FOUNDATIONS OF SCIENCE:
HOW SCIENTISTS DISCOVER TRUTHS ABOUT NATURE

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Through my personal intellectual journey, I have come full circle—in idealistic youth believing that science is a process through which we seek for truth, to a university student doubting that science really seeks truth, to now accepting that we learn truths through science. Along the way I've learned how science works by doing it. I've also learned that science is a powerful intellectual tool, but like any tool it has strengths and limitations that we can understand by exploring the foundational principles upon which it is built.

Science is a powerful intellectual tool, but like any tool it has strengths and limitations.

In order for my foundations of science to make sense, a brief sketch of my intellectual journey is necessary. As far back as I can remember, I loved science. As a child I wanted to understand how things worked. I received a chemistry set and microscope for Christmas before turning ten. In the summer of 1969 I turned twelve years old, and two pivotal events kindled my love affair with astronomy. I went to scout camp and earned the astronomy merit badge; the majesty of the heavens awed me. Two weeks later, Neil Armstrong walked on the moon. For the rest of my youth, I prepared to become an astronomer. I was supremely confident that science was the way to learn truths about nature. I now recognize that my understanding of science was naïve but typical for high school and beginning college students.

I entered Ricks College and studied physics under many wonderful professors who had a profound influence on me. Later, at BYU, I took two classes from Dr. Kent Nielson that completely changed my outlook on science. One was titled The History and Philosophy of Science. The other was called Science and Religion. The History and Philosophy of Science I now teach is modeled after Brother Nielson's course. I learned about those great scientists who forged our current understanding of the universe. I also learned how scientific theories effectively overturned man's accepted place in the universe. I was exposed to the work of Thomas Kuhn, one of the first scholars who taught that science is not the linear, methodical process of accumulating knowledge step by step as I had previously understood. Rather, it progresses by revolutions that not only overturn technical details but also affect how we see ourselves and our place in the universe.

This recognition led to an intellectual crisis. I was not sure I wanted to spend my working life within a system based on assumptions and subject to revolutionary changes. As a result, I did something rash—I joined the Navy. Now I don't recommend this course of action to everyone in intellectual crisis, but it worked for me. I had the chance to teach at Naval Nuclear Power School. There I discovered that I really enjoyed teaching and reconciled some of these feelings about science. I came to feel that science was worth pursuing, so after five years of active duty, I took my wife Nancy and our four children to Tucson, Arizona. We spent six wonderful, difficult (and poor) years in graduate school at the University of Arizona, where I graduated with a doctorate in planetary science. While there I became involved in virtually every facet of the scientific process. I performed cutting-edge research, wrote grant proposals, presented research at professional meetings, wrote professional research papers, and reviewed the papers of others. The only facet I didn't become involved in was scientific administration—and I was OK with that. I learned how the scientific enterprise works by being involved in the process first-hand.

Shortly before completing my degree, I was hired to teach at Ricks College. During the summer before I started, I received a post-doctoral fellowship at the NASA Ames Research Center near Palo Alto, California. It was a lonely summer because Nancy and the children were in Rexburg, but it was the intellectual capstone of my experience. I had time to read and ponder in a way that I had not been able to do before. I read the scriptures, Thomas Kuhn's *The Copernican Revolution*, and others. These works crystallized many of my experiences and thoughts about science's foundation from graduate school. It was a great season of personal revelation that prepared me for teaching at Ricks College and, later, BYU–Idaho. Many of the ideas I share here came out of that experience. I have continued to grow during my time here and have added additional details; I expect continuing growth.

It was a great season of personal revelation that prepared me for teaching.

