Fingerprint Analysis: Taking Evidence to a Whole New (Nano) Level

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This curriculum unit is recommended for:
Honors Forensic Science, Chemistry and Physics
Grades 10-12

Keywords: nanoscience, nanomaterials, nanotechnology, fingerprints, forensic science, fluorescence, sensors, biosensors

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This unit begins with a brief look at some current applications of nanomaterials in various contexts and then focuses on their use in the field of forensic science, particularly fingerprint analysis. The basics of fingerprints including their anatomy and development is discussed. The principles underlying fingerprint science are laid out, as are the various types and classifications of fingerprints. The advantages and disadvantages of several current methods for identifying latent fingerprints at crime scenes are discussed. Nanoscience is introduced as an area which may provide answers to some of the current problems in fingerprint analysis. The concept of nanoscale materials is explored. The properties of nanomaterials which make them useful in forensics are discussed. This paper then turns to the specific use of fingerprints to determine whether a person has handled or ingested illicit drugs or been exposed to explosives, poisons or toxins. Current research in the field of biosensors is reviewed with an eye toward working being done to develop quick, cheap and portable devices to enhance fingerprint imaging and extract information for investigative and security purposes. The paper concludes with materials and suggestions for classroom activities for use in teaching forensic applications of nanotechnology to high school students.

I plan to teach this unit during the coming year to 170 11th and 12th grade students in Honors Forensic Science.

Fingerprint Analysis:
Taking Evidence to a Whole New (Nano) Level

Introduction

Rationale

Forensic science is the application of science to the law. Its' purpose is to identify and analyze evidence for use in finding and prosecuting persons who commit crimes. Just a couple of decades ago, most people's vision of crime scene investigation – if they had one at all – was of a Sherlock Holmes-type detective walking around a crime scene examining "clues" with a magnifying glass. Some basic categories of forensics were widely used. In particular, fingerprint comparison has been a staple of crime scene investigation in this country since New York State prisons started using fingerprints as a method of identifying inmates in 1903.

In the 1990's, interest in forensic science exploded with the advent of a slew of crime scene television shows such as the *CSI* and *Law & Order* franchises. This in part spurred new interest in research in various fields of forensic science. In recent years, research and development in the area of nanoscience and nanotechnology has opened up whole new worlds of possibilities for forensic science. Using nanotechnology, scientists are now able to analyze the oil and sweat deposits from a fingerprint to determine if a person has not only handled illegal drugs, but also whether they have ingested them. The same techniques allow scientists to identify people who have recently handled certain toxins, like ricin or anthrax, or explosives. Scientists are also able to determine a person's gender, lifestyle, and diet from fingerprint residue. A big part of these achievements is due to advancements in the field of nanoscience.

Nanoscience is an area that has current and potential applications in so many arenas that effect students' lives. Fabrics made with nanomaterials are already being used to produce clothing that is water resistant and self-cleaning. Studies are being conducted on how nanomaterials can be used to increase the efficiency of solar cells. Nanoparticles are used in everything from sunscreens to cosmetics to food packaging. Medical applications include developing treatments specific to each patient for targeted therapies. Other countries are rapidly integrating nanoscience into their elementary and secondary curricula.[1] It is becoming increasingly important that students in the 21st century become literate in the area of nanoscience. With this curriculum unit, students will develop a working understanding of what nanoscience is and what roles it plays in their lives. They will be exposed to the scope of the developments made possible by advances in nanotechnology. Students will study the current applications of nanotechnology to forensic science, with a focus on advances in fingerprint technology. They will develop an understanding of how the research process works and will develop their critical thinking skills while analyzing the impact nanomaterials and nanotechnology may have on their lives. They will brainstorm potential applications of nanotechnology to the field of forensics and examine the ethical issues raised by some applications of nanotechnology. In short, they will learn to think like scientists!

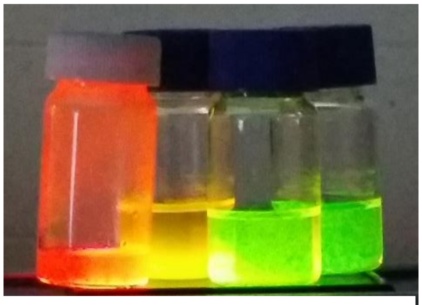
Demographics

William Amos Hough High School is a large suburban high school of 2,654 students located in the small town of Cornelius, North Carolina. Hough opened its doors in 2010 to serve the northern part of the Charlotte-Mecklenburg School District. The graduation rate is 93.8% and 95% of those graduates go on to either two- or four-year colleges. Twenty-four percent of the students are minorities. The student body is split evenly between males and females. Hough offers a comprehensive college preparatory program in the arts and sciences. Classes are taught at the Standard and Honors levels and 22 Advanced Placement (AP) courses are offered in conjunction with the College Board. The science program requires one earth science (Earth and Environmental Science or AP Environmental Science), Biology, and one physical science (Chemistry, Physics or Physical Science). Biology, Chemistry and Physics are also offered at the AP level.

Students are required to take either a fourth-year science or social studies course. Honors Forensic Science is a science elective offered to meet that requirement. Classes are made up almost entirely of juniors and seniors. Students should come to the class with a solid foundation in biology, chemistry and trigonometry. An understanding of vectors and forces from physics will be very helpful as well. Background knowledge of civics will help students place forensics in its proper context within the judicial and scientific communities. With the overwhelming popularity of forensics in popular culture, this course grabs students' interest while it teaches them valuable lab skills and sharpens their communication, critical thinking and problem-solving skills. It also enhances 21st century skills such as collaboration, use of technology and presentation skills.

Unit Goals

Students will take away three main concepts from this unit. First, they will understand what nanoscience and nanotechnology are and how they already impact students' lives. Nanoscience is the study of materials and their properties when the materials have at least one dimension in the range of 1-100 nanometers. A nanometer is one billionth of a meter. At that scale, materials have different physical, chemical, electrical and optical properties than they do on a macroscale. Even though they didn't know it, artisans as early as the 4th century were using nanoparticles to color the glass they used to make everything from ornate goblets to the Rose Window in the Cathedral of Notre Dame in Paris. Nanotechnology takes those special properties and puts them to work in a wide range of ways. For example, the fact that a material can change color depending on the size of the particle can be used to create sensors that detect certain chemicals or types of cells in the human body.



Fluorescing nanoparticles.
Credit: J. Smith

Next, students will come away with an understanding of current and potential applications of nanotechnology to forensic science. Nanotechnology is already in the world around us. It is being used to manufacture water-resistant and self-cleaning fabrics that can have long-range implications for the military and for consumers. Nanotechnology has been used to engineer nanoparticles that deliver chemotherapy drugs directly to cancer cells without damaging surrounding cells. Applications of nanotechnology to the field of forensic science are still in their infancy. Some things are already possible, such as raising a serial number on a firearm that had been scratched off and detecting toxins and poisons a person has been in contact with through the oils and sweat left with their fingerprints. Students will look at the science of fingerprint analysis where nanotechnology is already changing testing techniques and they will explore areas of forensic science that hold the most potential to contain the next great discovery in nanotechnology.

Lastly, students will develop stronger research, scientific literacy, presentation and critical thinking skills. Hough High School showed over 9% growth in all areas on end-of-course tests last year, exceeding district and state averages, but the area of scientific and data literacy fell short. The focus this year at Hough High School is data literacy and this unit offers a perfect opportunity to expose students to complex data sets and higher-level readings to improve these skills. Students will also be asked to think about the ethics involved in this new technology. They will develop opinions about the use of a person's fingerprints, without their knowledge or consent, for testing purposes. They will defend their positions in a unit cumulative debate.

Content Research

Fingerprint Basics

Fingerprints have been used since ancient times as a binding signature on contracts and other documents. Although they probably did not understand the science behind it, the Chinese and Egyptians understood that something about a person's fingerprint was unique to them and used fingerprints on important documents. Fingerprints have been used since the late 1800's to uniquely identify a person, although fingerprint evidence was not accepted as scientific evidence in a court of law in the United States until 1999.

In the Fingerprint unit we cover in Honors Forensic Science, students learn about the formation and anatomy of fingerprints. They then go on to learn to classify fingerprints by their type and how to match fingerprints using unique characteristics called minutiae. Students also practice rolling fingerprints, dusting for prints with various types of powders and tape lifting the prints to preserve them, as well as practicing techniques such as cyanoacrylate fuming and fingerprint development with ninhydrin and silver nitrate.

