Lesson 1:
Introduction to Sun Protection

Teacher Materials

Contents

Introduction to Sun Protection: Teacher Lesson Plan

Orientation

This lesson is an introduction to the context and need for sunscreen and the important health concerns it is designed to address. The goal is to spark students' interest by addressing a topic of personal significance and get them to draw on their existing knowledge to generate initial ideas about the driving questions of the unit. They will refine this understanding over the course of the unit and have a chance to reflect on their initial thoughts at the end of the unit.

- The Sun Protection: Understanding the Danger PowerPoint slide set explains the danger of skin cancer and the need to use sunscreen to protect our bodies. A brief introduction to the different kinds of electromagnetic waves and their energies sets the stage for differentiating between the two kinds of UV light from which we need to protect our bodies (UVA and UVB). The final slide in the set introduces the driving questions for the unit.
- The Summary of Radiation Emitted by the Sun: Student Handout is a useful tool for students to refer to throughout the unit to remind them of the key differences between radiation types.
- The Initial Ideas Worksheet gives students the chance to draw on their existing knowledge to formulate first thoughts about the unit. This is a great tool for eliciting students' prior knowledge (and possible misconceptions) related to the unit topics.
- The Ultra-Violet (UV) Protection Lab Activity gives students the chance to explore UV protection first hand by testing the strength of different kinds of blocking substances (for example sunscreens and tee-shirts) with UV sensitive beads.

Essential Questions (EQ)

What essential questions will guide this unit and focus teaching and learning?

1. What are the most important factors to consider in choosing a sunscreen?
2. How do you know if a sunscreen has "nano" ingredients?
3. How do "nano" sunscreen ingredients differ from most other ingredients currently used in sunscreens?

Enduring Understandings (EU)

Students will understand:

(Numbers correspond to learning goals overview document)

1. How the energies of different wavelengths of light interact differently with different kinds of matter.
6. How to apply their scientific knowledge to be an informed consumer of chemical products

Key Knowledge and Skills (KKS)

Students will be able to:

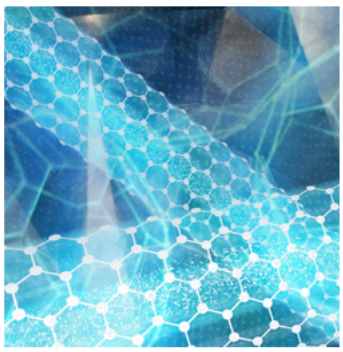
(Numbers correspond to learning goals overview document)

4. Evaluate the relative advantages (strong blockers, UVA protection) and disadvantages (possible carcinogenic effects, not fully researched) of using nanoparticulate sunscreens.

Introduction & Initial Ideas Timeline

Day	Activity	Time	Materials
Day 1 (50 min)	Show the Sun Protection: Understanding the Danger PowerPoint Slides, using the embedded question slides and teacher's notes to start class discussion. At the end of the presentation, hand out the Summary of Radiation Emitted by the Sun for students to refer to throughout the unit.	30 min	Sun Protection: Understanding the Danger PowerPoint Slides & Teacher Notes Computer and projector Copies of Summary of Radiation Emitted by the Sun: Student Handout
	Hand out the Clear Sunscreen Initial Ideas: Student Worksheet and have students work alone or in pairs to brainstorm answers to the driving questions. Let students know that at this point they are just brainstorming ideas and they are not expected to be able to fully answer the questions.	10 min	Copies of Clear Sunscreen Initial Ideas: Student Worksheet Clear Sunscreen Initial Ideas: Teacher Instructions
	Return to whole class discussion and have students share their ideas with the class to make a "master list" of initial ideas. The goal is not only to have students get their ideas out in the open, but also to have them practice evaluating how confident they are in their answers. This is also a good opportunity for you to identify any misconceptions that students may have to address throughout the unit.	10 min	
	Student Homework: Read the UV Protection Lab Activity: Student Instructions & Worksheet and fill in the Hypothesis section.	*15 min*	Copies of UV Protection Lab Activity: Student Instructions & Worksheet
Day 2 (50 min)	Ask if students have any questions about the lab. Have the students share their hypotheses and the rationales behind them.	10 min	UV Protection Lab Activity: Teacher Instructions & Answer Key

Have students work through the lab in teams of 2 or 3. After students have completed the data collection, they should work on the analysis section in their teams.	30 min	Lab Materials (as listed in the UV Protection Lab Activity: Teacher Instructions & Answer Key) *Note that some materials may need to be ordered ahead of time*
Have students share their analysis graphs with the whole class. Discuss the different results of the different groups and possible explanations for the results found. If there is time, combine the whole class's data into one super graph.	10 min	
Student Homework: Complete the Conclusion section of the lab	*30 min*	



Sun Protection

Understanding the Danger

NanoSense
the basic sense behind nanoscience

Why use sunscreen?