The Lord's Promise

One of the great revelatory experiences of my life occurred during that California summer while I was reading Doctrine and Covenants 121:26-31. I had read this section many times before. On this occasion, the verses came with great power, as though my eyes were opened to truths that I'd never understood before. Doctrine and Covenants 121, of course, is the Lord's response to Joseph's plea for help as he and his associates languished in Liberty Jail. The Lord promised the Prophet:

> God shall give unto you knowledge by…the Holy Ghost, that has not been revealed since the world began until now;
>
> Which our fathers have awaited with anxious expectation to be revealed in the last times, which their minds were pointed to by the angels, as held in reserve for the fullness of their glory;

> A time to come in the which nothing shall be withheld, whether there be one God or many gods, they shall be manifest.
>
> All thrones and dominions, principalities and powers, shall be revealed and set forth upon all who have endured valiantly for the gospel of Jesus Christ.
>
> And also, if there be bounds set to the heavens or to the seas, or to the dry land, or to the sun, moon, or stars—
>
> All the times of their revolutions, all the appointed days, months, and years, and all the days of their days, months, and years, and all their glories, laws, and set times, shall be revealed in the days of the dispensation of the fullness of times.

This incomparable promise tells us that both spiritual and temporal knowledge will be revealed during our day. Certainly the Lord could reveal scientific knowledge by direct revelation. However, it occurred to me that He is already revealing this type of knowledge through science. For example, I lived through the period of initial reconnaissance of our planetary system: Mariner 9 to Mars in 1972, the 1976 Viking mission's landings on Mars, the twin Voyager spacecrafts flying past Jupiter in 1979 and Saturn in 1981, Voyager 2's flyby of Uranus in 1986 and Neptune in 1989, the Magellan radar mission to Venus in 1990, and so on. Astronomers knew that Jupiter had twelve satellites and Saturn had nine before Voyager flew past, but even through the most powerful telescope on earth, these worlds appeared as mere pinpoints of light with no visible surface features. The times of their revolutions (rotations) were completely unknown, as were their glories, laws, and set times. Voyager transformed these pinpoints of light into real worlds with real surfaces, real geology, and real processes by which they operate. This transformation in our knowledge results directly from modern science. As a result, I now accept that science is a major source of truth about the physical universe. Consequently, I've spent a lot of time thinking about what science is, what questions it can legitimately ask, and what foundational principles it is based upon.

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Interaction Between Observation and Theory in Science

In two of my courses, I teach the philosophy of science: Ph 127, Descriptive Astronomy, and Ph/Phil 314, History and Philosophy of Science. I spend a week discussing the philosophy of science in Ph 127 and another four days summarizing the history of astronomy. In Ph/Phil 314, we discuss the subject the entire semester. I cannot honestly discuss what science has discovered in astronomy without placing our current state of scientific knowledge into perspective by teaching what science is, how it is accomplished, and how it developed historically. Below is a summary of what I teach in these courses.

The process we call science began with the Greeks about 600 BC. As far as we know, they were the first to develop the notion that much of nature can be understood and explained by natural processes instead of relying on actions of gods. Thus science, the systematic study of nature and its processes, was born. Two major philosophies about how to best discover nature's processes developed in ancient Greece: rationalism and empiricism. Both philosophies have had vocal adherents throughout history, and both are important in modern science.

Rationalism is the concept that man can understand the universe by pure reasoning. Plato was among the first to advocate this approach. Aristotle attempted to deduce the construction of the universe from first principles, although he believed that sense experience was also important. Other important rationalists include René Descartes, who deduced inertial motion from first principles, and Albert Einstein, who derived both the special and general theories of relativity using simple premises. Einstein was reportedly pleased when Arthur Eddington discovered that light bent when passing the sun precisely as Einstein predicted—but was not overly concerned about it. He believe his theory to be true, not because it predicted observations that were later observed, but because of its beauty and logical coherence.

Empiricism, on the other hand, claims that we can learn about nature only through observations made by the senses. Aristotle, rationalist that he was, was among the first to also emphasize the importance of sense experience. During antiquity, the medieval period, and the Renaissance, when most people believed in magic and the intervention of gods, pure empiricism did not have a strong following. It was not until Newton's time that empiricism began to be an important tradition. David Hume (who lived shortly before Newton) was among the first philosophers to attack the foundation of rationalism and emphasize the importance of sense experience. Newton himself represents a mixture of the two traditions. Although he derived his science more or less rationally, he emphasized that his science was useful only because it explained observations of the natural world. More recently, Edwin Hubble emphasized the importance of observation and placed only minor value on theory.

Because both rationalism and empiricism exist in science, there is no single "philosophy of science."

