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# Pollination Party

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## Introduction

Before I was a classroom teacher, I was an environmental educator on the Hudson River in Yonkers, NY. I pursued this career in particular because of the ways that it combined my love of teaching with my love of the outdoors, and it allowed me to engage with the local community in place-based nature programming. In moving from the outdoor classroom to the formal classroom, I found an even more powerful way to share a love of learning and foster more purposeful care of the natural world. One aspect of the natural world that is abstract, and often difficult to teach, is the many ways in which systems and cycles exist in nature. An example of an interconnected system is pollination, which is vital to global biodiversity and health, let alone food supply, medical fields, climate impacts, and more. Students in grades K-2 study pollinators in various forms in Virginia, but there are few resources in the curriculum used at my school that help students understand the ways in which pollinators function as a vital component in the health of local ecosystems. In this curriculum unit, I plan to use a One Health approach to teach my kindergarten students about pollination so that they are able to articulate its structures, functions, participants and behaviors in an age-appropriate way. While this scientific content knowledge itself is essential, it is also important to me that my students take away an essential understanding that as humans, we are not superior to the natural world—we must function equitably alongside other living things in order to maintain our own health, and the health of the natural ecosystem as a whole. Within the One Health model, we must focus on the health of the entire system because all living organisms are interdependent on one another. By focusing on these aspects, I hope to both improve my students' pollination systems knowledge, and action-plan realistic ways that we can support our health of our local pollinators at the school and community levels.

## Rationale

John B. Cary (JBC) Elementary School is a public elementary school in the Richmond Public Schools (RPS) District in Richmond, Virginia.[1] It is one of 25 elementary schools in the district, which also includes 1 charter school, 7 middle schools, 5 high schools, 3 specialty schools, and 5 preschools. The district serves roughly 21,000 students across the city of Richmond with a graduation rate of 74% for the 2022-2023 school year.

During the 2022-23 school year, 263 students were enrolled in JBC across grades K-5. Of those students, 49.8% identified as Black, 32.7% identified as white, 8.7% identified as Hispanic, 8.4% identified as multiple races, and 0.4% identified as Asian. Also, 11.8% of students were classified as students with disabilities who receive exceptional education services, and 54% of students were classified as "economically disadvantaged." English language learners accounted for 4.6% of students. JBC was accredited for 2022.

In 1954, JBC moved to its current location at 3021 Maplewood Avenue amidst school segregation in Richmond when its former location was renamed the West End School, which was to be used for Black students. JBC was opened as its segregated counterpart for white students, and it remained segregated until a shift to open enrollment in 1969, which was petitioned by a local group of citizens to the School Board. The school remains at its 3021 Maplewood Avenue location as an open enrollment school, though RPS considered closing the school due to low enrollment in 2012—in this year less than 39% of children who lived within the JBC school zone actually attended the school. Given the large number of city neighborhoods that JBC draws from, strong, effective teaching has the potential to impact students from different communities across Richmond. Additionally, focusing on pollination in an urban setting where over half the school is economically disadvantaged could have important impacts on the health of students and their families.

One unique aspect of JBC is that it was distinguished as a US Department of Education Green Ribbon School for the 2021-22 school year. Receiving this recognition award means that a school has engaged in "cost-saving, health promoting, and performance-enhancing sustainability practices…it is a one-time recognition of an institution's progress in the award's three sustainability focused pillars."[2] The school was able to show sustainability practices related to the three pillars of the Green Ribbon program, which are 1) reduce environmental impacts, 2) improve health and wellness, and 3) engage in environmental and sustainability education.

The school website describes the following ways in which being a Green School benefits the school community:

- "Green schools teach students about sustainability and the environment, giving them the tools to solve the global challenges we face now and in the future.
- Green schools support sustainability literacy through curriculum and instructional practices that are interdisciplinary, place-based and rooted in real-world context.
- Green school buildings are better for the planet because they reduce environmental impact, conserve resources and contribute to educating the next generation of environmental stewards.
- Green school buildings are better for communities because the process of creating greener schools requires learning, collaboration and engagement from the entire school community. The result of this process is a healthy, sustainable environment for learning and working that often becomes a source of civic pride."

JBC has a large campus bordering Byrd Park and has ample green space for community and school use. Outdoor spaces include open grass fields, a swing set, two playgrounds, a community garden, a butterfly garden, a Monarch waystation stop, a reforested plot of land, orienteering markers, and picnic areas (covered and uncovered).

JBC has many community partnerships through which it facilitated its work towards the three pillars of a Green School, including but not limited to the Chesapeake Bay Foundation, a local chapter of Kiwanis International, the Lewis Ginter Botanical Gardens, Fit for Kids, First Lady Pam Northam, and the Maymont Foundation. The

participation of these groups is documented in a mural painted near the community garden that is outside the school cafeteria, which highlights local produce and promotes recognition of produce that might be grown in the garden. A sign in front of the school boasts that JBC is a “No Child Left Inside School,” which is a program facilitated by the Chesapeake Bay Foundation in an effort to get school children into nature as much as possible. Though a direction or cohesive program has not yet been developed for these partnerships with the entire school community, some of these partners continued working with the student body at JBC in the 2022-23 school year when I joined JBC in the fall of 2022.

Though there are several active partnerships, there are very little means by which students or school members take responsibility for the work that has begun with support from the outside groups. For example, Fit for Kids is a local nonprofit that is the primary sponsor of JBC’s community garden, which their program describes as a “learning garden.” Fit for Kids Garden Educators utilize the VA Standards of Learning in garden lessons at partner schools, each of which they visit 24 times during the school year. A teacher who serves as the garden coordinator supports Fit for Kids in creating a schedule so that all classes have the opportunity to visit the garden programming on a bi-weekly basis. At JBC, Fit for Kids also hosts an after-school gardening club that meets once a week in the fall and spring. The role of garden coordinator does not extend beyond scheduling classes and attending gardening club at JBC at this time. Students and/or staff do not intentionally participate in the garden outside of their slotted gardening times, and there are not necessarily any explicit connections being made to the classroom curriculum.

Given that the same grade-level standards are being utilized by the program and the school, it would seem that more explicit and intentional connections could be made to helps students see sustainability as an overarching theme within the school community. I also would like to develop more concrete means of collecting qualitative data of science knowledge, such as pre- and post-assessments about science knowledge like pollination (the focus of this unit) —currently K-2 in RPS do not follow a formalized science curriculum, but rather create materials on a school-by-school basis to meet standards. At a time when RPS Science SOL scores are very low, we cannot allow our K-2 students to move to higher grades without science content knowledge and the ability to connect science to their own lives.

Through this unit, I hope to introduce my kindergarteners to all of the nature that we have at JBC, and to provide students with the opportunity to take greater investment in our ecological community at Cary. I want to inspire them to be active participants in caring for our local natural ecosystem—it benefits our local and global ecological health as a community. I would like to focus on the essential understanding that humans within these natural systems have the ability and onus to make purposeful choices which benefit nature, rather than just exploiting it. I hope that by modeling this type of teacher and student learning in kindergarten, we will be able to create more implicit curriculum connections and whole school structures at JBC that produce students who care about their natural world with equity, and understand the ways in which they can actively support more sustainable practices, even in kindergarten. The unit will culminate in a community action plan developed by the class with intentional steps we can take to keep our local pollinators (and our class) healthier all year.

