Plant Diversity Make-Up
Biology 1102

Name: ________________________
Section: __________

This exercise replaces your quiz and homework grade for the Plant Diversity lab. The majority of this exercise requires that you read the series of attached articles and answer the corresponding questions found below (15 pts.). All responses must be typed in YOUR OWN WORDS and in COMPLETE SENTENCES. Contact your TA's if you have any questions about this assignment.

**QUESTIONS FOR ARTICLE #1: "The Big Bloom"**

1. (1 pt.) Describe the fundamental characteristics that define angiosperms. In what ways do they differ from gymnosperms?
2. (2 pts.) Explain the steps involved in the reproduction of an angiosperm.
3. (1 pt.) According to the article, why would it be important for us to possess clear knowledge of the evolution of flowering plants?
4. (1 pt.) What key advantages and/or attributes did early angiosperms possess that allowed them to achieve success in a world once dominated by gymnosperms?
5. (1 pt.) The article refers to a certain "spark" that ignited the "great radiation". What was it, and what role did it play in angiosperm success?
6. (2 pts.) In your own words, explain the process of pollination in relation to the concept of coevolution.
7. (1 pt.) What benefits do angiosperms receive for producing nutritious fruits that animals (dinosaurs, birds, mammals, etc.) can consume as part of their diet?

**QUESTIONS FOR ARTICLE #2: "Pollinators' Decline Called Threat to Crops"**

1. (1 pt.) What factors does the article highlight as major reason for the decline in honeybee and bat populations?
2. (1 pt.) How might a decline in certain pollinator populations (e.g., insects) lead to major impacts on a population of larger *carnivores* in a given habitat? (Hint: think in terms of the many links in a food chain.)
3. (1 pt.) What steps have been taken by farmers in our part of the world to combat their shortages of honeybees? What possible downfalls exist with this strategy?

**QUESTIONS FOR ARTICLE #3: "Ants and Plants are in it Together"**

1. (2 pts.) Briefly describe the mutualistic relationship shared by ants and acacias in Africa. How does each benefit from this arrangement?
2. (1 pt.) What were the results of the experiment where the large animals that normally feed on acacias were taken out of the ecological equation? Why do scientists believe this occurred?

**Article #1:**

NATIONAL GEOGRAPHIC

# The Big Bloom

By Michael Klesius
National Geographic Magazine
July 2002

In the summer of 1973 sunflowers appeared in my father's vegetable garden. They seemed to sprout overnight in a few rows he had lent that year to new neighbors from California. Only six years old at the time, I was at first put off by these garish plants. Such strange and vibrant flowers seemed out of place among the respectable beans, peppers, spinach, and other vegetables we had always grown. Gradually, however, the brilliance of the sunflowers won me over. Their fiery halos relieved the green monotone that by late summer ruled the garden. I marveled at birds that clung upside down to the shaggy, gold disks, wings fluttering, looting the seeds. Sunflowers defined flowers for me that summer and changed my view of the world.

Flowers have a way of doing that. They began changing the way the world looked almost as soon as they appeared on Earth about 130 million years ago, during the Cretaceous period. That's relatively recent in geologic time: If all Earth's history were compressed into an hour, flowering plants would exist for only the last 90 seconds. But once they took firm root about 100 million years ago, they swiftly diversified in an explosion of varieties that established most of the flowering plant families of the modern world.

Today flowering plant species outnumber by twenty to one those of ferns and cone-bearing trees, or conifers, which had thrived for 200 million years before the first bloom appeared. As a food source flowering plants provide us and the rest of the animal world with the nourishment that is fundamental to our existence. In the words of Walter Judd, a botanist at the University of Florida, "If it weren't for flowering plants, we humans wouldn't be here."

From oaks and palms to wildflowers and water lilies, across the miles of cornfields and citrus orchards to my father's garden, flowering plants have come to rule the worlds of botany and agriculture. They also reign over an ethereal realm sought by artists, poets, and everyday people in search of inspiration, solace, or the simple pleasure of beholding a blossom.

