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Title:

A Bouquet of Flower Investigations and Activities

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Appropriate Level:

Sections of this lab are appropriate for biology students in General, Regents, Honors, and AP classes. *Name that Pollinator*, *The World's Best Artificial Flower!* and *Flower Dissection* could all be done by local level students. "*To form a pollen tube...or not to form a pollen tube*" is more appropriate for Regents, Honors, and AP level classes.

Abstract:

This series of four different lab activities all relate to flower reproduction. They have been designed to relate to each other and to stand alone.

Name that Pollinator focuses on adaptations for successful pollination. Both pollen and pollen vectors are examined. Observing, data gathering, making measurements through the microscope, and constructing tables are all emphasized. This lab would work equally well in ecology, evolution, or reproduction units.

The *World's Best Artificial Flower* is a cooperative learning venture which has students either construct 3-D models or write essays on a fictitious flower, pollinator, habitat system.

In *Flower Dissection*, students identify, remove, arrange, and tape down the essential and accessory parts of a flower. Students also examine pollen grains and the possibility of pollen tube formation.

"*To form a pollen tube...or not to form a pollen tube*," allows students to design their own experiment to investigate some variable influencing pollen germination. The parts of a research paper are outlined and students are expected to follow that format when writing their final report.

Special Notes:

These investigations should not necessarily all be used at one point during the year. They have been designed to allow students to see interrelationships. *Name That Pollinator* could be done early in the year when students are learning skills and techniques or during a unit on ecology. *The World's Best Artificial Flower* could be appropriate with ecology, plants, or evolution. *Flower Dissection* is more traditional and should probably be used as part of a plant reproduction unit. "*To form a pollen tube...or not to form a pollen tube*" should also be done during a plant unit and could serve as an extended activity suitable for portfolio inclusion. This particular activity lends itself to Honors and AP courses since students can go into great depth.

Time Required:

Each section is designed to take a minimum of one 45-minute lab period. Some outside work is required for all of the investigations except the flower dissection.

Additional Teacher Information

Materials

- Compound light microscopes: 10X and 40X objectives; higher magnification would be nice but not necessary
- Dissecting microscope (optional)
- Magnifying glasses
- Visuals (optional but one or more are desirable):
 - Flower poster
 - Pollinator poster (insects and flowers, butterflies or bats and flowers, etc.)
 - Flower model
 - Reference books for identifying flowers

(per group of two students):

- 2 depression slides
- coverslips (plastic or glass)
- 2 forceps
- fresh flowers of various types for observation
- fresh flowers for dissection
- fresh pollen (tobacco for pt III)
- 25 or 50 ml beakers or flasks
- 25 or 50 ml graduated cylinders
- 100 ml distilled water
- 1 roll of Scotch™ tape
- 2 scalpels or single edge razor blades
- 2 pipettes
- for Germinating Solution A (*directions below*)
 - Sugar (sucrose)
 - 0.001% boric acid solution
 - 0.001% CaCl₂
- for Germinating Solution B (*directions below*)
 - Corn syrup (Karo™ or comparable type)

When doing the pollen tube germination portion of this lab series, rather than having students prepare their own sugar solution, you may want to prepare it ahead of time. There are two different types of germinating solution. Type A is a formulation often recommended in the literature. Type B was discovered by chance, is reliable, and easy!

Germinating Solution A

To obtain a 20% concentration of germinating solution A, have students add enough water to 2 grams of sugar to reach a volume of 10 mL. For an entire class, you could add enough water to 20 grams of sugar to bring the volume up to 100 mL. One drop of 0.001% boric acid should be added to the sugar solution to prevent explosions of the pollen grains. One drop of 0.001% CaCl₂ should also be added. Calcium is needed for proper pollen tube growth. The sugar solution containing the CaCl₂ and boric acid can be prepared in advance and stored for up to a year in a freezer at -20°C.

Germinating Solution B

Prepare Germinating Solution B by adding enough water to roughly 35 ml of corn syrup to bring the volume up to 100 ml. The boric acid and calcium chloride may be added but don't seem to make any difference when tap water is used. The key to success is using flowers with ripe pollen.

Background Information

Pollen

Pollen ranges in size from 5 micrometers in the *Forget-me-not* to over 200 micrometers in the melons. The shape of all pollen seems to be roughly spherical. The wall of the pollen grain consists of two distinct layers with the exine being outermost. The exine is resistant to decay. It is often easy to recognize the species of plant responsible for producing the pollen grains being examined through the microscope because the exine exhibits patterns of sculpture characteristic of a family, genus, or species. The surface chemicals of the exine allow the stigma to recognize pollen of the same species through biochemical means. The intine, on the other hand, is composed of cellulose and immediately surrounds the cytoplasm. The intine decays quite rapidly and leaves the exine behind. When paleontologists talk of fossilized pollen, they are referring to the exines of pollen grain produced by prehistoric plants. Pollination strategies can be deduced through an examination of the shape and size of pollen grains.

