Name: ______________________________ Date: ____________________

Guided Learning: Evaluating Scientific Explanations (Part 2)

Plausibility
When determining the plausibility of an explanation, the first question a scientist asks is "How well does the explanation fit with established scientific theories?" At any given point in time, most scientists believe the prevailing theories about how the universe works. This is one critical way that science differs from many other subjects. For example, many economists believe one policy will be good for the country, and another large group of economists believe a different policy will lead to good results.

It is much less common in science for a large group of scientists to disagree with the prevailing theory on a topic, so any explanation that does not fit well with established theory has a major strike against it.

Quick Check: How does this relate to the first scenario from part I, where your cousin dropped a rock into ice water, and the ice water clouded up?

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Sometimes this means a good explanation is ignored because another theory is wrong. For example, light waves have a property called "polarization," which refers to their orientation in space. The lenses of some sunglasses absorb light tilted at one angle better than another, so if you rotate the lenses the view becomes lighter or darker. In the early 19th century, physicists did not have a satisfactory explanation for polarization. In 1821, Augustin-Jean Fresnel proposed a theory explaining polarization, but it did not fit the established beliefs of scientists at that time.

The physicists of his day thought everything—both light and matter—was composed of tiny particles called corpuscles that obeyed certain laws of motion. This was based on Isaac Newton's revolutionary views described in his *Principia* and *Opticks*. This theory did not fit Fresnel's explanation because Fresnel proposed that light traveled as a wave rather than as stream of particles. Even though Fresnel's theory passed experimental tests and reliably explained polarization and other phenomena of light, it was not accepted until Newton's theory of light was rejected decades afterward.

The degree to which an explanation matches established science is not the only factor used to judge its plausibility. Scientists also consider how much the theory relies on claims that cannot be directly confirmed. For example, scientists in Europe had mixed reactions to Newton's system of motion because Newton's theory required one to believe an invisible force existed between any two masses. Newton gave no explanation for this force, and scientists of his day failed to find any such force when they tested the hypothesis in their labs. This was a major stumbling block for scientists because the then-current theories of motion based on Galileo

Galilei’s and Christiaan Huygens’ work required no such faith in an unobserved, unexplained force.

In general, scientists have more confidence in explanations that have the fewest unconfirmable assumptions. This preference is often called **Ockham’s razor** or the **principle of parsimony**.

Quick Check: How does Ockham’s razor relate to the explanation given for Katrina Richard’s absence?

A third category used to judge an explanation’s plausibility is how well it matches observational evidence. Surprisingly, it is not important that a new theory match all observational evidence; in fact, practically no theory in the history of science perfectly matched all data when first proposed.

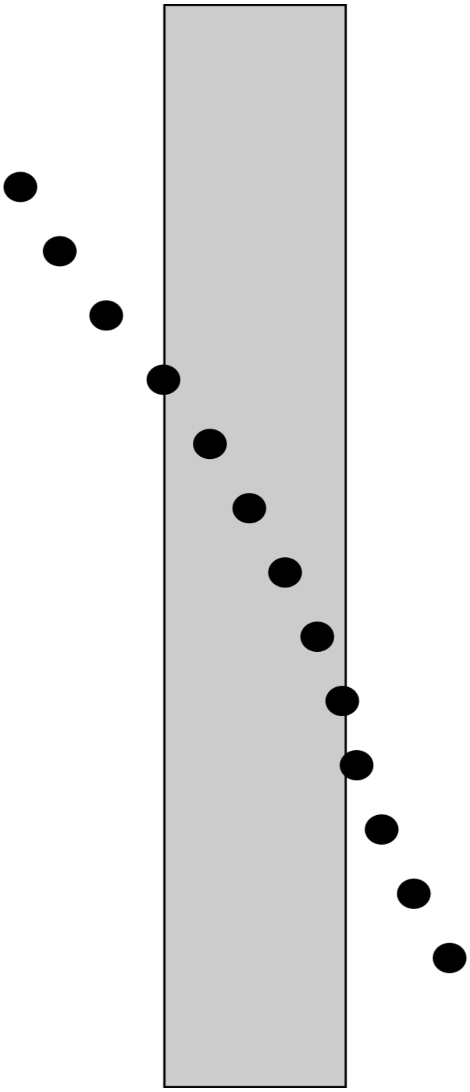
When a theory does not match an observation, it is not always clear whether the fault lies in the theory itself, the way the theory was applied, or the way the observations were interpreted. For example, consider your mother’s response to your explanation for why the zipper felt cold. It is reasonable to presume that the zipper felt colder than the cloth (even though they were the same temperature) for the same reason that other objects sometimes feel very hot. For example, a seat belt buckle is the same temperature as the cloth seats in a car, but the seat belt will often feel much hotter. Then your mother applied this idea to aluminum foil in an oven and found a situation where the explanation did not match her observation. Given that the foil is made of metal and had been in a very hot oven for 10 minutes, one would expect it to burn the skin according to your explanation, but it doesn’t.

