ACS
Chemistry for Life®

Celebrating Chemistry

NATIONAL CHEMISTRY WEEK AMERICAN CHEMICAL SOCIETY

Welcome to

Picture Perfect Chemistry

By Jackie Trischman, Ph.D.

Photography allows us to capture light as fixed images. You have probably seen many photographs in your life in all forms. They may have been print photos, pictures in magazines, or digital photos on a cell phone or tablet.

But have you ever wondered exactly *how* these photos get made? From the earliest days of photography, the answer has been **chemical reactions** caused by light. The first photo taken with a camera occurred in France in 1827. For almost 200 years since then, we've used cameras, film, and images printed on paper. These tools let us make pictures we can put in albums, picture frames, and galleries.

Anna Bertha Ludwig's hand, was taken by her husband Wilhelm Roentgen. *Courtesy of Wiki Commons*

Today, modern technology called *imaging* uses things like sound waves, many types of light, and even streams of **electrons** to make images we can't see with our eyes alone. These tools make the images we use for medicine, space exploration, research, and other areas.

Through medical **imaging**, we can see inside the human body. Medical X-rays, CT scans, and MRIs allow doctors to look inside our bodies in ways never possible before.

On Earth and in space, observatories use different types of imaging. These inventions help us see deeply into the universe and understand it.

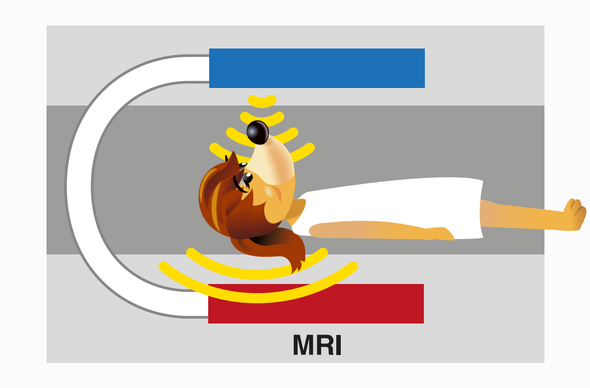
Radar uses radio waves to make images in our skies which air traffic controllers use to track the location of airplanes. Ground-penetrating radar can be used to locate pipes and cables underground. It can also be used to find ancient burial sites and structures.

We can also look at things that are very small, like single **molecules** or atoms, using advanced machines called electron microscopes. We use these special microscopes because atoms and molecules are so small that we can't even use X-rays, infrared light, ultraviolet light, sound, or radio waves to see them! These images open doors to new discoveries. In this issue of *Celebrating Chemistry*, you will learn more about how photography and imaging work. It is exciting to think about what we will be able to see in the future, thanks to the creativity of scientists and other creative people.

The Adventurous Journey of Medical Imaging

By Jackie Trischman, Ph.D.

Long ago, if someone felt sick, doctors had to use their knowledge and experience to guess what was wrong. They had to rely on what they could see or feel to diagnose what was going on inside a patient's body. But then a clever scientist named Wilhelm Conrad Roentgen had a breakthrough. He discovered a way to see inside the human body using X-rays, a special kind of light.



A simplified image of a patient in an MRI machine.
Note: actual MRI scanners do not use horseshoe-shaped magnets

With his discovery, Roentgen created the first X-ray image of a human hand. It was like having a superpower!

X-rays are invisible to the human eye and pass right through skin and most organs. However, because bones are made of dense materials that contain calcium, they absorb X-rays and create shadows wherever they are blocked. Medical professionals use film or a special sensor (like in a digital camera) to detect and capture the X-rays as they pass through the body.

Using X-rays was a major improvement over guessing what was happening inside someone's body. But X-rays also have limitations. As time passed, more brilliant minds joined the quest to improve medical imaging. They developed new types of scanners that let doctors easily see what was going on inside a patient, including:

- CT scanners — short for Computed Tomography, these provide 3-dimensional, detailed views of organs inside a patient's body, made by moving an X-ray scanner around the body.
- MRIs — short for Magnetic Resonance Imaging, these machines use strong magnetic fields and radio waves to capture images of body parts that are not bones.
- **Ultrasound** — these use sound waves to create images that doctors and patients can look at to understand what's going on inside organs and tissues in real time.

Each of these techniques has its own benefits, allowing doctors to see different parts of the body in amazing detail. They are used to detect and diagnose disease, check how well organs are working, and track how well a treatment is going. All this modern technology allows doctors to see much more than broken bones!

Scientists continue to dream big and push the boundaries of what is possible. Chemists work with computer scientists and physicists every day to invent new techniques and improve existing ones. As a result, they are making medical imaging even more powerful and precise.

Milli's Safety Tips: Safety First!

