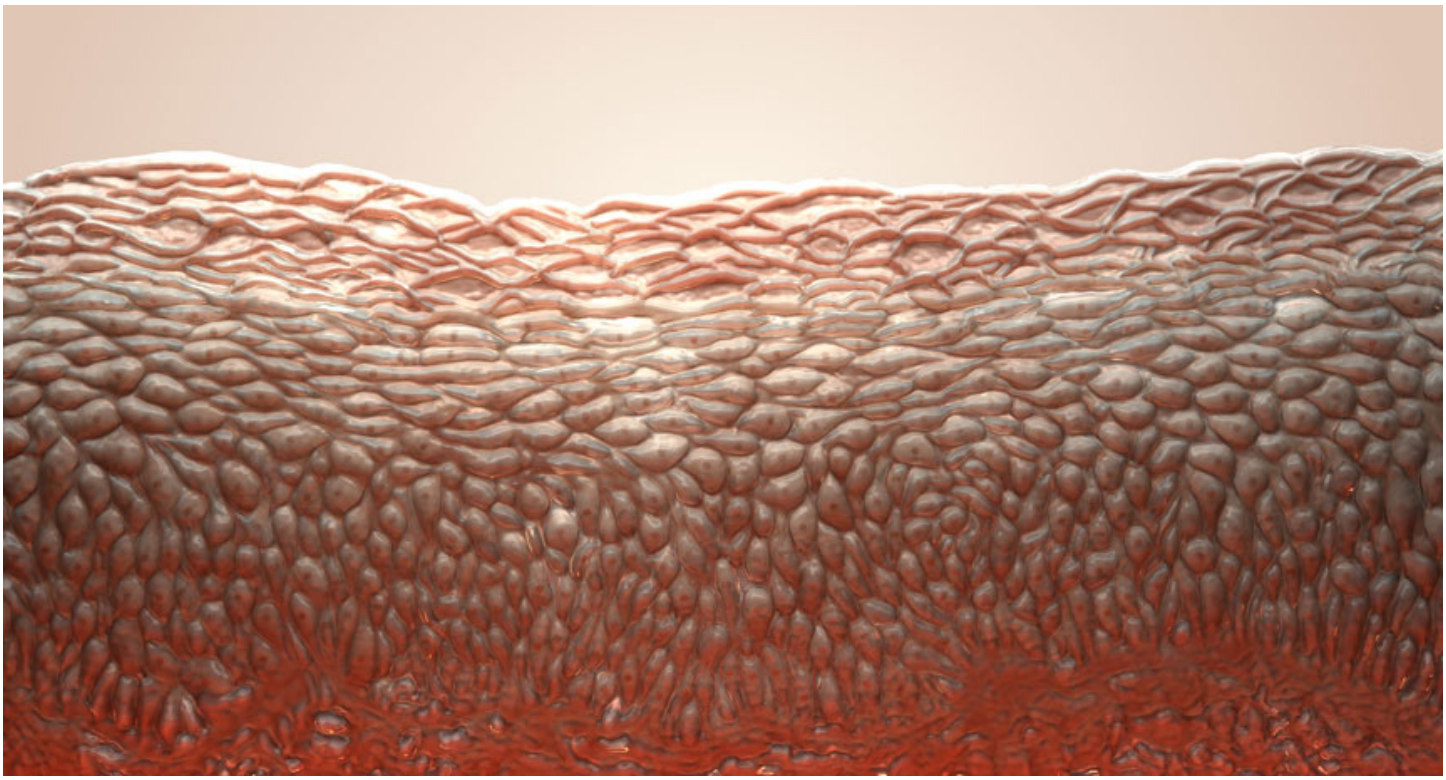
ScienceNews
IN HIGH SCHOOLS | EDUCATOR GUIDE



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December 9, 2017

Gene Therapy Fixes Rare Skin Disease

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

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About the Issue

Science News **article(s):** "Gene therapy fixes rare skin disease"

Readability score: 9.5

Science News for Students **article(s):** "Doctors repair skin of boy dying from 'butterfly' disease"

Readability score: 6.0

The article "Gene therapy fixes rare skin disease" describes how scientists used stem cells and gene therapy to replace 80 percent of the skin of a boy with a rare genetic disease. Students can focus on details reported in the article, follow connections to earlier articles about stem cells and gene therapy, and pursue cross-curricular connections to other major science topics in biology, chemistry and engineering. In a related activity, students can measure the density of skin touch receptors in different areas of the human body.

The Genes Foretell Flu Shot Response Educator Guide is another great resource for teaching about gene activity and protein production. The included activity allows students to gain a better understanding of influenza, its genome, mutations and vaccines.

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Article-based observation: Questions focus on how scientists used stem cells and gene therapy to replace 80 percent of the skin of a boy with a rare genetic disease, and what the researchers learned in the process.

Quest through the archives: Use this short section to explore other articles about stem cells and gene therapy, and ultimately compare applications of stem cell and gene therapies as reported by *Science News* since 1924.

Cross-curricular discussion:

Biological Sciences questions discuss stem cells, gene therapy and their applications. Prompts encourage students to examine their own opinions and beliefs about gene therapy.

Chemical Sciences questions address extracellular matrix proteins including laminins, collagens and others.

Engineering and Experimental Design questions deal with other potential applications of genetic barcoding of cells and skin modification, as well as the various ways in which researchers may use laminin proteins.

Activity: How sensitive?

Purpose: To design and execute an experiment to determine the relative sensitivity of touch receptors in different areas of human skin using the two-point threshold test.

Procedural overview: The two-point threshold test can be used to demonstrate the sensitivity of touch based on the number of touch receptors for different areas of human skin. Students can work in groups to report what they feel is happening when their skin is being touched at one or two points. Only one point may be perceived when the two touch points are in an area of skin with a low number of mechanoreceptor receptors. The minimum distance where two points can be correctly distinguished should be measured for different parts of the body, revealing the sensitivity of touch receptors in these different regions.

Approximate class time: 30-50 minutes.

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Standards

Next Generation Science	Common Core ELA
Motion and Stability: Forces and Interactions: HS-PS2-6	Reading Informational Text (RI): 1, 2, 4, 5, 7
From Molecules to Organisms: Structures and Processes: HS-LS1-1, HS-LS1-2, HS-LS1-4	Writing (W): 1, 2, 3, 4, 6, 7, 8, 9
Heredity: Inheritance and Variation of Traits: HS-LS3-1, HS-LS3-2	Speaking and Listening (SL): 1, 2, 4, 5, 6
Engineering Design: HS-ETS1-1, HS-ETS1-2, HS-ETS1-3	Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 7, 8, 9
	Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 7, 8, 9

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Article-Based Observation: Q&A

Based on the article "Gene therapy fixes rare skin disease":

1. Summarize the article by making brief statements defining "who, what, where, when and why."

Possible student response:

Who: A 7-year-old boy with junctional epidermolysis bullosa and scientists, including Tobias Hirsch and Michele De Luca.

What: Scientists work together and use stem cells and gene therapy to replace 80 percent of the boy's skin.

Where: Hirsch's lab is in Germany and De Luca's is in Italy. The article doesn't specify where the boy lives or had surgery.

When: Researchers fixed the boy's skin cells and grew grafts using the cells in September 2015. Skin graft surgeries on the boy occurred in October and November of 2015 and February 2016.

Why: The skin condition is caused by mutations in at least one of three genes needed to express a protein that helps attach the top layer of skin, called the epidermis, to deeper layers.

2. What causes the genetic skin disease this boy has? Be specific.

Possible student response: Patients with this disease have mutations in one of three genes (*LAMA3*, *LAMB3* or *LAMC2*) that produce parts of the protein laminin 332. Laminin 332 helps to attach the epidermis to deeper layers.

3. Why are children with this disease sometimes referred to as "butterfly" children? What is the frequency and prognosis for patients with this disease in the United States?

Possible student response: Children with this disease are sometimes called "butterfly" children because their skin is as fragile as a butterfly's wings. The top layer of skin can be easily rubbed off because it is not well attached to deeper layers. Even modest friction or bumping can cause severe blistering, both for external skin (resulting in visible blisters) and for mucus membranes inside the body (making breathing, swallowing and digesting food difficult). About 1 in every 20,000 babies in the United States is born with this disease, and more than 40 percent of those die before adolescence.

4. What treatment did this boy receive prior to the stem cell and gene therapies, and did the treatment work?

Possible student response: He received a skin graft from his father, but his body rejected the transplanted tissue.

5. How was new skin for the boy prepared in a lab?

Possible student response: Researchers took a 4-square-centimeter sample of unblistered skin from the boy's groin region and grew skin stem cells from that sample. A retrovirus was used to insert a healthy copy of *LAMB3* (the gene that is defective in the boy) into the cells, and sheets of the corrected skin cells were grown.

6. How well developed was the gene therapy technique before it was tried on this boy? What was the outcome for the boy?

Possible student response: Researchers had previously grown and replaced only 0.06 square meters of skin, but this patient needed approximately 0.85 square meters, about 14 times as much skin. About 80 percent of his skin seems fully functional, and he still has blistering in some untreated areas. Those affected regions of skin might be replaced with grafts in future surgeries, or cells without the mutation from treated areas on the boy's body may spread on their own into untreated areas. The boy is back in school and playing soccer.

7. What are two competing theories for how skin cells are naturally replenished?

Possible student response: (1) The skin is populated by a large number of stem cells, each of which can either copy itself or turn into various types of mature skin cells. (2) Only a small number of long-lived stem cells, called holoclones, produce short-lived progenitor cells that then become mature skin cells.

8. How were the boy's repaired cells monitored?

Possible student response: When the retrovirus added the healthy *LAMB3* gene to the lab-cultured cells, it landed in different regions of the DNA sequence in different cells. DNA samples from the boy's current skin cells can be compared with those from the lab-grown cells to identify which of the boy's skin cells came from which lab cells.

9. What do the results from tests of the boy's skin indicate about the two competing theories for how skin cells are naturally replenished?

Possible student response: At first, 91 percent of the boy's new skin cells were genetically different from holoclone cells, but after four months, only 37 percent of his new skin cells were genetically different from holoclone cells. This indicates that most of his cells were descended from the small number of genetically corrected holoclone cells, and that second theory mentioned in the answer above appears to be a better explanation.

10. What other questions do you still have after reading the article?

Possible student response: What are the similarities and differences between progenitor stem cells and holoclone cells? What other treatments have been given to children with this disease?

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Article-Based Observation: Q

Directions: Read the article "Gene therapy fixes rare skin disease" and then answer these questions:

1. Summarize the article by making brief statements defining "who, what, where, when and why."

2. What causes the genetic skin disease this boy has? Be specific.

3. Why are children with this disease sometimes referred to as "butterfly" children? What is the frequency and prognosis for patients with this disease in the United States?

4. What treatment did this boy receive prior to the stem cell and gene therapies, and did the treatment work?

5. How was new skin for the boy prepared in a lab?

6. How well developed was the gene therapy technique before it was tried on this boy? What was the outcome for the boy?

7. What are two competing theories for how skin cells are naturally replenished?

8. How were the boy's repaired cells monitored?

9. What do the results from tests of the boy's skin indicate about the two competing theories for how skin cells are naturally replenished?

10. What other questions do you still have after reading the article?

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Quest Through the Archives: Q&A

1. Can you find an article explaining more about stem cells? How does the article compare and contrast different types of stem cells?

Possible student response: The *Science News for Students* article "Explainer: What is a stem cell?" published 6/27/2013, describes the basic properties of stem cells. According to the article, naturally occurring stem cells may be divided into two categories: pluripotent stem cells that can give rise to any cell type in the body, and adult stem cells that can give rise to any cell type within a certain category of cells. The article also lists an artificially created, third stem-cell type called induced pluripotent stem cells (iPS cells). Researchers have developed methods to convert any cell type — even ones that aren't stem cells — into iPS cells. Researchers are attempting to find ways to use iPS cells to produce any desired cell type to aid patients.

2. Can you find an article that discusses the potential medical applications of induced pluripotent stem (iPS) cells? How do *in vitro* applications (outside the patient, in the lab) and *in vivo* applications (in a patient) compare?

Possible student response: The *Science News for Students* article "Stem cells: The secret to change," published 4/10/2013, gives several examples of medical applications of iPS cells. One early application is producing a variety of cell types for in vitro screening of new drugs to measure how effective they might be in a person. An example of an in vivo application is the possibility of treating patients with Pearson syndrome who cannot make their own red blood cells; other cells from the patient might be turned into iPS cells and then into red blood cells. Other examples of in vivo applications that have already been tested in nonhuman animals include using iPS cells to replace cells in a damaged retina to treat blindness and using iPS cells to replace neurons in a damaged spinal cord to treat paralysis. In general, in vitro applications require less safety testing and can be implemented sooner, but in vivo applications might have a more dramatic payoff for human health.

3. Can you find an article about using gene therapy to restore hearing? How does gene therapy compare with stem cell therapy?

Possible student response: The article "Gene therapy restores hearing in mice," published 7/8/2015, discusses how scientists successfully demonstrated a viral gene therapy vector in mice. The mice had a genetic mutation that caused their sound-sensing cells to die off, and the viral gene therapy vector contained a healthy copy of that gene. Injecting mice with the viral gene therapy vector caused the mice to have more sound-sensing cells and to be more responsive to noises than similar untreated mice. In general, gene therapy methods would add to or otherwise alter the genes in a patient's existing cells. If this type of gene therapy were to one day be used in people, researchers and doctors would have to be very careful that the patient's immune system does not attack the virus or the virus-infected cells, or that the virus does not create undesirable effects. Stem cell therapies, which also add cells to the patient, are most effective if those cells were originally derived from the patient, so that the patient's immune system will not attack them. These two methods are not mutually exclusive, so they can be combined, as they were in "Gene therapy fixes rare skin disease."

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Quest Through the Archives: Q

Directions: After reading the article "Gene therapy fixes rare skin disease," log in to your *Science News* in High Schools account and use the Search page to answer these questions. Make sure you adjust the filters to include articles written before 1999, if the question requires you to do so.

1. Can you find an article explaining more about stem cells? How does the article compare and contrast different types of stem cells?

2. Can you find an article that discusses the potential medical applications of induced pluripotent stem (iPS) cells? How do *in vitro* applications (outside the patient, in the lab) and *in vivo* applications (in a patient) compare?

3. Can you find an article about using gene therapy to restore hearing? How does gene therapy compare with stem cell therapy?

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Cross-Curricular Discussion: Q&A

Directions: After students have had a chance to review the article "Gene therapy fixes rare skin disease," lead a classroom discussion based on the questions that follow.

BIOLOGICAL SCIENCES

Discussion questions:

1. What are stem cells?

Stem cells can develop into many different cell types in the body. The new cells produced after stem cell division can either remain stem cells or can become another type of specialized cell. Stem cells can replenish other cells, serving as a sort of internal repair system. Pluripotent (sometimes called totipotent) stem cells, such as those found in early embryos, can give rise to any type of cell in the body, depending on the hormones, cell-cell signals and other stimuli that the stem cells are exposed to. Multipotent stem cells (sometimes called adult stem cells) can give rise to any type of cell within a limited range. For example, a hematopoietic stem cell could give rise to any of several different types of white blood cells, but not heart cells or liver cells.

2. How might stem cells be used for therapy?

Stem cells could be given the right stimuli to differentiate into specific cell types and regenerate damaged organs, limbs or other tissues. For example, if a person no longer has enough stem cells, induced pluripotent stem cells could be made from other adult cells, which could then help to replace damaged tissue. Cells from another person (or embryo) could theoretically be manipulated and used, but to avoid being attacked by the patient's immune system, they would need to come from a genetically similar or identical donor, or need to be genetically modified to look more similar to the patient's own cells.

3. What methods can be used to change the DNA in a cell for gene therapy?

A virus can be used to carry and insert new genes in DNA. Alternatively, if non-viral DNA is packaged properly, such as in a liposome bubble or on a nanoparticle, it can sometimes get incorporated into a cell's DNA. CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) and other techniques can be used to remove or edit existing genes within a cell.

4. How can gene therapy be used to repair genetic abnormalities in cells?

It is easier to do gene therapy under laboratory conditions in smaller numbers of cells instead of in a patient. Germline gene therapy is used on germ cells — embryos, sperm and eggs, or the cells that give rise to them; genetic modifications in these types of cells may help the resulting person and would be passed down to their children. Currently, germline gene therapy techniques are not used in people. Fertilized eggs that are modified using such techniques for research purposes are either not viable to begin with, or are not allowed

to develop into fetuses. Somatic cell gene therapy makes genetic changes to non-germline cells, and thus, would not be passed down to the patient's children. Somatic cell therapy is more successful when cells can be temporarily removed from a patient, treated with gene therapy in a lab, and then reintroduced in the patient. Somatic cell therapy was described in "Gene therapy fixes rare skin disease." Gene therapy of somatic cells while they remain inside a patient can be done, but it is harder to ensure that enough of the intended cells receive the therapy.

Extension prompts:

5. What are some potential risks of gene therapy?

A patient's immune system might attack a viral gene therapy vector or the patient's cells that have been infected by that viral vector. Non-therapeutic genes that remain in the viral vector and are necessary for its function might produce symptoms of infection or trigger unwanted cell division (cancer). New gene sequences that integrate in the wrong place might damage an important and previously healthy gene or trigger unwanted cell division (cancer). Gene therapy methods might accidentally target the wrong gene some of the time.

6. Students should assemble into groups based on which of the following statements best describes how the students feel. Once students gather into groups, allow students time to discuss their beliefs and do additional research. Have groups think about additional factors that could affect or change their position, like the cost and availability of gene therapy. Then have each group of students explain why they believe their statement and address counterarguments from other groups:

- *Gene therapy should not be used on humans.*
- *Gene therapy should be used on humans to cure potentially fatal illnesses ("butterfly" skin, cystic fibrosis), but not for any other reason.*
- *Gene therapy should be used on humans to cure potentially fatal illnesses, but also other, generally non-fatal health risks (tendency toward nearsightedness, obesity, baldness).*
- *Gene therapy should be used on humans to cure both fatal and non-fatal health risks, but also to alter intellect, physical appearance or any other characteristic students (or their parents) might desire.*
- *Gene therapy should be used on humans for any purpose, even giving people hearing ranges beyond what people can normally hear, the ability to see colors not normally visible to humans or tolerance to extreme temperatures.*

CHEMICAL SCIENCES

Discussion questions:

1. What are laminins? What is the extracellular matrix?

Laminins are large proteins that help to form the extracellular matrix, which is the scaffold between cells that cells can attach to so that a multicellular organism can keep its shape. Other important proteins in the extracellular matrix include collagens, elastins and fibronectins.

2. How do cells stick to the extracellular matrix?

Glycoproteins are proteins covered with sugars, and sugars can be very sticky. Glycoproteins, such as integrins protruding from the surfaces of cells, can stick to glycoproteins in the extracellular matrix (such as

laminins and fibronectins). In some cases, some hook-shaped proteins, such as cadherins on cell surfaces, directly grab hold of each other.

Extension prompts:

3. Mutations in laminin genes can cause the "butterfly" skin condition, but what are possible effects of mutations in collagen genes?

Collagen proteins are the most abundant component of the extracellular matrix and help to make it full and stiff. Mutations in genes that produce collagen proteins can make tissues hyperelastic. One example is Ehlers-Danlos syndrome, in which patients have very stretchy skin, plus potential joint or cardiovascular symptoms.

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion questions:

1. How could you use laminins for other applications?

Laminin proteins could be used to coat surfaces that cultured cells attach to when growing sheets of skin in the lab, make biological materials made of webs of proteins, pre-coat a medical implant so that tissues in the body would rapidly bind and potentially adapt to the implant or mass-produce extracellular matrix that could be surgically grafted onto wounds to help them heal more quickly.

Extension prompts:

2. "Gene therapy fixes rare skin disease" mentioned genetic-barcode-like analysis of cells. What other applications could there be for genetic barcoding methods?

Other genetic barcoding methods could include monitoring and responding to bacteria in the human body, different cancer cell lineages in a cancer patient, different lineages of a pathogen in an infected person (for mutation-prone pathogens such as HIV, tuberculosis or malaria), or keeping track of cloned animals in laboratory experiments or in agricultural use.

3. In addition to treating patients with the "butterfly" skin disease, what are some other possible applications of treating and growing skin?

Skin grafts could be used for burn patients and gene therapy could be used to treat skin cancer, susceptibility to and damage from sunburns and the effects of aging on skin, for instance. Gene therapy could also be used to alter the color or appearance of skin as well as make skin stronger and more resistant to damage.

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Cross-Curricular Discussion: Q

Directions: The following list of discussion questions is provided to help you take notes, brainstorm ideas and test your thinking in order to be more actively engaged in class discussions related to this article. All questions in this section are related to topics covered in "Gene therapy fixes rare skin disease."

BIOLOGICAL SCIENCES

Discussion questions:

1. What are stem cells?

2. How might stem cells be used for therapy?

3. What methods can be used to change the DNA in a cell for gene therapy?

4. How can gene therapy be used to repair genetic abnormalities in cells?

Extension prompts:

5. What are some potential risks of gene therapy?

6. Students should assemble into groups based on which of the following statements best describes how the students feel. Once students gather into groups, allow students time to discuss their beliefs and do additional research. Have groups think about additional factors that could affect or change their position, like the cost and availability of gene therapy. Then have each group of students explain why they believe their statement and address counterarguments from other groups:

- *Gene therapy should not be used on humans.*
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- *Gene therapy should be used on humans to cure both fatal and non-fatal health risks, but also to alter intellect, physical appearance or any other characteristic students (or their parents) might desire.*
- *Gene therapy should be used on humans for any purpose including giving people, if possible, hearing ranges beyond what people can normally hear, the ability to see colors not normally visible to humans or tolerance to extreme temperatures.*

CHEMICAL SCIENCES

Discussion questions:

1. What are laminins? What is the extracellular matrix?

2. How do cells stick to the extracellular matrix?

Extension prompts:

3. Mutations in laminin genes can cause the "butterfly" skin condition, but what are possible effects of mutations in collagen genes?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion questions:

1. How could you use laminins for other applications?

Extension prompts:

2. "Gene therapy fixes rare skin disease" mentioned genetic-barcode-like analysis of cells. What other applications could there be for genetic barcoding methods?

3. In addition to treating patients with the "butterfly" skin disease, what are some other possible applications of treating and growing skin?

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Activity Guide for Teachers: How Sensitive?

Purpose: To design and execute an experiment to determine the relative sensitivity of touch receptors in different areas of human skin using the two-point threshold test.

Background information: Skin is the human body's largest organ. It acts as a container to keep vital chemicals and nutrients in the body and as a barrier for keeping dangerous substances, including ultraviolet radiation from the sun, out of the body. Skin's common functions include maintaining a water and electrolyte balance, participating in vitamin D synthesis and sensing painful and pleasant stimuli.

Four different types of mechanoreceptors are encapsulated in the skin and provide information to the central nervous system about touch, pressure, vibration and skin tension. Meissner corpuscles, Pacinian corpuscles, Merkel disks and Ruffini corpuscles are considered high-sensitivity mechanoreceptors — even a weak mechanical stimulus can elicit nerve impulses in sensory neurons and deliver information to the brain or spinal cord.

The number and type of mechanoreceptors vary over the body. A mechanoreceptor's receptive field is the patch of skin that a neutron responds to and is dependent on the type of mechanoreceptor. The level of skin sensitivity depends on how many mechanoreceptors there are in a particular area of skin. The most sensitive areas of skin will have a large number of mechanoreceptors. A small area of skin on the palm of your hand, the top of your hand and your fingertips all have different numbers and types of mechanoreceptors, therefore, they have different tactile sensitivities.

Procedural overview: The two-point threshold test can be used to demonstrate the sensitivity of touch based on the number of touch receptors for different areas of human skin. Students can work in groups to report what they feel is happening when their skin is being touched at one or two points. Only one point may be perceived when the two touch points are in an area of skin with a low number of mechanoreceptors. The minimum distance where two points can be correctly distinguished should be measured for different parts of the body, revealing the sensitivity of touch receptors in these different regions.

Approximate class time: 30-50 minutes.

Materials:

- Activity guide for students: How sensitive?
- Dull toothpicks to perform two-touch threshold test. (Points should not be able to puncture the skin. Very narrow plastic coffee stirrer straws could also be used.)
- Rulers with millimeter marks
- Blindfolds

Notes to the teacher:
Students should work in groups. Three per group is a good number — one student as the test subject, one student to hold sticks to two adjacent locations of the test subject's skin and one student to measure the

distance between the two locations and record the results. Within each group, the students should rotate roles after the tests are complete for one subject so that each student gets the chance to do each part.

Blindfolds do not work perfectly, but students should promise not to try to peek when they are the test subject.

If you have microscopes and enough time, you could also have your students examine some related prepared slides such as these:

- Human skin with hair follicles, available from Home Science Tools
- Human skin with sweat gland, available from Home Science Tools
- Frog skin, available in this set from Home Science Tools
- Butterfly wing, available from Carolina Biological Supply Company

Possible questions for students:

1. Using the general instructions below, try the two-point threshold test and determine a more detailed, repeatable technique to administer the test on different areas of skin:

- Use two toothpicks to touch the palm of the hand of a blindfolded student at two different locations with the toothpicks.
- Measure the distance between those two locations.
- Record whether the blindfolded student reports that each poke feels like two different sticks or one.
- To make sure the blindfolded student isn't anticipating any number of points touching his or her skin, the experimenter should use a technique that tests one, two or three toothpicks at each distance between the toothpicks.
- Generally start two sticks at a certain distance apart from each other, and then try them at closer and closer distances.
- Measure and record the minimum distance between sticks for which the blindfolded student can distinguish two different sticks on the palm of the hand.

  Typical results are in the neighborhood of a millimeter or two.

2. Record the data from the first test subject's palm. Based on this data, each student should create a data table for four additional skin-testing locations. Other testing locations could be: on the back of the hand, on a fingertip, on the arm (try to avoid hairs — movement of hairs can also be sensed), on the back (through the shirt) or on the ankle, cheek or neck.

3. Write a numbered procedure for the two-point threshold test your group will use.

4. Perform the two-point threshold test on four additional areas for the first test subject. Measure and record the minimum distance between sticks for which the blindfolded student can distinguish two different sticks on the four additional areas. Each student should take a turn getting tested for all skin locations (if you are in a group of three, you should have data from 15 two-point threshold tests, five from each student).

Every group's data table will vary, but typical two-point threshold test answers are the following:
Back of the hand: in the neighborhood of a few millimeters.
Fingertip: in the neighborhood of a millimeter or so.
Arm: in the neighborhood of a centimeter or more, depending on which part of the arm.
Back: in the neighborhood of a couple centimeters or so.

Ankle: in the neighborhood of a couple centimeters or so.
Cheek: in the neighborhood of a millimeter or so.
Neck: in the neighborhood of a centimeter or two, depending on which part of the neck.

5. Which areas were best able to distinguish between one or two toothpick pokes?

Fingertips are probably most sensitive. Palm and cheek are also very sensitive.

6. Which areas were least able to distinguish between one or two toothpick pokes?

Back, arms, ankles, etc. are less sensitive.

7. How similar or different were the answers for different members of your group for the same region of the body?

Results should be fairly similar. If there is a real outlier, someone may have been intentionally skewing the data.

8. Why would it make sense for some areas to be more sensitive than others?

Areas that are more sensitive are most likely to explore objects (such as your fingertips) or most likely to warn you about something important (such as your face warning you of a crawling bug) — you really need to know exactly what is where. Other areas such as your back or arm are less sensitive — you just need to know that you have been touched somewhere there, and then you can use your other senses to investigate exactly where and by what.

9. Name any variable that may have confounded your results. If you were to redo the two-point threshold test again, what modifications would you make? How might the changes affect your results?

Student answers will vary.

10. Research the four types of mechanoreceptors. How are they similar and how are they different? Which mechanoreceptors are common in the areas of skin you tested? Does the research information agree with your results? Why or why not?

Student answers will vary.

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Procedural overview: The two-point threshold test can be used to demonstrate the sensitivity of touch based on the number of touch receptors for different areas of human skin. You can work in groups to report what you feel is happening when your skin is being touched at one or two points. Only one point may be perceived when the two touch points are in an area of skin with a low number of mechanoreceptors. The minimum distance where two points can be correctly distinguished should be measured for different parts of the body, revealing the sensitivity of touch receptors in these different regions.

Get started:

1. Using the general instructions below, try the two-point threshold test and determine a more detailed, repeatable technique to administer the test on different areas of skin:

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- Measure the distance between those two locations.
- Record whether the blindfolded student reports that each poke feels like two different sticks or one.

- To make sure the blindfolded student isn't anticipating any number of points touching his or her skin, the experimenter should use a technique that tests one, two or three toothpicks at each distance between the toothpicks.
- Generally start two sticks at a certain distance apart from each other, and then try them at closer and closer distances.
- Measure and record the minimum distance between sticks for which the blindfolded student can distinguish two different sticks on the palm of the hand.

2. Record the data from the first test subject's palm. Based on this data, each student should create a data table for four additional skin-testing locations. Other testing locations could be: on the back of the hand, on a fingertip, on the arm (try to avoid hairs — movement of hairs can also be sensed), on the back (through the shirt) or on the ankle, cheek or neck.

3. Write a numbered procedure for the two-point threshold test your group will use.

4. Perform the two-point threshold test on four additional areas for the first test subject. Measure and record the minimum distance between sticks for which the blindfolded student can distinguish two different sticks on the four additional areas. Each student should take a turn getting tested for all skin locations (if you are in a group of three, you should have data from 15 two-point threshold tests, five from each student).

5. Which areas were best able to distinguish between one or two toothpick pokes?

6. Which areas were least able to distinguish between one or two toothpick pokes?

7. How similar or different were the answers for different members of your group for the same region of the body?

8. Why would it make sense for some areas to be more sensitive than others?

9. Name any variable that may have confounded your results. If you were to redo the two-point threshold test again, what modifications would you make? How might the changes affect your results?

10. Research the four types of mechanoreceptors. How are they similar and how are they different? Which mechanoreceptors are common in the areas of skin you tested? Does the research information agree with your results? Why or why not?

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