Inquiry into Infectious Disease: It's a Germy World After All

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Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Summary
This lesson engages high school students in a demonstration of how germs are transmitted from person-to-person and involves them in an inquiry-based activity and webquest. Using these tools, they will determine the abundance and types of microbes that are found around them.

Learning Outcomes

- Students will describe the abundance and types of microbes around us and give examples of useful and harmful microbes.
- Students will carry out a guided bacterial plating experiment using sterile techniques — and analyze and communicate their results.
- Students will describe ways to protect themselves from infectious agents.
- Students will create a method to educate others about the importance of good hygiene (e.g., washing hands) and prevention of illness.

Materials

Material amounts are for a class of 32 students.

1. One (1) Glo Germ™ bottle (2 ounce liquid bottle will last several years)
2. One (1) ultraviolet (UV) light (small light or pen)

   Note: (Glo Germ and a UV or black light can be purchased from: http://www.hdd.net/cgi-bin/glogerm/hazel.cgi)

3. Agar plates (preferably Luria broth (LB) agar and at least 2–3 plates per group.

   Note: Instructors have the option to purchase supplies to make plates themselves or pre-made plates from a scientific supply company. (See options below.)

   Carolina Biological Supply Company: http://www.carolina.com
   a. Ready-to-use prepoured plates (packs of 10 each) — Item #216600
   b. Luria Broth Melt 'n Pour Agar Sets, 25 plates and 2 bottles — Item #216620
   c. Nutrient Agar Media Kit — Item #821045

   Science Kit and Boreal Laboratories: http://sciencekit.com
   a. Student Bacteria Experiment Kit — Item #WW4598901

   Ward's Scientific: http://wardsci.com
   a. Prepared Luria agar plates, package of 10 — Item #88 V 0903

Note: Powdered agar can be purchased at health food stores and is much better as bacteria — it cannot degrade into a soupy mess. It will not melt on a hot summer day. For example, if this option is used, the instructor will need at least 36 sterile Petri dishes (25x100 mm).

4. 1–2 bottles of 70% isopropyl alcohol for sterilization
5. 1–bacterial loop with Bunsen burner per group or at least 12 spreaders or sterile Q-tips (unopened box) per group
6. 1–biohazard waste bag or 1 large container of bleach
7. 1–incubator set to 37º C
8. 12–Sharpie®-like permanent markers for labeling plates
9. 1–box of Parafilm to close plates securely and help prevent contamination (Carolina Biological Supply) — Item #215600)
10. 1–bottle of anti-bacterial liquid soap, spray cleaner, and other items you may wish to include for testing
11. 12–computers and Internet access for groups to do research and work on creation of product for bacterial lab write-up and symposium
12. 32–copies of the handouts (inquirey into Infectious Disease: It's a Germy World After All experiment and the Stalking the Mysterious Microbe Webquest worksheet from It's a Germy World After All)

Total Duration: 6 hours

Procedures

Teacher Preparation

The instructor should prepare agar plates at least one day before the inquiry investigation. Agar plates should be stored in the refrigerator, upside down if possible until used. To minimize instructor prep time, pre-made Luria broth agar plates can be purchased (see materials section for options). Instructors should have knowledge of sterile plating techniques and handling and disposing of biohazard materials.

Step 1 — Duration: 30 minutes

Introduction

A few minutes before class, instructors should place a small amount of Glo Germ on the outside door handle of the classroom. As students enter the classroom, they will transfer Glo Germ to their hands (if they touch the door handle). Once students have entered the classroom, explain to the students that there has been an announcement from the local health department that there is an outbreak of an unknown germ. It is not known if the germ is a serious pathogen, but it is known that it can be detected by using an UV light. The germ will appear as bright orange streaks or spots under an UV light.

Instructors should turn off the lights and have students cup their hands to do the *unknown germ* test. Instructors should go from student to student and use the UV light to check hands for the unknown germ. Instructors can choose to separate those students who test positive for the unknown germ. After the students are tested, instructors should lead a discussion to determine what the students know about the following:

- What are germs? Are there different types?
- Where can germs be found?

- Are all germs dangerous (pathogens)?
- How do scientists observe and/or grow germs?
- How are germs transmitted?
- What ways can one limit exposure to germs?

Once the discussion is complete, have a student or two wash their hands and re-test using the UV light. Have a short discussion with students on the proper way to wash hands and discuss why it is important to human health and public safety. The Glo Germ website has videos on the proper way to wash hands, as does the Centers for Disease Control and Prevention (CDC) website.

Web Resources
Title: Glo Germ
URL: http://www.glogerm.com/
Description: This site sells Glo Germ products to help instruct the importance of handwashing.

Title: CDC — An Ounce of Prevention Campaign
URL: http://www.cdc.gov/ounceofprevention/
Description: This CDC website gives information on the Ounce of Prevention Campaign, promoting good hygiene. Instructors can download free hygiene posters and resources.

Title: CDC-Handwashing Guidelines
URL: http://www.cdc.gov/nceh/vsp/cruiselines/handwashing_guidelines.htm
Description: CDC website with guidelines for proper handwashing.

Step 2: Experiment **Duration: 3.5 hours**

Pass the Inquiry into Infectious Diseases Experiment to student groups (2–3 members). After students have had a few minutes to read and preview the lab, instructors should go over the objectives, the scientific method, and the investigation expectations with the class. Instructors will have to give a mini-lecture (5–10 minutes) on how to: 1] plate bacteria, 2] sterile technique, and 3] disposal of biohazard materials.

For the rest of the first class period, instructors should have students carry out **Steps 1–4** in the experiment. Students may not finish **Step 4** during the class period, but this can be assigned as homework or be continued the next class period. On day two, student groups must have the instructor approve their experimental procedures before they can carry out their investigations. Make sure to emphasize controls and variables. Instructors should have computers available when student groups finish their plating. Student groups can learn as much as they can about microbes using the Stalking the Mysterious Microbe Webquest worksheet and http://www.microbeworld.org/. This can also be done as homework or when groups have down time during their investigation.

The bacteria plates should take 1–2 days to grow in an incubator set at 37°C. It may be advantageous to plate at the end of the week, allowing for growth to occur over a weekend. On days 3 and 4, students should complete steps 6–7 in the experiment.

Web Resource

Title: Microbeworld
URL: http://www.microbeworld.org/
Description: This site educates about different types of microbes, where they live, and tools and techniques to study them. This site also includes information on current research and uses of microbes.