ALWAYS:

- Ask an adult for permission to do the activity and for help when necessary.
- Read all directions and safety recommendations before starting the activity.
- Wear appropriate personal protective equipment (safety glasses, at a minimum), including during preparation and clean up.
- Tie back long hair and secure loose clothing, such as long sleeves and drawstrings.
- Do not eat or drink food when conducting the activity.
- Clean up and dispose of materials properly when you are finished with the activity.
- Thoroughly wash hands after conducting the activity.

Jackie Trischman, Ph.D. *is Dean of the College of STEM at California State University, San Marcos.*

The Chemistry of Developing Photographs

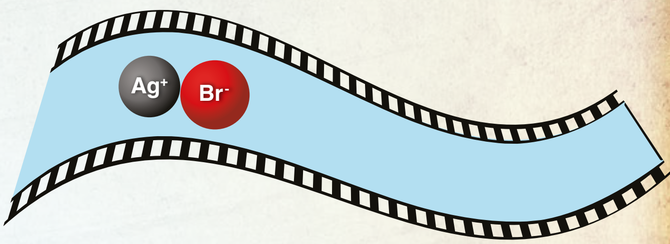
By Keith Micheal Krise, Ph.D. and Scott A. Williams, Ph.D.

In the early days of photography, people used much simpler cameras. These cameras could “capture” images and focus their light onto light-sensitive material called photographic **film**. To take a picture, a photographer would focus their camera **lens** and press a button. The lens would then open for a short time, and snap shut. The amount of time the lens stayed open would depend on how much light was available. A picture taken on a cloudy day would need a longer exposure than a bright, sunny day.

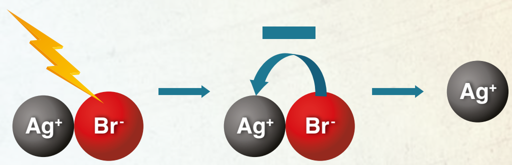
The moment the picture was taken, the film had to be kept in total darkness inside the camera. To take a new picture, the photographer would use a fresh section of film. The film was a long roll, and a photographer could expose many different frames before they needed to load new film into the camera.

What was on the film that made it photosensitive? This is where we get to see some interesting chemistry at work! In black-and-white photography, film was made by coating it with gelatin (the same ingredient found in Jell-O desserts). This kind of gelatin contained silver bromide (AgBr for short). This is a simple chemical like the table salt (sodium chloride, NaCl) that you have in your kitchen, but it contains silver instead of sodium. The silver in silver bromide has a positive charge, and the bromide has a negative charge. The opposite charges on the silver and bromide ions cause them to be held together by an electrostatic force.

When light strikes the silver bromide, it causes the negative charge on the bromide to transfer to the positive silver. Since a negative charge cancels a positive charge, this makes the silver neutral. While the positively charged silver **ion** is **transparent**, and allows light to pass through the film, the neutral silver is opaque, meaning it blocks light. This happens all over the frame of film, making a pattern of light and dark in the form of the image captured with the camera.



Ag^+ and Br^- ions in gelatin (blue) on the film surface.



Light causes a negative charge from bromide ion to move to Ag producing opaque Ag atoms

If the exposed film stays in the dark, any image on it is stable and will not change. But we don’t want to look at film only in the dark, so the film needs to be “fixed,” or locked in place. To do this, the photographer removed the film from the camera in a darkroom. Then they washed the film in a fixer solution that changed the positive silver ions remaining on the film into a form that was no longer sensitive to light. The image in the film was the reverse (or ‘negative’) of the actual scene captured.

The next step in the process was to shine light through the negative onto a piece of photographic print paper that was also light-sensitive. After this exposure, the photographic print had to be developed (using more chemistry). This process could take hours or even days because most people would send their film to a lab to have it created or developed and printed. It wasn’t until photos were developed that you knew whether you had taken a good picture or not. It should make you appreciate how fast and easy today’s digital photography works!

Keith Micheal Krise, Ph.D. *is Professor of Chemistry and Biochemistry at Gannon University.* ***Scott A. Williams, Ph.D.*** *is Professor of Inorganic Chemistry and Director of Materials Science and Engineering Graduate Program at Rochester Institute of Technology.*

Investigating Images in Invisible Inks – It's Incredible!

By David Heroux, Ph.D.

Introduction

Photography uses light to make a chemical change and create an image. The Anthotype/Sun Print activity in this issue of *Celebrating Chemistry* (located on pg. 11) is an example of a chemical change that uses sunlight.

In this activity, you will explore using heat, instead of light, to develop an image. Using heat to make invisible ink appear is an example of a chemical change. Another example of this kind of change is when food gets burnt.

Additionally, you will explore different materials that can be used as invisible inks on paper to make an image appear!

