



Independent Investigations in Infectious Disease

During this activity you will conduct an independent investigation in 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 a hypothesis (possible answer) to the question.
3. Make testable predictions based on the 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.
8. Additional conclusions.
9. Present your investigation to the class.

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 will necessitate redesign of steps 1 – 4 without completion of steps 6-8.

Read through steps 1 – 4 before beginning.

Step 1 - Choose a question - Working as a group, brainstorm questions you would like to answer. You can either propose your own questions, or use any of the questions provided below.

How do the number and variety of bacteria compare between

- Different areas of skin (lips, extremities, belly button)?
- The mouths of smokers vs non-smokers?
- The armpits of men vs women?
- The environment versus the human?

How resistant are bacteria from your body to antibiotics or spices?

Which environmental locations contain a larger number or variety of bacteria

Door knobs, toilet seat, table top, water faucet, etc?

How do the number and variety of bacteria compare between

- Washed and unwashed hands?
- Hands washed with regular vs anti-bacterial soaps?
- Hands washed with soap vs cleaned with rubbing alcohol?

After you have a list of questions you have brainstormed - choose one of your questions to answer during this investigation. When choosing which question you will answer, keep the following in mind -

- Is the question one that can be answered using the scientific method?
- In order for you to use scientific method to answer a question, there must be a way to make predictions. For example, questions that are opinions or preferences can no be answered using the scientific method.
- Is there a way to measure whether or not your predictions are met?
- Is this a question that you do not yet know the answer to and which would tell you something interesting or useful?
- Can the question be answered using the materials available in the classroom? Your teacher will give you a list of supplies and materials you can use.
- Does your teacher feel this question is appropriate and safe to answer in the classroom?

Write your question in the space below

Step 2 – Hypothesis Formation

Design a hypothesis 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 you do not know in advance whether your hypothesis will be correct or not, and educated because you base it on the knowledge you already have.

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 falsify 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 hypothesis (or hypotheses) below.

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.

For example – for 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 falsify) a hypothesis, the better.

Write your prediction(s) 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 will you take?

Who and/or where will you take them from?

How many places and/or individuals will you test?

For example for the hypothesis we have been working with we might decide to have five people wash their right hand but not the left hand. We could then swab the palms of each hand. We could then streak the swabs onto a plate.

Or, we could have 5 people wash their left thumb but not the right thumb. We could then have each person touch their thumbs onto a plate.

What type of media will you use?

If you wanted to look at most bacteria you could use LB plates.

If you wanted to distinguish between coliforms and non coliforms you could use EMB plates.

How will you measure the variety of bacteria?

Colony morphology?

Gram staining?

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?

For the above example, we might want to use an uninoculated swab to streak a plate to be sure the swabs and plates are not contaminated.

If you are using a differential medium or stain, include a known positive reaction and a known negative reaction to be sure the medium or stain is working as expected.

Note that as you design your experiment, you may find that you can not answer the questions you originally set out to answer. If this is the case, you can modify your question, hypothesis, and predictions, or choose a new question. It does not indicate a failure to have to choose a new question. Rather, it is a success and the sign of a great scientist to recognize that the question was inappropriate and redesign it.

On a separate piece of paper – write out an experimental design

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 to hand in. For now, however, it is important to keep your 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 performed.

Be sure the results are clearly labeled and dated so that later you will know what the results refer to.

Be sure to include the results of controls.

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

Step 6 - Analyze data

A good 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 for the experiment proposed above you could summarize your results in a table something like this.

	Colonies from unwashed thumb	Colonies from washed thumb
Person 1	20	17
Person 2	15	20
Person 3	2	0
Person 4	35	19
Person 5	19	20

After organizing your data, you will want to perform some calculations or graphs to see if your data support or falsify your hypothesis.

It might be useful to add a column showing the change in number of colonies following thumb washing. It could also be useful to calculate an average.

	Colonies from unwashed thumb	Colonies from washed thumb	Change in number of colonies after thumb washing
Person 1	20	17	-3
Person 2	15	20	+5
Person 3	2	0	-2
Person 4	35	19	-16
Person 5	19	20	+1
Average	18.2	15.2	

Statistics – In a real scientific setting, in order to determine whether your data support or falsify 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://www.Colorado.EDU/Research/hughes/usersguide.pdf>.

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 falsify 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 that we have not yet tested.

Hypotheses can however be falsified. Results can definitely show that a hypothesis is false. Note that it is not considered bad or a failure to prove a hypothesis false. By proving a hypothesis false, you eliminate one possible answer to your question. Further you add to support to other competing hypotheses. Scientists add support to their hypotheses by proving competing hypotheses (other answers to the same question) false.

Often the results of an experiment neither support nor falsify a hypothesis. There are many ways in which this happens.

- Controls show that one or more of the reagents were not working.
- Controls show that 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), redesign the experiment (if it is not answering the intended question), or sometimes even to rethink the question and hypothesis. As was the case with falsifying 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.

Below write a brief paragraph summarizing how your results support or falsify your hypothesis. You should also include how you would repeat or redesign your experiment to answer the intended question. Or if necessary, write a new question and hypothesis.

Step 8 – Additional conclusions

Your first major conclusion was whether your results supported or falsified your hypothesis, or if neither, what you needed to change in your experiments.

Some additional things to consider when reporting your conclusions

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.

What experiments could you perform to help clear up or explain any unexpected results?

What new questions did the results bring up?

What would you do next if you were to continue this work?