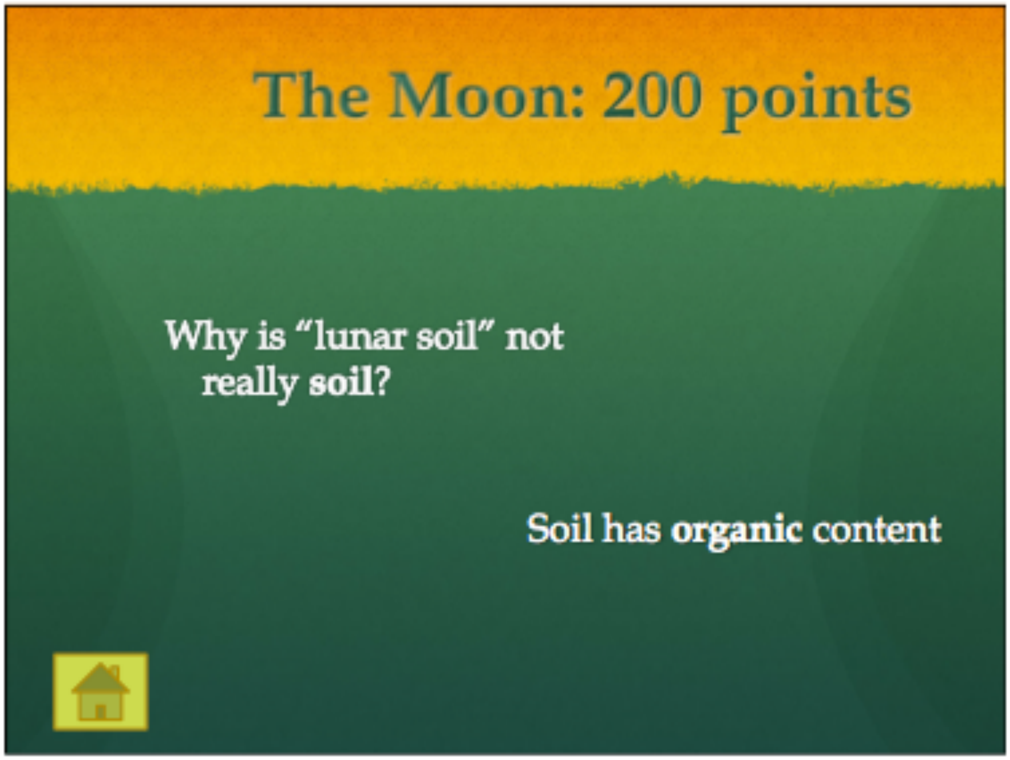

Plant Structures: 200 points
What structure carries sugars and water from the leaves to the roots of the plant?
The phloem

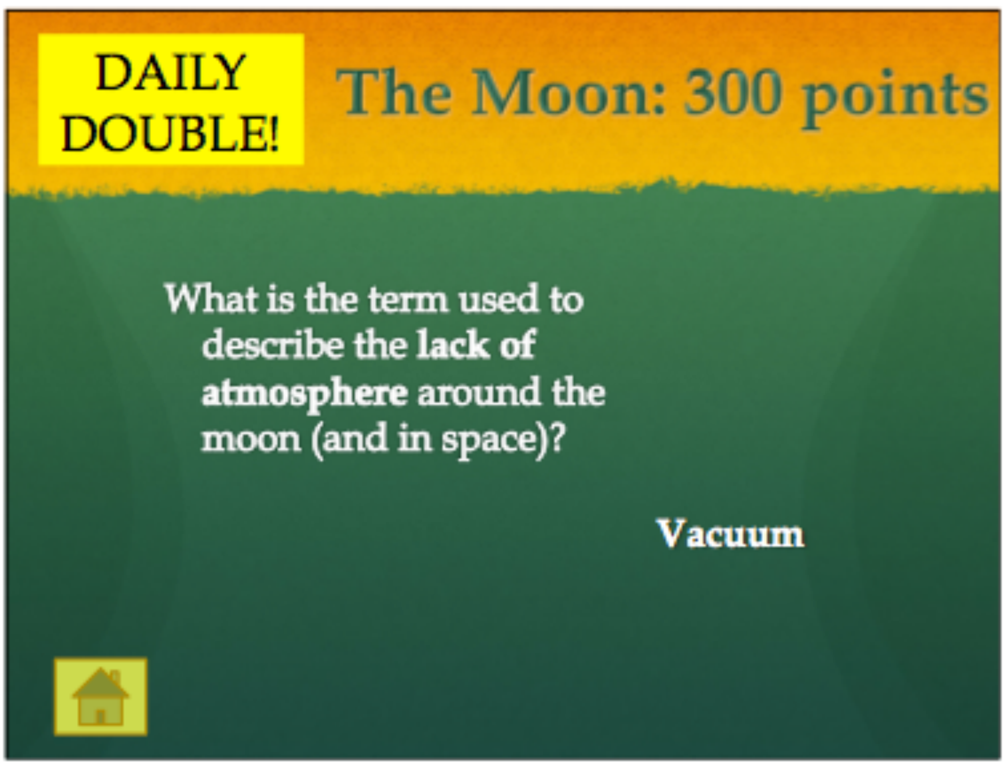

Plant Structures: 300 points
Where do the nutrients travel in nonvascular plants?
Directly into the cells

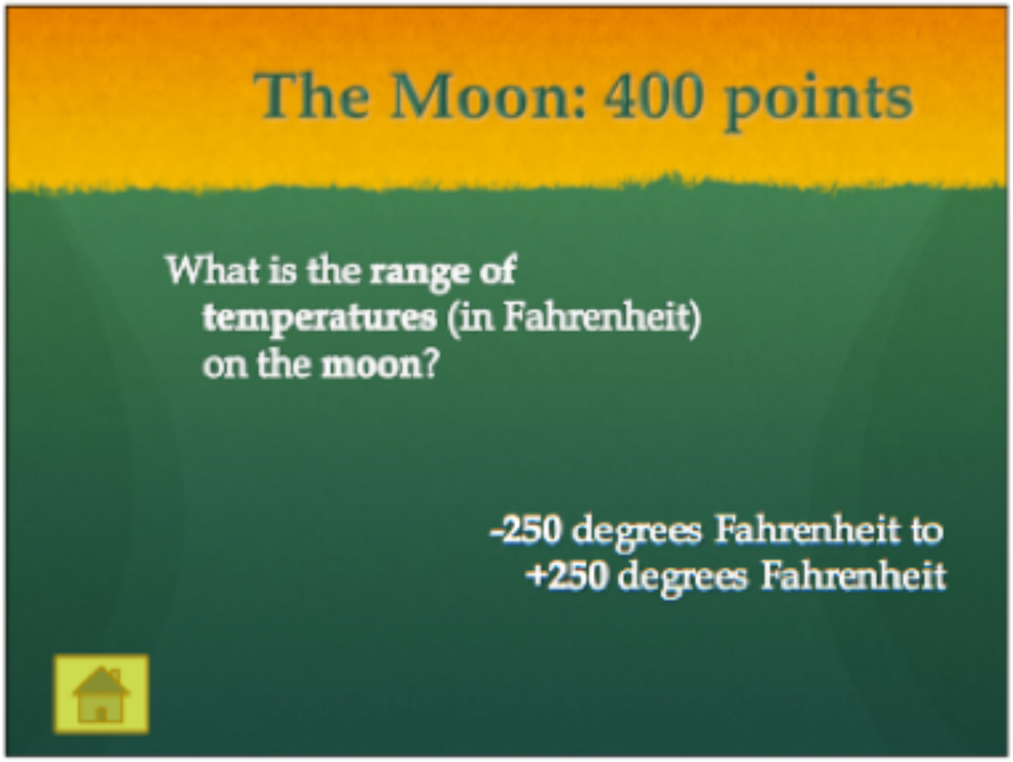

Plant Structures: 400 points
In woody plants, what part of the vascular system dies each year and hardens while a new layer grows over it?
The xylem

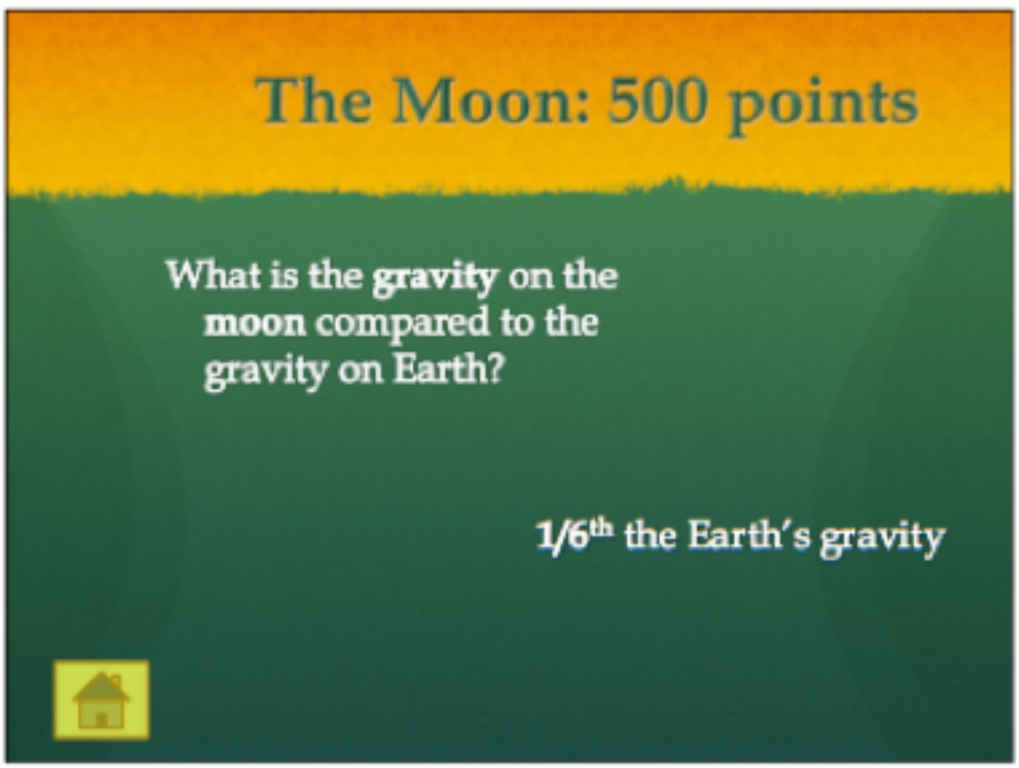

Plant Structures: 500 points
What do you call the openings in leaves that let gas in and out of the plant?
Stomata (one opening is called a stoma)

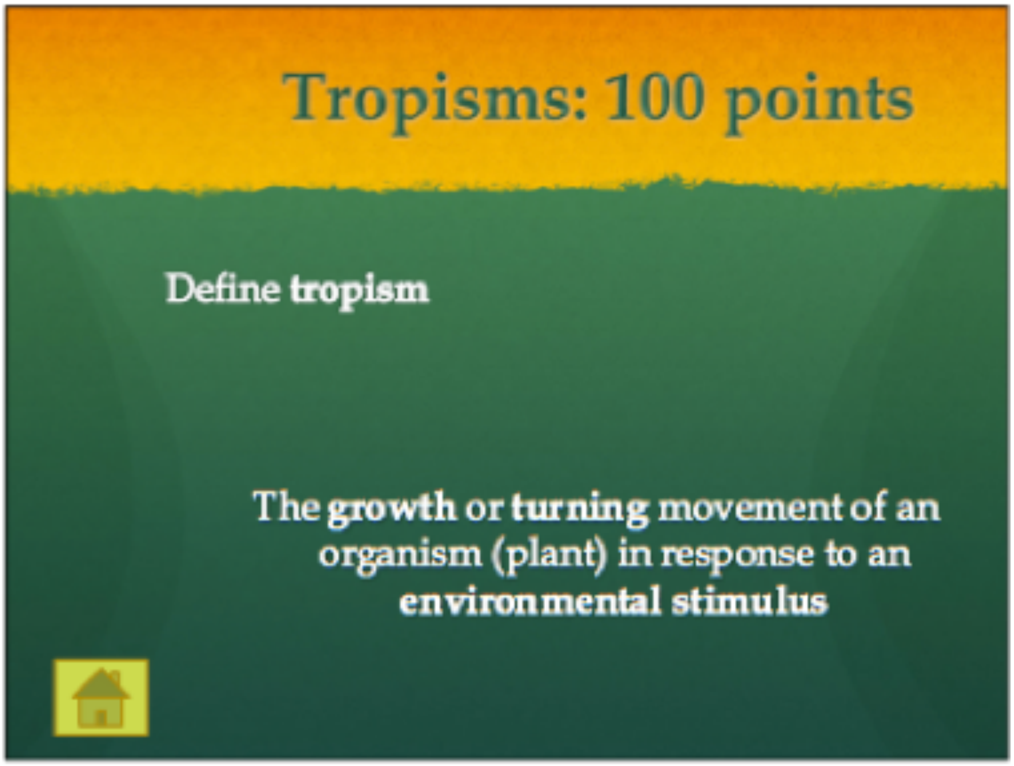

The Moon: 100 points
Is there liquid water on the moon?
No!