## Learning Objectives

In writing this unit, I hope to provide a purposeful and explicit pathway through which my kindergarten students are able to study pollination as a natural system. I've entitled it Pollination Party as an inviting and fun way to introduce the many roles, activities, and community members that are a part of the process of pollination. I want to explore topics that expose my kindergarteners to explicit scientific knowledge and model a One Health approach in caring for the health of our local environment at school. In this way, we are working on building academic and social-emotional skills, which heavily impact the kindergarten setting because it can be the first true school experience for many students. By focusing on pollination, I hope to provide a clear example of a system that students may be familiar with, such as bees and flowers, and build on the visible and invisible ways we interact with pollination at school. The health of our pollinators directly impacts our own health!

## Biodiversity and Pollination

Before we can go to the pollination party, we have to get ready by exploring why this topic should matter to us and our students. Don't worry-- I'll still give you time to get your party outfit ready!

Biodiversity is Earth's living variety in all of its forms and interactions. Biodiversity spans across many levels of organisms, including genes, species, communities, and ecosystems, where interactions occur with the local physical environment. The interactions of all of these levels and environments in our local communities feed into global biodiversity. We seek to have classrooms that are "biodiverse" in composition because these are the strongest learning communities, giving our students windows and mirrors for deeper learning and understanding.[3]

We can see biodiversity out of our classroom window by looking at all the plants, animals, and other living organisms. The air we breathe, the water we drink, and the food we eat are all dependent on the robustness of our biodiversity. Studies of ecosystems show innumerable interactions from the tiniest of microbes to the largest of mammals that foster the sustainability of our living Earth.

One such system of interactions is pollination. Many plants use seeds as a means of reproducing and spreading new plants. Flowers use pollination to make their seeds. The process of pollination is a mutually beneficial interaction between flowering plants and pollinators. Pollination occurs between flowers that are of the same species. Insect pollinators seek nectar (i.e. carbohydrates) or pollen (i.e. protein) from flowers. While the pollinators eat, they contact pollen through specific behaviors or body structures which allow them to carry and share pollen between the flowers they visit.[4]

For example, bees perform a specific behavior to get pollen out of some flowers. Plants like tomatoes release their pollen through two smalls holes in each anther. To help the plants release the pollen, bees bite the anthers and buzz to shake out the pollen. The buzz is a middle C tone, which can shake free thousands of pollen granules from a flower in just one second. Bees also have structural adaptations that help them retrieve and carry pollen. Bees have tiny hairs that make them look fuzzy. The hairs are primarily on the bee's

abdomen and legs, which helps them collect pollen on their bodies. The bees transfer pollen between the flowers they visit when pollen falls off or sticks to their hairs. Bees also use these hairs to carry nectar and pollen back to their nests to feed the hive.[5] These adaptations enhance bees' pollination efforts.

But pollinators are not the only ones with adaptations. Plants and pollinators have been evolving together for millions of years, resulting in many physical adaptations. These adaptations help attract pollinators to the plants (see Figure 1).[6]

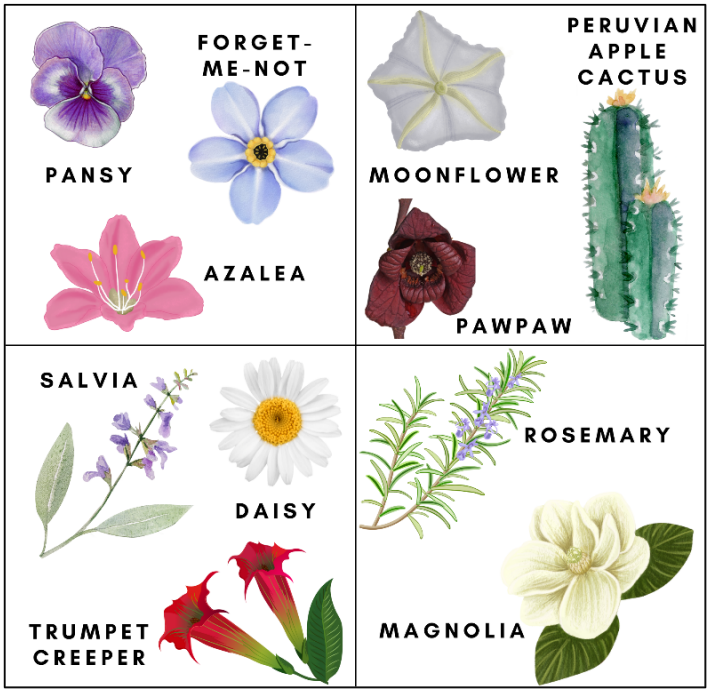


Figure 1. Shown are flowers with adaptations that attract pollinators.

Pansies, Azaleas, and Forget-Me-Nots are all examples of flowers that use their bright colors to attract pollinators. The colors of flowers often lead pollinators to the areas of nectar with patterns and pathways. Think of how common it is for the centers of flowers to be bright yellow—this is intentional attraction! Bees are particularly attracted to blue, violet, and purple flowers. It is no coincidence that flowers in the violet-blue shades make the highest amount of nectar. These flowers capitalize on bees' unique and complex sight systems. Though humans can see more colors than bees, bees are able to see a broader range of vision, including ultraviolet light. Some of the patterns on flowers appear in ultraviolet light, making them invisible to humans' naked eyes. For example, pansies have a nectar bullseye pattern but it is only visible in ultraviolet light. These patterns help pollinators easily find a plant's source of pollen and nectar.[7]

Some plants use their smells (both good and very bad) to attract pollinators. Flowers release scents to let pollinators know that they are ready for pollination. The Moonflower releases a sweet, dreamy smell into the air to attract nighttime pollinators like moths and bats. Pawpaw flowers smell like rotting flesh, which attracts carrion flies and scavenger beetles to pollinate them. Peruvian Apple Cactus releases a sweet scent as well, but for one night only! Local bats or moths will make their way to this plant on one evening a year.

In addition to their patterns, colors, and smells, some flowers have physical structures that support pollinators landing on them. The center of flowers like a Daisy are an easy landing pad for pollinators. Salvia flowers have a special mechanism for distributing pollen to pollinators in which a stamen acts a lever. When the pollinator

pushes into the flower's lower lever arm, the stamen drops a pollen packet. This is then pressed onto the pollinator by the upper lever arm, and is usually dropped on the top of the pollinator or its head. Salvia attracts a range of pollinators including bees, butterflies, and hummingbirds. The trumpet flower is shared like a long bell, which is the perfect shape for the long skinny beak of a hummingbird to pollinate it.

Other ways that flowers have adapted in ways that support pollinators include the location where they grow, or the timing during which they bloom. Magnolia flowers bloom near the ground or on lower portions of the plant to attract beetles from the ground. Some pollinators like the monarch butterflies will travel thousands of miles in migration, following the location of milkweed growth north from Mexico. Rosemary is an important early source of nectar and pollen for many pollinators, blooming as early as midwinter in some places because it can withstand cold temperatures. It also continues to bloom throughout spring and summer, making it a reliable food source for pollinators across seasons.

Adaptations like these help plants attract the maximum number of pollinators to their flowers. The more times a plant is visited by a pollinator, the more chances it has to make seeds. But the plants are not alone in needing pollinators. Without pollinators, most flowers would be unable to fertilize their seeds, meaning that there would be no fruit or nuts to consume. This would significantly impact the food sources of both humans and animals alike. Pollinators are responsible for nearly 1/3 of the food on our human plate, covering over 140 different crop plants.[8] Pollinators have an estimated market value of up to $577 billion USD annually, which represents about 10% of the global crop market.[9] Produce like apples, almonds, oranges, avocados, peaches, pears, plums, cherries, alfalfa, blueberries, vanilla, cranberries, tomatoes, kiwi, figs, coffee, strawberries, blackberries, raspberries, lemons, limes, eggplants, kumquats, nectarines, grapes, and cacao all depend on pollinators.[10] In regards to nutrients for health, pollinator-dependent plants contain more than 90% of the world's vitamin C, 100% of lycopene, and almost all of antioxidants b-cryptoxanthin and b-tocopherol, most of the lipid (74%), vitamin A (>70%), and related cartenoids (98%), calcium (58%), fluoride (62%), and folic acid (55%). This data implies that declines in pollinator populations could increase preventable human diseases that are linked to nutrient-rich diets, especially in places already vulnerable to nutrient deficiencies.[11]

Despite the vital role of pollinators in biodiversity and their impact on global food supply, medicine, and more, human beings have not acted as a collective to prioritize pollinator health. Human development has caused damage to pollinator populations through habitat loss, monoculture farming, and pesticide use. Many urban conservation efforts focus on connecting people to nature, such as through outreach, recreation facilities, and education initiatives, but these have not resulted in the change needed to keep pollinators healthy.[12] In my research of this topic, I observed that many of these programs also focus on one group of species, such as bees or butterflies. While I recognize the benefits of focusing on one core species, I wonder if are participants walking away with an understanding of the interdependencies that one species fosters? Ecosystems are critically interconnected, and can require changes across the entire system to create effective, healthy change. I work a second job as an outdoor educator for my local parks and recreation department, and I regularly observe that participants are excited to learn about nature, but there is often little follow through in connecting this learning to actionable efforts or changed behaviors in the local community. In other words, it isn't enough. We need to be doing something more intentional, more impactful, and in my opinion, more actionable. And I think it requires community participation. Just like my classroom shows more learning growth when all students are participating, our collective goals can be accomplished if local citizens are actually participating in bettering community health.

Many of the connections between the animal, plant, and human world happen in invisible ways, which can

make them challenging to teach. I have taught exceptional educations learners explicitly for the past 7 years and this challenge is only amplified for these students. Studies have shown that our students are not able to articulate scientific knowledge that is critical to understanding the ways that living organisms are interacting in systems like pollination.[13] Our students make transparent and non-transparent choices every day that can impact their health. It is critical that we are teaching science in a way that makes it visible and relevant to students. If students are not able to understand processes like pollination, they are not able to make the most impactful changes in their communities to support pollinators.

In a study conducted on college students majoring in biology, students in the study frequently intermingled the separate processes of fertilization, pollination, and seed dispersal. Students were often unable to articulate how plants are pollinated, and were not able to show specific content knowledge about the topic.[14] I reference this study in particular because the authors recommend implementing a Pollination Systems Knowledge Assessment (PKSA) to assess levels of pollination knowledge and to identify what parts of the pollination systems learner's struggle to understand.[15] The PKSA was designed to be adapted across grade levels so that educators can choose assessment components that relate to their content at an age-appropriate level. This is a first step towards helping teachers understand more concretely what their students do and do not know about pollination, which could lead to improved science instruction across education with coordinated efforts at data collection. Regardless of the broader impacts, we utilize pre- and post-assessments frequently in the classroom! Implementing more data-based instruction in science at my school is a high need based off students' overall low science standards of learning assessment scores over the past five years of instruction.

I think it is important to also note here that even the experts aren't exactly clear on what students really need to know—for example, the Entomological Society of America, the largest academic society of entomologists (aka people who study insects), has no formal criteria or standards for what students should know about pollination or pollination conservation. There is no systematic method for us to determine the success of implemented interventions in terms of pollination systems knowledge gains, nor to identify learners' misconceptions regarding pollinator knowledge that may hinder pollinator conservation behaviors.[16] And this just focuses on the bees! Even less is known about what students really know about other pollinators, like birds, bats, or moths.

A quick aside about answering their questions: please check the science! It is important that while I educate students on these topics to build their care in nature, I am also informing them of factual scientific knowledge. For example, I chose a book as a mentor text for this unit whose author included a set of references and research that she based her book on. Her sources include field guides, the US Forest Service, nature centers, and more. Kindergarteners are capable of learning about topics in detail, and trust me, they will have lots of questions! It is important that I am answering their questions to the best of my ability based on up to date, factual research.

Let me give you a fun mocktail fact to bring with you to the pollination party. Why do giraffes have long necks? (I'll give you a second to think and hopefully you did not skim ahead like your favorite sparkler in the classroom always does). You probably said it's because they need long necks to reach the tall trees in their environment, but you and I were both wrong. There is greater evidence that giraffes actually have long necks as an evolutionary adaptation related to reproduction; stronger and longer necks make male giraffes better fighters, when swinging their necks in battles to entice the attention of possible female-giraffe mates. You should go Google giraffe fights right now because if you were like me, you have never seen this before. I went to a few local bookstores after learning this to check out science books in the children's section for this giraffe

fact. Out of the ten books I picked up from the nonfiction section, all ten said giraffes have long necks to reach the leaves on tall trees. For me, this highlights the importance of doing content research; the reason you are reading this right now is to be an expert on these topics! It also points me towards making sure I am picking high-quality science or nonfiction texts to share with my students, where the science is accurate or most-reflective of current research.

Pollination is a very complex system, but there are ways to make it understandable for our students both in their real environment and through the use of visuals, like picture books, models, drawings, and photographs. Many of its structures are not visible to the naked eye and require specific scientific content knowledge to explain. I think it is important for me as a to discuss pollination in age-appropriate language, but I do not want to oversimplify it as a system for them. Building curious scientists starts in kindergarten!

## The Centerpiece

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The first guest we need to talk about is flowers, often a staple centerpiece at parties. Flowers (or angiosperms) are one of the drivers of evolution and without them, our living world would look and function vastly different. Angiosperms are a very successful group of plants because the structures of their flowers can take on many different forms and functions, allowing angiosperms to be highly biodiverse and speciose (containing many species). This variation in angiosperms can drive changes in biology through their interactions with one another as well as through their interactions with other living species.[17] In other words, angiosperms are inspiring co-evolution, which is the interaction between species that causes new traits to evolve. Angiosperms have biodiversity, and they also drive biodiversity in other species.

Keep in mind that yes, we are hosting a kindergarten party, but I think a moment spent here on flowers is important because our attention to them in my experience in primary grades has been very brief and simplistic compared to what I uncovered in my research.

Scientists have long studied and made assumptions about the ways that angiosperms have impacted biodiversity and ecosystems since their appearance 50 to 100 million years ago. Angiosperms have played an important evolutionary role in building forests and other habitats on land in addition to the more technical ways they have and continue to influence natural selection. Flowering plants became more common in the Cretaceous period, which aligned with the last 70 million years of the dinosaurs. It was after dinosaurs disappeared, perhaps when they were done trampling across them, when angiosperms really took off.[18] Thanks to this Angiosperm Terrestrial Revolution, more than a million species of modern insects evolved, including pollinators.

Angiosperms have biological features that have supported their own evolutionary success, such as special colors or other flower adaptations that attract pollinators and support pollination. We saw evidence of many of these in the section above (Fig. 1). But they also are an evolutionary driver for the organisms that pollinate them, as well as builders of special ecosystem structures to make homes and niches for endless species. Think of rainforests as a prime example. There are tens more species on each hectare of the Earth’s surface because of angiosperms. In turn, pollinators are responsible for important ecosystem roles, such as producing food, cleaning the air, stabilizing soil, or protecting from severe weather.[19]

So for this party, flowers are not just the centerpieces. They are *very* important guests. Flowers in the garden support a biodiverse ecosystem by attracting pollinators, providing coverage for plants, and helping the system adapt when needed. Let's get to know them a little bit better.[20]

The stamen is the male part of a flower (see Figure 2).[21] The stamen inside a flower makes fluffy granules called pollen. The pistil is the female part of a flower. It has a sticky stigma at the top, and tiny ovules inside the ovary at the bottom, which are eggs.

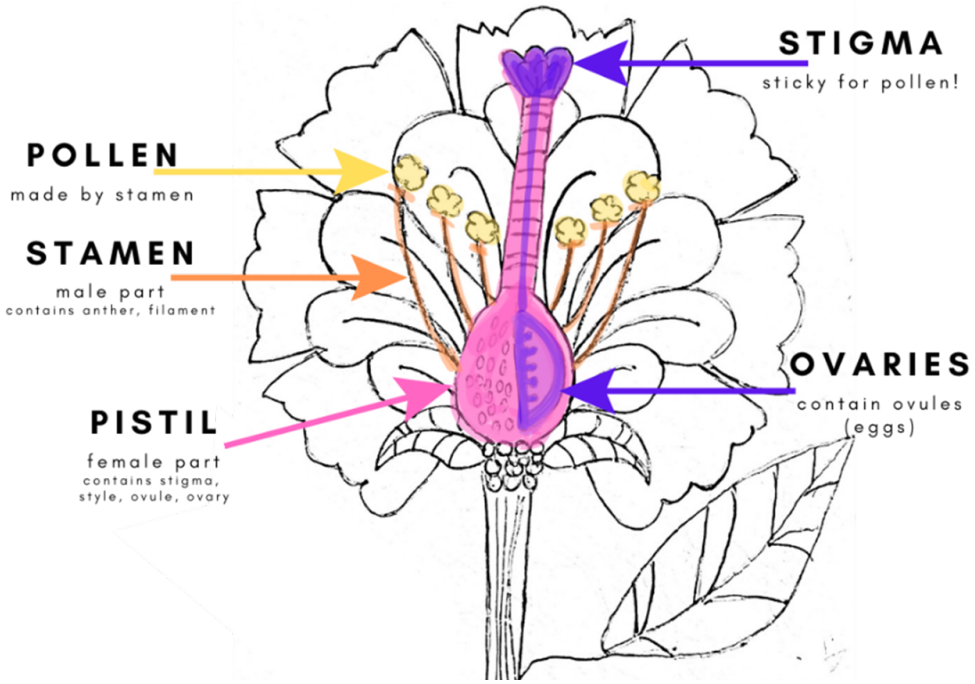


Figure 2. This diagram shows the parts of a plant used for pollination.

For flowers that require pollination, pollen has to land on the stigma for them to make a seed. Pollination occurs between flowers that are the same type, or species. Some flowers are self-pollinating, which means they can make their seeds by themselves, such as sunflowers for example. Many flowers need cross-pollination, which means that they need pollen from another plant to make their seeds. 75-95% of flowering plants require support with pollination.[22]

Pollination occurs when pollen is placed on the stigma. This is the first step towards a plant being able to make a seed. Fertilization occurs when the pollen makes it down the style (tube) into the ovary, and connects with an ovule (or egg). The pollen and the ovule each contribute half of the genetic information needed to make a seed.

Once the ovule and pollen meet, a new seed begins to grow. The flower changes as the seed gets bigger, such as its petals wilting and falling off. A pod or fruit grows in its place to protect the seed. There are a variety of ways that seeds get dispersed from flowers, including falling out of the pod, getting eaten and dispersed by animals, or traveling with the help of weather. Some seeds have structural adaptations that help them disperse, like maple seeds that have wings to help them move through the air or burdock seedpods that have burrs to help them stick to passing animals.

## Pollinators

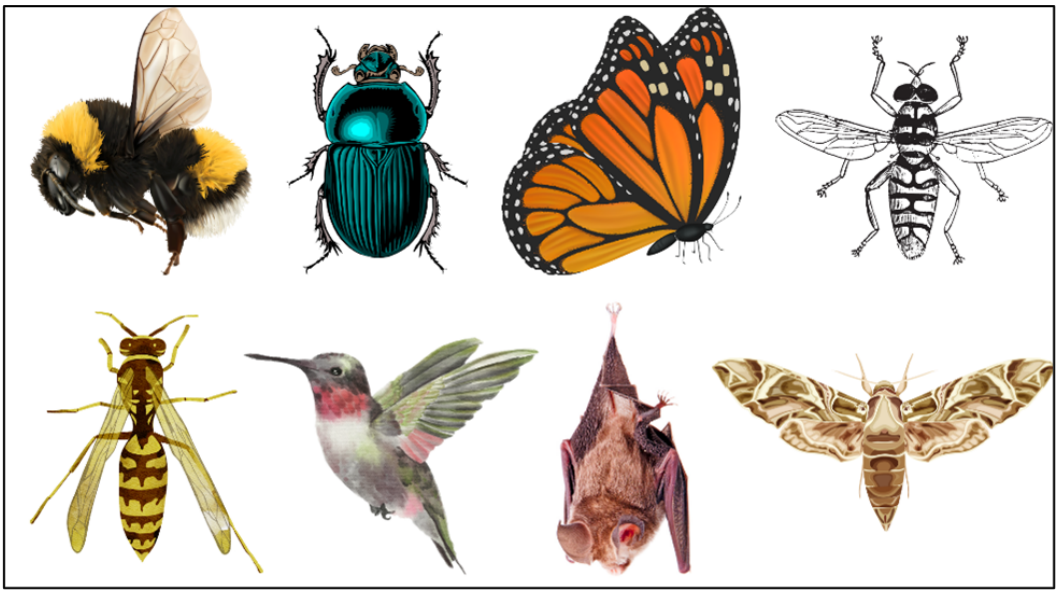

Figure 3. Some examples of pollinators include: bees, beetles, butterflies, flies, wasps, birds, bats, and moths.

It would be most impactful in this unit to teach your students about pollinators that are local to your school community, but in the absence of having that data to utilize, I have surveyed a broad range of possible pollinators that could be invited to the pollination party. [23] Below I'll give a brief sketch of common pollinators that may be included for the academic content in this unit. See Figure 3 above for some examples of these pollinators.[24]

What I might call the most popular or well-known pollinator is the bee. Bees are generally not particular about the kinds of flowers they will visit and pollinate a wide variety of plants. The nectar from flowers gives bees the energy they need to fly, as well as giving important nutrients to bee larvae in the hive. Many conservation efforts are focused on the honeybee, but there are many native bees that don't get all the buzz!

Beetles are pollinators that tend to stick to flowers that are near the ground, like magnolias. They are not the most intentional pollinators, often clumsy in nature. Beetles are also important scavengers to have in an ecosystem!

Butterflies prefer round flowers with long throats holding nectar, sticking their tongues down the tubes to reach their food. Salvia flowers are an example of this type of shape. Certain kinds of butterflies have relationships with specific plants, such as the Zebra Swallowtail butterfly and the Pawpaw plant. Watch out for the munching caterpillars these guests might bring to a garden! Butterflies also highlight the ways that a pollinator may need a plant for various reasons throughout its life cycle, such as being a safe spot to lay eggs, leaves serving as food for larvae, or the return of an adult to the plant for nectar or pollen.

Flies—they are not the most beautiful pollinator, but flies love scents! They are attracted to both sweet-smelling flowers as well as putrid smelling flowers, as well as liking weird flower textures. Many people regard flies just as pests, but they have an important job as pollinators.

Wasps are less effective pollinators than bees because they lack the fuzzy hairs that help bees transfer pollen. Wasps are an important guest to consider though because they will continue to pollinate in the absence of bees. They require high amounts of energy from nectar and pollen, which means they visit a wide variety of and number of flowers.

Hummingbirds are also a big fan of tube-like flower structures for their long thin beaks and tongues. The only hummingbird that breeds in my region of the East Coast of the United States is the Ruby-throated hummingbird. It travels up from Central and South America to reproduce. Hummingbirds love flowers like honeysuckle.

Bats are more common pollinators in tropical or desert climates, with some species like the Mexican long-tongued bat migrating thousands of miles to pollinate. Bats are responsible for the pollination of many tropical fruits like guava, mango, and bananas. They are very important members of an ecosystem for pest mitigation, eating thousands of insects nightly like mosquitoes and those that they find inside flowers. Bats usually like large white-colored flowers that open at night.

Did you know that there are ten moths for every one butterfly? Despite their greater variety, moths are not highlighted in many conservation campaigns or used widely as a representative for pollinators in children's literature or nonfiction. One reason for this may be that we do not visually see them as often because they tend to come out at night. They may not stand out as much as butterflies because they tend to have duller colors like browns, grays, and yellows. Moths are ideal pollinators for night-blooming flowers, especially sweet-smelling blooms or white and cream-colored petals-- these colors reflect moonlight, making them easier for moths to see in the night!

Now it's not a living organism, but you may want to consider inviting wind to your pollination party! Wind is responsible for pollination of many plants that produce grains and nuts, and of trees and grasses. Every kernel of corn on a cob is due to successful wind pollination. Wind also is an important pollinator for many of the grassy fields that livestock forage.

## Who else is at the party?

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So far, we have the following guests on our invited list: flowers, pollinators, and of course, ourselves! But we cannot forget all of the other important members of our ecosystem that help create healthy systems of pollination. We can consider all of these guests "fellow gardeners."[25]

**Plants**

We have explicitly discussed flowers, but they are not the only plants we should consider when discussing pollination with our students. I am framing our learning by using the garden as an example of a pollination system. Within the garden, there are flowering plants, as well as others that we may want to highlight. Trees give important shade, and attract community members like birds. Grasses attract insects and can help provide important niches in an ecosystem for these tiny organisms. Fungi and trees also provide nutrient networks for ecosystems, sharing and exchanging nutrients between their root systems. A mindful educator is also considering here native versus nonnative species—should there be any plants we leave out of our party

because they could be damaging to the local ecosystem?

**Other Animals**

Pollinators have been discussed in detail above, but there are many other animals that play a role in the health of pollination systems. Animals act as important seed dispersers, pooping out seeds that they have digested from plants and fruits. They also help mitigate pests in the garden. For example, ladybugs eat aphids that can destroy vegetation in gardens from their pesky munching. In terms of typical garden pests that we know damage plants, think about how we can invite the "good" bugs in—these pest-destroyers can vastly outnumber pests when they are given room to thrive and invited to the space. Earthworms help keep soil healthy by processing it and providing nutrients. Sometimes animals like deer are the pests that humans see in the garden, eating food being grown for human consumption. In planning my garden, I'm wondering if we should plan a way to include those local eaters, or will we exclude them from the garden with structures. As I learn more this year about what local eaters visit our school garden, I should have a better answer to that question!

**Soil**

Healthy soil is vital for a thriving pollination system. Fungi, innumerable bacteria, and other microbes occupy soil, sharing the space to help plants grow. An estimated 10 trillion bacteria can live in the top six inches of a square meter of well-tended garden soil.[26] These members help to aerate the ground, cycle nutrients, and mix soil's mineral and organic parts together. They are critical to helping balance food webs, recycling energy and nutrients to keep the ecosystem in balance. For example, rhizobial bacteria can take nitrogen gas from the air and convert it into a form of nitrogen that plants can use. Bacteria such as these provide nutrients that plants would not be able to use otherwise; they also help control harmful bacteria. Mycorrhizae fungi form on the outside surfaces of roots, penetrating between the root cells without damaging them to help with nutrient and water exchange. Fungi are important decomposers in the garden as well. Here it is also important to consider what we are adding to soil to help with nutrient exchange, such as fertilizers, pesticides, mulch or other additives like plant food. There are many ways to amend soil that is lacking in nutrients, density, or richness. For example, adding earthworms to tunnel in topsoil helps with drainage and nutrients from their castings. Organic matter like compost helps create humus where vegetable matter decomposes—think about all the tomatoes that drop in a garden! Keeping pesticides out of the garden is important for ecosystem health as well. There is increasing evidence of the damage that pesticides cause to human, animal, and environmental health. Educating students about pesticide use in soil and on plants can help them to be more mindful consumers and eaters. It is important for students to understand that soil is not just dirt, and it needs our care as well!

## Pollinators and Us

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Pollinators are vital and valuable members of our ecological communities, both at the local and global scales. Pollinators impact our health as humans in a variety of ways, including environmental quality, food access, or medicinal products and research. This diagram is a helpful visual to see the ways that pollinator health and human health interact.[27]

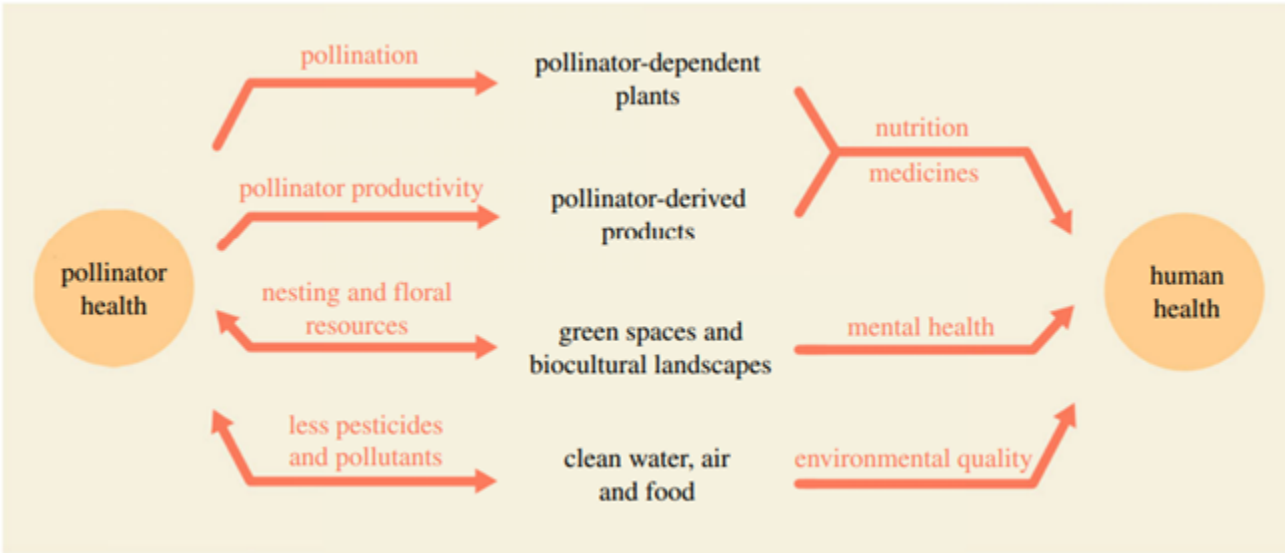


Figure 4. This diagram shows links between pollinator health and human health.

Both human health and pollinator health are dependent on plants, products, green spaces or landscapes, and clean water, air, and food. Current research shows that globally pollinators have experienced loss of habitat, chemical misuse, negative impacts from introduced or invasive species, and diseases or parasites.[28]

From an anthropomorphic perspective, pollinators impact overall environmental quality, which includes access to nutrition and access to products from plants like medicine. Pollinator impact extends to prevention of disease as well in relation to medicinal research on plants. There is also research that continues to be done on the positive psychological effects resulting from access to nature or green spaces.

With all the health that hangs in the balance, it saddens me to share that many pollinators are considered federally "listed species" in the United States, meaning that data shows these some of these organisms are beginning to disappear in their natural environments. In the past ten years alone, the United States has lost more than 50% of its managed honeybee colonies due to disease like Colony Collapse Disorder or due to impacts from pesticides and monoculture farming. Land use is a big driver of habitat loss and lack of forage space for pollinators like bees. Pollinators need foraging habitats with diverse plants that provide nectar. Activities like farming, housing development, and road construction can fragment pollinator habitats, breaking apart foraging spaces from where a pollinator lives. Pollinators are most healthy when they have access to a nearby range of food and access to clean, shallow water. I can't say that we are purposefully doing either of those things in our school green spaces right now. If human activities can disrupt natural systems, then we can also use our actions to restore them. When I think about caring for pollinators in cities like Richmond, I recognize we will have to transform our local landscape for a healthy pollination system. Though my school has taken steps in the right direction, we really haven't included nature's voice in our "greening." Urban development and its large-scale transformations of landscapes are responsible for high rate of species' extinction, particularly extensive and persistent losses of native species.[29]

Climate change could lead to even more negative effects on pollinators than those that we already have evidence of. There is risk of pollination-systems collapse if native pollinators are not integrated more into agricultural systems. A loss of pollinators, or lack of their diversity, could mean the loss of the co-evolved plants that depend on them as well as the loss of general plants that require animal or insect support for reproduction.[30] Loss of pollinator and plant diversity should be a grave ecological concern, but it certainly isn't

something I've ever really considered discussing in my classroom. Now my mind is changed.

Some global communities like the European Union are investing significant funding into the status of their pollinators, though it cannot be said that they United States has done the same at this time. We can act at the local level though! And it is through this lens that I present this unit to my kindergartners. It's a party! We can't be all doom and gloom.

## We can change.

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We have the ability to change the way we interact with the natural world. The overall health of Earth depends on the choices we make as human beings. Humans, plants, and animals all matter equally. We have to care for one another to stay healthy.

Our individual practices can benefit pollinators, such as: planting a diversity of flowering plants, preserving natural habitats, boosting nest sites for native pollinators, and reducing pesticide use.[31] Within the city, our individual yard choices impact the health of urban pollinators, which in turn impacts our human health. Further steps to support pollinators includes purposeful planting, such as planting companion flowers on the edges of gardens to attract pollinators, or advocating for public initiatives like Bee Cities, which work through existing city government structures to create pollinator pathways and facilitate mitigation efforts at the city level. In kindergarten, impacting individual choices starts at observation of and caring for our natural world. Observing nature helps us make invisible processes more transparent, brings awareness of our living and nonliving community members, and supports positive mental health. It helps students make concrete connections between the science they are learning in the classroom and the living processes that are happening outside the classroom window. We know that individual practices alone are not enough, as shown in many climate change mitigation efforts; however, the pedagogy shift that happens at the individual level matters. Teaching students through the lens of a One Health Model is one way to help change focus on the health of the individual to focus on the health of the community as a whole.

The US Centers for Disease Control and Prevention and the One Health Commission defines the One Health model as "a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment."[32] To put this in simpler terms, One Health is a model that seeks to ensure the well-being of people, animals and the environment through collaborative problem-solving.

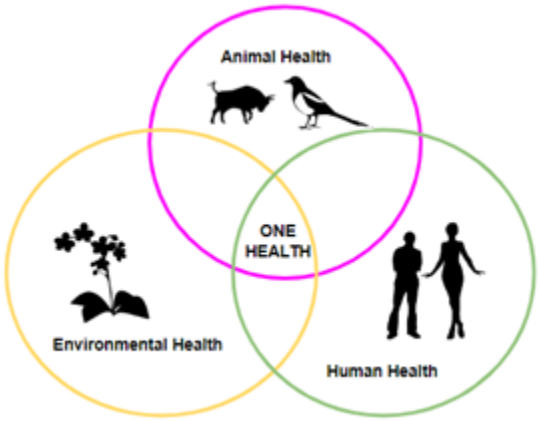


Figure 5. This image displays the One Health Model. (credit: Aliyah Hoye)

Within One Health, problem-solving focuses on the consequences, responses, and actions between these three circles of humans, animals, and ecosystems. One Health requires interdisciplinary collaboration, though it has yet to be taught broadly in medical schools, let alone in other areas of colleges or universities. By introducing this kind of thinking in kindergarten, I hope to inspire more students to think about the environment, animals, and humans equally. Just like we want to treat one another equitably in the classroom, we want to treat nature equitably.

Problem-solving within the One Health model sees community as a shared resource, and solutions should benefit all community members. Our school is a model of shared resource for students, families, staff, and the local community, but we have yet to wholly consider nature as a member of that community. We are dependent on the health of nature. We must interact with it in ways that keeps nature healthy in order to maintain our own health. Nature operates in systems and cycles, and we must acknowledge the ways that our lifestyle choices impact these systems and cycles. For those of us in cities where populations continue to rise due to ecological, financial, and socio-political reasons, our shared resources in urban areas are more at risk than ever without responsible management and investment. Cities are becoming more ecologically important as they grow.[33] As a teacher of future leaders of that city, it is critical that I teach students how to problem solve with all these party guests in mind.

## One Health through the Garden

As I mentioned in the rationale at the beginning of this unit, I want my students to take more ownership of the green spaces and resources that already exist at my school. One such space that is currently being underutilized is the garden. I plan to use the garden to facilitate hands-on, project-based learning in this unit. A garden is practical for size in an urban area, and many of the things students learn about the garden can be applied at home in their own plants or garden spaces. Students don't typically have access to large outdoor spaces in cities, but there are many community gardens in Richmond that students could also apply their knowledge. Place-based planning is important when cities consider traffic flow, parks and recreation spaces, or zoning. It is also very important for effective conservation efforts. Place-based learning would seem to be an important precursor to this kind of planning.

By working in the garden that is outside my classroom window, we will also be able to extend our classroom community to include nature with fidelity and ease of access, which allows me to incorporate this green space more easily across subjects. There is another perspective I considered when deciding the best way for my kindergartners to view and interact with a pollination system. One of my favorite gardener/ writers is Michael Pollan, who writes:

> "traditionally, when we have wanted to think about our relationship to nature, we have gone to the wilderness, to places untouched by man… Americans have a deeply ingrained habit of seeing nature and culture as irreconcilably opposed; we automatically assume that whenever one gains, the other must lose… There are many important things about our relationship to nature that *cannot* be learned in the wild. For one thing, we need, and now more than ever, to learn how to use nature without damaging it."[34]

Pollan views the garden as a place where humans are required to being together nature and culture. He argues that gardens are inherently local, and provide important local answers. To problem solve, Pollan states that the gardener has to work with nature if they want a successful yield, so while gardening is inherently anthropocentric, nature must be considered as a vital partner. It is possible to interact with nature without damaging it, and there is power in borrowing methods from nature itself to minimize our damage. Think about it like this—mowing a path through the grass is entirely different from mowing the entire lawn. One is a minor disturbance, while the other destroys thousands of niches within an ecosystem. Making small mindset shifts like this can help us move from individual to collective action. For my classroom, I think part of the move from individual to collective action will come through the sharing of information about and sharing products from our garden with families and school community members. This will be furthered by shared ownership of the space, and through explicit connection to interdisciplinary learning in the classroom.

## Teaching Strategies

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This unit explores the system of pollination through a pollination party, framing this content in a positive and joyful way for kindergarten students. At the kindergarten level, biodiversity is an awareness and in our current curriculum, it tends to be human-focused or from a human perspective. Using the One Heath model as a foundational lens for this unit, I am aiming to present students with a more equitable approach to learning about biodiversity. We will focus on the importance of having all of the guests at the party, who each play important roles in the health of the pollination system, i.e. the party. Each part of the model is represented through the guest list. For example, animal guests include bees, worms, and birds; human guests include partners, students, and teachers; environmental guests include plants, soil, and weather like wind. To help students build a better awareness and understanding of the importance of biodiversity, we will spend time in this unit on attention activities where students will be able to observe and study nature. We will use sit spots outside to journal about what nature we observe with our five sense, what parts of the system are visible, and ways we envision our green spaces. As a teacher in an urban environment, it can be hard to find what we envision as wild "nature" in the city, but I want to encourage you to observe a little more closely. By returning to the same sit spots in a regular routine, students will be able to see small changes in the environment that they may have missed before, such as the sun shifting through the seasons, animals who come and go, or

impacts changes they make have on natural spaces. This also supports students in actively engaging in place-based learning, where they will become experts on the natural environment of our school community.

Learning throughout this unit will incorporate hands-on activities that allow students to take individual ownership and collective action in the health of our pollinators at school. Through tools like a sensory table, working in the garden, and supplying students with their own toolkits for the outdoors, I plan on students get down and dirty with natural elements like soil or compost, plants, and some living organisms like caterpillars, worms, and bees.

## Classroom activities

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**Activity 1: Garden Observation**

Throughout the unit, students will engage in observation through their sit spots around the garden. We will begin with observation of the empty garden before we work in it, thinking about what could be there. We will get deeper into observation with tools like shovels, bug boxes, and hand lenses. We will also observe some healthy gardens in our community to see who and what we may want to include in our garden. Our goal will be to come back together as a class and combine our ideas to make a class garden plan. As we get close to the pollination party, we will engage in brief daily observations to see what changes are occurring and what care we may need to provide to our pollinators in preparation.

**Activity 2: Garden Trail Mix**

How do we decide what is good for the garden? We will begin by thinking about what snacks are healthy for us by planning and making a class trail mix. Then we will use gardening materials to make a trail mix to “feed” the garden, such as compost, soil additives, topsoil, worms, and other organic materials that add good nutrients to the garden community.

**Activity 3: Pollinators in Action**

In this activity, students will get to role play a day in the life of a pollinator. Students will have to reach into a bowl of cheese puffs to get a Starburst from the bottom, getting their fingers covered in the cheesy powder. This represents how a pollinator gets covered in pollen while trying to get nectar out of a flower. The student then travels to other coffee filter flowers around the room, where they will put down their Starburst and retrieve one from the new flower. In the process, students will be able to see how the cheesy powder (i.e. pollen) transfers from their fingers to the coffee filter flowers, much like pollen does from pollinators to flowers.

**Activity 4: Incorporating Living Organisms**

There are many ways to incorporate living organisms into this unit, such as hatching butterflies, having a bee demonstration from a local beekeeper, or keeping a worm farm. These could be additional daily observations, as well as important ways to see how pollinators may use an ecosystem differently depending on its life cycle stage. Plants are inherently worked into this unit through the garden, but I want to also focus on bringing green inside, such as engaging in growing plants in the classroom and transplanting them to the garden, or

giving each student a plant to take care of daily to help them understand how much attention goes into care of nature.

## Resources

**Student-facing resources for this unit could include:**

- *What's Inside a Flower?* (Mentor Text) by Rachel Ignotofsky was a core text that I used for content learning and its presentation to students in this unit. This is a beautifully illustrated text that includes many diagrams, examples, and color pictures to engage young learners about flowers. It also follows a logical scope and sequence for learning about flowers, such as teaching about the parts of a flower, then pollination, and then the different types of flowers. This is similar to how I envisioned this unit and it works well for planning purposes to utilize this text in sequence. It is factual and provides many references and resources to learn more as well!
- *Xander's Panda Party* (Mentor Text) by Linda Sue Park is a great model for how to plan a party, and how to consider what guests to invite. In this story, Xander is the only panda at the zoo, and he slowly has to expand his invitation list to include more and more species. While this text does not focus on pollinators, it would be helpful to use for student to visuals what kinds of different guests they may need to consider. It also teaches about some of the social-emotional skills required for a party, such as including others.
- The Epic collection on pollinators (Text Set) is a digital resource that includes fiction and nonfiction texts across various reading levels about pollinators. One of my favorite parts about Epic is that there are read aloud options, which is critical in kindergarten, and students can engage in a text of their choice rather than one that is just assigned to them. This allows students to interact with a range of pollinators and plants depending on their interests, rather than this just being teacher-directed.
- I have planned to create gardening toolkits for each of my students that includes shovels, gloves, hand lenses, journals, and pencils so that they can easily engage in observation and hands-on learning in the garden. Many of these items can be found at dollar stores so they do not require you to break the bank as a teacher!
- This year I am trying out a permission slip that gets signed by guardians at the beginning of the school year that allows me to take my students to our neighboring park throughout the year. This way we can take advantage of weather and learning opportunities to engage with our local nature year-round. If this is something you may be interested in doing with your class, I encourage you to reach out to your administration to see if this is possible to do at your school.

## Notes

[1] After this unit was composed, the Richmond Public Schools School Board changed the name of John B. Cary Elementary to Lois Harrison-Jones Elementary for the 2023-2024 school year.

[2] Andrea Falken*. U.S. Department of Education Green Ribbon Schools Fact Sheet 2023-2024.* April 24. 2023.

[3] I highly encourage you to learn more about the power of the windows and mirrors perspective if you have not come across this in literacy professional development yet. Fostering both aspects in our classrooms is critical for our students to look through windows at other backgrounds, cultures, or knowledge, as well as to look in mirrors or backgrounds, cultures, or knowledge that they share. In some ways, I am advocating for students to look at animals and plants in this way as well—in what ways are we the same, and in what ways are we different?

[4] Rachel Ignotofsky, *What's Inside a Flower*? (Solon, OH: Findaway World, LLC, 2023), 21-31.

[5] "The Why, What, When, Where, Who, How of Pollination." *Smithsonian Gardens*, October 25, 2021. https://gardens.si.edu/gardens/pollinator-garden/why-what-when-where-who-how-pollination/.

[6] Ignotofsky, 23-26. I created Figure 1 based off of content from these pages of the text.

[7] Sharla Riddle, "How Bees See and Why It Matters." Bee Culture, May 20, 2016. https://www.beeculture.com/bees-see-matters/#:~:text=They%20can%20also%20see%20blue,color%20much%20faster%20than%20humans.

[8] Doug Golick et al., "A Framework for Pollination Systems Thinking and Conservation." *Environmental Education Research* 24, no. 8 (July 12, 2017): 1143. https://doi.org/10.1080/13504622.2017.1349878.

[9] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. "Assessment Report on Pollinators, Pollination and Food Production." IPBES, 2016. https://www.ipbes.net/assessment-reports/pollinators.

[10] Smithsonian Gardens, "The Why, What, When, Where, Who, How of Pollination."

[11] Jennifer Marshman et al, "Anthropocene Crisis: Climate Change, Pollinators, and Food Security" *Environments* 6, no. 2 (February 21, 2019): 22. https://doi.org/10.3390/environments6020022.

[12] Some examples of citizen-science programs include Monarch Watch, Bumblebee Watch, or the Bumble Boosters Project. Larger organizations include groups like the Xerces Society or the Pollinator Partnership.

[13] Golick et al., 1153-1156.

[14] P. Citlally Jimenez et al., "Developing and Evaluating a Pollination Systems Knowledge Assessment in a Multidisciplinary Course," *International Journal of STEM Education* 9, no. 1 (2022) https://doi.org/10.1186/s40594-022-00368-6.

[15] Golick et al., 1156.

[16] Jimenez et al., 9-11.

[17] University of Vienna. "How flowers adapt to their pollinators: Modularity facilitates rapid adaptation of single floral organs to different pollinators." *ScienceDaily.* www.sciencedaily.com/releases/2019/12/191205130558.

[18] Bentol, Angiosperm Terrestrial Revolution, *Phytology*

https://nph.onlinelibrary.wiley.com/doi/epdf/10.1111/nph.17822

[19] Pollinator Partnership. “Pollination.” Pollinator.org, 2023. https://www.pollinator.org/pollination.

[20] Ignotofsky, 21-24.

[21] I created Figure 2 based off of images from Ignotofsky.

[22] Ignotofsky, 22-24.

[23] For more detailed information on pollinators, I highly recommend visiting the US Forest Service resources like their website, which contains photos and more on each of the pollinators listed here as well as others.

[24] I created this figure using open source images from Canva. I highly recommend this as a source for creating materials for your classroom!

[25] Nardi, James. *Discoveries in the Garden*. (Chicago: Univ. of Chicago Press, 2018), Ch 10.

[26] Nardi, 215.

[27] Lucas Garibaldi et al., “Exploring Connections between Pollinator Health and Human Health.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 377, no. 1853 (May 2, 2022). https://doi.org/10.1098/rstb.2021.0158.

[28] Pollinator Partnership.

[29] Damon Hall et al., “The City as a Refuge for Insect Pollinators.” *Conservation Biology* 31, no. 1 (January 14, 2017): 25. https://doi.org/10.1111/cobi.12840

[30] Marshman et al., 3.

[31] J. Hopwood et al., “Beyond the Birds and the Bees: Effects of Neonicotinoid Insecticides on Agriculturally Important Beneficial Insects.” Xerces Society. 2013. https://xerces.org/beyond-the-birds-and-the-bees/

[32] John Mackenzie and Martyn Jeggo, “The One Health Approach—Why Is It so Important?” *Tropical Medicine and Infectious Disease* 4, no. 2 (2019): 88. https://doi.org/10.3390/tropicalmed4020088.

[33] Marshman et al., 6-8.

[34] Pollan, Michael. *Second Nature: A Gardener’s Education*. (New York, NY: Grove Press, 1991), 190-201.

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## Appendix on Implementing District Standards

In Richmond Public Schools, we follow Virginia State Standards rather than the Common Core National Standards. This unit focuses primarily on science standards related to scientific investigation, such as describing physical objects or exploring through the five senses. Students will also engage with science standards on the basic needs of plants and animals, and their related life cycles. Though not explicitly written for social studies standards, this unit also touches on elements of responsible citizenship and being able to describe a community.