NanoSense 3

Too Much Sun Exposure is Bad for Your Body

- Premature skin aging (wrinkles)
- Sunburns
- Skin cancer
- Cataracts

Sources: http://www.oasishospital.org/previousnews.html; http://wohba.com/archive/2005_03_01_archive.html

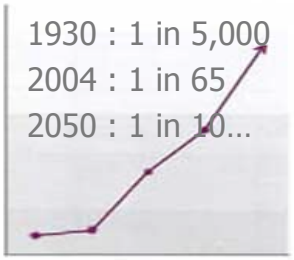
NanoSense 4

Skin Cancer Rates are Rising Fast

Skin cancer:

- ~50% of all cancer cases
- > 1 million cases each year
- ~ 1 person dies every hour

Probability of getting skin cancer



Causes of the increase:

- Decrease ozone protection
- Increased time in the sun
- Increased use of tanning beds

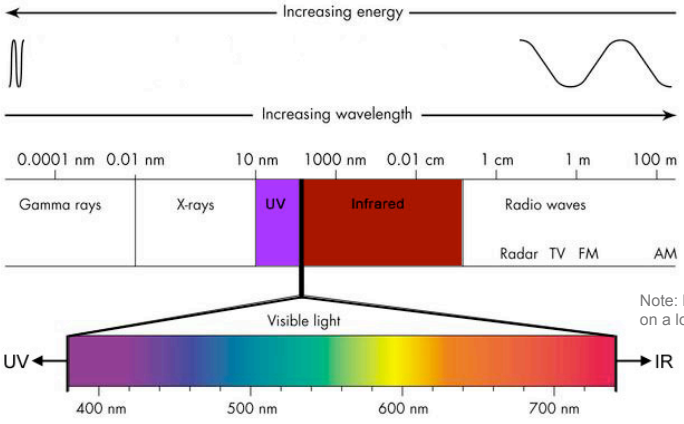
Sources: http://www.msnbc.msn.com/id/8379291/site/newsweek/ ;
http://www.skincarephysicians.com/skincancernet/whatis.html; http://www.msu.edu/~aslocum/sun/skincancer.htm

What are sun rays?

How are they doing damage?

The Electromagnetic Spectrum

- **Sun rays are electromagnetic waves**
  - Each kind has a wavelength, frequency and energy

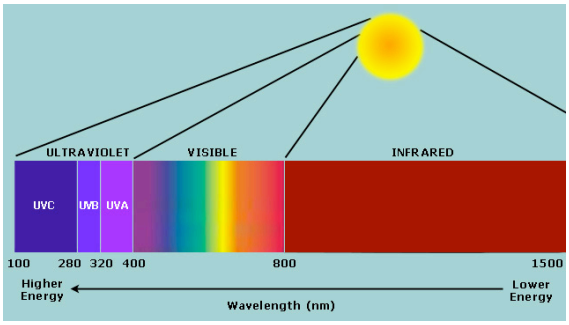


Note: Diagram drawn on a logarithmic scale

Source: Adapted from http://www.mhhe.com/physsci/astronomy/arny/instructor/graphics/ch03/0305.html

The Sun's Radiation Spectrum I

- **The sun emits several kinds of electromagnetic radiation**
  - Infrared (IR), Visible (Vis), and Ultra Violet (UV)

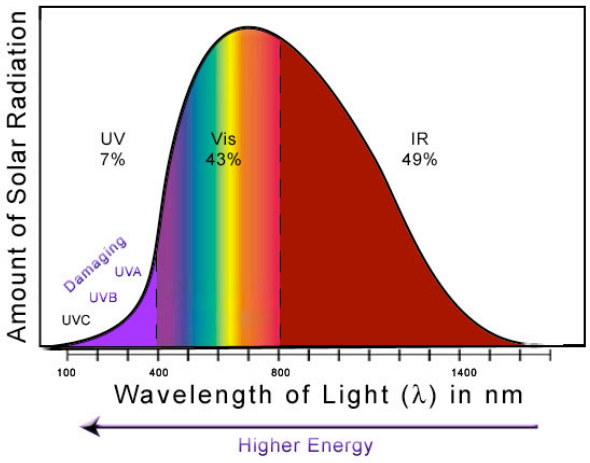


- **Higher energy radiation can damage our skin**

Source: http://www.arpansa.gov.au/is_sunys.htm

The Sun's Radiation Spectrum II

- **How much UV, Vis & IR does the sun emit?**

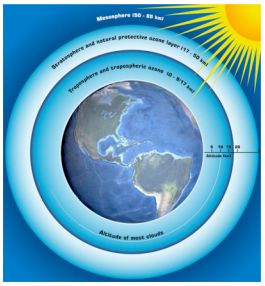


Source: http://www.arpansa.gov.au/is_sunys.htm

Does all the radiation from the sun reach the earth?

The Earth's Atmosphere Helps Protect Us

- **Some of the sun's radiation is absorbed by particles in earth's atmosphere**
  - Water vapor (H_20) absorbs IR rays
  - Ozone (O_3) absorbs some UV rays
  - Visible rays just pass through



- **Challenge Questions**
  1. What happens if the Ozone layer is partially or completed destroyed?
  2. Why are we concerned about UV, but not IR or visible light?

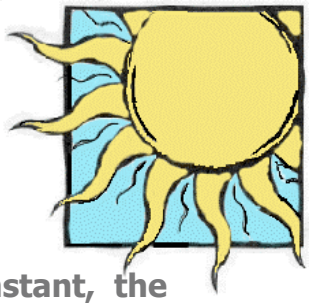
Source: http://www.space.gc.ca/asc/img/atmosphere-couche.jpg

How can the sun's rays harm us?