Pollen tube growth is a fascinating phenomenon. Once pollen makes contact with a compatible stigma, growth is initiated. The tube emerges from the pollen grain and begins digesting through the wall of a papillae cell of the stigma. Enzymes that primarily hydrolyze pectins and some cellulose are secreted. It is interesting to note that pollen tube growth is an example of tip growth. No cell division is involved. However, secretions that result in the reinforcing of the tube's cell wall and membrane are critical to the process. As the tube elongates, all of the cytoplasm is pushed forward to the tip. The sperm nucleus follows. Periodically a plug forms to keep the cytoplasm and nuclei in the tip and to isolate them from the rest of the pollen grain. Energy necessary for this process is stored in the pollen itself. Some nutrients may be obtained from the pistil, but only a very small amount. Once the tube has moved through the papillae cell and enters the rest of the stigma, growth is extracellular. The tube does not penetrate cells but moves between them. When growing through a stigma, the tube formed is quite straight. When pollen tubes germinate in a solution on a depression slide, growth is random and the tube formed seems to keep changing direction. The differences in tube formation in these two situations would be a good discussion question for your students.

Name That Pollinator

The poster(s) and model flower (if available) should be placed so students can easily refer to them. This way information is available and cues are provided without the teacher spending a vast amount of time lecturing and giving definitions.

Bring in a collection of flowers growing in local fields or gardens. If they are not available, purchase some mixed flowers from the florist or grocery store. Place a number of stalks of one flower type in a container and label it with a number. When students are working on the lab,

have them take one flower at a time, return to their work area, and make their observations. They should name the flower by number and then identify it via common knowledge or by using various flower guides provided by the teacher.

Students should have already learned how to use the microscope or at the least know the names and functions of the parts. You can use this lab to teach them how to make slides or to reinforce the technique. They can use this lab as a way to know how to estimate the size of objects viewed through the scope.

To make the estimation of the pollen grain size part of the lab easier, place a large outline of the microscopic field of view (a circle) on the overhead projector. Use a clear metric ruler that you can place across the diameter of the circle representing the microscopic field. Work through how to determine the size of the field, first in millimeters and then convert that figure to micrometers. Next scatter some paper hole punches over the field of view on the overhead. The paper punches represent pollen grains. Discuss with students what they should be doing when looking through the scope and attempting to determine how many pollen grains (hole punches) it would take to make a solid line across the diameter of the field of view. Ask for some estimates and then actually line the paper punches up to form a single solid line. Discuss how close the student estimates were. Then divide the number of punches into the diameter of the field in micrometers to obtain the size of one of the fictitious pollen grains.

Students will be working with the following chart, describing the characteristics of flowers pollinated by various pollinators:

Table 1: Pollinator-Flower Characteristics Chart

*Chart modified from USDA Forest Service,
http://www.fs.fed.us/wildflowers/pollinators/What_is_Pollination/syndromes.shtml, 2015.*

Pollinator	Type	Flower Traits				
		Color	Odor	Nectar	Pollen	Shape
<i>Bats</i>	Zoophily	Dull white, green, or purple	Strong musty; emitted at night	Abundant; somewhat hidden	Ample	Regular; bowl-shaped – closed during the day
<i>Bees</i>	Entomophily	Bright white, yellow, blue, or UV	Fresh, mild, pleasant	Usually present	Limited; often sticky and scented	Shallow; have landing platform; tubular
<i>Beetles</i>	Entomophily	Dull white or green	None to strongly fruity or fetid	Sometimes present; not hidden	Ample	Large, bowl-like; e.g. Magnolia
<i>Birds</i>	Zoophily, Ornithophily	Scarlet, orange, red, or white	None	Ample; deeply hidden	Modest	Large, funnel-like; cups; strong perch support

<i>Butterflies</i>	Entomophily	Bright, including red and purple	Faint but fresh	Ample; deeply hidden	Limited	Narrow tube with spur; wide landing pad
<i>Flies</i>	Entomophily	Pale and dull to dark brown or purple; flecked with translucent patches	Putrid	Usually absent	Modest in amount	Shallow; funnel-like or complex and trap-like
<i>Moths</i>	Entomophily	Pale and dull red, purple, pink, or white	Strong, sweet; emitted at night	Ample; deeply hidden	Limited	Regular; tubular without a lip
<i>Wind</i>	Anemophily	Dull green, brown, inconspicuous, less showy; petals absent or reduced	None	None	Abundant; small, smooth, not sticky	Regular; small and stigmas exerted

An extension to this activity might be to take students out to observe wildflowers and have them record flower traits and the types of pollinators seen visiting different flowers.