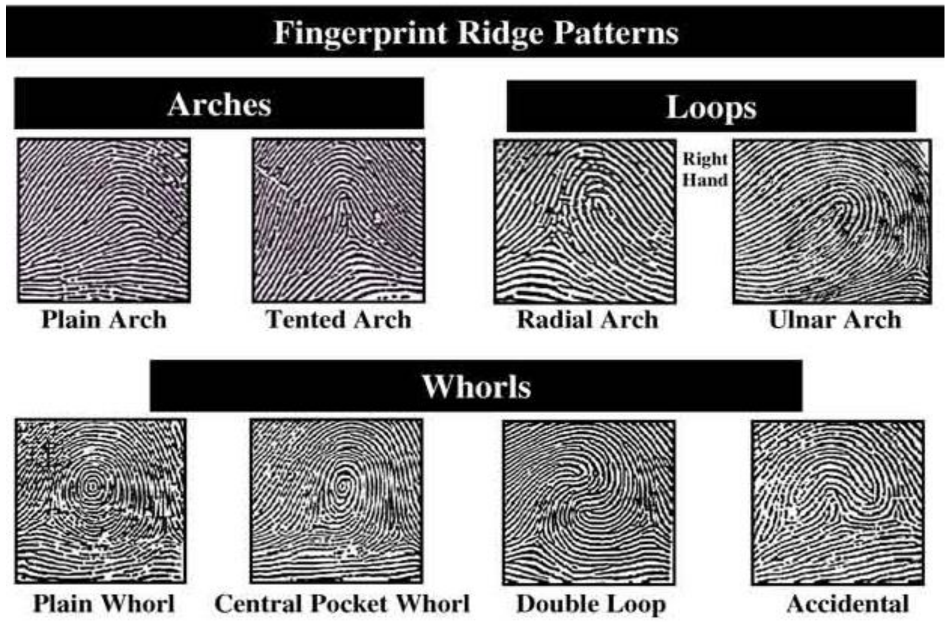
Fingerprints are the pattern of ridges and furrows found on the palm side of the fingers and thumbs. The science of fingerprint analysis rests on three principles. First, fingerprints are unique. Even identical twins do not have the same fingerprints. This is because while *in utero* each fetus' fingers press on different things in different ways and with different pressures while the prints are developing. This causes the fingerprints to develop with different details. Even each person's ten fingerprints are unique from each other. To date, no two fingerprints have been found to be identical.[2]

Second, fingerprints remain unchanged during a person's lifetime. Skin is made up of three layers. The dermis is the deepest layer and the epidermis is the surface layer of skin. Sandwiched between these two layers is another type of skin tissue called the basal layer. This layer grows much more quickly than the layers above and below it leaving nowhere for the basal layer to expand. Thus, it folds up on itself creating the patterns of ridges that can be seen on the surface as fingerprints. This happens at 12-16 weeks of development. There are many notorious cases of criminals trying to alter their fingerprints to avoid detection. Gangster John Dillinger burned his fingers with acid in an attempt to remove his prints. However, this generally results only in making the person's fingerprints even easier to identify due to the scarring involved.

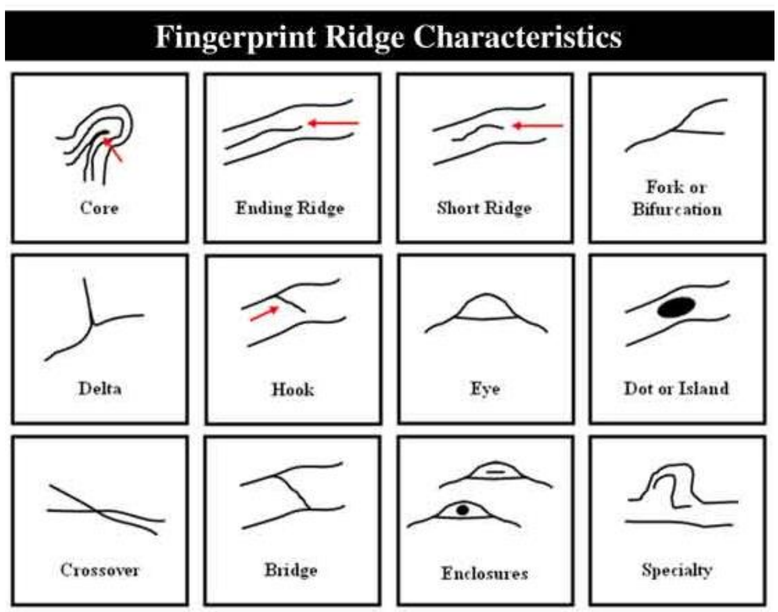
Lastly, fingerprints can be classified in such a way as to identify the individual to whom they belong. In the late 1890's, Sir E.R. Henry postulated that all fingerprints could be grouped into one of three types: loops, arches or whorls. Loops are the most common type of print, appearing in 60-65% of all fingerprints. Loops are characterized by ridges that enter the pattern from one side, curve around, and exit the pattern on the same side. There are two subgroups of loops: radial and ulnar loops. The difference between these is from which side of the finger the loop enters.

Arches are the rarest pattern, found in only 5% of all fingerprints. Arches are characterized by ridges that enter the pattern on one side of the finger and exit on the opposite side. There are two subgroups of arches. Plain arches look like a gentle wave flowing across the surface of the finger. Tented arches are spiked in the center, looking more like a blip on an EKG in the center than a wave.

Whorls comprise 30-35% of fingerprints and are characterized by spiral or swirled ridges. A plain whorl looks like a target or bulls eye in the center with completely separate concentric circles. In a central pocket loop whorl the ridge swirls in a spiral to the center of the print. Double loop whorls look very much like the Chinese "yin and yang" symbol while accidental whorls can take on different patterns, but most often look like mushroom caps.



Fingerprints contain different ridge details called minutiae. Each finger contains approximately 150 points of minutiae. Fingerprint examiners compare minutiae on an evidence print recovered from a crime scene to a suspect's fingerprints to determine if the two are a match. There is no minimum number of minutiae that have to match for a fingerprint examiner to declare that the two prints are a match, but 12 points is generally consider to be a good match. Below are examples of some of the most common types of minutiae.



Fingerprint Residue

In traditional fingerprint analysis, crime scene technicians or other law enforcement officials will examine a crime scene for three types of fingerprints. Patent prints are those that are readily visible to the naked eye. A person who had blood on their fingertips and touched a door as they were leaving a crime scene would leave a patent bloody fingerprint on the door. The second type of fingerprint is a plastic fingerprint. This type of print is a three dimensional impression left in a soft surface. When a person touches something like a wet bar of soap or fresh paint, they can leave a plastic print. The third type of fingerprint is a latent print and it is by far the most common type of fingerprint left at a crime scene. A latent print is not readily visible to the naked eye and some type of physical or chemical development process must be utilized to visualize the details of the print.

Latent fingerprints at a crime scene can be visualized by many different methods. The most common involve the use of powders, chemicals and alternative light sources.[3] Smooth, nonporous surfaces are brushed with some type of powder such as a black powder made from finely ground lava rock or a white powder if the background surface is dark. If fingerprints appear, they are photographed and then lifted with adhesive tape and put on a card to preserve them. Unfortunately, brushes can smear delicate ridge characteristics if applied with too much force or may fail to develop a latent print if not enough force is used. In addition, traditional powders stick not only to the sweat and oil deposits that make up the fingerprint detail, but also to the background surface, although not as strongly, which can make the ridge detail very difficult to see and analyze. Alternate light sources (ALS) emit a particular wavelength of light and can be used with different colored powders to visualize a latent print. Chemicals such as cyanoacrylate (Superglue) and ninhydrin can also develop latent prints. They react with specific components of the fingerprint to produce visible ridge details that can then be photographed for further examination and analysis. Many of these chemical techniques only work on certain types of surfaces, such as dry, nonporous places like glass or smooth metal. They are also destructive of the fingerprint itself as well as the surface the containing fingerprint so no further tests can be done.

The residue left behind when someone touches a surface contains a variety of compounds from numerous sources.[4] The outermost layer of skin, called the epidermis, constantly renews itself and in the process, produces several proteins which have been identified in fingerprint residue. It forms a protective layer of lipid compounds also excreted through the sebaceous glands. Several glands which excrete compounds found in fingerprint residue reside in the innermost skin layer called the dermis. These secretory glands include the sebaceous and eccrine glands. Exogenous sources such as dirt, food residue, cosmetics and the like also contribute to the residue left behind in fingerprints.

Sebaceous glands exist on most skin surfaces, concentrating on the scalp, forehead and face. A lipid-rich fluid known as sebum is secreted. Sebum contains triglycerides, fatty acids, wax esters, cholesterol and several trace organic compounds.[5] The eccrine glands also concentrate on the forehead, palms of the hands, and soles of the feet. They secrete sweat which is 99% water combined with various organic and inorganic molecules. Sweat also contains amino acids allowing for the development of fingerprints with ninhydrin. The total amount of amino acids in the sweat from fingerprints correlates to the general health, diet, gender and age of the person. Sweat also contains more than 400 proteins and polypeptides which have been associated with the body's immune response and antibacterial activity on the skin.

Besides the above, and most exciting to the field of forensic science, fingerprint residue has been shown to contain various drugs and their metabolites. For example, scientists can tell if someone is a smoker by the presence of cotinine, the metabolite of nicotine, in their fingerprint. While that may raise some privacy concerns, the ability to detect illegal substances such as heroin, cocaine, and cannabis and their metabolites offers law enforcement a new tool to combat the use and flow of illicit substances. A fingerprint taken from a person arrested for some minor crime will soon provide a wealth of information regarding much more serious concerns. The ability to distinguish between the drugs themselves and their metabolites can immediately inform law enforcement of whether they are dealing with a drug user or potentially a drug trafficker.

Scientists have the ability to quickly detect the presence of explosives and toxins such as ricin and anthrax from fingerprint residue. This has the potential to interrupt and prevent terrorist activities around the globe.

Currently two types of tests are performed to confirm the presence, identity and quantity of drugs present in a sample. At the crime scene, a presumptive test may be performed by law enforcement officers simply to determine if an unknown substance might be an illegal drug. If the result is positive, the substance must then be sent to a toxicology laboratory to undergo confirmatory tests. Confirmatory tests can identify the specific drug present and determine its concentration, from which its quantity can be calculated. The quantity is critical to subsequent legal proceedings since the level of criminal charges and sentencing ranges are directly related to the quantity of drug involved. Besides having to be performed in laboratories with expensive chromatography and spectroscopy equipment, traditional confirmatory tests can be limited in their specificity and sensitivity. They also require a relatively large sample size and are destructive in nature. This means there may not be a sufficient quantity of material remaining for the defendant in a criminal case to have his or her own tests performed which can result in the exclusion of the evidence from trial. Image the effect no drug evidence would have on a potential drug prosecution! Nanotechnology offers the solution to these problems: biosensors.

