Science and the Scientific Process

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WHAT'S COVERED

In this lesson, we are going to learn about science and the scientific process. We will examine science itself, the scientific method, the difference between laws and theories, and what scientific objectivity means. Specifically, this lesson will cover the following:

1. Descriptive and Experimental Science

Science is a process that humans use to understand their surroundings and how they work through testable experiments. It is a way of knowing how the natural world and our universe work. Science tries to do this by testing and explaining physical laws about the way the universe works.

In science, research is an important part of the process. And within it, there are two main categories: descriptive research and experimental research.

Type of Research	Description	Examples
Descriptive research	It is used to describe what is known about the world. It is most useful for analyzing relationships occurring in the real world but not for understanding causality.	Measuring the average rise (in feet) of global sea levels over the past 100 years Observing and recording the population distribution of a certain species of fish over 100 years in the Gulf of Mexico
Experimental research	It is great for drawing conclusions about causality. It is usually performed in a controlled situation, which allows scientists to observe relationships and causes of effects. It cannot fully represent reality because it is conducted in a controlled setting, which means that experiments do not always provide realistic results that explain the way the real world works.	Testing conditions that allow a certain invasive species to thrive in order to understand in what climates it will be a nuisance Experimenting on fish populations to understand the negative effects of oil spills and the technologies that might mitigate those effects

Both types of research are necessary and important forms of science. Each has its weakness. But they can often be complementary to each other. They help us understand the world around us and the factors that influence the way the world functions.

2. The Scientific Method

The scientific method is the foundation of science today, and it is made up of an iterative process of the steps described in the table below.

Step	Description
Observation	Scientists examine the way the world and the universe around them works.
Question Formulation	Once a scientist has observed a particular phenomenon, they will ask a question about that phenomenon, such as, why is the sky blue?
Research	Scientists will search for information in libraries and on the internet and discuss with peers. They gather as much information about the phenomenon as they can to try to answer the question.
Hypothesis	Scientists will formulate a hypothesis, which addresses the question, with a prediction about how the phenomenon works.
Testing	Scientists will use experimentation and other methods to test their hypothesis and their question.
Analysis	Scientists evaluate the data from their testing.
Conclusion	Based on the collected data and information, scientists determine whether their hypothesis was rejected or supported by the results and communicate their results to the wider scientific community.

Then the process is carried out again starting with observation first. The scientists eventually create a reliable and thorough body of research on that particular phenomenon in an iterative process.

Let's break this down with a real-world example.

IN CONTEXT

Observation: I watched a YouTube video about astronauts in space drinking water without gravity.

Question: Then I thought to myself, would two objects of different weight on Earth fall at the same speed if they were dropped from the same height?

Research: Then I Googled and found that there is a difference between mass and weight. Every bit of matter in space has a mass to it. But my weight is determined by the gravitational relationship between my mass and Earth's, as well as the distance between me and Earth.

Hypothesis: I predicted that the one with more weight would fall faster.

Testing: I went to the corner ice-cream shop and bought a double-scoop cone of ice cream. I walked outside and pulled out a paper clip. I held the ice-cream cone and the paper clip out in front of me at the same height and dropped them.

Analysis: I watched them both hit the ground at the same time.

Conclusion: I discovered that my hypothesis was wrong. Even though the ice-cream cone had more weight than my paper clip, they both hit the ground at the same time. I concluded that I needed to do more research on gravity.

I watched a few informational YouTube videos and read a few informational papers, and I discovered that while gravitational force is determined by mass and distance, acceleration due to gravity is determined by aerodynamics and resistance. The fact that I dropped those two objects at such a low height meant that the differences in their aerodynamics were negligible. And so their acceleration due to gravity was virtually the same to the naked eye.

This last bit begins the process again, as I might next try to drop two objects from an airplane to see if their aerodynamics affect which one reaches the ground first.

The scientific method is incredibly useful but not for every situation. There are some large-scale issues that might be too complicated to design an experiment for, such as trying to answer the question, "What would happen if Moon crashed into Earth?"

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3. Physical Laws and Scientific Theories

There is a difference between scientific theories and physical laws.

Physical laws are things that apply universally in nature. They are fixed and do not change.

> ↱ EXAMPLE Consider Sir Isaac Newton's law of gravity, which states that any two bodies in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. This is something that, at least at this point in history, is immutable and constant in nature.

Scientific theory is a collection of observations that fit together in a broader picture. Scientific theories are usually thoroughly tested, but cannot be proven, only supported. However, they can be disproven. They also can be changed and revised as new information is gathered. Scientific theory is different from the common use of the word **theory** in everyday language because scientific theory is backed up by significant research.

> ↱ EXAMPLE Consider the ancient scientist Ptolemy's theory that Earth was at the center of our solar system. This knowledge was used to predict the movement of celestial bodies. Repeated observation of celestial objects and calculations from retrograde motion supported this theory for 1,500 years until it was eventually disproved in Copernicus's time. It was replaced by the theory that the sun is at the center of our solar system. The Copernican theory that replaced it was simpler, more accurate, and required fewer assumptions about the way the universe worked than Ptolemy's theory.

TERM TO KNOW

Theory

A collection of observations that fit together into a broader picture.

4. Scientific Objectivity

In science, the goal of objectivity is paramount, meaning that preventing personal bias, opinions, and interests from influencing thinking, interpretation, and/or reported findings is important.

↱ EXAMPLE Think about two people who are talking about nuclear energy. They might arrive at the same conclusion through subjective and objective thinking. Person 1 might say, "I have a cousin who works in a nuclear power plant. And she gets sick all the time. Plus, I hate how ugly the plant is when I drive by. Nuclear power is dangerous." This is subjective thinking.

Person 2 might say, "According to research from a credible source, I discovered that people who work in nuclear facilities or manage the radioactive waste they produce are significantly more at risk to certain forms of cancer. Nuclear energy, if not properly managed, can prove more dangerous to human health than we think." This is objective thinking.

SUMMARY

In this lesson, we differentiated between **descriptive and experimental science**, learned what **the scientific method** is, understood the difference between **physical laws and scientific theories**, and what **scientific objectivity** is. And don't forget our key term for today, “scientific theory,” which is a collection of observations that fit together into a broader picture.

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TERMS TO KNOW

Theory

A collection of observations that fit together into a broader picture.