The World's Best Artificial Flower

The World's Best Artificial Flower is a cooperative learning activity. Hand out groupings of cards (separate document) to students to determine which group they will work with and the topics their group will investigate. Be sure that each grouping includes a habitat card, a flower color card, and a general characteristic card. Have students randomly draw a group of cards from the stack and search out the other members of their team. Feel free to change or customize the cards provided. Within each team, allow students to select which topic they want for specialization (pollinator, pollen, or flower). Students should have the option of creating a 3-D model, writing an essay, or drawing several illustrations with short descriptive paragraphs for their individual component of the project. For example, one group may have one student making a 3-D pollen model, another student making a 3-D flower, and the third student writing an essay describing the pollinator. All students must make it very clear how their part interrelates with the others. They must demonstrate how their particular system would be successful in the habitat assigned. The importance of tying all of their work together will be reflected in the fact each student receives two grades for this project. One will be for the overall project. The other will be for their individual piece.

Flower Dissection

Again, the poster(s) and model flower (if available) should be placed so students can easily refer to them. This way information is available and cues are provided without the teacher spending a vast amount of time lecturing and giving definitions.

Provide students with a simple flower such as a lily, tulip, daffodil, or gladiola. The reproductive parts need to be readily observable and removable. Check with a local florist to see if they have

any blooms too “mature” for use in arrangements. They may be willing to donate these to your science program. A local funeral home is another possible source of blooms. If you have a real problem obtaining enough flowers and pollen germination is not a concern, dehydrated lily blossoms can be purchased in many Asian food markets. If the flowers are soaked over night, students will have no difficulty picking them apart and locating the reproductive structures.

If you plan to do this part of the lab and want guaranteed results, start growing tobacco plants early in the year. Tobacco flower pollen readily germinates in a 20% sugar solution with the boric acid and CaCl_2 added. Tobacco plants will grow and flower for many years. Once you have an established plant, there is no problem obtaining viable pollen. Other pollens are less reliable. Experiment with what you have available! I have had very good luck with daffodil and tulip pollen. If you did not do the activity “Name That Pollinator, Part B” earlier in the year, you might want to check the teacher directions for hints on helping students estimate the size of pollen grains.

To form a pollen tube...or not to form a pollen tube

This provides students with the opportunity to design their own investigation. It is important for students to learn to ask their own questions and to analyze the results of their own work. Of course results for this lab will be varied. Just be sure that students design and carry out thoughtful, controlled experiments with multiple replicates. This would be a perfect time for the introduction of statistical analysis of results in order to determine the reliability of their data.

Answers to Questions

Name That Pollinator: Part A

1. Why is gymnosperm pollen typically larger than angiosperm pollen?

It is larger because it has one or more air bladders, which increase the surface area to volume ratio. This makes it better able to be carried by the wind and to contact the female reproductive structures of the same species.

2. Why would flowers of plant species that rely on wind pollination not be likely to produce large amounts of nectar or have showy, bright petals?

These species have not invested much energy in showy, nectar-laden flowers since it is not an adaptation that has been selected for. Since wind carries the pollen, animal pollinators are of no consequence.

3. What color adaptations do plants pollinated by nocturnal organisms show?

These flowers are usually white or some other light color which shows up in the dark.

4. Would the pollen grains of plants pollinated by insects be most successfully carried if they were textured with little spines or smooth? Explain your answer.?

Texturing and spines would allow pollen to more readily attach to the body of a pollinator. This would increase the likelihood of transport and pollination.

5. What advantage would it be to a plant to produce pollen that is sticky and often stuck to other pollen grains?

If one pollen grain chances to adhere to a pollinator, then a chain of pollen will be transported. This increases the chance of successful pollination.

Would more “stickiness” be even better? Explain.

Probably not. If the pollen is extremely sticky, it might not let go of the anther and attach to the pollinator. Or, the pollen, once stuck to the pollinator, might not be able to adhere to the stigma of a flower but might remain stuck to the pollinator.

Name That Pollinator: Part B

1. Do you think there could be more than one pollinator for some of your flowers? Add the pollinators to your chart where you think the evidence supports it.

