Paradigms Lost

Required Reading

Barash, D.P. (2015, October 27). Paradigms Lost. Aeon. Retrieved from

https://aeon.co/essays/sceince-needs-the-freedom-to-constantly-change-its-mind

Learning Outcomes and Connections to Course Outcomes

After completing this lesson, you will be able to:

- Describe the nature of the scientific approach to knowledge.
- Critically evaluate our obligation we have to try to understand the world accurately.
- Describe the nature of the scientific approach to knowledge.
- Identify key elements of the scientific method.
- Critically evaluate the obligation to understanding the world accurately by discussing scientific and pseudoscientific claims.
- Identify a paradigm shift in science and explain what these shifts imply for the development of the scientific method.
- Describe the sociological consequences of paradigm shifts.

Main Topics

- Science
- The Scientific Method
- Paradigm Shifts
- Science vs. Pseudoscience
- Falsification
- Objectivity and Subjectivity
- Plato's Cave Revisited

Introduction

This module examines the central question of Unit 1: *How do we know what is real* within the framework of science and the scientific method. The material in this article provides the background tools needed when other scientifically-themed articles in the course are read and analyzed, particularly articles reporting scientific findings (evolution, global warming, biotechnology) or some complementary articles that propose various hypotheses to explain certain human behaviours (war and genocide, altruism, fiction as adaptation).

We began our educational and philosophical journey with Plato's *Allegory of the Cave*, with the idea of questioning the reality of the world around us, trying to figure out the "true" nature of the universe. Now we study another important approach to knowledge and learn how the scientific method provides an answer to the central question in Unit 1: *How do we know what is real?*



Source: © istockphoto.com/ balono

While the topic of science may conjure up romantic images of “mad” scientists like Isaac Newton with dishevelled hair working late into the night on alchemical potions, or perhaps the more banal image of contemporary men and women in white lab coats peering through microscopes and painstakingly discovering and documenting data, it is important to set aside any preconceived notions you may have of science and the scientific method.

Thinking Critically

The scientific method, as you will learn, actually encompasses much of our everyday lives. Ask yourself, *how would your life be different without all the major scientific breakthroughs in technology and medicine?* It is important for you to apply the scientific method to the onslaught of new products, claims, or opinions disguised as science reaching you through every possible media. Do you believe every report you read about on the internet or a “breakthrough” reported on the news because it makes a sexy headline, or do you ask yourself the following key questions as in any scientific approach?

- What are the facts supporting the research?
- What are the credentials of the people doing the research?
- Is there a solid background of study and research, perhaps a theory that supports the results?
- Is the experiment reproducible by other experts in the field?
- And, finally, and probably most importantly, if the research is scientifically valid, how does this affect me and the way I live?

As David P. Barash (2015) highlights in this week’s reading, “science is one of humanity's most noble and successful endeavours, and our best way to learn how the world works." Our reading examines the way in which the scientific method provides each of us with a method for *how to think*: that is, *how to develop, test and verify what we consider to be real*.

A Matter of Perspective

To know something scientifically is one of a few ways in which we come to apprehend what is real. The scientific method is, after all, a process of asking and answering questions about the *natural* universe. While it takes a lot of education to be a scientist, one need not be a trained scientist to put the scientific method into practice; rather, the scientific method is accessible to all, open and democratic in tone. It is democratic in the sense that each citizen should be informed about the issues faced by their governments, and the scientific method can help every citizen become better informed about these facts.

When it comes to science, emotions and private beliefs about how the world should be are irrelevant. Science is descriptive, not prescriptive. That is, science describes the way the world is, not the way the world should be. In fact, as Barash points out in his article "many scientific findings run counter to common sense and challenge our deepest assumptions about reality." While we are entitled to hold our own beliefs on what we consider to be real, that in no way guarantees that these private or culturally held beliefs actually correspond to what is real.

Science

An interesting way of describing science and the scientific method is in the following quote from science-fiction writer, and scientist, Isaac Asimov: “Science does not purvey absolute truth, science is a mechanism. It’s a way of trying to improve your knowledge of nature, it’s a system for testing your thoughts against the universe and seeing whether they match.”