Because both trends exist in science, there is no single "philosophy of science." Different scientists emphasize the importance of one or the other of these philosophical outlooks. Einstein said, "I hold it true that pure thought can grasp reality, as the Ancients dreamed.... We can discover by means of purely mathematical constructions the concepts and the laws connecting them with each other, which furnish the key to the understanding of natural phenomena."[1] Paul Dirac, who predicted the existence of neutrinos from theory, states, "It is more important to have beauty in one's equations than to have them fit experiment."[2]

Stephen Hawking argues that the observations we make depend on the theory we have in our heads.[3] Collins and Pinch describe a controversy that Louis Pasteur had with Felix Pouchet over the concept of spontaneous generation.[4] Pasteur claimed that air did not contain a vital spirit that would cause life to spontaneously generate from a sterile substrate, but required some kind of germ or seed. He performed experiments to show this was true by sterilizing a nutritive solution, then exposing it to the air. He reported only the experiments that "worked," about ten percent of the total, assuming he had done something wrong or had contaminated the solution in the other 90 percent. Pouchet claims to have repeated the experiments without obtaining Pasteur's result. Collins and Pinch emphasize that Pasteur simply believed that spontaneous generation was false and was willing to ignore 90 percent of his experiments.[5] Theory was critically important to this great experimentalist.

On the other hand, Edwin Hubble emphasizes that theories come and go, but observations are the permanent contribution to knowledge.[6] In later years Einstein acknowledged the importance of theory matching observation. An individual scientist's philosophy depends on his or her experiences, training, and to some degree, the field of study. In my opinion, both rationalism and empiricism are important in modern science. I think that the interaction of observation and theory is the critical key that makes science work.

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The interaction between observation and theory leads to the next question: What questions can science answer? Science can answer only a limited set of questions. Edwin Hubble claims, "Science is the one human activity that is truly progressive."[7] Science is progressive, he argues, because science restricts its inquiry to questions "concerning which it is possible to obtain universal agreement." Agreement is "secured by means of observations and experiments." These "tests represent external authorities which all men must acknowledge, by their actions if not by their works, in order to survive."[8] In Hubble's view, science can only answer questions that can be addressed by objective observation. In other words, science has limitations.

What is an observation, at least as Hubble has in mind? Observations are sensory experiences that could come through the senses and instruments that extend the senses. In addition, they are restricted to those sensory experiences that a group of people would have regardless of the individual's point of view or emotional state. This statement defines what we mean by objectivity in science.

Examples abound in nature. A simple example will suffice. Suppose you throw a rock into the air. What do you see? The rock leaves your hand traveling upward. As it moves upward, it slows and comes to a stop. It then reverses direction and starts falling downward, gaining speed until you catch it. You saw this sequence of events with your eyes—it is a sensory experience. If you had a group of people with you, they would have the same sensory experience. What they saw would not depend on their point of view or emotional state. This observation would be admissible as a scientific observation. Each member of the group could repeat the experiment and would find the same thing. We could measure the position and speed of the rock at a number of different times and develop relationships between these physical properties. We could determine, for example, the relationship between the rock's speed, distance from your hand, and time by plotting these properties on graphs and discovering the mathematical relationships among them. Mathematical relationships summarize a large number of observations, and their development is one goal of modern science. Well-established experimental relationships are sometimes called the "laws of science." This term was once very popular but is ambiguous and has fallen into disuse.

Many scientists are engaged almost exclusively in making observations. However, observations by themselves are rather boring. We naturally want to know why the observed phenomena occur. Seldom is the reason plain—even when it seems obvious, we often get the wrong answer. For example, to the unaided eye, the stars really do look like they are circling the earth once each day. Discovering why a set of observations appears as it does requires an idea—a hypothesis. A hypothesis is an idea that explains what we observe.

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The 20th century philosopher of science Karl Popper argues that scientific hypotheses (and theories) are different from other possible explanations because they have the ability to make predictions. A prediction is an observation that should become apparent if the hypothesis is a correct description of nature. If a hypothesis makes no predictions, it is not testable and does not promote new knowledge. For example, I believe that the statement "God created the Heavens and the Earth" is absolutely true, but it makes no predictions; thus we cannot test it. It is not in danger of being proven false. Popper emphasizes that the ability of a scientific hypothesis to make predictions distinguishes science from all other human activities.[9]

Suppose we've created a hypothesis that predicts observations that have never been observed. The hypothesis inspires us to investigate. If observable phenomena come out as the hypothesis suggests, our faith in the correctness of the hypothesis increases. In addition, the observations may eliminate other possible hypotheses about the original observations. This hypothesis then becomes a scientific theory. A scientific theory is a hypothesis that has survived observational testing.

