



**Tools and Resources**

***“What’s Sunless Tanner?”***

February/March 2019

<http://www.acs.org/chemmatters>

**Teacher’s Guide:**



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**Tools and Resources**

***“What’s Sunless Tanner?”***

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# Connections to Chemistry Concepts

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| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Organic nomenclature** | When students study basic organic nomenclature, they often want to know how to read and understand the active ingredients listed on prescription and over-the-counter medicines. This article provides an opportunity for a student challenge: dissect the name of the compound dihydroxyacetone. |
| **pH** | As students study pH, information in this article refers to the importance of adjusting the pH to stabilize molecules such as dihydroxyacetone. |
| **Chemical reactions** | Information in this article brings chemical reactions into the real world for students who may not realize that the same chemical reaction, Maillard, can brown both food (toast) and skin (tan). |
| **Scientific process** | When introducing students to scientific processes, the use of Dr. Wittgenstein’s serendipitous discovery of the chemical in vomit that led to sunless tanning preparations presents a great example of how scientists work. The excitement of this “find” may encourage students to look for patterns and then test their own inferences. |
| **Electromagnetic spectrum** | The study of the electromagnetic spectrum is usually accompanied by high student interest in the waves that are most relevant to their lives: microwaves feed them and UV radiation tans them (and causes cancer). This article provides a good place in the curriculum to introduce the possibility of safer tanning procedures. |
| **Risk/Benefit** | Articles like this can help to prevent or help to mitigate (possibly even cure?) “chemophobia”. Providing both the benefits and the risks associated with specific chemicals can help students understand that chemistry is not something to be feared, but something to be understood and appreciated. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5:** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
  + **ELA-Literacy.RST.11-12.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  + **ELA-Literacy.RST.11-12.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
  + **ELA-Literacy.WHST.9-10.2F:** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  + **ELA-Literacy.WHST.11-12.1E:** Provide a concluding statement or section that follows from or supports the argument presented.

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the February/March 2019 issue:

Mixtures

Structural formulas

Environmental impacts of personal and societal decisions

Nanoparticles

Periodic properties

Phase changes

Green chemistry

* Consider asking students to read “Open for Discussion: Unpacking the Paleo Diet” on page 4 before they read “Making Sense of Milk” to learn why some people might choose not to consume dairy products.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles, and what they would like to explore further.
* Ask students if they have questions about some of the issues discussed in the articles.
* Encourage students to watch the videos and try the simulations suggested in some of the articles.

# Possible Student Misconceptions

1. **“I’ve heard that sunless tanning sprays prevent sunburns.”** No, sunless tanning sprays or creams do not prevent sunburns. Sunless tanning solutions contain a sugar such as dihydroxyacetone that reacts with the amino acids in dead skin. These cells, located on the upper surface of your skin, temporarily darken by the Maillard reaction to form a simulated tan. Sunless tanners do not protect the inner skin cells from UV radiation that can cause skin cancer and burn the skin.
2. **“I’ll always use sunless tanners that contain sunscreens to prevent burning.”** This sounds like a good idea; however, the American Academy of Dermatology suggests that to be safe you need to apply sunscreen every 2–3 hours; your sunless tanner works for 4–7 days, so it will far outlast the safety of its sunscreen. Unless you decide to stay indoors (at the Prom for example) with your new tan, you will need to severely restrict your time in the sun to the first 2–3 hours after tanning.
3. **“Good sunless tanners produce nice, even tans that should shield and protect my skin from burning, just like a suntan.”** No matter how even your tanner appears, it only reacts with the amino acids in the outer layer of dead skin cells. This provides no protection from UV radiation. UV rays penetrate the outer layers of the skin and trigger inner skin cells, melanocytes, to produce melanin, the brown pigment that causes tanning and helps protect skin from burning.
4. **“They say that using spray tanners is the best way to receive an even, sunless tan. And, you can do this yourself safely at home.”** Do-it-yourself sunless spray tanning can be dangerous at home. If you inhale the fumes, you run the risk of pulmonary disease or cancer. Moreover, the spray is only U.S. FDA-approved for your skin. Exposure to the spray on your eyes, lips or mucous membranes could cause severe headaches, nausea, or dizziness, and some think that in the bloodstream it could lead to cancer. Experts suggest that spray tanning should be done in a salon while wearing goggles.
5. **“I’m going to gradually build up my natural suntan to prevent skin cancer.”** Research shows that, while gradually building up natural suntans may help prevent sunburn, the suntan is evidence that the UV rays are also damaging the skin, possibly resulting in premature wrinkles and dark spots. In addition, the UV rays may cause oxidative damage to DNA in the deep-skin stem cells, leading to skin cancer.
6. **“My skin is naturally brown rather than tanned, so I don’t have to worry about getting a sunburn.”** Sorry, but no one is immune. Skin cancers such as melanoma can still occur in people who have darker skin pigmentation, so wear sunscreen and clothing that protects you from the sun’s UV radiation.
7. **“I’m very careful to go inside if my skin just gets a little pink or red, because I don’t want a real sunburn.”** Pink or red means that your skin has been burned. Your skin doesn’t need to blister, peel or become raw to indicate damage (mutations) to the DNA of your inner skin cells.
8. **“I don’t understand how the Maillard reaction can occur in bread since it doesn’t contain DNA.”** Bread *does* contain DNA; the bread wheat genome contains approximately five times more DNA than the human genome. Human chromosomes have two sets of chromosomes; wheat has six. Most of the wheat DNA is composed of repetitive sequences interwoven to form a dense, complicated genome composed of many base pairs. Bread also contains carbohydrates (sugars) that combine with the amino acids in wheat DNA; the Maillard reaction occurs when initiated by the heat in the toaster.