Within Asimov’s statement lies the core of the scientific endeavour, and while reason is fundamentally important in understanding the world, we must have phenomena that are *observable, measurable, testable and reproducible*. This is the realm of science and of scientific questioning, where we assume that there is an external, orderly reality *independent* of the human mind and we can understand this reality through reason, observation, and experimentation. This mechanism of knowledge will give us the best scientific explanation of the world around us based on *current* observations and *current* information.

A Matter of Perspective

A scientific theory does not claim absolute truth; it cannot do so because discoveries, often by accident and sometimes with the refinement of technology, can change our worldview — our paradigm or the assumptions through which we view reality. Our understanding of the natural world must be reassessed when new evidence is discovered and verified. Science, in principle, must course-correct when observation or experiment clashes with accepted theory.

The Scientific Method



Source: © istockphoto.com/ real444

As a method that aims to learn how the world works, science is a process of knowing that includes a long history of miscalculations and eventual self-correction. In these moments of error, we see the way scientific knowledge itself can change and lead to modifications in our understanding of nature, give us corrections and tweaks to our models of reality, and, at times, propel us toward a completely new understanding of the universe and humanity's position within it. We will see more of this in the next section on Paradigm Shifts.

Aristotle, an ancient Greek philosopher, contributed to the scientific method by claiming that to know something scientifically meant one know it logically. Aristotle started the scientific method, but many pioneering individuals from the Renaissance onwards have since improved the reliability of the method.

Thinking Critically

Think, for example, of Aristotle's law of non-contradiction. This law, as it applies to logic, states that a statement cannot be both true and untrue at the same time and in the same sense. For example, you cannot be both reading these words and not reading these words at the same time. These options are clearly mutually exclusive. You are doing one or the other, never both at the same time.

Logic and reason are two necessary tools in the study of mathematics and philosophy, but logic and reason do not sufficiently describe the scientific method; science requires more. In addition to logic and reason, to know something scientifically requires testing claims with experiments and observations.

Briefly stated, science begins with our **observation of phenomena**, then we formulate a **hypothesis or educated guess** explaining the phenomena, keeping our description as *simple as possible* using the Principle of Simplicity (known as Occam's Razor, a philosophical assumption; see examples here (http://examples.yourdictionary.com/examples-of-occam-s-razor.html)), and making **predictions** (using mathematics if possible). Finally, we **test our hypothesis**, or more specifically, its predictions, using experiments and observation. Try the following ranking activity to sort out these main points:

Scientific Method (http://astro.unl.edu/interactives/misc/ScientificMethod.html)

Materials reproduced from the Astronomy Education at the University of Nebraska-Lincoln Web Site (http://astro.unl.edu (http://astro.unl.edu)).

Essentially, we are looking for patterns in the behaviour of the universe, patterns that allow us to make connections through cause and effect and *try to* predict new behaviour. We collect facts, determine laws of nature, and *try to* figure out how the universe works.

Paradigm Shifts

For a moment, let's look at the sky as our ancestors did. Put aside what you know about planets and our place in the solar system today and observe the motion of the night sky in the following video, aptly titled

The Sky in Motion (http://apod.nasa.gov/apod/ap081231.html)

What do the patterns of behaviour reveal about the universe around us?

As we see in the time-lapse picture below, it appears as if the stars move around the earth in majestic, perfect circles: they rise in the east and set in the west, just as the sun and the moon do every day. Circular motion, for the ancients, was perfect and eternal.



Star Trails Over Indonesia
Source: HuiChieh (Photographer). (2014). *Star Trails Over Indonesia* [Photograph], Retrieved from http://apod.nasa.gov/apod/ap140818.html (http://apod.nasa.gov/apod/ap140818.html)

A Matter of Perspective

What do the words *sunrise* and *sunset* mean to you? Is the sun *literally* moving across the sky because it appears that way? Is it really moving around the earth? What does common sense tell you, if you did not know any better?

Other bright objects, the planets, also wander across the night sky, seemingly circling the earth. Another observation you would still make today (without modern technology) is that you do not feel the earth hurtling through space or you do not feel the earth spinning on its axis, giving us night and day. These common sense observations will lead you to the conclusion that the earth is *fixed and unmoving* at the centre of the universe.