"Before flowering plants appeared," says Dale Russell, a paleontologist with North Carolina State University and the State Museum of Natural Sciences, "the world was like a Japanese garden: peaceful, somber, green; inhabited by fish, turtles, and dragonflies. After flowering plants, the world became like an English garden, full of bright color and variety, visited by butterflies and honeybees. Flowers of all shapes and colors bloomed among the greenery."

That dramatic change represents one of the great moments in the history of life on the planet. What allowed flowering plants to dominate the world's flora so quickly? What was their great innovation?

Botanists call flowering plants angiosperms, from the Greek words for "vessel" and "seed."

Unlike conifers, which produce seeds in open cones, angiosperms enclose their seeds in fruit. Each fruit contains one or more carpels, hollow chambers that protect and nourish the seeds. Slice a tomato in half, for instance, and you'll find carpels. These structures are the defining trait of all angiosperms and one key to the success of this huge plant group, which numbers some 235,000 species.

Just when and how did the first flowering plants emerge? Charles Darwin pondered that question, and paleobotanists are still searching for an answer. Throughout the 1990s discoveries of fossilized flowers in Asia, Australia, Europe, and North America offered important clues. At the same time the field of genetics brought a whole new set of tools to the search. As a result, modern paleobotany has undergone a boom not unlike the Cretaceous flower explosion itself.

Now old-style fossil hunters with shovels and microscopes compare notes with molecular biologists using genetic sequencing to trace modern plant families backward to their origins. These two groups of researchers don't always arrive at the same birthplace, but both camps agree on why the quest is important.

"If we have an accurate picture of the evolution of a flowering plant," says Walter Judd, "then we can know things about its structure and function that will help us answer certain questions: What sorts of species can it be crossed with? What sorts of pollinators are effective?" This, he says, takes us toward ever more sensible and productive methods of agriculture, as well as a clearer understanding of the larger process of evolution.

Elizabeth Zimmer, a molecular biologist with the Smithsonian Institution, has been rethinking that process in recent years. Zimmer has been working to decipher the genealogy of flowering plants by studying the DNA of today's species. Her work accelerated in the late 1990s during a federally funded study called Deep Green, developed to foster coordination among scientists studying plant evolution.

Zimmer and her colleagues began looking in their shared data for groups of plants with common inherited traits, hoping eventually to identify a common ancestor to all flowering plants. Results to date indicate that the oldest living lineage, reaching back at least 130 million years, is Amborellaceae, a family that includes just one known species, *Amborella trichopoda*. Often described as a "living fossil," this small woody plant grows only on New Caledonia, a South Pacific island famous among botanists for its primeval flora.

But we don't have an *Amborella* from 130 million years ago, so we can only wonder if it looked the same as today's variety. We do have fossils of other extinct flowering plants, the oldest buried in 130-million-year-old sediments. These fossils give us our only tangible hints of what early flowers looked like, suggesting they were tiny and unadorned, lacking showy petals. These no-frill flowers challenge most notions of what makes a flower a flower.

To see what the first primitive angiosperm might have looked like, I flew to England and there met paleobotanist Chris Hill, formerly with London's Natural History Museum. Hill drove me through rolling countryside to Smokejacks Brickworks, a quarry south of London. Smokejacks is a hundred-foot-deep hole in the ground, as wide as several football fields, that has been offering up a lot more than raw material for bricks. Its rust-colored clays have preserved thousands of fossils from about 130 million years ago. We marched to the bottom of the quarry, got down on our hands and knees, and began digging.

Soon Hill lifted a chunk of mudstone. He presented it to me and pointed to an imprint of a tiny stem that terminated in a rudimentary flower. The fossil resembled a single sprout plucked from a head of broccoli. The world's first flower? More like a prototype of a flower, said Hill, who made his initial fossil find here in the early 1990s. He officially named it *Bevhalstia pebja*, words cobbled from the names of his closest colleagues.

Through my magnifying glass the *Bevhalstia* fossil appeared small and straggly, an unremarkable weed I might see growing in the water near the edge of a pond, which is where Hill believes it grew.