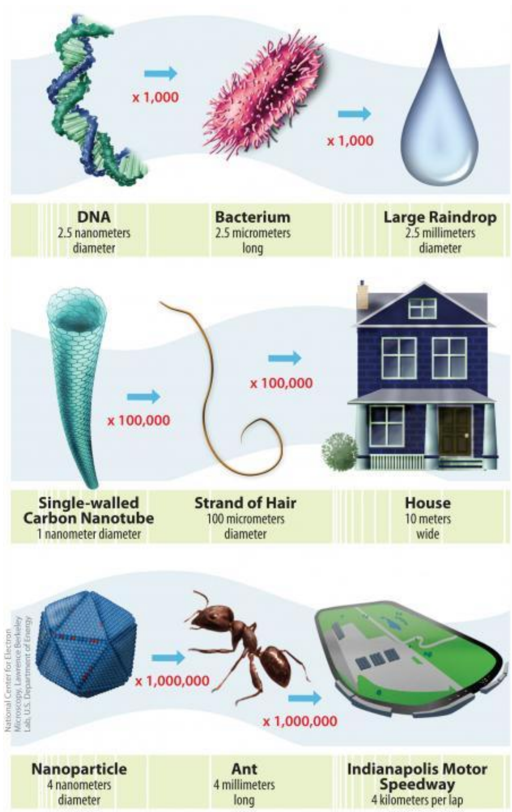
Nanotechnology Basics

In order to understand the exciting applications nanoscience has to offer to forensic science, it is first necessary to understand exactly what scientists mean when they discuss "nanoscience" and "nanotechnology." Nanoscience deals with studying materials at the nanoscale, that is materials that have at least one dimension between 1 and 100 nanometers (nm) on any side. Nanotechnology is the use and manipulation of nanoscale materials to produce new and better products and processes.[6] One nanometer is one billionth of a meter. Look at the following chart for some perspective.

Table 1. Metric prefixes

Prefix	Fraction	Definition	Exponent	Unit
n/a	1	Meter	10^{0}	m
Deci	1/10	1 tenth	10^{-1}	dm
Centi	1/100	1 hundredth	10^{-2}	cm
Milli	1/1,000	1 thousandth	10^{-3}	mm
Micro	1/1,000,000	1 millionth	10^{-6}	µm
Nano	**1/1,000,000,000**	**1 billionth**	$\mathbf{10^{-9}}$	**nm**
Pico	1/1,000,000,000,000	1 trillionth	10^{-12}	pm
Femto	1/1,000,000,000,000,000	1 quadrillionth	10^{-15}	fm

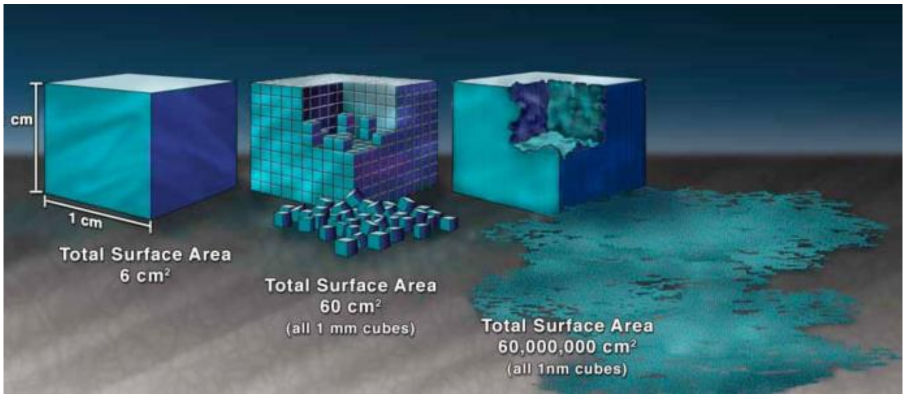
One nanometer is 3.937×10^{-8} inches or, stated another way, there are 2.54×10^{7} nanometers in one inch. However, these definitions aren't enough for most people to be able to visualize exactly how small that is. Consider these references: a single page of newspaper is about 100,000 nm thick, a human hair is 80,000-100,000 nm wide, a nanometer is about how much a human fingernail grows in one second, and a single gold atom is about one-third of a nanometer wide. The diagram below can help put things in perspective.



http://www.nano.gov/nanotech-101/what/nano-size

Image in public domain pursuant to White House Office of Science and Technology Policy

Matter at the nanoscale can have unique physical, chemical, electrical and biological properties. Some materials are better electrical conductors, some are much stronger, some reflect light differently or change colors. Take the simple physical property of surface area, for example. A one-centimeter cube of a material possesses a surface area of 1cm x 1cm x 6 sides or 6 cm^2. If the same volume of a material is cut into one-millimeter cubes, it would possess a surface area of 1mm x 1mm x 60 sides = 60 mm^2. Now if that same volume of material is cut into one-nanometer cubes, the resulting surface area would be 1nm x 1nm x 60,000,000 sides or 60,000,000 nm^2! As particles get smaller, there is more and more surface area available to interact and react with other particles. This can have huge implications when these particles are being used to detect target molecules such as poisons or drugs.



http://www.nano.gov/sites/default/files/nanocubes.jpg
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Optical properties of a material are the result of the interaction of light with the composition and atomic structure of the material.[7] Some examples are the color of the material and its fluorescence. For example, gold at a macroscale (i.e. a gold wedding ring) appears to be the expected shiny gold color. However, gold atoms at the nanoscale appear red. This change in gold's apparent color is due to the movement of its electrons. In bulk or macroscale metals, electrons are moving freely and randomly throughout the material. On the nanoscale, however, the particles are so small that the electrons are not free to move randomly throughout the material. There are limited, discrete ways in which the electrons can move. This changes the way light interacts with the gold atoms which in turn results in gold atoms appearing red at the nanoscale.

Biosensors

These special properties of nanomaterials allow scientists to use them in various types of sensors which can be used to detect illicit drugs, explosives and toxins. At its simplest, a sensor is a mechanism that has a component that detects whatever substance is being looked for, called the analyte, and a component that signals the presence of the detected substance, by physical, chemical or electrical means. Sensors are all around us. A solar cell absorbs energy from the sun and converts it to an electrical signal. A tire gauge senses the air pressure in your tires and converts it to a signal on a dial that lets you know if it is time to fill up. Cameras contain sensors that check the ambient light levels and send a message to the user to turn on the flash if it is needed. Traffic cameras sense motion and trigger the camera to take a picture. Even your stomach is a sensor. It knows when you have not eaten in a while and growls to signal you that it is lunchtime!

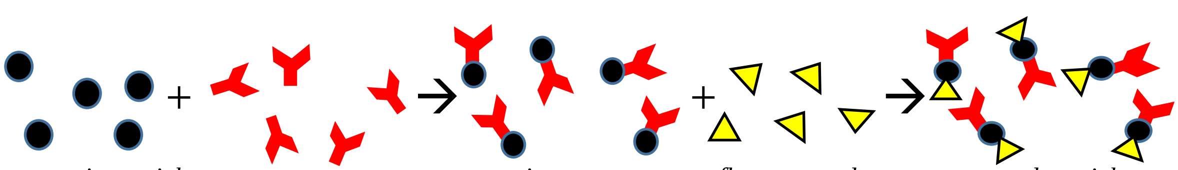
The detection component involves a molecular receptor that acts as a binding site for the analyte. The receptor is bound to some type of nanoparticle. The structure most often used in the analysis of fingerprints for illicit substances consists of an antibody bound to a gold or silver nanoparticle. The antibody is highly specific to the analyte, meaning it will bind only with that particular molecule. It must also be extremely sensitive in order to detect what may only be a single molecule of analyte in the sample. Many drugs (and their metabolites) such as heroin (morphine), cocaine (benzoylecgonine), cannabinol, and methadone have been detected in latent fingerprint residue.

The reporting component consists of a means to detect the change produced by the antibody-analyte interaction (i.e. an electric potential, heat, etc…) and turn it into a measureable signal (i.e. voltage, color change, etc…). The magnitude of the change in current or color is proportional to the concentration of the analyte, thereby giving a quantitative result.

Certain properties of nanoparticles make them an excellent choice for building sensors. Their extremely small size results in dramatically more surface area to which the antibodies can bind. Stability of the nanoparticles is also much improved by adding long hydrocarbon chains to gold particles or long amine chains to cadmium selenide or sulphide nanoparticles. They can be stored for long periods of time without losing their efficacy. They are also very durable and in some configurations can be reused many times, making them cost-effective.

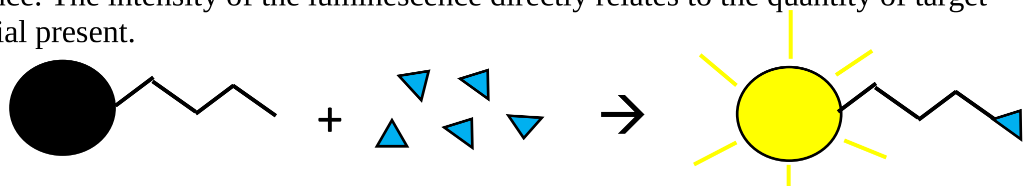
Nanobiosensing Techniques

The use of magnetic materials to bind with the antibodies has produced a technique that not only checks the fingerprint for the presence of drugs and metabolites, but which greatly enhances the ridge detail in the print itself allowing easier identification of the individual who donated the print. The process for detecting drugs and their metabolites in fingerprint residue begins with conjugating magnetic particles with the antibody specific to the drug for which the test is being performed. These conjugates are placed on the fingerprint and subjected to heat (approximately 37°C) for 30 minutes. The excess conjugate is then removed with a magnetic wand. A fluorescent dye is then used to label the bound conjugates and the fingerprint is examined with a stereomicroscope.