Within his approach, Aristotle had an apparently logical and self-consistent description of the universe, a cosmology divided into two realms: terrestrial and celestial. In many ways, his description found support in *common sense* observations, where we had the imperfect and changing earth contrasted with the *assumed* perfection in the heavens. Aristotle, building upon the work of other ancient thinkers, constructed a mechanism involving spheres that rotated around the earth with celestial objects attached to these spheres in the geocentric (earth-centred) model of the universe (further developed by another ancient thinker, Ptolemy):

From Earth to the fixed stars: the planetary order according to Aristotle (https://www.youtube.com/watch?v=Q8YhBLfWq0Q)

And the common sense evidence supports that notion, supports that hypothesis … and yet it is wrong.

Another logical, common sense observation is that a heavier object falls faster than a lighter object. Try this experiment: take a heavy book and a single sheet of paper. Now hold them at the same height and get ready to release them at the same time. What do you think will happen when you drop them? Let them fall and you will see that the book hits the ground before the paper does. Is it really the weight of the book that determines its rate of drop, or is there something else slowing down the paper? Still, the evidence of this crude experiment may compel you to associate the weight of an object and the way it falls, and many people did for millennia and some still do so today … and yet it is wrong.

Indeed, Einstein writes that Galileo Galilei is the father of modern science precisely because Galileo solidified the point that scientific knowledge must be knowledge that is both testable and reproducible. One of Galileo's famous experiments was testing whether or not heavier objects fall faster than lighter

objects. Galileo proved through an experiment that the previously entrenched assumption that heavier objects fall faster was incorrect. Through experiment, Galileo proved that the acceleration of a falling body was determined by the distance and time of the falling object, not its weight.

Thinking Critically

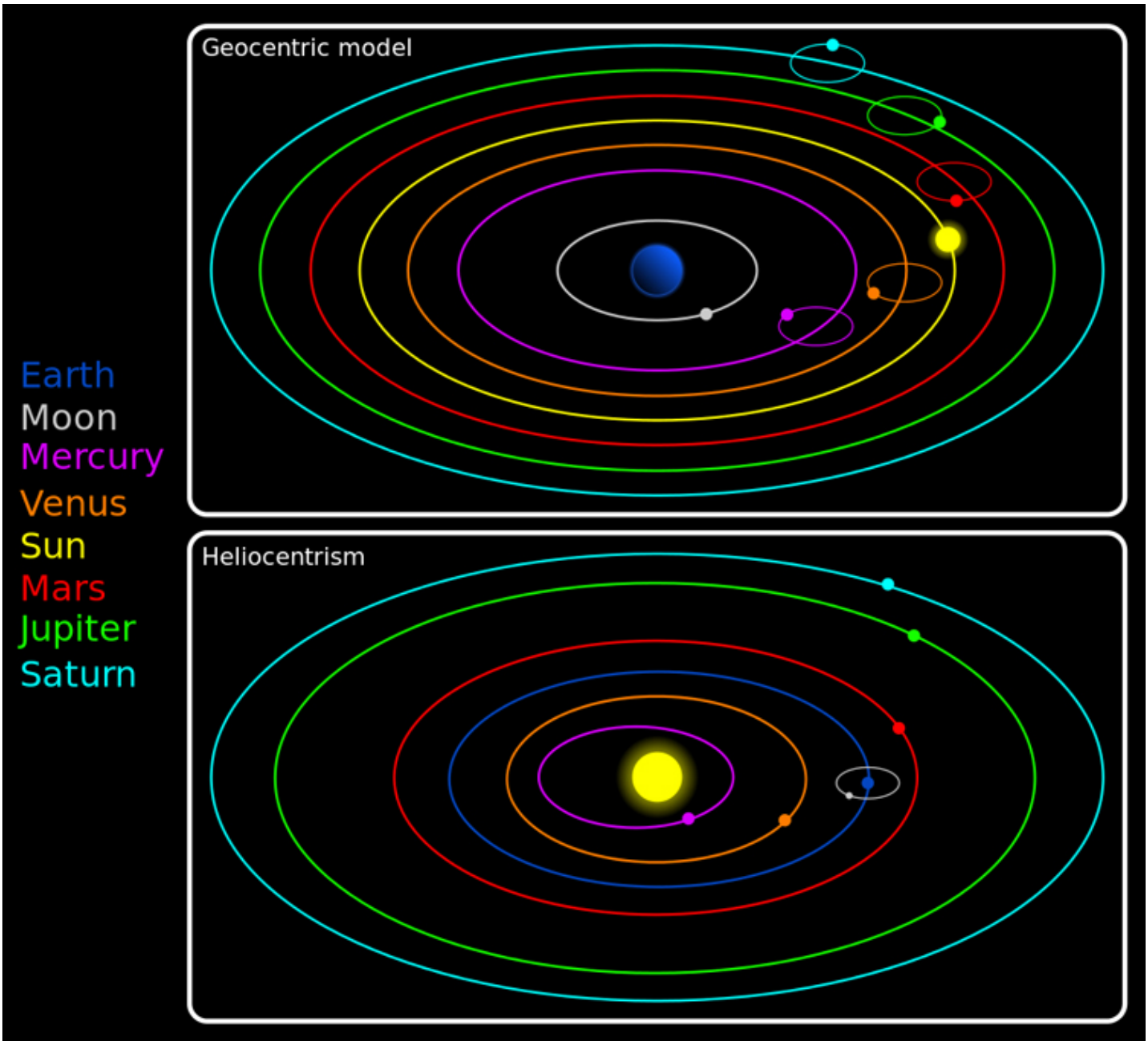
Let's revisit our paper and book experiment. You probably figured out (or already knew from your science education) that the paper dropped more slowly than the book because it was subject to the air slowing it down through resistance, much like a parachute slows down your fall from a plane. Since you probably can't afford to remove all the air from your room to create a vacuum (and it would not be advisable, anyway), take that piece of paper and crumple it up as much you can to reduce its area exposed to the air as it falls. Now repeat the experiment, and you will see, albeit crudely, that the heavy book and the feather-light paper hit the ground at the same time: the experiment contradicts an assumption.