SAFETY SUGGESTIONS

- Safety goggles required
- Do not eat or drink any of the materials used in this activity
- Thoroughly wash hands after this activity
- You will need an adult to help you use the oven to develop your pictures. Only adults should handle items being heated, and they should wear oven mitts.

Question to Investigate

What makes the best material for invisible inks?

Materials

- Paper
- Paint brushes, cotton swabs, or similar item for drawing your invisible picture
- Materials to test as invisible inks:
  - Fruit juice (lemon, apple, or orange juice)
  - Onion blended in food processor
  - Vinegar
  - Clear soda
  - Diluted honey
  - Milk
  - Sheet pan (cookie sheet)
  - Oven

Procedure

1. Select several of the invisible ink materials to test. Make sure to use a new cotton swab or paint brush with each ink tested.
2. Make a data table that includes the name of the materials you use to make an image, the time it takes for the image to appear, and the darkness of the image. Draw a picture using your invisible ink. When your drawing is done, use a pencil to print the name of the material used.
3. While you are drawing your image, have an adult preheat the oven to 350 ˚F/177 ˚C.
4. Place your picture(s) on a cookie sheet and have your adult helper place it in the oven for 5 minutes.
5. Have the adult remove the cookie sheet from the oven and wait for it to cool before handling.
6. Observe your image and record your data in your table.
7. Explore which "ink" forms an image faster by making new pictures and heating them for shorter times.
8. Which of your "inks" was the most invisible before heating? Which "ink" made the darkest image after heating? Use a scale of 1 to 5 to indicate how dark each one is.

What did you observe?

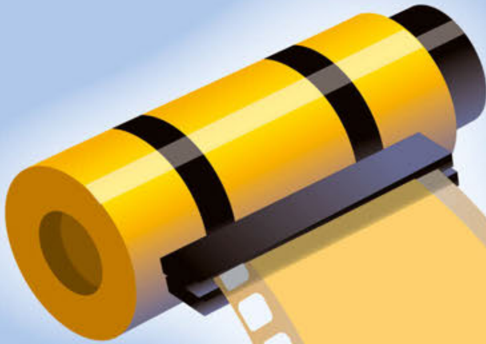
If you were a spy and wanted to send a message in invisible ink, which one of the inks you tested, if any, would you use?

How does it work? / Where's the chemistry?

The material in this activity used to make the invisible inks all contain acids or sugars. These acids react with the paper to form sugars. When heated, the sugars oxidize and turn dark.

David Heroux, Ph.D. *is the Leavy Family Professor of Chemistry at Saint Michael's College.*

Photography Through the Years



1500 - The first Pinhole camera (Camera Obscura) was used to trace an image.

1826 - Camera Obscura is used to make an image on metal plates coated with chemicals. This was when the first permanent photograph was taken! It took 8 hours to take this photograph!