Sun Rays are Radiation

- Light radiation is often thought of as a wave with a wavelength (λ) and frequency (f) related by this equation:

$$c = \lambda \times f$$



- Since c (the speed of light) is constant, the wavelength and frequency are inversely related

$$\lambda = \frac{c}{f} \qquad f = \frac{c}{\lambda}$$

- This means that light with a short wavelength will have a high frequency and visa versa

Source: http://www.pueblo.gsa.gov/cic_text/health/sun_uv/sun-uv-you.htm

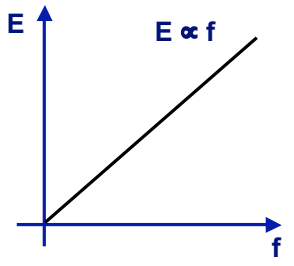
Radiation Energy I

1. Energy Comes in Packets

- The size of an energy packet (E) is determined by the frequency of the radiation (f)

$$E = h \times f$$

- Radiation with a higher frequency has more energy in each packet
- The amount of energy in a packet determines how it interacts with our skin



Radiation Energy II

2. Total Energy

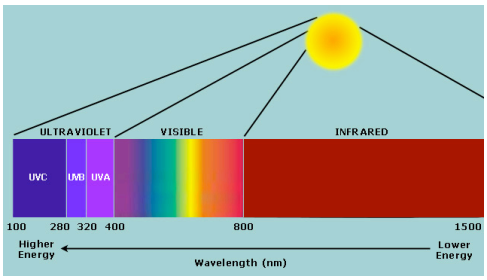
- This relates not only to how much energy is in each packet but also to the total number of packets arriving at a given location (such as our skin)

- Total Energy depends on many factors including the intensity of sunlight
- The UV Index rates the total intensity of UV light for many locations in the US daily: http://www.epa.gov/sunwise/uvindex.html

Source: http://www.epa.gov/sunwise/uvwhat.html

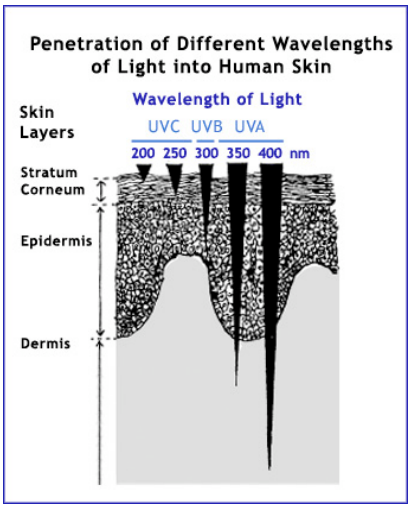
Skin Damage I

- The kind of skin damage is determined by the size of the energy packet (E = h * f)
- The UV spectrum is broken into three parts:
  - Very High Energy (UVC)
  - High Energy (UVB)
  - Low Energy (UVA)
- As far as we know, visible and IR radiation don't harm the skin



Source: http://www.arpansa.gov.au/is_sunys.htm

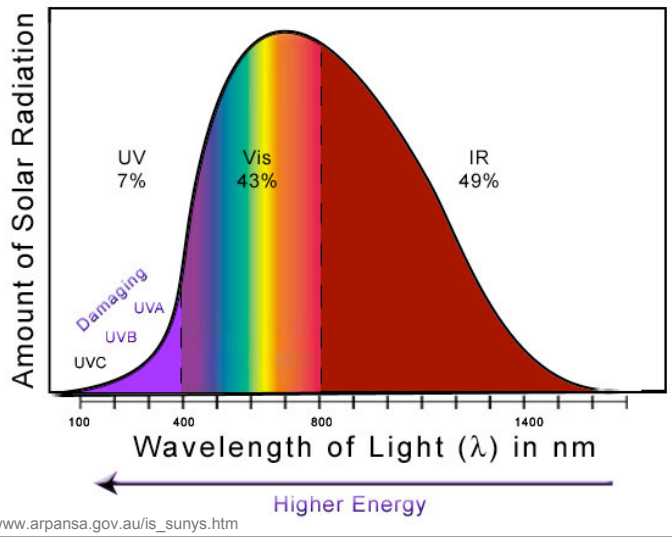
Skin Damage II



- Very high energy radiation (UVC) is currently absorbed by the ozone layer
- High energy radiation (UVB) does the most immediate damage (sunburns)
- Lower energy radiation (UVA) can penetrate deeper into the skin, leading to long term damage

Source: N.A. Shaath. The Chemistry of Sunscreens. In: Lowe NJ, Shaath NA, Pathak MA, editors. Sunscreens, development, evaluation, and regulatory aspects. New York: Marcel Dekker; 1997. p. 263-283.

Sun Radiation Summary I



Source: http://www.arpansa.gov.au/is_sunys.htm

Sun Radiation Summary II

Radiation Type	Characteristic Wavelength (λ)	Energy per Photon	% of Total Radiation Emitted by Sun	Effects on Human Skin	Visible to Human Eye?
UVC	~200-290 nm (Short-wave UV)	Increasing Energy High Energy	~0% (<1% of all UV)	DNA Damage	No
UVB	~290-320 nm (Mid-range UV)	Medium Energy	~.35% (5% of all UV)	Sunburn DNA Damage Skin Cancer	No
UVA	~320-400 nm (Long-wave UV)	Low Energy	~6.5% (95 % of all UV)	Tanning Skin Aging DNA Damage Skin Cancer	No
Vis	~400-800 nm	Lower Energy	~43 %	None Currently Known	Yes
IR	~800-120,000 nm Increasing Wavelength	Lowest Energy	~49%	Heat Sensation (high λ IR)	No

With all of this possible damage, it pays to wear sunscreen, but which one should you use?

Source: http://www.niehs.nih.gov/oc/factsheets/genes/home.htm

There are So Many Choices!

The Challenge: 3 Essential Questions

1. What are the most important factors to consider in choosing a sunscreen?
2. How do you know if a sunscreen has "nano" ingredients?
3. How do "nano" sunscreen ingredients differ from other ingredients currently used in sunscreens?