Here is a video replicating Galileo's experiment in a vacuum chamber:

World's biggest vacuum chamber/ from Human Universe: A Place in Space and Time (http://www.bbc.co.uk/programmes/p02985m0)

Staying with Galileo's ideas of experimentation, let's revisit Aristotle's cosmology for re-examination. Centuries after Aristotle, and decades before Galileo, Nicholas Copernicus proposed a different model of the universe. Aristotle's geocentric model was getting messier as corrections were made to it to make it mesh with observed (non-perfect) behaviour of the planets — tweaks that made the model unwieldy (the details are not important, but if you're interested, you can look up retrograde motion).

Copernicus proposed what was in many ways a more elegant system, although it too became messier with time: the heliocentric (sun-centred) model with the earth as just another planet orbiting the sun. Take a look at the two world systems below:



Geocentric versus Heliocentric models of the universe

Source: By Original image by Niko LangSVG version by User:Booyabazooka (Own work) [CC BY-SA 2.5 (http://creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons (https://commons.wikimedia.org/wiki/File%3AGeoz_wb_en.svg)

Many scientists, including Galileo, thought that heliocentrism was a *true* description of reality because of its elegance — it seemed simpler and more logical. But what was the problem? We have two models of reality, two systems that *explain the same observations*. The only way to distinguish the two is if one model can make a different, testable prediction.

Galileo's improvement of the newly invented telescope allowed him to discover *evidence* that the celestial realm was not perfect as was the belief of the day, going back to the ancient Greeks. He observed that:

- the cratered moon was imperfect,
- that the blemished sun was imperfect,
- that Saturn had a strange shape (from its rings),
- that Jupiter had objects orbiting it (its own moons) when it was believed that *everything* must orbit the earth,
- that there were far more stars in the heavens than explained by the ancient geocentric model,
- and that Venus went through phases just like the moon did in a month (full, crescent, *etc*), which cannot be explained by the geocentric model but the heliocentric model could.