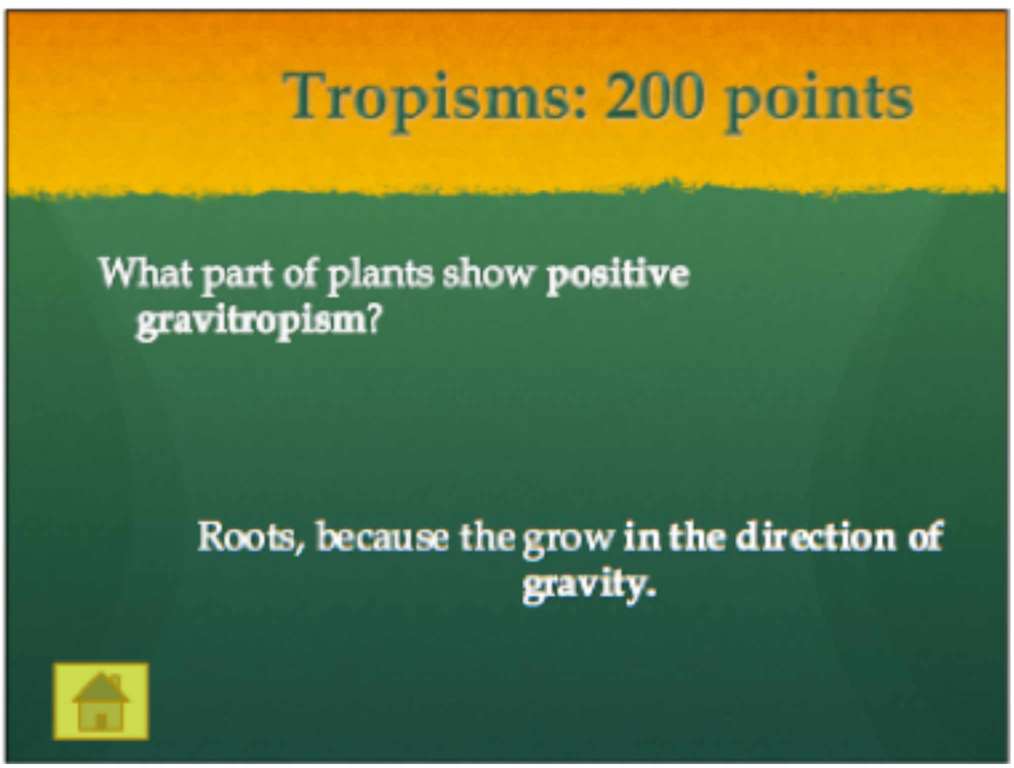

The Moon: 200 points
Why is "lunar soil" not really soil?
Soil has organic content

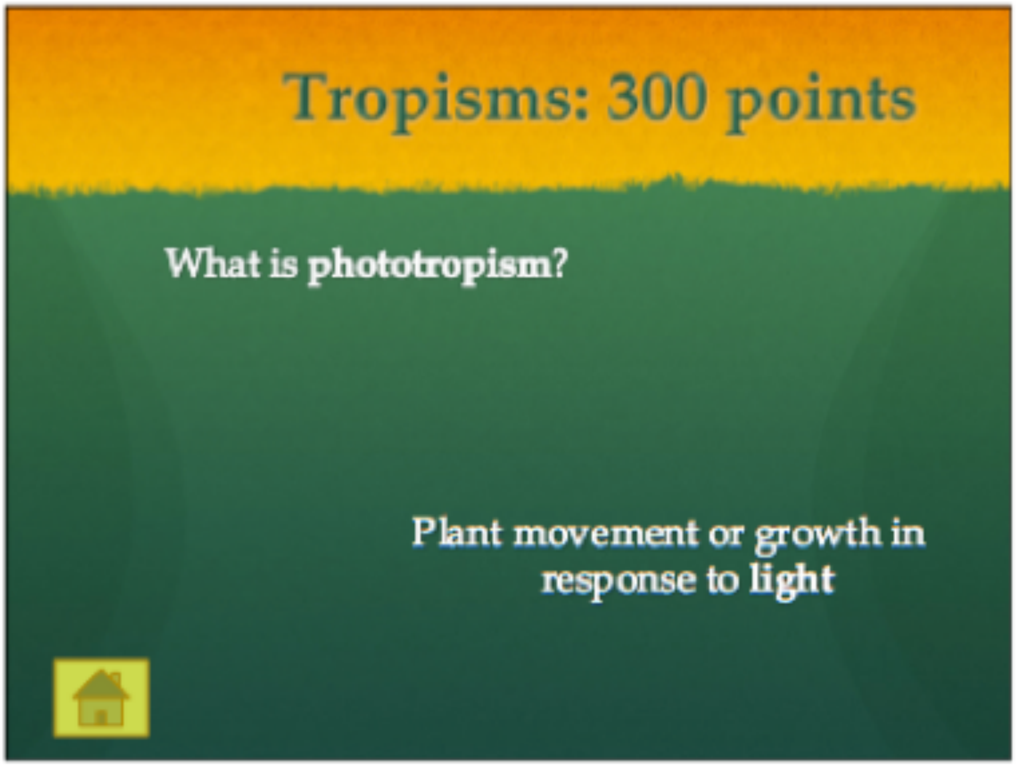

DAILY DOUBLE!
The Moon: 300 points
What is the term used to describe the lack of atmosphere around the moon (and in space)?
Vacuum

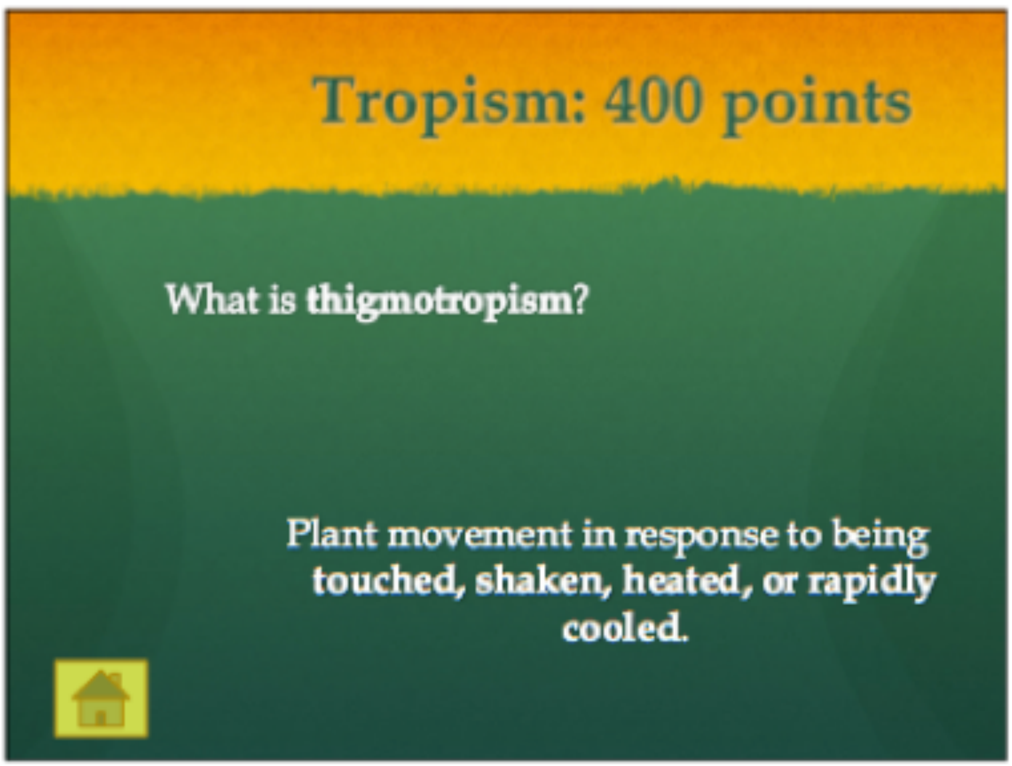

The Moon: 400 points
What is the range of temperatures (in Fahrenheit) on the moon?
-250 degrees Fahrenheit to +250 degrees Fahrenheit


The Moon: 500 points
What is the gravity on the moon compared to the gravity on Earth?
1/6th the Earth's gravity


Tropisms: 100 points
Define **tropism**
The **growth** or **turning** movement of an organism (plant) in response to an **environmental stimulus**


Tropisms: 200 points
What part of plants show **positive gravitropism**?
Roots, because the grow **in the direction of gravity.**