In this manner, we arrive at the critical relationship between empiricism and rationalism in modern science. The observations cry out for an explanation. A scientific hypothesis predicts phenomena that we should observe if the hypothesis is true. We test the hypothesis by trying to observe the predicted phenomena. If they appear, we gain confidence and the hypothesis becomes a theory. Even if they do not appear, we have still learned something about nature that we didn't before. Thus, the body of human knowledge grows because of the interaction between observations and theories. Both play a critical role in modern science.

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Falsifiability and Progress in Science

As a university student in the 1920s, Karl Popper was very impressed by Einstein's theory of relativity. He contrasted it with some of the theories coming from the social sciences in his day, such as Freud's theory of psychoanalysis and Adler's theory of inferiority.[10] For example, Adler explained human behavior as resulting from feelings of inferiority. The theory seems capable of explaining opposite human behaviors. For example, a man might push a child into the water with the intent to drown him because the man feels inferior and has to prove his manhood. On the other hand, a man might jump into the water to save a drowning child at peril of his own life because by doing so he overcomes his inferiority feelings and proves he is a man. The theory can seemingly explain all observations, so the theory is never in jeopardy. By contrast, Einstein's theory of relativity predicts that when our line of sight to a star skims by the sun, the light will bend around the sun and the star will appear to be in a slightly different place than it actually is. It predicts how much the star's light will be bent. If we go out and observe a star passing close to the sun, say, during a solar eclipse, we can measure how much (if any) the star's light bends. If the star's light bends by an amount different than predicted by the theory, we know that the theory is flawed. Thus, a theory is in jeopardy of being falsified. Popper became impressed with scientific theories that have this quality and argued that what truly distinguishes science from other areas of human learning is the ability of its theories to be falsified.

Popper cautions us about holding onto scientific theories (or any other knowledge we possess) too strongly. He emphasizes that all human knowledge is fallible.[11] He apparently does not believe in revelation. There are no untainted observations. We use some underlying theory to interpret the information that comes through our senses. Likewise, we depend on our traditions, languages, and culture.[12] As a result, we must continually look for errors. He suggests that we search for errors by subjecting our knowledge, including scientific theories, to the most severe tests we can devise. He claims that "only the falsity of the theory can be inferred from empirical evidence, and this inference is a purely deductive one."[13] As a result, Popper concludes that all theories, in fact all human knowledge, must be regarded as tentative. In other words, we cannot know that our theories are true—we must accept their truth by faith.

Functions of the Scientific Theory

If scientific theories cannot be finally proven true, we might wonder why we even ought to create them. The word "theory" often has a negative connotation, as if a theory were a mere guess, as in: "It's only a theory." Scientific theories are vitally important because they perform three essential functions.[14] Scientific theory describes nature, provides conceptual economy, and guides future research.

Because scientific theories perform these functions, it is important that we not condemn theories we disagree with. Each function helps us learn about our world and feel at home in it. Scientific theories are not mere guesses but represent our best efforts to understand nature within our limitations. They are exposed to the severest observational tests that scientists can devise. The development of modern technology based on scientific theory testifies to the power of the scientific process in describing nature.

Scientific Theory Describes Nature

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Scientific theories explain why what we observe occurs. They provide a description of nature that is adequate for our purpose. For example, most of us understand our world based on Newton's laws of motion and his law of gravity. Much of our technology is also based on these "laws." They were adequate for determining the trajectory needed to send the two Voyager spacecraft past Jupiter, Saturn, Uranus, and Neptune, and for landing men on the moon. Newton's laws provide a useful description of nature, one we can readily understand and exploit. Notwithstanding, we now know that Newton's laws do not describe nature completely. Einstein's general theory of relativity is required.