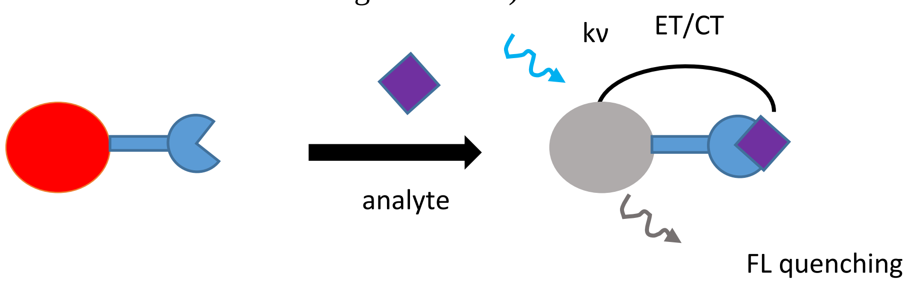
Another type of sensor useful in the context of fingerprint analysis is based on the use of quantum dots. They are the framework around which the biosensor is built. A quantum dot is a semiconducting nanoparticle with a fixed diameter. Because quantum dots are so small, their electrons are confined in very small spaces. At this size, the energy levels where the electrons usually exist are quantized (contain definite, discrete amounts of energy). As the size of the QD decreases, the distance the electron has to travel between energy levels increases. It takes more energy to excite the QD and more energy is released when the dot returns to its ground state. The amount of energy released correlates to a specific amount of emitted energy on the electromagnetic spectrum (in other words, a specific color). The result is an absorption or emission spectrum which identifies materials present. By manipulating the size of the QDs, any color of light can be produced from the same material.

Attached to the quantum dot is a sensing ligand. Its function is to detect the presence of the target analyte. Different biomolecules can be attached to the quantum dot to look for different analytes. This is known as a recognition site. The biomolecule can be an enzyme, an antibody, a protein or other biomolecule that can recognize the target molecule. Once the target is recognized, the quantum dot luminesces to signal its presence. The intensity of the luminescence directly relates to the quantity of target material present.

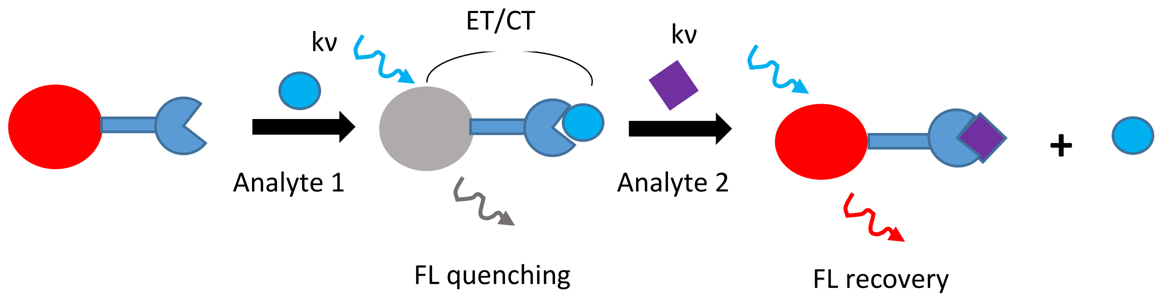


QD with sensing ligand — Analyte — Fluorescing QD signals presence of target molecule

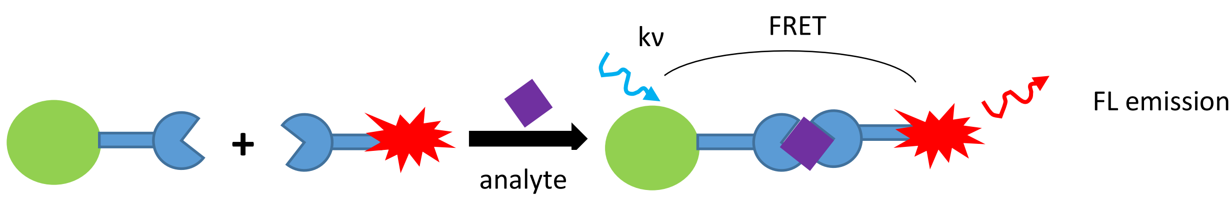
There are several mechanisms that cause the quantum dots to signal the presence of an analyte. The simplest is called quantum dot quenching. Quenching is any reduction in the level of fluorescence of a particle. A quantum dot is tagged with a fluorescent dye. Light is shined on the quantum dots. When the sensing ligand detects the presence of the analyte, the quantum dot acts as an electron donor and the dye no longer fluoresces. This is known as a "turn-off" mechanism. The diagram below illustrates this process. (Note: ET/CT stands for Electron Transfer/Charge Transfer.)



Another mechanism is used to detect the presence of two analytes simultaneously. The fluorescent dye-tagged quantum dot interacts with one analyte that does not fit perfectly with the sensing ligand but is sufficient to quench the QD's fluorescence. A second analyte is added, the ligand releases the first analyte and bonds with the second inducing fluorescence again. This is called a “turn off-turn on” mechanism.



A third mechanism for detecting an analyte with QD sensors is shown below. Two QD-based particles each with their own sensing ligand bind to the target molecule. A process known as Förster Resonance Energy Transfer (FRET) results in the input of one color of light and the output of another color, signaling the presence of the analyte. This is known as a color change reaction.



Biosensing technology offers many advantages over traditional drug testing methods. In the past, blood and urine were used to test for the presence of drugs. These fluids have their drawbacks however. A warrant generally needs to be obtained to force a suspect to give a blood sample for testing. The sample must be taken by a licensed physician or nurse. The suspect must be brought to the hospital for the sample to be taken. Testing fingerprint residue for the presence of drugs offers many advantages. Fingerprints are quick and easy to take and can be taken by police officers wherever the suspect is located. The samples do not require special conditions such as temperature controls for transport to a lab. Taking fingerprints is much less intrusive than taking other biological samples and generally does not require a warrant. In addition, analytes in fingerprints can be detected much longer after exposure to the drug than in blood or urine.

On the other hand, fingerprints can be taken without a person’s knowledge or consent. They can then be tested, revealing a wealth of information about an individual which most would consider private information. Anyone who has ever filled out HIPPA forms at the doctor’s office knows that legally prescribed medications are very private information. They can reveal a lot about a person’s health and lifestyle that the person may have had no intention of making public. It is well established that law enforcement may pick up and test items a person throws away, such as cigarette butts or coffee cups, since the act of throwing the item away clearly indicates the intention to no longer retain ownership of the material. The question rises here whether people “throw away” their fingerprints when they voluntarily touch surfaces in public. This question has big implications for the Fourth Amendment to the United States Constitution and will most likely see litigation in the years to come.

Instructional Implementation

Teaching Strategies

Nothing aids learning better than doing so this unit contains several labs. Students will be introduced to the concept of nanoscience with a lab where they will make nano ice cream. Students will use lab exercises to explore the physical, chemical and electrical properties of matter as they relate to the size of the sample. Students will work with fluorescence and quinine. They will conduct and compare several fingerprinting techniques including black powder, fluorescent powder, magnetic powder, cyanoacrylate fuming and ninhydrin developing. Readings and videos will be used to supplement students’ knowledge. Students will develop their critical thinking skills as well as their abilities to make and defend positions and to make public presentations.

Classroom Activities and Assessment

If you want to get to a kid’s heart, go through their stomach! Making Nano Ice Cream is a terrific unit opener. While it is more of a demonstration due to the liquid nitrogen than a lab for the students, explaining the many unique properties of materials at the nanoscale and then relating them ice cream is sure to get everyone’s attention. Your local college or university chemistry lab may donate the liquid nitrogen to you along with loaning you a Dewer flask in which to safely transport it. Be sure to observe best safety practices at all times when working with liquid nitrogen. If you are not entirely comfortable handling it, perhaps your local college chemistry department will lend you a professor or graduate student as well to conduct the demo! (See Appendix 2.)

Students generally cannot conceive of materials at the nanoscale. They are also usually not familiar with metric prefixes much past “milli-“. The Size and Scale activity allows them to explore their concept of relative size and get used to thinking on a very small scale. It also teaches metric prefixes from “deci-“ to “femto-“. (See Appendix 3.)

To introduce students to fluorescence, a simple demonstration is very effective. Tonic water contains quinine which comes from the bark of a tree. It has been used as a medicine in tropical countries for centuries. Under ultraviolet light, quinine fluoresces a bright blue. Ultraviolet light is high frequency, low wavelength energy that is just off the blue end of the visible spectrum. When high energy UV light is shone on quinine, electrons in the quinine absorb the energy and move to an excited state. When the electrons drop back down to their ground state, they release the extra energy as photons of light. Fluorescence is the visible light that can be seen when a material releases an electron. This demonstration also introduces students to the concept of quenching. Turning off fluorescence can also be a signal that an analyte is present in a material. When bleach is mixed into tonic water, the fluorescence disappears. Quinine absorbs ultraviolet light in its carbon-carbon double bonds and bleach breaks those bonds causing the fluorescence to extinguish. (See Appendix 4.)

Students should become familiar with several traditional fingerprinting techniques. They should practice rolling fingerprints using ink and dusting for fingerprints with traditional black powders and magnetic powders. Students should then be taught to lift these fingerprints with tape and preserve them on an index card. Be sure students notice how difficult it can be to read prints collected in this fashion. It is very easy to use too much powder when dusting producing very dark prints where the grooves in the prints retain so much powder that it is difficult to differentiate between them and the ridges. Students can also use too much or too little pressure when tape lifting thereby producing smudged or partial lifts. (See Appendix 5.)