Students should select several flowers that would reasonable indicate more than one pollinator. As long as their rationale is valid, their answer is fine.

2. Was creating and completing the chart an easy task? Why or why not?

Creating the chart is difficult. Answers will vary.

3. What additional information would make the task easier? Why? Remember that your task here is to determine how each flower is pollinated. Naming the flower and using the microscope to examine the pollen are both tools that allowed you to learn more about the pollen.

Answers will vary. They might mention knowing where the flower grows, when the blooms are open, what bugs/birds/weather are common at the time and in that region.

4. Which of the flowers you examined did you find the most interesting? Why?

Answers will vary. This question is merely an attempt to get students to reflect on the flowers they have been examining. They may select a flower for something as simple as color or scent. Some might like one best due to the size of the pollen or the physical characteristics of the pollen. As long as they have provided a thoughtful answer, it really makes no difference.

Flower Dissection

1. Does your flower produce more ovules than pollen grains or vice versa? In terms of reproductive success, why would this be important?

The flower produces more pollen grains. This is important because the pollen must be transported. Many pollen grains will be lost in the process and never make contact with the female reproductive parts. Large numbers increase the likelihood of pollination.

2. How is the stigma of your flower adapted to capture and hold pollen? Describe at least two such adaptations.

The stigma produces a sticky substance that captures pollen. The top of the pistil is enlarged so as to offer a greater surface area for pollen to land on.

3. Is your flower one that cross-pollinates or self-pollinates? Explain your answer using the size, shape, and location of reproductive parts, as well as, flower color, aroma, and other significant characteristics.

A flower that cross-pollinates would probably have a stigma that extends further out than the anthers. The anthers may ripen at a different time than the stigma. Both types might have

showy flowers to attract pollinators or they may be more drab. Both forms of pollination can occur either with or without animal pollinators.

4. Describe where pollination and fertilization occur. What is the primary difference between these two processes?

Pollination occurs when pollen lands on the stigma. Fertilization occurs when the sperm nucleus fuses with the egg nucleus in the ovule of the ovary of a flower. Pollination must take place before fertilization.

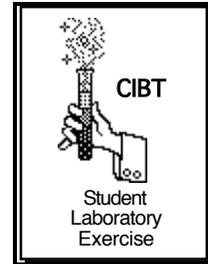
5. Attach your sketch of the pollen grains. Did the pollen eventually germinate? If no tubes appeared, explain why this may have happened

Answers will vary. Pollen tube germination may not have occurred due to an improper sugar concentration, of lack of enzymes produced by the stigma, or a problem with the pollen (freshness, fungal infection, etc.).

Bibliography

- Clay-Poole, Scott and I Slesnick. (1983) The Beauty and Biology of Pollen. *The American Biology Teacher*, (45)7, November, 366-370.
- Foote, MaryAnn. (1990). The Birds and the Bees...and the Bats. *The Science Teacher*, April, 27-29.
- Kandasamy, Muthugapatti, J. Nasrallah, and M. Nasrallah. (1994). Pollen-pistil interactions and developmental regulation of pollen tube growth in *Arabidopsis*.3405-3417.
- Motten, Alexander (1992). A Simplified Experimental System for Observing Pollen Tube Growth in Styles, *The American Biology Teacher*. (54)3, March, 173-176.
- Nering, William and N. Olmstead. *The Audubon Society Guide to North American Flowers*, Eastern Region, Alfred A Knopf: New York
- Otto, Towle, and Crider. (1965) Germinating Pollen Grains. *Biology Investigations to Accompany Modern Biology*, 226.
- Peterson, Roger Tory and M. McKenny. *A Field Guide to Wildflowers*. Houghton, Mifflin Company.
- Schlenker, Richard M. (1990) Student Research Report Writing, *The American Biology Teacher*. (52)8, November, 491-92.
- Sheridan, Philip. (1992). Dating Fossil Pollen: A Simulation. *The American Biology Teacher*, (54)1, January, 41-45.
- Taigen, Theodore, T. Terry, D. Wagner, and E. Jokinen. (1991). Plant Diversity, *Hands-on Biology: A Lab Manual for Introductory Biology*. 95-98.

Name That Pollinator: Part A



Name: _____ Date: _____

A Short History of Pollen

As autotrophs, plants form the basis of food chains without which we and other animals could not exist. Plant adaptations to insure pollination are crucial. For a plant to reproduce, the pollen (male gamete) must travel from the male sex organs of the flower to the female sex organs located in flowers of the same species. Usually the male and female sex organs occur in the same flower. However, sometimes a plant species produces separate male and female flowers on the same plant. In less common instances, some species produce male flowers on one plant and female flowers on another.