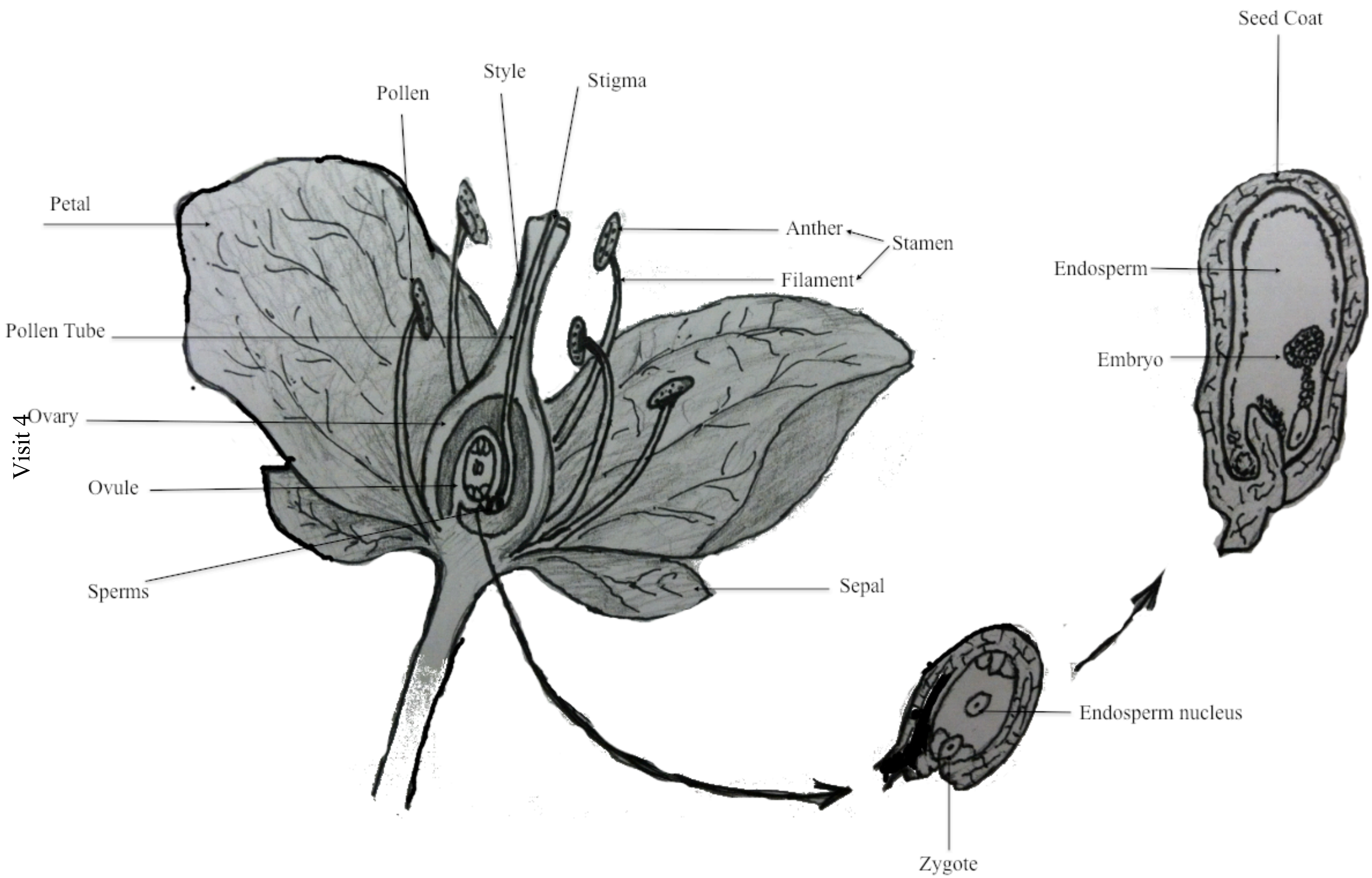

Tropisms: 300 points
What is **phototropism**?
Plant movement or growth in response to **light**


Tropism: 400 points
What is **thigmotropism**?
Plant movement in response to being **touched, shaken, heated, or rapidly cooled.**


DAILY DOUBLE!
Tropism: 500 points
What color light do phototropic plants respond to?
Red and blue


Daily Double!
As a team, decide how many of the points you already have you wish to wager.
If you get the question correct, you will earn double the points you wagered.
If you get the question incorrect, you will lose the points you wagered. Good luck

Visit 4



Petal
Pollen
Style
Stigma
Anther
Stamen
Filament
Pollen Tube
Ovary
Ovule
Sperms
Sepal
Seed Coat
Endosperm
Embryo
Endosperm nucleus
Zygote

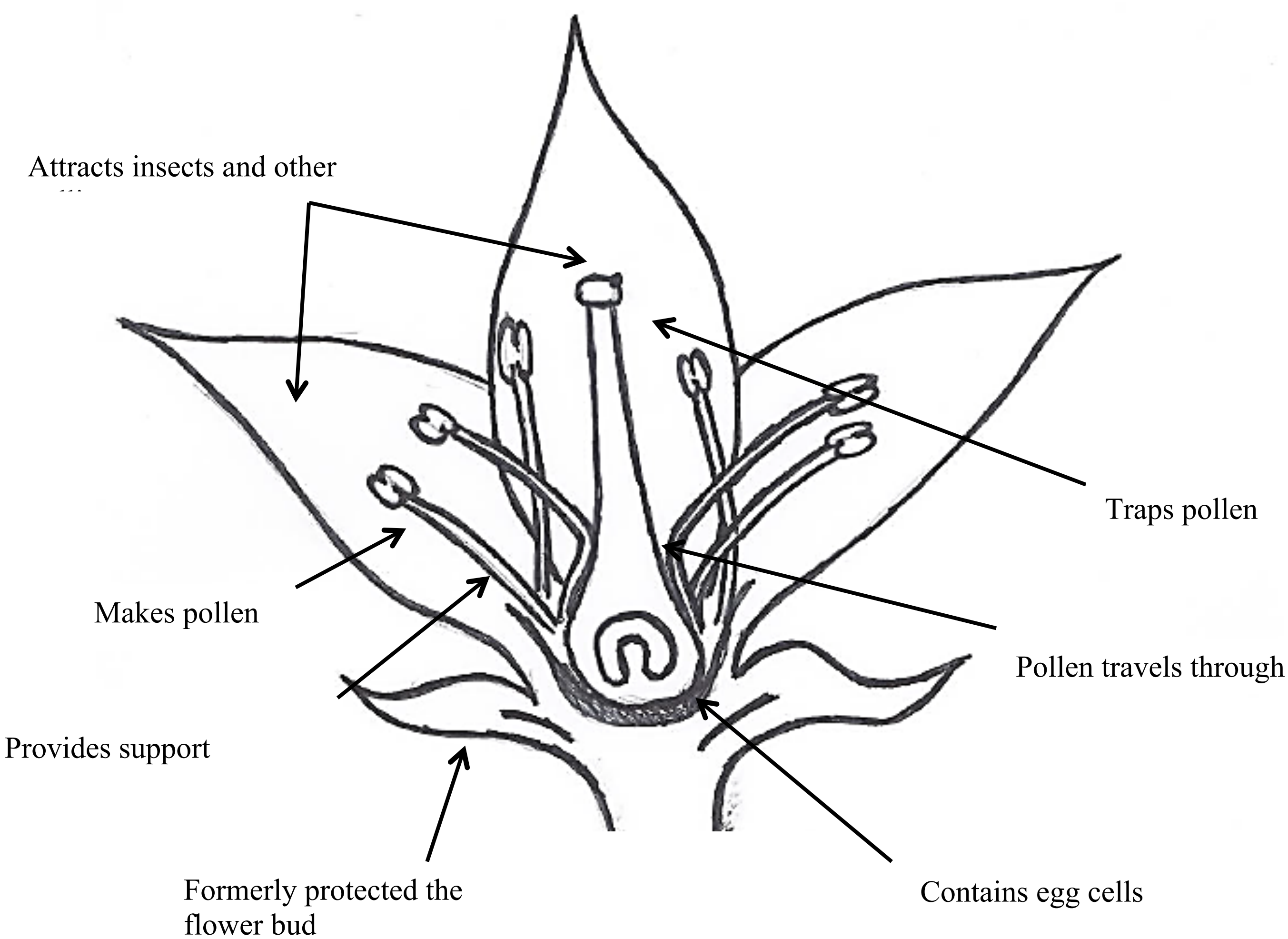
Name: ______________________________

Group: _________________________________

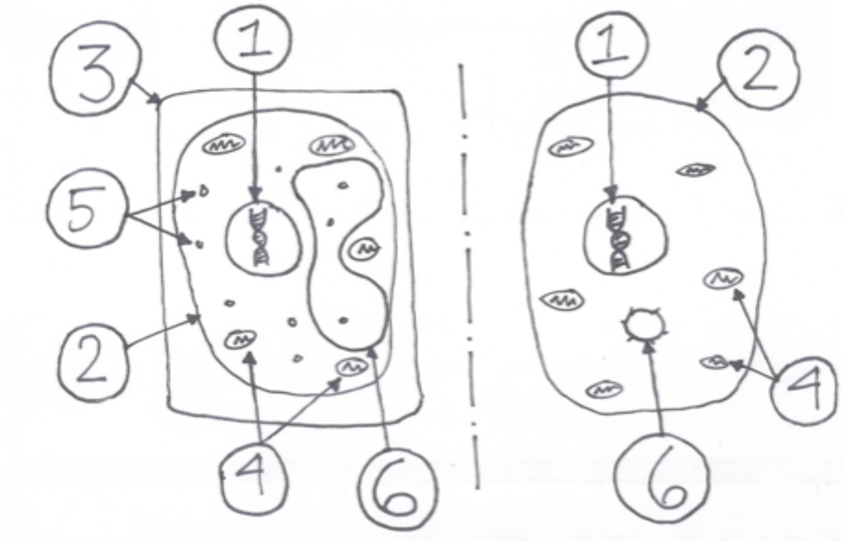
Plant Science Unit: Plant Anatomy

Using the definitions given and the notes from class, fill in the blanks to label the different parts of the flower.