Have students watch the short video from Arrogen called "Fingerprint Molecular Identification Process (FMID) to become familiar with what these biosensors do and how they work. https://youtu.be/mwkB98mZxoUN . Next, have students study the case of Brandon Mayfield. Mayfield is an Army veteran and attorney living in Washington State. In 2004, terrorists set off several huge explosions in a Madrid, Spain, train station. One hundred ninety-two people were killed and over 2,000 were injured. Within days, the FBI had arrested Mayfield, claiming that his fingerprint was found on a briefcase located in a van on a street in Spain which they determined was connected to the bombing. Denied any involvement, stating that he had never been to Spain. Mayfield was treated like a terrorist for two weeks. He hired his own fingerprint expert hoping to reveal an error in the earlier analysis, but his expert agreed that the fingerprint was his. Fortunately for Mayfield, Spain soon arrested a Moroccan man to whom they matched the fingerprint. Here is a nine-minute video about the case: http://www.bing.com/videos/search?q=brandon+mayfield+case&&view=detail&mid=8947406ADB33B9A1AD6D8947406ADB33B9A1AD6D&FORM=VRDGAR . Students can compare the fingerprints themselves with a fingerprint matching activity. (See Appendix 6.)

The use of fingerprints to test for drugs in a person's system is not without controversy. Students should be aware of the advantages and drawbacks of this emerging technology. Students should be able to conduct research, articulate opinions and defend them with evidence. First, have students read the article "Your Fingerprints Are About to Reveal a Lot More About You" from Popular Mechanics. It can be found here: http://www.popularmechanics.com/technology/security/a17172/your-fingerprpitns-are-about-to-reveal-a-lot-more-about-you/. Conduct a discussion of the article. Focus students not only on the things that nanotechnology allows us to do, but whether or not we should be doing them. Ask students to weigh the benefits of being able to easily access this type of information for medical and public safety purposes with the dangers of this information being improperly used by insurance companies and law enforcement. Encourage students to conduct outside research into the potential applications of biosensors and identify potential ethical issues with their use. When students are ready, students can engage in a class debate. To expand students' exposure to nanotechnology, as well as to avoid having to listen to the same debate over and over, a variety of prompt are offered for this activity. This activity can be used as a summative assessment. Prompts, directions for conducting a class debate and a scoring rubric are included. (See Appendix 7.)

Conclusion

The use of nanomaterials in forensic science is leading to new and better techniques for developing fingerprints and obtaining information from them. It is now possible to determine if a person has ingested illicit drugs or recently handled explosives by testing their fingerprint residue using various nanoparticles. As these techniques become more refined, portable devices will be perfected that can be used almost instantaneously to aid in safety and law enforcement applications.

The study of nanoscience and its applications is exploding. Countries, particularly in Asia, are developing curricula around the subject for their students beginning in the primary grades. There are so many applications of nanotechnology that we are currently aware of varying from textiles to law enforcement to medicine. There will be many more developments to come and if we want our students to be a part of this future, we need to begin exposing them to the world at a whole new nano level!

Student Resources

The www.CK-12.org website is an excellent resource for students to study any area of science which interests them. In particular, the page at http://www.ck12.org/book/NanoSense-Student-Materials/section/1.1/ offers students readings, powerpoints, quizzes and lab activities to explore nanoscience in more depth than is done in this curriculum unit.

"Nanotechnology: Big Things from a Small World" at www.nano.gov
This is a colorful, informative brochure introducing students to nanoscience and nanotechnology. The illustration regarding the scale of nanomaterials is particularly effective tool.

The article at http://www.explainthatstuff.com/nanotechnologyforkids.html by Chris Woodford does a good job of explaining the difference between nanoscience and nanotechnology and explains the scale, history, and current and potential uses of nanotechnology.

"Beyond Identification" is an accessible article about the development and benefits of nanoparticles for use in fingerprint identification and all of the other information that can be obtained from fingerprint residue. www.EvidenceMagazine.com

Teacher Resources

BBC News. Fingerprints Hidden Secrets. Video.
https://www.youtube.com/watch?v=OkYig55VnQk

> Great visual using ping-pong, soccer and cannon balls to explain how a mass spectrometer separates substances for identification.

Chakraborty, Dhritiman. A splendid blend of nanotechnology and forensic science. (2015)

> Article discusses latent fingerprints, DNA, gun crimes and security applications of nanotechnology. There are very good images of latent prints developed in various manners for comparison.

Hazarika, Pompi. Imaging of latent fingerprints through the detection of drugs and their metabolites. (2008)

> Older article, but it explains nanoparticle conjugates used in metabolite detection.

Hazarika, Pompi. Multiplexed detection of metabolites of narcotic drugs from a single latent fingermark. (2010)

> More recent article from the previous research team in which they describe a mechanism for testing a latent fingerprint for multiple drugs simultaneously. Excellent visuals that clarify the process.

Lad, Amitkumar. Overview of nano-enabled screening of drug-facilitated crime: A promising tool in forensic investigation. (2016)

> Excellent article explaining the advantages of using nanomaterials in drug detection. Also discusses biosensors and explains the mechanisms for identifying the most commonly used illicit drugs in fingerprints.

Su, Bin. Recent progress on fingerprint visualization and analysis by imaging ridge residue components. (2016)

> Very good article on the chemistry of fingerprints, what makes it possible to test them for drugs, and the techniques used for testing, including the role of nanomaterials in testing.

Zhou, Juan. Toward Biocompatible Semiconductor Quantum Dots: From Biosynthesis and bioconjugation to biomedical application. (2015)

> Difficult article to work through but worth the effort. The article explains quantum dot sensors and how they work as well as how they are used in specific applications including latent fingerprint drug detection. Many diagrams and visuals make the process somewhat easier.

Appendix 1: Teaching Standards

Charlotte-Mecklenburg Schools includes the following standards in its Honors Forensic Science curriculum:

HS-FS-F-1 Students will understand the characteristics of fingerprints that allow them to be systematically classified.

> HS-FS-F-1a Students will be able to describe the physiology of fingerprints.
> HS-FS-F-1b Students will be able to describe, compare and identify the different types of fingerprints.
> HS-FS-F-1c Students will be able to describe, compare and perform fingerprint detection techniques.
> HS-FS-F-1d Students will know the historical and current methods for fingerprint matching.

Additionally, after completing this unit, students will be able to:

- Describe the role of nanotechnology in fingerprint analysis,
- Describe the structure and functioning of a biosensor,
- Identify current and potential uses for nanomaterials in forensic science, and
- Articulate and argue for and against the ethical issues raised by the use of nanotechnology in new testing techniques.

This unit covers all four CMS objectives for fingerprint analysis. In addition, it introduces students to the field of nanoscience, which is not directly in the curriculum. It includes excellent extension material for the study of fingerprints and introduces students to an area of science to which they would not otherwise be exposed.

Appendix 2: Nano Ice Cream Demo

Introduce students to the concept of nanoscience with this fun activity. Nanoscience is the study of materials less than 100 nanometers long in at least one dimension. When ice crystals are formed by cooling water with liquid nitrogen, the crystals are much smaller than if they were frozen at higher temperatures. If fact, the crystals are only a few nanometers in diameter. This means the ice cream is smoother and creamier than regular ice cream and tastes better because there is less water to melt before tasting the flavors of the sugar and fat.

Materials:
a pint of milk (makes about 25 small servings)
A quart of heavy cream or half-and-half
8 tsp real vanilla
1 cup sugar
4 liters of liquid nitrogen
Any desired flavorings (chocolate or caramel syrup, candy pieces, peppermint flavoring, etc…)
Stainless steel bowl (do NOT use glass or ceramic bowls because the liquid nitrogen will cause them to shatter)
Long wooden spoon (it won't conduct cold as much as a metal spoon)
Heavy protective gloves like fireplace gloves
Goggles

Safety: Liquid nitrogen should only be handled by a trained adult! The adult should wear long sleeves as well as insulated protective gloves and goggles. The liquid nitrogen should be stored in a Dewar flask which should be kept covered. It is cold enough to liquefy oxygen which is dangerous. Covering the flask will keep this from happening.

Procedure:
1. Mix the milk, cream, vanilla and sugar in the stainless steel bowl until the sugar dissolves
2. Add desired flavorings.
3. Put on all protective gear and slowly add the liquid nitrogen. Use the wooden spoon to stir it until frozen (usually about 5-10 min). You will see foaming and bubbling as the liquid nitrogen boils off.
4. Serve ice cream to students. Ask them to make observations about the ice cream and how it compares to regular ice cream as they eat it. Then discuss the following questions.

Questions:
1. What role did nanoscience play in the making of the ice cream? How small is a nanometer?

2. Do a quick internet check and find current applications of nanotechnology. Describe the role nanotechnology plays in the application and why it is so special.
3. Can you think of any risks that may accompany this field of science?

Appendix 3: Size and Scale

Purpose: This activity is designed to get students thinking about the relative size of various objects and to put objects at the nanoscale in perspective.

Materials: Set of powers of 10 cards
Set of pictures of objects of various sizes
Copies of student handout

Procedure:

1. Split students into groups of 2-3.
2. Give each group a copy of the powers of ten cards and the pictures of objects cards.
3. Have students organize the powers of 10 cards from largest to smallest in a line in front of them.
4. Have students match the decimals with their powers of ten.
5. Have students place the pictures underneath the power of 10 card they believe the object belongs to. Some cards may be in between powers.
6. Have students record the placement of their cards on the Student Handout.
7. Discuss student responses.

Discussion Questions:

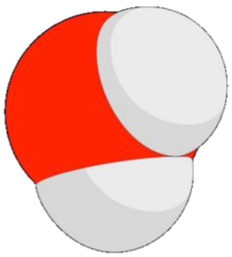
1. Which items were the hardest for you to place? Why?

   It is likely that the smallest objects will give students the most trouble because they are not used to dealing with matter on that scale. They may also not be familiar with some of the objects if they have not taken biology yet.