Sun Protection: Understanding the Danger: Teacher Notes

Overview

This series of interactive slides sets the context for the unit by describing the dangers of UV radiation and our need to protect ourselves against them. The final slide presents the three driving questions for the lessons in the unit.

Slide 1: Title Slide

Questions for Students: Do you wear sunscreen? Why or why not? Are there nanoparticles in your sunscreen? How do you know?

Slide 2: Why Use Sunscreen? (Question Slide)

Have your students brainstorm ideas about why it is important to use sunscreen.

Slide 3: Too Much Sun Exposure is Bad for Your Body

This slide describes the three main dangers of UV radiation:

- Premature skin aging leads to leathery skin, wrinkles and discolorations or "sun spots." Eyes can also be damaged by UV radiation leading to cataracts (damage to the eyes which causes cloudy vision).
- Sunburns are not only painful but are also a distress response of the skin giving us a signal that damage is being done.
- Skin cancer occurs when UV rays damage DNA in skin cells leading to genetic mutations. The mutated cells grow and divide uncontrollably forming a tumor. If caught early, the cancer can be removed; otherwise it can spread to other parts of the body and eventually cause death.

Slide 4: Skin Cancer Rates are Rising Fast

This slide describes the most dangerous consequence of UV radiation – skin cancer.

It is only recently that being tan came into fashion and that people began to spend time in the sun on purpose in order to tan. In addition, clothing today generally reveals more skin than it did in the past.

The use of tanning beds is not safe and a "base tan" only provides protection of about SPF 4.

Discussion Question for Students: Are there any other reasons that skin cancer **rates** might be rising?

Answer: Improvements in detection technology may mean that we identify more cases inflating the slope of the rise.

Slide 5: What Are Sun Rays? How are they doing damage? (Question Slide)

Have your students brainstorm ideas about what sun rays are and how they interact with our body.

Slide 6: The Electromagnetic Spectrum

Note: The illustrations of the waveforms at the extremes of the wavelength/energy spectrum are not to scale. They are simply meant to be a graphical representation of longer and shorter wavelengths.

You may want to discuss some of the properties and uses of the different parts of the electromagnetic spectrum further with your students:

- Gamma rays result from nuclear reactions and have a very high frequency and energy per photon (very short wavelength). Because they have a high energy, the photons can penetrate into cell nuclei causing mutations in the DNA.
- X-rays are produced in collision of high speed electrons and have a high frequency and energy per photon (short wavelength). Because they have a smaller energy than gamma rays, the x-ray photons can pass through human soft tissue (skin and muscles) but not bones.
- Ultra Violet Light is produced by the sun and has a somewhat high frequency and energy per photon (somewhat short wavelength). Different frequencies of UV light (UVA, UVB) are able to penetrate to different depths of human skin.
- Visible Light is produced by the sun (and light bulbs) and has a medium frequency and energy per photon (medium wavelength). Visible light doesn't penetrate our skin, however our eyes have special receptors that detect different intensities (brightnesses) and frequencies (colors) of light (how we see).
- Infrared Light is emitted by hot objects (including our bodies) and have a low frequency and energy per photon (long wavelength). Infrared waves give our bodies the sensation of heat (for example when you stand near a fire or out in the sun on a hot day.)
- Radio Waves are generated by running an alternating current through an antenna and have a very low frequency and energy per photon (very long wavelength). Because they are of such low energy per photon, they can pass through our bodies without interacting with our cells or causing damage.

Slide 7: The Sun's Radiation Spectrum I

Sun rays are a form of electromagnetic radiation. Electromagnetic radiation is waves of oscillating electric and magnetic fields that move energy through space.

Discussion Question for Students: What is the difference between UVA, UVB and UVC light?

Answer: They have different wavelengths, frequencies (UVC: ~100-280 nm; UVB: ~280-315 nm; UVC ~315-400 nm) and thus different energies.

Note: The division of the UV spectrum (as well as the division of UV, visible, infrared etc.) is a categorization imposed by scientists to help us think about the different parts of the electromagnetic spectrum, which is actually a continuum varying in wavelength and frequency.

Slide 8: The Sun's Radiation Spectrum II

The sun emits primarily UV, visible and IR radiation. < 1% of the sun's radiation is x-rays, gamma waves, and radio waves.

The amount of each kind of light emitted by the sun is determined by the kinds of chemical reactions occurring at the sun's surface.

Slide 9: Does all the radiation from the sun reach the earth? (Question Slide)

Have your students think about what might happen to the radiation as it travels through space.

If students bring up the idea of the ozone layer as protecting the earth, ask them to think about how it does this. (It does this by absorbing harmful UV rays – in other words capturing their energy so it doesn't reach the earth).

Slide 10: The Earth's Atmosphere Helps Protect Us

The earth's atmosphere is made up of several layers of gases surrounding the planet. The two closest layers are referred to as the troposphere (closest to the earth, where most clouds are found) and the stratosphere (farther from the earth, where the protective ozone layer resides). Beyond this there is (in increasing order of distance from the earth), the mesosphere, thermosphere and exosphere.

You may want to remind your students that absorption is the process by which atoms or molecules capture radiation energy.