"Here's why I think it could be a primitive flowering plant," said Hill. "*Bevhalstia* is unique and unassignable to any modern family of plants. So we start by comparing it to what we know." The stems of some modern aquatic plants share the same branching patterns as *Bevhalstia* and grow tiny flower buds at the ends of certain branches. *Bevhalstia* also bears a striking resemblance to a fossil reported in 1990 by American paleobotanists Leo Hickey and Dave Taylor. That specimen, a diminutive 120-million-year-old plant from Australia, grew leaves that are neither fernlike nor needlelike. Instead they are inlaid with veins like the leaves of modern flowering plants.

More important, Hickey and Taylor's specimen contains fossilized fruits that once enclosed seeds, something Hill hopes to find associated with *Bevhalstia*. Both plants lack defined flower petals. Both are more primitive than the magnolia, recently dethroned as the earliest flower, although still considered an ancient lineage. And both, along with a recent find from China known as *Archaefructus*, have buttressed the idea that the very first flowering plants were simple and inconspicuous.

Like all pioneers, early angiosperms got their start on the margins. In a world dominated by conifers and ferns, these botanical newcomers managed to get a toehold in areas of ecological disturbance, such as floodplains and volcanic regions, and adapted quickly to new environments. Fossil evidence leads some botanists to believe that the first flowering plants were herbaceous, meaning they grew no woody parts. (The latest genetic research, however, indicates that most ancient angiosperm lines included both herbaceous and woody plants.) Unlike trees, which require years to mature and bear seed, herbaceous angiosperms live, reproduce, and die in short life cycles. This enables them to seed new ground quickly and perhaps allowed them to evolve faster than their competitors, advantages that may have helped give rise to their diversity.

While this so-called herbaceous habit might have given them an edge over slow-growing woody plants, the angiosperms' trump card was the flower. In simple terms, a flower is the reproductive mechanism of an angiosperm. Most flowers have both male and female parts. Reproduction begins when a flower releases pollen, microscopic packets of genetic material, into the air. Eventually these grains come to rest on another flower's stigma, a tiny pollen receptor. In most cases the stigma sits atop a stalk-like structure called a style that protrudes from the center of a flower. Softened by moisture, the pollen grain releases proteins that chemically discern whether the new plant is genetically compatible. If so, the pollen grain germinates and grows a tube down through the style and ovary and into the ovule, where fertilization occurs and a seed begins to grow.

Casting pollen to the wind is a hit-or-miss method of reproduction. Although wind pollination suffices for many plant species, direct delivery by insects is far more efficient. Insects doubtless began visiting and pollinating angiosperms as soon as the new plants appeared on Earth some 130 million years ago. But it would be another 30 or 40 million years before flowering plants grabbed the attention of insect pollinators by flaunting flashy petals.

"Petals didn't evolve until between 90 and 100 million years ago," said Else Marie Friis, head of paleobotany at the Swedish Natural History Museum on the outskirts of Stockholm. "Even then, they were very, very small.

A thoughtful woman with short brown hair and intense eyes, Friis oversees what many experts say is the most complete collection of angiosperm fossils gathered in one place. The fragile flowers escaped destruction, oddly enough, thanks to the intense heat of long-ago forest fires that baked them into charcoal.

Friis showed me an 80-million-year-old fossil flower no bigger than the period at the end of this sentence. Coated with pure gold for maximum resolution under an electron microscope, it seemed to me hardly a flower. "Many researchers had overlooked these tiny, simple flowers," she said, "because you cannot grasp their diversity without the microscope."

So we squinted through her powerful magnifier and took a figurative walk through a Cretaceous world of tiny and diverse angiosperms. Enlarged hundreds or thousands of times, Friis's fossilized flowers resemble wrinkled onion bulbs or radishes. Many have kept their tiny petals clamped shut, hiding the carpels within. Others reach wide open in full maturity. Dense bunches of pollen grains cling to each other in gnarled clumps.

Sometime between 70 and 100 million years ago the number of flowering plant species on Earth exploded, an event botanists refer to as the "great radiation." The spark that ignited that explosion, said Friis, was the petal.

"Petals created much more diversity. This is now a widely accepted notion," Friis said. In their new finery, once overlooked angiosperms became standouts in the landscape, luring insect pollinators as never before. Reproduction literally took off.