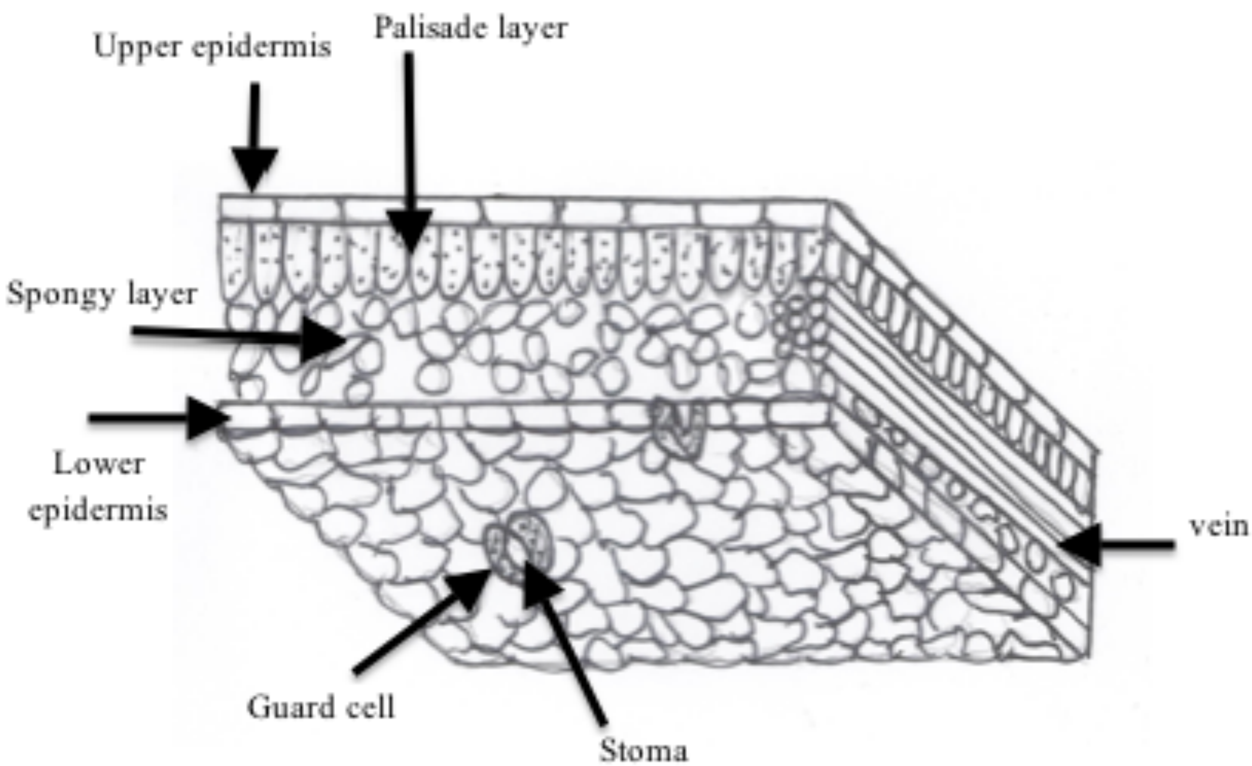
Parts of a Flower

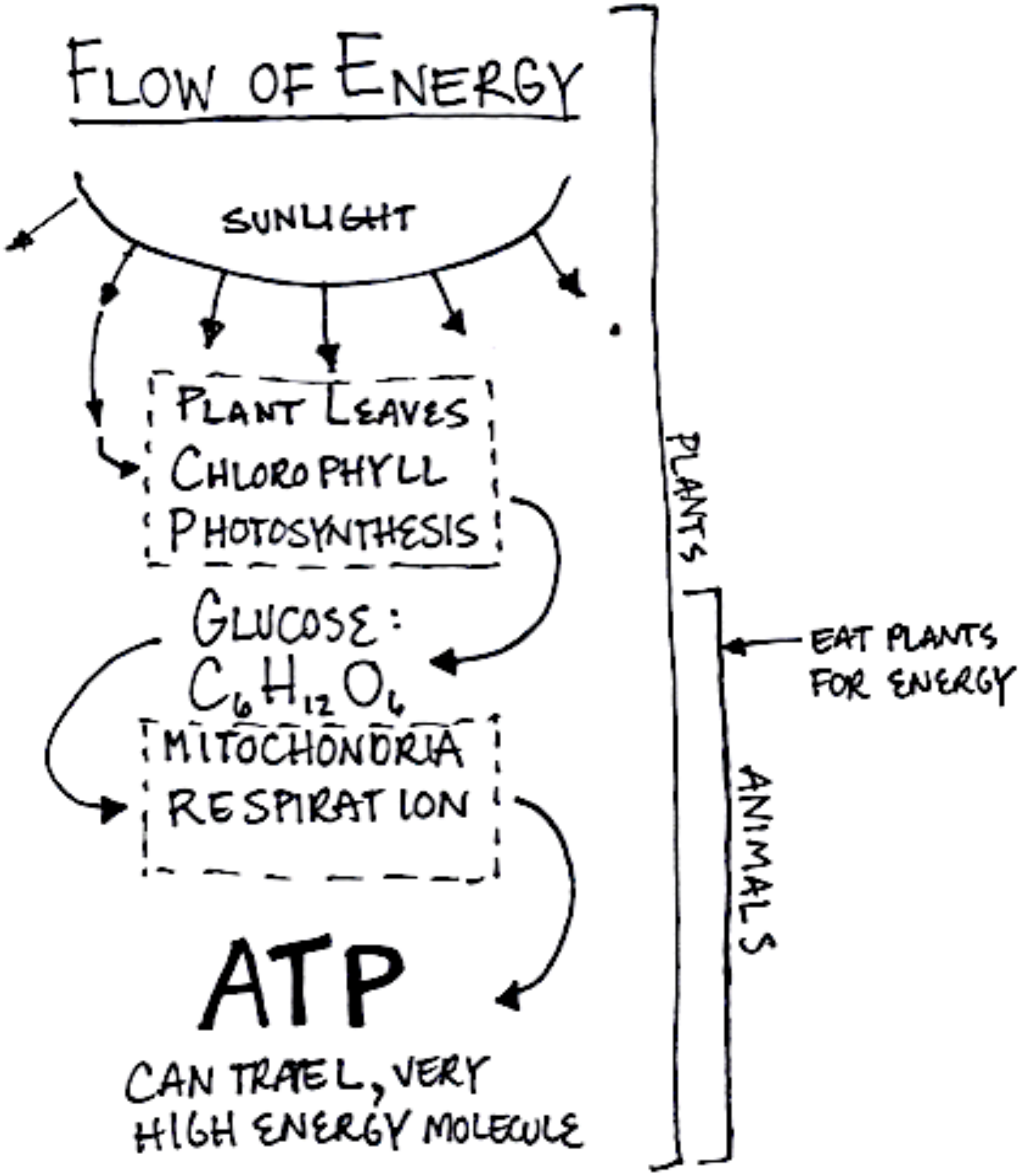


Visit 5



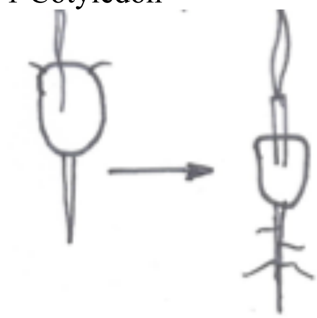
1. Nucleus
2. Selectively permeable cell membrane
3. Cell wall
4. Mitochondria
5. Chloroplasts
6. Vacuole



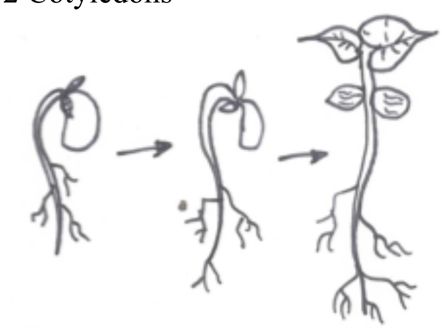

FLOW OF ENERGY
SUNLIGHT
PLANT LEAVES
CHLOROPHYLL
PHOTOSYNTHESIS
GLUCOSE:
$C_6H_{12}O_6$
MITOCHONDRIA
RESPIRATION
ATP
CAN TRAVEL, VERY
HIGH ENERGY MOLECULE
PLANTS
ANIMALS
EAT PLANTS
FOR ENERGY

Monocots	Dicots
"mono" – 1	"di" – 2

1 Cotyledon



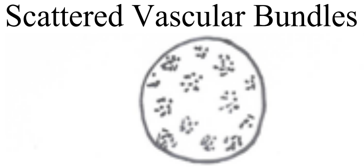
2 Cotyledons



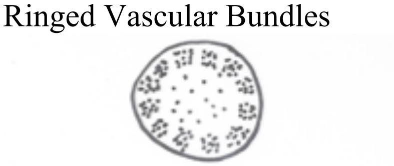
Parallel Veined Leaves

Net-Veined Leaves

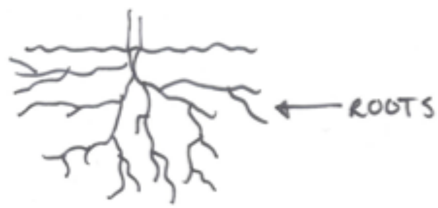
Scattered Vascular Bundles



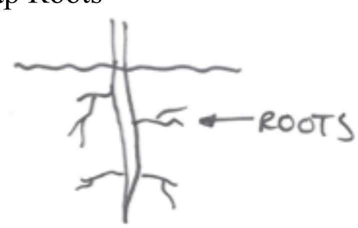
Ringed Vascular Bundles



Fibrous Roots



Tap Roots



Visit 6

Jeopardy: Game 2

Biosphere Unit: WPI IQP Team

Laura Piccione, Chris Bailey-Gates, Nicholas Deisadze

Plant Classifications	Flower Structure	Plant Functionality	Cells	Review
100	100	100	100	100
200	200	200	200	200
300	300	300	300	300
400	400	400	400	400
500	500	500	500	500

Plant Classifications: 100 points

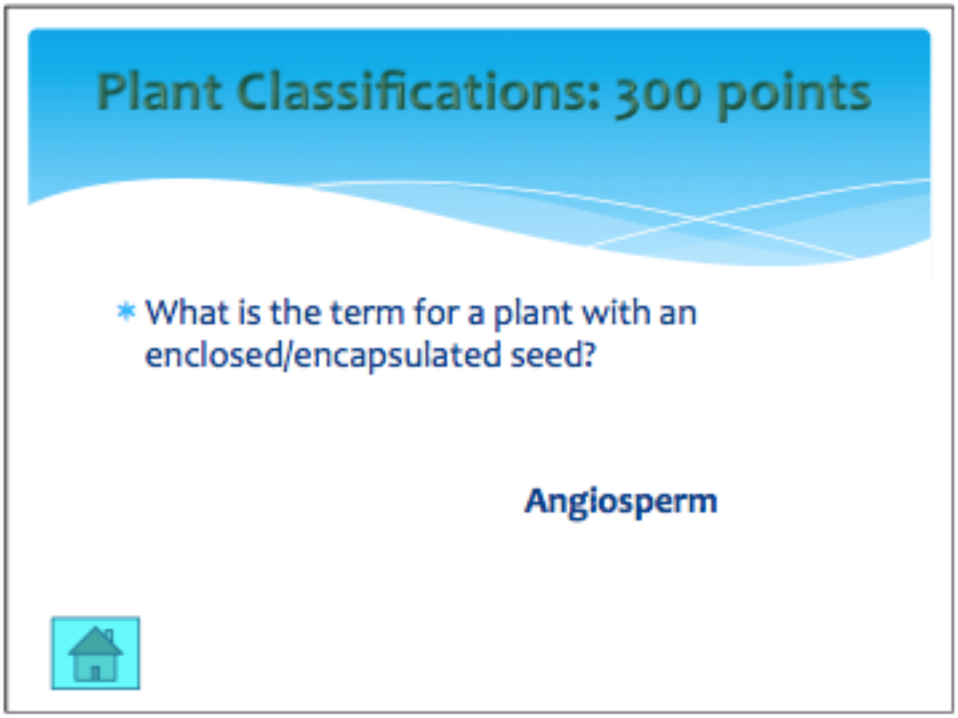
* A plant has 5 petals – is it a monocot or a dicot?