Answers to Challenge Questions on Slide:

1. What happens if the Ozone layer is partially or completed destroyed?

As the ozone layer is depleted, more of the UV light emitted by the sun will reach the earth. UV depletion is cause by several chemicals used by humans, particularly the CFCs (chlorofluorocarbons) used in many old-style aerosol sprays. Though international agreements limiting the use of such chemicals has helped the problem, the fight continues. As the Canadian Space Agency reports, in 2000:

"Observations showed a strong depletion of the ozone layer over the Arctic, by as much as 60% in some layers of the atmosphere. In the lower stratosphere, near the South Pole, the hole reached a record size in spring 2000, measuring 28.3 million kilometers. The affected area extended to the southern tip of South America."

(Source: http://www.space.gc.ca/asc/eng/sciences/ozone_layer.asp)

2. Why are we concerned about UV, but not IR or visible light?

We are concerned about UV radiation because it is higher in energy than IR and visible radiation (this will be covered in more detail in the following slides). Even though there

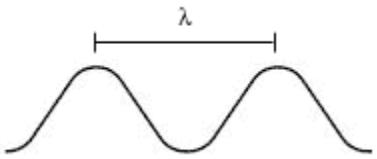
is less of it, it has the potential to damage humans, while it is currently thought that IR and visible radiation do not.

Slide 11: How can the sun's rays harm us? (Question Slide)

Have your students brainstorm ideas about how sun rays might interact with our body. What part(s) of our body do they interact with? How do they affect them?

Slide 12: Sun Rays are Radiation

If students are not already familiar with the concept of wavelength, it may help to draw a wave on the board and indicate that the wavelength is the distance between peaks.



The speed of light in a vacuum is always the same for all wavelengths and frequencies of light. (c = 300,000,000 m/s)

You may wish to point out to students that the letter 'c' is the same c in the famous $E=mc^2$ equation showing the relationship between matter and energy.

You may also want to discuss the concept that all light travels at the same speed in the same medium and that this does not depend on the frequency or wavelength of the wave. For example, in other mediums (e.g. air, water) light travels slower than in a vacuum. The speed of all light in water is ~225,563,909 m/s (only 75% of speed in a vacuum.)

Slide 13: Radiation Energy I

Example: Imagine that you are outside your friend's window trying to get their attention. You can throw small pebbles at the window one after another for an hour and it won't break the window. On the other hand, if you throw a big rock just once, you will break the window. It doesn't matter if all the pebbles put together would be bigger and heavier than the one rock; because their energy is delivered as separate little packets, they don't do as much damage. The same is true with energy packets.

h is Planck's constant (6.26×10^{-34} J s)

Slide 14: Radiation Energy II

Total Energy can not be predicted by the frequency of light.

You may want to talk with your students about the different things that the total energy depends upon. For example: time of day (10am-2pm is the most direct and strongest sunlight), time of year, amount of cloud cover (though some UV always gets through), altitude.

You may want to explore the UV index site with your students and look at how the index varies by location.

Slide 15: Skin Damage I

Discussion Question for Students: Which kinds(s) of UV light do you think we are most concerned about and why?

Answer: The theoretical answer would be UVC>UVB>UVA in terms of concern because of energy packet size. This is true for acute (immediate) damage, though as shown in next slide, UVA has now been found to cause damage in the long term. UVC is currently not a major concern because it is absorbed by the atmosphere and thus doesn't reach our skin.

Slide 16: Skin Damage II

Premature aging is caused by damage to the elastic fibers (collagen) in the dermal layer of the skin. Because UVA radiation has a lower frequency and thus lower energy per photon, it is not absorbed by the cells of the top layer of the skin (the epidermis) and can penetrate deeper into the skin (to the dermis) where it does this damage.

Both UVA and UVB can enter the cell nucleus and cause mutations in the DNA leading to skin cancer.

Most of the rapid skin regeneration occurs in the epidermal layer. The dermal layer does not regenerate as quickly and thus is subject to long term damage.

Slide 17: Sun Radiation Summary I

This slide and the following one sum up the differences between the different kinds of radiation emitted by the sun. There is a corresponding student handout that students can use as a quick reminder during the course of the unit.

This graph contains the all the information about wavelength, frequency, energy and amount of each kind of radiation emitted by the sun. Note that the different "kinds" of radiation are really points on a continuum.

Common Misconception: We see "black light" (UVA light) because it is close to the visible spectrum.

The Real Deal: If that were true, we would be able to see all objects as bright under black light and that doesn't happen. For example at a party only certain clothes appear bright. What actually happens is that black light causes some materials to fluoresce or phosphoresce meaning they absorb the UVA light and re-emit violet light in the visible spectrum that our eyes can detect.

Slide 18: Sun Radiation Summary II

This slide and the previous one sum up the differences between the different kinds of radiation emitted by the sun. There is a corresponding student handout that students can use as a quick reminder during the course of the unit.

This chart summarizes the all the information from the previous graph and lists the effects of each kind of radiation on the human body.

Note: Different diagrams may have different cutoffs for the divisions between UVA, UVB, UVC, visible and IR. This is because the electromagnetic spectrum is a continuum and the divisions between categories are imposed by scientists, thus not always well agreed upon.

Example: What determines if it is a "warm" versus a "hot" day? If you set the cutoff at 80 degrees Fahrenheit does that mean that a change from 79°F to 81°F is more meaningful than a change from 77°F to 79°F?

Slide 19: With all of this possible damage, it pays to wear sunscreen, but which one should you use? (Question Slide)

Discussion Questions for Students: What do you look for when you are buying a sunscreen and why? Do you think that your sunscreen is doing a good job to protect you?

Answers will vary. The goal of the discussion is for students to get their existing knowledge out on the table and to start to think critically about the consumer decisions they make and how they relate to science.