He found flaws in the geocentric description of reality and began the paradigm shift from the earth-centred model to Copernicus' heliocentric model. Galileo's evidence was not definitive, convincing proof of Copernicus' description of reality, although it contributed to the shift in paradigm and energized a **scientific revolution**. Although the evidence was damaging to the geocentric model, to a degree, you should note that even Galileo's *observations did not show clear evidence that the earth actually moved*; that fact became *measurable* in the nineteenth century, two centuries after Galileo.

Assumptions about what we know to be real need to be examined and tested. This is what we can glean from Galileo, and other scientists such as Newton and Einstein; for example, Charles Darwin, who, based on *evidence*, gave us a new description of human origins and an elegant mechanism for change in a species. Testing hypotheses and revisiting assumptions can lead to a new way of thinking which can contradict entrenched ways of understanding what is real: a **paradigm shift**. Paradigm shifts help us to clarify the central question of Unit 1: *How do we know what is real?*

Kuhn's paradigm shift (https://www.youtube.com/watch?v=3cp6pEzx3uw)

Sometimes the answer to our central question of this unit, as evident with Newton, Darwin, Einstein, and Galileo, requires revisiting and testing your scientific theory and other times it requires you to revisit and revise your scientific experiments. Either way, if one aims to know what is real scientifically, both theory and experiment need to be continually revisited and examined so that the knowledge is reproducible.

We also should not think of these paradigms as confined to the world of science and of interest only to other scientists. Although Einstein's modification of our idea of gravity and his verified predictions may hardly raise an eyebrow among the non-scientific public, think about the paradigm shift when we transitioned — not smoothly — from humanity's perceived location at the centre of the universe to

humanity losing its place of centrality in the solar system, in the galaxy, and within the universe itself. Think about the seismic changes these shifts can unleash whether they are scientific, philosophical, religious, or sociological. These paradigm shifts will have ripple effects with ramifications that can change *everything*.

Science vs. Pseudoscience

Thinking Critically

As you read, reflect on how the scientific method differs from pseudoscience. A grasp on the methods of science, in contrast to the methods of pseudoscience, should help you to make life's important decisions in a more informed way and prevent you from being swept up by the current conspiracies or false claims flooding the Internet.

You do not have to look far to find misconceptions, conspiracy theories, myths, hoaxes, bad science, misinterpretations, and pathological science (eugenics, cold fusion). It's also interesting that sometimes the line between science and pseudoscience can be blurry (the demarcation problem), and there are cases in the past when what was considered science became pseudoscience (geocentric model, alchemy, phrenology, *etc.*) and what was perceived as pseudoscientific entered the realm of respectability (meteorites, continental drift, *etc.*)

Thinking Critically

Here are some questions to consider when reading the section in the article on pseudoscience:

- Why is astrology or fortune telling a pseudoscience?
- How do conspiracy theories differ from scientific theories?
- What is the role of skepticism in science and pseudoscience?
- How is the impact of pseudoscience affecting some government policies?
- Why do you think people accept many pseudoscientific claims so easily and without question?
- Why is it important to ask questions and to be skeptical?
- How can education change the public's acceptance of questionable claims?
- Is it possible for a pseudoscience to become science, and vice-versa?

Here is an interesting video with ten questions to ask when examining extraordinary claims:

Michael Shermer: Baloney Detection Kit (https://www.youtube.com/watch?v=eUB4j0n2UDU)

Falsification

Albert Einstein declared that, “No amount of experimentation can ever prove me right; a single experiment can prove me wrong.” This is the idea of Karl Popper’s falsification — experiments can never prove a scientific theory as absolutely true, but they *can* prove that it is *false*, or “falsify” it. A hypothesis or theory might survive many tests and seem to be true for years; but with scientific “facts” that may always change under new testing conditions or with new evidence in the future.

Carl Sagan, one of the great scientists of the twentieth century, once said, “extraordinary claims require extraordinary proofs.” Currently there exist many extraordinary claims on how vaccines, in particular the MMR (measles, mumps, and rubella) vaccine, cause autism spectrum disorders.