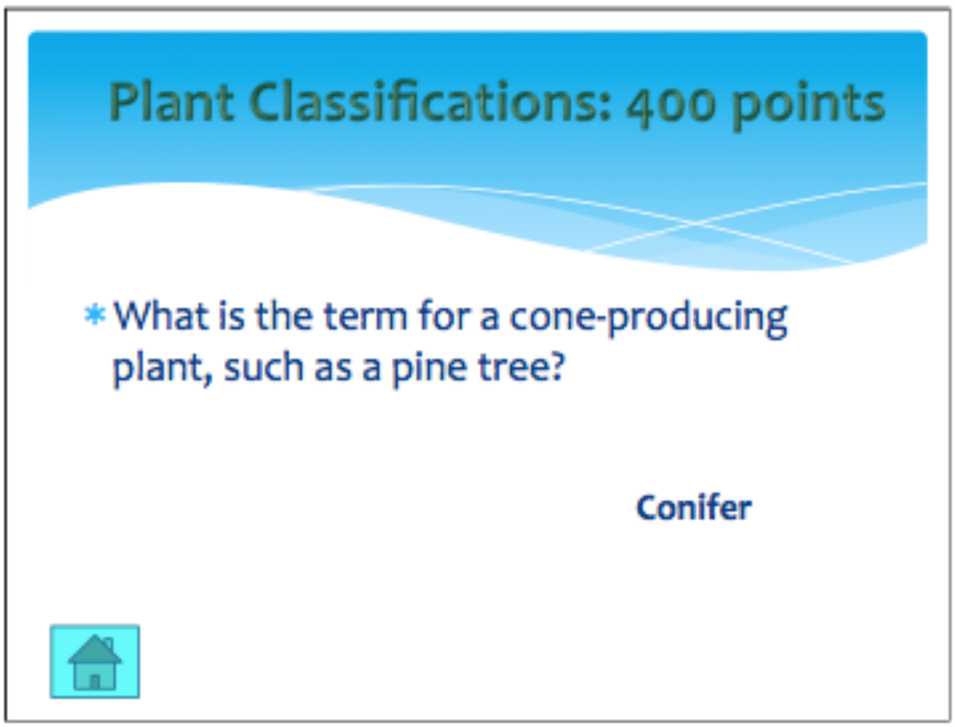
Dicot

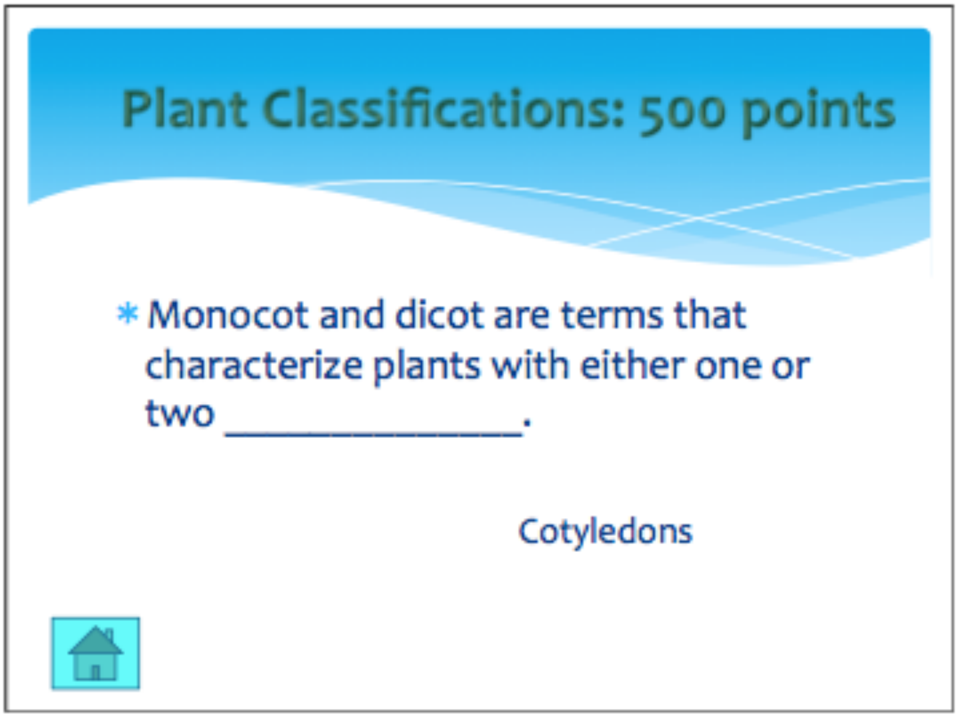
Plant Classifications: 200 points

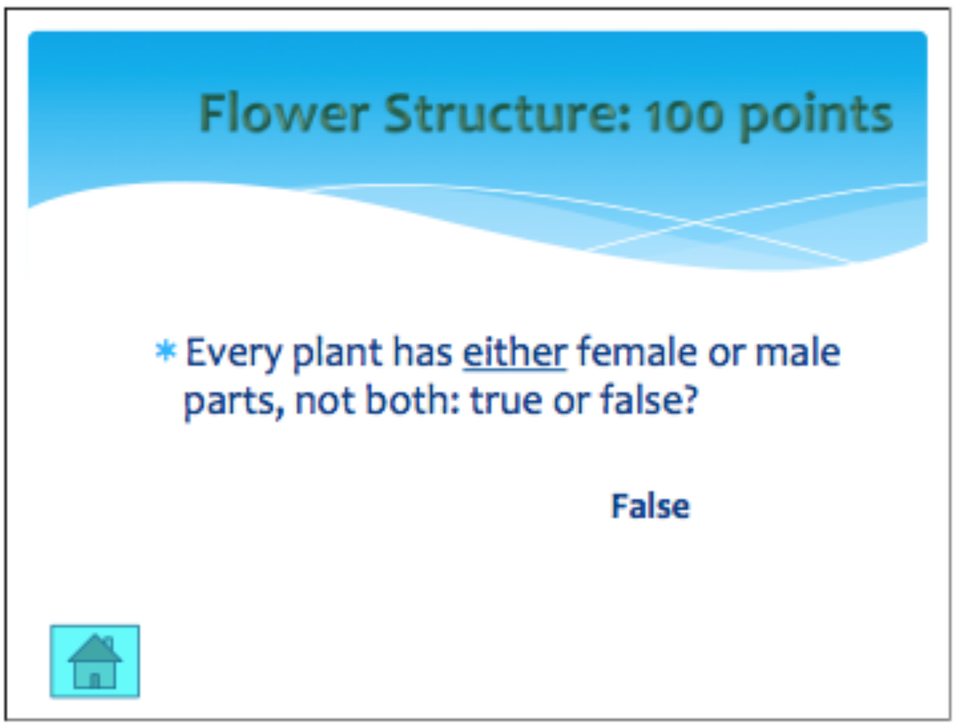
* The leaf of a plant has veins that run parallel along its length – is this a monocot or a dicot?

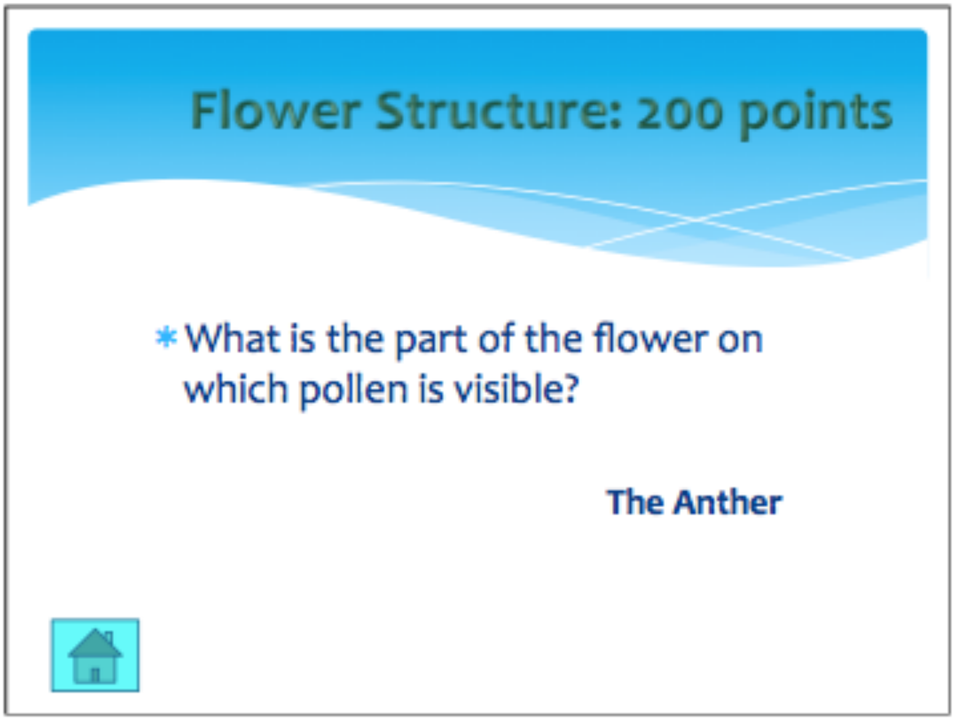
Monocot

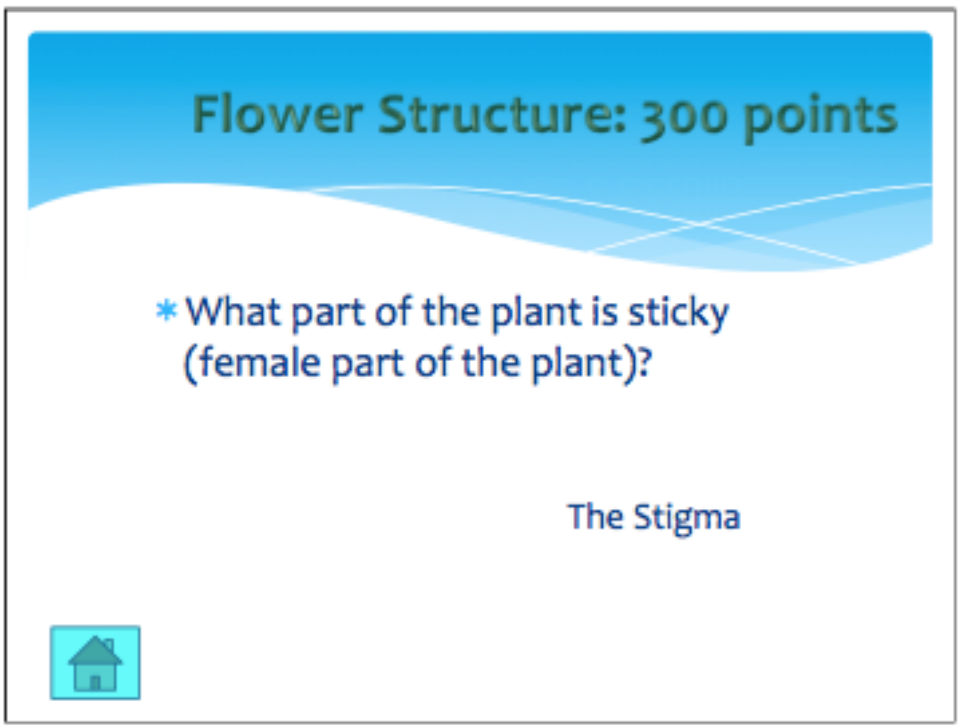

Plant Classifications: 300 points
What is the term for a plant with an enclosed/encapsulated seed?
Angiosperm

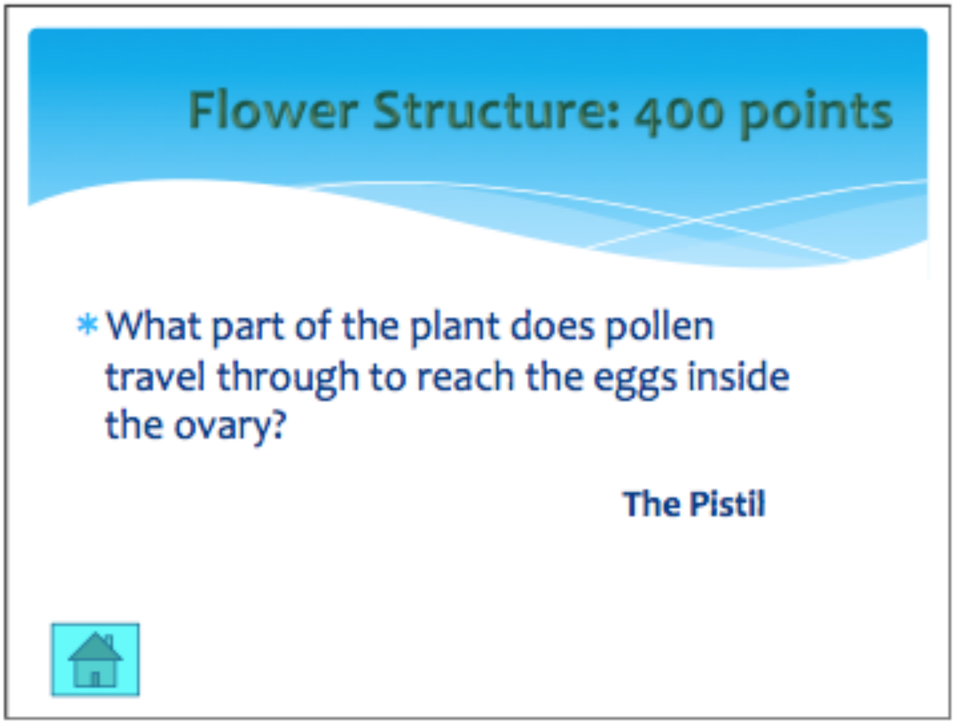

Plant Classifications: 400 points
What is the term for a cone-producing plant, such as a pine tree?
Conifer

