Scientific Thought:

A Developmental Perspective

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The English term science was derived from the Latin *scientia* meaning knowledge or "to know." In *The Oxford English Dictionary* one encounters multiple early meanings of science and its equivalent in several languages. The term was sometimes employed to celebrate the science (knowledge) and wisdom of God and to distinguish between true knowledge and opinion. The word Science was also used to portray the idea of firm truths based on an understanding of cause and effect. In the Medieval Period, the term science was often used to refer to a particular branch of knowledge. The seven liberal sciences, also referred to as the seven liberal arts, consisted of the trivium (grammar, rhetoric, and logic) and the quadriviam (arithmetic, geometry, astronomy, and music). Pejorative meanings of the word science are also encountered throughout history in claims that abstractions, complex formulas, and pompously complex language sometimes serve only to obfuscate or to confuse. The word scientist, referring to one with expertise in one of the sciences or with special methodological skills, was not used until the 19th century.

The meanings of the term science, as we know the term at the outset of the 21st century, did not come about quickly as the result of a sudden breakthrough or insight. Indeed, intellectual precursors of science are found in ancient times and in all periods of history, but there were developments, especially in the Renaissance and early modern period (from 1600), that are particularly important to the substantive and methodological characteristics of science, as it is currently understood. In this article, I review four intellectual precursors that contributed to the development of science and that continue to

characterize and define basic contemporary scientific attitudes. Following that background I turn to a discussion of contemporary meanings of science.

Intellectual Precursors of the Scientific Spirit

As noted, the word science in early usage was often associated with what was regarded as true knowledge. Such "true knowledge" might have been based on authority or on a valid deductive argument marked by appropriate application of the rules of logic. Thus, in early usage, the term science did not convey the idea of knowledge based on controlled experimental methods. Evolving new meanings however, gradually surfaced in the work of luminaries such as Galileo Galilei, Isaac Newton, Francis Bacon, and René Descartes. Bacon and Descartes in particular hoped to hammer out a conception of science based on methodological considerations. That is, they hoped to clearly articulate and clarify the unique intellectual processes that were leading to the ground-breaking discoveries surfacing in the name of science in the 17th Century. Thus, Bacon and Descartes stand at the threshold of the modern period as important early philosophers of science. Their work contributed to the idea that science is more than a systematized body of knowledge; it is a way of knowing based on specific assumptions and methodological procedures that guide the intellectual process. Bacon and Descartes clearly tied science to what later was known as epistemology, that special branch of philosophy that studies the problems of human knowledge and the conditions and methods used to assess truth. They also understood that certain long held attitudes, specifically attitudes toward authority, tradition, curiosity, skepticism, and naturalism stood in the way of the development of a scientific age. A key to understanding the nature of science hinges partly on an awareness of the evolution of curiosity, skepticism, naturalism, and what I will call "eschewing first

things." A brief exploration of each of these topics is warranted.

Curiosity. For centuries, curiosity was widely regarded as a mark of vanity, an intellectual vice, a dangerous sin, evidence of foolish pride, and an affront to God. Curiosity represented a lack of obedience and was sometimes blamed for "the fall of human beings" in the Garden of Eden. The fear of curiosity is illustrated in lines from Robert Browning (2007, p.147) in his poem "A Woman's Last Word."

Where the apple reddens,

Never pry --

Lest we lose our Edens,

Eve and I

Lines from John Milton (1979, book 8, p. 205) in his *Paradise Lost* convey an attitude that persisted for centuries.

Solicit not thy thoughts with matters hid,

Leave them to God above, him serve and fear.

Umberto Eco, (1980) in his novel "The Name of the Rose" captures a common attitude in the Medieval Period when a young novitiate confesses to an older monk that he is troubled by "the yearnings of the mind, which wants to know too many things." The predictable reply is "And that is bad. The Lord knows all things, and we must only adore his knowledge" (p. 221).

In a thoughtful article on the history of curiosity, Harrison (2001) pointed out that Francis Bacon realized that curiosity must be enfranchised and become a necessary component of the scientific spirit. But how could Bacon possibly combat centuries of deeply embedded religious criticism of curiosity? Harrison pointed out that Bacon

employed a clever tactic by first joining the ranks of those who were critical of curiosity. Yes, curiosity could indeed lead to self-centered arrogance, pride, obsession with trivial matters and conceit. On the other hand, the world, after all, was God's creation and a better understanding of that creation could feed Christian charity by the development of new knowledge that would bring comfort to the sick, the poor, and the disadvantaged. Bacon was saying that curiosity is not necessarily a sin, rather put to the proper use, it could be a vehicle for good works. Bacon's appreciation for the benefits of curiosity was strongly echoed by other 17th and 18th century philosophers so in time, what had been a vice would become a virtue. Curiosity is a virtue vital to all modern thought and specifically to the modern development of the scientific spirit. The suppression of curiosity enfeebles all intellectual processes, but is especially injurious to the scientific spirit.