Supplemental Documents

Title: Inquiry into Infectious Diseases Experiment
Description: Student experiment instructions and worksheet

Title: Stalking the Mysterious Microbe
Description: Webquest worksheet

Conclusion **Duration: 2 hours**

Students should create posters or PowerPoint presentations based on **Step 8** of the Inquiry into Infectious Diseases: It's a Germy World After All. Instructors should briefly explain the nature of science, and that research is conducted in a community with peer review. Scientists often attend poster or PowerPoint sessions to learn what is new in their field and to share information. Instructors may have to allow extra time either in class or as homework for students to complete **Step 8** (Inquiry into Infectious Diseases: It's a Germy World After All) and remain ready for sharing their investigations in a class symposium on microbes and health. After the symposium, instructors should lead a wrap-up discussion about what was learned from the activities and reinforce prevention strategies.

Supplemental Documents

Title: Bacterial Symposium Rubric
Description: This rubric is used to grade student presentations given at the bacterial symposium.

Assessment

Instructors should use the provided grade rubrics or create their own rubrics for assessing the student experiments and posters or PowerPoints from the symposium.

Modifications

Extensions

Instructors may choose to extend the lesson by adding a survey and graphing analysis component. The class would be assigned to come up with viable survey questions (no more than ten) that could be given to other classes, people in their neighborhood, each other, etc.).

If your school district does not support the administration of surveys, school nurses might be able to provide information on what types of illnesses are showing up or how many students are sick with a particular illness or set of symptoms and sent home on a weekly or monthly basis. Students can track this information and publish it via a podcast, newsletter, school newspaper, or class report. They can also extend this by educating other students on ways to prevent illness through posters, podcasts, newsletters, e-mail

listservs, etc. Additionally, instructors may extend the lesson by adding activities from CDC's EXCITE! website or the Biological Sciences Initiative (BSI) — a Howard Hughes Medical Institute (HHMI) funded program).

Both the CDC EXCITE! and BSI websites provide instructors with resources and activities that include (but are not limited to): epidemiological studies; mathematical modeling; antibiotic resistance; antigenic shift; host-parasite interactions; surveillance; public policy; and outbreak investigations.

HHMI provides resources such as the holiday lecture series on infectious diseases and biointeractive virtual lab activities. Instructors can show videos such as *Outbreak* (1995, loosely based on Richard Preston's novel, *The Hot Zone*) or Nova's *The Most Dangerous Woman in America,* or read excerpts of novels such as *Hot Zone* by Richard Preston (Random House, Inc., 1994) or *Survival of the Sickest* by Sharon Moalem and Jonathan Price (HarperCollins Publisher, 2007). Nova provides instructor resources and activities to support the video and story of Typhoid Mary.

Web Resources

Title: BSI HHMI, University of Colorado Teacher Resources on Infectious Diseases
URL: http://www.colorado.edu/Outreach/BSI/k12activities/activities.html
Description: A site that includes several resources, activities, and laboratory investigations on biology topics.

Title: CDC's EXCITE! website
URL: http://www.cdc.gov/excite/ScienceAmbassador/ambassador_pgm/lessonplans.htm
Description: A site that includes several lesson plans and resources from the Science Ambassador program, a collaborative product of teachers and CDC scientists and personnel.

Title: HHMI: For Educators
URL: http://www.hhmi.org/resources/educators/
Description: A site that includes several resources such as free DVD videos, pamphlets, biointeractive webquests and virtual laboratory activities.

Title: Nova: The Most Dangerous Woman in America
URL: http://www.pbs.org/wgbh/nova/typhoid/
Description: A site that supports the Nova video, The Most Dangerous Woman in America, the story of Typhoid Mary.

Other Modifications

Instructors can chose a specific experiment-related question for groups that need more direction and give them a more structured handout (See Inquiry Into Infectious Disease: It's a Germy World After All Modified Experiment worksheet) to help them with the experiment.

Education Standards

National Science Education Standards

SCIENCE AS INQUIRY, CONTENT STANDARD A
As a result of activities in grades 9–12, all students should develop the following:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE, CONTENT STANDARD B
As a result of activities in grades 9–12, all students should develop an understanding of the following:

- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

LIFE SCIENCE, CONTENT STANDARD C
As a result of their activities in grades 9–12, all students should develop understandings of the following:

- The cell
- Molecular basis of heredity
- Biological evolution
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

EARTH AND SPACE SCIENCE, CONTENT STANDARD D
As a result of their activities in grades 9–12, all students should develop an understanding of the following:

- Energy in the earth system
- Geochemical cycles
- Origin and evolution of the earth system
- Origin and evolution of the universe

SCIENCE AND TECHNOLOGY, CONTENT STANDARD E
As a result of activities in grades 9–12, all students should develop the following:

- Abilities of technological design
- Understandings about science and technology

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES, CONTENT STANDARD F
As a result of activities in grades 9–12, all students should develop understanding of the following:

- **Personal and community health**
- Population growth
- Natural resources

- Environmental quality
- Natural and human-induced hazards
- Science and technology in society

HISTORY AND NATURE OF SCIENCE, CONTENT STANDARD G
As a result of activities in grades 9–12, all students should develop understanding of the following:

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

Specific descriptions of 9–12 content standards can be found at
http://www.nap.edu/readingroom/books/nses/html/6e.html

Colorado State Standards

STANDARD 1: Students apply the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.

STANDARD 3
Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment. (Focus: Biology — Anatomy, Physiology, Botany, Zoology, and Ecology.)

STANDARD 5: Students understand that the nature of science involves a particular way of building knowledge and making meaning of the natural world.

Descriptions of K–12 standards can be found at:
http://www.cde.state.co.us/cdeassess/documents/OSA/k12_standards.html

Illinois State Standards

STATE GOAL 11: Understand the processes of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

STATE GOAL 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences.

STATE GOAL 13: Understand the relationships among science, technology and society in historical and contemporary contexts.

Specific descriptions of 9–12 content standards can be found at:
http://www.isbe.state.il.us/ils/science/standards.htm

Inquiry into Infectious Diseases Experiment

Inquiry Into Infectious Disease: It's a Germy World After All
Kristin Donley and Stephanie Jarem
CDC's 2008 Science Ambassador Program

Objective: During this activity you will conduct an independent investigation related to infectious disease. You will use the scientific method to carry out your investigation.

Scientific Method: Scientific method is the method scientists use to answer questions. The scientific method follows the steps listed below.

1. Choose a question.
2. Design two hypotheses (possible answers) to the question — one sentence each
3. Make testable predictions based on each hypothesis.
4. Design experiments to answer the question and see whether the predictions are met.
5. Perform experiments and collect data.
6. Analyze data including graphs and tables if necessary.
7. Determine whether your results support or falsify your hypothesis and additional conclusions.
8. Present your investigation to the class at the [insert school name here] Annual Bacteria Symposium.