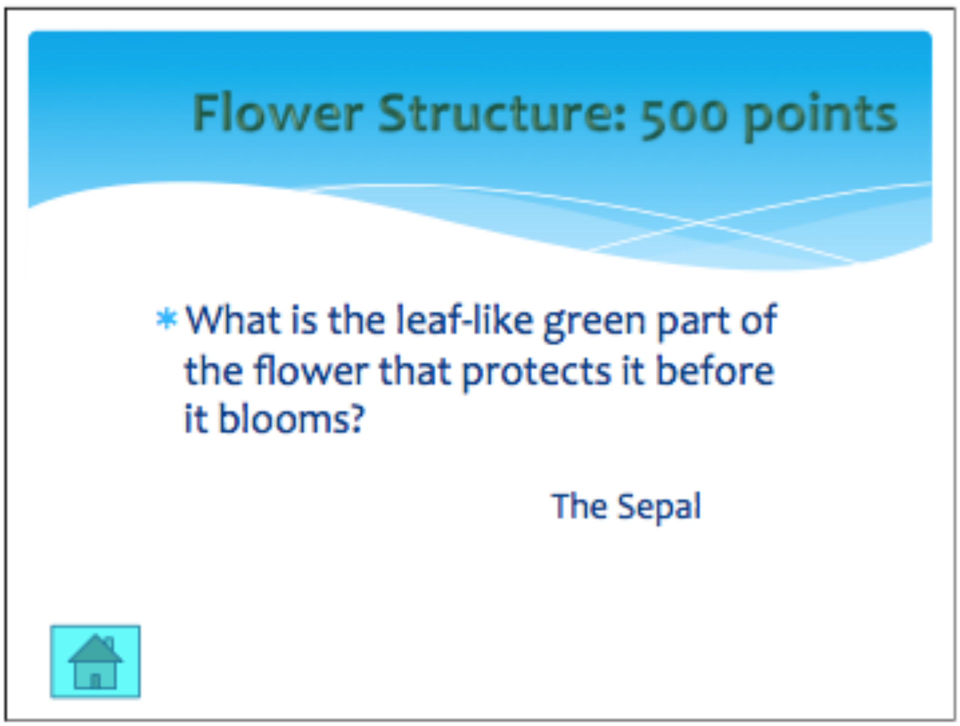

Plant Classifications: 500 points
Monocot and dicot are terms that characterize plants with either one or two ______________.
Cotyledons


Flower Structure: 100 points
Every plant has either female or male parts, not both: true or false?
False


Flower Structure: 200 points
What is the part of the flower on which pollen is visible?
The Anther


Flower Structure: 300 points
What part of the plant is sticky (female part of the plant)?
The Stigma


Flower Structure: 400 points
What part of the plant does pollen travel through to reach the eggs inside the ovary?
The Pistil


Flower Structure: 500 points
What is the leaf-like green part of the flower that protects it before it blooms?
The Sepal

Plant Functionality: 100 points

* Why is the stigma sticky?

So that pollen can stick to it for pollination and fertilization

Plant Functionality: 200 points

* Why is it beneficial for angiosperms to have an enclosed seed?

To help protect the seed (and provide nourishment for germination)

Plant Functionality: 300 points

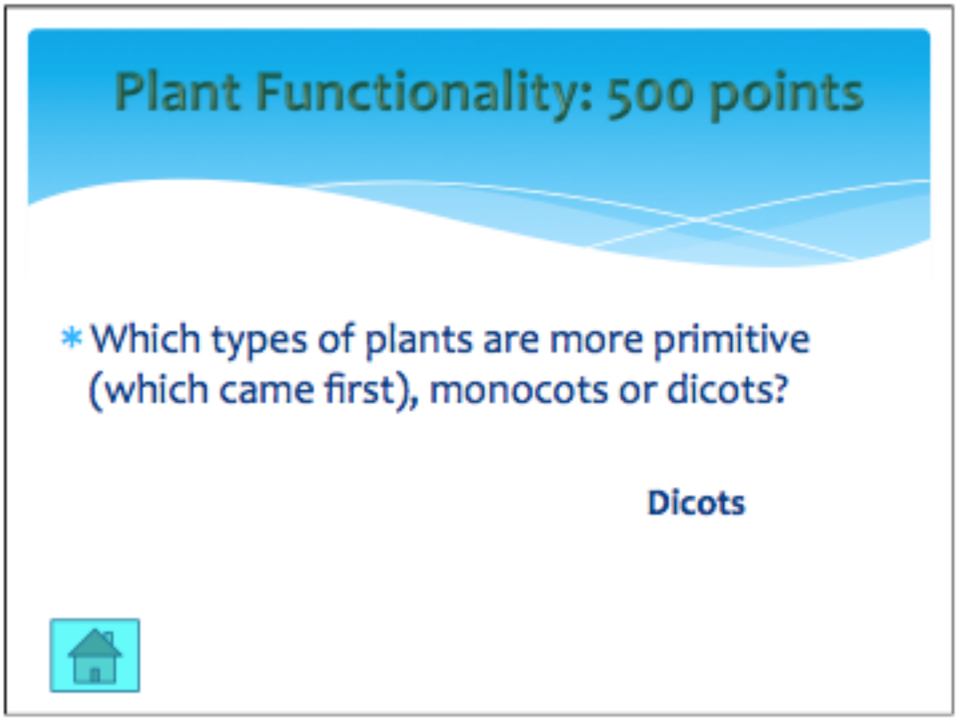
* Monocots (such as palm trees) produce wood: true or false?

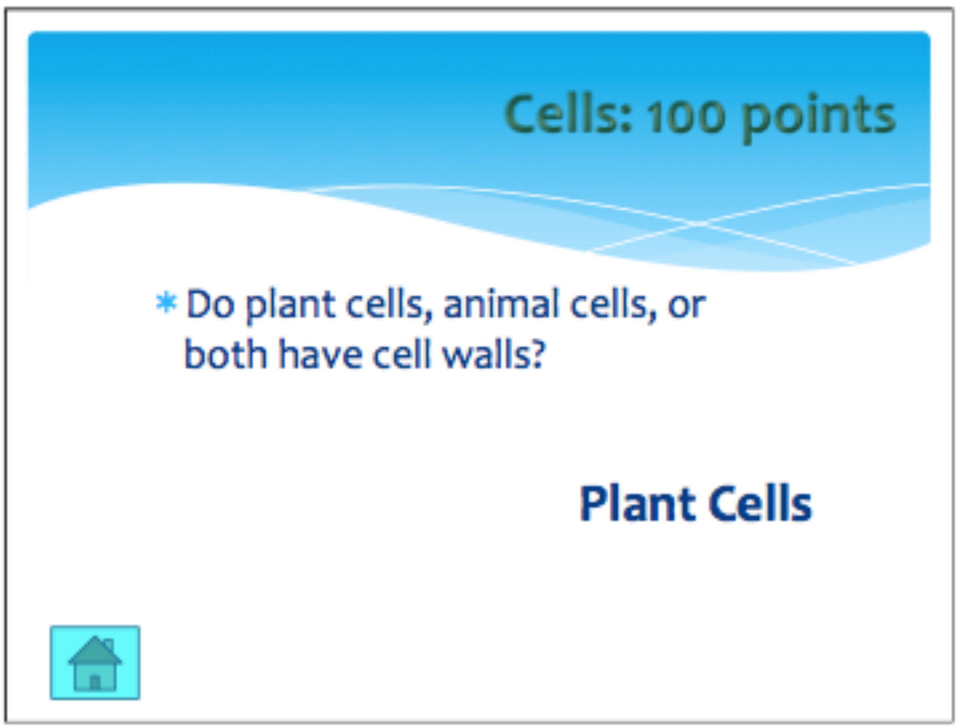
False

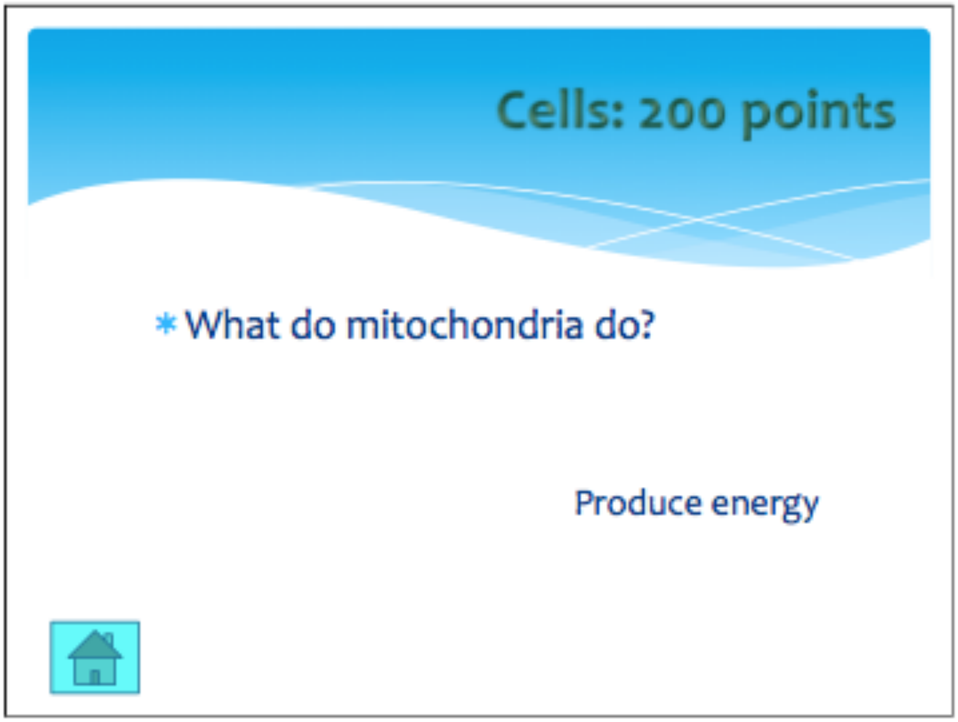
Plant Functionality: 400 points

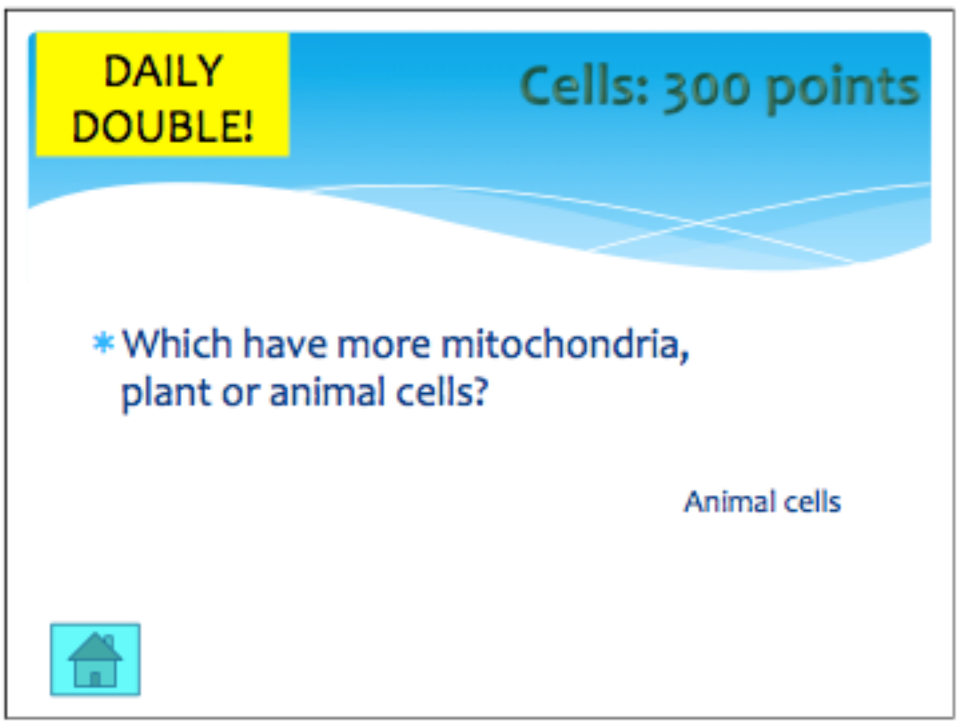
* Why is fruit useful in seed dispersal?