Skepticism. The skeptical school of thought initiated by Pyrrho (c. 360 - c. 270 B.C.E.) was resurrected in the 16th century by Michel de Montaigne (1533-1592). In his famous essay, *Apology for Raimond Sebond*, Montaigne launched a powerful attack on all human knowledge (Montaine, 1960). Motivated by his disgust with Protestant-Catholic wars, Montaigne launched a trenchant attack on the ignorance, blind certitude, presumption, and arrogance that serve as underpinnings for war and other outrageous behaviors. He argued that Virtue should be the product of genuine knowledge and such knowledge would include a deep awareness of the shaky grounds of all our human pretensions. Montaigne hung a little sign by his desk "What do I know?" The answer, for all who are honest -- not much!

Montaigne attacked knowledge claims based on authority, tradition, and

revelation as well as claims associated with reason and science. Nothing was sparred. Scientific claims change with time, reason can be flawed, emotion tinctures all of our cognitive structures, our senses may not mirror external reality, authorities, no matter how they have been revered, have been proven wrong over and over again. In short, we are all beggars in matters of knowledge and the world would be much better off if humility could somehow replace arrogance and certitude. In an age of bloodshed resulting from religious wars, Montaigne's skepticism captured the public imagination. His skepticism was so compelling that, in the words of Durant and Durant (1961), "His influence pervaded three centuries and four continents" (p. 413). Following his work, the merits of a skeptical attitude could be juxtaposed with the folly of the blind certitude that had motivated religious violence. Following Montaigne, early philosophers of science explicitly recognized the value of skepticism and doubt as pivotal values in scientific methodology. Both Descartes and Bacon acknowledged the influence of Montaigne on their work and both men believed that a skeptical doubting attitude was an important characteristic of scientific work. Thus skepticism, once viewed as a moral weakness, was gradually elevated as an intellectual and moral virtue.

Naturalism - Naturalism includes the belief that causal forces are inherent in nature itself and produce effects without the intervention of any paranormal or supernatural powers. One way to understand naturalism is to explore some of the things it rejects. One of the first things it rejects is illustrated in the works of Al-Ghazali, a prominent and respected 12th century Islamic scholar and mystic. Al-Ghazali argued that cause and effect as natural concepts are created by human beings (see Rubenstein, 2003, p. 85). Al Ghazali illustrated by noting that any two things, such as "the quenching of thirst and drinking,

satiety and eating, burning and contact with fire, light and the appearance of the sun . . . [are connected] due the prior decree of God, who creates them side by side" (see Al-Ghazali, 2000, p. 166). According to Al Ghazali there is nothing inherent, no power, no causal force, in water *per se* apart from the action of deity that quenches thirst. There is nothing intrinsic in one magnet that results in the attraction or the repulsion of another; nothing intrinsic in fire *per se* that could produce a burn. All the things that happen in the natural world, all the unimaginable trillions of events (no matter how small or large) taking place in a given instant reside in deity alone and not in any power that resides in nature by itself. Such a philosophy, taken literally, undercuts the motivation to explore nature in its own right. Prior to Al-Ghazali there had been important advances in science and philosophy in the Islamic world illustrated in the works of scholars such as Avicenna, Rhazes, and Alhazen. The work of Al-Ghazali, however, marks an unfortunate turning point in Islamic science. In the words of Watt (1965) following Al-Ghazali "there are no further great names in the philosophical movement in the Islamic east" (p. 1041).

Naturalistic philosophers strongly reject beliefs such as those encountered in the work of Al Ghazali partly because such beliefs are counterintuitive and partly because they can have such a smothering effect on scientific inquiry. Furthermore, Al Ghazali's contention that all causality resides in the action of deity alone comes along with very difficult problems such as how to account for all the brokenness, misdirection, and evil in the world. All events, according to the extreme anti-naturalism of Al-Ghazali, must somehow revert back to God, so our chief intellectual work must be theological rather than scientific. Over time, Al Ghazali became more and more of a recluse and a mystic contemplating the inscrutable nature of his God and fatalistically resigning himself to the

course of events in a world fordone by the incomprehensible decrees of God.

