TOO MUCH OF A GOOD THING (1 Hour)

Addresses NGSS
Level of Difficulty: 4
Grade Range: 3-5

OVERVIEW

In this activity, students will explore the potential dangers of overusing certain antibacterial products such as soaps, shampoos and other wash products.

Topic: Microbiology, Natural Selection and Adaptations

Real-World Science Topics

- An exploration of biological and evolutionary processes that lead to resistant bacteria known as "superbugs"
- An exploration of how genetic changes can create beneficial characteristics (known as adaptations) which allow organisms to better survive in changing conditions

Objective

After completing this activity, students should be able to explain how certain chemicals found in antibacterial agents can lead to strains of resistant "super" bacteria and why this is dangerous.

NGSS Three-Dimensions

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. **Analyzing and Interpreting Data** • Represent data in tables and/or various graphical displays (bar graphs, pitographs, and/or pie charts) to reveal patterns that indicate relationships. • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.	**3-LS3.B: Variation of Traits** • Different organisms vary in how they look and function because they have different inherited information. • The environment also affects the traits that an organism develops. **3-LS4.B: Natural Selection** • Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. **3-LS4.C: Adaptation** • For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.	**Patterns** • Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. **Cause and Effect** • Cause and effect relationships are routinely identified, tested, and used to explain change. **Stability and Change** • Change is measured in terms of differences over time and may occur at different rates.

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Siemens SCIENCE Day
LEARNING BY DOING

Planning and Carrying Out Investigations

- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Analyzing and Interpreting Data

- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Analyze and interpret data to provide evidence for phenomena.

Constructing Explanations and Designing Solutions

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.

MS-LS4.B: Natural Selection

- Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

MS-LS4.C: Adaptation

- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Patterns

- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
- Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

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Background Information

Is bacteria good or bad?

Bacteria can be both good and bad. Some bacteria cause diseases but many are completely harmless and in some cases very beneficial. For example, in humans some strains of bacteria help us with digestion while others help in the production of vitamins.

Can bacteria easily mutate and change to better survive the changing condition of their environment?

Because bacteria reproduce rather quickly and have a relatively small genome (set of DNA), they tend to mutate rather easily. Because of this, colonies of bacteria can quickly develop adaptations. These adaptations allow the bacteria to survive better in the changing conditions of their environments.

Is the statement, "what doesn't kill you makes you stronger" true for bacteria?

In a sense, this statement is true. As bacteria are exposed to a different environment or chemical for extended periods of time, the weaker and less resistant bacteria tend to die off. However, the stronger bacteria tend to mutate and adapt to the new environment or chemical exposure. These mutant bacteria are said to be resistant. Over many generations, these resistant bacteria multiply. If these bacteria are disease-causing, they can become a huge heath risk because they are harder to treat and/or kill. These type of bacteria are often referred to as "superbugs."

Are all antibacterial products created equal?

No. Only some antibacterial products contain the chemical triclosan or it close relative triclocarban. These two chemicals have proven to cause resistant bacteria in laboratory test. Unlike the chemical triclosan which lingers on the skin and gradually kills bacteria over an extended period of time, alcohol-based hand sanitizers work quickly at killing bacteria and then evaporate. Bacteria tend to mutate more efficiently if exposed to a chemical or adverse condition over a prolonged period of time. This is not the case with alcohol-based sanitizer; they do their job and then dissipate.

How can chemicals such as triclosan found in antibacterial products lead to resistance in bacteria?

Because chemicals such as triclosan leave a residue on the skin after application, bacteria are exposed to low levels of the chemical over a long period of time. This sets up an ideal situation for bacteria to mutate and adapt. The weaker bacteria die off leaving the genetically supierior bacteria. These stronger bacteria can mutate and become genetically resistant to chemical exposure.

Do all scientists agree that triclosan can be a potential danger?

No. Some scientists argue that these laboratory findings cannot be recreated in real-world situation and should therefore not be considered dangerous.

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Materials Needed for Student Activity

Materials Needed for Demonstration:

- Antibacterial hand soap containing triclosan (see label on soap)

Materials Needed to Prepare for the Student Activity:

- Pure grape or cranberry juice (unsweetened in case of spills)
- Baking Soda
- Cookie sheets (with sides)
- Bacteria cutout templates (included in activity)
- Scissors or paper cutter
- Permanent marker

Materials Needed for Each Team of 2-3 Students:

- 4 labeled snack-size zip bags filled with paper bacteria (see "Teacher Preparation" section for details)
- Cotton swabs
- Small plastic cups

Teacher Preparation

Before students arrive you will need to prepare the following materials.

Preparing the paper bacteria cutouts:

- **A note before beginning.** Keep in mind the end goal it so make 5 piles of cut pieces using the templates included in this activity. Make sure to keep 5 distinct piles (beneficial in water, beneficial in baking soda, disease-causing in water, disease-causing in baking soda, and disease-causing with mutation) because there is no way to tell the difference between the cutouts soaked in baking soda verses water pieces once you have cut them out.
- Prepare a baking soda solution by mixing about 3 to 4 tablespoons of baking soda with about 1 liter of warm water and mixing well.
- Pour the baking soda solution into a cookie sheet (or other flat container that can hold fluid). Enough to cover a few sheets of stacked paper.
- Pour about the same amount of filtered (or distilled) water into a second cookie sheet/container.
- Next you will need to print the bacteria cutouts using the templates provided. Note that there are 100 cutouts per pages. Calculate how many bacteria cutouts you will need to print using the following formulas:

Number of teams X 33 = "beneficial bacteria cutouts" to be soaked in water (see example for help)

Number of teams X 30 = "beneficial bacteria cutouts" to be soaked in baking soda

Number of teams X 14 = "disease-causing bacteria" cutouts to be soaked in water

Number of teams X 15 = "disease-causing bacteria" cutouts to be soaked in baking soda

Number of teams X 11 = "disease-causing bacteria with mutation" cutouts to be soaked in baking soda (none are soaked in water)

(For example: If there were 5 teams in my class, I would need 165 beneficial bacteria cutouts (5 x 33 = 165). This means I would need to print 2 pages of them and soak 1 full pages plus 65 from the 2nd page.)

- Print the correct number of templates for each type of bacteria.
- Place the templates in the appropriate cookie sheet and soak for 30 seconds or so.
- Allow sheets to air dry for several hours. For quicker drying, place sheets in microwave on high heat until dry.
- Cut out the bacteria pieces. Use a paper cutter to significantly speed up this process. **Remember to keep the cut pieces in 5 distinguishable piles.**
- Prepare 4 zip bags (per team) with bacteria cut outs as follows:
- Using a permanent marker, label the bags:
  "Initial bacteria collection at 7:00 AM"
  "Bacterial collection 12:00 PM"
  "Bacterial collection 5:00 PM"
  "Bacterial collection 10:00 PM"
- Fill the bags according to the chart below.

Bag	Beneficial in water	Beneficial in baking soda	Disease-causing in water	Disease-causing in baking soda	Disease-causing with mutation
7:00 AM	11	9	2	4	0
12:00 PM	9	8	3	2	1
5:00 PM	7	8	4	4	3
10:00 PM	6	5	5	5	7

- Prepare cups of cranberry or grape juice:
  Label each cup *"Antibacterial Soap with Triclosan"* (1 cup per team)
  Fill each cup about 1/3 of the way full with undiluted juice.
  Place a cotton swab in each cup

STEPS FOR *TOO MUCH OF A GOOD THING*

1. **Warm-up Activity:** Ask students to write a sentence in their science journals or a blank sheet of paper using one of the following three sentence stems.
   Bacteria are good because....
   Bacteria are bad because...
   Bacteria are good and bad because...

   Write the three sentence stems on the board so students can reference those as they write their sentence. Handout the student page for this activity as they write.

2. After students have had some time to complete their sentence, ask for a few volunteers to share. Use this discussion time to inform students about the diversity of bacteria and the fact that bacteria can be good as well as bad. Students need to understand that some bacteria can cause diseases such as Tuberculosis, food poisoning, pneumonia, and strep throat. It is equally important that students understand that most bacteria are not harmful at all, and in fact, are extremely beneficial to humans. Some beneficial bacteria help us digest our food, produce needed vitamins, and these good bacteria crowd out bad bacteria.

3. Students should be encouraged to fill in the Fact vs. Myth Box on their handout as discussions take place throughout the activity.

4. Show students a bottle of pre-purchased antibacterial soap (containing triclosan) and explain that it is a special kind of soap with a chemical. This chemical stays on your skin even after you have washed and dried your hands and slowly kills some kinds of bacteria.

5. Pose the question, "are antibacterial soaps such as this [show the soap] a good thing or a bad thing?" Allow students to argue and discuss this question before moving on to the next portion of the activity. At this point, do not give students an explanation to the question. Allow them to explore the answer as they complete the activity.

6. Read the following paragraphs to the students.
   "Today you will take on the role of a research scientist. The question posed to you is, "what effects do antibacterial soaps containing triclosan have on bacteria?" [Write this question on the board for students to reference.]

   You will be given samples of bacteria collected from a test subject over the period of a day. The subject is using antibacterial soap containing triclosan at various times during the day. It is your job as a scientist to study, record and analyze the data from the collections. You must answer the question posed to you as a scientist and make a recommendation to others about using or not using soaps such as this one [show the soap].

   Because only highly trained microbiologists can work with real disease-causing bacteria, we are going to use other materials to simulate what microbiologists have discovered in labs."

7. Divide students into teams of 3 or 4. Give each team a cup labeled "antibacterial soap with triclosan" and a baggie labeled "beginning bacteria collection". Make sure students know that the solution in the cup simulates antibacterial soap. Point out that there are different kinds of bacteria in the bag and that they are labeled for distinction.

8. Ask students to open the bag, count the bacteria and record the data on their student handout.

D) Have students spread the bacteria (pieces of paper) out on the table. Using a cotton swab, rub a bit of the antibacterial agent (grape juice solution) from the cup on each one of the bacteria. If the bacteria turns a green color, the chemical kills it. Students should record their data in the column labeled "Use of soap with triclosan 7:10AM."

<;) Ask students to discard the material from the first test. Give them a second bag labeled "bacteria collection 12:00PM." Repeat the steps outlined above until all of the bacteria samples are tested.

<<) Ask students to graph their data on their student handout using a line graph.

_sp teacher should graph the data on the board as students complete the graph on their student sheet.

<=) Give students time to graph and analyze their data. Based on the data analysis, students should work together to develop a recommendation about using antibacterial soaps on a frequent basis. They must be able to justify their recommendation using data.

<>) Have a couple of groups give their recommendations and justifications to class.

<?) **Wrap-up:** Discuss the following points with students.

- Bacteria are extremely small and cannot be counted or collected as simply as they did in this simulation. Microbiologist must use very specialized methods to count and collect these bacteria.
- Some laboratory experiments using antibacterial agents that contain triclosan have shown results similar to the results they saw in their simulation. This has led some scientist to warn consumers that over using antibacterial agents with chemicals such as triclosan can lead to disease causing super-bacteria that are resistant to chemicals such as antibacterial agents and antibiotics.
- There is ongoing research on this topic and some scientists argue that such findings in the laboratory do not necessarily mean that it happens in real-world settings.
- Antibiotics have proven to have similar affects on bacteria as well.
- There is concern among doctors and scientists that resistant super-bacteria could cause a deadly outbreak sometime in the future.
- For more information on this topic, see the 2007 *Scientific American* article "Strange But True: Antibacterial Products May Do More Harm Than Good" by Coco Ballantyne.

Extension Activity

Challenge students to find and document products containing triclosan or triclocarban in their home. Give students a chance to share how many and what products they found. You should encourage them to look at cleaning products, soaps, shampoos, lotions, hand sanitizers, toothpastes, laundry detergents, or anything else labeled "antibacterial."

Sources

http://www.tufts.edu/med/apua/about_issue/agents.shtml
http://www.fda.gov/forconsumers/consumerupdates/ucm205999.htm
http://www.beyondpesticides.org/antibacterial/triclosan.php

Ballantyne, Coco. "Strange but True: Antibacterial Products May Do More Harm Than Good." Scientific American, 07 June 2007. Web. 20 Apr. 2013.

TOO MUCH OF A GOOD THING
STUDENT HANDOUT

Name:

Date:

Bacteria: Truth vs. Myth Box

As you learn facts and/or myths about bacteria, record them in the box below.

Facts	Myths

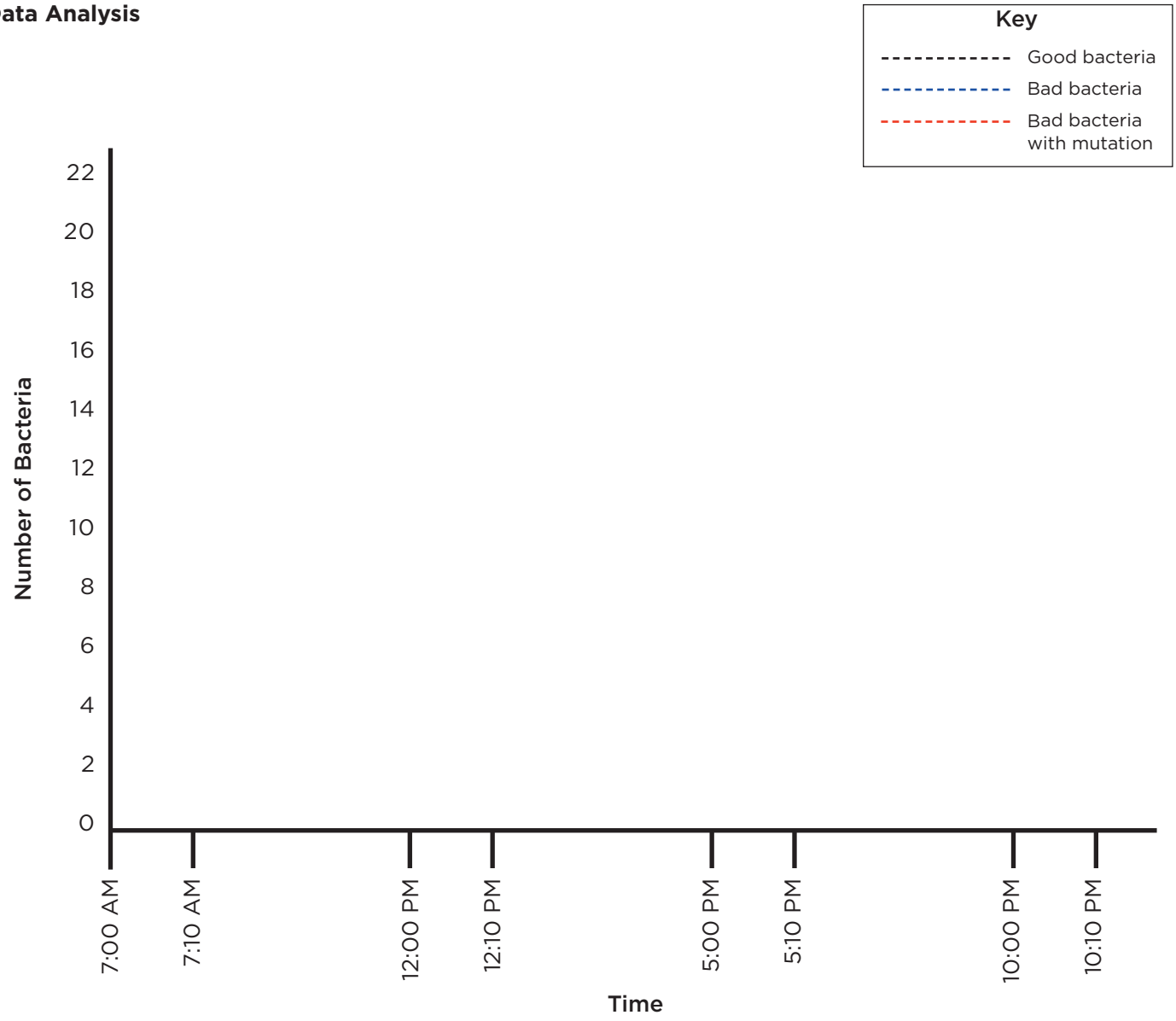
What is the name of the antibacterial chemical agent found in some soaps that you will be studying today?

_____

Data

	Initial bacteria collection	Use of soap with triclosan	Bacteria collection	Use of soap with triclosan	Bacteria collection	Use of soap with triclosan	Bacteria collection	Use of soap with triclosan
Time of Action	7:00 AM	7:15 AM	12:00 PM	12:10 PM	5:00 PM	5:10 PM	10:00 PM	10:10 PM
Beneficial Bacteria								
Disease-causing Bacteria								
Mutant Disease-causing Bacteria								

Data Analysis



Recommendation: Based on your data analysis, write a recommendation to your friends about using antibacterial products such as soaps, shampoos, and other wash products that contain chemicals such as triclosan. You must include the following terms: resistant bacteria, mutation, antibacterial, and triclosan.

Bacteria: Truth vs. Myth Box

As you learn facts and/or myths about bacteria, record them in the box below.

Facts	Myths
Examples: • Bacteria can be good and bad • Some bacteria help in digestion • Some bacteria help produce important vitamins • Antibacterial agents with chemicals, such as triclosan, slowly kill bacteria • Bacteria's genetic material tends to change and mutate to help it survive changing conditions • Laboratory studies show that long-term exposure to chemicals, similar to triclosan, can cause resistant strains of bacteria to form	Examples: • All bacteria are harmful and cause disease • All antibacterial agents contain chemicals such as triclosan. • All bacteria mutate and are able to survive harsh environments. • All scientists agree that triclosan can cause resistant bacteria that are harder to killed with antibiotics and antibacterial agents.

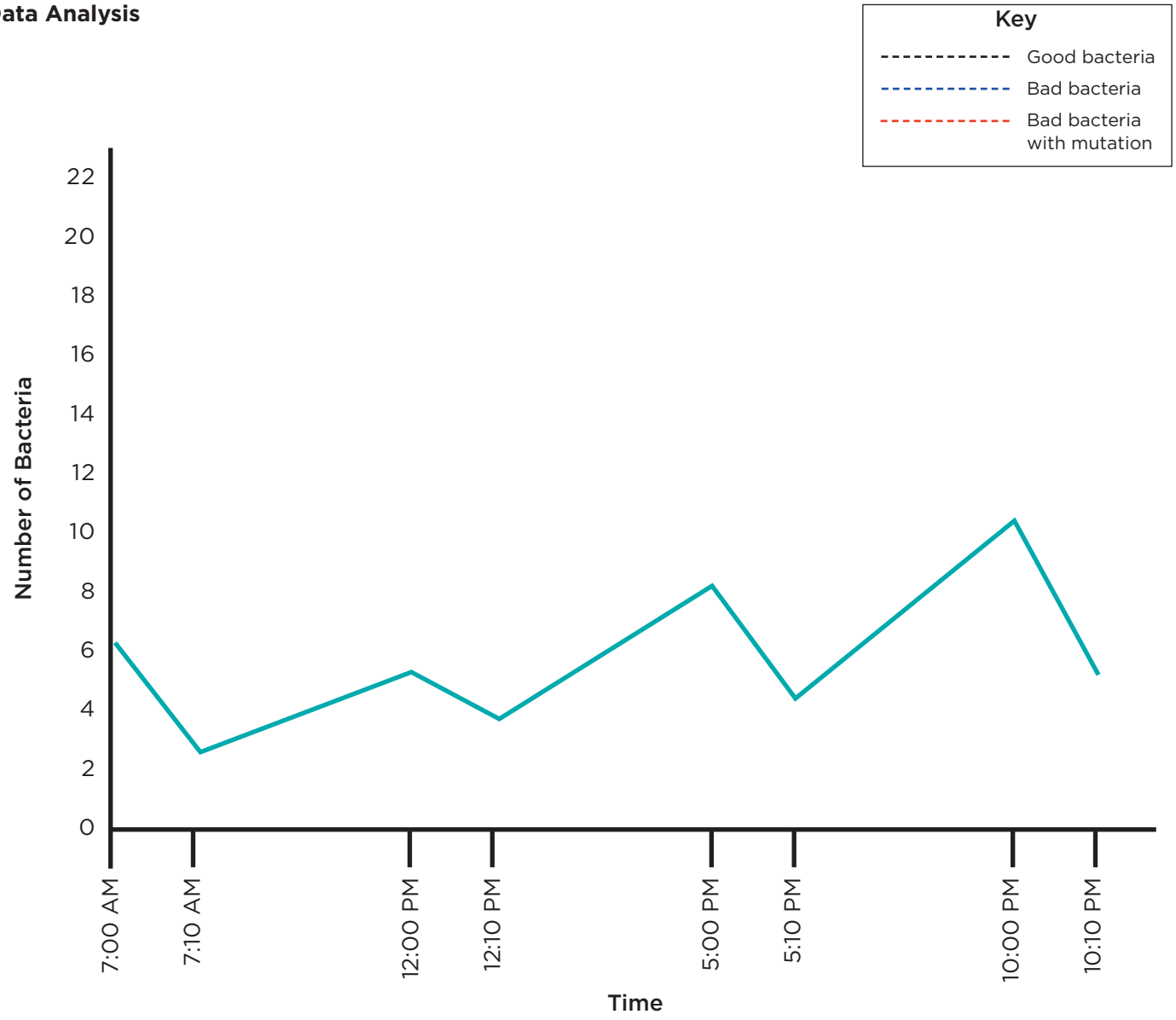
What is the name of the antibacterial chemical agent found in some soaps that you will be studying today?

Triclosan

Data

	Initial bacteria collection	Use of soap with triclosan	Bacteria collection	Use of soap with triclosan	Bacteria collection	Use of soap with triclosan	Bacteria collection	Use of soap with triclosan
Time of Action	7:00 AM	7:15 AM	12:00 PM	12:10 PM	5:00 PM	5:10 PM	10:00 PM	10:10 PM
Beneficial Bacteria	20	11	17	9	15	7	11	6
Disease-causing Bacteria	6	2	5	3	8	4	10	5
Mutant Disease-causing Bacteria	0	0	1	1	3	3	7	7

Data Analysis



Recommendation: Based on your data analysis, write a recommendation to your friends about using antibacterial products such as soaps, shampoos, and other wash products that contain chemicals such as triclosan. You must include the following terms: resistant bacteria, mutation, antibacterial, and triclosan.

Answers will vary.

TOO MUCH OF A GOOD THING

BENEFICIAL BACTERIA TEMPLATE - 100 COUNT

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LEARNING BY DOING

Beneficial	Beneficial	Beneficial	Beneficial	Beneficial
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TOO MUCH OF A GOOD THING

DISEASE-CAUSING BACTERIA TEMPLATE - 100 COUNT

Siemens SCIENCE Day
LEARNING BY DOING

Disease-causing	Disease-causing	Disease-causing	Disease-causing	Disease-causing
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TOO MUCH OF A GOOD THING

DISEASE-CAUSING WITH MUTATION BACTERIA TEMPLATE - 100 COUNT

Siemens SCIENCE Day
LEARNING BY DOING

Disease-causing with Mutation	Disease-causing with Mutation	Disease-causing with Mutation	Disease-causing with Mutation	Disease-causing with Mutation
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