Although the scientific method is written as a series of distinct steps above, it is actually a process where all steps influence each other. For example, the question one chooses is influenced by what materials are available and what experiments can be performed. Thus, it is often impossible to do steps 1 and 4 separately from one another. Similarly, once an experiment is performed, it may become obvious immediately that the experimental design is flawed, which necessitates redesigning Steps 1–4 without completion of steps 6–8.

Read through the lab procedure steps before beginning.

Step 1: Choose a question. Working as a group (2–3 students), choose one of the following questions to develop and carry out an investigation.

How do the number and variety of bacteria compare between

- Different areas of skin (lips, extremities, hands)?
- The armpits of men vs. women?
- The environment vs. the human?
- Washed and unwashed hands?
- Hands washed with regular vs. anti-bacterial soaps?
- Hands washed with hand sanitizer vs. cleaned with rubbing alcohol?
- Which environmental locations inside your classroom contain a larger number or variety of bacteria door knobs, table tops, water faucets, cell phones, pencils, etc?

Write your question in the space below

Step 2: Hypothesis Formation
Design two hypotheses related to your question. Remember that a hypothesis is a possible answer to the question. A hypothesis is also often described as an educated guess. A guess, because it is not known in advance whether the hypothesis is correct, and educated because it is based on the knowledge already possessed.

For example – if the chosen question is: *How do the number of bacteria compare between washed and unwashed hands?*
A reasonable hypothesis based on existing knowledge could be: *There will be more bacteria on unwashed hands than on washed hands.*
You can also design a series of hypotheses (different possible answers) for the question. This technique is often used because one way of adding support to a hypothesis is to reject other possible hypotheses (answers).
For example, for the above question, you could have two different hypotheses:

A. *There will be more bacteria on unwashed hands than on washed hands.*
B. *There will be less bacteria on unwashed hands than on washed hands.*

Write your hypotheses below limiting each to one sentence.

Step 3: Make predictions based on your hypothesis.
Predictions are experimental outcomes that will be true if your hypothesis is correct. You may want to consider experimental design when making your predictions (see **Step 4** below). Predictions can easily be written as if – then statements.

In reference to hypothesis A above, a possible prediction would be:
If there are more bacteria on unwashed hands than washed hands, then more colonies will grow on a plate swabbed from unwashed hands than on a plate swabbed from washed hands.

It is good to have more than one prediction based on more than one experimental design. The more different ways you can support (or reject) a hypothesis, the better.

Write your predictions below.

Step 4: Design an experiment to answer your question.

You might want to consider the following when designing your experiments.

- What types of cultures (swabs) will you take?
- Who and where will you take them from?
- How many places and/or individuals will you test?
- What type of media will you use?
- How will you measure the variety of bacteria?
- How will you measure and observe colony morphology?
- How will you measure the number of bacteria?
- Counting colonies of each different type?
- How will you ensure an equal sample size in all samples?
- What controls will you include?
- What are the dependent vs. independent variables?

For a control, use a non-inoculated swab to streak a plate to be sure the swabs and plates are not contaminated. Note that as you design your experiment, you may find that you can not answer the questions originally set out. If this is the case, you can modify your question, hypothesis, and predictions, or choose a new question. It does not indicate a failure if choosing a new question. Rather, it is a success and the sign of a great scientist to recognize that the question was inappropriate and needs to be redesigned.

Write out an experimental design below. Once you have written the procedure, have your instructor approve it.

Step 5: Perform experiments and collect data
When collecting data, it is not necessary to write it in the format you will hand in. (You will reorganize and rewrite your data in a neat format later.) For now, however, it is important to keep you results well labeled and dated. For example, patent lawyers often check scientists' notebooks when trying to decide who should get patent rights on a given result. Be sure to note the results from each experiment that you perform. Be sure the results are clearly labeled and dated so that later you will know what the results refer to — *and be sure to include the control results*.

Note all your results and observations on a separate piece of paper, including results of any controls.

Step 6: Analyze data
A first step to analyzing your data is to organize all the results you have noted while performing your experiments. Tables and graphs can be a good way of summarizing your data.

For example, in one of the experiments proposed above you could summarize your results in a table like this.

Person Swabbed	**Number of Colonies from unwashed hand**	**Number of Colonies from washed hand**	**Difference in number of colonies |(unwashed – washed)|**
Person 1	20	17	3
Person 2	15	20	5
Person 3	19	14	5
Person 4	32	19	13
Person 5	19	13	6
Average	21	13	6.4

Statistics: In a real scientific setting, in order to determine whether your data support or reject your hypothesis, you would need to perform a statistical analysis to determine whether the difference between your results above was "significant." A discussion of statistical techniques that could easily be adapted to this type of investigation is available at http://faculty.vassar.edu/lowry/VassarStats.html.

Summarize your results on a separate piece of paper, including any tables, graphs, or calculations you feel are appropriate.

Step 7: Decide whether your results support or reject your hypothesis.
Results of an experiment never prove a hypothesis. Hypotheses can never be proven. Instead, experiments support hypotheses. The more supporting evidence is obtained, the more the hypothesis is supported. This is because no matter how much the data support the hypothesis, there are still other possible explanations not yet tested.

Hypotheses can, however, be rejected. Results can definitely show that a hypothesis is false. Note that it is not considered bad or a failure to reject a hypothesis. By proving a hypothesis false, you eliminate one possible answer to your question. Furthermore, you add to the support of other competing hypotheses. Scientists add support to their hypotheses by rejecting competing hypotheses (other answers to the same question). Often the results of an experiment neither support nor falsify a hypothesis. There are many ways in which this happens and some examples follow:

- Controls show one or more of the reagents were not working
- Controls show the experiment was not designed to answer the intended question
- Results show that the experiment was not designed to answer the intended question

When the results of an experiment neither support nor falsify a hypothesis, it is necessary to repeat the experiment (if there is a problem with the reagents). It may be time to redesign the experiment (if it is not answering the intended question), or even to rethink the question and hypothesis. As was the case with rejecting hypotheses, this is not bad science or a failure. Rather it is good science to recognize the problems with experiments and questions — and to repeat and redesign them as necessary.

On a separate sheet of paper, write a brief conclusion summarizing how your results support or reject your hypothesis. You should also include any possible sources of error and how you would repeat or redesign your experiment to answer the intended question. Also, be sure to include the answers to the following questions:

- How do your results fit with what is already known about this question. If your results are contradictory to what is already known, comment on what might explain the difference — you will have to do some research — your instructor will show you how to cite your sources
- What experiments could you perform to help clear up or explain any unexpected results?
- What new questions did the results bring up?
- Why is this experiment important to society and you as an individual?
- What would you do next if you were to continue this work?