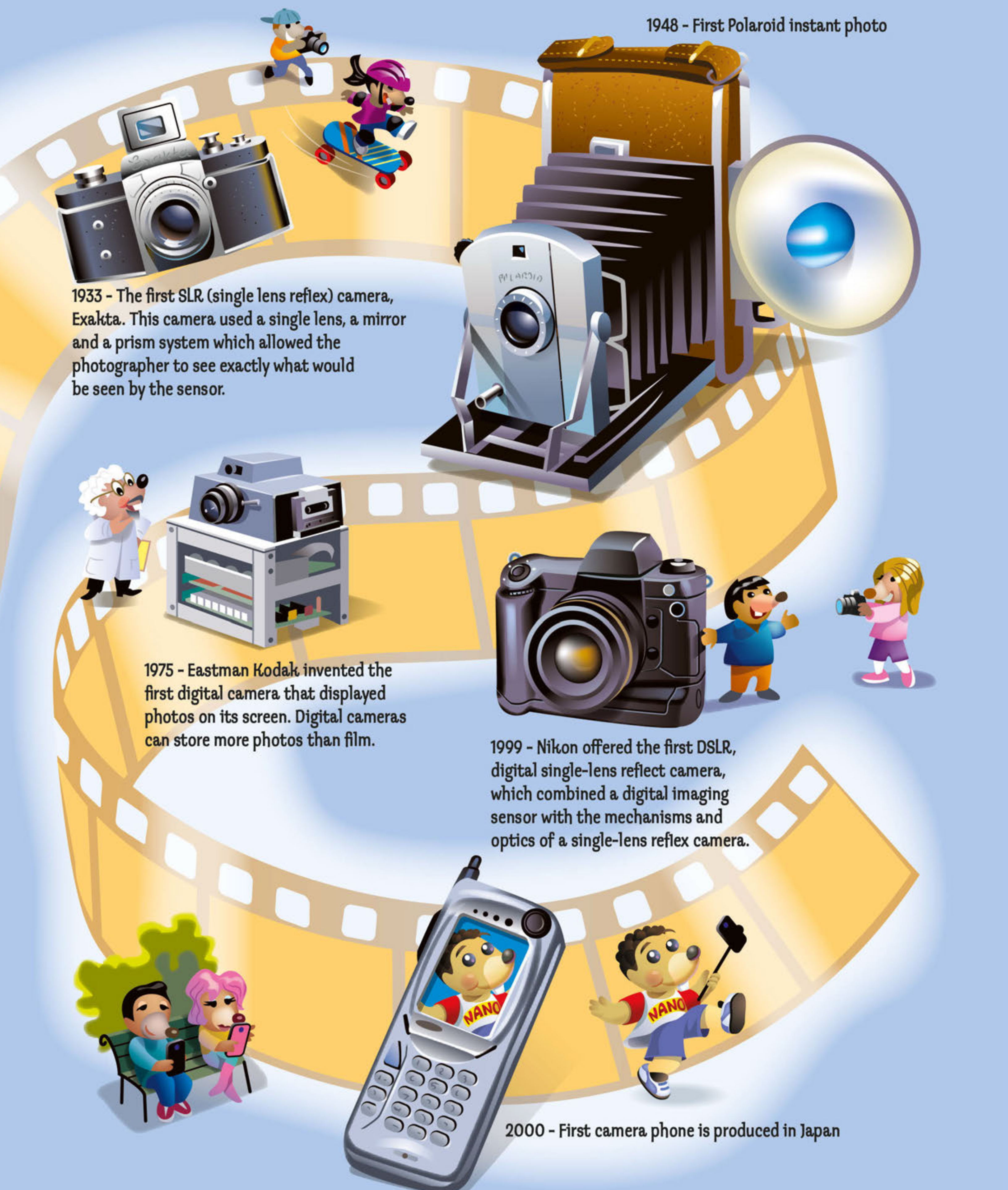
1839 - The first glass negative was used in Daguerreotype process which involved exposure to make a negative and then processing it with chemicals to develop and fix the image. These photos were one of a kind and took only 15 minutes to take the photo.

1851 - The wet collodion process becomes the standard as the photographs made by this method are more detailed and sharper. Also the wet **collodion** process produces a negative that can be used to make duplicate photos.

1913 - The first handheld camera Leica was sold. This camera had 35mm film.

1861 - First color photograph was made by taking multiple images through red, green, and blue filters. Then these images were overlaid to make a colored image.

1888 - Kodak made the first film camera, which had a 20-foot film roll that held 100 photos. This made photography available to all! These photographs were 2.5 inches.