Newton's laws are often described as approximations of general relativity. Numerically this is true. When applied in conditions of slow speed and low gravity, the equations that describe Einstein's theory reduce to the equations that describe Newton's laws of motion. However, Newton's laws and Einstein's theory are vastly different ways of describing why the universe works the way it does and are based on different assumptions about the nature of time and space. Both cannot be "the truth." Nevertheless, Newton's laws are adequate for describing and exploiting most natural phenomena.

Scientific Theory Provides Conceptual Economy

A scientific theory relates a number of otherwise unconnected observations and makes them easier to remember. It helps us see patterns that would not otherwise be obvious. This concept is called "conceptual economy."

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Examples abound throughout science. Newton's laws of motion together with his law of gravity explain why the planets orbit the sun and why the moon orbits the earth. In addition, they allow accurate prediction of celestial objects' future positions (astronomy), explain why rocks thrown into the air follow a parabolic path (terrestrial physics), and describe why the atmosphere of the earth gets thinner as we go higher in the sky (atmospheric science). The theory provides a mental picture that allows us to reproduce these observations in our minds. As a result, we remember them more easily.

This function of scientific theory explains the tendency of textbook authors to state the theory and then offer supporting observations. The human mind remembers information better in categories than in individual pieces. As a result, if we get the theory into our heads, it is much easier to remember the data. Consequently, when scientific data is first introduced, it is almost always done within the context of the prevailing scientific theory. Introducing the data first would probably make science more difficult than it already is (alas!). This tendency to teach things in reverse order does not change the tentative nature of scientific theories but explains one reason why it is difficult to give them up after they are proven false before a new theory is in place.

Scientific Theory Guides Future Research

Good scientific theories predict observations that never would have been thought of if the theory had not been developed. Newton's theory of motion and gravity predicts the behavior of baseballs, rockets, cars, airplanes, and so on. This is why scientific theory is vital to the progress of science. Without scientific theory, we would not have made most scientific discoveries. In this way, theories help us learn new truths about nature. Even theories that are eventually proven false are important because they lead to further observation.

Assumptions in Modern Science

Every system of human thought is built on a set of underlying axioms, or assumptions. An assumption is a concept that cannot be proven but serves as the foundation upon which the rest of the system is built. For example, Euclidian geometry makes certain assumptions about the construction of space. Some of these are: two points determine a unique line, three points determine a plane, and two parallel lines never intersect. The proofs that we performed in geometry used these (and other) assumptions, coupled them together logically, and constructed theorems. These concepts seem perfectly reasonable based on our experience in the world. However, there is no way to prove them for certain. The geometrical proofs we did in high school are only as valid as the truth of these assumptions.

Modern science is based on a set of underlying assumptions.

Likewise, modern science is based on a set of underlying assumptions. They serve as the foundation upon which all observations are interpreted. These assumptions are based on the philosophy of the culture in which the science is performed. Many of our assumptions are quite different from those made anciently. Assumptions can have "evidence" that supports them, but they are not observations because they are not sensory experience, and they are not hypotheses or theories because they make no predictions. Here are five fundamental assumptions made by modern science:

Man can understand the universe: The triumph of the ancient Greeks was to presume, not that the universe was operated solely by some gods or other, but that there were natural patterns to be ascertained and understood by the human intellect. This leap was not made by the Egyptians, Babylonians, Romans, or Chinese. Western culture inherited this notion from the Greeks. Although it seems to make sense to us, why should the universe be inherently transparent to human reason? The fact that the physical universe appears to conform to relatively simple rules that follow the language of mathematics is sometimes taken as evidence that the universe can be understood. However, this axiom must stand without proof. It is the bedrock of all other assumptions. Without it, the scientific enterprise is doomed from the start.

Theories should be quantitative and testable and should fit observations: This assumption is a statement of methodology and philosophy. It presumes that modern science (as explained above) is the best way to discover truths about the natural world. It also presumes that mathematics can describe the physical universe.