# Anticipating Student Questions

1. **“What was the rare metabolic disease that Dr. Wittgenstein was treating in children when she discovered the tanning effects of dihydroxyacetone?”**Dr. Wittgenstein was treating children who had glycogen storage disease. This is a metabolic disorder caused by the lack of enzymes that regulate the synthesis and degradation of glycogen in the body. Glycogen is a polysaccharide form of glucose, the form that is stored as energy in humans, animals, fungi, and bacteria.
2. **“The names sound familiar, so are melanoidins related to melanin?”** Yes, melanoidins are pigments formed when dihydroxyacetone reacts with amino acids to form a sunless tan (the Maillard reaction). This reaction occurs in the outer layers of your skin and does not offer protection from the damage caused by UV rays.Melanin is the natural coloring pigment located in deep layers of your skin that provides limited protection for your skin from UV radiation.
3. **“Why do sunless tanners only last 3**–**10 days?”** Everyone’s skin cycle is different, but most outer skin sheds every 3–10 days, these outer dead skin cells are the ones that have been “tanned” by sunless tanners. So the sunless tan will fade as the outer dead skin cells replace themselves with new untanned skin cells.
4. **“How long does it take for a tan to be produced by a sunless tanner spray or solution?”** The sunless tanning process takes approximately 6–10 hours for the full tan to develop. For the best results, do not shower, sweat profusely, or wash off the tan during this time.
5. **“What happens in your skin to produce a natural tan?”** A natural suntan is the body’s protective response to UV exposure. In an effort to protect the skin from burning, UV rays interact with DNA to initiate a response that signals deep skin cells to produce more of the tan-colored pigment melanin.
6. **“How much skin protection does a natural tan provide?”** A natural base tan only provides a Sun Protection Factor (SPF)of 3 or less; the American Dermatology Association recommends a sunscreen or clothing with SPF 30 or more.
7. **“Are there any dangers involved in the use of sunless tanners?”** As long as you a) recognize that your fake tan offers no protection from the sun’s UV rays, b) use sunscreen and/or UV protective clothing, and c) do not inhale or expose your lips, eyes and mucous membranes to the tanner, no dangers have been specifically identified and the products are deemed safe by the U.S. FDA. The primary downside is that, to maintain your tan, you will have to reapply the solution every 4–7 days.
8. **“What is the relationship between a suntan and a sunburn and why do they occur?”** The body naturally tries to defend itself against damaging UV rays. At first, the inner skin cells receive a signal to produce more melanin, which tans your skin. Then as you remain in the sun, this system is overwhelmed by the UV rays, causing inner-skin-cell DNA mutations, plus burning and blistering of the skin.

# Activities

**Labs and demos**

**“The Most Effective Sunscreen” MS/HS Lab (60 min):** During this AACT lab, students will test the amount of UV protection provided by various sunscreens as measured by UV bead detectors. Complete student instructions are provided, and there are additional resources for the teacher. (Access is restricted to AACT members, but the article will be available for free until February 1, 2019, at <https://teachchemistry.org/classroom-resources/the-most-effective-sunscreen>)

**“The Maillard Reaction” demo or student lab from video (3:59):** This video shows how the Maillard reaction can be tested in test tubes heated in a water bath. The set-up is clearly demonstrated and could be repeated easily as a demo or a student mini-lab. (<https://www.youtube.com/watch?v=SLAz3oiMi8Q>)

**Media**

**“What is the Maillard Reaction?” video (2:10):** This brief *Scientific American* video discusses the Maillard reaction and explains how thousands of flavor compounds can be produced by using proper cooking temperatures to react various sugar and amino acid combinations. (<https://www.youtube.com/watch?v=c7WI41huAok>)

**“The Maillard Reaction” video (3:01):** This video shows the process of roasting (caramelizing) coffee beans and how the length of time spent in the Maillard phase determines the strength of the coffee. A long period of time produces molecules of high molecular weight in the beans, which forms a more viscous, darker cup of coffee; hence, “dark roast”.