Slide 20: There Are So Many Choices!

This slide is an animation presenting the many different sunscreens available and the many different claims their labels make.

Slide 21: The Challenge: 3 Essential Questions

These three questions will guide the upcoming unit:

1. What are the most important factors to consider in choosing a sunscreen?
2. How do you know if a sunscreen has "nano" ingredients?
3. How do "nano" sunscreen ingredients differ from other ingredients currently used in sunscreens?

Each of the unit activities will help students develop their ideas about the questions. By the end of the unit, students should be able to explain and justify their answers to each question. For now, use the Clear Sunscreen Initial Ideas Worksheet to gives students the chance to brainstorm their initial answers to these questions before they begin the unit.

Clear Sunscreen Initial Ideas: Teacher Instructions

The goal of this exercise is to have your students "expose" their current ideas about sunscreens and human use of nano-products before they engage in learning activities that will explore these questions. You should let your students know that this is not a test of what they know and encourage them to makes guesses which they will be able to evaluate based on what they learn in the unit. You may also want to have your students share their ideas with the class (there are no "bad" ideas at this stage) and create a giant class worksheet of ideas. Students can then discuss whether or not they think each of these statements is true and why.

Write down your initial ideas about each question below and then evaluate how confident you feel that each idea is true. At the end of the unit, we'll revisit this sheet and you'll get a chance to see if and how your ideas have changed.

1. What are the most important factors to consider in choosing a sunscreen?	**How sure are you that this is true?** Not Sure	Kind-of Sure	Very Sure	**End of Unit Evaluation**
2. How do you know if a sunscreen has "nano" ingredients?	**How sure are you that this is true?** Not Sure	Kind-of Sure	Very Sure	**End of Unit Evaluation**
3. How do "nano" sunscreen ingredients differ from most other ingredients currently used in sunscreens?	**How sure are you that this is true?** Not Sure	Kind-of Sure	Very Sure	**End of Unit Evaluation**

Ultra-Violet (UV) Protection Lab Activity: Teacher Instructions & Answer Key

Summary of Materials to Order Ahead of Time

Source: Educational Innovations (www.teachersource.com)

Portable UV light - 1 (#UV-635, $10.95 each)

Purple UV beads -1 set (#UV-PUR, $6.95 per 250 bead package)

UV Bead Color Guide - 1 set per lab group (#UV-360, $2.95 each)

Clear UV blocking glass - 1 set (#FIL-235, $9.95 per set of two discs)

Introduction

It is important to protect our skin from damaging UV radiation, but how do we know how well we are protecting ourselves? Is wearing a light shirt at the beach as effective as wearing sunscreen? Is it better protection? Do thicker, whiter sunscreens protect us better than transparent sprays? Can we tell how well something will block UV by looking at its appearance?

Lab Explanation

In this lab students should discover that opacity and UV blocking are not related. Clear substances can be UV blockers and some opaque substances are not very good UV blockers. This is true because UV and visible light have different wavelengths and frequencies, thus they can interact differently with the same substance.

Research Question

In this lab you will be investigating the following research question:

- Does the appearance of a substance (its opacity) relate to its ability to block UV light?

Opacity

The *opacity* of a substance is one way to describe its appearance. Opacity is the opposite of how transparent or "see-through" something is; for a completely opaque substance, you cannot see through it at all. Opacity is a separate property than the color of a substance – for example, you can have something that is yellow and transparent like apple juice or something that is yellow and opaque like cake frosting.

Hands-On Opacity Examples

- Yellow frosting and yellow food coloring in water
- Grape juice (full concentration and several glasses of watered down versions)
- Stained glass (show different pieces of the same color but varying opacity)

Hypothesis

Do you think that UV blocking ability relates to a substance's opacity? Would you expect transparent or opaque substances to be better UV blockers? If you are right, what implications does this have for how you will protect yourself the next time you go to the beach? Write down your best guesses to answer these questions and explain why you think what you think.

Judging Student Hypotheses

Student answers may say that they are, are not, or are partially related. Student answers should not be judged on the correctness of the hypothesis, but can be evaluated on:

- The consistency of the answer (if they do relate than they should predict opaque substances to block better, if they don't relate, neither group of substances should be expected to be better blockers)
- Their justification for their answer (are they basing it on personal experience, scientific knowledge, etc.)

Materials

- Assorted white substances varying in opacity (for example: different sunblocks, sunscreens, sungels, glass pieces, white t-shirts of varying thicknesses, white tissue paper, white paper of varying thicknesses, laundry detergent, white paint, white face makeup)
- Eight paper cups
- One micro spoon
- Sunscreen Smear Sheet (Xerox form at the end of the lab onto acetate transparencies)
- Black construction paper (For judging opacity of white substances)
- UV light source (Available from Educational Innovations, Inc., #UV-635, direct sunlight on a bright day will also work)
- UV sensitive bead testers (Made from the following, instructions below)
    - UV sensitive beads (Available from Educational Innovations, Inc., #UV-PUR)
    - Large wooden craft sticks
    - Super glue
- UV bead color guide (Available from Educational Innovations, Inc., #UV-360)
- Cotton swabs (for apply sunscreen to the Sunscreen Smear Sheet)
- Alcohol wipes (for cleaning sunscreen off the Sunscreen Smear Sheet)

Making UV Beads into "Bead Testers"

To make the beads into bead testers you will need to melt them and glue them to wooden craft sticks. This makes them much easier for handling and applying sunscreen:

Here are the directions for melting and mounting the beads as discs.