In this case your explanation was correct and your mother made an error in how she applied it. Aluminum foil is incredibly thin and light, so the amount of heat it can send into your skin is limited. This is why it does not feel nearly as hot as the much thicker iron bars in your oven.

Furthermore, a new explanation is often like a first draft of an essay. It is a basic idea that can be revised or refined. Often a new theory is the work of a single person or small group with limited data, equipment, and funding. If the theory looks promising, more scientists can start to work with it and polish it.

For these reasons, theories are not greatly penalized when they fail to match observations unless the discrepancy is so basic that there appears no way to emend the theory. Very often these apparent mismatches between theory and observation turn out to be instances where the theory was misapplied. For example, for over half a century after Newton proposed his system of motion, it gave the wrong answer when used to calculate the orbit of Earth’s moon. The problem was not with Newton’s theory. The problem was that scientists were not using it correctly. (In particular, they failed to adequately account for the gravitational pull of the Sun.)

Occasionally the opposite occurs. A mismatch between theory and observation turns out to be due to a flaw in the theory. Most of the time, these mismatches are tolerated as long as scientists have reason to believe that the theory can be corrected. For example, Newton's theory of light depended on the claim that light travels faster in water than in air. He claimed light appeared to bend when passing through a glass because the glass attracted the light particles, causing an acceleration in the direction of the glass without accelerating them in the direction perpendicular to the surface. This is illustrated at right. The particles move down at a constant velocity, but their horizontal velocities are tugged toward the glass. This acceleration meant the particles had to be moving fastest while within the glass.



With this assumption, Newton was able to explain refraction using his laws of motion. Newton's theory ran into difficulty in the early 19th century because it did not match other observations scientists made about light, including polarization, diffraction, and interference. However, these discrepancies did not cause scientists to abandon Newton's theory because there was some hope that a modification of his theory could account for these phenomena.

The situation changed when Jean Bernard Léon Foucault showed in 1850 that light travels more slowly in water than in air. This disproved a critical assumption in Newton's theory. The claim that light moves faster through water than through air was considered so important to Newton's theory of light that scientists considered the theory unsalvageable after Foucault's discovery.

Recap

Scientific theories can be evaluated based on their reliability and their plausibility.

A reliable theory:

- has had its predictions validated by testing.
- makes clear predictions about scenarios rather than only explaining data after the fact.
- makes predictions in a wide range of contexts so it can be tested in many different ways.

A plausible theory:

- is compatible with accepted theories in other fields of science.
- has few unconfirmable assumptions.
- matches observational data.

Venus' atmosphere reflects sunlight to observers on Earth much like the Moon does. For someone on Earth to see Venus as a full circle, the Sun, Earth, and Venus must be nearly aligned with either the Sun at the center or the Earth at the center.

In 1610, Galileo made one of the most important observations in the history of astronomy. Through his telescope, he found that Venus exhibits a complete set of phases, much like the Moon. Astronomers knew that Venus was never on the opposite side of the Earth from the Sun because it was never seen in the midnight sky. However, the established model for the solar system did not allow Venus to be on the opposite side of the Sun either. It always called for Venus to be roughly in between the Sun and Earth. Thus, Galileo's discovery that Venus sometimes shows up as a full circle in the sky was similar to Foucault's observation that light travels more slowly through water than in air. It was so damaging to the prevailing theory that scientists did not consider the theory salvageable.

There was great disagreement about which alternate theory should take the old theory's place. Most scientists supported one of three systems:

- Copernicus' system placed the Sun at the center of the solar system, and the motion of each planet was based on a collection of circles linked together and built up on top of one another.
- Tycho Brahe claimed the planets went in circles around the Sun, which itself went in a circle around the Earth.
- Kepler claimed the planets moved in ellipses around the Sun.

Use library and Internet resources to evaluate these three theories based on the criteria for reliability and plausibility described in this unit. *You should evaluate these theories from the perspective of an early 17th-century astronomer, based on what the scientists of that time knew or thought to be true*.

Your evaluation should be 2–3 pages long and correctly cite the sources you used.

Do not use any source whose author you cannot identify. For any source you use, indicate why the source is reliable. Use multiple sources to verify the facts in your analysis.