# The Case of the Stolen Painting: A Forensic Mystery

[MUSIC PLAYING]

Hi. My name is Sydney Bergman and I'm a biology teacher at School Without Walls high school, a public magnet high school in Washington DC. Today, in this video, we're going to be talking about using forensic evidence to solve crimes. I'm going to ask you to help me solve a crime.

At its peak, CSI and its spin-offs had more than 40 million viewers per week. Shows like CSI familiarized audiences with the use of forensic evidence, particularly DNA evidence. DNA has been used as forensic evidence since the 1980s. But many people don't realize that forensic evidence, including DNA, can be collected from a variety of sources.

In this video, we're going to be examining an unusual source of forensic evidence. But before we do that, we need to think about what constitutes forensic evidence and what perhaps does not constitute forensic evidence. In this first activity, I'm going to ask you to brainstorm what you think constitutes forensic evidence, what you're not sure constitutes forensic evidence, and then what you don't think constitutes forensic evidence. Work independently, and then in pairs or in groups as your teacher instructs. I'll see you when you're done.

Let's review what kinds of evidence do or do not constitute forensic evidence. You're probably most familiar with evidence, like human DNA, including things such as blood, bodily fluids, and materials directly pertinent to the crime - bullet casings, fingerprints, et cetera. While these are great sources of forensic evidence, other materials may constitute valid sources, particularly for crimes where some or all of the crime was committed outdoors, and therefore in contact with non-human, biological and geological evidence.

Here is the case I would like you to help me solve: the case of the stolen painting. A famous painting was stolen from a museum and a suspect is apprehended later. The suspect's car could contain evidence that forensic investigators use to associate with the location of the stolen painting. Forensic investigators would likely collect evidence from the suspect, from their home, from their garage, from the museum where the painting is stolen, and from the car itself.

In this activity, I'm going to ask you to come up with the material that could constitute forensic evidence and material that you believe would not constitute forensic evidence. Take a moment, work independently, and then as your teacher instructs. And I'll see you back in a minute.

Let's discuss the evidence you would want to collect in a forensic investigation. Crime scene investigators would want to collect any material, such as biological material or material that had been in contact with biological material, such as blood, hair, skin samples; or environmental evidence that includes sediment, material from the road, as well as material collected from areas in the car where it accumulates. Particular to the car, material found on the exterior of the car that's unlikely to be washed, such as the wheel wells or the spoiler, or the interior of the car that's been in contact with the suspect's feet, such as the interior floor around the gas and brake petals, may yield forensic evidence. Taken together, all of these can build a profile of where suspect might have been and if they are conceivably associated with the crime in question.

Although you might not think of them immediately, pollen and plant materials can be used as evidence by forensic scientists. Forensic scientists are scientists, and therefore they need to acquire a lot of knowledge about substances that can be used as evidence in solving a crime. Today, you'll be asked to examine various kinds of plants that can be used as forensic evidence to help solve the case of the missing painting. The next two segments will introduce you to a variety of plants and ask you to think like a scientist would, to help solve the crime.

Plant material, particularly pollen, has the benefit of being durable, identifiable, and connected to a particular place and occasionally time. However, to understand how pollen can be used in a forensic context, you must first understand the relationships between plants and living things similar to plants. Your teacher will be asking you to review pictures of plants and organisms that are not plants, but are similarly in a forensic context. Take a few minutes and determine which organisms or sets of organisms you think are the most closely related. It's OK if you don't know the answer first, just go with your first instinct.

Let's review the previous activity. Which sets of plants do you think were the most closely related? Some of you may have been able to tell which plants are most closely related just by looking. But many of you probably had some questions about how you can tell if plants are closely related or not. Looking at organisms' appearances can be useful in determining their traits. But it's useful for scientists, like forensic investigators, to know a lot about plants in order to use them in criminal investigations.

Let's review some of the basic characteristics of plants. Plants and algae are photosynthetic. They use sunlight energy, carbon dioxide from the air, and water to manufacture their own food. Since photosynthetic organisms need to hold so much water, they have cell walls, in addition to a cell membrane, made of cellulose, a type of sugar.

Fungi, unlike plants, are not photosynthetic, and so need other sources of food, similar to the way that people need food to eat. It may surprise you, but fungi are more closely related to people than they are to plants. Here you can see a micrograph, a picture taken through a microscope, of green algae. The green comes from chloroplasts, a part of plant and algal cells, that performs photosynthesis.

Plants, but not algae, have cuticle. Cuticle is a waxy covering that helps plants keep moisture in, since water is necessary for plant structure and for photosynthesis. If you've seen water roll off a leaf, that's because of cuticle. Many plants have xylem, a series of thin tubes that delivers water from the roots of the plant to the leaves of the plant, through a process called capillary action.