1. Preheat oven or toaster oven to 300ºF.
2. Cover a cookie sheet with aluminum foil.
3. Arrange beads on the cookie sheet. Place them one inch from each other and make sure they are laying flat on the sheet.
4. Place beads in oven and set timer for 15 minutes.
5. When 15 minutes is over, the beads should have melted and now look like clear discs.
6. Remove from oven to cool. They will harden to white discs within five minutes.
7. Using super glue, attach one disc to a large wooden craft stick. Each student group should have three disc sticks, one labeled "C1" for Control 1, one labeled "C2" for Control 2, and the third labeled "E" for Experimental.

Alternative Option: Super glue two discs directly onto the UV bead color guide tube. If you choose to do this, mount the beads while they are slightly malleable and not cooled completely—approximately 1-2 minutes after removing melted beads from the oven.

Choosing Substances for Students to Test

You will want to have a selection of substances that range in both blocking ability and appearance (from clear to opaque). Here are some suggestions of substances to use:

- "Old" zinc-oxide sunblock that goes on white (As a substitute, Desitin is a cream sold for diaper rash that contains 40% zinc oxide.)
- "New" nano zinc-oxide sunblock that goes on clear
- A variety of regular sunscreens
- Clear sunscreen gels or sprays
- Clear UV blocking glass or plastic (A set of two clear plastic discs, one UV blocking, one not is available from Education Innovations, Inc., #FIL-235, $9.95 per set of two discs)
- White t-shirts of varying thickness
- Liquid laundry detergent (the ones with whitener will block some UV light)
- Old white t-shirts (if the old ones have been washed many times with whitening detergent they will block some UV light)
- White paper of vary thickness (tissue paper, printer paper, construction paper)
- White paint or white face make-up

Important Notes on Using Sunscreens

- Make sure to tell students not to put the sunscreen on their bodies in case of an allergic reaction
- To avoid mess, you may want to have sunscreens available to students in a bowl or large cup

Procedure

Part I: Choose Your Samples

Goal: Choose a group of substances from the ones provided by your teacher that you think will best help you determine if opacity is related to UV blocking.

❒ Obtain eight small paper cups. Obtain a small sample of each of the substances you have chosen. Label each cup with the name of the substance.

Tip: Try to choose substances that vary in their opacity and that you would expect to vary in their blocking ability.

Part II: Judge the Opacity

Goal: To make observations about the appearance (opacity) of the substances you chose, using your eyes as the instruments.

❒ Obtain a Sunscreen Smear Sheet. Place it on top of a black sheet of paper.

❒ Label one square with the name of each substance you are going to test.

❒ Use the micro spoon to measure out the first substance (make sure to use an equal amount of all the other substances).

❒ Then use the cotton swab to smear the substance onto the Sunscreen Smear Sheet, evenly covering a whole square with a thin layer. (For solid substances, just place them on top of the sheet).

❒ How well can you see through the substance to the black sheet of paper?

❒ Use the Opacity Guide on the next page to rank each sample on a 1 to 5 scale.
Use 5 to represent no opacity (you cannot see the substance at all).
Use 1 to represent complete opacity (you can't see any black through the sample).

❒ Record your observations into the Data Chart in this packet.

❒ Repeat for each of your substances.

Opacity Guide

Part III: Test the UV Blocking

Goal: Use UV-sensitive beads to determine how effective your chosen substances are in blocking UV-light.

Student Question: Why don't we judge UV blocking ability with our eyes?

Answer: Because our eyes can't detect UV light, we need to use something that can

- ❒ Obtain 3 UV bead testers:
  - Bead Tester "C1" for Control 1. This bead will always be kept out of the UV light and will show you the lightest color that the bead can be. Keep this in the envelope until you need it.
  - Bead Tester "C2" for Control 2. This bead will always be exposed to the UV light and should always change color to let you know that the UV light is reaching the bead. This bead will show you the darkest color that the bead can reach.
  - Bead Tester "E" for Experimental. Keep this in its envelope so that it is not exposed to any UV light while you are not using it.

Checking Bead Tester C1 and C2

- ❒ Use UV bead color guide to record the initial bead color number (2-10) of C1 on your data chart.
- ❒ Expose C2 to the UV light for 30 sec. and quickly compare it to the UV bead color guide. Record the bead color number (2-10) on your data chart.

Using Bead Tester E with Your Substances

- ❒ To test the UV blocking of a substance, hold Bead Tester E under the square for that substance on the Sunscreen Smear Sheet. (For solid substances, just hold Bead Tester E directly behind them).
- ❒ Expose Bead Tester E (covered by the substance) and Bead Tester C2 (uncovered) to your UV lamp (or direct sunlight) for 30 secs.
- ❒ Take both Bead Testers out of the light, uncover Bead Tester E, and observe any changes to the color of the beads using the UV bead color guide. Record the bead color number (2-10) for both E and C2 on your data chart.

Tip

For solid substances, student may confuse the shadow cast by the object with the color change of the bead. The best way to accurately judge the color change of a bead with a shadow on it is by placing the color guide in the shadow as well.

- ❒ Repeat for each of your substances.

Data Chart

Initial C1 Bead Color Number_____ **Initial C2 Bead Color Number_____**

Substance Name (Include SPF if applicable)	Appearance (Describe)	Opacity (1 to 5 rating)	Color of UV bead "E" (2 to 10 rating)	Color of UV bead "C2" (2 to 10 rating)	Observations and Notes

Analysis

Tip

Students may have difficulties understanding that "no pattern" can be an important and informative finding. After giving students a chance to work on the analysis section in their groups, you may want to have them come together as a class to discuss their results and focus specifically on what it means to not have a pattern and how you know whether you have "no pattern" or "not enough data." If there is time, you may want to combine student data into one giant chart and discuss the results with students.

