Scientific Investigation

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CHAPTER 1 Scientific Investigation

- Define and describe the scientific method.
- Summarize the characteristics of a scientific hypothesis.
- Develop a scientific hypothesis.
- Explain the importance of communicating results.

How do scientists obtain new knowledge?

All the information in textbooks had to come from somewhere. In the sciences, new information about the natural world is a result of scientific investigations. These investigations are shaped by the scientific method.

Scientific Method

The **scientific method** is a process used to investigate the unknown (**Figure** 1.1). It is the general process of a **scientific investigation**. This process uses evidence and testing. Scientists use the scientific method so they can find information. A common method allows all scientists to answer questions in a similar way. Scientists who use this method can reproduce another scientist's experiments.

Almost all versions of the scientific method include the following steps, although some scientists do use slight variations.

1. Make observations.
2. Identify a question you would like to answer based on the observation.
3. Find out what is already known about your observation (research).
4. Form a hypothesis.
5. Test the hypothesis.
6. Analyze your results and draw conclusions.
7. Communicate your results.

Making Observations

Imagine that you are a scientist. While collecting water samples at a local pond, you notice a frog with five legs instead of four (**Figure** 1.2). As you start to look around, you discover that many of the frogs have extra limbs,

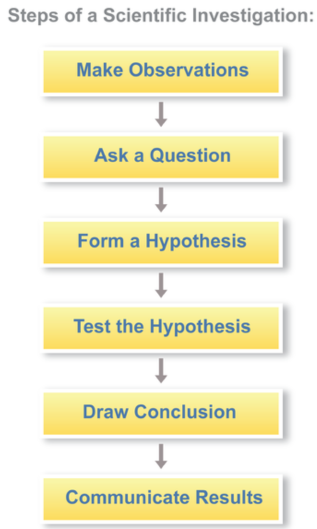

FIGURE 1.1
Steps of a Scientific Investigation. A scientific investigation typically has these steps.

extra eyes, or no eyes. One frog even has limbs coming out of its mouth. These are your **observations**, or things you notice about an environment using your five senses.

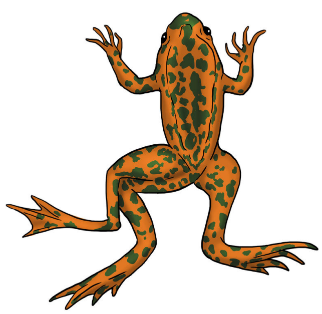

FIGURE 1.2
A frog with an extra leg.

Identify a Question Based on Your Observations

The next step is to ask a question about the frogs. You may ask, "Why are so many frogs deformed?" Or, "Is there something in their environment causing these defects, like water pollution?" Yet, you do not know if this large number of deformities is "normal" for frogs. What if many of the frogs found in ponds and lakes all over the world have similar deformities? Before you look for causes, you need to find out if the number and kind of deformities is unusual. So besides finding out *why* the frogs are deformed, you should also ask: "Is the percentage of deformed frogs in this pond greater than the percentage of deformed frogs in other places?"

Research Existing Knowledge About the Topic

No matter what you observe, you need to find out what is already known about your questions. For example, is anyone else doing research on deformed frogs? If yes, what did they find out? Do you think that you should repeat their research to see if it can be duplicated? During your research, you might learn something that convinces you to change or refine your question. From this, you will construct your hypothesis.

FIGURE 1.3
A pond with frogs.

Construct a Hypothesis

A **hypothesis** is a proposed explanation that tries to explain an observation. A good hypothesis allows you to make more predictions. For example, you might hypothesize that a pesticide from a nearby farm is running into the pond and causing frogs to have extra legs. If that's true, then you can predict that the water in a pond of non-deformed frogs will have lower levels of that pesticide. That's a prediction you can test by measuring pesticide levels in two sets of ponds, those with deformed frogs and those with nothing but healthy frogs. Every hypothesis needs to be written in a way that it can:

1. Be tested using experiments to collect evidence.
2. Be proven wrong.
3. Provide measurable results.
4. Provide yes or no answers.

For example, do you think the following hypothesis meets the four criteria above? Let's see. Hypothesis: "The number of deformed frogs in five ponds that are polluted with chemical X is higher than the number of deformed frogs in five ponds without chemical X." Of course, next you will have to test your hypothesis.

Test Your Hypothesis

To test the hypothesis, an **experiment** will be done. You would count the healthy and deformed frogs and measure the amount of chemical X in all of the ponds. The hypothesis will be either true or false. Doing an experiment will test most hypotheses. The experiment may generate evidence in support of the hypothesis. The experiment may also generate evidence proving the hypothesis false. Once you collect your data, it will need to be analyzed.

Analyze Data and Draw a Conclusion

If a hypothesis and experiment are well designed, the experiment will produce results that you can measure, collect, and analyze. The analysis should tell you if the hypothesis is true or false. Refer to the table for the experimental results (**Table** 1.1).

TABLE 1.1: Deformed Frog Data

Polluted Pond	Number of Deformed Frogs	Non-Polluted Pond	Number of Deformed Frogs
1	20	1	23
2	23	2	25
3	25	3	30
4	26	4	16
5	21	5	20
Average:	23	Average:	22.8

Your results show that pesticide levels in the two sets of ponds are different, but the average number of deformed frogs is almost the same. Your results demonstrate that your hypothesis is false. The situation may be more complicated than you thought. This gives you new information that will help you decide what to do next. Even if the results supported your hypothesis, you would probably ask a new question to try to better understand what is happening to the frogs and why.

Drawing Conclusions and Communicating Results

If a hypothesis and experiment are well designed, the results will indicate whether your hypothesis is true or false. If a hypothesis is true, scientists will often continue testing the hypothesis in new ways to learn more. If a hypothesis is false, the results may be used to come up with and test a new hypothesis. A scientist will then communicate the results to the scientific community. This will allow others to review the information and extend the studies. The scientific community can also use the information for related studies. Scientists communicate their results in a number of ways. For example, they may talk to small groups of scientists and give talks at large scientific meetings. They will also write articles for scientific journals. Their findings may also be communicated to journalists.

If you conclude that frogs are deformed due to a pesticide not previously measured, you would publish an article and give talks about your research. Your conclusion could eventually help find solutions to this problem.

Discovering the Scientific Method

A summery video of the scientific method, using the identification of DNA structure as an example, is shown in this video by MIT students: https://www.youtube.com/watch?v=5eDNgeEUtMg .

Summary

- To study new problems, scientists use the scientific method; this includes making observations, forming a hypothesis, designing an experiment, and drawing conclusions.

Explore More

Use the resource below to answer the questions that follow.

- **Control Variables** at http://www.youtube.com/watch?v=hjCvIbYoi-w (7:05)

MEDIA

Click image to the left or use the URL below.

URL: http://www.ck12.org/flx/render/embeddedobject/57464

1. What is the difference between a dependent and an independent variable?
2. How many dependent variables do you want in an experiment?
3. What are control variables?
4. Why are control variables important?

Review

1. What steps are usually included in the scientific method?
2. What are the features of a good hypothesis?
3. Why is it important for a scientist to communicate the results and conclusions of a study?

References

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