(<https://www.youtube.com/watch?v=9gASsB1AeC8>)

**Lessons and lesson plans**

**“Sun & Skin” research lesson for grades 9**–**12 (several days):** In this AAAS lesson, students work in groups to answer research questions that apply to a virtual scenario (a beach vacation). Appropriate links are provided for students to study the impact of UV radiation and ways to protect the skin; the lesson contains links, questions, discussion, and suggestions for a final summary activity. (<http://sciencenetlinks.com/lessons/sun-skin/>)

**“UV Light Detecting Beads” chemistry lesson:** This lesson contains a variety of hands-on ways to explore UV radiation; it introduces the electromagnetic spectrum and the wavelengths of UV, the chemistry of UV beads, and it provides several relevant classroom activities and extensions, such as UV-sensitive silly putty and fingernail polish. (<http://cdn.teachersource.com/downloads/lesson_pdf/UV-AST.pdf>)

**Projects and extension activities**

**“Chemistry Sandwiches” grades 11**–**12 chemistry take-home project (90:00):** This project (developed with NSF funding for the MS state lesson plans) involves kitchen cooking, so it must be done under proper parent/guardian supervision; students will study several chemical reactions including the Maillard reaction as they make and bake bread, brown meat, and caramelize peppers and onions to make a sandwich. (<https://www.gk12.msstate.edu/lessonplans/272_INSPIRE_LP_mclaurin_020112.pdf>)

**“Chemistry of Summer”, 3 videos (2**–**3 min. each), 15 questions/experimental design suggestions:** all contained within the site,excellent material from an ACS ChemClubs publication. <https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/summer.html>) (This lesson is available free at this URL.)

* **“How Sunless Tanners Work: Tan in a Can Chemistry” Bytesize Science (2:50):** Describes Dr. Wittgenstein’s discovery and explains how sunless tanners work.(<https://youtu.be/qP22ODuCip4>)
* **“Repelling the Rays: Chemistry of Sunscreens” Bytesize Science (3:39):** Explains UV radiation and how sunscreens work. (<https://youtu.be/wopwVVsbvWI>)
* **“Sunscreen SPF explained—Speaking of Chemistry” ACS *Chemical and Engineering News* (2:52):** Explains SPF in sunscreens. (<https://www.youtube.com/watch?v=pXR5F6mYal0>)
* Many of the 15 questions for students to consider suggest experimental designs to test their ideas.

The three videos above with individual URLs are located inside the lesson and accessed by the menu located in the upper left corner of the video screen shown in the lesson.

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles and Teacher’s Guides published from the first issue in October 1983 through April 2013.**

**The DVD is available from the ACS for $42 ($135 for a site/ school license) here:** [***http://www.acs.org/chemmatters***](http://www.acs.org/chemmatters)***.***



“Sun Alert” contains a good illustration and description of the layers of human skin, plus a table showing the effects of UV radiation (A, B, and C) on the skin; calculation of SPF rating for sunscreens; and the concern about indoor tanning salons that advertise their process as absolutely safe (disputed by the U.S. FDA). (Baxter, R. Sun Alert. *ChemMatters*. 1998, *16* (2), pp 4–6)

“Open for Discussion: A Tan—Quick, Easy, and Safe?” discusses the safety of various tanning options including outdoor sun, tanning beds, and sunless products; the electromagnetic spectrum, UV radiation, and dihydroxyacetone are also discussed in this one-page article. (Sitzman, B. and Goode, R. A Tan—Quick, Easy, and Safe? *ChemMatters*. 2012, *30* (1), p 5)

“Two Is Better than One” explains why toast tastes better if toasted twice, first to evaporate the water and then a second time to undergo the Maillard reaction; a nice infographic shows the Maillard reaction and explains the chemistry that occurs while food browns. (Husband, T. Two Is Better than One. *ChemMatters*. 2012, *30* (4), pp 9–11)

The Teacher’s Guide for the December 2012 *ChemMatters* article above provides additional information about the chemistry behind the Maillard reaction and includes several resources from food chemistry.

The Teacher’s Guide for the April 2013 *ChemMatters* barbecue article uses a diagram to describe the Maillard reaction between glucose and an amino acid to form melanoidins; an unpleasant effect of the Maillard reaction: proteins and sugars in the lens of an aging eye are highly susceptible to forming cataracts and causing macular degeneration and diabetic retinopathy when they undergo the Maillard reaction; the products of this reaction form aggregates that scatter light and impede vision.