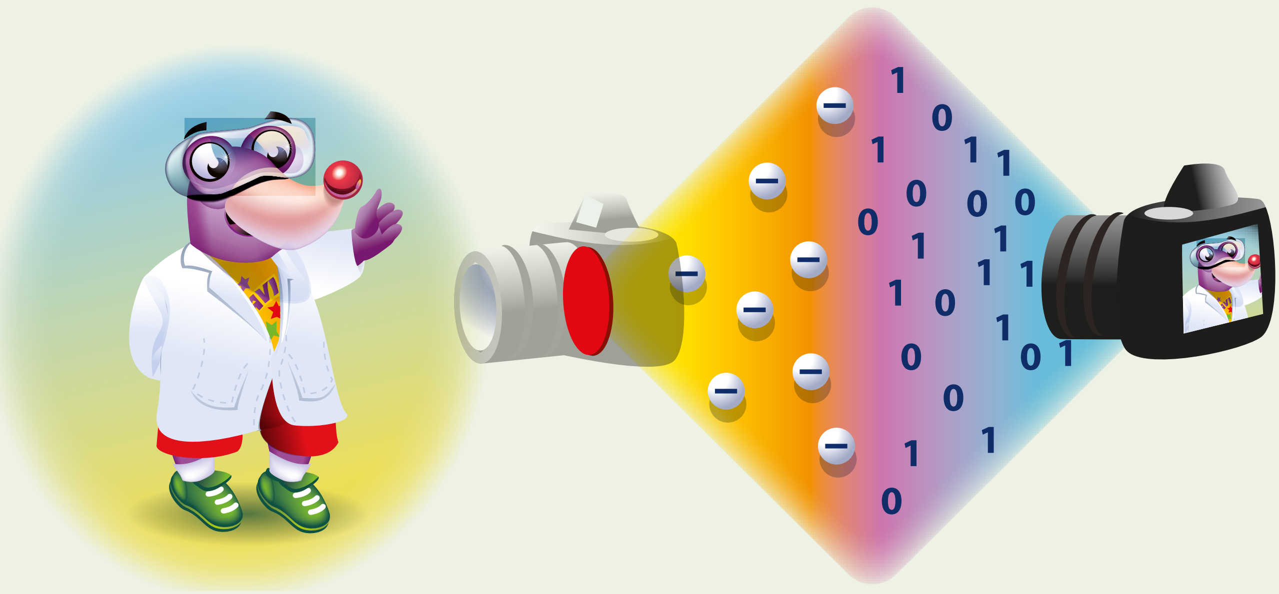
1948 - First Polaroid instant photo

1933 - The first SLR (single lens reflex) camera, Exakta. This camera used a single lens, a mirror and a prism system which allowed the photographer to see exactly what would be seen by the sensor.

1975 - Eastman Kodak invented the first digital camera that displayed photos on its screen. Digital cameras can store more photos than film.

1999 - Nikon offered the first DSLR, digital single-lens reflect camera, which combined a digital imaging sensor with the mechanisms and optics of a single-lens reflex camera.

2000 - First camera phone is produced in Japan



The Science Behind Digital Imaging

By Oksana Love, Ph.D. and Robin Tanke, Ph.D.

Most ways of collecting images are based on the contact of light with materials. Film cameras catch images on light sensitive film that is developed into pictures using special processes. Digital cameras use a light sensitive detector or sensor instead of film, and this allows you to see your picture instantly. It is not magic…it's science!

How does it work? Light from an object makes its way to a sensor (see figure 1) in a camera. On the sensor there are millions of cells called photocells. Each photocell takes one bit of information about the entire picture. Each photocell is like a tile in a mosaic (see figure 2) with each tile or photocell capturing one piece of the picture. The more photocells a camera has, the more detail can be captured in the picture.

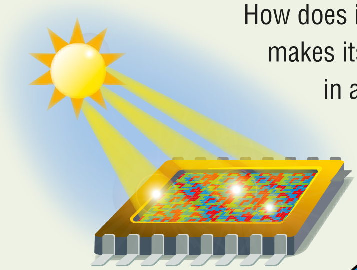


Figure 1. Camera Sensor

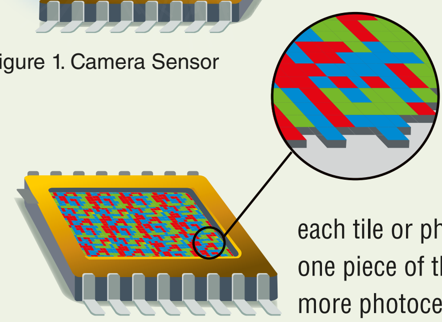


Figure 2. Mosaic containing hundreds of tiles

When the light reflecting off an object or image reaches a photocell, electrons are freed or let off. If the amount of light that reaches the photocell increases, the number of freed electrons increases. The number of freed electrons is measured and changed into the digital codes of "ones" and "zeroes." This information is shown on your camera screen as an image.

It may be surprising, but photocells only capture brightness, not color. For this reason, this process only makes black and white images. So how do we get colorful pictures?

Colors in a photographic, or camera image, are usually based on the three primary colors: red, green, and blue. **Filters** of the colors are placed on different photocells. Some photocells would have red filters on them, some green, and some blue. Each **pixel**, or smallest part of an image, has only one-color filter, so it can only show one color. If we combine all the colors from each pixel, they mix together, and the picture isn't very clear. So how do we get perfectly clear and colorful pictures? Believe it or not, there is a computer in your camera!

A computer program in your camera does the calculations to guess what color and brightness should be in each part of the image. Millions of calculations happen in just a few seconds after you press the button to take a picture. The better the calculations, the better the picture.

Today, we use smart phone cameras to take pictures. Thanks to the amazing way technology has helped us to capture light and turn it into a photo.

__Oksana Love, Ph.D.__ is an Assistant Professor at University of North Carolina- Asheville and __Robin Tanke, Ph.D.__ is a Professor of Chemistry at University of Wisconsin- Stevens Point.

Imaging Without Light

By Robin Tanke, Ph.D.

Introduction

All matter is made of very small units called **atoms**. Atoms are so small they cannot be seen using a regular microscope. Scientists have discovered a way to "see" atoms using a special instrument called a scanning probe microscope (SPM). A probe with a single atom at its tip is pulled across a surface and reacts to differences in the atoms at the surface of the material. It is a little like a person being able to read words in Braille by feeling raised dots on a page with their fingertips.

In this activity, we will model how we can get an image made of an object without observing it directly.

Question to Investigate

How can we create images without light? How can we imagine a material that cannot be seen?