Cross-pollination and fertilization offer adaptive advantages to plant species. The evolution of a variety of pollination strategies is reflected in the structure and development of pollen grains. There are three main categories of pollination: wind, water, and animals. Wind and animals are the most common.

Wind pollination originated with the gymnosperms (conifers) such as pines and spruces. Conifers produce pollen that is uniquely structured to drift on the wind. Their pollen has one or more bladders (little sacs) that increase the surface-to-volume ratio thus making them more buoyant. To be successful, drifting pollen must adhere to sticky plant sap formed by a female sex organ of the same species. The typical size of pollen produced by conifers ranges from 40-130 micrometers.

During prehistoric times, some conifer pollen would have landed on the ground—just as it does today. Insects, such as beetles, crawling around on the ground searching for food could have come into contact with the pollen. As they continued their search for food in and around the female sex organs of the conifers, the beetles could have pollinated the plants. For these conifers, insect pollination would be much more successful than wind pollination. Random changes in the insects and conifers over time made the process even more likely. Hence, plants and insects have coevolved.

Angiosperms, flowering plants, evolved later than gymnosperms. The more attractive their flowers were to insects, the more frequently the insects would visit, thus circulating greater amounts of that flower's pollen. This would lead to more seeds being produced that carried the genetic code of the flower insects found more attractive. In their coevolution, angiosperms benefited from increased dispersal of the male gamete (pollen); and the insects were provided with carbohydrates, amino acids, and lipids from the nectar and pollen. Any chance mutations that made one flower more attractive than another to foraging insects would provide that flower

with a selective advantage. Pollen grains range in size from 12-40 micrometers in angiosperms that are pollinated by insects.

Different types of pollination are categorized accordingly. **Zoophily** is a form of pollination in which pollen is transferred by vertebrates, like birds, bats, or deer. **Ornithophily** is a form of zoophily in which birds transfer pollen. **Entomophily** describes pollination by insects.

Anemophily refers to pollination by wind. Most gymnosperms, grasses, and many trees use this form of pollination. Most pollens that are allergens are distributed anemophilously.

Read through Table 1: *Pollinator-Flower Characteristics Chart* (Page 3). Then answer questions 1–5, which start below. Next lab time, be prepared to apply what you have learned from the above reading and the chart in an analysis of actual flower blossoms.

Questions

Answer the following questions on your own paper.

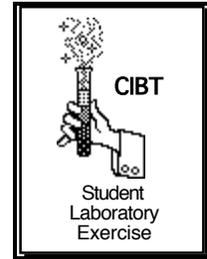
1. Why is gymnosperm pollen typically larger than angiosperm pollen?
2. Why would flowers of plant species that rely on wind pollination *not* be likely to produce large amounts of nectar or have showy, bright petals?
3. What color adaptations do plants pollinated by nocturnal organisms show?
4. Would the pollen grains of plants pollinated by insects be most successfully carried if they were textured with little spines or smooth? Explain your answer.
5. Of what advantage would it be to a plant to produce pollen that is sticky and often sticks to other pollen grains? Would even more “stickiness” be better? Explain.

Table 1: Pollinator-Flower Characteristics Chart

Chart modified from USDA Forest Service,
http://www.fs.fed.us/wildflowers/pollinators/What_is_Pollination/syndromes.shtml, 2015.

Pollinator	Type	Flower Traits				
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<i>Birds</i>	Zoophily, Ornithophily	Scarlet, orange, red, or white	None	Ample; deeply hidden	Modest	Large, funnel-like; cups; strong perch support
<i>Butterflies</i>	Entomophily	Bright, including red and purple	Faint but fresh	Ample; deeply hidden	Limited	Narrow tube with spur; wide landing pad
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<i>Moths</i>	Entomophily	Pale and dull red, purple, pink, or white	Strong, sweet; emitted at night	Ample; deeply hidden	Limited	Regular; tubular without a lip
<i>Wind</i>	Anemophily	Dull green, brown, inconspicuous, less showy; petals absent or reduced	None	None	Abundant; small, smooth, not sticky	Regular; small and stigmas exerted

Name That Pollinator: Part B



Name: _____ Date: _____

It is your task to determine how each of the flower specimens provided by your teacher is pollinated when in its natural environment. Carefully examine the flowers. On your own paper, make a chart that includes columns for:

1. The name of the flower.
2. How you think the flower is pollinated.
3. An explanation of each of the flower's characteristics that helped you to decide on its method of pollination.
4. The estimated diameter of each pollen type observed. Record the diameter in micrometers (μm). Follow the steps outlined below:

- (a) Place a few drops of water in the well of a clean depression slide. Then gently dip the flower up and down in the water in the well. This should result in the transfer of pollen from the flower to the slide. Next cover the mount (water-pollen mixture in the well) with a clean cover slip.*

**To do this, hold the cover slip at about a 45° angle to the slide and move it toward the drop. When the water touches the edge of the cover slip, it will spread along the edge. Then gently lower the cover slip into place. Do not press on the cover slip. It should rest on top of the water. A good wet mount slide should have no air bubbles. If you have many, add a drop of water to the edge of the cover slip. It will draw under and remove the air bubbles. If this does not work, remove the cover slip, dry the slide, and start again.*

- (b) Focus on the pollen using 100X magnification. Estimate how many pollen grains it would take to form a solid line of pollen across the diameter of the 100X field.

Record this number. _____ pollen grains across the field

- (c) Next divide this number into the diameter of your 100X field. (If you have never made this determination, place a clear plastic metric ruler on the stage of your microscope just as you would a slide. Using 100X magnification, focus on the metric markings of the ruler.)

Estimate the diameter of the field using millimeters and convert it to micrometers (1 millimeter equals 1,000 micrometers.)

The size of a single pollen grain is _____ micrometers.

5. A sketch (to scale) of each type of pollen grain observed. Follow the directions below:

- (a) Draw a line one centimeter long, which will serve as a reference to scale your illustration. One centimeter will represent a distance of 25 micrometers.

- (b) After estimating the size of the pollen for each flower examined, use the scale to sketch the pollen in the appropriate place on your chart. Be sure to include characteristics of each pollen variety. Show what the outer surface of the pollen looks like.

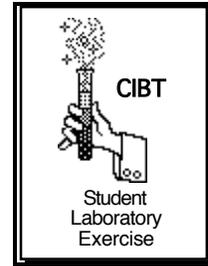
6. Repeat the above process for six different flowers.

After you have completed your chart, use complete sentences to answer the following questions on a separate sheet of paper. Record your answers on the same paper as your chart.

Questions

1. For which of your flowers do you think there could be more than one pollinator? Explain why you feel some could have more than one while others would not. Add the pollinators to your chart where you think the evidence supports it.
2. Was deciding the type of pollinator in each case an easy task? Why or why not?
3. What additional information would make the task easier? Why? Remember that your task here is to determine how each flower is pollinated. Naming the flower and using the microscope to examine the pollen are both tools that allowed you to learn more about the pollen.
4. Which of the flowers you examined did you find the most interesting? Why?

The World's Best Artificial Flower



Name: _____ Date: _____

This will be a group project. Your teacher will hand out cards, and you will find the other members of your team by locating two other people with a card set that matches yours. Each team's task is to invent a flower that can survive in a specified habitat, design pollen of the appropriate size and surface texture to be produced by the flower, and create a pollinator (wind and water are not possibilities!) that can successfully transport the pollen from the male to the female reproductive structure of your plant species.

The team should be divided so that one person is the pollen expert, another the flower specialist, and the third person is the pollinator authority. The information on the cards provides a few of the flower's characteristics and habitat. You cannot change the characteristics or habitat. However, you are free to go beyond what the cards indicate in the design and construction of your flower, pollinator, and pollen models. All three must function together so that the flower is reproductively successful and the pollinator is able to obtain what it requires from the flower.

Each member of the team will be responsible for either creating a three-dimensional model or writing a description of the part of the system they are in charge of. For example, the flower expert may decide to construct a three-dimensional model and label key parts of the flower the team designs. The pollen person might want to write a description of the pollen and include a number of illustrations with their work. The pollinator authority may choose to construct a three-dimensional model of the pollinator and write a short description of how it transports the pollen.

Once you have selected roles, record the name of the team member by the task each has chosen.

Pollen Expert: _____

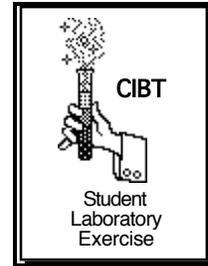
Flower Specialist: _____

Pollinator Authority: _____

As a group, decide on what information you will need and how you can best obtain and share that information.

Your completed models and research will be due on _____.

Flower Dissection



Name: _____ Date: _____

Flower structures can be divided into two groups: the essential organs and the accessory organs. The essential organs are the reproductive structures, the *stamen* and the *pistil*. The accessory organs are the petals and the sepals. They surround and protect the essential organs.