Step 8: Prepare a poster or PowerPoint of your inquiry investigation. Include all **Steps 1–7**. You will be sharing your knowledge with other groups at the [insert school name] Annual Bacteria Symposium. Research is a community effort and your group will be required to share your knowledge with other groups. As an entire scientific community,

you will discuss general conclusions you make from the inquiry experiments performed in class. **Use the space below to take notes from each of the other group's experiments. Write down each group's question, their conclusions, and any questions you have about their investigation.**

Independent Investigations in Disease. Modified with permission from BSI (with funding from the Howard Hughes Medical Institute), University of Colorado, June 2008: http://www.colorado.edu/Outreach/BSI/k12activities/infectious.html

Modified Investigation Worksheet

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Name: _____ **Period:** _____

Group Members Names: _____

1. **Write the question of your experiment below.**

2. **Write your hypotheses and predictions below.**

3. **List the step-by-step procedure used (including the sterile technique that you followed) below.**

4. **What were the controls? What were the variables?**

5. **Results: On a separate sheet of paper, draw your plates and label the pictures. Also, include a table of results.**

6. **Graph any results such as colony number and type. You may want to use Excel to do this.**

7. **Write your conclusion below. See the experiment for further details.**

Please note: This activity is based on an experiment by CU Boulder's BSI, with funding from the Howard Hughes Medical Institute. Modified with permission from Biological Sciences Initiative, University of Colorado, available at URL: http://www.colorado.edu/Outreach/BSI/k12activities/infectious.html

Inquiry into Infectious Disease Experiment Rubric

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Group members:

Lab Section	1=F	2=D	3=C	4=B	5=A
Title, Purpose, Hypotheses, Background: At least two hypotheses with predictions; background (if applicable) includes vocabulary and example/application.					
Procedure: Repeatable, verifiable, concise, clear, all measurements/units included, lists controls and variables (independent vs. dependent).					
Data/Analysis: All measurements/units included and represented in a table format; verbal descriptions; labeled pictures; graphical representation has a title; axes are labeled with units; correct use of legend; and data points are accurate. Graph has a summary label/statement of describing what the graph is about, professional quality					
Conclusion: **1.** Restate purpose and results (include actual numerical data and observations). **2.** Explain how data agrees with hypothesis. **3.** What could possibly have gone wrong (experimental errors)? List at least 2: measurement problems; things not working the way you expected, etc. **4.** What would you have done differently? What would you use if you could? Would you try anything else? **5.** What did you learn? How does this lab relate to what you are studying?					
Grammar/Mechanics: There are few or no grammatical and/or sentence structure errors. Work represents group's own words.					

Average Score (total of scores/5): _____ Grade: _____

Comments:

Bacteria Symposium Presentation Rubric

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Group members: _____

Category	Scoring Criteria	Points	Student Evaluation	Teacher Evaluation
Presentation ***40 points***	**Report is a Poster or in PowerPoint.** There are few or no grammatical and/or sentence structure errors. Work represents group's own words and there is no cutting and pasting from the Internet.	**10**		
	Use of backgrounds, colors, graphics with appropriate citations makes project easily readable, interesting, and effective. This project needs to be laminated and published!	**10**		
	Report given in such a way that others could accurately understand and duplicate the experiment. Presentation is clear, concise, and accurate. The Scientific method was followed.	**10**		
	All members participate equally; no sections of the scientific method or information are missing.	**10**		
Lab Safety ***10 points***	No group members were cited for safety violations. Clean-up was satisfactory (dishes washed and put away, counters cleaned, all supplies returned, bacteria plates properly disposed of). *(Proper lab safety gear must be worn **at all times**.)*	**10**		
Score	**Total Points**	**50**		
Student-evaluation	Students are expected to evaluate their own or other's work. If the difference between the students and teacher's score is large, groups will meet with the instructor to sort out why there is a difference.			
Comments:				

Stalking the Mysterious Microbe Webquest

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Directions: Go to the following web site: http://www.microbeworld.org/ and complete the following questions and activities.

1. Click on: **Meet the Microbes** (the link is at the top of the page).

a. What is a microbe? Why are microbes important? How old are they? How big are they?

b. Click on the link: **Virus or Bacterium?** Read the information and complete the table:

Microbe Type	**Labeled Drawing of Microbe**	**Structures or Parts of the Microbe**	**Mode of Reproduction**	**Differences between a Bacterium and a Virus**
Bacterium				
Virus				

c. Click on the **Types of Microbes** link (at the top or at the left hand side) and fill out the table below:

Microbe Type	**Types of and description of microbe (include classification)**	**Main characteristics that make them different from other microbes**	**Origins**
Archaea			
Bacteria			
Fungi			
Protista			
Viruses			
Microbial mergers			

d. Click on the links below the **Archaea** link and then for the microbes in part B above in grey and fill out the table below. Do the same for the links underneath the bacteria, fungi, and viruses links.

Microbe Type	What they look like	Where they are found	What they eat	How they move
Archaea				
Bacteria				
Fungi				

e. Fill out the following table on protista by clicking on the links underneath in grey.

Sub-Types and description of protist	Give description of types of sub-types	List at least 2 interesting facts about the sub-type
Algae	Green Algae:	
	Dinoflagellates:	
	Diatoms:	
Protozoa	Apicomplexans:	
	Ciliates:	
	Flagellates:	
	Sarcodinia:	
Slime molds	No further sub-types	
Water molds	No further sub-types	

2. Click on the **Where They Live?** link on the top under meet the microbes or to the left hand side. Answer the following:
    a. *Name at least three places microbes live.*

    b. *Can you think of any places that microbes might not live?*

3. Click on the **Discovery Timeline** link at the top under meet the microbes or to the left hand side.
    a. Using the timeline, place major discoveries on the table below.

Time Period	**List of major discoveries and/or events**
1870s–1880s	
1890s–1900s	
1910s–1920s	
1930s–1940s	
1950–1960s	
1970s–Present	

    b. What do you think was the most important event and why?

4. Click on the **Tools and Techniques** link at the top of the page underneath meet the microbes or to the left hand side. Fill out the table below. You may include drawings or pictures of the tools/techniques in your description/definitions.

Tool or Technique	**Description or definition of tools or techniques and why they are important (e.g., function)**
Microscopes: light and electrons	
Culture equipment: Petri plates and flasks; culture media; pipettes, and swabs	
Genetic Tools and Techniques: PCR; genes and genome sequencing; 16s RNA; microarrays	

5. Click on the **Did You Know?** link at the top of the site, and then on the **Gross … you didn't wash your hands** link. Answer the question of whether you always wash you hands after going to the bathroom.

    a. What are the results? Why do you think the reported answer from this website is so much higher than the observations made of people actually using the bathroom?

    b. Why is it so important to wash your hands? When should you wash your hands?

    c. Take the wash your hands quiz.

d. Click on the **www.washup.org** link and list any interesting information below.