This action is when water climbs up small tubes against gravity. If you've ever gotten the bottom of your jeans wet and had the water climb up to your knees, you've experienced capillary action. Mosses do not have xylem, so have to live in areas that are relatively moist because they cannot transport water as a result.

The following picture shows a cross-section of a plant stem. The xylem is the wider of the tubes in the following picture and has been stained so it's outlined in pink. Plants with xylem also have another set of tubes called phloem. These deliver sugars from leaves, where it's produced, to wherever the plant needs sugar. It can also deliver sugars from the roots or stems, where many plants store sugars, to where it is needed. Ferns, evergreens, and flowering plants use xylem and phloem for transport.

In this next activity, you will be asked to reexamine the pictures of plants you examined previously, but this time with a bit more information. Using this information, you may want to reassess your previous classification of plants and their relationships to one another. When you are done, complete this chart that describes each category of plant's general characteristics.

Let's review the previous activity. There are major divisions between plants, and between plants and non-plants, based on their characteristics. For example, fungi, like the mushroom shown in the picture, aren't photosynthetic, so are not closely related to plants and algae. Green algae doesn't have cuticle, but is photosynthetic and is more closely related to plants than to fungi.

Mosses have cuticle, but not xylem or phloem, so are less closely related to other plants than these plants are to each other. While these distinctions are important, it's also important for forensic investigators to know how plants reproduce, because one method, pollen, is a powerful forensic tools for associating suspects or objects with specific locations. Some plants, including familiar plants like evergreens and flowering plants, use pollen and seeds to reproduce.

Pollen carries the cells that help the plant reproduce and is highly durable, so it can travel long distances from a parent plant, via wind, water, or pollinating animals. Pollen comes in many shapes and sizes depending on the plant species. In this picture, you can see pollen from a variety of plants. Having pollen that is a durable and can travel long distances, benefits the plant by increasing the genetic diversity of its offspring so that some of the offspring may look very different from the parent or have resistance to certain diseases. It's also good for people, since pollen is durable, so it can be used as forensic evidence.

Plants that do not use pollen to reproduce, such as mosses and ferns, instead use spores. But these are not as durable as pollen and require water in order to be kept moist to help the plant reproduce. The following picture shows sori, the spore-producing parts of ferns. Sori look like a little orange or brown dots on the underside of leaves. Fungi and green algae are not plants, but also use spores to reproduce. These can also be helpful in a forensic context, since they can link a person or object to a specific location.

Lastly, some plants have flowers, in addition to pollen and seeds, as well as producing fruit. Rather than relying on wind or water to distribute pollen, many flowering plants use pollinators, animals that are attracted to certain colors and smells and will help the plant distribute its pollen. Here you can see a flower with pollen.

Plants that produce pollen, but don't have flowers, such as evergreens, have to produce a lot of pollen and use either the wind or water to distribute it. Plants use pollen to distribute reproductive cells and encourage genetic diversity. Pollen can be distributed by three main methods, wind, water, or animals.

In the following activity, you will use your knowledge of plants and how they reproduce to complete the chart you began earlier. You will also be asked to complete a diagram that details plants and their characteristics that will be useful in completing your forensic investigation.

In the last activity, I asked you to classify plants based on their characteristics, particularly based on how they reproduce. I hope you found that evergreens, the gymnosperms, and flowering plants, the angiosperms, are more closely related to one another than they are to other plants, because they both produce pollen and seeds. However, I hope you found that angiosperms, the flowering plants, are distinct, because they produce flowers and fruit and are largely pollinated by animal pollinators, in addition to producing pollen and seeds.

Both spores and pollen are useful in terms of forensic evidence. Spores are not as sturdy, but they are likely to be close to the plant they originated from. Pollen is durable, which is good for analysis, but can sometimes travel very far, more than 50 miles from the plant it originated from.

Knowing the pros and cons of various kinds of evidence and when to apply that knowledge is an important part of forensic investigation. Wind-distributed pollen generally spreads according to local wind currents, but is clustered around the plant that disperses it. Plants that use wind-distributed pollen generally produce a lot of light pollen so that it can be blown to nearby plants. Much of it may be gathered around the base of large trees, if trees use wind-distributed pollen, because it is collected via rainwater and deposited at the base of the tree.

Water-distributed pollen is generally light and distributed via local waterways. But much of it is prone to degradation, because of the chemical makeup of the pollen, so it isn't of great value in forensic evidence. Animal-distributed pollen is generally found in the area around the plant it originated from and is therefore very valuable in forensic investigations, because of its limited distribution. Animal-distributed pollen often relies on the co-evolution of plants and animals, that is plants evolved to appeal to one or a few animal pollinators through smells, colors, flower size, flower number, timing of flowering, et cetera.