As you study a typical flower, note how the parts are adapted for the production and protection of seeds. In this activity you will:

- (a) examine the external structure of a flower
 - (b) study the arrangement and structure of the male and female reproductive parts of the flower
1. Obtain a single flower and observe its parts carefully. At the tip of the flower stem is a swelling called the *receptacle*. From it, several circles or whorls of parts extend. If present, the *sepals* form the outermost part. They are leaf-like structures and generally green in color. Sometimes the sepals are the same color as the petals or appear to be an extra set of petals of a different hue. Careful examination of the bloom will allow you to detect which are the petals and if there are sepals present. The function of the sepals is to protect the inner part of the flower during the bud stage of development.

The *petals* are found directly inside the sepals. As you know, the color and the odor of the petals is to help attract pollinators. Look into the center of your flower and notice that all the parts are arranged around the center– it is *concentric*. Notice the reproductive parts.
 2. You will be taping the parts of the flower in an arrangement similar to their actual positions when the flower is intact. Gently remove the sepals (if present) and tape them in a large circle on a sheet of plain paper. Be sure to leave enough room for attaching the central flower parts you will add later. Refer to Figure 1 below.

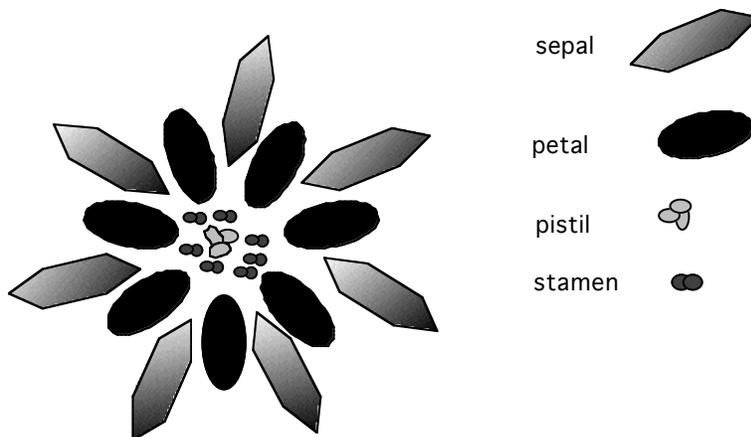


Figure 1: Illustration of Flower Part Arrangement

3. Next, carefully remove the petals. (If a stamen seems to stick to a petal, gently free it and save it for later.) Do the petals have an odor? Arrange the petals in a whorl just inside the circle of sepals on your sheet. Tape them down.
4. The star-like structures just inside the petals are the stamen, the male reproductive organs. The *anther* is the enlarged top of a stamen while the *filament* is the thin structure that supports the anther.

In order for fertilization to occur, the sperm nucleus located in a pollen grain must reach the egg nucleus in the ovule of the pistil. The pollen grain germinates, or grows a long tube down through the pistil after it lands on the sticky, sugary material of the stigma. This germination can be observed if pollen grains are placed in a solution with the proper sugar concentration.

- (a) Place a few drops of germinating solution in the well of a depression slide. Transfer some of the flower's pollen to the slide by gently dunking what is left of it up and down in the germinating solution. Add a cover slip. Immediately observe and sketch the pollen grains according to the directions outlined in steps (b) - (d).
- (b) Focus on the pollen using 100X magnification. Estimate how many pollen grains it would take to form a solid line of pollen across the diameter of the 100X field.
Record this number. _____ pollen grains across the field.
- (c) Next divide this number into the diameter of your 100X field. (If you have never made this determination, place a clear plastic metric ruler on the stage of your microscope just as you would a slide. Using 100X magnification, focus on the metric markings of the ruler.
Estimate the diameter of the field using millimeters and convert it to micrometers (1 millimeter equals 1,000 micrometers.)
The size of a single pollen grain is _____ micrometers.
- (d) Draw a line one centimeter long. This will serve as a reference to scale your pollen illustration. Each one centimeter should represent a distance of 25 micrometers. Using this scale, sketch the pollen observed. On your sketch, indicate the amount of magnification and the actual size of the pollen.
- (e) Check every 3 to 5 minutes to see if any pollen tubes have started to germinate. Sketch pollen with the tube once germination occurs.

If no pollen tubes are visible by the end of the laboratory period, place your slide in a Petri dish and check it the next time you have class. To insure that it remains wet, place a damp paper towel under the slide in the Petri dish before closing it.

5. Remove the male reproductive parts and tape them to your sheet just inside the petals. Label the filament and the anther of one stamen.