6. Go to two other places on this site and fill out the table below. You will have to create two interesting questions with the answers regarding the information at each of the two links. Be creative!

Link Map: link(s) you went to	**1st Question: about link information**	**Answer to 1st question**	**2nd Question: about link information**	**Answer to 2nd question**

Stalking the Mysterious Microbe Webquest Answer Key

Inquiry into Infectious Disease: It's a Germy World After All

Kristin Donley and Stephanie Jarem
CDC's 2008 Science Ambassador Program

Directions: Go to the following website: http://www.microbeworld.org/ and complete the following questions and activities.

Note: The answers were obtained directly from the website.

1. Click on **Meet the Microbes** (the link is at the top of the page).

    a. What is a microbe? Why are microbes important? How old are they? How big are they?

Microbes are single-cell organisms; so tiny that millions can fit into the eye of a needle.

They are the oldest form of life on earth. Microbe fossils date back more than 3.5 billion years to a time when the Earth was covered with oceans that regularly reached the boiling point, hundreds of millions of years before dinosaurs roamed the earth.

Without microbes, we couldn't eat or breathe.

Understanding microbes is vital to understanding the past and the future of our planet and ourselves.

Microbes include **bacteria** (*back-tear-ee-uh*), **archaea** (*are-key-uh*), **fungi** (*fun-jeye*), and **protists** (*pro-tists*).

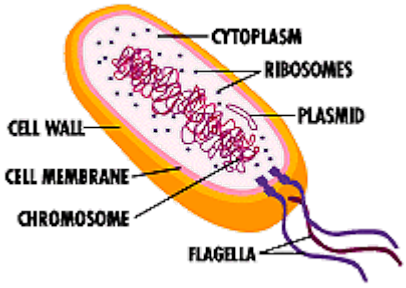
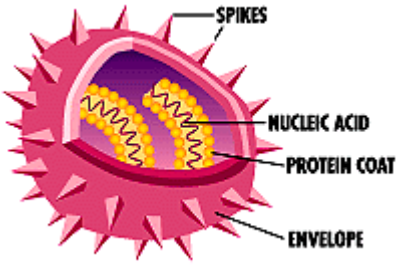
So how small are microbes?

Well, let's say we could enlarge an average virus, the smallest of all microbes, to the size of a baseball.

An average bacterium would then be the size of the pitcher's mound.

And just one of the millions of cells that make up your body would be the size of the ballpark!

b. Click on the link: **Virus or Bacterium?** Read the information and complete the table.

Microbe Type	Labeled Drawing of Microbe	Structures or parts of the Microbe	Mode of Reproduction	Differences between a Bacterium and a Virus
Bacteria	 http://www.microbeworld.org/microbes/virus_bacterium.aspx	Single celled prokaryotic — no nucleus, cell wall, ribosomes, or circular chromosome	Binary fission-mitosis	*Size — larger *Parts — more parts, a living cell *Mitotic reproduction
Viruses	 http://www.microbeworld.org/microbes/virus_bacterium.aspx	Spiky envelope, DNA or RNA, no cell organelles	"Moochers," they live and reproduce inside a host cell	*Size — smaller *Not a traditional cell — are they alive? *Reproduction is parasitic

c. Click on the **Types of Microbes** link (at the top or at the left hand side) and fill out the table below.

Microbe Type	**Types of and description of microbe (include classification)**	**Main characteristics that make them different from other microbes**	**Origins**
Archaea	Prokaryotes crenarchaeota *(kren-are-key-oh-ta)*, which are characterized by their ability to tolerate extremes in temperature and acidity. The euryarchaeota *(you-ree-are-key-oh-ta)*, which include methane-producers and salt-lovers; and the korarchaeota *(core-are-key-oh-ta)*, a catch-all group for archaeans about which very little is known. **Methanogens *(meth-an-oh-jins)* —** archaeans that produce methane gas as a waste product of their "digestion," or process of making energy. **Halophiles *(hal-oh-files)* —** those archaeans that live in salty environments. **Thermophiles *(ther-mo-files)* —** the archaeans that live at extremely hot temperatures. **Psychrophiles (*sigh-crow-files*) —** those that live at unusually cold temperatures.	Although many archaea have tough outer cell walls, these walls contain different kinds of amino acids and sugars than those found in bacteria. Archaeal cell membranes also are chemically distinct from bacterial membranes with differing lipid structures and chemical links. This means that drugs that slow or kill bacteria by interfering with their ability to produce certain key proteins have no effect on archaea.	Archaeans are among the earliest forms of life that appeared on Earth billions of years ago. It's now generally believed that the archaea and bacteria developed separately from a common ancestor nearly 4 billion years ago. Millions of years later, the ancestors of today's eukaryotes split off from the archaea. So historically, archaeans are more closely related to us than they are to bacteria.
Bacteria	Prokaryotes Examples of: *Bacillus anthracis* causes anthrax, a deadly disease in cattle and a potential bioweapon against humans. *Brucella abortus* causes	Type of cell wall, shape, and method of movement	Bacteria and their microbial cousins the archaea were the earliest forms of life on Earth. And may have played a role in shaping our planet into one that could support the larger life forms we

Microbe Type	Types of and description of microbe (include classification)	Main characteristics that make them different from other microbes	Origins
	breeding losses in livestock. *Cyanobacteria* (formerly known as blue-green algae) live in water, where they produce large amounts of the oxygen we breathe. *Escherichia coli* (a.k.a. *E. coli*) live in the gut, where it helps digest food and produces Vitamin K. The "bad" strain of *E. coli* O157:H7 causes severe foodborne sickness. *Lactobacillus bulgaricus* helps turn milk into cheese, yogurt, and other dairy products. *Bacterium tuberculosism Mycoba* causes tuberculosis, a major killer from the past that has recently resurged with the advent of AIDS. *Rhizobia* convert free nitrogen into a form that the plants can use in order to grow. *Staphylococcus* (a.k.a. *staph*) can cause serious infections and is one of the most drug-resistant bacteria. *Streptococcus pneumoniae* causes strep throat, meningitis, and pneumonia. *Streptomyces griseu*s makes the antibiotic streptomycin.		know today by developing photosynthesis. Cyanobacteria fossils date back more than 3 billion years. These photosynthetic bacteria paved the way for today's algae and plants. Cyanobacteria grow in the water, where they produce much of the oxygen that we breathe. Once considered a form of algae, they are also known as blue-green algae. Bacteria are among the earliest forms of life that appeared on Earth billions of years ago. Scientists think that they helped shape and change the young planet's environment, eventually creating atmospheric oxygen that enabled other, more complex life forms to develop. Many believe that more complex cells developed as once free-living bacteria took up residence in other cells, eventually becoming the organelles in modern complex cells. The mitochondria *(mite-oh-con-dree-uh)* that make energy for your body cells