A Matter of Perspective

Optional Resources

Vaccines are not associated with autism: An evidence-based meta-analysis of case-control and cohort studies (http://www.sciencedirect.com/science/article/pii/S0264410X14006367)

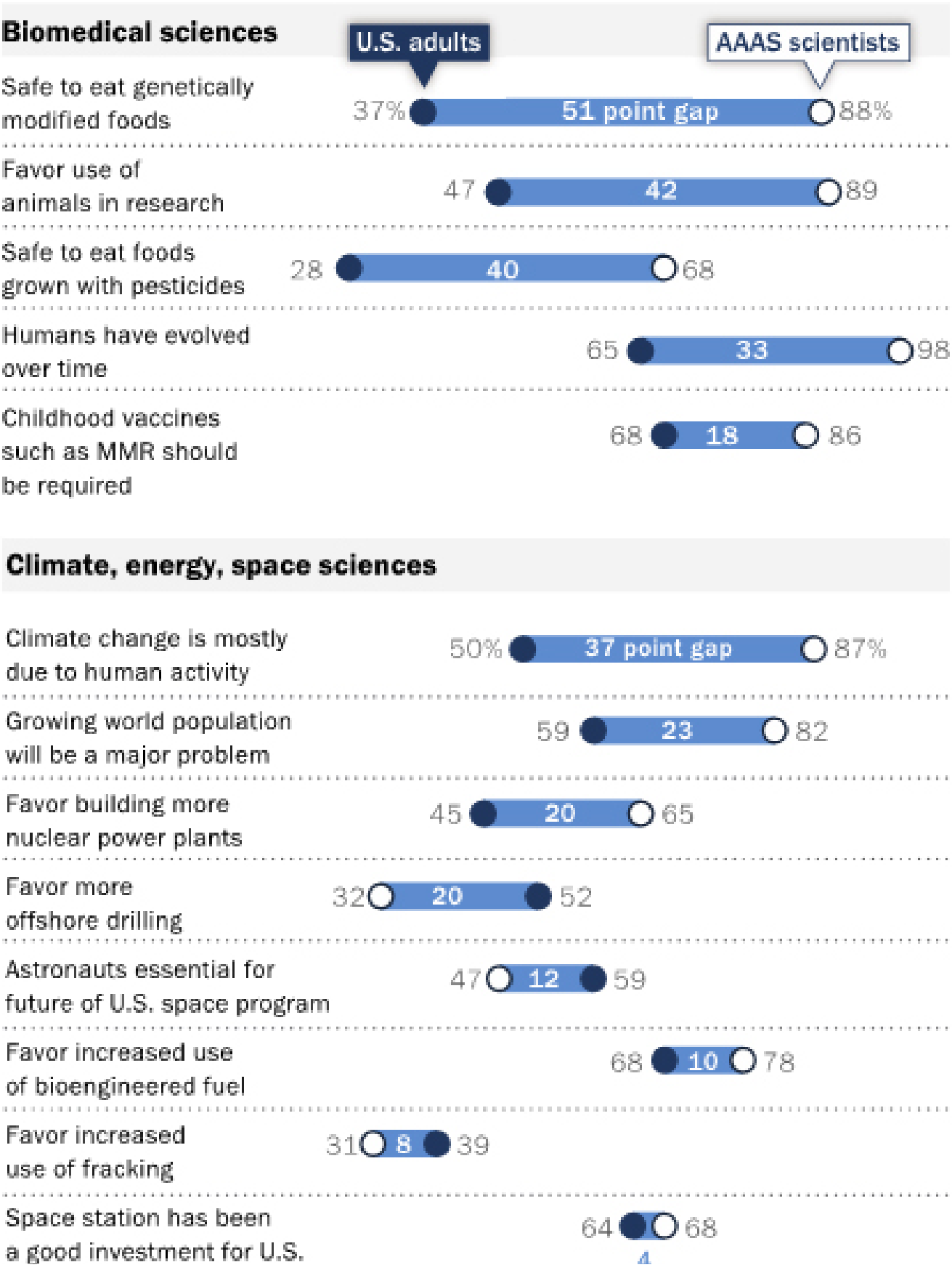
No link between MMR vaccine and autism, yet another study suggests (http://globalnews.ca/news/1953939/no-link-between-mmr-vaccine-and-autism-yet-another-study-suggests/)

So, consider that the proposed hypothesis that there is more than a correlation between a vaccine and these disorders, there is a causal link. Now, following the rules of science, we must test its merit. We observe and experiment, gather data, analyze the results and determine whether the hypothesis survives testing, or it fails and suffers falsification.