Materials

- Two rectangular, flat refrigerator magnets.
- Be sure to check them to make sure they stick to the refrigerator

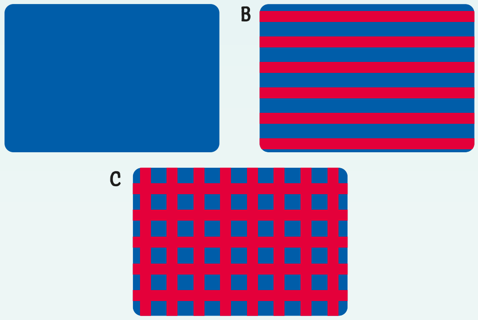
What did you observe?

When the probe magnet is moved in one direction, it should move smoothly across the surface. But when pulled across in the perpendicular direction, the probe magnet "bounces" over the surface. This shows that there may be a force that cannot be seen but can be detected. In this case, the invisible force is a magnetic field!

Procedure

1. Place one magnet so its plain side is facing *up*. This is the material to be analyzed.
2. Lay the second magnet on top of the first magnet, so its plain side is facing *down*. This is your probe.
3. Pull the second magnet over the surface of the first. Describe how it feels when you do this.
4. Turn your top magnet perpendicular to the first magnet, and then pull it over the surface. How does it feel? Is it the same as before?

Based on the interaction that you feel, which of the three diagrams best represents how the magnet's force is arranged: A, B, or C?



How does it work? / Where's the chemistry?

Because atoms are too small to observe with light, we must use other properties to image them. Atoms are surrounded by **electrons** that can interact with the outer electrons of a probe atom. The probe then records changes in force as it moves across the surface.

This activity is a model of how an SPM works. The surface of the magnet seems smooth, and we cannot see a pattern. However, using another magnet as a probe, an image can be created. We cannot see atoms, but with an SPM, we can identify their arrangement.

Robin Tanke, Ph.D. *is Professor of Chemistry at University of Wisconsin – Stevens Point.*

ANSWER: B

The Adventures of Meg A. Mole, Future Chemist

Dr. Olivia Kuzio

In honor of this year's National Chemistry Week theme, "Picture Perfect Chemistry," I traveled to Los Angeles, California to meet Dr. Olivia Kuzio. Dr. Kuzio is an Assistant Scientist at the Getty Conservation Institute, where she and other scientists "advance conservation practice in the visual arts."

What does this mean? Dr. Kuzio explained, "I am a scientist who works in an art museum. I use special cameras that create images of the works of art that I study. They also help me identify the materials the artist used and how they applied them, and also how the materials have changed over time."

How exciting! I wanted to learn more. Dr. Kuzio continued, "I am interested in learning what kinds and colors of paints certain artists preferred, and I study how and why some of those paints have faded over time. Sometimes, when I perform imaging that uses X-rays, I wear a special instrument called a **dosimeter** to make sure I am not exposed to the rays, which can be harmful."

If you work in a museum, I asked, how can you do this type of work? "I do much of my work in an imaging studio. It looks like a behind-the-scenes movie set, because it is full of cameras and lighting equipment," she said. Dr. Kuzio showed me her imaging studio, which was amazing.

I asked Dr. Kuzio which part of her job she likes the most. "It is an amazing privilege to see and work with beautiful, well-known works of art, up close and unframed, every day," she shared. "For instance, one of my current projects is a painting by Vincent van Gogh."

I asked Dr. Kuzio if she was interested in science when she was growing up. "Yes!" she answered. "I really liked that science 'made sense,' and that you could always find the correct answer — *if* you understood the steps to get to it." She always enjoyed being surprised by scientific discoveries. "In one experiment, I remember crushing up cereal, mixing it in water, and using a magnet to extract the iron from it. I knew that iron was a mineral essential to a healthy diet. But I could hardly believe what I saw — that there was actual metal in the food that I was eating!" Dr. Kuzio recalled the encouragement she'd received from her family. "My parents are an engineer and a teacher and always encouraged me to follow my curiosities about the ways the world works," she explained.

I really enjoyed my visit to Los Angeles with Dr. Kuzio. It is neat to know that in the same city where movies are made, there is also great art chemistry!

Personal Profile

Favorite color? Green

Favorite pastime/hobby? I like to read, hike, and travel to explore new cities and museums.

Very interesting project you were part of? Studying the paints that van Gogh liked to use the most, and how those paints have faded over time. I helped conservators and curators understand what his paintings may have looked like when the paint was fresh and unfaded. This helps us understand van Gogh's art as he wanted it to look.

Accomplishment you are most proud of? I recently ran (and finished) a 50-mile-long trail race!

Anthotype Printing with Turmeric … Sun Prints!

By Jackie Trischman, Ph.D.