Knowing how a plant is pollinated can give a better understanding of its pollen distribution patterns. In addition to considering pollen distribution, forensic investigators may also consider other factors, such as the percentages of pollen present in specific areas or on samples taken from various points on a suspect's vehicle or clothing.

In the next activity, you will complete a map to help you determine the potential location of the missing painting. Read through the directions and shade in the map according to the pollen locations and percentages. Then, using your map, determine the location or possible locations of the missing painting.

Let's review the previous activity, including the probable location of the painting. By using your map, you can narrow the location of your search to the area where the spores from ferns, pine pollen, and shrub pollen overlap, namely squares 5 G, 6 G, 5 H, and 6 H. You probably disregarded the oak pollen, since it was spread over a lot of the forest. This is what's called the background pollen profile of an area, which can be useful in other investigations, but not necessarily in this one.

I want to emphasize that forensic analysis, such as pollen distribution analysis, is useful in associating a suspect or object with a specific place, but isn't in and of itself conclusive. I also want to emphasize that knowing about plants and their reproductive strategies can be useful in a forensic context. Students who study plant sciences can be employed as forensic palynologists or generalized crime scene investigators.

This is the optional stopping point in the video. If you're choosing to stop, thank you so much for joining me. And I hope you've learned a little bit about plants and your uses in a forensic setting. If you choose to continue, the next segment will focus on the forensic uses of plant DNA in associating suspects and objects with a specific location.

DNA can be used in crime scene investigation. DNA can be processed in such a way to produce a DNA fingerprint that, like an actual human fingerprint, is unique to a specific person or plant. Gel electrophoresis, separating DNA fragments based on their size, is a way of analyzing DNA and connecting DNA to a specific person or plant.

The following picture shows a DNA banding pattern for humans. The leftmost column contains a ladder, a way of measuring how far DNA fragments of specific sizes travel on this particular gel. Plants have DNA that is unique, to a certain extent, to individual plants. Depending on the condition of pollen found, DNA can be extracted from pollen and analyzed, or extracted from other plant materials and analyzed.

In this next activity, you will be asked to consider DNA banding patterns from various organisms, to demonstrate how these banding patterns can be used to identify specific plants or people. To produce these banding patterns, techniques are used to focus on one or several sites within an organism's DNA.

Let's review the previous activity. As you can see from the banding pattern, the seedpods collected from the suspect's car are a match to those collected from the suspected crime scene. Generally, forensic investigators want to compare DNA from items collected from a scene to items found with the suspect. They test DNA at more than one location within the genes.

Let's summarize the major points of the video. Plants and pollen constitute forensic evidence. Knowing types of plants and their reproductive strategies allows investigators to utilize plants in this context. And plants, like people, have characteristic DNA sequences that ca be used as a tool in investigations.

If you're interested in learning more about these techniques, including PCR and gel electrophoresis, please see the BLOSSOMS video "Using DNA to Identify People" that's listed on your screen. I hope you learned a little bit about plants and their use in a forensic context. Thank you so much for your time.

Thank you so much for spending time with me watching my BLOSSOMS video. This lesson was originally conceived to help students, particularly students in lower-level classes such as college prep or non-honors biology, understand the major divisions between plants and see a practical application for plants. The original idea for the lesson came from my having a forensic investigator come in and talk to students in my class about the forensic applications of pollen.

The investigator I had come in was actually a graduate student getting her degree in forensics. And she was really able to engage students in understanding why knowing about plants is important and understanding the divisions between plants and applying that knowledge. So my conception for the lesson was to try and take that experience that my students had and apply it to a broader audience.

My objectives for the lesson were to have students not only be able to understand these divisions between plants, but to be able to communicate those divisions to one another and to apply it in something that involves sort of some graphical approach, as well as sort of talking to one another and then writing things out occasionally, so that they would have multiple modalities for how they wanted to learn about plants. I also wanted to give a context for understanding plants. A lot of times students, especially urban students, are very divorced from the natural world. And so just giving them an understanding of the "why" behind understanding plants was important.

So my objectives for the lesson were that students understand the evolutionary divisions between plants, that they could use pollen distribution analysis, like those used by forensic investigators, to locate an object, but understand that it was really just about overlapping ranges of pollen and spores and various other evidence. And to understand that plants, like people, have DNA and that DNA is to a certain extent particular to a specific plant.