2. What prefixes go with each power of ten?

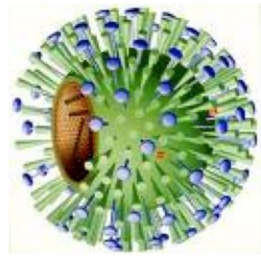
Prefix	Fraction	Definition	Exponent	Unit
n/a	1	Meter	10^0	m
Deci	1/10	1 tenth	10^{-1}	dm
Centi	1/100	1 hundredth	10^{-2}	cm
Milli	1/1,000	1 thousandth	10^{-3}	mm
Micro	1/1,000,000	1 millionth	10^{-6}	µm
Nano	**1/1,000,000,000**	**1 billionth**	$\mathbf{10^{-9}}$	**nm**
Pico	1/1,000,000,000,000	1 trillionth	10^{-12}	pm
Femto	1/1,000,000,000,000,000	1 quadrillionth	10^{-15}	fm

width of a
water molecule



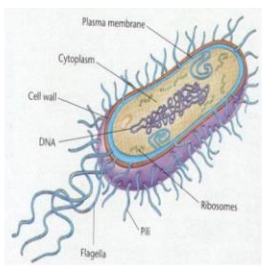
diameter of a
carbon nanotube

diameter of a
flu virus



wavelength of
visible light

width of a
bacterium



diameter of a
red blood cell

thickness of a
human hair

thickness of a
penny

diameter of a
quarter

width of a
standard envelope

height of a typical
5-year-old child

length of a
standard city bus

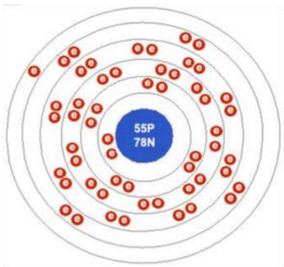
length of a
soccer field

distance walked in
20 minutes

cruising altitude of
an airplane

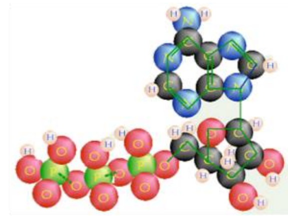
distance a car can
travel on a
freeway in 1 hour

diameter of a
cesium atom



diameter of a
DNA double helix

length of an
ATP molecule



width of a
transistor in a
computer chip

width of a single
bit on a DVD

diameter of a
strand of Merino
wool

length of a
dust mite

length of a
typical amoeba

width of a
wedding ring

width of an
electrical outlet
cover

height of a typical
pro basketball
player

height of a
2-story house

length of a
5-car train

3x the height of
the Empire State
Building

height of
Mt. Everest

altitude of official
start of “outer
space”

10^{-10} m (1 angstrom)	10^{-9} m (1 nanometer)	10^{-8} m (10 nanometers)	10^{-7} m (100 nanometers)
10^{-6} m (1 micrometer)	10^{-5} m (10 micrometers)	10^{-4} m (100 micrometers)	10^{-3} m (1 millimeter)
10^{-2} m (1 centimeter)	10^{-1} m (1 decimeter)	10^{0} m (1 meter)	10^{1} m (10 meters)
10^{2} m (100 meters)	10^{3} m (1 kilometer)	10^{4} m (10 kilometers)	10^{5} m (100 kilometers)

0.0000000001 m (1 angstrom)	0.000000001 m (1 nanometer)	0.00000001 m (10 nanometers)	0.0000001 m (100 nanometers)
0.000001 m (1 micrometer)	0.00001 m (10 micrometers)	0.0001 m (100 micrometers)	0.001 m (1 millimeter)
0.01 m (1 centimeter)	0.1 m (1 decimeter)	1.0 m (1 meter)	10.0 m (10 meters)
100.0 m (100 meters)	1000.0 m (1 kilometer)	10000.0 m (10 kilometers)	100000.0 m (100 kilometers)

Answer Key

Object	Size	Units
Width of a water molecule	3.0×10^{-10}	Meters
Diameter of a cesium atom	5.2×10^{-10}	Meters
Diameter of a carbon nanotube	1.0×10^{-9}	Meters
Diameter of a DNA double helix	2.0×10^{-9}	Meters
Length of an ATP molecule	1.2×10^{-8}	Meters
Width of a transistor in a computer chip	9.2×10^{-8}	Meters
Diameter of a flu virus	1.0×10^{-7}	Meters
Width of a single bit on a DVD	2.5×10^{-7}	Meters
Wavelength of visible light	6.0×10^{-7}	Meters
Width of a bacterium	1.0×10^{-6}	Meters
Diameter of a red blood cell	7.0×10^{-6}	Meters
Diameter of a strand of Merino wool	2.0×10^{-5}	Meters
Thickness of a human hair	1.0×10^{-4}	Meters
Length of a typical amoeba	1.0×10^{-4}	Meters
Length of a dust mite	4.2×10^{-4}	Meters
Thickness of a penny	1.6×10^{-3}	Meters
Width of a wedding ring	5.0×10^{-3}	Meters
Diameter of a quarter	2.4×10^{-2}	Meters
Width of an electrical outlet cover	6.0×10^{-2}	Meters
Width of a standard envelope	1.0×10^{-1}	Meters
Height of a typical 5-year-old child	1.1×10^{0}	Meters
Height of a typical pro basketball player	2.0×10^{0}	Meters
Height of a 2-story house	7.0×10^{0}	Meters
Length of a standard city bus	1.3×10^{1}	Meters
Length of a soccer field	1.0×10^{2}	Meters
Length of a 5-car train	5.0×10^{2}	Meters
3x the height of the Empire State Building	1.5×10^{3}	Meters
Distance walked in 20 minutes	1.6×10^{3}	Meters
Height of Mt. Everest	8.8×10^{3}	Meters
Cruising altitude of an airplane	1.0×10^{4}	Meters
Altitude of official start of "outer space"	8.0×10^{4}	Meters
Distance a car can travel on a freeway in 1 hr	1.0×10^{5}	Meters

Name: ________________________ Date: ______________ Block: ______

Once you put all of the cards in order from largest to smallest, record your data in the following chart. The last column is to make any corrections you may need to make.

Object (largest to smallest)	**Size**	**Corrections**

Appendix 4: Exploring Fluorescence

Purpose: To introduce and explain to students the concept of fluorescence using quinine

Materials:

- Tonic water containing quinine
- 2 clear plastic cups
- Medicine dropper
- Bleach
- UV light
- Plastic coffee stirrer or spoon

Safety: Be sure to handle the bleach carefully. If it gets on skin, rinse with water immediately. If it gets in eyes, immediately rinse with water and seek medical attention. If students are using the bleach, they should wear goggles.

Procedure:

1. Pour about a cup of quinine-containing tonic water into a clear plastic cup.
2. Darken the classroom as much as possible.
3. Shine the UV light on the water and have students make observations. It should fluoresce a bright blue.
4. After everyone has had a chance to see the effect of the UV light on the tonic water, and while still shining the UV light on the tonic water, place 2 drops of bleach into the tonic water. Have students make observations immediately and then again after you stir the mixture. If there is no change in the tonic water, add a couple more drops of bleach.

Questions:
1. What causes the quinine to fluoresce? Describe what is happening.
2. What effect does the bleach have on the fluorescence? Why does this happen?

Appendix 5: Fingerprinting Lab

A good fingerprint lab should have the students practicing techniques to roll their fingerprints in ink, dust their prints off solid surfaces, lift their prints after dusting and match fingerprints. A great extension is to let the students try cyanoacrylate (Superglue) fuming. Below are directions for one way to run this lab.

Part 1: Rolling Prints

Purpose: Allow students to become proficient in various fingerprinting techniques including rolling, dusting, lifting and examining prints..

Pre-Lab Questions:

1. What are the characteristics of the three basic categories used for fingerprint analysis?
2. Describe what to look for to identify the subgroups of each basic category of fingerprints.
3. What are minutia? Describe some examples of minutia.
4. What is a known print, a latent print, a plastic print and a patent print?
5. What is the most common type of fingerprint found at a crime scene?
6. What is AFIS? How many prints does it contain?

Lab 1: Rolling Prints and Examining Prints

Materials: fingerprint ink (a regular inkpad will work too; it just will not wash off as easily!)
Ten-print cards (see below)
Baby wipes, for cleaning up

Safety: No special precautions are needed.

Procedure:

Part 1 Rolling Prints

1. Wash your hand with soap and water and dry completely. Excess dirt and oils on your fingers will affect the quality of the print.
2. Hold out your right thumb in front of you in a “thumbs up” sign and twist your hand all the way to the right. Notice how it feel to hold your thumb in that position. Now move your thumb all the way to the left. That should feel much more comfortable to you. You will always roll your prints from the <u>uncomfortable</u> side to the <u>comfortable</u> side. Test it each time because the direction changes from your thumb to your fingers and from hand to hand.

3. Using light even pressure, roll your right thumb on the inkpad. You want to get ink from one side of your thumbnail to the other and from the top of your thumb down to the first knuckle.
4. Now, in one move, lightly roll your thumb in the correct square on the fingerprint card from the extreme right to the extreme left. Be sure your thumb is flat on the paper. The easiest way to do this is to put the square for the finger you are rolling on the edge of the desk. That way your hand does not get in the way as you roll. You may want to practice a few time on plain paper before you try it on the fingerprint card. If you are doing it right, you will get a fingerprint that is square, not oval.
5. Repeat this procedure with your remaining nine fingers always checking to see which direction is uncomfortable to start and that you are rolling from nail to nail and tip to knuckle.
6. TIPS: Lift your finger directly up after rolling to avoid smudging. Also, do not roll back over your print because you think you missed a spot. You will wind up with a blurry mess.
7. At the bottom of the fingerprint card there is space for you to ink your four fingers on each hand and press all four down lightly and simultaneously. These prints should be ovals. Repeat that straight up and down motion with your two thumbs.
8. Write your name at the top of the fingerprint card.

Part 2 Examining Prints

1. Carefully examine your fingerprints. Look for the overall patterns (loops, arches, whorls). Label each fingerprint with the correct pattern and subgroup.
2. Examine the ridges of the fingerprints for different minutia. Fingerprint examiners generally look for 12-15 unique features per finger. Find and label 10-12 unique features on one of your fingerprints.