Microbe Type	Types of and description of microbe (include classification)	Main characteristics that make them different from other microbes	Origins
			is one example of such an organelle.
Fungi	Eukaryotic	They range in size from the single-celled organism we know as yeast to the largest known living organism on Earth — a 3.5-mile-wide mushroom. Dubbed “the humongous fungus,” this honey mushroom (*Armillaria ostoyae*) covers some 2,200 acres in Oregon’s Malheur National Forest. Visible fungi such as mushrooms are multicellular entities, but their cells are closely connected in a way unlike that of other multicellular organisms. Plant and animal cells are entirely separated from one another by cell walls (in plants) and cell membranes (in animals). The dividers between fungal cells, however, often have openings that allow proteins, fluids and even nuclei to flow from one cell to another. A few fungal species have no cell dividers: just a long, continuous cell dotted by multiple nuclei spread throughout.	It started out 2,400 years ago as a single spore invisible to the naked eye, then grew to gargantuan proportions by intertwining threads of cells called *hyphae*.
Protista	Eukaryotic	Protists fall into four general subgroups: unicellular algae, protozoa, slime molds, and water molds. Green algae grows in masses that form slick, green scum on pond surfaces. Plasmodium vivax, the parasite that causes malaria, lives part of its life cycle in mosquitoes and the other part in human hosts where it infects and ruptures blood cells in large	Its ancestors from 500 million years ago probably gave rise to today's multicellular plants.

Microbe Type	Types of and description of microbe (include classification)	Main characteristics that make them different from other microbes	Origins
		numbers. Phytophthora infestans is the water mold responsible for the Great Potato Famine that killed nearly a million people in Ireland in 1846–1847.	
Viruses	Viruses are strange things that straddle the fence between living and non-living. On the one hand, if they're floating around in the air or sitting on a doorknob, they're inert. They're about as alive as a rock. But if they come into contact with a suitable plant, animal, or bacterial cell; they spring into action. They infect and take over the cell-like pirates hijacking a ship.	virus is basically a tiny bundle of genetic material — either DNA or RNA — carried in a shell called the viral coat, or capsid, which is made up of bits of protein called capsomeres. Some viruses have an additional layer around this coat called an envelope. That's basically all there is to viruses. Viruses can't metabolize nutrients, produce and excrete wastes, move around on their own, or even reproduce unless they are inside another organism's cells. They aren't even cells. Yet viruses have played key roles in shaping the history of life on our planet by shuffling and redistributing genes in and among organisms and by causing diseases in animals and plants. Viruses have been the culprits in many human diseases, including smallpox, flu, AIDS, certain types of cancer, and the ever-present common cold. Examples of: *Adenoviruses* are used in experimental gene therapy treatments to deliver therapeutic genes. *Bacteriophages* are being explored as tools to treat bacterial infections by targeting and destroying	We don't know!

Microbe Type	Types of and description of microbe (include classification)	Main characteristics that make them different from other microbes	Origins
		infectious bacteria. *Human Immunodeficiency Virus (HIV)* is responsible for the AIDS pandemic. *Human papillomavirus* causes cervical cancer. *Influenza* causes the flu, which killed some 21 million people worldwide in 1918. *Lambda phage* is useful in cloning DNA. *Potyviruses* cause disease in a wide variety of important agricultural plants. *Tulip mosaic virus* causes streaks in tulip petal coloration, resulting in flowers sold at premium prices. *Variola major* causes smallpox. Although eradicated worldwide in the late 1970s, remaining stores could be used to create deadly bioweapons.	
Microbial mergers	Prokaryotic (symbiotic bacteria)	Over millions of years of evolution, we humans have worked out a mutually beneficial partnership with the microbes that came to inhabit our guts. In return for their aid in digestion, we give them a stable, protected home and plenty of nutrients via the food we eat. We need them as much as they need us. *Rhizobia* are bacteria that form nodules on the roots of legumes to supply them with nitrogen; in return, the plants provide the bacteria with carbohydrates. *Mycorrhizae* are soil-dwelling fungi that act as extensions of plants' roots, enabling them to vastly increase their nutrient-absorbing network. The plants provide the fungi energy in the form of	Millions of years

Microbe Type	Types of and description of microbe (include classification)	Main characteristics that make them different from other microbes	Origins
		carbohydrates. *Zooxanthelle* are photosynthetic algae that live inside the body tissues of coral polyps. They provide nutrients to their polyp hosts in exchange for a protected, stable environment and nutrients they need for growth. Lichens are an alliance of fungi and algae that allows each to grow in environments where neither could survive alone, like deserts, rocks, or tree bark.	

d. Click on the links below the **Archaea** link and then for the **Microbes** in part B above in grey and fill out the table below. Do the same for the links underneath the bacteria, fungi and viruses links.

Microbe type	What they look like	Where they are found	What they eat	How they move
Archaea	Some archaea look like little rods or tiny balls Like bacteria, archaea lack a true nucleus. Both bacteria and archaea usually have one DNA molecule suspended in the cell's cytoplasm contained within a cell membrane. Most, but not all, have a tough, rigid outer cell wall.	Hydrothermal vents and sulfuric waters	hydrogen gas, carbon dioxide and sulfur. One type of salt-loving archaean uses sunlight to make energy, but not the way plants do it.	some get around like bacteria, using long hair- or whip-like appendages called flagella that stick out of their cell walls and act like a microscopic outboard motor to get them where they are going.
Bacteria	There are thousands of species of bacteria, but all of them are basically one of three different shapes. Some	Bacteria can be found virtually everywhere. They are in the air, the soil, and water, and in and on plants and animals, including	Some bacteria are photosynthetic *(foe-toe-sin-theh-tick)* — they can make their own food from sunlight, just like	Some bacteria have hair- or whip-like appendages called flagella used to 'swim' around. Others produce thick

	are rod- or stick-shaped and called bacilli *(buh-sill-eye)*. Others are shaped like little balls and called cocci *(cox-eye)*. Others still are helical or spiral in shape.	us.	plants. Also like plants, they give off oxygen. Other bacteria absorb food from the material they live on or in. Some of these bacteria can live off unusual "foods" such as iron or sulfur. The microbes that live in your gut absorb nutrients from the digested food you've eaten.	coats of slime and 'glide' about. Some stick out thin, rigid spikes called fimbriae to help hold them to surfaces. Some contain little particles of minerals that orient with the planet's magnetic fields to help the bacteria figure out whether they're swimming up or down.
Fungi	Fungi are eukaryotic organisms. This means that their DNA-containing chromosomes are enclosed within a nucleus inside their cells. (The chromosomes of bacteria and archaea are not walled off inside nuclei, making them prokaryotic organisms.)	Fungi can be found in rising bread, moldy bread, and old food in the refrigerator, and on forest floors. Most decompose non-living things, but some damage crops and plants. A few cause problems in people, such as *Candida*, which causes yeast infections.	Fungi absorb nutrients from living or dead organic matter (plant or animal stuff) that they grow on. They absorb simple, easily dissolved nutrients, such as sugars, through their cell walls. They give off special digestive enzymes to break down complex nutrients into simpler forms that they can absorb.	Fungi are basically static. But they can spread either by forming reproductive spores that are carried on wind and rain or by growing and extending their hyphae.

e. Fill out the following table on Protista by clicking on the links underneath in grey.