To create this lesson, I reviewed a good number of articles on forensic palynology and the use of forensic trace evidence in palynology and sort of applied techniques that folks who actually work in the field use in performing investigations like this one. Unfortunately, this kind of investigation is actually largely performed outside the United States, so it isn't very well know. It's largely performed in England and in New Zealand, where it's actually standard to have a forensic palynologist at your crimes scene with you. However, the FBI and other organizations interested in crime scene investigation are promoting the use of forensic palynology and other sort of more arcane trace evidence analyses, as well as sort of standard DNA analysis.

I had also had the opportunity in making this lesson to talk to someone who had been running the DNA, or had been part of the DNA lab for the state of New Jersey for about 30 years. And he said that one of the things they're really pushing for in the use of DNA and identifying plants isn't actually in a crime context, but is also in an agricultural context. So investigating things like plant patent fraud, but with plants. So if you're growing patented plants, they can test for those genes. So it actually will apply to more than just missing stuff, or murder and such, but sort of in a broader civil context.

In terms of the actual sort of execution of this lesson plan, what I would really recommend doing is taking sort of frequent short breaks with the video, and we tried to build those in; to have students work individually, and then collaboratively, pairs, groups, whatever works for you; and then to sort of share out a little bit as a class. So that the breaks are used to effectively help students brainstorm, but also support students, particularly students who might be a little bit lost in the brainstorming parts of the lesson, who don't have a good sort of prior knowledge of forensics, at least be able to talk to their classmates and get ideas from there.

The other thing I would really recommend doing is for the mapping analysis, if you have students who might take a little bit more time with it or are perfectionists about coloring, which many students are, using that as a break, and then assigning it as homework. So beginning it in class, assigning it as homework, and then reviewing the map during your next class section. So that way, students who accomplish that really quickly, can kind of get it done. Everyone has a solid grounding in what they need to do. But the students who take a little bit longer or who want to cover every single thing perfectly, even though it's a sketch map, can do that and it's not eating up class time.

I mentioned sort of prior knowledge. The prior knowledge I was assuming for the video involved that students would be familiar with plants, that there were different kinds of plants, which some students are not. Assuming that they knew sort of some basics about plants and cells, so looking at what photosynthesis is. It's touched on briefly, but most people spend a lot more time on that. Knowing about plant cell walls, so understanding the difference between plant and animal cells. And then also knowing that sort of an increased geographic distribution for your pollen would increase the genetic diversity of your offspring.

So they would kind of need to know what genetic diversity meant, in order to fully appreciate that. And if you're really interested in that, I have a couple of follow-up extensions for the lesson that can really sort of enhance those aspects.

The last part that they would need to know about it is what DNA maybe is, or at least that it can be particular to a specific person. CSI and other crime scene shows, kids love them. They are more and more familiar with DNA evidence from that. And so even with your most low-level kids, it's probably no surprise that there is DNA. But I was sort of assuming that they came in with that knowledge, and that's obviously up to you to gauge for your classroom.

In terms of extending this lesson, I have a couple of suggestions. One is from the Cornell Institute for Biology Teachers, CIBT, who have fantastic resources, just all about plants, in addition to some other fantastic resources. And they have one activity called designing the world's most perfect artificial flower. And it's asking students to really examine the plant- pollinator relationship and the co-evolution of plants and pollinators. And that what works for one plant, to be bright and pretty and floral to help attract bees, is not going to work for another plant that needs to attract flies, and so needs to be sort of red and stubby and smell like dead meat.

And so kids actually really get into that. They design flowers, they draw flowers, blah, blah, blah, but that's a really nice extension. The other extension I have in there that I would encourage, is doing just a DNA extraction from strawberries, bananas, peas, some plant material. Most of them are polyploids. You're able to get a really good amount of DNA out of them. Some of what you get might be lignin. We're not going to pretend that it's not, but it's OK, or pectin. But most of what you get is actually DNA.

And so doing just even a simple extraction to teach them hey, plants have DNA, they're alive, even though they don't move, can be really, really powerful for kids. I've actually seen people with that one, take it, and then they isolate their DNA, purify it. And you can actually quantitate it using basic spectroscopy. So if you really want to take it the next level, that's another option available to you.

Lastly, obviously the DNA piece in this video, in terms of gel electrophoresis and PCR, was a little bit sort of abbreviated, mostly for time. I would encourage you, if you're at the point where it would fit well in your curriculum, to take a look at that. The other video mentioned, using DNA to identify people, has a really excellent breakdown of doing PCR, electrophoresis, and then staining and visualization.

If that's an option available to you, based on materials and equipment, I would encourage you to do that. Not just with your upper-level students, but some of version with all your students, so that they can see these technologies they see on TV. They can also appreciate that these technologies are not instantaneous, unlike TV, and that they are more complicated and involve a lot more work than you what CSI would have you believe.

Again, I want to thank you for spending time with me. And I hope this video was valuable to you. Thanks.