The scientific community has discredited — falsified — this proposed causal link with evidence-based research. This extraordinary claim is scientifically false yet many parents in North America, contrary to all the scientific evidence, still choose not to vaccinate their children, undoubtedly because of websites that contain misguided information on this topic. **Why** might so many parents dismiss scientific evidence to the contrary and choose to support a theory that makes false claims about life-saving vaccines? As the following image shows you, the gap between scientists and the public is profound.

Opinion Differences Between Public and Scientists

% of U.S. adults and AAAS scientists saying each of the following



Survey of U.S. adults August 15-25, 2014. AAAS scientists survey Sept. 11-Oct. 13, 2014.
Other responses and those saying don't know or giving no answer are not shown.

PEW RESEARCH CENTER

Source: Pew Research Center. OPINION DIFFERENCES BETWEEN public and Scientists. Retrieved from http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/pi_2015-01-29_science-and-society-00-01/ (http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/pi_2015-01-29_science-and-society-00-01/)

Objectivity and Subjectivity

Sometimes, people support hypotheses and "theories" that are not falsifiable because the scientific community has been wrong about its claims in the past. Other times, people just want the belief to be true and disregard any evidence that suggests otherwise. To build on key concepts from your assigned article here, many argue that the scientific method is **subjective** and **value-laden** and therefore cannot be purely **objective**.

A Matter of Perspective

An extreme example to help you understand the key concepts in this section on when science goes wrong could be the application of seemingly "neutral" and "objective" scientific principles that supported the inhumane practice of eugenics in Canada and elsewhere in the early twentieth century.

For more information on the practice of eugenics in Canada, click on the links provided:

- The "Eugenics" entry in The Canadian Encyclopedia (http://www.thecanadianencyclopedia.ca/en/article/eugenics/)
- The Eugenics Archives website (http://eugenicsarchive.ca/)

Before going forward, it is important not to discredit the scientific community because of such extreme misapplications of the scientific method in the service of such intolerant social policies. Instead, it is critical to recognize that the lesson to learn from this tragic abuse is the importance of holding scientists and non-scientists alike accountable to the rigorous demands of the scientific method. That is, it is imperative to continuously test and examine every assumption on what we consider true.

Having said this, it should be mentioned that some critics do support **relativism**, which claims that it is impossible for the scientific method to be purely objective. Relativists believe that scientific research merely reflects the biases of the individual or the values of multinational corporations and

communities. In this perspective, science—not just sometimes, but always—serves ideological beliefs or profit motives; however, as you will learn from your assigned reading, this position is extreme and not widely supported.

A more measured and appropriate response to the debate on the status of science is expressed near the end of Barash's essay. Reflecting on the merits of science as a way of knowing, Barash writes: "Denied the comforting blanket of illusory permanence and absolute truth, we have the opportunity and obligation to do something extraordinary: to see the world as it is, and to understand and appreciate that our images will keep changing, not because they are fundamentally flawed, but because we keep providing ourselves with better lenses. Our reality hasn't become unstable; it's just that our understanding of reality is of necessity a work in progress."

Plato's Cave Revisited

In Plato's *Allegory of the Cave*, when the prisoner escaped to the outside world, he found another level of understanding, where new knowledge replaced the assumed knowledge of the past. Now imagine the prisoner seeing the night sky for the first time, watching the movement of bright objects that displayed perfect circular motion around the earth. Imagine the prisoner making these observations over a period and creating a hypothesis describing a universe where earth, obviously, was at the centre of all things. After all, this is what common sense observation tells you. Logic and reason tells you that this must be "true."