Non-natural or supernatural forces have historically been construed anthropomorphically as benevolent or malevolent. Fear of malevolent forces is evident in many religious traditions and is graphically present in the religious traditions of Judaism, Christianity, and Islam. In each tradition, the malevolent work of the devil or devils is illustrated in parables and in stories that were sometimes intended as historical narratives of actual events. Though demonological explanations are ubiquitous throughout history, they reached an apogee in the Christian world in the 16th and 17th centuries. In their classic book, *The Malleus Maleficarum* (translated as "The Witches Hammer or the Hammer Against Witches") Dominican monks Heinrich Kramer and James Sprenger (1971) outline the kinds of things devils and their disciples can do and how they do them (pp. 89-193). Among other things, Devils and their cohorts can cause hailstorms and all kinds of other tempests, infect animals with diseases, destroy crops, cause miscarriages, interfere with all reproductive capacities, kill babies, have sexual intercourse with humans, or cause any physical or psychological malady.

In the 16th and 17th centuries naturalistic philosophers, physicians, and scientists initiated strong arguments against demonological explanations of events that could more profitably be construed in naturalistic terms. It was argued that demonological explanations are unnecessarily complicated, filled with *post hoc* theory-saving additions, and lack demonstrable predictive and heuristic value. Such objections are illustrated in a book titled *Physics for the Inquiring Mind* by Eric Rogers (1960) who asks that you imagine yourself to be in a conversation on the subject of friction with Faustus who speaks for devils. Faustus argues that invisible devils push against an object such as a

brick and it is the perfect counter action of devils that is the cause of friction when you attempt to push the brick across a surface. You might inform Faustus that friction is decreased if oil is placed on the surface over which the brick is to be pushed. Faustus is not so easily defeated because he declares that oil drowns the demons and that is why friction is decreased. Rogers cleverly leads the reader through several simple scenarios designed to defeat Faustus and his demonological explanations, but in each scenario Faustus is able to come up with a *post hoc* but complicated explanation of why it is that demons are the real cause of friction. For example, rough surfaces are generally associated with greater friction than smooth surfaces. Faustus declares that is because demons live in the pores of surfaces and there are more pores in rough than smooth surfaces, hence more demons. Though Faustus appears to be able to come up with post hoc saving demonological explanations for friction phenomena, his explanations quickly begin to stretch credulity. The naturalist can provide much simpler and more productive explanations than those offered by Faustus.

Naturalists and possibly the public at large were also motivated by the excesses resulting from what Carl Sagan (1996) called "The Demon-Haunted World." Beliefs in demons came with tragic moral consequences as tens of thousands, mainly women, were tried for witchcraft and brutally tortured or sentenced to death, usually by burning or hanging. The work of philosophers such as René Descartes and Benedict Spinoza and physicians such as Johann Weyer (1515-1588) contributed to the demise of demonology. Weyer argued that many who were accused of witchcraft were deranged and that their behavior could be explained naturalistically. Descartes found no place for demons in his attempts to understand the relationships between brain processes and behavior. Spinoza

boldly denied the existence of demons.

Though demons and other paranormal forces were gradually replaced by naturalistic perspectives in the physical, chemical, biological, and engineering sciences, large segments of the American population continue to believe in demonic forces as explanations for selected emotional and behavioral disorders. A Harris poll reported by Stoddard (2007) showed that more Americans (62%) believe in the devil than in Darwin (42%). Fear of demons and demonic forces is also illustrated in the apparent growth of exorcism as a treatment for some emotional and behavioral disorders (see Euteneuer, 2010). Belief in demons is a continuing source of tension between certain traditional selected faith communities and standard contemporary scientific approaches to disordered behaviors as practiced by psychiatrists, neuroscientists, and psychologists.

Eschewing First Things

A final precursor of the scientific spirit is illustrated in the capacity to recognize and suspend preconceptions and favored hypotheses and theories. Intellectual inquiry, from a scientific standpoint, is hopelessly corrupted if we know at the outset of an investigation that there are special ideologies that will inevitably be confirmed or words of authority that cannot possibly be doubted or contradicted. William James, in his classic *Pragmatism*, refers to an "attitude of looking away from first things, principles, 'categories,' supposed necessities; and looking towards last things, fruits, consequences, facts" (James, 1907/1943, pp. 54-55). James is adamant in rejecting "fixed principles, closed systems, and pretended absolutes and origins." "Looking away from first things" means that the observational task is to allow the empirical flow of events to lead where they will without necessarily affirming those things we think we know beforehand.