Simple laws are better: This assumption says that if two theories explain the same observations, we accept the simpler one. This idea is now called "Occam's razor" after a thirteenth century scholastic, William of Occam, but the concept began with Plato. An example of this assumption's power is Copernicus' introduction of the sun-centered solar system. Copernicus' development of this assumption caused him to reject complex geometric models in favor of the geometrically simple (but conceptually difficult) sun-centered solar system. Although it seems reasonable to accept the simplest system that will explain the observations, how do we know the universe is fundamentally simple? Perhaps it is grossly complex, beyond our wildest imagination. The proposition of Occam's razor cannot be proven true. It is an assumption, an expression of belief in how the universe operates.

Uniformitarianism: Scientists presume that the laws and theories that we discover through science apply throughout space and in time. These laws have operated since near the beginning of the universe. This means that the earth and its neighborhood are a representative example of the universe as a whole. This assumption is one of the two postulates that Einstein presumed to develop the theory of relativity.

This assumption allows geologists not only to understand how the earth got to its present condition, but permits construction (in principle) of the history and future of the earth. Likewise, it allows astronomers to presume that other stars are governed by the same "laws" that govern our part of the universe, both now and in the distant past. Without it, we severely limit the part of the universe we can study and understand.

Mechanism (naturalism): Naturalism presumes that every observation is produced by a describable mechanism. The laws of nature act on inert matter. Laws acting on matter produce every observation. Extended to its logical extreme, life itself, including human life and behavior, results from the laws of nature acting on inert matter.

This assumption is perhaps the most powerful of all and perhaps the most potentially devastating. At first glance, there seems to be nothing wrong with it. Several references in modern scripture refer to the notion that things work by law (for example, Doctrine and Covenants section 88, especially verses 34-38, 42-44). If nature is a big machine, we ought to be able to subdue nature, in accordance with divine direction. This is the hope of science, and we have seen it benefit humanity in many, many ways.

However, if pushed to its logical conclusion, the assumption of mechanism implies that human beings are simply complex machines. We have nothing that could be termed an immortal soul. When we die, that is the end. In essence, we have no eternal purpose. Thus, we may as well eat, drink, and be merry, for tomorrow we die. This conclusion is exceptionally unpleasant—and contrary to the message of the gospel of Jesus Christ.

The Role of Faith in Science

The term "faith" has several meanings. The Book of Mormon prophet Alma defined faith as "not to have a perfect knowledge of things; therefore if ye have faith ye hope for things which are not seen, which are true" (Alma 32:21). This definition implies that a person can have faith only in things that are true. Certainly salvation can be based only on truth.

The apostle Paul, however, gives a more liberal definition of faith. According to him, faith is "the substance of things hoped for, the evidence of things not seen" (Hebrews 11:1). Using this more general scriptural definition, faith is the basis for considering something true that has not

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actually been observed. This definition of faith does not require blind acceptance. Indeed, we use many evidences to convince ourselves that something is true. The point, however, is that if we cannot actually observe it, we must rely on faith to accept it.

No one doubts that religion is based on faith. Few if any of us have seen God, so we accept His existence by faith. We accept the atonement of our Savior Jesus Christ by faith. As Latter-day Saints we accept Joseph Smith as a prophet by faith. We are not eyewitnesses; the witnesses have passed on. This is not to say that faith in these fundamental doctrines is blind. On the contrary, there are many evidences of God's existence and the validity of Christ's work, if we choose to see them. Tangible evidence of Joseph Smith's prophetic work is the Book of Mormon. If one does not accept the Book of Mormon's origin as Joseph Smith explained, one must put forward and believe in an alternative theory of its origin.

I contend that faith plays precisely the same role in science. Science requires faith in at least three ways: acceptance of science's assumptions, acceptance of theories as "true," and acceptance of observations of modern science.

Accepting the assumptions of modern science is an act of faith.

Accepting the assumptions of modern science is an act of faith. As noted above, all scientific theories are founded on underlying assumptions. The statements listed as assumptions seem to be correct statements. They seem logical to us. However, these assumptions can never be proven either by observation or by logic. Their acceptance is an act of faith. The assumptions seem ordinary and sensible to us mostly because we grew up with them. Many of them would not have made sense to ancient or Renaissance philosophers.