Sub-Types and description of Protist	Give description of types of sub-types	List at least 2 interesting facts about the Sub-type
Algae	Green Algae: The most clearly plant-like algae, this species gets its namesake hue from high levels of chlorophyll.	Answers will vary
	Dinoflagellates: Dinoflagellates have long whip-like structures called flagella that let them turn, maneuver and spin about through the water. About 90% of these algae dwell in the ocean.	
	Diatoms: These algae hardly look like plants, but more like flying saucers, tiny canoes or cigars, lobed leaves, the undersides of mushroom caps, striated ribbons, or filigreed Christmas ornaments. Whatever their shape, all diatoms have shell-like, brittle cell walls made out of silica (glass) and pectin. The walls are two interlocking halves or shells that fit together like a pillbox.	
Protozoa	Apicomplexans: These protozoa are obligatory intracellular parasites: they must spend at least part if not all of their life cycle in a host animal. Apicomplexans are characterized by the presence of special organelles (tiny organ-like structures) located at the tips (apices) of the cells. These organelles contain enzymes that punch through, slice open and otherwise penetrate host tissues.	Answers will vary
	Ciliates: Ciliates are covered in part or entirely with what look like little bristles called cilia	
	Flagellates: Similarly complex single-celled organisms, flagellates have whip-like	

	appendages called flagella sticking out of their cells. Sarcodinia: This subgroup of protozoa includes the familiar shape-shifting amoebas, as well as heliozoa, radiozoa, and foraminifera (or forams for short). Sarcodina are best known for their pseudopods ("false feet") used for locomotion and feeding.	
Slime molds	No further sub-types	Slime molds have traits like both fungi and animals. They have very complex life cycles involving multiple forms and stages. During good times, they live as independent, amoeba-like cells, dining on fungi and bacteria. But if conditions become uncomfortable — not enough food available, the temperature isn't right, etc. — individual cells begin gathering together to form a single structure. This happens when the cells give off a chemical signal that tells all of them to gather together. The new communal structure produces a slimy covering and is called a slug because it so closely resembles the animal you sometimes see gliding across sidewalks. The slug oozes toward light. When the communal cells sense that they've come across more food or better conditions, the slug stops. It then slowly does a kind of headstand. Cells in the slug now begin to do different things. Some of the cells form an anchor for the upended slug. Others in the middle of the slug begin making a stalk and some at the tip turn into what's called a spore cap and others become spores in that cap. When a

		drop of rain or strong wind knocks the spore cap hard enough, the spores go flying out. These spores are like plant seeds. Each of them becomes a new amoeba-like cell when they land and each goes off on its merry way.
Water molds	No further sub-types	Officially named Oomycota, they are also known as downy mildews and white rusts. Water molds were long considered fungi because they produce fungi-like filamentous hyphae and feed on decaying tissue like rotting logs and mulch. The Oomycota species *Phytophthora infestans* caused the Great Potato Famine that killed nearly a million people in Ireland in 1846–1847. The water mold virtually wiped out the country's potato crops, which were an essential staple in the Irish diet (sometimes the only food on the table.) In addition to widespread starvation and malnutrition, the potato blight led more than 1.5 million Irish to flee the country. Because nearly all of the country's potato crops were clones of a few original imports from South America, they had no natural ability to resist the pathogen. Another water mold nearly wiped out the entire French wine industry. *Plasmopara viticol* (also known as downy mildew of grapes) was brought to Europe in the late 1870s on vines from America meant to be bred with French vines in hopes of yielding hybrids with a greater ability to ward off attacks by aphids. The infestation led to the use of the first fungicide, a mixture of copper sulfate and lime,

		which became known as the Bordeaux mixture for its role in saving the French vines. Other water mold species can cause disease in fish.

2. Click on the **Where They Live?** link on the top under meet the microbes or to the left hand side. Answer the following:
   a. *Name at least three places microbes live.*

   Microbiologists have found microbes living just about everywhere: in the soil, water, and air; in animals, plants, rocks and even in us! Examples: Inside us, hydrothermal vents, hot springs, etc.

   b. *Can you think of any places that microbes might not live?*

   They are EVERYWHERE!

3. Click on the **Discovery Timeline** link at the top under meet the microbes or to the left hand side.
   a. Using the timeline, place major discoveries on the table below.

Time Period	**List of major discoveries and/or events**
1870s-1880s	See: http://www.microbeworld.org/microbes/timeline1.aspx and print timeline!
1890s-1900s	
1910s – 1920s	
1930s -1940s	
1950s – 1960s	
1970s – Present	

   b. What do you think was the most important event and why?

Answers will vary. Look for good support.

4. Click on the **Tools and Techniques** link at the top of the page underneath **Meet the Microbes** or to the left-hand side. Fill out the table below. You may include drawings or pictures of the tools/techniques in your description or definitions.

Tool or Technique	**Description or definition of tools or techniques and why they are important (e.g., function)**
Microscopes: light and electron	Microscopes are to microbiology what telescopes are to astronomy. The earliest microscopes were simple instruments consisting of one or more crude glass lenses similar to those used to make early spectacles. The invention of the first true microscope is credited to the Jansen family of Middleburg, Holland, around 1595. Later, in the 17th century, Dutch cloth merchant and amateur scientist Anton van Leeuwenhoek enlightened the world to what he dubbed "animacules" such as protozoa found in standing water. Using microscopes he made himself, Leeuwenhoek wrote up what he viewed in pond water, plant material, even gunk scraped off his teeth. He was the first to identify sperm and red blood cells. There are two basic types of microscopes: light microscopes and electron microscopes. **Light microscopes:** Light microscopes can magnify an object up to 1,000 times. Good light microscopes are powerful enough to view most algae, fungi, and protozoa. High-quality light microscopes generally allow viewing of bacterial cells, too. They can't view viruses, however, as these tiny objects are smaller than a wavelength of visible light (about 0.2 microns). Nor can they readily allow scientists to examine individual tiny parts of cells in detail. To view extremely tiny objects, scientist use electron microscopes. **Electron microscopes:** Electron microscopes