Lab 2 Dusting for Prints

Materials: Black fingerprint powder
Fingerprint brush
Dry erase boards, windows or other non-porous surfaces to put prints on
3 x 5 Index cards (one per student plus some extras for do-overs)
Clear packing tape
Scissors

Safety: No special precautions are required for this lab.

Procedure:

1. Touch your index and middle fingers of both hands to the side of your nose or your forehead.
2. Without touching anything else, lightly press those four fingers onto a clean dry erase board.
3. Take your brush and dip it in a TINY amount of black powder. Tap the brush on the side of the jar to remove the excess powder.
4. Lightly swirl the brush over your fingerprints. Too much pressure will smear the prints.
5. Carefully examine your four prints and choose the best one or two to lift.
6. Cut a smooth piece of packing tape about five inches long.
7. Lay the tape down over your print and lightly press the tape down over the print in one motion.
8. Slowly and carefully lift the tape off the board.
9. Carefully place the tape on an index card and label the card with your student ID number only. Use a blue or black pen only.

Lab 3 Magnetic Fingerprint Powder

Materials: Magnetic fingerprint powder
Magnetic brush
White boards or other non-porous surface
Clear packing tape
Scissors

Safety: There are no special precautions for this lab.

Procedure:

1. Using the same procedure as in Lab 2 above, put down four fingerprints on the white board.
2. Use the magnetic brush to dip a little magnetic powder out of the bottle. Lightly brush it back and forth over your prints.
3. Once the print is fully visible, lift the best print in the manner described in Lab 2. Write your student ID number only on the index card.
4. Paper clip your two index cards to your ten-card and turn all three in.

Post-Lab Questions:

1. Describe the proper technique for rolling fingerprints. What is one tip you discovered that made rolling prints easier?
2. What was the most common minutia you found on the prints you collected?

3. What percentage of each of the three main fingerprint classifications did you have?
4. If you were at a crime scene and you wanted to dust a black car for fingerprints, what would you do?
5. Most fingerprint examiners are satisfied that fingerprints are a match if they have 12-15 points of minutia in common. Knowing what you now know about fingerprints, do you feel that is sufficient for a match? Why or why not?

Assessment Activity

1. Take all of the students' fingerprint cards and select the better of the two index cards for each student.
2. You will want to split students up into groups of about 6 students. Take the same number of sets of fingerprint cards as people in each group. Given-cards with names on them and one stack of shuffled index cards with student ID's on them.
3. Students must match the index card prints to the correct ten-card. It is not a match until they have identified 12 points of minutia in common on each index card print and ten card and at least 3 team members agree that the print is a match.
4. Students should just submit a list of names and student ID numbers for grading.

APPLICANT

LEAVE BLANK

TYPE OR PRINT ALL INFORMATION IN BLACK

LAST NAME NAM | FIRST NAME | MIDDLE NAME

FBI | LEAVE BLANK

SIGNATURE OF PERSON FINGERPRINTED

ALIASES AKA

O R I

RESIDENCE OF PERSON FINGERPRINTED

DATE OF BIRTH DOB
Month Day Year

CITIZENSHIP CTZ

SEX	RACE	HGT.	WGT.	EYES	HAIR	PLACE OF BIRTH POB

DATE | SIGNATURE OF OFFICIAL TAKING FINGERPRINTS

YOUR NO. OCA

LEAVE BLANK

EMPLOYER AND ADDRESS

FBI NO. FBI

CLASS

ARMED FORCES NO. MNU

REASON FINGERPRINTED

SOCIAL SECURITY NO. SOC

REF.

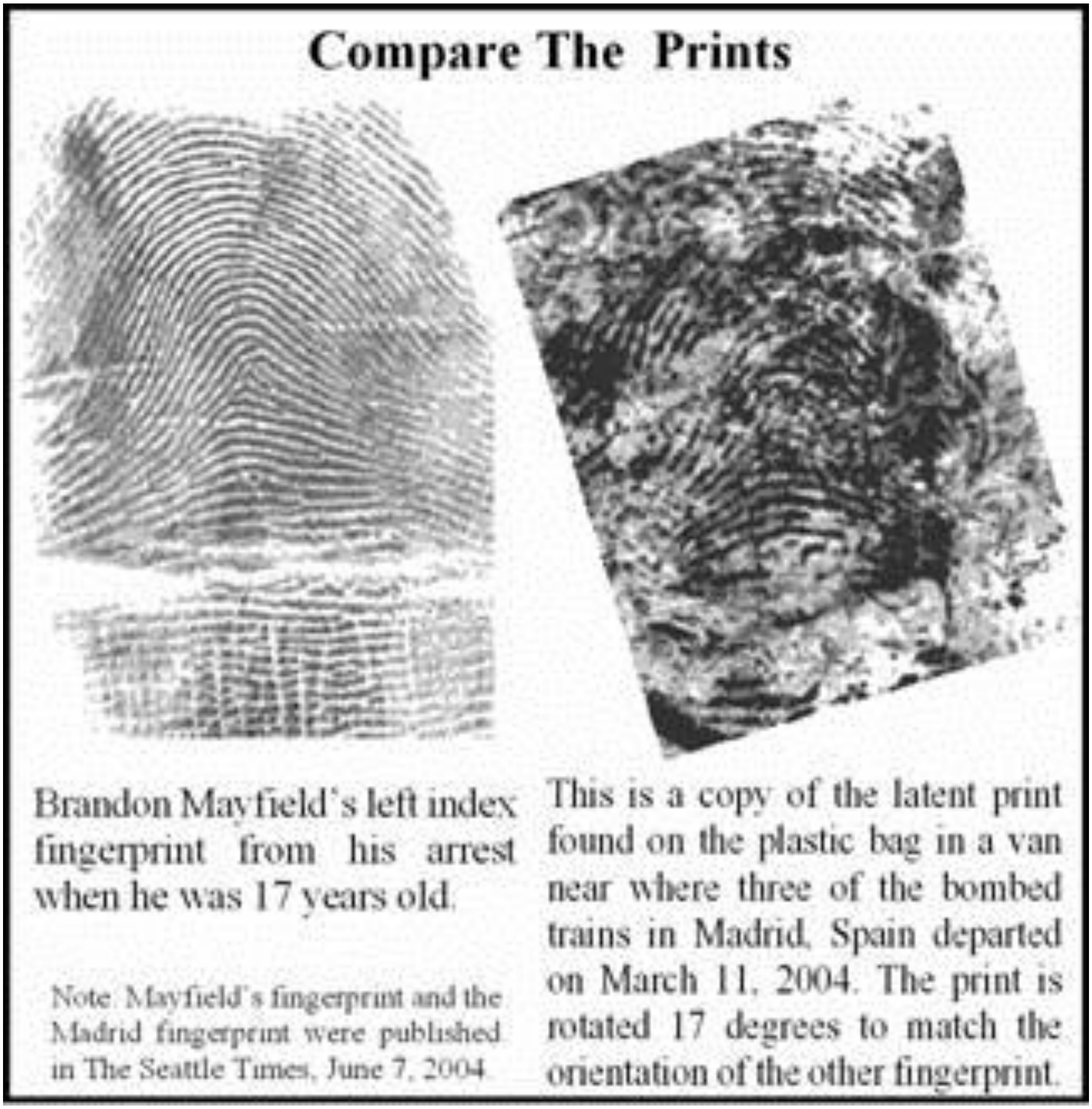
MISCELLANEOUS NO. MNU

1. R. THUMB	2. R. INDEX	3. R. MIDDLE	4. R. RING	5. R. LITTLE
6. L. THUMB	7. L. INDEX	8. L. MIDDLE	9. L. RING	10. L. LITTLE

LEFT FOUR FINGERS TAKEN SIMULTANEOUSLY | L. THUMB | R. THUMB | RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY

Appendix 6: Case Study – Brandon Mayfield

Compare the two fingerprints below. Find at least twelve points of minutia on each fingerprint. Are the fingerprints a match? Defend your answer.



Appendix 7: Ethics in Science

This activity can serve as a summative assessment for this unit, alone or in conjunction with a more formal written test. Students love to argue. The idea here is to focus the arguing on a topic relating to the use of nanotechnology in forensic science. To set up a debate, follow these steps:

1. Split students up into teams of two or three students, depending on class size. Be sure you have an even number of teams.

2. For each *pair* of teams, write a debate prompt based on what you have covered in this unit. Some examples are listed below.

3. Either allow teams to sign up for the prompt of their choice (two teams per prompt) or assign two teams to each prompt.

4. Again allow teams to choose, or assign, either the “pro” side or the “con” side to each individual team.

5. Give teams a copy of the rubric that will be used to grade them and discuss how the debate will work and your expectations. Each team will have 4 minutes to present their arguments for their positions. The affirmative side always goes first, followed by the negative side. Both team members can speak during this time or one can speak during this part and the other team member can handle the rebuttal. After both teams have had their 4 minutes to present their cases, allow them 3 minutes to prepare to rebut their opponent’s case. They should already be familiar with the arguments on the other side of their issue, but they may need to quickly look up relevant facts to use to specifically rebut points made by the other team. Then give each team 2 minutes for rebuttal. In this phase, the negative side goes first.

As an added incentive to the rest of the class to pay attention, I will pick two non-presenting teams to act as judges for each debate. They will each complete a rubric for each team and each person is responsible for asking each team at least one relevant question regarding their position (two questions per person total – one for each side). Their questions should make the debaters use evidence from their classwork as well as their research to substantially answer the questions. Judges get a grade for the relevance and insightfulness of their questions, so they have an incentive to actively listen and participate. Questions are posed to the two sides after the rebuttal is complete.

The rubric you complete as each team argues will include spaces for you to include a summarized grade from the student rubrics as well as a space to add in points when these debaters act as judges in someone else’s debate. A sample rubric follows these instructions.