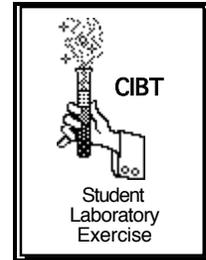
When a stamen is mature, four pollen sacs can typically be observed inside of each anther. Seen through a magnifying glass or dissecting microscope, these pollen sacs look like bulging tubes. Within the pollen sacs are cells that undergo meiosis and form pollen grains. The sperm are produced within the pollen grains. When mature, the sacs burst open releasing the dust-like pollen grains.

6. With a scalpel, carefully cut the pistil from the stem just underneath the ovary. Then cut the ovary in half crosswise. Save the lower part. Place the upper part with the stigma and style still attached in the center of your arrangement and tape it in place. Label the pistil, stigma, style, and ovary.
7. Use a magnifying glass or dissecting microscope to examine the ovary cross-section not taped to your lab sheet. You should notice that within the ovary are hollow chambers where ovules develop. The ovules are attached to the ovary by tissue called the placenta. During pollination, the pollen grains are trapped by the sticky, sugary material of the stigma. A pollen tube grows down through the stigma and style of the pistil to an ovule in the ovary. It creates a passageway for the sperm nucleus formed in the pollen grain. The sperm nucleus enters the ovule and fertilizes the egg nucleus. After fertilization, the ovule forms into a seed. The ovary develops into a fruit and contains all the developing ovules (seeds).

When you have finished arranging, taping, and labeling your flower parts, answer the following questions. Use complete sentences.

1. Does your flower produce more ovules than pollen grains or vice versa? In terms of reproductive success, why would this be important?
2. How is the stigma of your flower adapted to capture and hold pollen? Describe at least two adaptations.
3. Is your flower one that cross-pollinates or self-pollinates? Explain your answer using the size, shape, and location of reproductive parts, as well as, flower color, aroma, and other significant characteristics.

“To form a pollen tube... or not to form a pollen tube”



Name: _____ Date: _____

There are many factors influencing the germination of pollen grains. Sugar solution concentration is one of these. Various pollens differ in their requirements. Some will produce pollen tubes in 5% sugar solutions while others require 35% solutions. Some pollen will not germinate unless it is activated by enzymes and other chemicals present in the stigma of flowers of its species. Whether or not the pollen is old, has had its protoplasm consumed by fungi, or has been destroyed by some other agent must all be considered. It is now time for you to design and carry out your own scientifically controlled investigation of pollen. You can work with the pollen of one species or many. You can work with any of the variables mentioned in this paragraph or, you can discuss with your teacher an idea you have and would like to investigate.

Write your experiment so that it includes: an hypothesis, a list of materials, and step-by-step procedures. Submit your design to your teacher for discussion. Once you have received approval, you may begin!

Be sure to keep careful records of your procedures and results. Your final lab report should contain the following sections:

- **Abstract**

This is usually found at the beginning of a report and is an overview of the research described in detail in the report. It should provide enough information so that the reader will know what the report is about and make them want to read further. One or two paragraphs should be adequate.

- **Introduction**

A number of items are included here. There should be background information about the problem being researched. In this case it would be information regarding pollen tube germination and the variable you have selected to test. Citations from the literature should appear in this section and can be in one of two forms:

- a) Smith (1995) found that...
- b) It was noted that... (Smith, 1995).

This way, if readers want more information they can look up the articles by Smith. More details about the source will appear in the Literature Cited section of the report. Other things covered in the introduction are the reason for conducting the experiment and the hypothesis or research question.

- **Methods or Procedures**

The procedures used in the experiment should be reported in a clear, step-by-step manner. This section should be written in enough detail that anyone reading the report would be able to replicate the experiment.

- **Data or Results**

It is in this section that the results of the experiment are reported in writing and supported with tables and figures. The inclusion of tables and figures without any written description of the findings is not acceptable. The written report is what details the findings while tables and charts provide a visual overview. Table titles are printed above the table and the word “Table” is always capitalized. When a table is discussed in the text of the report, it is also capitalized. The titles of figures are printed under the figure and are also capitalized.

- **Discussion and Conclusion**

First state any conclusions you feel can be made based on your experimental results. This should relate back to the hypothesis or research question. Background information should be included to support any conclusion. This section should also include a discussion concerning how sure you can be of your conclusions, what may have been inferred, assumed but may not be true, what else needs to be done to support your conclusion(s), and what new questions are now apparent.

- **Literature Cited**

This is a list, arranged alphabetically by authors’ last name, of all of the articles cited in the report.