* Animals can eat the fruit and help "transport" the seeds


Plant Functionality: 500 points
* Which types of plants are more primitive (which came first), monocots or dicots?
Dicots


Cells: 100 points
* Do plant cells, animal cells, or both have cell walls?
Plant Cells


Cells: 200 points
* What do mitochondria do?
Produce energy


DAILY DOUBLE!
Cells: 300 points
* Which have more mitochondria, plant or animal cells?
Animal cells

Cells: 400 points

* What does selectively permeable (like the plasma membrane) mean?

It allows some things to pass, but not others

Cells: 500 points

* What is the main organelle found in every cell that contains all the information, or "coding," of that cell?

* Nucleus (contains DNA or deoxyribonucleic acid)

Review: 100 points

- In the following formula for photosynthesis:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

name the elements C, H, and O

Carbon, Hydrogen, and Oxygen

Review: 200 points

- In the following formula for photosynthesis:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

name the molecules:

Carbon Dioxide $\rightarrow CO_2$

$H_2O \leftarrow$ Water

Glucose $\rightarrow C_6H_{12}O_6$

$O_2 \leftarrow$ Oxygen

Review: 300 points

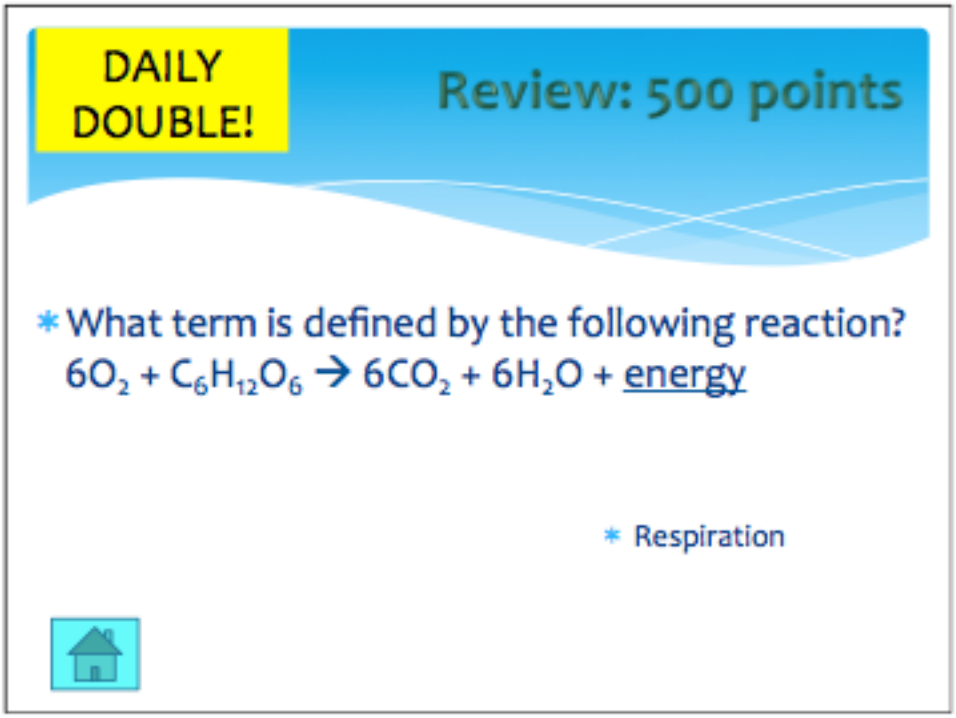
* The ______________ brings nutrients and water from the roots to the leaves, while the ______________ brings sugars from the leaves to the rest of the plant.

Xylem; phloem

Review: 400 points

* In ATP (adenosine triphosphate), how many phosphate groups are there?

Three (**tri**phosphate)


DAILY DOUBLE!
Review: 500 points
What term is defined by the following reaction?
$6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O +$ energy
Respiration


Daily Double!
As a team, decide how many of the points you already have you wish to wager.
If you get the question correct, you will earn double the points you wagered.
If you get the question incorrect, you will lose the points you wagered. Good luck!

Chapter 3, Lesson 1: How do plants meet their needs?

Vocabulary

- **Photosynthesis**
  - The reaction in leaves that uses carbon dioxide, water, and sunlight to make glucose and oxygen
  - $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
- **Chlorophyll**
  - Green pigment in plants that captures sun's energy, this energy is used for photosynthesis
- **Respiration**
  - Process in which oxygen combines with sugars to produce energy, carbon dioxide, and water
- **Transpiration**
  - Loss of water from the plant, causing negative pressure (suction) and pulling water and nutrients through the xylem
- **Vascular Plant**
  - A plant that has transport tissues for carrying water, food, and nutrients to its cells
- **Nonvascular Plant**
  - A plant that lacks tissues for carrying water, food, and nutrients
- **Xylem**
  - Plant tissue that carries water and nutrients from a plant's root to its leaves
- **Phloem**
  - Plant tissue that carries food from the leaves to other cells
- **Adaptation**
  - Species change over time in ways that are suited to its living environment

Core Concepts

- **How do plants meet their needs?**
  - What do they need?
    - Water (H_2O), carbon dioxide (CO_2), and sunlight for photosynthesis
    - Oxygen is combined to the glucose (sugar) made through photosynthesis in a process called respiration, where oxygen combines with the sugar (glucose) to produce energy, carbon dioxide, and water
    - Nutrients/minerals in the soil
    - Warmth: not too hot or cold
      - *Most plants survive from just above freezing (32° to around 100° Fahrenheit, arctic plants as low as 14° and desert plants as high as 122°*
  - How do they get what they need?
    - Photosynthesis occurs when plants take in carbon dioxide and water, and react to form sugar and oxygen. This provides the plants with sugar (glucose) for food/energy
      - *$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ means that 6 molecules of carbon dioxide and 6 molecules of water, with sunlight, react to form a molecule of glucose and 6 molecules of oxygen*
      - *Photosynthesis occurs in the leaves of the plants, specifically in the organelles (small organs) called chloroplasts. In chloroplasts, a green pigment called chlorophyll captures the sun's energy*
      - *Sugar is stored in the plant for energy, and oxygen is released into the air*

- Vascular plants use their vascular tissues (xylem and phloem) to transport nutrients from different parts of the plant
  - *The xylem brings the nutrients and water from the roots up to the leaves of the plant*
  - *The phloem brings the sugars from the leaves, where photosynthesis occurs, to the other cells of the plant*
  - *Transpiration is when there is a loss of water from the plant, which causes negative pressure (suction) through the xylem, pulling up water and minerals*
- Nonvascular plants do not have tissues to transport materials through the plant, so they cannot grow as large
  - *They do not have roots; each cell directly absorbs water and nutrients from the soil or air*
  - *Nonvascular plants require water for sexual reproduction; the male cells must swim through water to get to/fertilize the female sex cell*

Biosphere Unit: extra information

- **What is an ecosystem?**
  - A community and its non-living surroundings
    - The living parts are called biotic
    - The nonliving parts are abiotic
  - Different species rely on each other for:
    - Food – animals eat plants and other animals, plants require sunlight, water, and carbon dioxide in the atmosphere and environment to make food
    - Air – animals require oxygen to breathe, and give out carbon dioxide; plants need carbon dioxide for photosynthesis, and give out oxygen
    - Shelter – humans use plants as building material, such as wood for houses or cotton for clothing
      - *Humans use animals for things like leather, furs, and wool*
      - *Animals use plants for shelter, like living in trees or building nests*
- **What is a lunar base?**
  - A place on the moon in which astronauts could live, along with plants and animals if designed correctly
    - It is closed off so that it can contain things necessary to maintain an atmosphere containing oxygen, carbon dioxide, water, etc.
  - What challenges would a lunar base pose?
    - Difference in gravity – the moon has $1/6^{th}$ the earth's gravity
    - Air/atmosphere – the moon has basically no atmosphere, carbon dioxide and oxygen are necessary for plant/animal life, atmosphere is important for blocking radiation and maintaining a habitable temperature
    - Days/night (sunlight) – the moon has varying night and day lengths; plants need sunlight at regular intervals for photosynthesis
    - Soil – plants need the minerals from soil to grow. Soil has organic content (material from things that were once living)

Chapter 3, Lesson 2: How do plants respond to their environment?

Vocabulary

- **Tropism**
  - A growth response of a plant toward or away from something in its environment
- **Gravitropism**
  - The growth response of plants to gravity
- **Positive gravitropism**
  - (Root) Growth towards the direction of pull of gravity
- **Negative gravitropism**
  - Growing away from the pull of gravity
- **Phototropism**
  - The growth response of plants to light
- **Solar tracking**
  - The ability of a plant to track and face the sun, as sun moves from east to west
- **Long day plants**
  - Plants that flower when the days are longer than nights (also called short night plants)
- **Short day plants**
  - Plants that flower when nights (darkness) are longer than days (also called long night plants)
- **Thigmotropism**
  - Growth response to touch
- **Dormant plants**
  - Plants when they are inactivated (sleeping) when it is cold
- **Annual plants**
  - Plants that germinate, grow, flower, make seeds and die within one growing season
- **Perennial plants**
  - Plants that return and carry out their regular life activities year after year

Core Concepts

- **How do plants respond to their environments?**
  - Plant response to their environments (tropisms) help plants grow and proliferate (reproduce and spread)
    - For example, phototropism (light) and gravitropism (gravity) help plants get sunlight, while thigmotropism (touch) helps plants grow around objects that touch them to support themselves
- **Plant rhythms**
  - Plants must adapt to the changing seasons, and respond to changes in temperature and changes in the lengths of day
    - Long-day plants flower when there are more than a certain number of daylight hours, while short-day plants flower when there are fewer than a certain number of daylight hours
      - *They are really detecting the length of night, or darkness, not the length of light exposure!*
  - Some plants germinate, flower, make seeds, and die within one growing season (annual plants)
  - Other plants return year after year (perennial plants)

Chapter 3, Lesson 3: What are some types of plants?

Vocabulary

- **Angiosperm**
  - A flowering vascular plant whose seeds are surrounded by a fruit ("covered seed")
- **Gymnosperm**
  - A vascular plant that produces seeds that are not surrounded by a fruit ("naked seed") also considered **nonflowering plants**
- **Conifer**
  - A type of gymnosperm whose seeds develop inside the cone
- **Fern**
  - A vascular plant that reproduces without seeds
- **Spores**
  - Cells that can grow into a new plant without joining with other cells
- **Moss**
  - A small plant that lacks vascular tissues, true roots, stems, and leaves
- **Sexual reproduction (plant)**
  - When an egg and sperm cell join to form a new plant
- **Asexual reproduction (plant)**
  - When a new plant is formed without the joining of a sperm cell and egg cell
- **Embryo**
  - A seedling or a tiny plant inside the seed

Core Concepts

- **Mosses, Liverworts, and Hornworts**
  - Mosses are nonvascular plants that require water to reproduce. They do not have true roots, stems or leaves, and absorb nutrients by cell to cell contact.
    - Mosses reproduce using spores in the asexual generation, and sperm and eggs in the sexual generation. They must have water in order to reproduce.
- **Ferns**
  - Ferns are also vascular plants that require water to reproduce. They have roots, stems and leaves, as well as xylem and phloem tissues. Leaves grow on long structures called fronds.
    - Ferns also require water to reproduce. Their asexual generation produces using spores on the underside of leaves while their sexual generation uses sperm and eggs.
    - When a spore is released and reaches the ground, a small heart-shaped structure forms. When sperm and eggs are produced and meet on this structure, fronds can begin to form.
- **Gymnosperms**
  - Gymnosperms are also vascular plants. Gymnosperms produce seeds that contain an embryo. Their seeds are not protected by a fruit, and are known as naked seeds. Conifers are a type of gymnosperm that produce cones and have needle-like leaves.
    - Conifers produce both male and female cones: the males produce pollen (which contain sperm) while the females produce egg cells. Both types of cones are found on the same tree.