6. Allow at least one class period for students to research their prompt from both sides of the issue. Instruct them that they must present at least 3 strong facts for their side during the debate. These facts can come from classwork and/or research but must be explained in a manner that demonstrates knowledge of the principles underlying the science of nanotechnology.

7. Set up your room on debate day in a manner conducive to having 4 students talk to the audience. They should have some sort of podium or desk to keep their notes organized on and visible to them. Ask one student to act as a timer so you do not have to watch the clock as well as the students. With preparation and guidance, your students will hopefully dazzle you with their oratory skills and their newfound knowledge of nanoscience and nanotechnology!

Sample Prompts:
1. Fingerprints a person unknowingly leaves behind can be used to test that person for illicit drugs.
2. All people should be subjected to testing for explosives before they fly.
3. No two fingerprints are alike.
4. If we can build it, we should.
5. Biosensors should be used to test all children at birth for various types of disease.
6. The dangers of nanotechnology outweigh the potential benefits.

NANOTECHNOLOGY DEBATE RUBRIC

Student Name: ____

Position: ____

Prompt: ____

____

Criteria	1	2	3	4	Score/Notes
Organization and Clarity Arguments and positions are stated clearly and organized in a logical manner that advances the argument	Unclear in most parts; audience has no idea what your position is	Clear in some parts but not over all; audience may not be sure what your position it	Mostly clear and orderly in all parts, audience can be pretty sure what your position is	Completely clear and orderly presentation; Audience knows exactly what your position is.	
Substance of Arguments Multiple relevant reasons are given to support viewpoint	No relevant reasons given to support viewpoint	One relevant reason given to support viewpoint	Two relevant reasons given to support viewpoint	Three or more relevant reasons given to support viewpoint	
Use of Examples, Facts and Evidence On-point examples, facts and other evidence are given to support reasons.	Little relevant supporting evidence for any reason	Some relevant supporting evidence given for some reasons	Much relevant evidence given for most reasons	Many relevant supporting examples and facts given for each reason	
Use of Rebuttal Arguments made by the other teams are responded to and dealt with effectively.	No effective counter-arguments made	Few effective counter-arguments made	Some effective counter-arguments made	Many effective counter-arguments made	

Presentation Style Tone of voice, use of gestures, and level of enthusiasm are convincing to audience.	Few style features were used; none convincingly	Few style features were used convincingly	All style features were used, most convincingly	All style features were used convincingly	
Teacher Score:					/20
Average of two student judges' scores	Score 1: ___________ Score 2: ___________ Average: _____________				/20
Score for judging	Student asked each side at least one relevant, reasonably insightfully question which required the use of evidence to support their answer.				1 2 3 4 5
TOTAL SCORE					/45

Notes

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[1] Lu, Chow-Chin. *Effect of nanotechnology instruction on senior high school students*. Asia-Pacific Forum on Science Learning and Teaching, Vol. 12, Issue 2, Article 12 (December 2011).
[2] In the notable case of Brandon Mayfield, the U.S. attorney's fingerprints were erroneously matched to prints found at the scene of the Madrid train bombing in 2004. Analysts found 15 points of minutia that matched, leading to the conclusion that perhaps more stringent guidelines as to what exactly constitutes a match may be in order. See http://www.bing.com/videos/search?q=madrid+train+bombing+brandon+mayfield&&view=detail&mid=8947406ADB33B9A1AD6D8947406ADB33B9A1AD6D&FORM=VRDGAR.
[3] www.forensicsciencesimplified.org/prints/how.html. Accessed August 25, 2016.
[4] Su, Bin. Recent progress on fingerprint visualization and analysis by imaging ridge residue components. Anal Bioanal Chem (2016) 408:2782.
[5] Bin.2782.
[6] What's So Special About Nanoscale? http://www.nano.gov/nanotech-101/special. 2016.
[7] http://nanosense.sri.com/activities/sizematters/properties/SM_Lesson3Teacher.pdf

Bibliography

Chakraborty, Dhritiman. 2015. "A Splendid Blend of Nanotechnology and Forensic Science." *Journal of Nanotechnology in Engineering and Medicine* 6: 10801-1 - 10801-6. Accessed June 4, 2016.

Article discusses latent fingerprints, DNA, gun crimes and security applications of nanotechnology. Several great fingerprint images clarify information.

Chen, Yung-fou. 2011. "Forensic Applications of Nanotechnology." *Journal of the Chinese Chemical Society* 58: 828-835. Accessed June 4, 2016.

Article covers the beginnings of nanoscience with Dr. Richard Feynman's speech in 1959 and focuses on tools used to analyze nanomaterials including the Atomic Force Microscope, Dynamic Light Scattering, abnd Raman Microspectroscopy. It then discusses various forensic applications including development of latent fingerprints, enhanced PCR, questioned documents, time of death determinations and more.

Hazarika, Pompi. 2008. "Imaging of Latent Fingerprints through the Detection of Drugs and Metabolites." *Angew. Chem.Int. Ed.* (Wiley-VCH Verlag GmbH & Co.) 47: 10167-10170. Accessed June 4, 2016. doi:10.1002/anie.200804348.

Older article but explains nanoparticle conjugates used in metabolite detection.

Hazarika, Pompi. 2010. "Multiplexed Detection of Metabolites of Narcotic Drugs from a Single Latent Fingermark." *Analytical Chemistry* (American Chemical Society) 82 (22): 9150-9154. Accessed October 23, 2016. doi:10.1021/ac1023205.

From some of the original researchers in the application of nanotechnology to drug detection in latent fingerprints, this article takes the science of searching for evidence of drug use forward with new techniques that allow scientists to test for multiple drugs in the same print. Excellent visuals that clarify and explain the process.

Horswell, Jacqui, and Stuart J. Dickson. 2003. "Use of biosensors to screen urine samples for potentially toxic chemicals." *Journal of Analytical Toxicology* 27: 372-376. Accessed May 27, 2016.

Jones, M. Gail. 2011. "We Scream for Nano Ice Cream." *Science Activities* (Taylor & Francis Group, LLC) 48: 107-110. Accessed July 31, 2016. doi:10.1080/00368121.2010.535223.

Great activity to do in class if it is possible to handle liquid nitrogen safely in the classroom.

Lad, Amitkumar N. 2016. "Overview of nano-enabled screening of drug-facilitated crime: A promising tool in forensic investigation." *Trends in Analytical Chemistry* 80: 458-470. Accessed July 31, 2016.
Excellent article explaining the advantages of using nanoparticles in drug detection. Also discusses biosensors and explains the mechanisms for identifying the most commonly used illicit drugs.

Lindsay, S.M. 2010. *Introduction to Nanoscience.* Oxford: Oxford University Press.
Michelini, Elisa. 2013. "Field-deployable whole-cell bioluminesccent biosensors: so near and yet so far." *Anal. Bioanal Chem* 6155-6163. Accessed October 18, 2016. doi:10.1007/s00216-013-7043-6.

A textbook on nanoscience which gives a solid overview of the subject.

Lu, Chow-Chin. *Effect of nanotechnology instruction on senior high school students*. Asia-Pacific Forum on Science Learning and Teaching, Vol. 12, Issue 2, Article 12 (December 2011).
Paper discussing the advantages of teaching nanoscience to children as early as elementary school.

"Nanotechnology: Big Things from a Tiny World." *National Nanotechnology Initiative.* 01 01. (2016) Accessed April 21, 2016. www.nano.gov.

Well-illustrated, color brochure about nanoscience and nanotechnology with information on applications and impacts of nanotechnology. Contains lists of resources for further study. An excellent introduction to the topic for students.

Nouailhat, Alain. 2008. *An Introduction to Nanoscience and Nanotechnology.* London: ISTE.
A textbook with good background information on nanoscience. Some of the material on nanotechnology is outdated.

Peveler, William. 2016. "Selectivity and Specificity: Pros and Cons in Sensing." *ACS Sensors* (American Chemical Society) A-D. Accessed October 23, 2016. doi:10.1021/acssensors.6b00564.

Clear discussion of selectivity and sensitivity and each has improved with new advances in nano-assisted drug testing.

Pitkethly, Mike. 2009. "Nanotechnology and forensics." *Materials Today* 12: 6. Accessed May 27, 2016.

Redshaw, Natalie. 2007. "A preliminary investigation into the use of biosensors to screen stomach contnets for selected poisons and drugs." *Forensic Science International* 172: 106-111. Accessed May 27, 2016.

Su, Bin. 2016. "Recent progress on fingerprint visualization and analysis by imaging ridge residue components." Edited by S Daunert. *Analytical and Bioanalytical Chemistry* 408: 2781-2791. Accessed September 12, 2016. doi:10.1007/s00216-015-9216-y.

Excellent article on the chemistry of fingerprints, what makes it possible to test them for drugs, and the techniques used for testing. Includes the role of nanomaterials in testing.

2016. *What are Quantum Dots?* 01 01. Accessed May 27, 2016. http://www.nanosysinc.com/what-we-do/quantum-dots/.

Brief article on the basics of quantum dots.

2016. *What's So Special About Nanoscale?* 01 01. Accessed April 28, 2016. www.nano.gov/nanotech-101/special.

Yanez-Sedeno, P.L. 2014. "Biosensors in Forensic Analysis: A Review." *Analytica Chimica Acta* 823: 1-19. Accessed April 28, 2016. doi:10.1016/j.aca.2014.03.011.

Zhou, Juan, Yong Yang and Chun-yang Zhang. 2015. "Towards Biocompatible Semiconductor Quantum Dots: From Biosynthesis and Bioconjugation to Biomedical Application." *Chemical Reviews* 115: 11669-11717. Accessed July 31, 2016. doi:10.1021/acs.chemrev.5b00049.

Difficult article to work through but worth the effort. The article explains quantum dot sensors and how they work as well as how they are used in specific applications including latent fingerprint drug detection. Many diagrams and visuals make the process somewhat easier.