Introduction

Turmeric is a deeply yellow-orange colored spice commonly used in Indian food. But its uses extend far beyond just adding flavor. Curcumin, a chemical found in turmeric, is known for its health benefits and for its long-time use as a fabric dye.

This remarkable chemical is also a photosensitizer. That means it reacts in certain ways when exposed to light. This fact allows us to use\c in anthotype printing, a method popular in the 19th century. Anthotype printing uses plant products and exposes them to the sun to produce images on materials like paper and cloth. In this activity, you will create an anthotype print, also known as a sun print!

SAFETY SUGGESTIONS

- Splash goggles required
- Protective clothing suggested
- Do not eat or drink any of the materials used in this activity
- Rubber gloves suggested

Materials

- 1 teaspoon (about 5 mL) of turmeric powder
- 2 teaspoons (10 mL) of borax (found in the laundry section of grocery stores)
- 3 tablespoons (45 mL) of isopropyl rubbing alcohol
- ½ cup (120 mL) of warm water
- 1 sheet of copier or printer paper (make sure it's non-glossy)
- The object you wish to print (a negative) — this could be a flower, a leaf, or other flat object
- Two 1-cup (about 240 mL) containers
- Spoon
- Sponge or brush
- Spray bottle
- Coffee filter or cheesecloth
- Photo frame glass (to weigh down your print as it develops)
- Paper towels

Procedure

1. For the best results, do this activity on a sunny day.
2. Wear gloves and an apron to protect your hands and clothes. Turmeric will stain anything it touches!
3. Mix the turmeric powder and alcohol in one of the 1-cup containers.
4. Strain the mixture by pouring it through a coffee filter or cheesecloth into the second container. Keep the liquid and discard the filter. This liquid is your dye.
5. Do this next step out of the sunlight, in a place with low light. On a layer of paper towels, use the sponge or brush to cover the paper with dye as evenly as possible. Let it dry for 15 minutes. This will be your "film."
6. Place the object you want to print (the negative) on the paper. To make a print with the deepest colors, choose opaque objects (ones that light cannot pass through). If your object allows light through in different amounts, you will get different depths of color on your print. You are only limited by your creativity!
7. Place your negative and film setup under the photo frame glass to keep the paper and negative flat.
8. Now place your setup on a flat surface where the sun can shine on it. Once you position your setup, do not move it. The amount of time you leave your setup in the sun will depend on the time of day, the weather, and the level of contrast you want to give your image. When the background turns from a deep yellow-brown to a pale yellow, you are ready for the next step.
9. While waiting for your image to "develop," add the borax to the water, and pour it into the spray bottle.
10. When you notice the background color of your image has become much lighter than the area under the negative, remove the negative from the sun.
11. Place your print on a paper towel. Shake your borax solution well, and with the help of an adult spray a thin layer of it onto the print to keep your image from fading any more. Wait about 10 minutes and observe any changes to the color of the image in darker yellow.
12. Let your image dry. To get a different effect, try making some changes. For example, you can change your dye concentration by using more or less turmeric. You can also choose a different type of negative object to put on the film or change how long you leave it exposed to sunlight. What effect did you like the best?

How does it work?

Curcumin in the turmeric absorbed the energy from the sunlight. This caused the curcumin to rapidly break down and lose its color. Once reacted, the dye bonds more strongly to the paper.

The curcumin was protected only while it was under the negative. If we stopped here, it would react to the light and the image would be bleached away within a few hours or days. The borax or sodium borate solution stops the photoreaction from happening and reacts with the curcumin in a way that darkens the colors.

Jackie Trischman, Ph.D. *is Dean of the College of STEM at California State University, San Marcos.*

Words to Know

Molecules - groups of atoms bonded together.

Chemical Reaction - the process of atoms and molecules creating or breaking bonds; often leads to a change in color, smell, temperature, or other changes in properties.

Ions - atom or molecule that has lost or gained one or more electron.

Ultrasound - medical imaging technique that uses sound waves to see organs, muscles, and other tissues inside the body.

Colloid - a mixture of different small particles made up of many molecules that are too small to see with the naked eye.

Film - thin strip of material coated with light sensitive chemicals used to take pictures.

Filters - materials that let through light of certain wavelengths.

Transparent - describes a material or substance that light can pass through.

Atom - the basic building block of matter and chemistry, made of protons, neutrons, and electrons.

Lens - transparent material with a curved surface to make an image larger or smaller.

Imaging - capturing a visual representation using different forms of energy than visible light.

Dosimeter - a tool that measures radiation.

Pixel - smallest visible color units on a display screen.

Electron - a tiny particle with a negative charge.

Why should you never trust an atom? They make up everything!