Now you need to analyze your data to see if it helps to answer the research question: Does the appearance of a substance (opacity) relate to its ability to block UV light? One of the ways that scientists organize data to help them see patterns is by creating a visual representation. Below you will see a chart that you can use to help you analyze your data.

To fill in the chart, do the following for each substance that you tested:

1. Find the row that corresponds to its opacity.
2. Find the column that corresponds to its UV blocking ability.
3. Draw a large dot • in the box where this row and column intersect.
4. Label the dot with the name or initials of the substance.

After you have filled in the chart, answer the analysis questions that follow.

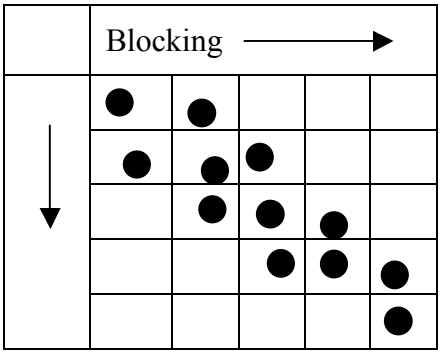
UV Blocking Ability → / Opacity ↓	No Blocking (10)	Low Blocking (8)	Medium Blocking (6)	High Blocking (4)	Total Blocking (2)
5 Fully Transparent					
4					
3					
2					
1 Fully Opaque					

1. Look at the visual representation of your data that you have created and describe it. Note any patterns that you see. Remember that seeing no pattern can also give you important information.

Answer

Ideally the dots will be scattered randomly throughout the graph and not show any pattern. Individual data sets may show some concentration of dots in a particular part of the chart due to the substances tested, but there should not be a "line" of dots in any direction that would indicate a correlation between opacity and UV blocking ability. You may want to discuss with students the difference between a pattern (most dots are in the lower left corner) and a relationship (dots form a line showing how one variable varies with the other.)

2. What pattern would you expect to see if there is a relationship between the appearance of a substance (opacity) and its ability to block UV light? Draw the pattern by coloring in the grid below.



Tip

Students might say the opposite (a diagonal line running from the bottom left to the top right indicating that more transparent substance block better) which is possible (though counter-intuitive). If they say this, ask them to justify why they think this would be.

3. Does your chart match the pattern you would expect to see if there is a relationship between opacity and UV blocking ability?

   ☐ Yes

   ■ No

   ■ I'm not sure

Tip

Either the 2nd or the 3rd answer can be correct; students should not have data that supports a relationship between the variables.

4. What does this answer mean in practical terms? What does it tell you about well you can judge the effectiveness of sun protection by looking at its appearance? How might this affect your sun protection activities?

Answer

The answer of "no pattern" means that you cannot tell how well something will protect you from the sun by looking at its appearance. For example, clear sunglasses can provide UV protection to your eyes and a white tee-shirt may not fully protect the skin underneath. This means that it is very important to pay attention to SPF (and other) ratings of sun protection and not make assumptions based on appearance.

5. Do you think that increasing the number of substances you tested would change your answer? Why or why not?

Answer

No, adding substances will help clarify the answer in situations where the data is not clear, but it should not change an answer strongly supported by the data.

6. How confident are you that the answer you came up with is correct? Do you think that increasing the number of substances you tested would change *how sure you are* of your answer? Why or why not?

Answer

Students should discuss their confidence in relation to their data. For example the amount of data points they have, the range of substances they tested (and that were available to them).

More data points would make the existence (or lack of a pattern) more clear. It also increases confidence that the data points found were not "flukes" but representative of the overall pool of possible substances to test.

Conclusions

1. Answer the research question:

☐ Yes, there is a relationship.

■ No, there is not a relationship.

■ I'm not sure if there is a relationship.

Tip

Either the 2nd or the 3rd answer can be correct; students should not have data that supports a relationship between the variables.

2. This is how the evidence from the experiment supports my answer: (Make sure to be specific and discuss any patterns you do or do not see in the data.)

Answer

Students should discuss how their data compares to what data for a pattern would look like.

3. Identify any extra variables that may have affected your experiment:

Answer

Possible answers include the amount (thickness) of sunscreen applied and incomplete cleaning of sunscreen from previous trial.

If you are using natural sunlight, the amount of UV light shining on the beads may also vary between trials. If this is the case, students should notice differences in the bead color number for C2 between trials.

4. How could you control for these variables in future experiments?

Answer

Possible answers include measuring sunscreen for application and the use of disposable tester sticks.

5. What changes would you make to this experiment so that you could answer the research question better?

Answer

Possible answers include using more substances (students should give examples) and using better measurement tools (for example beads with a permanent color change, a digital color reader etc.).

6. All experiments raise new questions. Sometime these come directly from the experiment and others are related ideas that you become curious about. What is a new research question that you would want to investigate after completing this experiment?

Answer

Possible answers include the relationship between color (hue) and blocking ability, the relationship between blocking claims (advertising) and blocking ability and the relationship between amount applied (of sunscreen) and blocking ability.

Sunscreen Smear Sheet

Sample:	Sample:	Sample:	Sample:

Sample:	Sample:	Sample:	Sample:

Sunscreen Smear Sheet

Sample:	Sample:	Sample:	Sample:

Sample:	Sample:	Sample:	Sample: