

## Introduction • Lesson 3

# Multiplying Microbes

**Class periods required:** One 30-min. class period

**Supplement section:** Introduction PA PAS For FCS: 9.3.3, 9.3.6 B, 9.3.9 B

**National Education Standards:** FCS 8.2.1, 8.2.3, 8.2.5, 9.2.1, 9.2.3, 9.2.5; LA 2, 035, 132, 278; MA 1, 2, 3, 130, 173; SC 5, 042.

## LESSON SUMMARY

Students will learn about the exponential growth of bacteria. They will then learn what conditions are required for bacterial growth, and how food is preserved.

## Objectives

**The students will:**

- Complete the Bacterial Growth Worksheet to identify that bacteria grow exponentially and the conditions needed for bacterial growth.
- Identify how bacterial growth is controlled in foods by correcting the situations in the Bacterial Growth Worksheet.
- Find a newspaper article that discusses food preservation methods or an article on how quickly bacteria spread.

## Materials Provided

**Overheads:**

1. Multiplication Time Line
2. Exponential Multiplication
3. Scientific Notation
4. Bacterial Growth Requirements
5. Water activity ( $A_w$ )
6. Preservatives
7. Bacterial Danger Zone

**Worksheets:**

1. Evaluation of Food at Home
2. Bacterial Growth worksheet

**Teacher Information Sheets:**

1. Bacterial Growth Worksheet Answers
2. Evaluation for NIE Activity
3. Water Activity Fact Sheet

*(See [www.csiro.au/](http://www.csiro.au/) and search for 'water activity'. Click on 'water activity in food.')*

## Suggested Presentation Aids

- A large jar full of 256 jellybeans

## LESSON PLAN

### Introduction

- (Overhead 1) Show the students the large jar of jellybeans, asking them to pretend that the jellybeans represent a bacterial colony made up of 256 single-celled bacteria. Ask them how many bacteria they think had to be present in the first place to end up with 256 in the colony (Answer: 1). Then ask them how long they think it takes to produce all 256 bacteria (Answer: 2 hours and 40 minutes). Explain that while it takes a person about 20 years to multiply, bacteria need only about 20 minutes when growth conditions are good.
- (Overhead 2) Explain that bacteria grow exponentially, which means that each individual cell divides into two cells, with the same genetic material as the parent cells. When the cell divides, it becomes two daughter cells, which then divide themselves. If each division takes 20 minutes, it's easy to see how 256 can grow in just 2 hours and 40 minutes.

### Lesson sequence

- **Scientific Notation** (Overhead 3) Explain to the students that due to the way they multiply, bacterial numbers increase very rapidly, quickly reaching very large numbers. Scientists need a short way of expressing these large numbers. Therefore, numbers of bacteria in foods are often expressed using scientific notation. For example, 256 bacteria in a food would be expressed as  $2.56 \times 10^2$  in scientific notation.
- **Bacterial Growth Requirements** (Overhead 4) What conditions do bacteria need to grow? Well, just like people, bacteria need warm temperatures. Most types of bacteria can't live above 140°F, which is about the temperature food gets when you cook it, or below 30°F, which is refrigeration temperature. It also takes time for bacteria to grow. Most types need about two to four hours to grow enough cells to make you sick. Bacteria also need nutrients. If we don't give the bacteria any food to feed on, they can't grow. Bacteria need lots of moisture as well. Just like people, they need a source of water to live. Ask the students to name places around the classroom they think bacteria would likely grow.
- **Control of Bacterial Growth** (Overheads 5-7): Tell the students that in order to keep our food fresh and safe, we need to do several things to keep bacteria and other microorganisms from growing:
  - Change the water activity of the food. Water activity describes the amount of moisture that is available in a food. Bacteria, and other microorganisms, need foods with high water activities in order to grow. Often foods like potato chips are dried and kept in a sealed bag to keep the water activity low. Foods like banana crême pie have a high water activity and must be refrigerated so bacteria can't grow.
  - Add preservatives to the food. Preservatives are chemicals that keep bacteria and other microorganisms from growing. They can also act to improve the appearance, moisture, and texture of the food. Sodium nitrate in cured meats acts to prevent microbial growth and spoilage. It also enhances color and flavor. Acetic acid in ketchup and pickles lowers the pH so bacteria can't grow. It also gives a tangy flavor to the food. Sodium propionate in bread and bakery products keeps the bread fresh by preventing bacteria from growing.
  - Control the temperature of the food. During processing, foods are heat treated (pasteurization, canning, boiling) to kill any microorganisms already present in the raw ingredients. The foods may then be stored at cold temperatures (refrigeration or freezing) to control any further growth.

## Closure

- Play a game with jelly beans as prizes. Ask the students to try to calculate different growth times and numbers. For example, if it takes bacteria 20 minutes to multiply once, how long would it take them to multiply 10 times? 15? 25? (Answer: 200 min, 300 min, and 500 min.) How many bacteria would you get if you started out with one and waited 20 minutes? 60 minutes? 100 minutes? (Answer: 2, 16, and 64.) If the students have trouble calculating this, you can use jellybeans to show them.

## Suggested Learning Activities

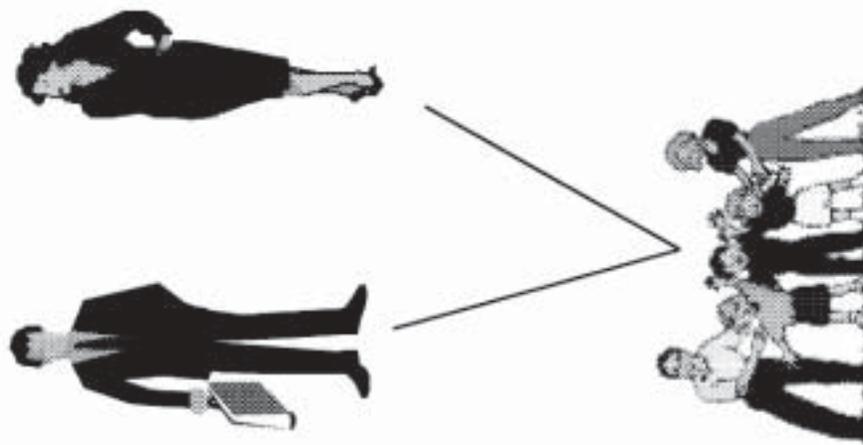
- Make a table about the food at your house (Worksheet 1). In the first column list the food name. Then make a column listing how you think the food was preserved (changing the water activity, temperature processing, addition of preservatives). In the third column indicate whether or not you think bacteria could still grow in that food.
- Find a newspaper article(s) that discusses food preservation methods (hints and tips for safety, new procedures, etc.), or an article on how quickly bacteria can spread, conditions needed for bacterial growth, and how to prevent bacterial growth. Write a summary of the article and present it to the class.

## Evaluation

- Bacterial Growth Worksheet (Worksheet 2 and Teacher information sheet 1) problems are solved correctly.
- Newspaper article report about food preservation methods or how quickly bacteria spread, conditions needed for bacterial growth, and how to prevent bacterial growth (Teacher information sheet 2, evaluation sheet).
- Quiz #3.
- Examination #1 at the end of the Introduction unit.

# Overhead 1

## Multiplication Time Line



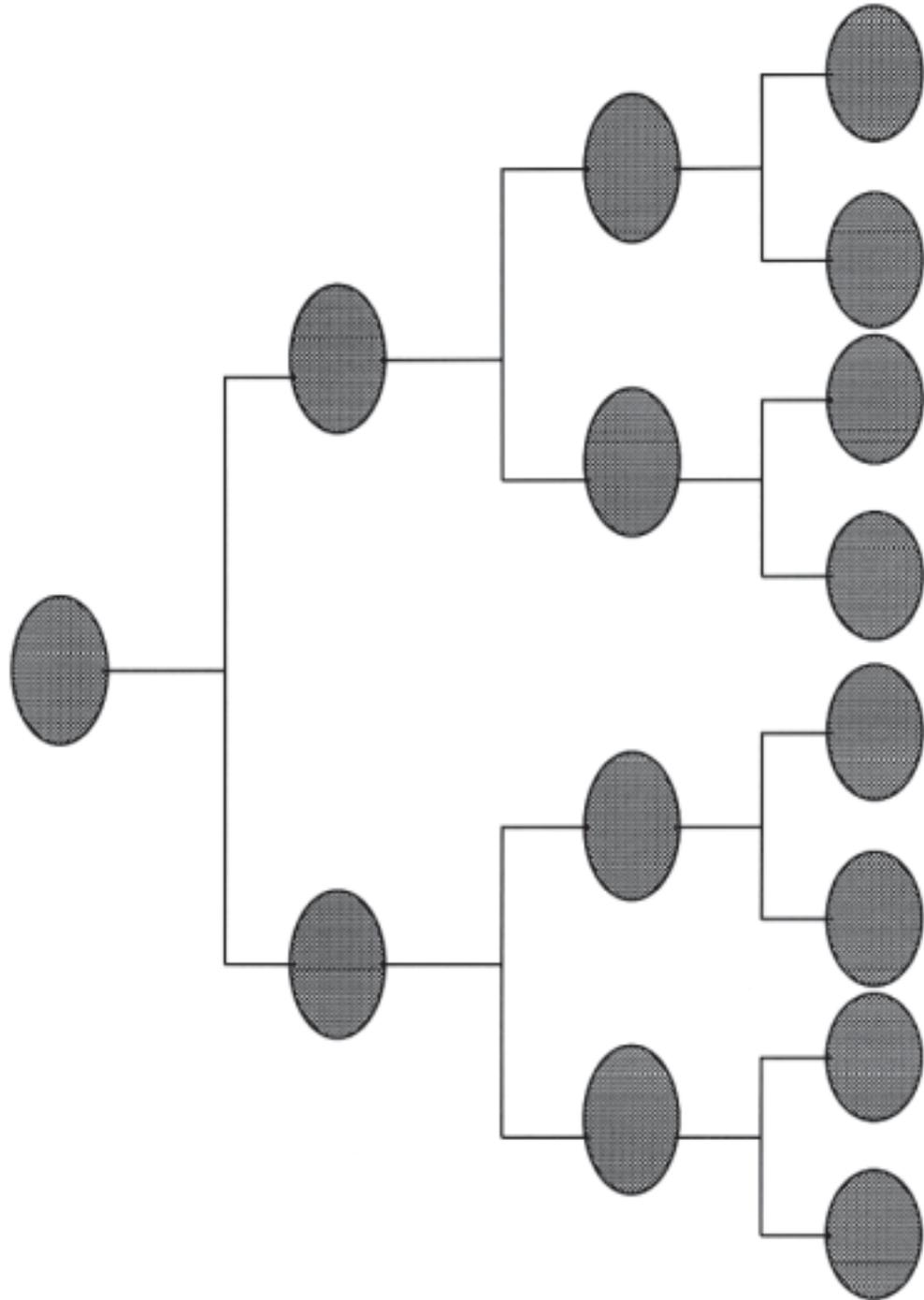
People: about 20 years



Bacteria: about 20 minutes

## Overhead 2

# Exponential Multiplication



**Overhead 3**

Number	Scientific Notation
1	$1 \times 10^0$
10	$1 \times 10^1$
100	$1 \times 10^2$
1000	$1 \times 10^3$
10,000	$1 \times 10^4$
100,000	$1 \times 10^5$
1,000,000	$1 \times 10^6$

**Overhead 4**

# Bacterial Growth Requirements

- **Temperature**

Most pathogens grow best at temperatures between 40 and 140°F.

- **Time**

It usually takes 2 to 4 hours for enough bacteria to grow to make people sick, but some types can make you sick right away.

- **Nutrients**

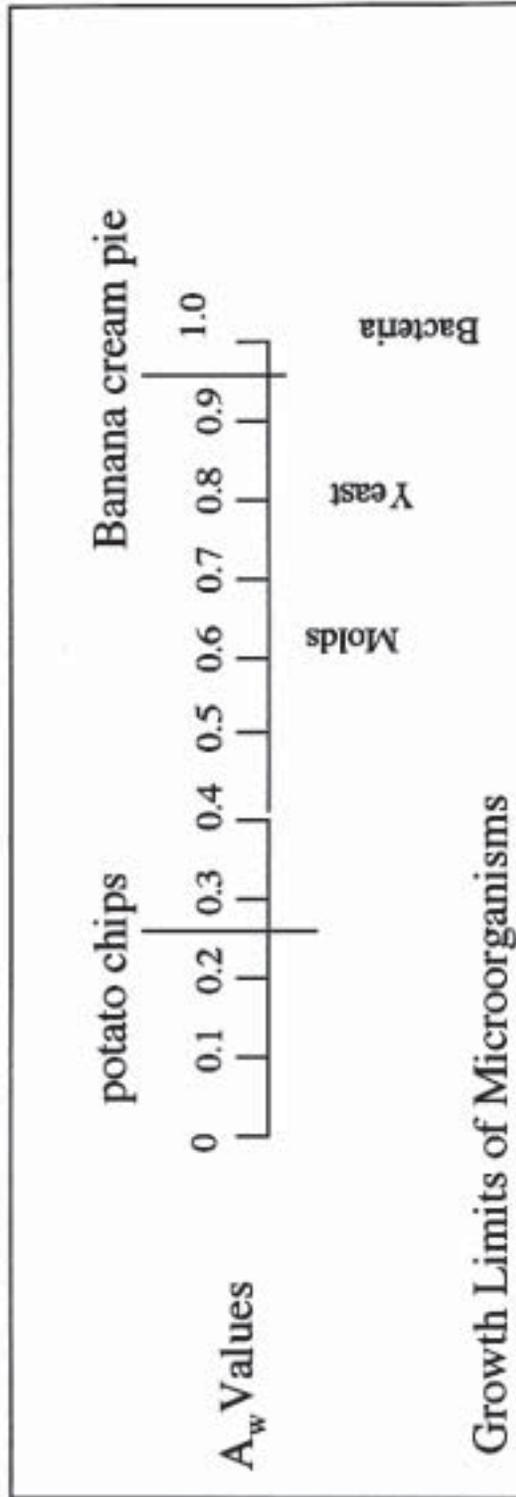
Bacteria, just like people, need food in order to grow.

- **Moisture**

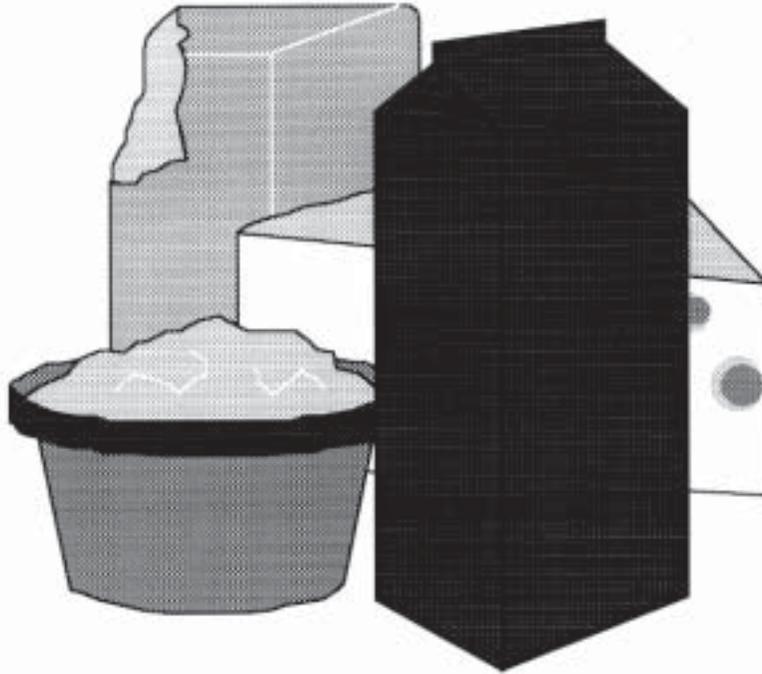
Bacteria can grow best when they have plenty of moisture available.

# Overhead 5

## Water Activity ( $A_w$ )



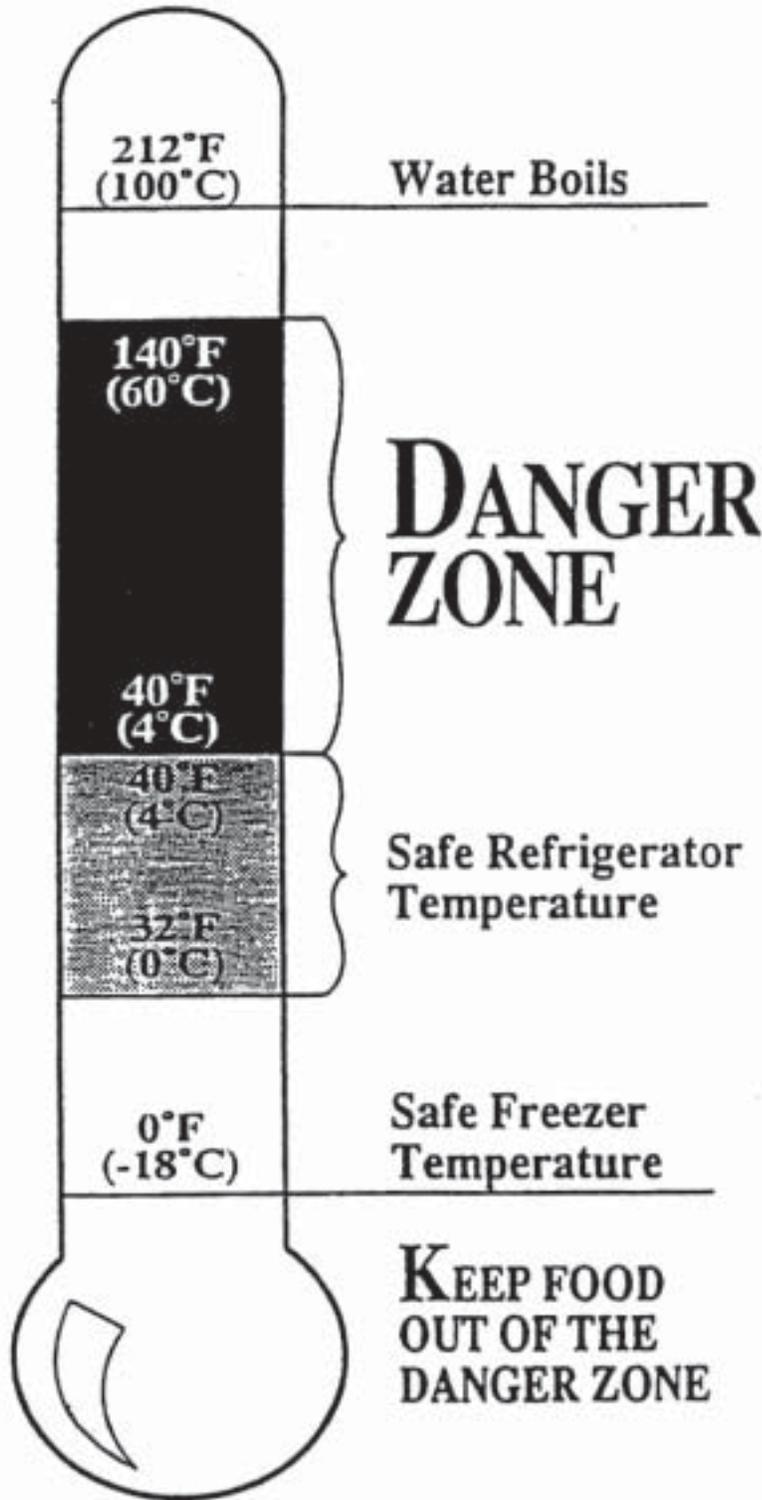
## Overhead 6



### Preservatives

- Sodium nitrite in cured meats
- Acetic acid in ketchup and pickles
- Sodium propionate in bread and bakery products

# Overhead 7





1. What are the most common methods of food preservation in the foods at home?

2. Do these food preservation methods kill the bacteria?

3. What can be done to prevent further multiplication of bacteria in the food?





## Teacher information sheet 1

### Answer Key

## Bacterial Growth Worksheet

**Directions: Solve the following problems. You may use a calculator, but be sure to show your work.**

1. Fred was making a macaroni salad, but he couldn't find a spoon so he used his hands to mix in the dressing. There were four *S. aureus* bacteria on his hands, which contaminated the salad. Fred then took the salad to a picnic, where it was left out, unrefrigerated for two hours. How many *S. aureus* grew in the salad? Was this salad safe to eat?

*20 min. for S. aureus to double once, so in two hours can double six times.*

$$4 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 512 \text{ or } 5.12 \times 10^2$$

*No. It takes only about 100 bacteria to make someone sick.*

2. Katie got the milk for the picnic at 9:00 in the morning. When she was getting ready to leave at 12:00 in the afternoon, she realized she had left the milk out on the counter. If the milk contained  $1 \times 10^2$  bacterial cells in the morning, how many do you think it contained in the afternoon?

*20 min. to double once, so can double nine times in 3 hours.*

$$100 \times 2 = 51,200 \text{ or } 5.12 \times 10^4$$

3. Sue brought potato chips and banana creme pie to the picnic. On the way there her car broke down, and she arrived two hours late. She decided to go ahead and serve both items. Based on what you have learned about water activity, do you agree with her decision? Why or why not?

*The potato chips should be fine because they have low water activity (see Water Activity Fact Sheet). The banana creme pie should not be served because it has enough moisture to allow bacteria to grow.*

4. Sean's grandma came to the picnic, and a couple of days later she came down with a bad case of listeriosis from eating a food containing *Listeria*. What food do you think she could have eaten at the picnic to get this disease?

*Milk.*

**Teacher information sheet 2**

Name \_\_\_\_\_

Class/Period \_\_\_\_\_

Date \_\_\_\_\_

**Evaluation for NIE Activity**

Grade the NIE activity on the following criteria using the 0-4 rating scale. Four is the highest rate and zero is the lowest rate. Write comments in the boxes under the rating for each criterion.

<b>Criteria</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>0</b>
<b>Content:</b> Information is correct, complete, and useful.					
<b>Neatness:</b> Clean, organized, and not sloppy.					
<b>Spelling:</b> All words spelled correctly.					
<b>Handed in on time:</b> Handed in on due date. A point is deducted for each day late.					
<b>Time Management:</b> Time used wisely and working on project at allotted time.					

## Teacher information sheet 3

### Water Activity in Food

Water in food which is not bound to food molecules can support the growth of bacteria, yeasts and molds (fungi). The term water activity refers to this unbound water.

The water activity of a food is not the same thing as its moisture content. Although moist foods are likely to have greater water activity than are dry foods, this is not always so; in fact a variety of foods may have exactly the same moisture content and yet have quite different water activities.

### The typical water activity of some foodstuffs

Type of product	Water Activity ( $a_w$ )
Fresh meat and fish	.99
Bread	.95
Aged cheddar	.85
Jams and jellies	.8
Plum pudding	.8
Dried fruit	.6
Biscuits	.3
Milk powder	.2
Instant coffee	.2

### Measuring water activity ( $a_w$ )

The water activity scale extends from 0 (bone dry) to 1.0 (pure water) but most foods have a water activity level in the range of 0.2 for very dry foods to 0.99 for moist fresh foods.

Water activity is in practice usually measured as equilibrium relative humidity (ERH).

The water activity ( $a_w$ ) represents the ratio of the water vapour pressure of the food to the water vapour pressure of pure water under the same conditions and it is expressed as a fraction. If we multiply this ratio by 100, we obtain the equilibrium relative humidity (ERH) that the foodstuff would produce if enclosed with air in a sealed container at constant temperature. Thus a food with a water activity ( $a_w$ ) of 0.7 would produce an ERH of 70%.

### Predicting Food Spoilage

Water activity ( $a_w$ ) has its most useful application in predicting the growth of bacteria, yeasts and moulds.

For a food to have a useful shelf life without relying on refrigerated storage, it is necessary to control either its acidity level (pH) or the level of water activity ( $a_w$ ) or a suitable combination of the two. This can effectively increase the product's stability and make it possible to predict its shelf life under known ambient storage conditions.

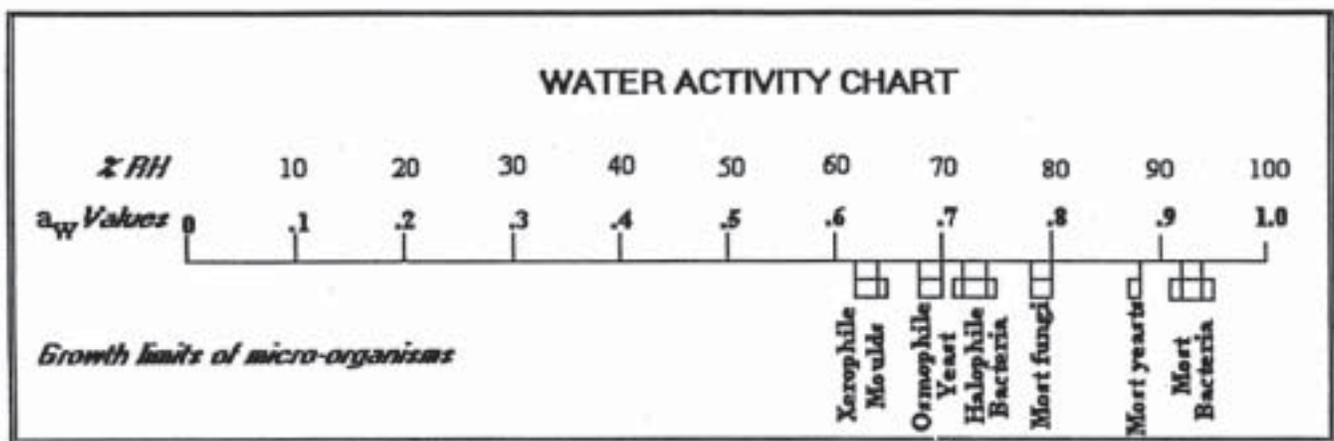
Food can be made safe to store by lowering the water activity to a point that will not allow dangerous pathogens such as *Clostridium botulinum* and *Staphylococcus aureus* to grow in it.

The diagram below illustrates the water activity ( $a_w$ ) levels which can support the growth of particular groups of bacteria, yeasts and moulds. For example we can see that food with a water activity below 0.6 will not support the growth of osmophilic yeasts. We also know that *Clostridium botulinum*, the most dangerous food poisoning bacterium, is unable to grow at an  $a_w$  of .93 and below.

The risk of food poisoning must be considered in low acid foods ( $\text{pH} > 4.5$ ) with a water activity greater than 0.86  $a_w$ .

*Staphylococcus aureus*, a common food poisoning organism, can grow down to this relatively low water activity level. Foods which may support the growth of this bacterium include cheese and fermented sausages stored above correct refrigeration temperatures.

### Water Activity Chart



### Semi-moist foods

For foods with a relatively high water activity correct refrigeration is always necessary. These include most fresh foods and many processed foods such as soft cheeses and cured meats.

However many foods can be successfully stored at room temperature by proper control of their water activity ( $a_w$ ).

These foods can be described as semi-moist and include fruit cakes, puddings and sweet sauces such as chocolate and caramel.

When these foods spoil, it is usually the result of surface mould growth. Most moulds cease to grow at a water activity level below about 0.8, but since some moulds will grow slowly at this  $a_w$ , it is usually recommended that products of this type do not have an  $a_w$  greater than 0.75.

While this will not ensure complete freedom from microbial spoilage, those few yeasts and moulds which do grow at lower water activities need only to be considered when special shelf life conditions must be met. For example a commercial shelf life over twelve months might be required for confectionery; in these circumstances an  $a_w$  below 0.6 would be required.

**Quiz 3****Unit: Introduction****Lesson: Multiplying Microbes**

Name \_\_\_\_\_

Class/Period \_\_\_\_\_

Date \_\_\_\_\_

**Matching: Match the vocabulary terms in column A with the definitions in column B. Write the letter of the definition in column B in the space next to the terms in column A.**

**A****B**

_____ 1. Exponential Multiplication	A. Microorganisms that can be either helpful or harmful in foods.
_____ 2. Preservatives	B. A type of shorthand used by scientists to express very large numbers.
_____ 3. Bacteria	C. A measure of the water in foods that is not bound to food molecules and can support the growth of bacteria, yeasts, and molds.
_____ 4. Water Activity	D. A term describing bacterial growth and the doubling of numbers at each generation.
_____ 5. Scientific Notation	E. Chemicals that keep bacteria and other microorganisms from growing.

**Short answer: Write short answers to the following questions and statements. Use complete sentences when answering questions.**

1. If it takes bacteria 20 minutes to divide once, how long would it take for 15 divisions? How many bacteria would you get if you started out with two and waited 400 minutes? (20 points)
  
2. List three methods of food preservation. For each method, give an example of a food that is preserved that way. (30 points)
  - 1.
  - 2.
  - 3.

3. How would you express the following using scientific notation? (10 points)

A. 456

B. 17,000,000

C. 1

4. List the four bacterial growth requirements:

A.

B.

C.

D.

5. How is bacterial growth controlled in foods?

## Quiz 3 Key

**Unit: Introduction**

**Lesson: Multiplying Microbes**

**Matching: Match the vocabulary terms in column A with the definitions in column B. Write the letter of the definition in column B in the space next to the terms in column A.**

A	B
<u>D</u> 1. Exponential Multiplication	A. Microorganisms that can be either helpful or harmful in foods.
<u>E</u> 2. Preservatives	B. A type of shorthand used by scientists to express very large numbers.
<u>A</u> 3. Bacteria	C. A measure of the water in foods that is not bound to food molecules and can support the growth of bacteria, yeasts, and molds.
<u>C</u> 4. Water Activity	D. A term describing bacterial growth and the doubling of numbers at each generation.
<u>B</u> 5. Scientific Notation	E. Chemicals that keep bacteria and other microorganisms from growing.

**Short answer: Write short answers to the following questions and statements. Use complete sentences when answering questions.**

- If it takes bacteria 20 minutes to divide once, how long would it take for 15 divisions? How many bacteria would you get if you started out with two and waited 400 minutes? (20 points)
  - $20 \times 15 = 300$
  - $400/20 = 20$  divisions and  $2^{20} = 2,097,152$  or  $2.10 \times 10^6$
- List three methods of food preservation. For each method, give an example of a food that is preserved that way. (30 points)
  1. *Decreasing the water activity. ex: crackers*
  2. *Adding preservatives. ex: packaged snack cakes*
  3. *Temperature control. ex: ice cream*
- How would you express the following using scientific notation? (10 points each)
  - A.  $456 = 4.56 \times 10^2$
  - B.  $17,000,000 = 1.70 \times 10^7$
  - C.  $1 = 1.0 \times 10^0$
- List the four bacterial growth requirements.
  - a. *temperature*
  - b. *time*
  - c. *nutrients*
  - d. *moisture*

5. How is bacterial growth controlled in foods?

*a. Change the water activity of the food. Water activity describes the amount of moisture that is available in food. Bacteria and other microorganisms need foods with high water activities in order to grow.*

*b. Add preservatives to the food. They can act to improve appearance, moisture, and texture of the food.*

*c. Control the temperature of the food. During processing, foods are heat treated (pasteurization, canning, and boiling) to kill any microorganisms already present in the raw ingredients.*

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