Scientific investigations have all too often resulted in data that have run contrary to every reasonable expectation, theory, or hypothesis. History provides abundant examples of the disproof of things we once knew "with certainty." An immobile earth, a sun that orbits the earth, and light that always moves in a straight line were “first things” that had to be abandoned in the face of overwhelming contradictory scientific evidence. Who could have predicted that we would someday be able to “look through” flesh to identify underlying skeletal structures? There were also moral "first things" including the belief that, in all things, women were intellectually inferior to men and that slavery, as an institution, had a moral or even a religious basis. Throughout history, human beings have been willing to die and kill for "first things." The capacity to eschew "first things" amounts to nothing less than an empirical openness that leads to a deep appreciation for the complicated, effusive, novel, and serendipitous qualities that reside everywhere in the natural world.

Science at the Outset of the 21st Century

Curiosity, skepticism, naturalism, and the capacity to eschew first things are all precursors of the scientific spirit, but also remain integral to contemporary scientific thinking and practice. If these precursors remain as enduring values, many other things have changed. Francis Bacon observed "the art of discovery may advance as discoveries advance" (Bacon, 1620/1960, p. 120). His words were prophetic as there has been a continuing proliferation of new instruments, statistical and mathematical methods, technical developments, theories, and models that alter and shape the way scientists think and practice. Bacon realized that science would be a dynamic ever-changing enterprise in contrast with the static and stale ways of thinking that have marked some periods of

history. The dynamic nature of science has led historian of science Stephen G. Brush (1974) to ask, somewhat humorously but very thoughtfully, whether the History of Science should be rated X? Brush shows that history may be subversive because it will inevitably challenge fixed or idealized notions of science. Brush demonstrates that students of history will inevitably learn that scientists have used a variety of methods and have often solved problems in unorthodox ways. Paul Feyerabend, a philosopher of science, argued that "The idea of a method that contains firm, unchanging, and absolutely binding principles for conducting the business of science meets considerable difficulty when confronted with the results of historical research -- there is not a single rule, however plausible, and however grounded in epistemology, that is not violated at some time or other" (Feyerabend, 1975, p. 23). Joel Hildebrand, a former president of the American Chemical Association, has questioned the idea that there is *one* scientific method (Hildebrand, 1957). Echoing the same sentiment, Nobel Prize winner, P. B. Medawar argued "There is indeed no such thing as 'the' scientific method" (Medawar, 1984, p. 51). The methods of field biologists or astronomers, for example, appear to be different from the methods of wet-lab chemists or experimental psychologists who manipulate variables in the laboratory.

Science is often conceived in terms of its content, but it should also be conceived as an attitude and as a set of ever evolving methodologies. The scientific attitude is one of epistemic humility motivated by skepticism and by the knowledge that the procedures and results of a scientific study are sure to be checked in the laboratory or field by other scientists. Epistemic humility is the capacity to forego certitude and to allow events to run their course without having to affirm what we thought we knew beforehand. Though

scientific methodologies have mutated and proliferated there is nevertheless some degree of consensus as to what counts as canonical scientific practice in given time periods. At a minimum, contemporary science involves an open and disciplined structuring of observational tasks. An open structuring refers to the public nature of science wherein all observational procedures and conditions are communicated in a manner so explicit and clear that other scientists can replicate them. Repeated failure to replicate the results of a study is the kiss of death in science. There are, of course, one-time events such as a close encounter with a meteor or a comet, but even in such events, scientific observational procedures and conditions are explicit and the data collected in one observatory are cross checked with data in other observatories.

Science, as it is now understood, is marked by a bewildering array of new technologies, methods and models that could not have been anticipated in earlier periods. Particle accelerators, a variety of new imaging techniques, space telescopes, refrigerated centrifuges, double-blind methods, nanotechnologies including molecular self-assemblies, statistical meta-analysis and a great host of other new tools and methods are now an everyday part of an ever growing scientific arsenal. Bacon was indeed prophetic when he said that "the art of discover may advance as discoveries advance."

Some Values of Science.

Scientific methodology includes a built in method for settling disputes that is sadly missing in other ways of knowing. This is one reason science is there for everybody regardless of religion, nationality, race, or political affiliation. Expressions such as Arian physics, Christian biology, or Muslim chemistry, reflect profound misunderstandings of the vertical qualities of scientific methodologies that stubbornly refuse to be contained or

captured by the limiting boundaries of religious, political, or national ideologies. One of the most important virtues of science, borrowed from philosophy, is encountered in its self-critical or meta-theoretical endeavors. From its inception in modern history, there has been a respected place for intellectual work in the philosophy of science as an independent and valued disciplinary activity. For all of its gifts to humankind, we have yet to realize the freedom, integrity, honesty, openness, love of knowledge, and beauty in the scientific enterprise.

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