        - When eggs are mature, the female cone becomes sticky in order to attract pollen to fertilize their eggs.
        - Gymnosperms do not need water to reproduce
- **Angiosperms**
    - Angiosperms are vascular plants that also produce seeds. They produce flowers and protective seeds which are surrounded by a fruit
        - Angiosperms do not need water to reproduce.

Chapter 3, Lesson 4: How do angiosperms reproduce?

Vocabulary

- **Sepal**
  - The part of flower that protects it before it blooms (usually green and leaf-like)
- **Stamen**
  - Male reproductive organ that consists of the anther and filament
- **Anther**
  - Part of the stamen that produces pollen grains
- **Filament**
  - Is a stalk that connects anther to the plant
- **Pistil**
  - Female reproductive organ of a flower, located at the center of flower.
- **Pollination**
  - The first step in angiosperm reproduction, during which pollen from an anther lands on a stigma of a flower of the same kind
- **Fruit**
  - Ripened ovary of a flowering plant
- **Self-pollination**
  - Pollination in which transfer of pollen occurs within the same flower; or between different flowers of the same plant
- **Cross pollination**
  - Pollination in which transfer of pollen occurs from anther of one plant's flower to the stigma of a flower of the same kind of plant
- **Fertilization**
  - The sperm cells from the pollen grains enter the ovules and join with the egg cells
- **Tubers**
  - Underground stems of some plants that swell to store food
- **Grafting**
  - Manual, asexual reproduction in which two parts of different plants are joined together to form a single plant that has characteristics of both parents.

Core Concepts

- **Flower parts**
  - Angiosperms are vascular plants that produce fruits from their flowers, which are the reproductive organs.
  - Some angiosperms have flowers so small that you might not notice them, such as grasses and grains. Others, like oak trees, have flowers that hardly look like flowers at all.
- **Plant anatomy**
  - The largest and most noticeable parts of flowers are their petals, which are often colorful and scented to help attract pollinators
  - Below the petals are the sepals, which protect the plant and provide nourishment when it first develops
  - In the center of the flower are several stem-like structures called stamens, the flower's male reproductive organs (anther at the top, and filament which stems from the plant to the anther)

- At the center of the flower is the female structure, the pistil, which contains the stigma (sticky part at the top that catches pollen), the style (the stem-like part), and the ovary (the part that contains the egg cells)

- **Pollination**
  - Pollination is the first step in angiosperm reproduction; when pollen from one plant lands on the stigma of another of the same kind of plant, the a tube from the pollen grain grows down through the style and into the ovary to fertilize the eggs
  - Things that improve the chance of pollination are bright petals, strong scents, production of nectar, heavy and sticky pollen (for sticking to animals), or light and powdery pollen (for being carried by the wind)
- **Fruits and seeds**
  - Angiosperms can be divided into monocots and dicots. Monocots have one seed leaf ("mono") while dicots have two seed leaves ("di").
    - Monocots
      - *One cotyledon, flower parts in threes, parallel leaf veins, scattered vascular bundles, fibrous roots*
    - Dicots
      - *Two cotyledons, flowers parts in 4s or 5s, webbed leaf veins, vascular structures in rings, taproots;* ***more primitive than monocots***
  - Seeds have evolved to be spread in many different ways, including sticking to animals, having wings to be carried by the wind, or being able to be passed through an animal's digestive system.
- **Asexual Reproduction**
  - Asexual plants reproduce without using any seeds at all.
    - Leaf cuttings are parts of a plant that have been removed from a main plant. Many or these can grow into an entirely new plant.
    - Runners are structures that spread from a plant, producing an entirely new plant.
    - Tubers, such as potatoes, have eyes that can form a new plant.
    - Grafting is a term that refers to removing part of a plant and attaching it to another plant to get characteristics of both plants.

Plant and animal cells

Vocabulary

- **Plasma membrane**
  - A semi-permeable or selectively permeable membrane that regulates what moves in and out of the cell
- **Cytoplasm**
  - The gel-like substance filling the cell, enclosed by the plasma membrane, that holds all the organelles of the cell and molecules that freely float within the cell
- **Nucleus**
  - The organelle that stores the genetic material and information of the cell; the nucleus contains DNA and is enclosed by a double layered membrane
- **Mitochondria**
  - The energy producing organelles of the cell; animal cells have many more mitochondria than do the plant cells
- **Vacuole**
  - A space within a cell's cytoplasm that is enclosed by a membrane and usually contains fluid
  - Animal cell vacuoles are used mostly for food uptake and molecular transport, and are small in size and numerous
  - Plant cell vacuoles are used mostly for storing water and organic molecules like glucose; the plant usually contains one large vacuole
- **Cell wall**
  - The outermost layer of plant cells that protects the cell, maintains shape, and prevents the intake of too much water (preventing the bursting of the cell)
- **Chloroplasts**
  - Plant cell organelles that are responsible for carrying out photosynthesis, and contain the pigment chlorophyll

Core Concepts

- **The plasma membrane**
  - The selectively permeable or semi-permeable plasma membrane allows certain things to pass freely, through diffusion (natural movement from higher to lower concentration – for example, if you put die in a cup of water, it not stay in one place; it will spread out through the entire cup of water until there is an equal distribution of die)
  - Other things must pass through gated channels that are specific to certain molecules (for example, a person getting money from a bank might need to use their card to get in, while someone without the card or proper identification might not be able to open the door)

Final Exam

Matching: *Match each term with its meaning, and write the corresponding letter on the provided line. (4 points each)*

____ **1.** The vascular tissue that carries water and nutrients from a plant's roots to its leaves

____ **2.** The vascular tissue that carries sugars from the leaves to each of the plant's cells

____ **3.** The response of a plant to light
____ **4.** The response of a plant to gravity
____ **5.** Cells that grow to become new plants without joining with other cells (Ferns and Mosses use them)

____ **6.** The name of a group of plants whose seeds are not surrounded by a fruit

____ **7.** A flowering vascular plant whose seeds are surrounded by a fruit

____ **8.** The first step in angiosperm reproduction

A. angiosperm

B. gravitropism

C. gymnosperm

D. phloem

E. phototropism

F. pollination

G. spore

H. xylem

True or False: *Answer "T" for true or "F" for false on the provided line. (4 points each)*

____ 9. A plant whose leaves have parallel veins is a **monocot.**
____ 10. The anther is the **female** structure on a flowering plant.
____ 11. Plants **do not** react to their surroundings.
____ 12. Egg cells can be found in the **ovary** of an angiosperm.
____ 13. Animal cells **do not** have cell walls.
____ 14. The organelle in plant cells in which photosynthesis occurs is the **chloroplast**.
____ 15. Animal cells undergo respiration to convert glucose to energy; plant cells **do not**.
____ 16. The products of photosynthesis are **glucose** and **carbon dioxide**.
____ 17. A conifer is an example of a **gymnosperm**.
____ 18. Ferns and mosses **do not** need water to reproduce.

Multiple Choice: *For the following questions, write the letter of the best choice on the provided line. (3 points each)*

____ 19. What is the name of the process by which water leaves plants through stomata?

A. photosynthesis
B. respiration
C. transpiration
D. tropism

____ 20. Which three things must plants have to make their own food by photosynthesis?

A. carbon dioxide, water, and darkness
B. carbon dioxide, water, and sunlight
C. water, sunlight, and oxygen
D. nutrients, water, and oxygen

____ 21. A plant is bending toward a light source. What is this response called?

A. absorption
B. gravitropism
C. phototropism
D. respiration

____ 22. Which process takes place when sperm cells from pollen grains enter ovules and join with egg cells?

A. fertilization
B. soil formation
C. nectar production
D. transpiration

____ 23. The gravity on the moon is ______________ the gravity of the Earth.

A. the same as
B. 1/2
C. 1/6th
D. 1/12th
E. there is no gravity on the moon

Short Answer Questions: *Answer the following questions in complete sentences. (6 points each)*

24. Compare and contrast the stems, leaves, and number of parts of monocots and dicots.

____

____

____

____

25. Why are the stigmas of angiosperms as well as the female cones of conifers sticky?

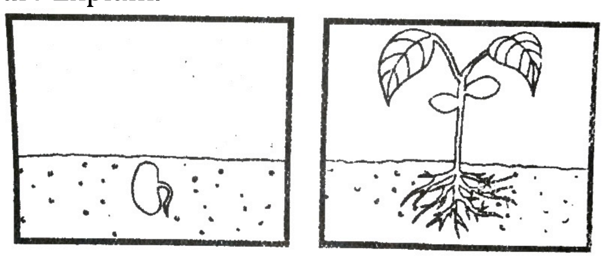
____

____

____

____

26. The drawings show a bean seed and a young bean plant. In which one of these would photosynthesis occur? Explain.



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Appendix D EVALUATIONS OF TEAM AND UNIT

BIOSPHERE UNIT EVALUATION

WPI Interdisciplinary Qualifying Project: 6th Grade MCAS-S Preparation

Ms. Deb Conn, please answer the following questions regarding the Biosphere Unit:

	Not well				Very well
How well did you think the WPI team was prepared for teaching?	☐	☐	☐	☐	☑
How effective was the way in which the team taught?	☐	☐	☐	☐	☑
How well did the team utilize a variety of teaching methods to reach each student?	☐	☐	☐	☑	☐
How well did the team incorporate hands-on activities into the lesson plans?	☐	☐	☐	☐	☑

	Not well				Very well
How well did the material taught correspond to the textbook/current curriculum?	☐	☐	☐	☐	☑
How well do you think the students responded to the Biosphere unit?	☐	☐	☐	☐	☑
How well do you believe this unit encouraged an interest in science?	☐	☐	☐	☐	☑
How well do you think this unit prepared students for the MCAS-S?	☐	☐	☐	☑	☐

	Not well				Very well
How well was the level of detail formatted toward the students' capabilities?	☐	☐	☐	☐	☑
How well did the team connect with the students?	☐	☐	☐	☐	☑

What do you think the team could have improved upon in its teaching?
Longer time with hands-on materials. There were notes presented and due to limited time with students the dissections etc were rushed.

What do you think the team could have improved upon in the subject matter taught?
They were very thorough -

How well do you think the team incorporated hands-on activities into the lesson plans?
As well as they could with time restrictions

How well do you think the students responded to hands-on activities? (Compared to the team's teaching alone? Compared to the standard curriculum without the team?

The team tried to incorporate hands-on - as stated previously - time was an issue.

Do you believe the Biosphere Unit enhanced the current curriculum? Why or why not?

Yes, it definitely enhanced the curriculum - always wonderful to have someone in addition to the classroom teacher.

Any other critiques/comments:

The WPI students were wonderful - they worked hard to accomodate the departmentalized feature of our 6th grade students.