# Web Resources for More Information

**Structure of human skin**

This article contains a good diagram and description of the three layers of the skin, accompanied by a description and the location of common skin cancers (melanoma, basal cell carcinoma, squamous cell carcinoma).

(<https://www.webmd.com/skin-problems-and-treatments/picture-of-the-skin#1>)

“UV Radiation and the Skin” is an excellent research paper that contains a detailed diagram of the epidermis, with a description of the functions of each layer. UV radiation’s effects on human health are discussed as complex.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3709783/>)

**Maillard reaction**

“The Accidental Scientist” article explains the initial discovery by Louis-Camille Maillard early in the early twentieth century. The accidental discovery by World War II soldiers—that when powdered, dehydrated eggs were browned, the result was very distasteful—led to understanding the chemistry of the earlier Maillard discovery.

(<https://www.exploratoriumedu/cooking/meat/INT-what-makes-flavor.html>)

This article begins with an excellent infographic showing the non-enzymatic (without enzymes) guide to the Maillard reaction, including a list of some of the classes of products. History of discovery and development of the mechanism is given along with information about the importance of pH and temperature.

(<https://exploratorium.edu/cooking/meat/INT-what-makes-flavor.html>)

**Risks/Risky behavior**

Increased rates of melanoma in young people living in southern beach communities led researcher Natalie R. Gassman, University of Southern Alabama Mitchell Cancer Institute, to study intentional tanning practices of high school and college students, including outdoor, indoor, and spray-tanning practices. The paper “Intentional tanning behaviors among undergraduates on the United States’ Gulf Coasts” includes research protocols and statistical analysis, with a discussion of findings.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5883533/>)

“Sunless Tan Doesn't Take Away Risk of Cancer” was published in *Medical Daily*, a medical and nutritional news website, published by *Newsweek* magazine. The article quotes a study from the University of Minnesota showing that young adults who use sunless tanners are in danger of developing skin cancers because they frequently engage in risky outside behaviors such as declining to seek shade, use sunscreens, or wear UV protective clothing.

(<https://www.medicaldaily.com/sunless-tan-doesnt-take-away-risk-cancer-426537>)

**Dermatologystudies**

A survey published in the *American Academy of Dermatology* discusses survey results from young adults that indicate a large percentage of them lack understanding of the consequences of tanning—and few of them care. The article recommends self-tanning over UV exposure, provides instructions on how best to apply sunless products, and includes warnings about the need for sunscreen to accompany them.

(<https://www.aad.org/media/news-releases/dermatologists-give-young-adults-something-to-tweet-about-tanning-s-out>)

This paper, published in the *Journal of Clinical and Aesthetic Dermatology,* reviews methods of tanning used today; the forms of skin cancer related to types of UV radiation; and the side effects of dihydroxyacetone tanners, particularly those in spray form. While once thought to react with only the dead outer layer of skin cells, current research shows that, when used constantly, as much as 11% of the dihydroxyacetone penetrates deeply into the epidermis and dermis skin layers.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4345932/>)

**Fake tan infographic**

The infographic “The Chemistry of Fake Tan” shows structural formulas of dihydroxyacetone and erythrulose (often used in combination with dihydroxyacetone), two sugars that react with amino acids to form tans; it provides a description of the chemistry involved in the ”fake” tanning process and provides information about the potential risks of sunless tanning.

(<https://www.compoundchem.com/2014/08/07/faketan/>)

Erythrulose (shown in the infographic above), found naturally in red raspberries, is a sugar with a structure similar to dihydroxyacetone, except that it is a tetrose carbohydrate that contains a ketone group (C4H2O4), so it reacts with amino acids in proteins of the outer layer of dead skin cells; while not approved by the U.S. FDA, it is often used with dihydroxyacetone to produce a longer tan.

(<https://en.wikipedia.org/wiki/Erythrulose>)

**Research studies**

University of Minnesota researchers concerned with the increase in melanoma skin cancer in the U.S. interviewed 27,000 sunless tanners, men and women 18 years or older, to determine their potential for behavior that could increase the risk of skin cancer. They found that the use of sunless tanners was associated with risky sun cancer behaviors such as failure to use sun protection (clothing or lotions); results of their study were published in the *Journal of the American Medical Association* (JAMA).

(<https://www.ncbi.nlm.nih.gov/pubmed/30046802>) (Abstract available here full text available with subscription or free personal account.)

The increasing incidence of skin cancer has led to the demand for safer tanning methods and to studies such as those reviewed in “A Review of Common Tanning Methods” published by *The Journal of Clinical and Aesthetic Dermatology*. In this article, various forms of skin cancer due to exposure to UVA or UVB radiation outdoors or at inside tanning bed salons are described, plus the research involving the use of over-the-counter topical sunless tanners and tanning pills is described.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4345932/>)