Interaction between insects and flowering plants shaped the development of both groups, a process called coevolution. In time flowers evolved arresting colors, alluring fragrances, and special petals that provide landing pads for their insect pollinators. Uppermost in the benefits package for insects is nectar, a nutritious fluid flowers provide as a type of trading commodity in exchange for pollen dispersal. The ancestors of bees, butterflies, and wasps grew dependent on nectar, and in so doing became agents of pollen transport, inadvertently carrying off grains hitched to tiny hairs on their bodies. These insects could pick up and deliver pollen with each visit to new flowers, raising the chances of fertilization.

Insects weren't the only obliging species to help transport flowering plants to every corner of the Earth. Dinosaurs, the greatest movers and shakers the world has ever known, bulldozed through ancient forests, unwittingly clearing new ground for angiosperms. They also sowed seeds across the land by way of their digestive tracts.

By the time the first flowering plant appeared, plant-eating dinosaurs had been around for a million centuries, all the while living on a diet of ferns, conifers, and other primordial vegetation. Dinosaurs survived for another 65 million years, and some scientists think this was plenty of time for the big reptiles to adapt to a new diet that included angiosperms.

"Just before the dinosaurs disappeared, I think a lot of them were chowing down on flowering plants," says Kirk Johnson of the Denver Museum of Nature & Science. Johnson has unearthed many fossils between 60 and 70 million years old from sites across the Rocky Mountain region. From them he deduces that hadrosaurs, or duck-billed dinosaurs, subsisted on large angiosperm leaves that had evolved in a warm climatic shift just before the Cretaceous period ended. Referring to sediments that just predate the dinosaur extinction, he said, "I've only found a few hundred samples of nonflowering plants there, but I've recovered 35,000 specimens of angiosperms. There's no doubt the dinosaurs were eating these things."

Early angiosperms were low-growing, a fact that suited some dinosaurs better than others. "Brachiosaurs had long necks like giraffes, so they were poorly equipped for eating the new vegetation," says Richard Cifelli, a paleontologist with the University of Oklahoma. "On the other hand ceratopsians and duck-billed dinosaurs were real mowing machines." Behind those mowers angiosperms adapted to freshly cut ground and kept spreading.

Dinosaurs disappeared suddenly about 65 million years ago, and another group of animals took their place—the mammals, which greatly profited from the diversity of angiosperm fruits, including grains, nuts, and many vegetables. Flowering plants, in turn, reaped the benefits of seed dispersal by mammals.

"It was two kingdoms making a handshake," says David Dilcher, a paleobotanist with the Florida Museum of Natural History. "I'll feed you, and you take my genetic material some distance away."

Eventually humans evolved, and the two kingdoms made another handshake. Through agriculture angiosperms met our need for sustenance. We in turn have taken certain species like corn and rice and given them unprecedented success, cultivating them in vast fields, pollinating them deliberately, consuming them with gusto. Virtually every nonmeat food we eat starts as a flowering plant, while the meats, milk, and eggs we consume come from livestock fattened on grains—flowering plants. Even the cotton we wear is an angiosperm.

Aesthetically, too, angiosperms sustain and enrich our lives. We've come to value them for their beauty alone, their scents, their companionship in a vase, a pot, on Valentine's Day. Some flowers speak an ancient language where words fall short. For these more dazzling players—the orchids, the roses, the lilies—the world grows smaller, crisscrossed every day by jet-setting flowers in the cargo holds of commercial transport planes.

"We try to deliver flowers anywhere in the world within 24 hours of when they're cut," said Jan Lanning, a senior consultant with the Dutch Floricultural Wholesale Board, the world's turnstile for ornamental flowers. "The business has really globalized."

On my way home from Friis's lab in Sweden, I had stopped in the Netherlands, the world's largest exporter of cut flowers. I asked Lanning to try to explain the meaning of his chosen work. He leaned forward with a ready answer.

"People have been fascinated by flowers as long as we've existed. It's an emotional product. People are attracted to living things. Smell, sight, beauty are all combined in a flower." He smiled at an arrangement of fragrant lilies on his desk. "Every Monday a florist delivers fresh flowers to this office. It is a necessary luxury."

Later that day in Amsterdam's Van Gogh Museum I spied a group of admirers crowded before a painting. I made my way there and pressed in among them. Suddenly I was staring at "Sunflowers," one of van Gogh's most famous works. In the painting the flowers lean out of a vase, furry and disheveled. They transported me to my barefoot youth at the edge of my dad's garden on a humid summer evening alive with fireflies and the murmur of cicadas.

The crowd moved on, and I was alone with "Sunflowers." My quest had come to this unexpected conclusion, an image of the first flower I can remember. Did van Gogh elevate the flower to an art form, or did the flower harness van Gogh's genius to immortalize itself in oils and brushstrokes? Flowering plants have conquered more than just the land. They have sent roots deep into our minds and hearts. We know we are passing through their world as through a museum, for they were here long before we arrived and may well remain long after we are gone.

**Article #3:**

washingtonpost.com

# Pollinators' Decline Called Threat to Crops

*By Juliet Eilperin*
Washington Post Staff Writer - Thursday, October 19, 2006; Page A10

Birds, bees, bats and other species that pollinate North American plant life are losing population, according to a study released yesterday by the National Research Council. This "demonstrably downward" trend could damage dozens of commercially important crops, scientists warned, since three-quarters of all flowering plants depend on pollinators for fertilization.

American honeybees, which pollinate more than 90 commercial crops in the United States, have declined by 30 percent in the last 20 years. This poses a challenge to agricultural interests such as California almond farmers, who need about 1.4 million colonies of honeybees to pollinate 550,000 acres of their trees. By 2012, the state's almond farmers are expected to need bees to pollinate 800,000 acres.

Gene E. Robinson, an entomologist at the University of Illinois and one of the 15 researchers who produced the report, said U.S. farmers had to import honeybees last year for the first time since 1922, underscoring the extent of the problem.

"The honeybee industry is at a critical juncture," Robinson said. "The time for action is now."

A number of factors have cut pollinators' numbers in recent decades, the researchers said. Introduced parasites such as the varroa mite have hurt the honeybee population, and pesticides have also taken a toll. Bats, which carry pollen to a variety of crops, have declined as vandalism and development have destroyed some of their key cave roosts.

John Karges, a Nature Conservancy conservation biologist who works with the endangered Mexican long-nosed bat in West Texas, said the bat's U.S. population fell from 10,000 in 1967 to 1,000 in 1983. The species feeds on nectar from the agave plant, which can be used to produce a sweetener as well as tequila.

"This bat is rare and suspected of declining rangewide," said Karges, adding that it can now be spotted only at one protected cave site in Big Bend National Park. "I don't think anyone's looking at it annually or closely."

The declines have been gradual and in some instances are hard to quantify, the committee concluded. But the panel's chairwoman, entomologist May R. Berenbaum of the University of Illinois, said in a statement that there is already cause for alarm.
"Despite its apparent lack of marquee appeal, a decline in pollinator populations is one form of global change that actually has credible potential to alter the shape and structure of terrestrial ecosystems," Berenbaum said.

Animals carry pollen -- which they pick up inadvertently while feeding on a plant's nectar -- and transfer it from one flowering plant to another, sometimes over significant distances. The process not only boosts plant production but increases species' genetic diversity.

Animal pollinators fertilize more than 187,500 flowering plants worldwide; scientists believe these plants, called angiosperms, gained ecological dominance more than 70 million years ago in part because animals help them disperse their pollen so broadly. Other pollinators include hummingbirds and butterflies, as well as wild bees.

In many ways, pollination works as a chain in which even the largest animals depend on small insects, said committee member Peter Kevan, a professor at the University of Guelph, Ontario.

"Canadian black bears need blueberries, and the blueberries need bees" for pollination, Kevan said. "Without the bees you don't have blueberries, and without the blueberries you don't have black bears."

Despite this crucial link, Robinson said, many ordinary citizens fail to grasp how important pollinators are to food production.

European researchers have also documented serious declines: The diversity of bee species has declined by 40 percent in Britain and 60 percent in Holland since 1980. Europeans have more detailed records of pollinators than Americans, said University of Arizona entomologist Stephen Buchmann, partly because they have more amateur taxonomists keeping track of them.

So far, North American farmers have responded to the shortages by importing bees from Europe and elsewhere, but this strategy carries risks. These imported bees could bring new pests, parasites and diseases along with them, the study warned; the varroa mite came to the United States along with packaged bees.

The National Research Council panel called on scientists and government to collect more data on pollinator populations, and the U.S. Postal Service unveiled four stamps to help raise public awareness of the issue.


"We don't want to become a report on the shelf," said Michael Ruggiero, director of the U.S. Geological Survey's Integrated Taxonomic Information System. "We want to be a cause for action."

## *Article #3:*

# Ants and plants are in it together

**Mutualism is a good deal both for biting ants and African acacia trees**

Todd Palmer / AP

**By Randolph E. Schmid**
Associated Press

WASHINGTON - Call it the rule of unintended consequences — drop your guard because one threat goes away and an unexpected menace jumps up and smacks you. And new research shows it even applies to African acacia trees.

For thousands of years these thorny shrubs have provided food and shelter to aggressive biting ants, which protect the trees by attacking animals that try and eat the acacia leaves.
Called mutualism, it's a good deal for both the trees and the ants.

Scientists studying the decline in large animals in Africa wondered what would happen if they no longer were eating the leaves. So they fenced off some of the acacias, so elephants, giraffes and other animals couldn't get to them.

Surprisingly, after a few years the fenced-in trees began looking sickly and grew slower than their unfenced relatives.

It turns out that without animals eating their leaves the trees no longer bothered to take care of their ants — they reduced nectar production and made fewer swollen thorns that the ants could live in.

The result: The protective ants either began damaging the plant or were replaced by other insects that ate holes in the bark.

"Although this mutualism between ants and plants has likely evolved over very long time-scales, it falls apart very, very rapidly," said Todd Palmer, an assistant professor of zoology at the

University of Florida.

"Over the course of only 10 years, we found that when mammals could not eat plants, the plants began to have less use for the ants, and therefore began to reduce their 'payments' to the ants, in the form of nectar," Palmer, who is currently in Kenya, explained in an interview via e-mail. Palmer's findings are reported in Friday's edition of the journal Science.

"If you had asked me 10 years ago 'what would happen if you took large mammals out of the system,' I would have answered 'I'll bet the trees would be really happy!'" he said.

But instead, because the browsing animals are the driving force behind the tree paying out benefits to the ants, when the payments diminish, the ants that protect the tree begin to starve and its colonies become smaller.

Some ants reduced their defensive behavior and began tending colonies of scale insects that bore into the plants and extract sugars. Others were replaced by other ant species that eat elsewhere and encourage the presence of wood-borer beetles, which eat holes in the trees that the ants can then use as home.

"So, that's one lesson from the research, to me: The human-induced decline of big herbivores in Africa can have some pretty dramatic and non-intuitive consequences for the communities in which these large mammals live," Palmer said.

Ted R. Schultz, a research entomologist at the Smithsonian Institution's National Museum of Natural History, said that removal of the browsing animals turns out to be worse for the plant "is surprising and it's not the kind of thing anybody would have been likely to predict in advance."

Schultz, who was not part of Palmer's research team, said the report shows that mutualisms are finely balanced and complex.

"The system reported here is a balance of a number of players — the trees, the browsing mammals, the main ant and three other ant species, with the ants all competing for the trees. Remove one of the players — the browsing mammals — and all the other moving parts rearrange themselves in a way we hardly could have predicted." he said.

So, can the trees recover their protective ants if large animals start nibbling on then again?

Palmer means to find out by exposing the trees again to browsing, "to see how quickly trees will re-induce their investments in symbiotic ants, and in turn, whether such reinvestment will be enough and in time, or too little, too late."

The research was funded by the U.S. National Science Foundation, the Smithsonian Institution, National Geographic Society and the African Elephant Program of the U.S. Fish and Wildlife Service.