As we have learned, the prisoner may have replaced the ignorance of the cave with another darkness; of course, he has learned something: he can look back and see how he was wrong in the past. The scientific approach would be to question his new reality as well: Is this world system true? Is there yet more to be discovered? Will new evidence in the future change the worldview … *again*? Should questioning cease?

And as you would note from our lesson, many years later the escaped prisoner would create a new hypothesis of reality, with evidence finally supporting the idea that the celestial spheres were nothing but illusion. And, with this, should the prisoner now rest and declare that he has learned all there is to know?

In short, this is part of *your* obligation in understanding the world accurately, in critically thinking about what is shadow and what is not, what is "true" and what is false. The world around you provides a complexity and confusion of possible shadows, from the media that delivers news, extraordinary claims on the internet, pseudoscience, altered and rejected histories, commercials, miracle products, conspiracies, political perspectives, and sometimes a murky mixture of all of these.

The scientific method is a tool to help you sort it out and make important decisions that affect *you* directly.

Summary



Source: By NASA, ESA, and The Hubble Heritage Team STScI/AURA) [Public domain], via Wikimedia Commons (https://commons.wikimedia.org/wiki/File%3AHubble2005-01-barred-spiral-galaxy-NGC1300.jpg)

As should be clear by now, there are limits to what one can know scientifically. In fact, scientists only know a very small percentage of what there is to know about our universe. The scientific method need not be viewed as a cold and calculating method that led to the creation of our modern disenchanted world stripped of its beauty and mystery. Rather, each year, frontier science discovers new things about our natural world, ranging from the previously unknown species that live in the depths of our oceans to the formation of our most distant galaxies. This method has utterly transformed our way of understanding the world in a way that is bound to leave everyone filled with awe and wonder regarding the complexities of our natural world.

Science, however, can only describe the natural world. It cannot provide us with meaning and understanding on how to live in the world. For these ways of knowing we need to turn to cultural, religious and traditional ways of describing ultimate reality.

Additional Resources

- Why is Science Important? (https://vimeo.com/3531977)
- Public and Scientists' Views on Science and Society (http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/)
- The Known Universe (http://apod.nasa.gov/apod/ap100120.html)
- The Celestial Sphere (http://astro.unl.edu/naap/motion2/animations/ce_hc.html)
- Paths of the Stars (http://astro.unl.edu/naap/motion2/starpaths.html)
- Astronomy Picture of the Day (http://antwrp.gsfc.nasa.gov/apod/astropix.html)
- The Galileo Project, from Rice University (http://es.rice.edu/ES/humsoc/Galileo)
- What Is Pseudoscience? Distinguishing between science and pseudoscience is problematic by Michael Shermer; Aug 16, 2011 (http://www.scientificamerican.com/article/what-is-pseudoscience/)
- Science and Religion: Lessons from History? (http://www.sciencemag.org/content/282/5396/1985.full)

Breaking Science News Stories (typically frontier science):

- Popular Science (http://www.popsci.com/)
- Gizmag (http://www.gizmag.com/)
- Science Friday (http://www.sciencefriday.com/)
- NewScientist (http://www.newscientist.com/)
- EurekAlert! (http://www.eurekalert.org/index.php)
- Science Daily (http://www.sciencedaily.com/)
- Science News Online (https://www.sciencenews.org/)
- Science/AAAS (http://news.sciencemag.org/)
- Scientific American (http://www.sciam.com)
- Nature (http://www.nature.com/news/index.html%20)

- 📰 CBC News: Technology & Science (http://www.cbc.ca/news/technology)
- 📰 Science and Technology for Canadians (http://www.science.gc.ca/default.asp?lang=en)
- 📰 Physics World (http://physicsworld.com/)
- 🔗 American Museum of Natural History (http://www.amnh.org/)
- 📰 National Geographic (http://news.nationalgeographic.com/news/)
- 📰 Smithsonian (http://www.smithsonianmag.com/science-nature/%20)
- 📰 The New York Times — Science (http://www.nytimes.com/pages/science/index.html)
- 📰 The Globe and Mail — Science (http://www.theglobeandmail.com/technology/science/)
- 📰 Google News — Science (http://news.google.com/news/section?pz=1&cf=all&ned=ca&topic=snc&ict=ln)