Accepting a scientific theory as truth is an act of faith in two ways. First, accepting a scientific theory as truth (especially if one pushes the theory to its logical limits) requires accepting science's assumptions. Second, even if the assumptions are true, a scientific theory, according to Popper, can never be proven true, only false, unless we can actually observe it in operation—which is exceedingly rare. For example, rejecting God's existence because the theory of evolution "explains" how man came to be without His intervention is an act of faith. The history of science is full of examples of theories that were accepted as absolute truth only to be falsified eventually.

Accepting the observations of other scientists as true is, to some degree, an act of faith. No single person can possibly make all the observations that have been made. No one has enough time or equipment. At some point, we have to accept the observations of others on faith. However, modern science has an advantage that observations can, at least in principle, be repeated. If I am really suspicious about what another scientist has done, I can repeat the experiment or observation. If I don't observe what the original scientist claimed, I make it known. In this way, science is a self-policing enterprise. Routinely during the history of science, scientists have overturned observations claimed by others.

The Apostle Paul wrote, "for now we see through a glass, darkly, but then face to face" (1 Corinthians 13:12). Scientifically, we can never know for certain when we have arrived at the correct answer. We cannot know whether our assumptions about the universe are correct. As a result, faith is the guiding principle of our lives, whether we believe in God or not. Faith serves the same role in science as it does in religion.

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Strengths and Limitations of Science

One of the most difficult notions for most people, including scientists, to accept is that science has limitations. I like to compare science to one of the tools in our intellectual toolbox. Every tool is important. However, every tool has a set of strengths and a set of limitations. These come from the way the tool is designed. We would not use a hammer to take the lug nuts off of our tires. If we did, we'd likely break something and it wouldn't do the hammer any good either. But we don't throw the hammer away just because it can't do every job. We understand its strengths and limitations and use it for those jobs it performs well but use a different tool for other jobs.

In like fashion, science has strengths and limitations. I list only a couple here although there are many more. I have become convinced that we discover truths about nature by observation, and through science develop useful descriptions that we can use to predict nature's behavior. Additionally, science is self-correcting—because it is open to public scrutiny inaccurate observations and theories do not last. These strengths make science a worthwhile endeavor.

Science also has limitations. Elder Richard G. Scott identified two of them. "First, we never can be sure we have identified absolute truth, though we often draw nearer and nearer to it. Second, sometimes, no matter how earnestly we apply the method, we can get the wrong answer."[15] I could add several others to the list, including limitations in the types of questions science can address (although scientists often use it to address questions outside its purview), its dependence on underlying axioms that are determined in part by cultural attitudes, and its progress by revolution rather than by a steady upward course.[16]

Through my experience, I've come to the conclusion that science is a marvelous tool for discovering truths about nature. Like any tool, it has strengths and limitations. Nonetheless, I have come to believe that God uses science to fulfill part of His glorious promise to the Prophet Joseph. This is why I believe it is important to become acquainted, by means of the tool of science, with what He has wrought.

Notes

1 Quoted in J.D. Barrow, *The World within the World* (Oxford: Oxford University Press, 1990), 349.

2 Quoted in P. Davies, *The Mind of God* (New York: Simon and Schuster, 1992), 176.

3 Stephen W. Hawking, "My Position," in *Science and its Ways of Knowing*, ed. J. Hatton and P. B. Plouffe. (Upper Saddle River NJ: Prentice-Hall, 1997), 63-67.

4 H. Collins and T. Punch, "The Germs of Dissent: Louis Pasteur and the Origin of Life," in *Science and its Ways of Knowing*, ed. J. Hatton and P. B. Plouffe (Upper Saddle River NJ: Prentice-Hall, 1997), 37-45.

5 Ibid.

6 Edwin Hubble, *Realm of the Nebulae* (New York: Dover, 1936), 207.

7 Ibid., 1.

8 Ibid., 1-4.

9 Karl Popper, *Popper Selections*, ed. D. W. Miller (Princeton: Princeton University Press, 1985), 121.

10 Ibid., 479.

11 Ibid., 73.

12 Ibid., 51-53.

13 Ibid., 102.

14 Thomas S. Kuhn, *The Copernican Revolution* (Cambridge: Harvard University Press, 1957), 36-40.

15 Richard G. Scott, "Truth: The Foundation of Correct Decisions," *Ensign*, November 2007.

16 Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1970), 210.