About Celebrating Chemistry

Celebrating Chemistry is a publication of the ACS Office of Science Outreach in conjunction with the Committee on Community Activities (CCA). The Office of Science Outreach is part of the ACS Division of Education. The National Chemistry Week (NCW) edition of *Celebrating Chemistry* is published annually and is available free of charge online or in print through your local NCW Coordinator. Visit **www.acs.org/ncw** to learn more.

About the American Chemical Society

The American Chemical Society (ACS) is one of the world's largest scientific organizations. ACS members are chemists, chemical engineers, and other professionals who work in chemistry or chemistry-related jobs. The ACS has more than 173,000 individuals in our global community across 140 countries. Members of the ACS share ideas with each other and learn about important discoveries in chemistry during scientific meetings held several times a year, through the ACS website, and through the many peer-reviewed scientific journals the ACS publishes. ACS members carry out many programs that help the public learn about chemistry. One of these programs is National Chemistry Week, held annually during the third full week of October. ACS members celebrate by holding events in schools, shopping malls, science museums, libraries, and even virtually online! Activities at these events include carrying out chemistry investigations and participating in contests and games. If you'd like more information about these programs, please contact us at **outreach@acs.org.**

PRODUCTION TEAM

Robin Polk, Editor
Sri Balasubramanian, Editor
Eric Stewart, Copyeditor
Michael Tinnesand, Copyeditor
Rhonda Saunders, Designer
Jim Starr, Illustrator

TECHNICAL AND SAFETY REVIEW TEAM

Bettyann Howson, Safety Reviewer
Weslene Tallmadge, Safety Reviewer
Sara Delgado-Rivera, Translation Reviewer
Cristina Bartolomei, Translation Reviewer
Lynn Hogue, Age-appropriateness Reviewer

NCW 2024 THEME TEAM

Veronica Jaramillo 2024 Co-Chair
Jackie Trischman 2024 Co-Chair
Dave Heroux
Faith Yarberry
Susan Hershberger
Keith Krise
Sherri Rukes
Monica Sekharan
Oksana Love
Robin Tanke
Lori Stepan
Eileen DiMauro
Betty Jo Chitester
Cary Supalo
Ashley Blystone
An-Phong Le

ACS DIVISION OF EDUCATION

Terri Chambers, Vice President, Education and Career Development
Nancy Bakowski, Director of Academic Engagement and Outreach
Lily Raines, Sr. Portfolio Manager, Office of Science Outreach
Ayanna Lynch, Program Specialist, Office of Science Outreach
Sri Balasubramanian, Program Specialist, Office of Science Outreach

ACKNOWLEDGMENTS

The articles and activities used in this publication were written by theme team members of the ACS Committee on Community Activities under the leadership of **Lori Stepan**. Meg A. Mole's interview was written by **Kara KasaKaitas**. The translation for *Celebrando la Química* was done by **ACSI Translations**. The front cover illustration concept is by **Dave Heroux**. The center spread illustration concept is by **Veronica Jaramillo**.

REFERENCES

https://commons.wikimedia.org/wiki/File:First_medical_X-ray_by_Wilhelm_R%C3%B6ntgen_of_his_wife_Anna_Bertha_Ludwig%27s_hand_-_18951222.gif

https://www.nobelprize.org/prizes/physics/1901/rontgen/biographical/

https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/magnetic-resonance-imaging-mri#:~:text=The%20strong%20magnetic%20field%20created,and%20send%20back%20radio%20signals

http://www.film-photography-blog.com/film-processing-chemistry-how-does-it-work/

https://www.explainthatstuff.com/how-film-cameras-work.html#:~:text=through%20the%20camera.-,How%20does%20a%20film%20camera%20work%3F,at%20the%20back%20(brown)

https://www.acs.org/content/dam/acsorg/education/outreach/celebrating-chemistry/2016-ncw-celebrating-chemistry-english.pdf (pg. 5)

https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/camera-obscura-ancestor-modern-photography#:~:text=In%20500%20b.c.%2C%20the%20philosopher,Aristotle's%20experiments%20went%20no%20further

https://www.fi.edu/en/history-resources/daguerreotype-photography

https://www.kva.se/en/news/nobelpriset-i-fysik-2009-2/

https://www.shortcourses.com/guide/guide1-3.html

https://education.mrsec.wisc.edu/wp-content/uploads/sites/283/2017/07/SPM_magnet_full_instructions.pdf

https://engineerdog.com/2015/03/12/why-do-refrigerator-magnets-only-stick-on-one-side/#:~:text=How%20it's%20made%3A,to%20a%20strong%20magnetic%20field

Division of Education, Office of Science Outreach • 1155 Sixteenth Street NW, Washington, DC 20036
800-227-5558 • outreach@acs.org • www.acs.org/outreach

Want to learn more about our moles? Check out www.acs.org/moles