Tool or Technique	Description or definition of tools or techniques and why they are important (e.g., function)
	use streams of electrons instead of light to create images. Scientists don't see the images directly through lenses as they do with light microscopes. Instead, the machinery of the electron microscope generates a picture on a TV or computer screen. There are three types of electron microscopes: transmission electron microscopes (TEM), scanning electron microscopes (SEM) and scanning-tunneling electron microscopes (STM). TEMs transmit electron beams through a thin section or slice of a specimen to create an image. TEMs are particularly useful for studying the insides of cells. With SEMs, the specimen is usually coated with an ultra-thin layer of gold atoms. The electron beam scans over the surface of the specimen, exciting electrons on the surface. When these surface electrons are emitted (as secondary electrons), they are collected by special devices that create an image out of them. SEMs are especially useful for studying the surfaces and structures of cells. With their great depth of field, SEMs produce 3-D images. STMs can display things as infinitesimal as the individual atoms on an object's surface. They scan specimen surfaces in the same way as SEMs, but they use an electrically charged tip that is placed within nanometers of the surface of the specimen. Electrons "jump" between the tip and the specimen surface in what's called the tunneling current, hence the name of this kind of microscope. As the tip is moved back and forth across the specimen, the current varies according to whether the tip is right over an atom or over the space or trough between atoms. A computer creates an image based on these differences in current.

Tool or Technique	Description or definition of tools or techniques and why they are important (e.g., function)
Culture equipment: Petri plates and flasks; culture media; pipettes and swabs	When microbiologists want to identify microbes in a sample or study microbes in-depth, they often try to culture, or grow, the microbial cells in their labs. The scientists can then manipulate the cells or their environments to see what effects these changes have on the organisms. Petri plates are clear glass or acrylic dishes with lids that fit together like the two halves of a pillbox. Nutrients in either solid or liquid form can be put in them. Flasks are glass or acrylic bottle-like containers that can hold nutrients in liquid form. Microbes require nutrients to grow. These are supplied by either solid or liquid culture media. The standard solid medium is nutrient agar, a gelatinous substance derived from seaweed. The basic liquid medium is nutrient broth, typically a mix of water, meat extract peptone, and sodium chloride. Some microorganisms are more finicky than others and require media enriched with growth-promoting ingredients such as animal blood, glucose or egg. Examples of commonly used enriched media are blood agar, chocolate agar, and Loeffler medium. Microbiologists also sometimes use special media called differential media that contain various chemicals designed to distinguish microbes by the appearances their colonies take on as they grow. Pipettes combine the workings of a straw and a syringe in one instrument. Scientists use them to draw up liquids from one vial, flask, or other container and squirt them in measured amounts into another flask, test tube, or other vessel. Microbiologists use inoculating loops or swabs principally to inoculate Petri plates with microbial cells. Loops are thin pieces of metal shaped into a small loop at one end. To inoculate a plate, a microbiologist would first sterilize the tip of the swab or loop. Then he

Tool or Technique	Description or definition of tools or techniques and why they are important (e.g., function)
	would dip or rub the loop over a contaminated surface or in a prepared sample. He then brushes the tip of the swab or loop across the nutrient agar in a plate in a series of zig-zag patterns. The zig-zagging pattern causes microbial cells to be laid down in smaller clusters, allowing distinct and separate colonies to grow.
Genetic Tools and Techniques: PCR; genes and genome sequencing; 16s RNA; microarrays	PCR allows scientists to extract and analyze bits of microbial DNA from samples, meaning they don't need to find and grow whole cells. PCR is an essential element in DNA fingerprinting and in the sequencing of genes and entire genomes. Basically, it's like a technique to photocopy pieces of DNA. In a matter of a few hours, a single DNA sequence can be amplified to millions of copies. Scientists also use molecular tools to extract and compare bits of a particular kind of RNA from samples in order to determine if previously known or new microbes are present in a particular environment. This technique is widely used as a biomarker and for microbial ecology studies. It uses a particular kind of RNA known as 16S ribosomal RNA, or 16S rRNA. Ribosomes are the gene-translating machines in all living things. When a gene on a piece of DNA is copied into a strand of messenger RNA and ferried out of the cell nucleus into the cell fluid, ribosomes there latch onto this mRNA. The ribosomes move along the mRNA strand, reading the code contained in its sequence of nucleotide bases (the As, Gs, Cs, and Us, since U replaces T in RNA) and stringing the right amino acids together based on the code to build protein chains. Scientists also use sequencing to spell out from start to end every single nucleotide in an organism's DNA — its entire genome. Gene and genome sequencing involve a variety of computers, software programs, automated sequencing machines, fluorescent dyes, lasers,

Tool or Technique	Description or definition of tools or techniques and why they are important (e.g., function)
	and other tools. The development of machines that can quickly chop up, separate, realign, and read bits of DNA have greatly speeded up the sequencing process. What used to take a person working by hand to do in a year can now be done by machines in just a few hours. Scientists use gene and genome sequences to precisely compare and differentiate organisms. If a microbiologist is studying bacteria that bioremediate, or break down, toxic wastes and wants to know which specific genes are active when that bacterium is degrading, say, PCBs, he would likely use a tool called the DNA microarray. Microarrays enable scientists to monitor the activities of hundreds or thousands of genes at once. All microarrays (also called DNA chips or gene chips) work on the basic principle that complementary nucleotide sequences in DNA (and RNA) match up like the two halves of a piece of Velcro® coming together. A microarray consists of an orderly arrangement of bits of genetic material in super-tiny spots laid down in a grid on a suitable surface, often a glass slide with a specially chemically treated surface.

5. Click on the **Did You Know?** link at the top of the site, and then on the **Gross … you didn't wash your hands** link. Answer the question of whether you always wash you hands after going to the bathroom.

    a. What are the results? Why do you think the reported answer from this website is so much higher than the observations made of people actually using the bathroom?

    Answers will vary, but look for good rationale of why the answers are different.

b. Why is it so important to wash your hands? When should you wash your hands?

You carry millions of microbes on your hands. Most are harmless, but you can pick up some that cause illnesses, such as colds, flu, and diarrhea. When we forget to wash our hands, or don't wash them properly, we can spread these germs to other people, or give them to ourselves by touching our eyes, mouths, noses or cuts on our bodies.

c. Take the wash your hands quiz.

d. Click on the **www.washup**.org link and list any interesting information below.

Answers will vary.

6. Go to two other places on this site and fill out the table below. You will have to create two interesting questions with the answers regarding the information at each of the two links. Be creative!

Link Map: link(s) you went to	**1st Question: about link information**	**Answer to 1st question**	**2nd Question: about link information**	**Answer to 2nd question**
Answers will vary				
Answers will vary				